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Exploring accident causation in the
construction industry

by
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Abstract

The construction industry has a longstanding reputation for offering dangerous work and has above average rates of occupational injuries and fatalities. Although fatalities have more than halved in the last 20 years, there continues to be more than one construction worker death on average per week. Earlier construction research has generated a wealth of data portraying a clear profile of accident types, but has failed to reveal what happened – the causal factors. In response to this lack of information the Health and Safety Executive (HSE) sponsored this research, the main component of which has been to undertake detailed examination of construction industry accidents.

Lacking any precedent of earlier or related work, an important precursor to data collection was a review of the resources that might inform development of the methodology. The path of progress in accident research was explored through evaluation of accident causation models. The need to identify active and latent factors using a systems approach was identified. Desirable features of the systems approach were isolated and, against these criteria, construction accident models were evaluated. Construction accident models were found to be too technically orientated and focused upon human failings to fulfil the criteria for the systems approach. Nevertheless some gave good representation of failure potential through the project lifecycle, and these features were isolated for later inclusion during development of the data collection methods. To complement the theoretical development, perceptions of accident causation were gathered from groups of construction industry practitioners', by the use of focus groups.

Ergonomics methods were used as a framework for development of the accident investigation methods. Key features from the construction accident models, findings from focus groups, and analyses from a number of key resources concerning construction industry accidents were built into these. Forty construction accidents were studied. These entailed site visits, interview with accident-involved personnel, their supervisors or managers, and (where possible) evaluation of the accident area conditions, equipment, task type and related instructions or procedures. Findings showed a catalogue of problems affecting all build phases,

from conceptual design and scheduling of the project timeline, sub-contracting, work organisation and managerial issues, to factors at operational level and task execution. Given the construction industry accident history, task based failures concerning equipment, materials, PPE and task technique were expected. However, the extensive range of problems concerning the appointment, scheduling, organisation, instruction, training, role and co-ordination of personnel on site indicated that these aspects too were important contributing factors in accident causation.

Construction and ergonomics specialists appraised site findings; these data were used to identify areas where more detailed exploration might further inform the exploratory process. This was undertaken for thirty of the accidents and included interviews with a range of personnel - designers, planners, managerial staff, industry suppliers, and manufacturers of tooling, equipment and machinery. The information from them supplemented and reinforced many of the findings from site data and also gave a perspective of the latent conditions under which they worked themselves. Designers, planners and managerial staff were affected by many communication and role identity problems. Manufacturers and suppliers also appeared isolated from the learning and information loop and received inconsistent feedback on the performance and failures of their products.

Drawing the findings of the research together it is suggested that the main problems within the industry arise from (1) inadequate communication and consultation throughout the organisational and extra-organisational hierarchy; this includes ancillary service providers to the industry - the manufacturers and suppliers (2) the adoption of a rule based, highly proceduralised approach, with multiple and burdensome interventions to control both process and individuals. These lack socio-technical principles; there is inadequate attention to the needs and working methods at operational levels, where high decision latitude and autonomy is required to accommodate the perpetual flux and unique circumstances that typify much of the working day and (3) the reliance upon a hazard and risk assessment approach to identify latent conditions. Hazard identification and risk assessment may identify potential 'active factors' in accident causation, but are poor or not appropriate for

the identification of factors that affect performance and which are contributory in accident causation.

Appraisal of the accident investigation processes used in industry identified numerous problems with reporting and interpretation, and it was concluded that they are not efficient ways to explore latent conditions. Recommendations for improvements include the development of 'performance assessments'; a supplementary system (to synchronise with the risk assessment process) for assessment of factors that affect performance and which are contributory in accident causations, the latent conditions. Benchmarking with industries that have moved away from the traditional organisational and safety management approaches is also advised. It will be an additional challenge to devise changes that are compatible with the unique construction management and contracting methods - any interventions will need careful management, leadership, participatory processes and cross-disciplinary development.

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Table of Contents

<u>1</u>	<u>INTRODUCTION</u>	<u>1</u>
<u>1.1</u>	<u>Overview of the research strategy</u>	<u>3</u>
1.1.1	Rationale for research methodology	3
1.1.2	Aim and objectives of the research	4
1.1.3	The research programme.....	4
1.1.4	The research team roles and contribution	5
1.1.5	Industrial liaison.....	6
1.1.6	Project boundaries	7
1.1.7	Structure of the thesis	7
<u>2</u>	<u>CONSTRUCTION INDUSTRY - CURRENT STATUS</u>	<u>9</u>
<u>2.1</u>	<u>International construction industry accident and injury profile.....</u>	<u>9</u>
<u>2.2</u>	<u>UK Construction industry accident and injury profile</u>	<u>10</u>
2.2.1	Employer reporting via RIDDOR	10
2.2.2	Individuals reporting via the Labour Force Survey	12
<u>2.3</u>	<u>Key points from all resources</u>	<u>13</u>
<u>2.4</u>	<u>Estimated costs of accidents</u>	<u>13</u>
<u>2.5</u>	<u>Improvement measures affecting the construction industry.....</u>	<u>15</u>
2.5.1	Previous government led research	15
2.5.2	Construction specific initiatives and targets for improvement	16
2.5.3	General initiatives to improve health and safety.....	19
2.5.4	General legislative initiatives	20
2.5.5	Construction legislative initiatives	21
2.5.6	Training initiatives	24
<u>3</u>	<u>LITERATURE REVIEW – ACCIDENT CAUSATION.....</u>	<u>26</u>
<u>3.1</u>	<u>Accident data information sources</u>	<u>26</u>
<u>3.2</u>	<u>Historical perspective upon understanding of the term ‘accident’</u>	<u>27</u>
3.2.1	Medical usage.....	27
3.2.2	Industrial usage	28
<u>3.3</u>	<u>Defining the meaning of ‘accident causation’</u>	<u>29</u>
3.3.1	Defining ‘accident’.....	29
3.3.2	Defining ‘cause’	30
<u>3.4</u>	<u>Information sources contributing to understanding.....</u>	<u>31</u>
<u>3.5</u>	<u>Approaches to modelling accident causation</u>	<u>32</u>
3.5.1	Fragmented approaches.....	32
3.5.2	Multi-factorial events	32
3.5.3	Systems approaches	35
3.5.3.1	Models of human and general failure.....	36
3.5.3.2	The model of Organisational Accident Causation.....	37
3.5.3.3	Summary of latent conditions.....	39
<u>3.6</u>	<u>Contributions from inter-disciplinary knowledge sources</u>	<u>41</u>
3.6.1	Summary of ergonomics principles	41
3.6.2	Psychological and behavioural factors.....	42
3.6.2.1	Individual variability	42
3.6.2.2	Risk taking.....	43
3.6.2.3	Traditional approach to human error	44
3.6.2.4	Classification of human error	45

3.6.2.5	New approach to human error	48
3.6.3	Engineering approaches	48
3.6.3.1	Physical defences.....	48
3.6.3.2	Behavioural defences.....	49
3.6.3.3	Defence failures.....	49
3.6.4	Work organisation issues	51
3.6.4.1	Developments in work organisation	51
3.6.5	Organisational goals.....	52
3.6.5.1	Defining safety culture	53
3.6.5.2	Safety management.....	54
<u>3.7</u>	<u>Overview of main issues in accident modelling.....</u>	<u>55</u>
3.7.1	Epidemiological data.....	56
3.7.1.1	Epidemiology and human error	57
3.7.1.2	Epidemiology and systems aspects.....	58
3.7.1.3	Epidemiology and construction data	59
3.7.2	Summary table of inter-disciplinary knowledge sources	59
<u>3.8</u>	<u>Transferring accident causation models into practice</u>	<u>63</u>
3.8.1.1	Criticisms of accident causation models.....	63
3.8.1.2	Criticisms of human factors /ergonomics approaches.....	64
<u>3.9</u>	<u>Accident investigation</u>	<u>64</u>
3.9.1	Accident types and consequences	65
3.9.2	Major accident - assessment techniques	66
3.9.2.1	Human error assessment techniques.....	66
3.9.2.2	System assessment techniques.....	67
3.9.3	Major incident - data representation	67
3.9.3.1	Use of analytic trees.....	67
3.9.3.2	Accident mapping.....	68
3.9.3.3	Tabular representation	69
3.9.4	Minor accidents - assessment and analysis	69
3.9.4.1	Accident investigation – documentation	69
3.9.4.2	Accident investigation – observation and interview.....	70
3.9.4.3	Accident investigation – current practice	70
3.9.4.4	Problems associated with the collection of accident histories	71
3.9.5	Cause attribution and hindsight bias	72
3.9.5.1	Role differences in attributing cause	72
3.9.5.2	Event types in attributing cause.....	72
3.9.5.3	Bias and hindsight in accident investigation	72
3.9.5.4	Resolving cause attribution and hindsight bias	73
<u>3.10</u>	<u>Overview of main issues in accident investigation.....</u>	<u>74</u>
<u>3.11</u>	<u>Construction industry accident models.....</u>	<u>75</u>
3.11.1	Alternative model of accident causation	76
3.11.1.1	Model evaluation	77
3.11.1.2	Further work	79
3.11.2	The distractions theory of accident causation	79
3.11.2.1	Model evaluation	80
3.11.2.2	Further work	81
3.11.3	Accident root causes tracing model (ARCTM)	81
3.11.3.1	Model evaluation	82
3.11.3.2	Further work	83

3.11.4	Constraint response model of accident causation	83
3.11.4.1	Model evaluation	87
3.11.4.2	Further work	89
3.11.5	The modified loss causation model (MLCM)	89
3.11.5.1	Model evaluation	91
3.11.5.2	Further work	92
3.11.6	Summary of findings concerning construction accident models .	92
<u>3.12</u>	<u>Summary of the literature review</u>	<u>94</u>
<u>3.13</u>	<u>Critique of the literature review.....</u>	<u>96</u>
<u>4</u>	<u>PHASE ONE – INFORMATION SEARCH.....</u>	<u>98</u>
<u>4.1</u>	<u>Methodology.....</u>	<u>98</u>
4.1.1	The nature of focus groups.....	99
4.1.2	Aims and objectives	100
4.1.3	Development of the discussion material	100
4.1.3.1	Whittington et al. 1992	100
4.1.3.2	Suraji et al. 2001	101
4.1.3.3	Isolating discussion areas	101
4.1.4	Choice of participants	102
4.1.5	Information for participants	103
4.1.6	Data collection tools.....	104
4.1.7	Procedure.....	104
4.1.8	Analysis.....	105
<u>4.2</u>	<u>Results - Focus group data.....</u>	<u>106</u>
4.2.1	Project Concept, Design and Procurement.....	106
4.2.1.1	Client background.....	106
4.2.1.2	Strategic design considerations.....	107
4.2.1.3	Allocation of resources	109
4.2.1.4	Selection of contractors	109
4.2.1.5	Safety considerations	110
4.2.1.6	Client team.....	111
4.2.1.7	Legislation	113
4.2.2	Work Organisation and Management	113
4.2.2.1	Project management and supervision	113
4.2.2.2	Work scheduling.....	115
4.2.2.3	Resources.....	116
4.2.2.4	Safety considerations	118
4.2.2.5	Site layout and transport	120
4.2.2.6	Job roles at work organisation level	120
4.2.3	Task factors	122
4.2.3.1	Tools, equipment and materials.....	122
4.2.3.2	Task supervision and communication	123
4.2.3.3	Task, techniques and safety factors	124
4.2.3.4	Training in task and health and safety skills.....	124
4.2.3.5	Work load and time constraints	125
4.2.3.6	Financial considerations	126
4.2.3.7	Environmental conditions.....	127
4.2.3.8	Design of task area.....	127
4.2.3.9	Job roles at task level.....	127
4.2.4	Individual factors	128

4.2.4.1	Age, attributes and experience.....	128
4.2.4.2	Competency issues.....	129
4.2.4.3	Attitudes and conformity.....	130
4.2.4.4	Health status and fitness for work	130
4.2.4.5	Exclusion of discussion themes.....	131
<u>4.3</u>	<u>Questionnaire results</u>	<u>131</u>
4.3.1	Project concept, design and procurement.....	131
4.3.2	Work Organisation and Management	132
4.3.3	Task factors	133
4.3.4	Individual factors	133
<u>4.4</u>	<u>Discussion of questionnaire data</u>	<u>133</u>
<u>4.5</u>	<u>Data validation.....</u>	<u>139</u>
4.5.1	Consultation about data analysis method and interpretation.....	139
4.5.2	Open forum validation sessions	139
4.5.3	Materials.....	139
4.5.4	Validation method.....	140
4.5.5	Validation results	141
<u>4.6</u>	<u>Summary of the focus group studies</u>	<u>142</u>
<u>4.7</u>	<u>Critique of the focus group studies.....</u>	<u>143</u>
<u>5</u>	<u>PHASE TWO – METHODOLOGY FOR ACCIDENT STUDIES.....</u>	<u>145</u>
<u>5.1</u>	<u>Aims and objectives.....</u>	<u>146</u>
<u>5.2</u>	<u>Appraisal of available data collection techniques</u>	<u>146</u>
5.2.1	Appraisal of existing accident investigation techniques	147
5.2.1.1	Appraisal of ergonomics assessment techniques.....	147
5.2.1.2	Appraisal of construction industry accident investigation techniques.....	147
5.2.1.3	Appraisal of information supplied by the research partners	149
5.2.1.4	Appraisal of information supplied by the project sponsor.....	149
5.2.1.5	Appraisal of focus group findings	150
5.2.2	Evaluation and integration of the resource range.....	150
<u>5.3</u>	<u>Development of site based data collection techniques</u>	<u>151</u>
5.3.1	Reaffirmation of the enquiry needs.....	151
<u>5.4</u>	<u>Generating materials to fulfil information needs.....</u>	<u>153</u>
5.4.1	Recording accident details and descriptive site data.....	154
5.4.2	Gathering subjective opinions from site personnel	154
5.4.3	Timing an accident study	157
5.4.4	Data collection by the visiting researcher	157
5.4.5	Pilot study and iterative review of techniques	158
<u>5.5</u>	<u>Ethical issues and their impact upon data collection methods</u>	<u>159</u>
<u>5.6</u>	<u>Development of a sampling strategy</u>	<u>160</u>
5.6.1	Representation of UK construction industry types	160
5.6.2	Representation of UK construction accident types	160
<u>5.7</u>	<u>Constraints upon site based data collection.....</u>	<u>161</u>
5.7.1	Difficulties with accident notifications	161
5.7.2	Lack of balance in sector participation	162
5.7.3	Barriers to data collection	162
<u>5.8</u>	<u>The accident study procedure</u>	<u>162</u>
5.8.1	Notification of accidents to the research team	162

5.8.2	Site liaison and visit organisation	163
5.8.3	Site based data collection	164
<u>5.9</u>	<u>Analysis and representation</u>	<u>164</u>
<u>5.10</u>	<u>Summary of the methodological development</u>	<u>167</u>
<u>6</u>	<u>PHASE TWO - PROFILE OF THE RESEARCH SAMPLE</u>	<u>169</u>
<u>6.1</u>	<u>Data representation</u>	<u>169</u>
6.1.1	Description of industry types included in the sample	169
6.1.2	Description of the sample build and organisational data	169
6.1.2.1	Description of accident types included in the sample	170
6.1.2.2	Description of baseline incident conditions	171
<u>6.2</u>	<u>Profile of participants included in the research</u>	<u>172</u>
<u>6.3</u>	<u>Profile of accidents included in the research</u>	<u>174</u>
<u>6.4</u>	<u>Overview of accident specific results</u>	<u>195</u>
6.4.1	Active failures	195
6.4.2	Site factors	195
6.4.3	Organisational factors	197
<u>6.5</u>	<u>Critique of data representation and the accident specific analysis</u>	<u>198</u>
<u>7</u>	<u>PHASE TWO - QUALITATIVE ANALYSIS</u>	<u>201</u>
<u>7.1</u>	<u>Issues to be considered in results categorisation</u>	<u>201</u>
<u>7.2</u>	<u>Solution to categorisation of project data</u>	<u>201</u>
7.2.1	Rationale for the reporting of findings	202
7.2.2	Arrangement of interviewee responses	204
7.2.3	Cross-referencing data analysis with accident studies	204
<u>7.3</u>	<u>Results according to Design and Task Execution factors</u>	<u>204</u>
7.3.1	Design and Task Execution : PCDP phase failures	205
7.3.1.1	Build scheduling	205
7.3.1.2	Detail and design of the structure	205
7.3.1.3	Detail and design of the site layout	206
7.3.2	Design and Task Execution : WO & M phase failures	207
7.3.2.1	Procurement of hardware	207
7.3.2.2	Managing the provision of task resources	207
7.3.3	Design and Task Execution : Task phase failures	208
7.3.3.1	Tool qualities	208
7.3.3.2	Material qualities	209
7.3.3.3	Equipment qualities	210
7.3.3.4	Personal protective equipment (PPE)	213
7.3.3.5	Task technique	215
7.3.4	Summary of results according to design and task execution factors	216
<u>7.4</u>	<u>Results according to Planning, Scheduling and Management factors</u>	<u>218</u>
7.4.1	Planning, Scheduling and Management : PCDP phase failures	218
7.4.1.1	Appointment of sub-contractors	218
7.4.1.2	Defining contractor responsibilities	220
7.4.1.3	Ownership of proactive safety behaviour	220
7.4.2	Planning, Scheduling and Management: WO& M phase failures	221
7.4.2.1	Labour supply and appointment	221
7.4.2.2	Determination of competence	221

7.4.2.3	Identification and surveillance of fitness for work	222
7.4.2.4	Supervision of experienced and inexperienced operatives	222
7.4.2.5	Establishing working hours	223
7.4.2.6	Time pressures upon workload	225
7.4.2.7	Monitoring performance and providing motivation	227
7.4.2.8	Pay and remuneration	228
7.4.2.9	Provision of welfare facilities	228
7.4.2.10	Documenting accident events	229
7.4.2.11	Managing accident investigation	229
7.4.2.12	Identification of accident remedial action	231
7.4.2.13	Providing opportunities for operative consultation and communication	232
7.4.3	Planning, Scheduling and Management : Task phase failures...	233
7.4.3.1	Ground, floor or foot placement areas	233
7.4.3.2	Workspace provision	234
7.4.3.3	Housekeeping	234
7.4.3.4	Environmental conditions	234
7.4.3.5	Organisation of tasks between different trades or operatives	235
7.4.4	Summary of results according to Planning, Scheduling and Management factors	236
<u>7.5</u>	<u>Results by information transfer factors</u>	<u>239</u>
7.5.1	Information Transfer factors : PCDP phase failures	239
7.5.1.1	Pre-contract information	239
7.5.2	Information Transfer factors : WO & M phase failures	240
7.5.2.1	Risk assessments	240
7.5.2.2	Method statements	241
7.5.2.3	Ownership of provision of information transfer	242
7.5.3	Information Transfer Factors : Task phase failures	243
7.5.3.1	Styles of training provision	243
7.5.3.2	Site induction	244
7.5.3.3	Toolbox talks	245
7.5.3.4	On the job learning	245
7.5.3.5	Transferring training into practice	245
7.5.4	Summary of results according to Information Transfer factors .	247
<u>7.6</u>	<u>Results by role, skills, abilities and attitudes</u>	<u>249</u>
7.6.1.1	Role clarity of those in safety grades	249
7.6.1.2	Role clarity of those in supervisory / management grades	250
7.6.1.3	Role clarity of those in operative grades	252
7.6.1.4	Skills development by trade, apprentice and NVQ schemes	254
7.6.1.5	Skills development by CSCS training schemes	255
7.6.1.6	Individual capabilities	255
7.6.1.7	Attitudes towards safe practice	255
7.6.1.8	Attitudes affecting work motivation	257
7.6.1.9	Report on rated responses for stress, job satisfaction and social support	259
7.6.2	Summary of results according to role, skill and attitude factors	262
<u>7.7</u>	<u>Summary of qualitative site data</u>	<u>264</u>
<u>7.8</u>	<u>Critique of the qualitative site data analysis</u>	<u>267</u>

8	<u>PHASE THREE – LATENT CONDITION FOLLOW-UP</u>	<u>269</u>
8.1	<u>Methodology.....</u>	<u>269</u>
8.1.1	Aims and objectives	269
8.1.2	Technique used for accident study latent factor identification ..	270
8.1.2.1	Review by research team specialists.....	270
8.1.3	Research boundaries to latent conditions follow-up	270
8.1.4	Researcher criteria for evaluation of follow-up suggestions.....	271
8.1.4.1	Commonality of construction and ergonomist opinions.....	273
8.1.5	Data collection methods.....	273
8.1.5.1	Generation of data collection techniques.....	273
8.1.6	The range of enquiry routes used in data collection	274
8.1.6.1	Accident specific data collection	274
8.1.6.2	Generic data collection	274
8.1.7	Analysis and representation	275
8.2	<u>Profile of the research sample.....</u>	<u>276</u>
8.3	<u>Profile of latent conditions for the accident sample</u>	<u>276</u>
8.4	<u>Validation of researcher findings.....</u>	<u>277</u>
8.5	<u>Techniques used for results categorisation.....</u>	<u>292</u>
8.5.1	Distinguishing accident direct and generic follow-up	292
8.5.2	Categorisation of latent conditions.....	292
8.5.3	Presentation style	294
8.6	<u>Development of build plan and design</u>	<u>294</u>
8.6.1	Build scheduling.....	295
8.6.1.1	Factors affecting the development of project timelines.....	295
8.6.2	Detail and design of the structure.....	296
8.6.2.1	Designers' perspective.....	296
8.6.2.2	Contractors' perspective	297
8.6.2.3	Use of proprietary products	297
8.6.2.4	Lack of design.....	297
8.6.2.5	Drivers to lead innovation	298
8.6.3	Site layout.....	299
8.6.3.1	Provision of utility supplies	299
8.6.3.2	Barriers to efficient supply set-up.....	299
8.6.3.3	Space for welfare facilities	300
8.6.4	Contractual influences.....	300
8.6.4.1	Partnered projects	300
8.6.4.2	Perceptions of Design and Build contracts.....	300
8.6.4.3	Perceptions of Construction Management contracts	301
8.6.4.4	Clients' perspective upon contract types	302
8.6.4.5	Contractual essentials and barriers	302
8.7	<u>Transfer and management of build requirements</u>	<u>303</u>
8.7.1	Procurement of hardware	303
8.7.1.1	Ownership of procurement decisions	303
8.7.2	Influences upon selection and purchasing criteria	303
8.7.2.1	Financial considerations	304
8.7.2.2	Marketing strategies.....	305
8.7.2.3	Boundaries of hardware supply	306
8.7.2.4	Mixing brand products and components.....	307
8.8	<u>Provision of Hardware and materials</u>	<u>307</u>
8.8.1	Compatibility for task purposes	307

8.8.1.1	Product qualities	308
8.8.1.2	Tool: Product compatibility.....	308
8.8.1.3	Structure: Product compatibility.....	309
8.8.1.4	Environment: Product compatibility.....	310
8.8.1.5	PPE: Task compatibilities.....	310
8.8.2	Compatibility for human interaction.....	311
8.8.2.1	Product: User specification.....	311
8.8.2.2	Product: Handhold design.....	312
8.8.2.3	Product: Movement and manipulation.....	312
8.8.2.4	Product: Interface for perceptual characteristics	313
8.8.2.5	Product: Hazard exposure.....	315
8.8.2.6	Product: Maintenance	315
8.8.3	Manufacturer design developments	316
8.8.4	External factors influencing design.....	317
8.8.4.1	Design ownership issues.....	318
8.8.4.2	Overseas influences	318
8.8.4.3	Standards and specifications.....	319
8.8.5	Operative task technique	320
8.8.6	Summary of latent conditions according to design and task execution factors	321
8.8.6.1	Development of build plan and design	322
8.8.6.2	Transfer of management and build requirements	323
8.8.6.3	Hardware and execution of the work.....	324
8.9	<u>Planning Scheduling & Management</u>	326
8.9.1	Recruiting and organising contractors	327
8.9.1.1	Contractor appointment criteria.....	327
8.9.1.2	Barriers to sub-contractor appointment	327
8.9.2	Factors affecting personnel management and task conditions...	328
8.9.2.1	Skills and health related appointment criteria	328
8.9.2.2	General work organisation.....	329
8.9.2.3	Housekeeping	329
8.9.3	Summary of latent conditions according to Planning Scheduling and Management factors	329
8.10	<u>Information transfer</u>	331
8.10.1	Communication of design requirements	331
8.10.1.1	Designer: Site liaison.....	331
8.10.1.2	Manufacturer: Customer liaison	332
8.10.1.3	Dissemination of accident related information.....	333
8.10.2	Assessing and defining safe practice.....	334
8.10.2.1	Risk assessments and method statements	334
8.10.2.2	Training related issues	335
8.10.2.3	Provision of product information.....	336
8.10.2.4	PPE related issues.....	337
8.10.3	Summary of latent conditions according to Information Transfer factors	338
8.11	<u>Role, skills, abilities and attitudes</u>	341
8.11.1	Role and skills development	341
8.11.1.1	Safety advisers: roles and skill development.....	341
8.11.1.2	Architects and designers: roles and skill development.....	341
8.11.1.3	Senior site management : roles and skill development.....	342

8.11.2	Shortcomings affecting optimum role execution	343
8.11.2.1	Supervisors / managers	343
8.11.2.2	Operatives	343
8.11.2.3	Designers	344
8.11.3	Summary of latent conditions according to Role, Skills, Abilities and Attitudes	344
8.12	Summary of latent condition data.....	345
8.12.1	Transferability of information.....	351
8.13	Critique of the latent condition data analysis	351
9	APPRAISAL, REVIEW AND RECOMMENDATIONS	354
9.1	The research perspective.....	355
9.1.1	Summary and critique of the research programme	355
9.1.1.1	Literature review.....	355
9.1.1.2	Phase One	356
9.1.1.3	Phase Two.....	356
9.1.1.4	Phase Three.....	357
9.1.2	Appraisal of the research methodology.....	357
9.1.2.1	Methodology evaluation	358
9.1.2.2	Supplementary critique issues	360
9.1.2.3	Secondary appraisal of construction accident models	361
9.2	The applied perspective	365
9.2.1	Review and recommendations – proposals for industry	365
9.2.1.1	Design and task execution: Build scheduling.....	365
9.2.1.2	Design and task execution: Design ownership and liaison issues	366
9.2.1.3	Design and task execution: Contractual influences	367
9.2.1.4	Design and task execution: Site layout and information requirements	367
9.2.1.5	Design and task execution: Product procurement and supply	368
9.2.1.6	Design and task execution: Product design, compatibilities and user specification	369
9.2.1.7	Design and task execution: Personal protective equipment (PPE)	370
9.2.1.8	Planning, scheduling and management: Sub-contractor appointment and identity.....	371
9.2.1.9	Planning, scheduling and management: Labour appointment and determination of competence	371
9.2.1.10	Planning, scheduling and management: Health status and fitness for work	371
9.2.1.11	Planning, scheduling and management: Operative supervision	372
9.2.1.12	Planning, scheduling and management: Working hours, pay and remuneration.....	372
9.2.1.13	Planning, scheduling and management: Time pressures, trade overlap, performance and motivation	373
9.2.1.14	Planning, scheduling and management: Welfare facilities.....	373
9.2.1.15	Planning, scheduling and management: Accident investigation	373

9.2.1.16	Planning, scheduling and management: Consultation and communication.....	375
9.2.1.17	Planning, scheduling and management: Provision of suitable task conditions	375
9.2.1.18	Information transfer: Assessing and defining safe practice	376
9.2.1.19	Information transfer: Instruction, guidance on safe practice and skills development	376
9.2.1.20	Roles, skills, abilities and attitudes.....	378
9.2.1.21	Summary of proposals for industry	379
9.2.2	Overview of construction industry initiatives	379
9.2.2.1	'Rethinking Construction' initiatives	379
9.2.2.2	General initiatives to improve health and safety	380
9.2.2.3	General legislative initiatives	380
9.2.2.4	Construction industry legislative initiatives.....	381
<u>9.3</u>	<u>Contribution to knowledge and directions for future work</u>	<u>382</u>
<u>9.4</u>	<u>The way forward.....</u>	<u>383</u>
9.4.1	Integrating the accident investigation, risk and performance assessment processes.....	383
9.4.2	Construction accident modelling.....	385
<u>9.5</u>	<u>Conclusion</u>	<u>386</u>
10	<u>REFERENCES</u>	<u>389</u>
11	<u>APPENDICES.....</u>	<u>404</u>
Appendix 1.	Focus group questionnaire	404
Appendix 2.	The focus group rating scales.....	407
Appendix 3.	Focus group validation sessions.....	409
Appendix 4.	Conference paper	415
Appendix 5.	Conference paper	422
Appendix 6.	Data collection proformas	428
Appendix 7.	The rating scales for stress, job satisfaction and social support.	445
Appendix 8.	Data collection techniques – latent conditions.....	446
Appendix 9.	Accident study data	451
Appendix 10.	Ethical issues	614

List of Tables

Table 1.	The research team	6
Table 2.	Rates of fatal and over 3 day absences per 100,000 construction workers, 1996	9
Table 3.	Injury profile of construction workers 1992 - 2002 – Numbers affected	11
Table 4.	Percentage of injury types to construction workers by kind of accident in 1996 - 2001/02 (provisional)	12
Table 5.	Costs arising from accidents, injuries and ill health at work	14
Table 6.	Pan industry initiatives in 'Rethinking Construction'	17
Table 7.	"Respect for People" Steering Group initiatives	18
Table 8.	National and construction industry 'Revitalising Health and Safety' targets	20
Table 9.	Glossary of roles of construction industry personnel described in CDM	22
Table 10.	Over view of responsibilities under the Construction (Design and Management) Regulations, 1994	23
Table 11.	Summary of Health and Safety in Construction Guidance	24
Table 12.	Evolution of information used in the modelling of accident causation	32
Table 13.	Domino Theory approaches	33
Table 14.	Descriptions of active and latent failure types	37
Table 15.	Summary of contributory factors in accident causation	40
Table 16.	Factors affecting interactions in ergonomics	42
Table 17.	Behaviour types, error representation and solutions	47
Table 18.	Hierarchy of control	49
Table 19.	Common failings in training and procedures	50
Table 20.	Safety culture summarised	54
Table 21.	Recommendations for safety management improvement from 'Research into management, organisational and human factors in the construction industry'	55
Table 22.	Overview of the systems approach	56
Table 23.	Example characteristics and conditions associated with accident events	62
Table 24.	Example diagnostic approaches used in evaluation of systems failure	67
Table 25.	Overview of the systems approach and data collection methods	75
Table 26.	Example failures identified in accident data analysis	76
Table 27.	ARCTM failure types	81
Table 28.	Example factors of the Constraint- Response Model	86
Table 29.	Constraint- Response Model - proximal factors	86
Table 30.	Main headings of MLCM taxonomy (abridged version)	90
Table 31.	Strengths and weaknesses of construction accident models	93
Table 32.	Overview of systems approach integrated with construction model strengths	94
Table 33.	Focus group categories	102
Table 34.	Project Concept, Design and Procurement	103
Table 35.	Work Organisation and Management	103

Table 36.	Task Factors	104
Table 37.	Individual Factors	104
Table 38.	Sample focus group agenda	105
Table 39.	Content appraisal of construction industry accident investigation tools	148
Table 40.	Value of resources used in development of accident study materials	151
Table 41.	Enquiry areas for site based data collection of the work situation	156
Table 42.	Nature of revisions to study data collection techniques	158
Table 43.	Construction profile sampling strategy	160
Table 44.	Percentage representation of reportable injuries to construction industry workers for the time period 1996/7 – 1999/00 (provisional)	161
Table 45.	Practicalities of an accident study	164
Table 46.	Distribution of the accidents studied	169
Table 47.	Distribution of accident types	170
Table 48.	Temporal details of accident sample	171
Table 49.	Description of task and activities within the accident sample	171
Table 50.	Job roles of participants included in the site-based interviews	173
Table 51.	Criteria used to categorise data collected during accident studies	174
Table 52.	Summary of site based accident study data	194
Table 53.	Active failures within the accident study sample	195
Table 54.	Site factors within the accident study sample	197
Table 55.	Organisational factors within the accident study sample	198
Table 56.	Categorisation of site data findings	202
Table 57.	Summary of results according to design and task execution factors	216
Table 58.	Working hours according to job role	224
Table 59.	Payment for sickness absences	225
Table 60.	Payment for holiday absences	225
Table 61.	Accident record forms to fulfil regulatory requirements	229
Table 62.	Summary of results according to Planning, Scheduling and Management factors	236
Table 63.	Summary of results according to Information Transfer factors	247
Table 64.	Employment and educational training of personnel in a safety role	249
Table 65.	Summary of results according to Role, Skills, Capabilities and Attitude factors	262
Table 66.	Summary of qualitative site data findings	266
Table 67.	Further exploration suggested by project specialists	272
Table 68.	Overview of research pursuit for the follow-up proposed by specialists	276
Table 69.	Summary of latent condition accident study data	291
Table 70.	Profile of resources used in latent factor data collection	292
Table 71.	Distribution of interviewees included in latent factor work	293
Table 72.	Categorisation of latent conditions	294
Table 73.	Summary of site latent conditions: Design and task execution	322
Table 74.	Summary findings for site data and latent conditions	350

Table 75.	Follow-up suggestions for the final ten accidents	351
Table 76.	Abridged summary of the site data and latent conditions findings with tentative annotation of the construction model attributes	364
Table 77.	Project concept, design and procurement – Mean values (standard deviation in brackets)	407
Table 78.	Work organisation and management – Mean values (standard deviation in brackets)	407
Table 79.	Task factors – Mean values (standard deviation in brackets)	408
Table 80.	Individual factors - Mean values (standard deviation in brackets)	408

List of Figures

Figure 1.	Overview of the research programme.....	5
Figure 2.	'Rethinking Construction' 'drivers' and 'targets for improvement'	16
Figure 3.	Accident cause levels.....	34
Figure 4.	Models of human and general failure	36
Figure 5.	A model of organisational accident causation	38
Figure 6.	Interactions in ergonomics.....	41
Figure 7.	Types of human failure.....	46
Figure 8.	Alternative model of accident causation.....	77
Figure 9.	The Distractions Theory	80
Figure 10.	ARCTM Model (abridged version)	82
Figure 11.	The Constraint- Response Model of accident causation.....	84
Figure 12.	The Modified Loss Causation Model	90
Figure 13.	Phase One of the research.....	98
Figure 14.	Project concept, design and procurement – Mean responses.....	135
Figure 15.	Work organisation and management – Mean responses.....	136
Figure 16.	Task factors – Mean responses	137
Figure 17.	Individual factors – Mean responses	138
Figure 18.	Phase Two of the research	145
Figure 19.	Developing search terms for the accident study methods	152
Figure 20.	Accident selection process.....	163
Figure 21.	The benefits of combining 'accident' and circumstantial information	203
Figure 22.	Rated responses for stress, job satisfaction and social support	261
Figure 23.	Information transfer – the central role	267
Figure 24.	Phase Three of the research	269
Figure 25.	Process used to collect latent factor information.....	275
Figure 26.	Constraints impacting on product development, purchase and use	324
Figure 27.	Content of review and recommendations	354
Figure 28.	Current and proposed assessments to prevent accident causation	384
Figure 29.	Revised model of accident causation.....	385

1 INTRODUCTION

The construction industry has a longstanding reputation for offering dangerous employment, both in the UK and internationally (Health and Safety Executive 1978, Health and Safety Executive 1988, Bureau of Labor Statistics 2001, Health and Safety Executive 2000). Whilst formerly the sector with the highest fatality rates, UK construction deaths currently (2000/01 data) fluctuate at ~ 32% of all worker fatalities (Health and Safety Commission 2001a). Fatality numbers have more than halved in the last 20 years, indicating tremendous improvements, yet death and major injury rates remain high (Health and Safety Commission 2001a). In the past five years there has been a mean fatality rate of 82 deaths per year - more than one construction worker death per week (2.2.1¹).

Statistics from the Department of Trade and Industry indicate that the UK construction industry has manpower of approximately 1.5 million workers. This figure has increased steadily (approximately 10%) since 1996. Employees are predominantly male (only 12 - 13% of construction workers are female) and there is a high ratio of self-employed to employed workers (Department of Trade and Industry 2002). There is tremendous variety in the type of projects undertaken and a number of different styles for managing and financing a build project. Consequently there are perpetual fluctuations in demand for manpower, managed by casual or subcontracting of employment and specialist works (Whittington et al. 1992) and resulting in low employment security (Helander 1981). At site level, construction work is divided between many different trades. Longstanding problems associated with these employment types include physically straining and often monotonous work, weather exposure, lengthy commutes or spells working away from home and coping with poor site conditions (Koningsveld 1997).

The varied organisational structure, work environment and profile of employment all pose unique challenges to the efficiency of management in the construction sector. Analyses of data from earlier government sponsored research into construction

¹ Cross-reference style, used throughout the thesis, that refers to related or supplementary information in another section - in this case section 2.2.1

fatalities (Health and Safety Executive 1978, Health and Safety Executive 1988), (2.5.1) and the RIDDOR reporting scheme (Health and Safety Executive 1999b), (2.2.1) has generated a wealth of evidence portraying accident causes, such as failings in safe systems of work, maintenance, material failures and poor supervision and training. However, these analyses, although rightly revealing a clear profile of accident types, patterns and trends from which to generate intervention, failed to reveal what happened; they do not indicate the causal factors.

There has also been government sponsored research into the factors affecting construction safety management (Ministry of Labour 1967, Whittington et al. 1992), (3.6.5.2). Despite the time interval between each there were many recommendations in common (such as improvements in training, communication, work planning for example). The Whittington et al. (1992) Contract Research Report –‘Research into management, organisational and human factors in the construction industry’, identified headquarter, site and individual factors (1:2:1 ratio) in an analysis of 30 case studies of construction accidents. However, their analyses were impeded by access to accident data that was insufficient and incomplete; it was only through interviews with safety, site project management and client personnel that they were able to explore and advise upon factors affecting safety management.

Since the 1992 report, new legislation, the Construction (Design and Management) Regulations 1994, has been introduced (Health and Safety Commission 2001b) (2.5.5), which accommodated many of the Whittington et al. (1992) recommendations. The key feature of this legislation is the placement of new duties upon clients, client agents, designers and contractors to account for, co-ordinate and effectively manage all stages of the construction process, from conception and design through to undertaking the work and making arrangements for subsequent maintenance and repair. Concurrently during the 1990s there have also been positive reports of safety improvements on construction sites by changing personnel behaviour (Robertson et al. 1999). More recently, in the past five years, there has been the implementation of extensive government initiatives for all round improvements in the construction industry (2.5.2 and 2.5.3).

In spite of these interventions, accident rates in the industry remained unacceptably high. The Health and Safety Executive (HSE) invited proposals to investigate accident causation in the construction industry.

1.1 Overview of the research strategy

The current research developed from the HSE Mainstream Research Market 1998/9 'Competition for Ideas' and commenced in October 1999. The research application and programme was devised by the Project Directors, Dr Roger Haslam (Department of Human Sciences), Dr Alistair Gibb (Department of Civil and Building Engineering) and Dr Diane Gyi (Department of Design and Technology) at Loughborough University. An important component of the HSE funding was to work in collaboration with a team from UMIST (Dr Roy Duff and Dr Akhmad Suraji, Department of Civil and Construction Engineering) who were already researching and had modelled construction accident causality by analysis of the HSE 'FOCUS' database reports (a database of HSE Inspector reports).

The proposal was to undertake a three-year research programme, the main focus of which was the detailed investigation of 100 construction accidents. This thesis concerns the study of 40 construction accidents, of which 30 were subject to further detailed exploration of latent factors. Four researchers completed the remaining site based accident studies. The chapters for Phases One, Two and Three were prepared by the author and form the main body of this thesis. They were also used by the project directors who, supplementing these data with findings from the outstanding site based accident studies, prepared the contract research report.

1.1.1 Rationale for research methodology

This was the first large-scale study involving data collection of a range of construction accidents using an ergonomics approach; there is no precedent in use of such methods for construction accident investigation. All previous construction related work has entailed analysis of third party data (HSE inspector reports or provision of case study material) and is vulnerable to the nature of investigation, and style of documentation and analysis by those involved (3.9.5). For example, HSE inspectors consider the accidents primarily in the context of enforcement and potential for legal proceedings - as such the depth or direction of investigations may be unduly biased towards this

outcome. There is also a history of poor notification of reportable accidents (2.2.1). More simple problems, possibly caused by lack of time or insight, may also result in insufficient data (Whittington et al. 1992) and subsequent inadequacies in comprehensive analysis (Gyi et al. 1999). Inadequate baseline data does not serve well in the formation and implementation of policy.

1.1.2 Aim and objectives of the research

The aim of the research was to explore the nature of accident causation in the construction industry.

The objectives of the research were to:

- Review theories of accident causation and explore initiatives into construction accident modelling for use in the research methodology
- Identify aspects that should be addressed in construction accident investigations
- Undertake detailed investigation of a representative sample of 40 construction accidents
- Provide guidance on better use of accident data
- Provide guidance upon the outcomes of the research

1.1.3 The research programme

The research plan was developed as a three-phase process of data collection. An overview of the integration of research activity and input from industry is provided in Figure 1. The nature of the inputs and integration of information are described further in the chapters for each relevant phase.

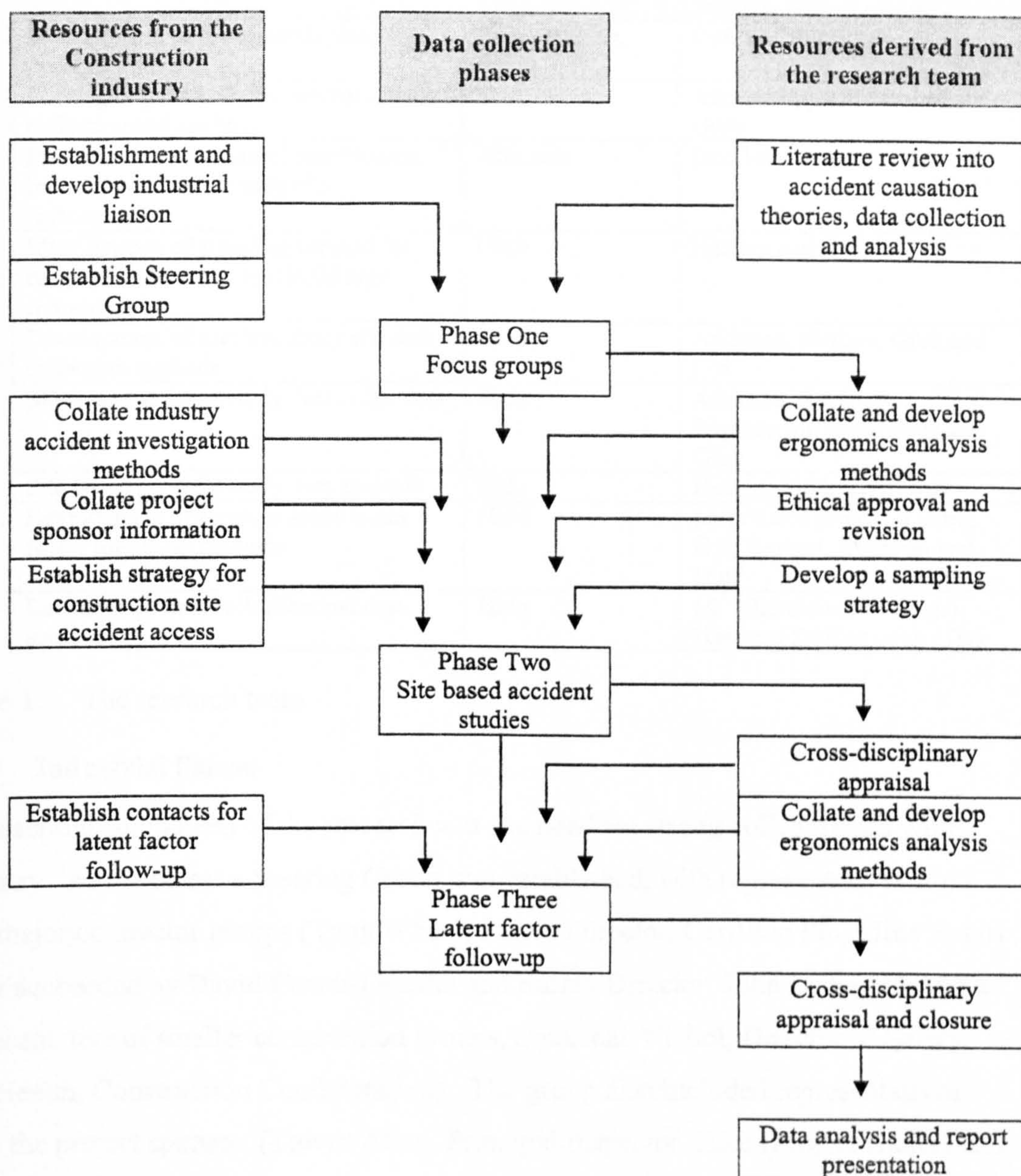


Figure 1. Overview of the research programme

1.1.4 The research team roles and contribution

The research was undertaken by a total of nine people. The author, Sophie Hide, was a research student between November 1999 and October 2002. Sarah Atkinson (nee Hastings), Research Associate in the Health and Safety Ergonomics Unit, Loughborough University was appointed half time on the project for the first two years. Two researchers from the Department of Civil and Building Engineering, Loughborough University, assisted with data collection in the final year of the research. Roles are described in Table 1 below.

	Lead role	Further contribution
Development of the research plan	Haslam, Gibb, Gyi	Duff and Suraji
Focus group method development, data collection and analysis	Hide	Atkinson (questionnaire) and Gibb
Preliminary evaluation of construction industry accident investigation techniques	Atkinson	(and later revision) Hide
Identification of sampling method for range of build sector and build type representation	Gibb	Haslam and Gyi
Development of accident study site data collection methods	Hide	Atkinson, Haslam, Gibb and Gyi
Site based accident study data collection	Hide	Atkinson, 2 x Civil Engineering researchers and Gibb
Site based accident study data analysis	Hide	Haslam, Gibb, Gyi, Duff
Development of accident study latent factor follow-up methods	Hide	(& practice protocol) Gibb, Gyi, Haslam, Atkinson and Duff
Latent factor data collection and data analysis	Hide	(& validation of findings) Haslam / Duff or Gibb / Gyi

Table 1. The research team

1.1.5 Industrial liaison

An essential component of the research was the need for strong collaboration with industry. At the outset a Steering Group was established, with representatives from two major contractor groups (Tony Wheel, Safety Director, Carillion Plc; Mike Evans (later succeeded by David Cowan) Health and Safety Director, John Laing plc, and a representative of smaller construction groups, Suzannah Nichol, Director of Safety and Health, Construction Confederation). The group also included representatives from the project sponsor, (Trevor Allan, Principal Inspector, HSE (Project leader) and Bob Tunnicliffe (HSE Inspector, HSE), and Tom Mellish representing the TUC, in addition to the researchers from Loughborough University and UMIST.

Industrial collaborators offered assistance in the publicity and establishment of field contacts. There were also numerous other publicity measures and ‘calls for assistance’, through use of HSE press release and newsletters, through contacts of construction specialists on the research team, through conferences & workshops and through news sources of the construction industry (magazines and other news articles).

1.1.6 Project boundaries

At the project outset, it was established that accidents already under investigation by HSE Inspectors would be not be included. There were a variety of reasons – to avoid duplication of effort, to avoid situations where interviewees were already under duress and fear of enforcement action, and to avoid generating information that might be subpoenaed as evidence. This precluded all fatal accidents and some major incidents.

Just prior to commencement of accident data collection, the investigation requirements of HSE Inspectors (to increase their field work and analysis of major accidents) increased. This further reduced access to major accidents; nevertheless there were many other incidents with risk potential for more serious outcomes – management of the accident sample is discussed in Phase Two.

To further distance the research from HSE investigation (to avoid any misconception and enhance distinction during field studies) it was suggested by the project Steering Group that data collection by the researchers should be called ‘accident studies’. This expression was used henceforth in this thesis.

1.1.7 Structure of the thesis

The research is presented over eight further chapters. The first two extend the introduction to the research and explore accident causation and modelling. The next five chapters describe the methodology, data collection and results for Phases One to Three. The final chapter identifies the outcomes and concludes the research. The content of each chapter is discussed below:

Chapter Two gives a profile of construction accidents and injuries and introduces improvement measures that have been undertaken by the construction industry and Health and Safety Executive

Chapter Three introduces the history of accident causation and the knowledge sources that have contributed to understanding. Construction accident models are appraised in the light of these findings

Chapter Four introduces Phase One of the research, the information search using focus groups among industry personnel to explore their perceptions of accident causation

Chapter Five introduces the methodological approach and resources used to develop accident study techniques for Phase Two of the research

Chapter Six provides a profile of the accident sample and participants during site data collection

Chapter Seven reports the qualitative analysis used in analysis of findings from site data collection

Chapter Eight introduces Phase Three of the research, the deeper exploration by follow-up of the accident latent conditions

Chapter Nine offers a review of the findings, proposes recommendations and identifies areas where further enquiry is required. It also concludes the research

2

CONSTRUCTION INDUSTRY - CURRENT STATUS

This chapter provides a broad base of information about the construction industry. Firstly it expands upon information provided in Chapter One about the construction industry accident and injury profile, from both an international and UK perspective. Data sources, and the misperceptions that might arise through under-reporting are also described. Tremendous costs arise from the effects of accidents and, through understanding of these, the chapter concludes with an introduction of the range of improvement initiatives that affect, or have been generated by, the construction industry.

2.1 International construction industry accident and injury profile

Construction fatal and major injury rates continue to be key concerns in the UK, yet data comparisons reveal that the UK figures are in fact considerably lower than nearest comparable figures in the United States and are among the lowest when compared with other European Union countries (Health and Safety Executive 2000). Even accommodating the fidelity of differing reporting strategies across EU countries (government inspectorate data is used in the UK and is thought to be less comprehensive than social security system or insurance company data used elsewhere in the EU), the UK appears to experience a considerably lower rate (per 100,000 construction workers) of fatal and over three day absences (Table 2, Health and Safety Executive 2000).

EU mean		Great Britain	
Fatal	Over 3 day absence	Fatal	Over 3 day absence
13.3	8000	5.6	2700

Table 2. Rates of fatal and over 3 day absences per 100,000 construction workers, 1996

In 2001 the United States construction industry, with ~ 9 million workers, had the highest level of fatalities among all employment types. The mean number of fatalities in the years 1996 – 2000 was 1135/year, representing a fatality rate of 13.3 (per 100,000 workers, (Bureau of Labor Statistics 2001). Data of injury and absence are collected differently in the United States; however under-reporting is also felt to be a problem there, especially due to fear of loss of work and negative publicity

(Zimmerman et al. 2001). Zimmerman et al. report that annual surveys exclude the self-employed or small businesses with less than ten employees, despite the fact that (in combination) these constitute 80% of construction establishments.

The International Labour Organisation estimates that four percent of the world's Gross Domestic Product (GDP) disappears with the costs of absences resulting from work related ill-health, treatments and the provision of resulting disability benefits (International Labour Organization 2002).

2.2 UK Construction industry accident and injury profile

Notwithstanding the impression gained of construction accidents and injuries in the international arena, the construction industry has one of the highest rates of fatal and major injuries among all industry types within the UK (Health and Safety Commission 2001a). Around 7.3 million working days were lost through injury in 2000/01 and the majority of these (7.1million) were reportable (over 3 days) absences (Health and Safety Commission 2002b). Data that compare these by industry types and adverse outcomes are generated through two separate resources – (i) by employer reporting and (ii) from householder responses via national survey.

2.2.1 Employer reporting via RIDDOR

Employer reporting concerns obligatory notification according to specifications of the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR 1995, Health and Safety Executive 1999b). Within these regulations, reporting is required under stipulated circumstances, such as work induced fatalities, major injuries (generally resulting in hospitalisation), injuries resulting in absences of three days or more, specified dangerous occurrences and work related ill-health. The Health and Safety Commission publish analyses of these data. Summary findings of the number of construction industry workers with reportable conditions (combining self-employed and employed personnel) are reproduced in Table 3. The marked changes in major injury and over 3 day absence figures from 1996 reflect a changed reporting structure and obsolescence of the preceding Regulations, the Notification of Accidents and Dangerous Occurrences Regulations 1980 (NADOR).

	Worker fatalities	Fatalities (rate per 100,000 workers)	Major injuries	Over 3-day absence
1992/93	96	5.9	2745	12719
1993/94	91	5.7	2574	11073
1994/95	83	5.1	2627	11174
1995/96	79	5.0	2477	14735
1996/97	90	5.6	4054	9666
1997/98	80	4.6	4326	10265
1998/99	65	3.8	4656	9576
1999/00	81	4.7	4749	10504
2000/01	105	5.9	4708	9796
2001/02p	79	4.2	4480	9587

(p = provisional)

(Health and Safety Commission 2001a)

(Health and Safety Commission 2002b)

(Health and Safety Executive 2002d)

Table 3. Injury profile of construction workers 1992 - 2002 – Numbers affected

Data reveal a gradual decline in construction fatalities during the 1990s. However fatalities peaked in the year 2000/01 with 105 deaths reported - a 31% increase from the preceding year. Data for 2001/02 indicate that construction worker fatal injury rates were lower than in most of the 90s. Of the 249 deaths (provisional) reported across all industries in the year 2001/02, 79 (32%) of these affected construction industry workers (Health and Safety Executive 2002d).

Construction fatalities rates vary by age group, with no clear pattern for each year. For example in the combined years 1999/00 – 2000/01, 45% of fatalities affected the 35 – 54 year age bands. In the reporting year 2000/02 (p), however, fatalities rates were higher still for the 20-24 and 55 plus age groups (Health and Safety Executive 2002b).

Injury types that caused construction fatalities are reproduced in Table 4, which compares latest available data with mean values for the preceding five years. Almost half of all construction fatalities are the result of falling from a height. Data reveal that construction fatalities from falls from a height have reduced in the past 5 years, whereas other injury types, such as being 'struck', are mostly unchanged in this time period or fluctuate with no particular trend. Falls from a height predominately concern structures or equipment such as roofs, ladders or scaffolds.

	Fatalities		Major injuries		Over 3 day absence	
	1996/2001 mean	2001/02	1996/2001 mean	2001/02	1996/2001 mean	2001/02
Falls from height	53%	47%	36%	30%	13%	10%
Struck by a moving vehicle	11%	14%	2%	2%	1%	1%
Struck by a moving / falling object	13%	15%	19%	18%	18%	16%
Trapped by something collapsing / overturning	7.2%	5%	-	-	-	-
Slip and trip – same level	-	-	20%	26%	18%	22%
Handling, lifting or carrying injury	-	-	9%	9%	35%	35%
Other	-	19%	-	14%	-	15%

Source: (Health and Safety Executive 2002a) &
(Health and Safety Executive 2002c)

Table 4. Percentage of injury types to construction workers by kind of accident in 1996 - 2001/02 (provisional)

Data also reveal construction worker injury types resulting in major injuries and absences over three days. Falls from a height are also the most common injury source for major injuries but, as with over 3 day absences, injuries arising from slips and trips and being struck by a moving or falling object are much more prevalent. Injuries arising from slips and trips have had increased influence in incidences of major and over 3 day absences in the 2001/02 period. Over 3 day absences are most commonly caused by injuries arising from handling, lifting or carrying and this remains consistent with data from the preceding 5 years.

2.2.2 Individuals reporting via the Labour Force Survey

The second information source is the British household Labour Force Survey (LFS). Within this, and at three yearly intervals, the HSE has included additional questions concerning workplace accidents and injuries, and any subsequent absence resulting from these (Health and Safety Commission 2002b). These data are compared with RIDDOR statistics to identify commonality or disparity in reporting, and to explore trends across industries.

Comparison of RIDDOR and latest available LFS figures (2000/01) indicate that over recent years and across all employment areas, there has been a 1-2% decline in the level of reporting by employers. Even at a reporting rate of only 52% (1999/2000) the construction industry reporting rates compare favourably with general reporting rates across all employers types, whose estimated reporting of RIDDOR reportable injuries

was 44% (Health and Safety Commission 2002b). Nonetheless, data have revealed that construction workers major injury rates are currently the lowest since 1996 (Health and Safety Commission 2002a).

Information concerning 'construction workers' has combined figures for employees and the self-employed. The self-employed constitute approximately 35% - 38% of construction workers, yet RIDDOR: LFS data comparisons show that the self-employed reported less than 5% of their injuries. The self-employed experience a higher injury rate than employees and this is attributed to higher risk occupations of self-employed personnel in the industry (Department of Trade and Industry 2002).

2.3 Key points from all resources

Data analysis from both RIDDOR and LFS resources has identified summary trends of the construction industry and construction industry employees over the past two years:

- Construction trades and unskilled jobs are reported to be among the top 20 riskiest occupations. These 20 occupations represent ¼ of all occupations and employment, but more than half of all reportable injuries in 1999/2000.
- The construction industry has above average rates of work related injury (as do transport, storage and communication, agriculture, manufacturing, public administration and extraction sectors).
- Construction workers have the highest rate of working days lost among all employees, with 40% of those suffering work related injury being absent for over three days.
- In 2000/02, the construction industry lost 1 196 500 working days and of these 1 169 400 (24.3days average absence) were due to reportable injuries (97.7%)
- Construction workers with least time with their employers (or experience of being self-employed) have the highest rates of reportable injuries

(Health and Safety Commission 2002b)
(Health and Safety Executive 2002b)

2.4 Estimated costs of accidents

Selected RIDDOR, Labour Force Survey and case study data have been the subjected to detailed analysis to identify costs arising from workplace accidents and work-related ill health (Health and Safety Executive 1997a, Health and Safety Executive 1999a). Whilst sampling and data collection methods inhibit direct comparisons between different years, data for the two collection periods in 1990 and 1995/96

(Table 5) indicate the considerable and consistent costs to employers, to individuals and their families and to society as a whole - as a result of accidents, injuries and dangerous occurrences in the workplace.

Costs to employers		Costs to individuals / families		Costs to the British economy	
1990	1995/96	1990	1995/96	1990	1995/96
£4 - £9 billion / year	£3.5 - £7.5 billion / year	£5 billion / year	£5 - £6 billion / year	£6 - £12 billion / year	£9.9 - £14.1 billion / year
To <u>individuals and their families</u> these costs include: - <ul style="list-style-type: none">• Loss of or reduced income• Loss of capacity to pursue work of comparable remuneration• Additional expenditure for health care uptake• Losses in general welfare and quality of life.			To <u>society in general</u> these costs include: - <ul style="list-style-type: none">• Loss of economic output (national payments for support of the debilitated worker or their families)• Resource costs (administrative, health service and HSE investigative costs to tax payers)• Human costs (arising from pain, grief and suffering)		
To <u>employers</u> these costs include: - <ul style="list-style-type: none">• The costs of accident investigation, provision of first-aid and support of the debilitated worker in post• Worker absence consequences (such as provision of cover or overtime and any losses affecting production output, quality and delays meeting contractual obligations)• General costs arising from administrative duties (such as organising sickness absence payments and arranging for cover or recruitment and provision of training for replacement staff)• Replacement of damaged goods, materials, plant and equipment; payment of increased premiums for liability insurance• Fines / penalties imposed by regulatory bodies or for legal proceedings• Loss of goodwill both within and outside the company.					

(Davies and Teasdale 1994)
(Health and Safety Executive 1999a)

Table 5. Costs arising from accidents, injuries and ill health at work

These findings apply to industry as a whole, yet an important contribution to these outcomes has been evidence arising from construction industry case study data. Accidents were sampled in a range of different UK industries (including, manufacturing, transport, petro-chemical, health care and construction) in a series of 13 – 18 weeks case studies. For the construction case study, accidents occurring on a supermarket build were evaluated in the context of losses to the employer (Table 5). These data showed that accident costs in the construction sample (£700,000) constituted 8.5% of the tender price (value £8 million) and that uninsured costs were 11 times greater than the insurance premium costs (Health and Safety Executive 1997a). Unique to the construction case study was that an overwhelming proportion of the sample (3570+) were non-injury accidents.

2.5 Improvement measures affecting the construction industry

The current methods of data analyses described above reveal the current trends and patterns of construction accident causation analyses. Analysis by integration of RIDDOR and self-reported data is only a recent development and, whilst the HSC have always presented findings of annual NADOR / RIDDOR reportable figures, earlier detailed governmental research initiatives have been instrumental in the evolution of understanding and generation of interventions.

2.5.1 Previous government led research

As precursors to the current research into accident causation in the construction industry, there have been a number of governmental research initiatives, incorporating both survey techniques and retrospective analyses of construction fatalities. Of note there are four reports. Two are epidemiological studies of fatality data (Health and Safety Executive 1978, Health and Safety Executive 1988). The other two are industry surveys, one of a sample of accident cases (Ministry of Labour 1967), the other relating to safety management in construction (Whittington et al. 1992), (3.6.5.2).

The studies have been important data sources, for revelation and identification of trends and patterns and for proposals in support of the generation of improvements. In spite of the twenty-four year gap between the first and last studies, there are common themes to many of the accident profiles (the high fatality rates associated with falls, for example). The two epidemiological studies were 10 years apart and the second, 1988 study, reported that there had been little change in basic causes of construction fatalities in the preceding 10 years – of the 739 deaths included they felt that 90% could have been prevented, 70% of these by positive management action.

Nonetheless, recommendations for improvement have successively focused upon design and organisation of site, choice of materials, equipment and PPE, proper supervision and allocation of responsibilities, housekeeping, workforce training, the planning of a safe system of work and issues associated with individual behaviour and motivation.

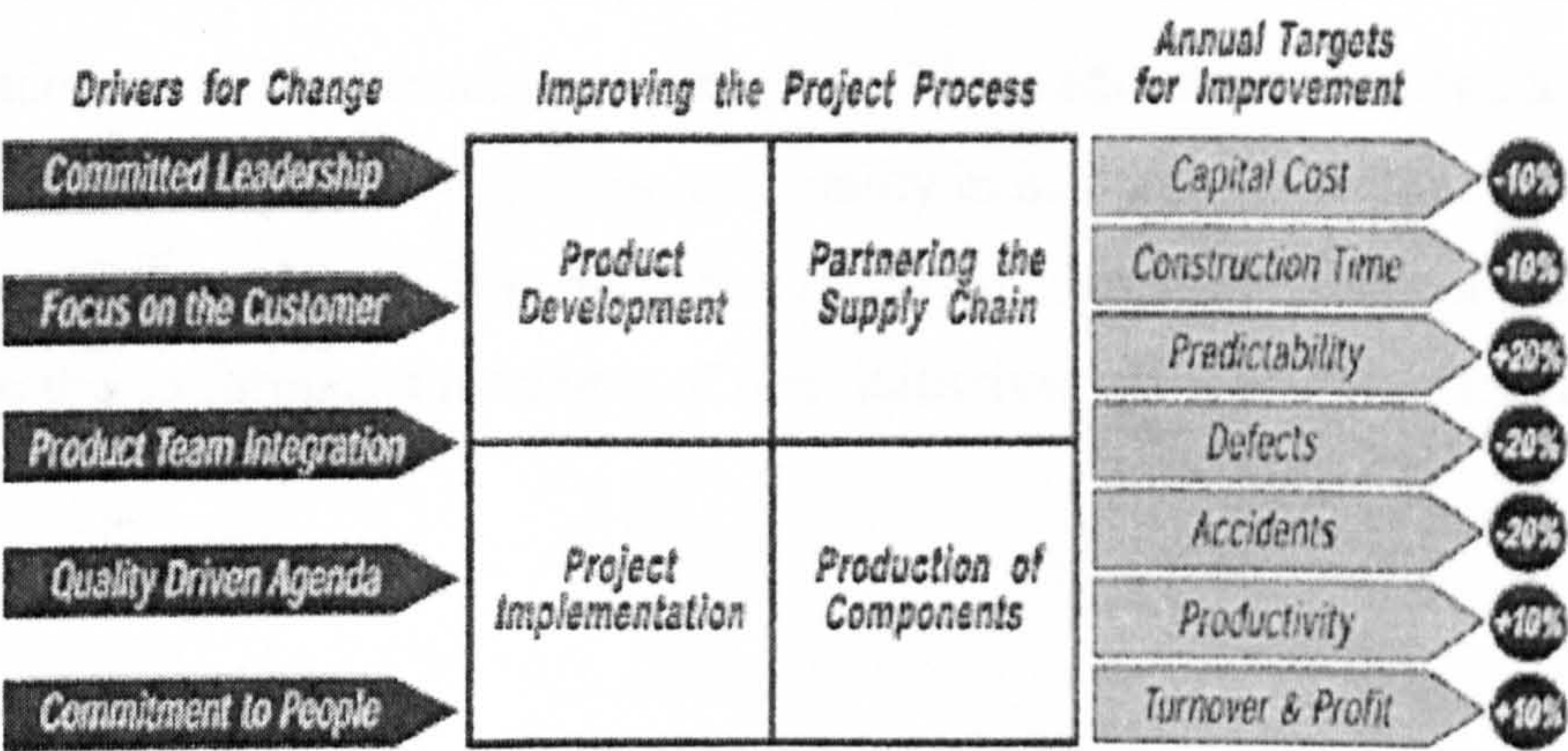
More recent improvement initiatives draw upon these recommendations, but have also been based upon recommendations published by the ‘Construction Task Force’ (led by Sir John Egan) in July 1998.

2.5.2 Construction specific initiatives and targets for improvement

The ‘Construction Task Force’ was a government initiative, commissioned by John Prescott (Deputy Prime Minister), to assess the efficiency of the construction industry. Egan’s report, ‘Rethinking Construction’, identified widespread under achievement in terms of profits and investment in capital, research, development and training (Department of Trade and Industry 1998b). Targets and ‘drivers for change’ were proposed, to improve construction productivity and profits, and to reduce defects and accidents.

There were five ‘drivers for change’ – these are described below and shown, with the targets for improvement, in Figure 2:

- **Committed leadership** – management commitment to change
- **A focus on the customer** – emphasis on fulfilling client /consumer needs
- **Integrated processes and teams** – dissipate fragmented production / process operations
- **A quality driven agenda** – avoid waste and uncontrolled costs
- **Commitment to people** – improved facilities, respect and development opportunities



Source: (Strategic Forum for Construction 2002)

Figure 2. ‘Rethinking Construction’ ‘drivers’ and ‘targets for improvement’

Organisations representing house building, private sector building and local government building (later amalgamated as Rethinking Construction Ltd), were subsequently charged with determining objectives and methods for implementation of the ‘targets for change’. Pan industry initiatives focused on the development of demonstration projects (used to publicise initiatives) and key performance indicators (used to measure outcomes) (see Table 6). Close collaboration with the Construction Best Practice Programme, (a Department of Trade and Industry initiative) promoted group effort and dissemination of examples of improved performance throughout industry.

Initiatives	Role	Application
Demonstration project programme	Forefront organisations demonstrate innovation and change that can be measured and evaluated.	Off-site fabrication, standardisation, use of new technology, respect for people initiatives, partnering and supply chain integration and other process improvements.
Key performance indicators	Measures, directed towards achievement of the ‘targets for improvement’. Against which all demonstration projects are measured and benchmarked.	Client satisfaction – product & services; defects - safety; cost predictability in design & construction; time predictability - design & construction; profitability; productivity – cost, time.

Table 6. Pan industry initiatives in ‘Rethinking Construction’

The organisations also incorporated a number of working groups. These had a specific remit to explore and develop the initiatives whose contribution would impact upon the success of the demonstration projects. These addressed aspects such as ‘environmental sustainability’ and ‘design quality indicators’ and ‘respect for people’. The ‘respect for people’ working party specifically incorporated accident reduction objectives: the performance measures of their initiatives are reproduced in Table 7.

Respect for People Steering Group		
Initiatives	Development of toolkits, checklists and key performance indicators to improve performance on people type issues.	
Performance measures and criteria used in assessment	Employee satisfaction	1-10 rating (reflecting opinions of pay, job control, sense of achievement, respect from supervisors / co-workers)
	Staff turnover	Employee turnover as a % of full-time equivalent (FTE)
	Absence from work	Sickness absence as a % of normal working time
	Safety	Reportable accident rates
	Working hours	Hours per week, including overtime
	Travel time	Home to work travel time
	Training and development	Number of training days per employee per year. % of workforce qualified / certified
	Pay	Gross earnings per FTE
	Investors in People	Measured against existing standards for training and development of people

Source: (Rethinking Construction 2000)
(Department of Trade and Industry 2002)
(Investors in People 2003)

Table 7. “Respect for People” Steering Group initiatives

‘Rethinking Construction’ was retained as the umbrella term to describe the initiatives adopted by the construction industry, construction clients and the government to improve performance. A body of industry representatives, the ‘Strategic Forum for Construction’, was established in 2001 to lead and overview progress with the implementation of initiatives among the organisations and working groups. To accelerate change and secure continuous improvement three specific ‘drivers’ have been the subject of renewed intervention and guidance, and are currently ongoing:

- **Client leadership** – following a Clients Charter for change
- **Integrated teams and supply chains** – improved relationship continuity of supply chain
- **People issues** – especially health and safety

Appraisal of ‘Rethinking Construction’ progress was last undertaken in 2002. There had been over 400 ‘demonstration projects’ and, when compared with the Key Performance Indicators results show improvement in all areas, the most successful of which was safety, with a 100% improvement in accident rates – i.e.: Reportable accidents on demonstration projects were 50% lower than the construction industry mean (Strategic Forum for Construction 2002). These initiatives are ongoing and

findings from the current research will be incorporated to direct and guide future initiatives.

2.5.3 General initiatives to improve health and safety

In close allegiance to the 'Rethinking Construction' initiatives is the 'Revitalising Health and Safety' strategy that has been adopted by the Health and Safety Commission (Health and Safety Commission 2000). Essentially the 'Revitalising Health and Safety' strategy had close allegiance with the 'Rethinking Construction' initiatives (although for the attention of all industry types). Launched for consultation (again, by John Prescott, Deputy Prime Minister and by Bill Callaghan, Chair of the Health and Safety Commission) in 1999, the aim was to review and identify new approaches that could inject new life into the health and safety initiatives; a 25 year review after the introduction of the Health and Safety at Work Act 1974.

The responses generated a ten-point strategy of aspects to be targeted for improvement:

- Promote better work environments
- Promote a happy, healthy and productive workforce
- Prioritise occupational health
- Engage small firms in participating
- Motivate employers to improve health and safety performance
- Cultivate self-regulation
- Establish worker: employer partnership on health and safety issues
- Provide leadership through government procurement
- Significantly improve education
- Technical design to improve health and safety

(Health and Safety Commission 2000)

A ten-year plan was made, setting targets for reductions in work related absences and ill health across UK workplaces by 2010. Individually, industries were invited to set their own targets for improvement and reduction in fatalities, injuries and ill health. The Construction Industry Advisory Committee (CONIAC), representing the HSE and

key industry stakeholders, undertook this (Working Well Together 2001). The national objectives and construction industry targets are reproduced in Table 8.

	All industry targets	Construction industry targets
To reduce the number of working days lost from work related injury and ill-health	By 30% by 2010	20% by 2004/5 and by 50% by 2009/10
To reduce the incidence of fatal and major injury accidents	By 10% by 2010	by 40% by 2004/5 and by 66% by 2009/10
To reduce the incidence of work related ill health	By 20% by 2010	by 20% by 2004/5 and by 50% by 2009/10
To achieve half the targets by	2004	-

Table 8. National and construction industry 'Revitalising Health and Safety' targets

2.5.4 General legislative initiatives

The construction industry, as with any other area of work, has to comply with the duties defined by the Health and Safety at Work Act, 1974. As an enabling Act, many regulations have been created to provide suitable detail; the Regulations, in many cases, fulfil the requirements of European Union (EU) directives (Cronor 2002). EU initiatives arising from the Single European Act, 1986 introduced directives for enactment by member states. From these, and originating as the Framework Directive, came the Management of Health and Safety at Work Regulations (MHSW), 1992 (revised 1999). This directive stipulated duties upon employers to take a systematic approach to the management of health and safety at work through the following measures:

- Identify hazards and assess the risk of harm in work activities
- Determine methods to prevent and/or control risk
- Monitor control measures where necessary
- Provide information and training to staff

These measures form a common approach to risk reduction within other related health and safety directives (eg. manual handling of loads) and are also applicable in the construction industry.

2.5.5 Construction legislative initiatives

A later directive from the EU concerned the 'Construction Sites Directive', "for the implementation of minimum safety and health requirements at temporary or mobile construction sites" (Commission of the European Communities, 1992). This was implemented in the UK as two sets of regulations. For the most part implementation fell within the Construction (Design and Management) Regulations, 1994. Later regulations, the Construction (Health, Safety and Welfare) Regulations, 1996 implemented Annex IV of the 'Construction Sites Directive' and drew together and updated related but disparate industry guidance of a more technical nature.

The Construction (Design and Management, 1994) or 'CDM' Regulations follow the systematic approach to management of health and safety at work, with construction specific guidance. CDM applies only to projects lasting more than 30 days, or where more than 500 person days are expended (Health and Safety Commission 1995). The aims of CDM are:

- A strategic approach to health and safety in project design, procurement, planning, preparation and execution
- Effective management and co-ordination of health and safety throughout a project
- Selection only of those with competence and resource
- Improved management of construction work

(Allan 2000, p. 91)

CDM requires the preparation of documentation for the consolidation of health and safety information. These are the 'Health and Safety Plan' and the 'Health and Safety File':

- The H&S plan is developed in two phases - initially in outline form during the pre-tender phase to alert interested contractors to key health and safety issues and the nature of the project. Later, during the construction phase, the plan is developed to include information about

procedures, emergency, work, welfare and communication arrangements.

- The H&S File records information for use by those involved in any later construction, maintenance, renovation or cleaning work after completion.

CDM explicitly, and for the first time, defined clients and designers roles in construction health and safety (Health and Safety Commission, 2001b). CDM also specified responsibilities of those involved in the construction lifecycle, including clients, designers, planning supervisors, principal contractors and contractors. A glossary of roles is provided in Table 9; their responsibilities are overviewed in Table 10.

Client	An organisation or individual for whom a construction project is carried out. Includes developers and agents acting on behalf of clients. Clients may initiate a 'one-off' build project or be serial clients with experience of many projects.
Designer	Prepares or arranges for the preparation of drawings and design detail for construction works, specifications of articles and substances and undertake analysis, calculations and related preparatory work. They include a range of architects, engineers, surveyors, and anyone who contributes to the development or revision of the design process
Planning Supervisors	Ensures that those who carry out design work, particularly during the design phase collaborate and pay attention to risk reduction. They ensure that all necessary health and safety documentation for the build is compiled
Principal Contractor	The main or managing contractor of the construction work. They must be competent and adequately resourced
Contractors	Those that undertake the construction work. They may be utility providers, specialist or general contractors or self-employed

(Health and Safety Commission 2001b)

Table 9. Glossary of roles of construction industry personnel described in CDM

The CDM Regulations have been the subject of controversy since introduction. Initial investigation revealed that the planning supervisor role and burdensome paperwork were the main problems (The Consultancy Company Ltd, 1997). Following industry consultation (Health and Safety Commission, 2001b) the 'Approved Code of Practice and Guidance' were revised (and recently re-issued, Health and Safety Commission, 2001c), to clarify role requirements and rationale for the recommended actions.

	Client	Planning Supervisor (PS)	Designer	Principal Contractor (PC)	Contractor
	All appointers must ensure that appointees are be competent and adequately resourced for health and safety All guidance facilitates existing requirements under HASAWA and MHSW				
Concept and Feasibility	Appoint a PS Supply PS with info to identify hazards	Notify HSE of project	Inform client of the CDM duties		
Design and planning		Ensure preparation of pre-tender H&S Plan Ensure completion of the H&S File			
Tender / Selection	Appoint PC	Update HSE of project changes Advise client of contractor competence Advise contractor of designer competence	Where appointing, ensure contractor competence	Ensure preparation & update of H&S Plan Ensure co-operation between contractors Make rules & ensure compliance	
Construction phase	Ensure H&S Plan suitable	Advise client on suitability of H&S Plan	Apply hierarchy of risk control in design Ensure adequate H&S information in design Where appointing, ensure designer competence Co-operate with PS and other designers	Control / restrict site access Provide PS with H&S file info Direct and monitor contractor work Ensure contractors provide training & information	Co-operate with PC Comply with PC direction & rules Inform & train employees When appointing, ensure designer and contractor competence
Commissioning and handover	Provide H&S Plan	Deliver H&S File to client		Ensure consultation opportunities Where appointing ensure designer & contractor competencies	

(Health and Safety Commission 2001b)

Table 10. Over view of responsibilities under the Construction (Design and Management) Regulations, 1994

The Construction (Health, Safety and Welfare) Regulations, 1996 address practical measures to achieve healthy and safe construction sites. The content of the regulations overlap and complement material covered in other regulations, either specific to the construction industry or applicable to workplaces generally. These resources are compiled comprehensively as practical guidance to plan, organise, monitor and review health and safety for the construction phase (Health and Safety Executive 2001). Guidance distinguishes three aspects of construction site health and safety measures (Table 11). Guidelines are either of a technical nature or propose methods to facilitate a systematic approach to management of health and safety at work.

Organising the site	Risk control on site	H&S management / legislation
Work conditions (site state, material requirements, sub-contracting) Work organisation (appointment, supervision and training criteria) Site layout and environment Provision of welfare facilities Emergency arrangements	Practical instruction / technical advice Health hazard control Use of PPE	Interacting legislation requirements (eg. MHSW, CDM) Procedural requirements (eg. Risk assessments, Method Statements) Provision of training Monitoring H&S

(Health and Safety Executive 2001)

Table 11. Summary of Health and Safety in Construction Guidance

The HSE also have a range of free information sheets concerning construction health and safety.

A supplementary feature, unique to the construction industry, is the use of a ‘method statement’ (or safety method statement). The intention of a method statement is to draw together the risk assessment(s) and varied hazard information for a particular job (especially for complex or unusual works). It should also set out the work plan, process and control measures, and is used as an information source for employees (Health and Safety Executive 2001).

2.5.6 Training initiatives

Much of the workforce training within the industry operates under the auspices of the Construction Industry Training Board (CITB). The CITB works in partnership with industry and the government and is concerned with providing assistance in all areas of workforce recruitment, training and qualification (CITB 2003).

The industry has a highly mobile workforce and to ensure training provision (and avoid skills vacuum) the CITB are charged with collecting a levy from industry (where the annual wage bill exceeds £61k) and this is used for providing grants for qualifying and developing the workforce. Grants can be claimed for CITB training of 30 minutes duration and above. Shorter training would typically include in-house training such as induction or toolbox talks (TBT's, which are short, on the job training session by a competent worker). There are also funds for general skills day courses (> 6 hours) and for ongoing development, such as NVQ schemes or apprenticeship training for example (CITB 2003).

The CITB also administer the Construction Skills Certification Scheme (CSCS), a formal registration scheme of the training received by each worker and which may be used by sites to identify competent personnel. Each worker is provided with a registration card (credit card style) that records his or her achievements. A day's health and safety training is a minimum requirement and there are also distinct qualifying criteria for accreditation of each subsequent level of training (CSCS Ltd 2001).

3 LITERATURE REVIEW – ACCIDENT CAUSATION

This chapter commences by introducing the resources available for occupational accident investigation and also provides different perspectives on the meaning of the term ‘accident’. Current understanding of accidents often indicates that there are multiple causes, yet this has not always been the case. The inter-disciplinary knowledge sources, and integration of their findings in the development of a systems approach are explored, and later used as a foundation upon which to evaluate construction accident models. The literature review also addresses the practicalities of accident investigation, for use both in evaluation of the construction accident models and to inform later methodological development in Phase Two.

3.1 Accident data information sources

There is a tradition of looking at non-occupational accidents such as those occurring in domestic settings or the transport sector. However, much of the data used in understanding occupational accident causation have been derived from accidents and human reliability assessment relating to high risk, high technology sectors (Kirwan 1995). Whilst accident likelihood might be low, sectors such as petrochemical, travel (including space, aviation, shipping and rail), and nuclear are vulnerable to and have experienced catastrophic events. Investigation of such events has revealed multiple failings affecting design and equipment, systems operations and procedures (Wilson and Rajan 1995). In contrast to the wealth of information concerning high risk high technology sectors, Kirwan (1995) describes only early stages of comparable interest in other industries that have low technological complexity, yet higher risks resulting in a larger number of isolated fatalities.

More recently there has been a concentration of accident research in medical settings (with different technology and outcome patterns again). Selective use and adaptation of the principals and approaches used in other industries has permitted investigation of causal factors in this unique environment (e.g. Taylor-Adams et al. 1999).

It is necessary to be cautious in the application of previous industry wide findings and methods in the context of the unique environment of the construction industry.

However, whilst not all aspects may be relevant or transferable, a review of previous findings and materials has revealed generic issues (and shortcomings in earlier approaches) that have been appropriated for this research; these are discussed from 3.5 onwards, and introduced by review of the historical perspectives of accident causation.

3.2 Historical perspective upon understanding of the term 'accident'

The HSE describe an accident as “any undesired circumstances which gives rise to ill health or injury, damage to property, plant, products or the environment, production losses or increased liabilities” (Health and Safety Executive 1997b, p. 76). The openness and flexibility within the term appears to offer inclusion of any ‘situation’ that might induce some form of ‘adversity’. However, alternative definitions and viewpoints, from a historical perspective and, more recently, from accident researchers, reveal a certain amount of controversy surrounding use of the term ‘accident’. Understanding of these aspects enables insight into the different perceptions of what defines ‘accident’ and possible connotations that have had to be acknowledged in the development of theories of accident causation.

3.2.1 Medical usage

Green (1997) describes some early references relating to the development of epidemiological data and adoption of the term ‘accident’. These relate to sixteenth and seventeenth century studies of City of London ‘Bills of Mortality’ (precursors to the population census studies of today). In the process of development of classification systems, those data that did not readily fit within the chosen classifications were labelled ‘accident’. Terms such as ‘lacking regular patterns’, ‘arbitrary’ or ‘non-rational causes’ described events that were outside the boundaries of classification and were associated with fate or Acts of God (Green 1997).

Green notes late twentieth century enlightenment concerning risk factors and correlations between them in accident events, but provides examples that indicate a disciplinary divide. Where medical statistics are concerned, the term ‘accident’ continues to be associated with unpredictable or chance occurrences. A recent Editorial from the British Medical Journal (BMJ) indicates that the argument has perpetuated to the current day and that the term ‘accident’ is no longer welcomed in

their publication (Davis 2001). Davis notes the lead for this movement from North America; BMJ correspondence from UK contributors raised a number of objections to this missive, suggesting international differences in perceptions of meaning of the word accident as well. Henceforth (in medical fields) Davis proposed that the word be replaced by a record of intent (such as unintentional act, violence, suicide etc.) and causal mechanism (such as vehicle crash, poisoning etc.).

Thus a record of the inducing factors appears to be the chosen way forward in the medical field, yet the dispute draws attention to the interests and perspectives of different disciplines. For those with a purely therapeutic role the consequence or outcome effect upon the individual is the primary interest (Thygerson 1977). In the medical field knowledge of causal factors will be derived through clinical examination, and by the quality of information provided by investigators. Alternatively, for those with an investigative role it is the antecedent events that are of primary concern (Thygerson 1977).

3.2.2 Industrial usage

In an industrial context, early associations with the term 'accident' had clear connotations with the apportioning of blame (Sass 1987). Sass proposed that the 'blame' type approach was especially prevalent prior to introduction of worker compensation schemes – a means to absolve an employer of financial responsibility in the event of an employee claim. As an example of the widespread acceptance of this attitude, Farmer (1932) quotes from a report by the H.M Chief Inspector of Factories in 1918. In describing the efficiency of machinery safety guarding, he reported that,

.. where absent, this accounted for less than 35% of accidents; the remainder largely being attributed to 'negligence', 'carelessness', 'want of thought' and most of all a 'lack of proper appreciation of danger' (Farmer 1932, p. 3).

Even at the time of publication in 1932, Farmer proposed that guard avoidance was due to bravado and disdain – and that coercion and 'putting up with the discomfort of using a guard' was the solution. Early research into accidents was inter-linked with studies associated with the two World Wars. Through the Industrial Fatigue Research Board (later the Industrial Health Research Board, IHRB), (Greenwood and Woods

1919) and (Newbold 1927) findings from accident rate analyses introduced the concept of accident proneness and unequal liability (3.6.2.1), which had significant influence on research thinking into the 1930s (cited by Surry 1968).

Surry (1968) notes a step change in approach to accident research since the 1940s (especially initiated by IHRB work during the Second World War), from reliance upon findings arising from descriptive accident statistics to exploratory research into human performance.

.. Applied Psychologists asked specific questions about the efficiency of human production. By this time it was recognized that the multitude of factors contributing to accidents were not amenable to direct or simple control. More economically satisfactory for immediate results were the studies of human output ... study of performance influencing factors has flourished. (Surry 1968, p. 17).

There had been considerable advancement in understanding of accident causality at least by the late 1950s, with the development of theories of 'multiple causality' (3.5.2) and a 'systems approach' to accident investigation (3.5.3). The Robens Report (Great Britain, Parliament 1972), acknowledged a range of contributors to failure occurring throughout an organisation; information that was pivotal in development of the Health and Safety at Work etc. Act, 1974 (Great Britain Parliament 1974), the enabling Act to current health and safety legislation.

3.3 Defining the meaning of 'accident causation'

Literature review reveals that previous accident researchers have interpreted each term, 'accident' and 'cause' or 'causation', differently. Whilst the use of these terms is adopted in the thesis, it is important nonetheless to be aware of the emphases attributed and the significance that grammatical choices have had in the development of understanding.

3.3.1 Defining 'accident'

As in the medical field, there has been considerable debate about the semantics of the term 'accident'. Researchers have used a number of alternative nouns, adjectives or described classes or characteristics that embody the accident event.

The nouns 'accident', 'incident' and 'mishap' are attributed different meaning and interpretation, the choice of which appears to be determined by the outcome of the event (such as injury, damage, production adversity). On the one hand an accident is described as a subset of incident. Reese (2001) states that an accident implies failure, damage or injury, whereas incident additionally implies adversity to production. On the other hand, an incident is a subset of accident (Perrow 1999) where consequences are minor and least disruptive. An alternative perspective has been to avoid use of either word and use the all-embracing term 'mishap' instead (Ferry 1988); yet this noun has also been used to describe an accident without injury (Surry 1968). Surry (1968) also notes that judgment on whether an accident has occurred may vary among lay public, victims and those with specialist knowledge.

There is also a temporal aspect that distinguishes accident and occupational ill health. Ill health, such as work-related musculo-skeletal disorders may have a sudden onset (and for administrative purposes be called an accident (Pheasant 1991)), or be insidious, resulting from exposure or sensitisation over long time periods.

A variety of different adjectives have been adopted to describe accident criteria. Typically these express lack of foreseeability, intention and control – example terms include 'unplanned' (Thygersen 1977, Reese 2001) and 'uncontrolled' (Heinrich et al. 1980), 'unintended' and 'untoward' (Perrow 1999) and 'unexpected' (Reese 2001). Judgemental terms are also used, such as 'unsafe and avoidable' (Thygersen 1977) and 'uncontrollable' (Reese 2001).

An alternative viewpoint is that there is no one encompassing definition of an accident, more so an accumulation of defining features. Perrow (1999) describes an accident as 'damage to a defined system that disrupts the ongoing or future output of that system' (p. 64). He distinguishes between component failure accidents (part, unit or sub-system failure) and system accidents (with multiple failures).

3.3.2 Defining 'cause'

The term 'cause' has also been disputed because of the inferences that can be made from the word. Selected sources proposed that the word 'cause' should be discouraged because:

- It encourages listing of insurmountable problems & inevitability, rather than encouraging search for solutions
- It has an air of finality, discourages deeper exploration and masks underlying complexity of range of influencing factors (Surry 1968, Kletz 1994)
- It implies blame and may lead to defensiveness
- It encourages fatalism or generalisations without proper isolation of the issues (Kletz 1994)

Alternative terms such as ‘related’, ‘contributory factors’ (Surry 1968) or ‘factors increasing liability’ (Woodcock 1989) have been mooted. From an alternative perspective, Kletz (1994) proposed that instead of the unhelpful cause listing, accidents should be explored with underlying best practice in mind (such as “why did *x* not happen”), in order to develop an event chain of the accident precursor stages.

Factors affecting decision making and the qualities of causal attributions in accident investigation are discussed further in 3.9.5.

3.4 Information sources contributing to understanding

The development of knowledge concerning accident causal factors has been generated from the contributions of a variety of different disciplines (Rasmussen 1990). Major contributors appear to be the sciences of psychological and behavioural issues, engineering innovation, organisational development and advances made in the use of epidemiological data.

Table 12 outlines the developments in each knowledge source and how these have been employed as a common resource for current day accident causation modelling. From fragmented understanding through to appreciation of multi-factorial issues and finally systems approaches, there has been ever greater assimilation of the inter-disciplinary knowledge – this assimilation is represented by the fading and eventual loss of horizontal lines between each of the information sources. Development of the interdisciplinary knowledge and evolution of the accident causation model and systems approaches are discussed in the next two sections.

		Development of understanding in accident causation				
		≤ 1920's			≥ 1990's	
Epidemiological sources	Data analysis to identify target areas	Public health and occupational reporting schemes		Increase in complexity of analyses	General public reporting schemes	EU initiatives for standardisation
		Fragmented understanding → Multi-factorial events → Systems approach				
Individual variability	Behavioural and personality factors	Accident proneness	Unequal liability	Risk taking	Sensation seeking	Human error
Engineering approaches	Technical and environment factors	Technical and environment adaptation		Hierarchy of control		Man-machine interface
Work organisation issues	Job and Psychosocial factors	Speed and pressure of work		Job design theories	Socio-technical systems	Factors affecting performance

Table 12. Evolution of information used in the modelling of accident causation

3.5 Approaches to modelling accident causation

3.5.1 Fragmented approaches

Understanding of causal factors early in the 20th Century was fragmented. Technology was relatively straightforward compared to the complex systems of today. Although there was a developing understanding of the varied contributions of human behaviour and technical / environment issues, the interdependency of these factors was not understood (Hale and Glendon 1987)

3.5.2 Multi-factorial events

The next development in understanding was that an accident is the outcome of gradually developing series of multiple contributory factors (Thygeson 1977). Heinrich and Granniss (1959) described a series of five factors that they called the ‘Domino Theory’. These factors ‘invariably occur in a fixed and logical order’ and Heinrich and Granniss (1959) used the domino symbol for each of the five factors to represent interdependency – one domino fall initiated the downfall of later dominos. With the removal of a domino from the sequence the fall cycle would be broken.

In the first ‘Domino’ model the accident factors predominantly concerned the human failings that contributed to ‘unsafe acts’. Unsafe acts, compared with unsafe conditions were thought to account for accident causation in a ratio of 85:15 (Heinrich

and Granniss 1959). The philosophy was that by isolation and extraction of undesirable human fallibilities (such as inherited undesirable personality traits and detrimental acquired behaviour), the precursor events in an accident sequence would be halted.

The Domino Theory has been subjected to a number of revisions; these retain the domino graphic but substitute the sequence of human failings with a loss control approach, (Heinrich et al. 1980). Table 13 shows the initial model and later revisions from the 1970s.

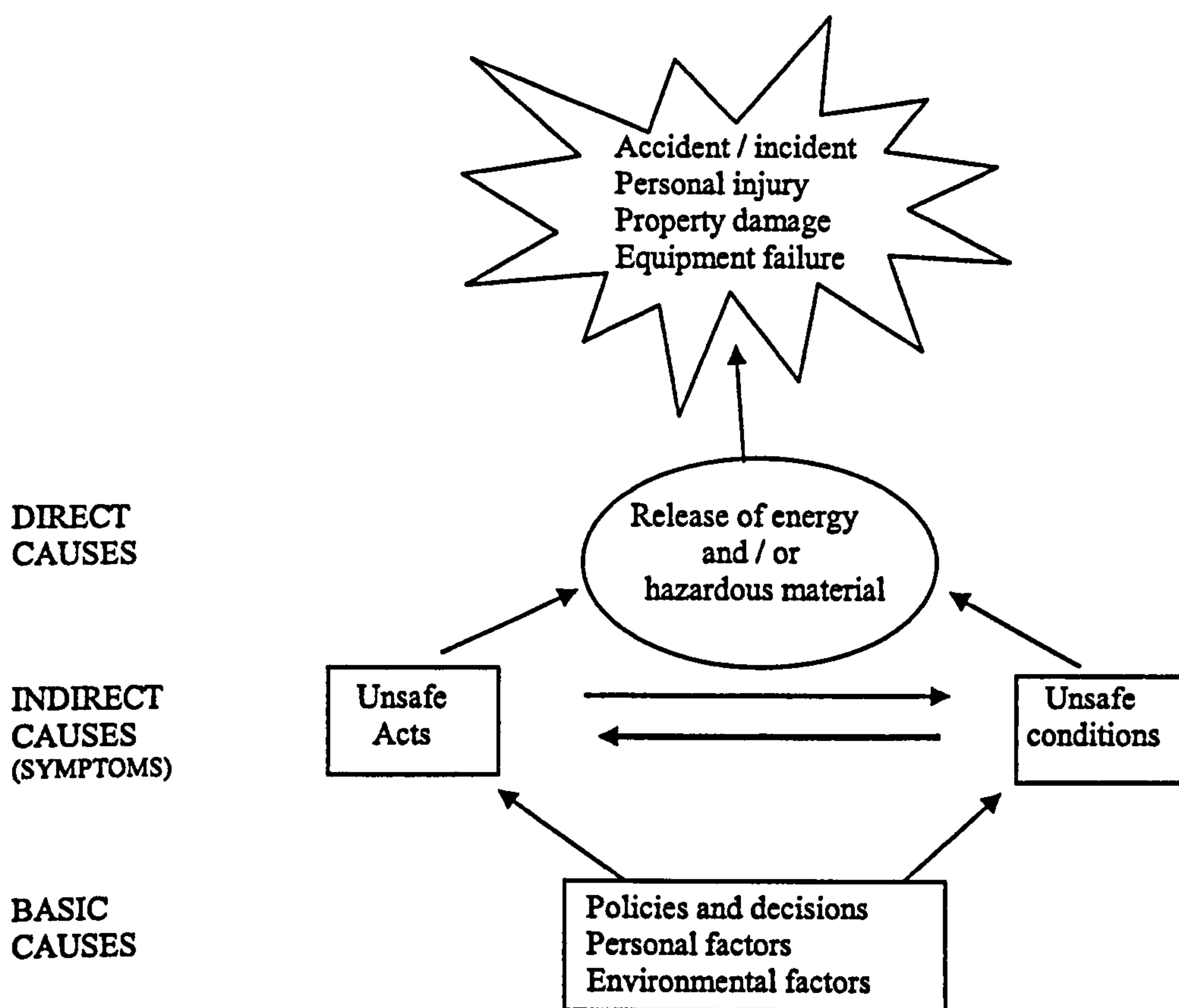
Domino One	Domino Two	Domino Three	Domino Four	Domino Five	
Ancestry /Social environment	Fault of person	Unsafe acts. Mechanical / Physical hazard	Accident	Injury	(Heinrich and Granniss 1959)
Lack of control in management - planning - organising - leading	Basic causes – Personal failings or poor work factors	Immediate cause – unsafe acts and conditions	Accident by contact – with energy source	Injury, damage or loss	(Bird 1974)
Management structure - objectives - organisation - operations	Operational errors – manager and supervisor behaviour and actions	Tactical errors – affecting employee behaviour and working conditions	Accident - incident	Injury or damage	(Adams 1976)

Cited by (Heinrich et al. 1980)

Table 13. Domino Theory approaches

Development of the Domino Theory shows the progressive understanding of a link between antecedent events within the organisational process - the contribution of managerial functions (Bird 1974) and organisational strategies (Adams 1976).

However, using the Domino Theory, the accident route continues to be seen as a process of interlinked sequential factors. Alterative theories, not using the domino graphic, but incorporating comparable sequential factors were also proposed, (e.g. Zabataki 1975, cited by Heinrich 1980) and continue to be used. Reese (2001, p. 107), for example, attributes causal factors to three classes and these are reproduced in Figure 3:



(United States Department of Labor. Mine Safety and Health Administration 1990, cited by Reese 2001)

Figure 3. Accident cause levels

- **Direct causes** - Immediate events or conditions leading to an accident
 - Energy (mechanical, electrical, chemical, thermal, radiation)
 - Hazardous materials (gas, poison, corrosive, explosive agent)
- **Indirect causes** - Not causal in themselves, but increased accident probability
 - Unsafe acts (failure to work safely, horseplay, use of drugs / alcohol)
 - Unsafe conditions (exposure to inadequate environment)
- **Basic causes** - Root causes that if corrected would prevent recurrence
 - Policies and decisions (inadequate health, safety and personnel arrangements)
 - Personal factors (inadequate behaviour & training, physical and mental capabilities, motivation and attitude)
 - Environmental factors (unsafe facility design / location and operating procedures)

These latter models incorporate many of the concepts of systems theory (Carter and Corlett 1983). However, the focus of this approach continues to promote isolation of negative aspects (inadequacies and unsafeness). It is not apparent that the approach explores the nature or quality of the faults, such as intermediate failure or even positive features of behaviour, organisation and design that mitigate adversity or the severity of the accident event. These issues are discussed further later, but an alternative approach to accident causation has developed from the exploration and modelling of human and general failures, and in the distinction of active and latent factors in accident causation (Reason 1990b).

3.5.3 Systems approaches

‘System’ describes inter-dependent entities, such as humans, machines and ‘other things’ that interact in the pursuit of a common goal (Sanders and McCormick 1992). Entities of the system relate to each other in a hierarchical order. Errors become apparent at boundaries between each stage and any changes impact upon the function of the system as a whole (Stanton and Baber 1996). In order to adopt a systematic approach, it is necessary to consider the inter-relationship between the person, job and organisation (Health and Safety Executive 1997b). These aspects encompass a wide range of different features and are introduced in Table 16.

With the systems approach, failure is deflected from concentration upon ‘unsafe acts’ or accident ‘perpetrators’. More so, failure is seen to be a reflection of, or shaped by, the outcome of organisational strategy; its culture, management and decisions (Department of Health 2000). Failures are considered multi-causal in origin and initiating factors are generated through two routes:

Active failures - Errors and violations are effected by front-line (Reason 1990a) or system (Mathews et al. 2000) operators, who directly initiate or create a hazardous or undesirable system state (Center for Chemical Process Safety 1994).

Latent failures - When combined with local triggering factors (such as active or technical failures) failures lying dormant (as resident pathogens) within the system become apparent. These are created by organisational decisions (Reason 1990a), such

as any of the engineering, design or management policy levels (Center for Chemical Process Safety 1994) .

3.5.3.1 Models of human and general failure

By defining the basic elements of a productive system “Decision makers, line management, preconditions, productive activities and defences”, Reason (1990a page 478) proposed a ‘General framework for accident causation’ showing possible human failure types that can occur through the system phases. Based upon this Wagenaar et al. (1990) revised the approach, ‘a general accident scenario’ and suggested general failure types that could occur at each stage. These are reproduced in Figure 4. Although there is no reference to ‘domino’s’ these show similar sequential stages to the latter two Domino Theories described in Table 13.

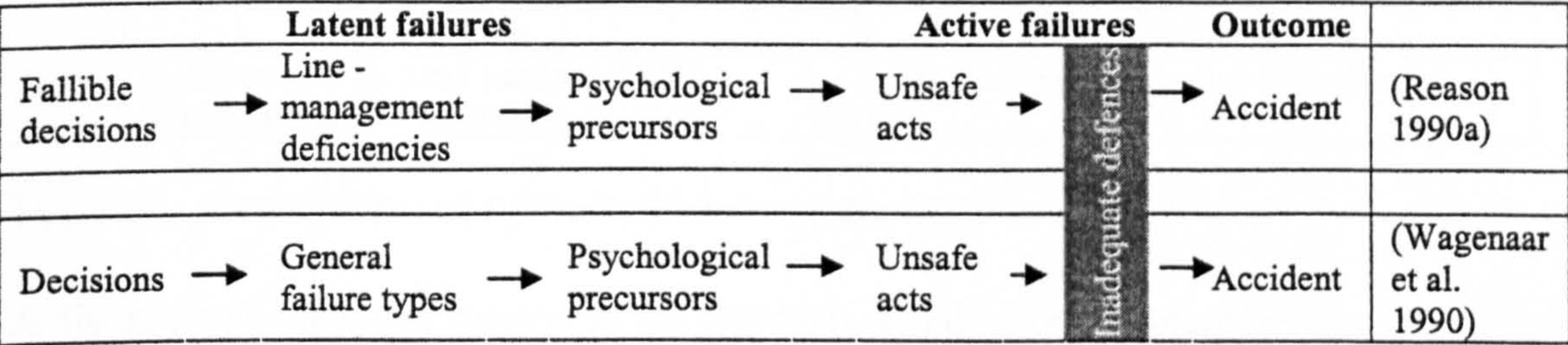


Figure 4. Models of human and general failure

In order to explain the meaning attributed to each of the sequential stages, a summary of descriptions from each resource is reproduced in Table 14. There are different emphases within the first three stages of each. However, in spite of this a range of human and general failure types have been indicated through the production system stages.

General framework for accident causation (Reason 1990b)		General accident causation scenario (Wagenaar et al. 1990)
Fallible decisions		Decisions
There can be resource conflict for safety and production goals Manifestation of safety and production success is dissimilar	↓	As the feedback loop becomes greater with each of the following stages management decision-making is delayed
Line management deficiencies		General failure types
Competence will influence outcome of fallible decisions Different deficiency types can have far reaching consequences	↓	There are three failure types generated through human behaviour, physical environment and management practices
Psychological precursors		Psychological precursors
Preconditions include tasks, environment and hazards Multiple different combinations of conditions create 'token' active failures	↓	Precursors distinguish skill, rule and knowledge based behaviour
Unsafe acts		Unsafe acts
An error or violation committed in the presence of a potential hazard	↓	Varied error types constitute unsafe acts. They have different intent and presentation
Defences		Defences
Defences may be local barriers and/or operational and/or engineering controls	↓	Extra defences can never be foolproof

Table 14. Descriptions of active and latent failure types

A distinction adopted by Reason in his approach is that types of preconditions or psychological precursors have the potential for multiple connotations and creation of different event tokens. Reason advocated that in accident investigation the identification of event 'types' offers the potential to control or disable many event 'tokens'. This approach to accident investigation has been also been adopted elsewhere as 'cause-orientated' rather than 'event-orientated' (Shappell and Wiegmann 1997) and concept-dependent rather than concept-specific (Dekker 2002) accident investigation.

3.5.3.2 The model of Organisational Accident Causation

The stages of the 1990 models are simplified in a more recent variant - the model of Organisational Accident Causation, (Reason 1995, reproduced in Figure 5). There is a grammatical shift from use of abstract nouns, such as 'fallacies, deficiencies and precursor (events)', towards description by more concrete nouns, such as 'organisational, workplace and person/team' that are not defined by pre-judgement or any form of emotional loading as a basis for data collection. Within this Reason (1995) also distinguishes two important factors:

- The latent failure pathway can directly affect the efficiency of defences. This can occur independently of the sequential failures of the active failure pathway.
- Interdependent organisations, such as manufacturers, suppliers, maintainers, customers, regulators, accident investigators etc. influence the pathway at many different points and in many different ways.

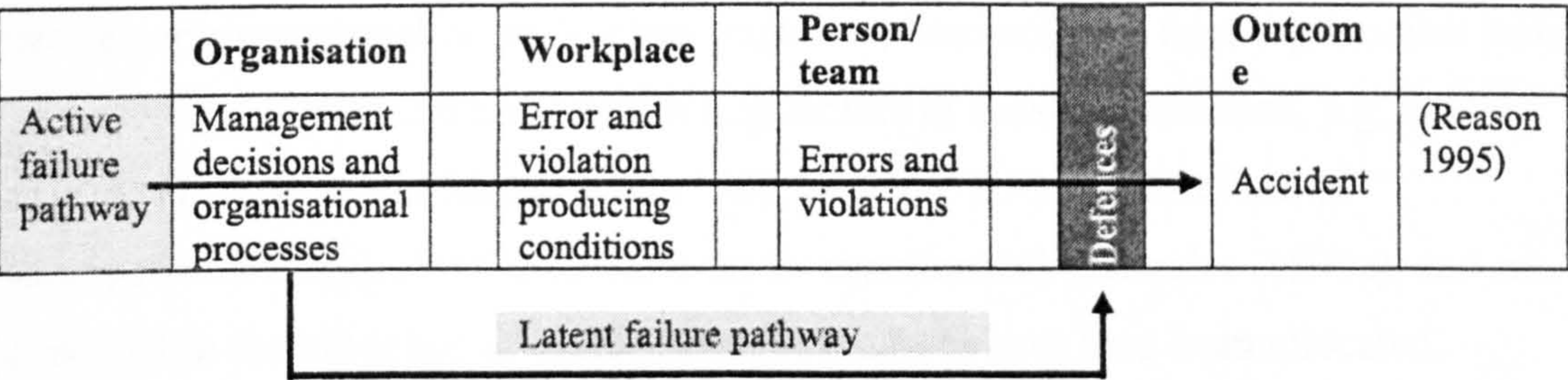


Figure 5. A model of organisational accident causation

Latent failures (also referred to as ‘latent conditions’ to avoid deferred blame to senior managers (O’Hare 2000)) are ever present and provide the conditions under which an accident can occur. As such they may be considered contributory in nature but are not necessarily directly causal (Spurgeon and Young 1980). Reason (1990b), referred to these as organisational and workplace factors, Wagenaar et al. (1990) referred to many of these latent factors as ‘general failure types’, but they have also been referred to as ‘Performance shaping factors (PSF)’ or ‘Performance influencing factors (PIF)’ (Redmill and Rajan, 1997). Preferences for the term vary; the Center for Chemical Process Safety (1994) also prefer the term PIF - affording it a more qualitative association than the quantitative connotation of PSF adopted by the nuclear industry.

Rasmussen (1997) offers an alternative term, ‘Behaviour shaping mechanisms’ that result from the ‘dynamic state’ of interaction between the organisation and extra-organisational factors. The ‘dynamic state’ (compared with traditional controlled production systems) involves perpetual flux, arising from fast technological change, rapid development of information and communication technology, and aggressive commercial tactics. It is the work system constraints, boundaries of acceptable performance and subjective criteria guiding adaptations to change, that define the ‘behaviour shaping mechanisms’. Svedung and Rasmussen (2002) later developed a

representation of this dynamic state using graphic representation - accident mapping (3.9.3.2).

3.5.3.3 Summary of latent conditions

Example latent conditions have been compiled in Table 15. Information from resources with plentiful examples was used; these each employed a variety of grouping of terms and offered examples that were of both type and token. In order to create some commonality, anchor headings have been collated from ergonomics texts of workplace assessment and contributing factors in accident causation, e.g. Grey et al. (1987), Sanders and McCormick (1992, page 667), Finnish Institute of Occupational Health (1989), Institute for Occupational Ergonomics (1998a), and are recorded in the left column. Data from the resources have then been allocated according to failure types and tokens events. The allocations are intended to offer distinction to disparate data rather than introduce a classification that was not necessarily intended in the source material.

Anchor headings	Types	Tokens
Extra-organisational issues	Government policy, regulatory decisions	
Organisational goals	Strategic decisions Generic organisational processes Safety culture	Unspoken attitudes, unwritten rules, poor management of health and safety, poor safety culture
Work organisation	Workload, social support, personnel availability, team management, communication channels, roles / responsibilities	High workload, Time pressures, skill / personnel shortages, low pay, poor communications and co-ordination, social pressures, conflicts, poor teamwork
Work scheduling	Pace, duration, repetition, frequency, hours and shift working, breaks	Monotony, fatigue, effects of unsociable hours or poor shift patterns
Target / payment issues	Rewards, benefits	
Workplace layout	Movement and access opportunities	Poor workplace design, inadequate or restricted space
Equipment, tooling, machinery		Inadequate supplies, poor human-machine interface, poor maintenance, hardware defects, poorly designed automation
Task characteristics	Workload and interaction with other tasks, criticality, complexity, attention requirements	Stress effects, boredom, disturbances, interruptions
Environment	Lighting, temperature, noise, humidity, control of conditions	Bad housekeeping, unpleasant conditions, environmental extremes
Training	Job role	Insufficient or inadequate training and experience
Supervision		Poor supervisor-worker ratios, ineffective supervision, leadership shortcomings
Procedures / instructions	Accuracy, sufficiency, style, applicability, detail, ease of use, revision and access	Unworkable or ambiguous procedures, missing or unclear materials
Defences	PPE	Inadequate PPE, lack of safety systems and barriers, inadequate responses to previous accidents
Personal factors	Capabilities, skills, experience, personality, health status, attitudes, motivation, risk perception, attitudes to safety	Low status, badly calibrated risk perception, low skill, incompetence, health problems, home life problems, dependency problems

(Redmill and Rajan 1997)

(Reason 1997)

(Health and Safety Executive 1999d)

(Svedung and Rasmussen 2002)

Table 15. Summary of contributory factors in accident causation

3.6 Contributions from inter-disciplinary knowledge sources

Reflecting the longstanding study of human capabilities and fallibilities, the information that has contributed towards understanding of accident causation is dominated by psychological and behavioural resources. Engineering approaches and enhanced understanding of the impact of work organisation and organisational factors have also contributed knowledge, but historically they have been ranked more as ‘contributory factors’, with less of immediacy to the accident event.

All aspects from each of the inter-disciplinary sources are embraced within the principles of ergonomics. In order to accommodate wide and diverse information sources ergonomics principles are summarised below; these embrace the ‘contributory’ factors. Where the information has also been directly associated with accident causation this is described in later sections.

3.6.1 Summary of ergonomics principles

“Ergonomics (or human factors) is the scientific discipline concerned with the understanding of the interactions among human and other elements of the system, and the profession that applies theory, principles, data and methods to design in order to optimise human well-being and overall system performance”

(Marshall 2000)

By understanding the principles of perception, interpretation, decision-making and operation of the ‘human-machine system’ compatibility of user and process needs can be accommodated (Kroemer and Grandjean 1997).

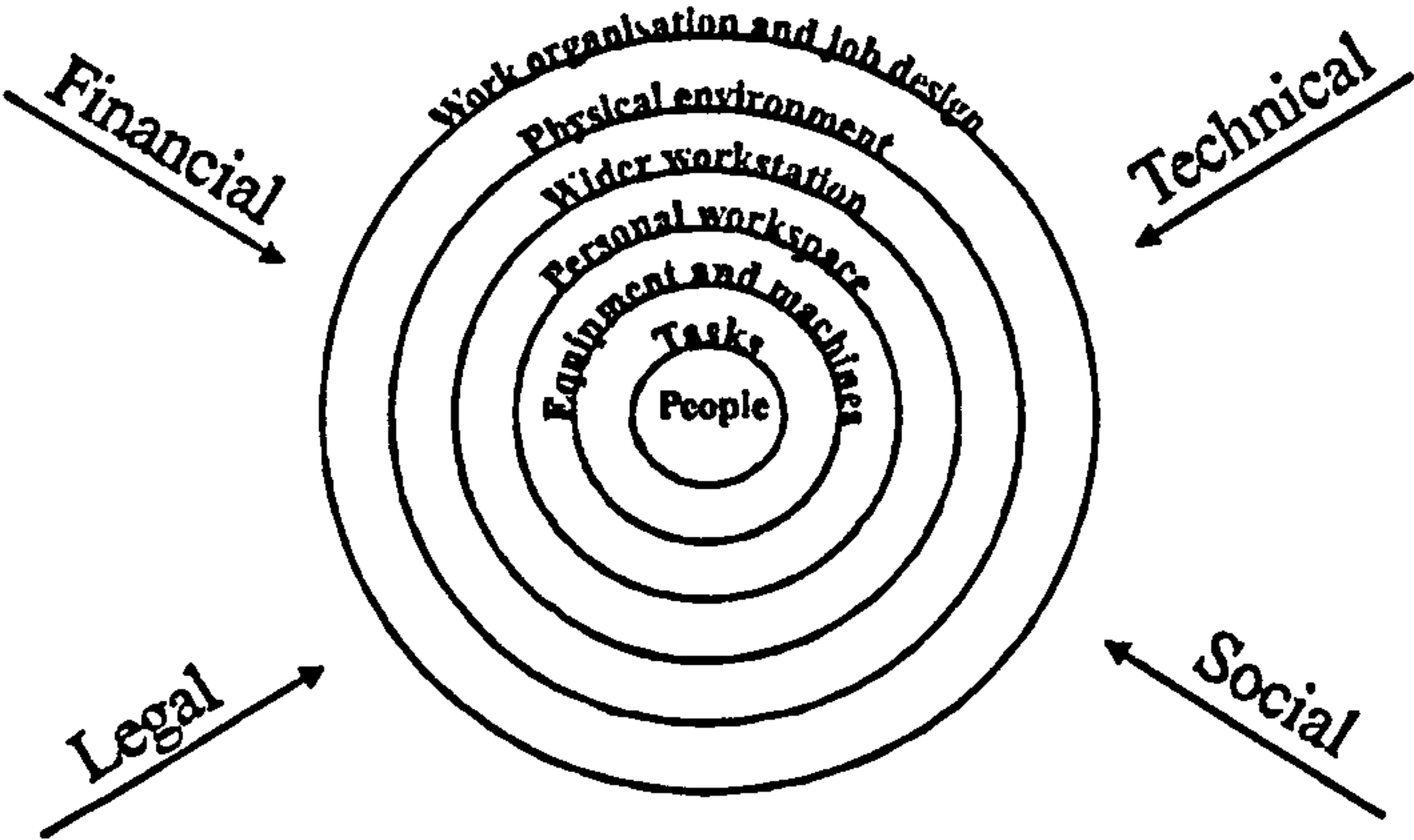


Figure 6. Interactions in ergonomics

Figure 6, (Grey et al. 1987) draws together interacting factors, showing not only immediate task: equipment: environment factors, but also the contribution of organisational and extra-organisational influences upon the person as part of the system. These interacting factors are summarised in Table 16.

People	Demographic characteristics, health status, physical, physiological, sensory, cognitive and psychosocial capabilities and previous experiences
Tasks	Physical demands such as - dynamic and static workload, handling, fine, manipulative work, movements, posture, repetition and rest. Mental demands such as task complexity, problem solving, decision making, monitoring. Physical / mental demand mix
Equipment and machines	Physical fit incorporating anthropometry and biomechanics. Equipment: machine: tool and task / performance compatibility. Information presentation, response, operation and feedback of performance
Personal workspace	Comfort and performance arising from interaction with equipment, workspace and layout
Wider workstation	
Physical environment	Environmental conditions such as lighting, noise, climate, dust, radiation etc., and the impact upon task performance, comfort, health.
Work organisation and job design	Psychosocial factors - work scheduling (shift, pace), management style & culture (communication, team working, use and introduction of new technology), payment (incentives, value), workload (mental / physical demands, skill, control, ownership), interpersonal relations (peers, supervisory and management style, social support), employment concerns (job security, organisational stability, role clarity, development opportunities).

(Cordiner et al. 1998)
(National Occupational Research Agenda 1999)

Table 16. Factors affecting interactions in ergonomics

3.6.2 Psychological and behavioural factors

The understanding of behavioural issues in accident causation developed from the early research that isolated human fallibilities or characteristics as accident causal factors (the blame type approach). Research progress saw development through to conjecture on the contributions of personality attributes in accident causation, through to a quest for understanding of factors that affect performance or the implications of human error in the system.

3.6.2.1 Individual variability

The early research of Greenwood and Woods (1919, cited by Lawton and Parker 1998b), identified variability in individual’s propensity for accidents. Their evaluation revealed that certain people, as a result of their personal characteristics, had

a higher affinity for accidents; this individual susceptibility was named 'accident proneness'. Although the research was popular and spawned a number of related studies, the concept was attacked from the 1950s for lack of account of workplace hazards, exposure to risk (Lawton and Parker 1998b, Sass 1987) and for poor methodological design (Hale and Glendon 1987). Nonetheless, the term was by then integrated into the English language and had also been used as a tool by 'management' to excuse them from removal or control of workplace hazards (Lawton and Parker 1998b, Sass 1987).

A supplementary facet of accident proneness theory is that susceptibility fluctuates over time, and that where there are 'accident repeaters' this occurs for limited periods in a person's lifetime. This 'unequal-liability theory' was initially hypothesised within a few years of accident proneness theory (Newbold 1927, Farmer and Chambers 1926, cited by Lawton and Parker 1998b). Despite similar criticisms of early methodological techniques, acknowledgement of individual differences and accident association persists. This is especially supported by findings from epidemiological studies, both from individual studies and from longitudinal studies; example associations are shown in Table 23.

Brown (1995) describes additional theories relating to personal characteristics or behaviour. He includes 'pure chance theory' for all those exposed to the same objective risk and also introduces biased liability, whereby previous accident experience can limit or enhance their liability for subsequent accident involvement. As there is inadequate information concerning duration of effect and interacting factors, this theory is not used for data collection (Brown 1995). Nonetheless, in their review of research into attitudes and motivation Lawton and Parker (1998a) note a positive effect upon risk perception, associated with a history of previous accident association.

3.6.2.2 Risk taking

Aside from risk perception there are also divided feelings about the causes of risk taking behaviour. The foundation of the dispute concerns the proposal of 'risk homeostasis theory' (proposed by Wilde, 1982). Individuals are deemed to have an innate level of acceptable risk and, under circumstances where hazards vary from 'normal', alter their behaviour to retain constancy (McKenna, 1988). Dispute centres

on generalisation from the origins of the theory (mostly road traffic data) into an occupational setting and also on the possibility of alternative reasons for such behaviour (Lawton and Parker 1998a). The main dissenter of risk homeostasis theory, McKenna (1988), proposed that risk taking is an outcome of 'sensation seeking' (Zuckerman and Neeb 1980). Sensation seeking describes a desire for thrills, adventure, disinhibition and susceptibility to boredom. High scorers favour stimulating behaviour and are more apt to put themselves in risky situations in real life – Zucherman also claims a biochemical link and basis for risk taking (Zuckerman and Neeb 1980). The existence of these arguments continues to be acknowledged yet their impact upon decision making skills remains an area requiring further research (Lawton and Parker 1998a).

3.6.2.3 Traditional approach to human error

The final and most influential aspect of individual influence upon accident causation is human error. Human error is described as 'an inappropriate or undesirable human decision or behaviour that reduces, or has the potential for reducing, effectiveness, safety, or system performance', Sanders and McCormick (1992, p. 656). The concept of human error derived a firm foundation from "Heinrich's" (1959) longstanding (and frequently quoted) apportioning of "the 80:20 ratio" of human to technical causes for accidents (Brehmer 1993). Heinrich's terminology included attributes such as 'recklessness', 'violent temper', 'inconsiderateness', and 'ignorance of safe practice' (Heinrich and Granniss 1959 and Heinrich et al. 1980). These terms show close association with the blame culture approach already popular and rife at the time of initial presentation of Heinrich's work in the 1930s (Woodcock 1989).

The concept of blame is rife at all organisational levels. There is widespread attribution, among workers and management, of 'carelessness' as a predominant cause of accident causation (Powell et al. 1971) and the construction industry is no exception (Leather 1987). Woodcock (1989) proposed that where 'carefulness' (even at the expense of efficiency or expediency) can mitigate accident potential, then this is the most easily identifiable identifier of 'accident cause'. Blame is frequently attributed to the operators involved in 'the dynamic flow of events' (Rasmussen 1990, p. 453), yet the apportioning of blame to individuals has been criticised for a number of reasons. Fear of retribution may induce a reluctance to report minor accidents or

near misses, resulting in the loss of learning experience (Center for Chemical Process Safety 1994). In addition, operative blame justifies shallow accident investigations, permitting closure with little deeper exploration of contributory factors and exploration of responsibilities among those with a design, planning or organisational role (Wagenaar 1990).

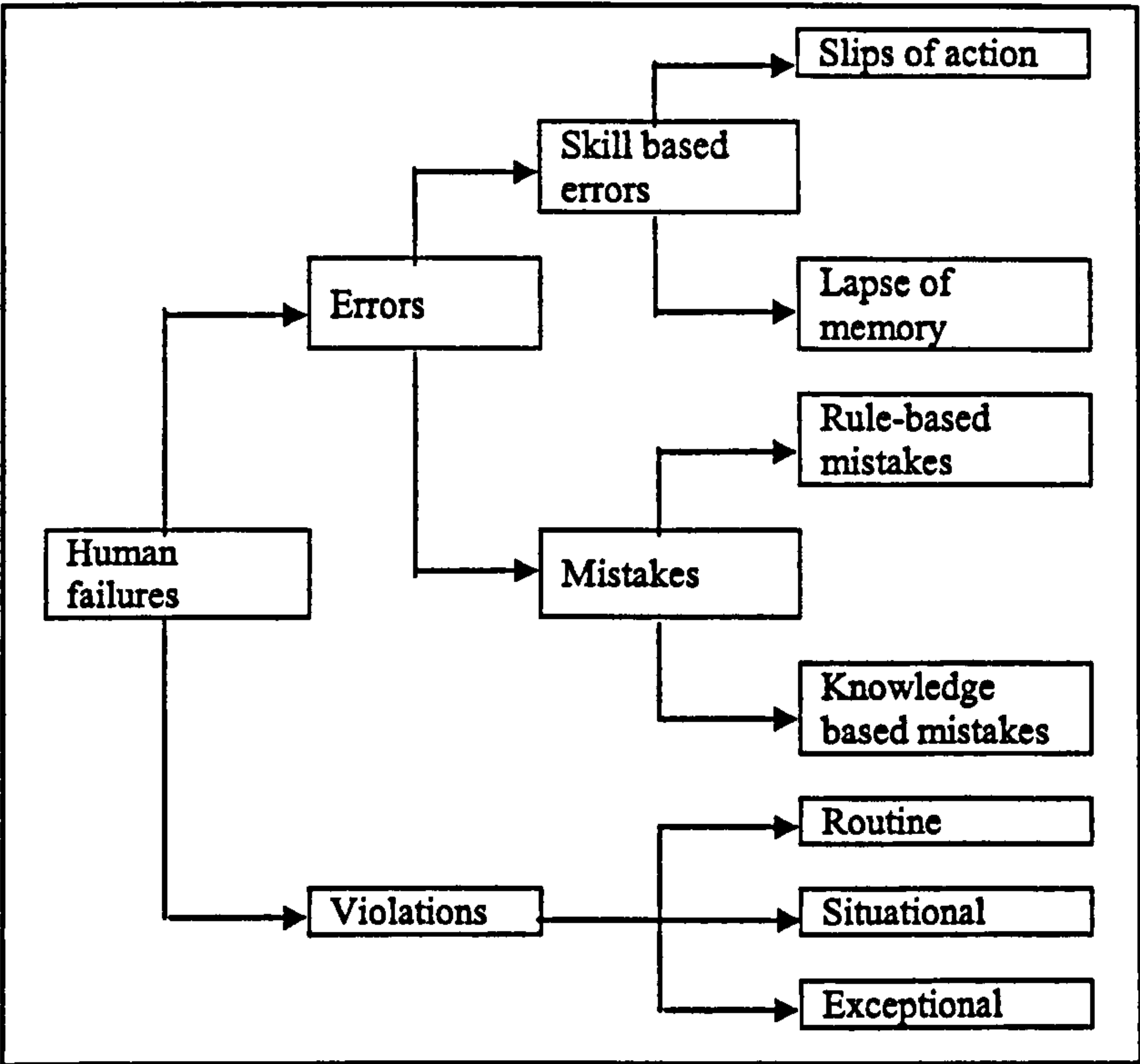
Blame can also be quite subtle; Woodcock (1989) noted that while there is insistence that blame is not used, this is inconsistent where there is breakdown of procedures and systems to the responsibilities of defined parties. Blame also implies delinquency, which in turn invites sanctions entirely inappropriate for non-deliberate events (Reason 1995). Wagenaar et al. (1990) criticised focus upon targeting of unsafe acts because 'perpetrators' can be unaware of risks or their violations. Because people make 'slips' not all unsafe acts can be prevented and because people misdiagnose and make mistakes. The experience of error is part of the knowledge development process and contributes to learning the boundaries of acceptable performance (Rasmussen 1990). Finally, human capacities for resourcefulness and ingenuity whilst dealing with novel or emergency situations are also important mitigators of accident potential (Health and Safety Executive 1999d).

3.6.2.4 Classification of human error

Developments in cognitive psychology during the 1970s advanced understanding of human error by exploring the types of conditions where errors occur and the form that they take (Reason 1990b). A number of classification systems have been developed. Earlier classifications identified information processing failures that could occur in the course of receiving information, decision-making, goal selection and effecting action (e.g. Surry 1968 and later revised Hale and Glendon 1987). Essentially a 'yes/ no' response to successive cues, the methods have been criticised for the supposition involved and inter-expert disagreement in classification (Sanders and McCormick 1992).

Later developments incorporated different levels of functioning and Reason (1990) drew these together by means of a comprehensive model, summarising 'psychological varieties of unsafe acts'. Recently updated (Health and Safety Executive 1999c,

reproduced in Figure 7), the model distinguishes between errors and violations in the generation of human failings.



Health and Safety Executive 1999c, page 12

Figure 7. Types of human failure

The first branch of human failures distinguishes different error types. These combine the skill, rule, knowledge classifications devised by Rasmussen (1982, 1983), (which already incorporated earlier research upon slips and mistakes (Norman 1981) and categorisations of discrete actions (Swain and Guttman 1983, cited by Sanders and McCormick 1992). The skill, rule, knowledge classification concerns levels of decision-making and the type of errors that can be made at each stage. These are described in Table 17, with typical representations of the error types and proposed management solutions.

	Skill based behaviour	Rule based behaviour	Knowledge based behaviour	
Description	Involves little conscious monitoring and generally comprise well practiced physical activities.	Involves processing of information and the use of predetermined rules to direct action.	Involves conscious generation of solutions to deal with unique situations	(Center for Chemical Process Safety 1994)
Error representation	Slips include failure to execute 'to plan' a given sequence of steps in task activities. Lapses are activities or stages that are forgotten.	The adoption of familiar patterns of behaviour may be inappropriate when task conditions vary	Misdiagnosis or miscalculation may result	(Health and Safety Executive 1999d)
Detection	Errors are relatively easy to detect	Mistakes are more difficult to detect and may pass un-noticed		(Mathews et al. 2000)
Solution management	Design changes to enhance error tolerance	There may be improvement with personnel selection or training to convert activities to skill based behaviour		(Shappell and Wiegmann 1997)

Table 17. Behaviour types, error representation and solutions

The second branch of human failure concerns the different types of violations that can occur. Routine violations are deliberate acts, but nonetheless many reflect normal and unofficial practice by a work group. Reason (1990b) cites two influential factors - (1). The natural human tendency to take the path of least effort, and (2) an indifferent environment, whereby safety procedures are rarely sanctioned. Alternatively, situational violations occur where there are conflicting demands (such as time pressure, staff equipment and material shortages or inclement weather conditions) or where circumstances indicate that normal rule based behaviour is unsafe. Calculated risk taking, in exceptional circumstances, describes actions taken as a problem solving approach (Health and Safety Executive 1999d). Violations may also have sabotage qualities, reflecting motivational problems in the workplace (Shappell and Wiegmann 1997). Solution management for violations encompasses a range of approaches affecting training, risk assessment and work scheduling /organisational strategies (Shappell and Wiegmann 1997, Health and Safety Executive 1999c).

3.6.2.5 New approach to human error

Methods for identification of human error have had long been criticised for their lack of accommodation of the work and environment (Surry 1968). A focus on human fallibilities (such as forgetfulness, carelessness etc.) will be ineffective without proper address of the underlying circumstances common to many accidents (Department of Health 2000) and this is reinforced by the conditions that contribute towards error and violation. Incompatibilities or competing goals between people and the work system create conditions for human error (Center for Chemical Process Safety 1994). Dekker (2002) describes the 'new view' whereby human error is a symptom rather than a cause of accidents.

3.6.3 Engineering approaches

Information derived from early industrial accident analyses (3.2.2) revealed that the hazards implicated in accident causation were often mechanical in nature. Accidents were perceived as a form of harmful or uncontrolled energy transfer (Haddon 1973, Johnson 1980) or deviation from the controlled system element (McDonald 1972, Kjellen 1983, cited by Koorneef and Hale 1997). Measures to reduce accidents and injuries entailed the control or distancing of human exposure to these energy hazards, typically by the introduction of defences using barriers such as safe-guarding of machinery (Hoyos and Zimolong 1988) or protective equipment (Center for Chemical Process Safety 1994).

3.6.3.1 Physical defences

Defences have been improved in a number of ways. These include selection of materials that will retain their integrity and reliability under process or environmental exposures. Such resistance includes acceptable responses to stress, strain, wear and corrosion (Stranks 1996). In construction, Koningsveld 1997, notes trends and developments in parts pre-fabrication, new building materials and new finishing techniques.

Knowledge of a wider hazard range (such as environmental, chemical, radiation and vibration sources) has increased with technological advancement. Using principles of 'Hierarchy of Control', the barrier approach has been developed as a universal hazard management technique (Reese 2001). Typically, control is achieved by sequential

progress through the stages in Table 18. The final solutions often incorporate a combination of interventions. The approach mirrors Regulatory risk control measures (2.5.4):

Hierarchy of Control	Increasing defences
1. Elimination	Cease activity or hazard source. Automate process
2. Substitution	Alternative and less hazardous products or equipment
3. Isolation	Screens, barrier, system containment or failsafe operation
4. Engineering controls	Environment (control of ventilation, noise, light, noise, vibration) Workspace and equipment (design of machinery and tools)
5. Personal protective equipment (PPE)	As a last resort. To enhance existing control measures

Table 18. Hierarchy of control

3.6.3.2 Behavioural defences

Engineering approaches have also been used to control unsafe acts such as negligence, carelessness etc. by use of intervention strategies to encourage behavioural changes among workers. These include measures, such as direction (through procedures, training, instruction etc.), leadership by example, the setting of goals and the use of both positive and negative feedback as incentives to improve behaviour (DeJoy 1986).

3.6.3.3 Defence failures

Engineering and behavioural approaches to control are criticised because the human within the system receives analogous treatment as hardware (Center for Chemical Process Safety 1994). Where user requirements have not been properly considered incompatibilities can result in losses to the organisation and individual.

Bainbridge (1987) for example, describes these types of problems with the use of automation. Firstly, there is a tendency to automate only those functions amenable to automation, which leaves fragmented activities for the operator and loss of continuity in the task. Secondly, reduced interaction can also create conditions for degradation in skills and operator vigilance. More general problems are that ergonomics principles are not applied. This can be because of lack of knowledge of problems or because of lack of insight into the significance of shortcomings. Underestimations arise from a range of preconceptions (design for ‘average’, workers can adapt, problems are minor, instruction or training will solve any problems) or because of lack of insight into the benefits of user centred design (Cordiner et al. 1998).

Whilst it is acknowledged that behavioural defences have their value, without due attention to task workload and interface requirements, the potential for repeated failure will remain (Center for Chemical Process Safety 1994). That employee motivation is guided by incentives that correspond to their social and physical needs (Hoyos and Zimolong 1988) is also criticised for the assumption that all behaviour is amenable to free choice (Center for Chemical Process Safety 1994) and that lack of motivation is a significant contributor to work accidents (Wagenaar et al. 1990). To protect the system from human unreliability, approaches such as dismissal or disciplinary action are adopted. Control is also increased by supplementary training and by the introduction of increasingly complex and lengthy procedures (Stanton and Baber 1996, Dekker 2002), yet there are some common problems associated with training and procedures; these are summarised in Table 19.

	Training	Procedures
Inadequate reflection of task practice	Lack of task analysis or revision in line with an evolving work process Lack of appropriate evaluation of effectiveness Lack of consideration of concurrent demands upon operators	
Inappropriate goals	Lack of training needs analysis & determination of refresher training needs	Underlying reasons are not understood and alternative actions are executed instead
Inappropriate style for transferring information	Inappropriate theoretical: practical mix. Inappropriate learning environment. Reliance on lengthy & unverified on-the-job training	Voluminous or inappropriate language and presentation style. Appropriation of regulatory materials as instructions

(Reason 1997)
(Sanders and McCormick 1992)
(Center for Chemical Process Safety 1994)
(Rasmussen 1997)

Table 19. Common failings in training and procedures

There are also criticisms that multiplicity of defences or ‘defence in depth’ (Rasmussen 1997), may create a false sense of security and, in themselves, introduce alternative hazards. Extra defences may camouflage system failure resulting in more serious consequences at the point of system failure (Wagenaar 1990). Possible reasons for this are the introduction of solutions in a piecemeal fashion and without due consideration of system compatibility. ‘Segmentalism’ characterising impervious organisational boundaries (Kanter 1984, cited by McDonald 1997) can contribute towards this. Stanton and Baber (1996) encapsulate the fallacies of many engineering approaches, in that: -

- these are reactive post-accident measures

- they do not explicitly address the employee: technology relationship
- they may be appropriate immediately, but are not necessarily sustainable
- they may overlook insidious activities that impact on performance, productivity and user compatibility

(Stanton and Baber 1996, p. 215).

3.6.4 Work organisation issues

The behavioural defences – training, use of procedures, motivational campaigns etc., - are measures that traverse the domain of work organisation. The evaluations of effectiveness showed unfortunate effects where development and integration had not been appropriately applied or evaluated.

Work organisation issues accommodate the factors remaining from Table 15 and Table 16 (that have not already been addressed): - work organisation, work scheduling, hours of work, work-rest schedules, shift work, target / payment issues, task characteristics (job design), skill and effort requirements, degree of worker control and supervision (interpersonal relationships).

Many work organisational factors are not traditionally associated with accident causation yet the increase in understanding of ‘contributory factor types’ reveals that these issues, traditionally viewed in the context of performance, productivity, quality etc., are relevant. However, even among the few incidences where there are direct accident associations the evidence is not always conclusive (Table 23, p.61).

3.6.4.1 Developments in work organisation

Much development in work organisation has evolved through the understanding of psychosocial issues. Psychosocial issues incorporate those issues that are not physical in nature (Cordiner et al. 1998), but are a manifestation of the interaction between the individual(s) with their surroundings (National Occupational Research Agenda 1999). Intrinsic to the individual are personal attributes such as attitudes, motivation, personality etc. Personal attributes (for example) are shaped by learning and experience and in turn there is additional effect by factors both from within and outside the workplace (Cordiner et al. 1998).

A significant influence to much of the current knowledge of work organisation and job design theories is derived from work of the Quality of Working Life movement and socio-technical theorists (Bridger 1995). The traditional industrial approach had required adaptation by workers where there was a 'technocentric' approach to productivity (perhaps according to the nature of workflow, scheduling or style of managing the work). Socio-technical systems focused upon joint optimisation – fulfilling technical requirements in parallel with the personal needs and social networks among those who undertake the work (Warr 1987, Eason, 1988). Progressive understanding of factors affecting motivation, social needs etc. were foundation knowledge in determination of desirable job characteristics and job design theories (Carayon and Lim 1999).

An alternative perspective concerning psychosocial factors is their association with occupational stress (Smith 1981). Imbalance or mismatch of psychosocial factors can lead to stress - an adverse reaction to excessive pressures or other types of demand placed upon individuals. While traditionally associated with ill health effects, the role of stress upon failures in human performance has been (Carter and Corlett 1983) and is again an area of current interest (RoSPA 2002, Lawton and Parker 1998b).

3.6.5 Organisational goals

Organisational aspects were described by Reason (1990b), and addressed the conflicts in goal setting and resource allocation that can occur in the upper echelons of an organisation. There is a trend towards use of information technology for improved logistics (Koningsveld 1997), but whatever the planning and communication methods, there is different information denoting success. Productivity goals generally have an immediate and discernable effect, whereas in contrast safety related goals have traditionally been measured by their failure (accident and ill health figures) and lack of certainty that investment will yield the desired results (Reason 1990b).

The realisation of safety and performance goals is, essentially, a desire to improve competitiveness (Reason 1997) and this underlies the Total Quality Management (TQM) approach (Buchanan 1998a). Just-in-time measures are often introduced as part of this drive for competitiveness. These measures are directed at fulfilling the

needs of the end user, using a 'pull' rather than 'push' demand system (Myazaki 1992, Jackson and Martin 1996).

Success will also reflect the strategy and culture of an organisation. In allegiance with the socio-technical systems approach Perrow (1999) described organisational strategy from the perspective of 'coupling' in an organisation. Tight 'coupling' (invariant sequences, one method to achieve goal, little slack in supplies, equipment, personnel etc.) described organisations with a high level of control. Alternatively, loose 'coupling' described organisations with a more flexible strategy, able to accommodate fluctuations in work sequences, methods, and use of technology and resources. To achieve flexibility in an organisation, alternative methods of work organisation (e.g. group working) and job design (e.g. multi-skilling) provide comparable adaptability among personnel (Buchanan 1998b).

Organisational goals are also influenced by extra-organisational factors, such as legislative and local government requirements and the customer: client base.

3.6.5.1 Defining safety culture

It is the actions and decision at the top level that determine the culture of an organisation, and this is also applicable to safety. A number of descriptions of safety culture exist (McDonald 1997); the term appears to be used interchangeably with safety climate and health and safety culture / climate. As an example the HSE describe:

'The safety culture of an organisation is the product of individual and group values, attitudes, perceptions, competencies and patterns of behaviour that determine the commitment to, and the style and proficiency of, an organisation's health and safety management. Organisations with a positive safety culture are characterised by communications founded on mutual trust, by shared perceptions of the importance of safety and by confidence in the efficacy of preventative measures.'

(ACSNI 1993, cited by Health and Safety Executive 1997b).

In more general terms, evaluation of the resources used to identify safety culture components are beyond the scope of this literature review, but for completeness and later reference, the facets that make up and are essential in the achievement of a health and safety culture are recorded in Table 20.

The facets of an informed safety culture
<ul style="list-style-type: none"> • A ‘reporting’ culture – of errors and near misses + knowledge elicitation of steady state • A ‘just’ culture – determining boundaries of acceptable behaviour • A ‘flexible’ culture – decentralised decision making and a divergent skill base • A ‘learning’ culture – ability to evaluate information and take positive action
(Reason 1997)
To achieve a positive health and safety culture HSE promote:
<ul style="list-style-type: none"> • Control – top down commitment and allocation of responsibilities for health and safety • Co-operation – pooling knowledge and experience through participation at all levels • Communication – H&S information must flow into, within and out of the organisation • Competence – that employees are adequately skilled and experienced in their role
(Health and Safety Executive 1997b)

Table 20. Safety culture summarised

3.6.5.2 Safety management

It is beyond the scope of this research to comprehensively describe the field of safety management, but interview data from the two governmental research initiatives into construction accident causation (Ministry of Labour 1967, Whittington et al. 1992) summarise many findings and subsequent recommendations. The 1967 report focused upon the importance of management commitment to safety, proper provision of safety advice (especially at the planning stage), requirements to wear protective equipment, the use of a safety committee to co-ordinate different contractor groups and the need for measures to accommodate ‘multiplicity’ of contractors in a work area.

There have been some changes in terminology or emphasis in the 25-year interval between each publication, yet many of the findings remained relevant and were repeated in the latter publication. Summarised, the findings of the 1992 report defined three areas of safety management improvements (Table 21):

Within individual companies
Develop effective reporting systems & data bases to feedback on company performance and decision making
Integrate safety goals with other company objectives
Aim for comprehensive safety management systems:
<ul style="list-style-type: none"> • Establish lines of responsibility and control • ensure safety competence of contractors • define pan-industry safety requirements • introduce systematic risk management • improve supervision • increase subcontractor and workforce participation • effectively sanction and enforce policy • develop a safety monitoring system for organisational, project and site management levels • encourage large companies to train commonly employed sub-contractors
Industry-led initiatives
Develop a more effective training infrastructure
Develop a comprehensive policy for training and supervision of site management / first line supervision
Improve information flow of accident and technical risk management data across industry
Establish common safety requirements and certification (analogous to BS5750)
Client-led initiatives
A higher client profile to ensure adequate consideration of timelines, costing, safety and programming
General operating climate
Legislative changes to promote proactive safety management, client responsibilities and minimum safety management standards
Insurance premium changes to reflect good management
HSE changes to
<ul style="list-style-type: none"> • provide guidance on safety management • introduce a more systematic approach to data collection and incident investigation • develop more practical safety guidance for SMEs

(Whittington et al. 1992, pp 124-128).

Table 21. Recommendations for safety management improvement from ‘Research into management, organisational and human factors in the construction industry’

Whilst not specific to the construction industry, more recent and primary guidance for safety management is provided by the HSE (Health and Safety Executive, 1997b).

3.7 Overview of main issues in accident modelling

Evaluation of progressive development of the knowledge base concerning accident causation has enabled the isolation of key features in modelling the systems approach - these are reproduced in the first column of Table 22. Evaluation of findings using an ergonomics approach (incorporating findings from the contributory inter-disciplinary research) has highlighted the areas that should be explored in accident investigation (Table 15 & Table 16). Remedial measures have been attributed variable success and the investigation must evaluate the appropriateness of these for both users and the work process. Comments on failings in accident investigation are isolated as key points to be avoided. These issues are summarised in Table 22.

Systems approach	Accident investigation	Key points
IDENTIFY Managerial, organisational and extra-organisational influences	<ul style="list-style-type: none"> Explore the range of influences and conditions that impact human performance Explore compatibility of barrier / control interventions for user & process 	AVOID over concentration on individual fallibilities AVOID the many forms of 'blame' AVOID technocentrism
IDENTIFY latent conditions independent of the accident sequence		
IDENTIFY types rather than tokens		
IDENTIFY the influence of dynamic states upon subsequent performance and adaptations		

Table 22. Overview of the systems approach

These criteria will be used in evaluation of construction accident models (3.11). However, much information concerning the nature of construction industry accidents is derived from epidemiological data, and thus it is necessary first to introduce this resource.

3.7.1 Epidemiological data

Epidemiology is concerned with the study of patterns and determinants of damage in populations (Shepherd et al. 2000). Section 3.2 described the historical factors influencing understanding of the term ‘accident’. Initially the classification ‘accident’ served as an umbrella term to describe outlying or vicarious events, but data collection and improved analysis strategies later permitted the collection of more usable and productive information. Sources and collective findings of modern day UK national accident, injury and ill health data statistics have been described in the introduction. The development of a sophisticated reporting and analysis system has proved invaluable in isolating data patterns, distributions and associations (age, gender, work experience etc.) in accident causation.

An initiative to improve and create commonality of reporting among EU member states has recently been launched (European Commission 2000). An early trial of the new methodology shows the potential for improved understanding of accident causation through the introduction of recording of deviation (sourced by people, products, environment etc.), but notes limitations, especially for more minor

accidents, as a result of inadequacies in design and completion of accident report forms (Hanna-Kaisa and Marko 2002).

Criticisms levied against the source material and methodological approaches are not new. Pitfalls of dependency upon epidemiological data are summarised by Surry (1968); although development of the EU classification systems indicates considerable progress, weaknesses or bias in source materials are concerns still relevant to current practice.

- Reporting may be 'claim' rather than accident related and be biased by data collectors. Findings are entirely reliant upon the quality and integrity of reporting
- The main purpose lies in the accounting of accidents by severity / frequency. Statistical analyses find accident associations, rather than 'why' it happened. There may be a revelation of significant common elements rather than investigation of accident antecedents, encouraging the researcher to deduce assumptions rather than explore data

(Surry 1968)

3.7.1.1 Epidemiology and human error

Epidemiological studies have revealed some associations with human error type and accident consequence, which gives some insight into the risk factor and consequence associations described above. For example studies of aviation accidents have revealed that fatalities had greatest association with goal selection or decisional factors (O'Hare et al. 1994). Similarly major aviation accidents have been associated with judgement errors, whereas minor accidents have been more associated with procedural accidents (Wiegmann and Shappell 1997).

Mathews et al. (2000) compared the results of Wiegmann and Shappell (1997), Feyer et al. (1997) (Australian occupational fatality data), and Salminen and Tallberg (1996) (National Finnish serious and fatal occupational accidents) to identify error distribution. They reported that, among the aviation data as a whole, violations had greater association with major accidents, accounting for 17% of the data, whereas among minor events mistakes accounted for 58% of accidents and slips and lapses the

remainder. The two national data sources revealed very similar patterns to each other: skill based mistakes had greatest association with fatalities (66% and 55% respectively) whereas rule and knowledge based mistakes each accounted for 10% – 14% of the remaining fatality cases.

3.7.1.2 Epidemiology and systems aspects

Understanding of multi-factorial events and systems approaches to accident causation has enabled considerable improvements in the collection, categorisation and analysis of epidemiological data. Pioneers in developing an epidemiological tool for occupational accident research are Williamson and Feyer who, through analyses of a 3-year period of Australian fatality rates (1020 fatalities) and associated coroner details, developed a behavioural epidemiology tool for use in accident causation research (Williamson and Feyer 1990). The model requires distinction of up to three precursor events to the accident and eight categories of contributory events

- Precursor events (can be selected from any of the four categories) ‘environmental, equipment, medical and behavioural*’.

* Behavioural events used two error classifications –error of omission or commission (Swain 1963) and behaviour based error by skill, rule or knowledge (Rasmussen 1982)

- Contributory events can be any from the categories ‘environmental, equipment, medical, work practice, supervision, training, task error and other’

Whilst attribution of behavioural events appears to exclude ‘violation’, Williamson and Feyer nonetheless found that 91.2% of the fatalities included precursor events of human error or ‘poor work practices’ such as poor supervision and training. Upon later re-evaluation of the data Feyer et al. (1997) concluded that unsafe practice varied for different error types – skill base errors were associated with individual worker practices, PPE and safety equipment; rule based errors were associated with general equipment practices; and knowledge based errors with management practices.

3.7.1.3 Epidemiology and construction data

In the UK, the Health and Safety Commission provide an annual report of epidemiological data; current findings relating to the construction industry were introduced earlier (2.2.1). Preceding this method, there were two large studies (independent of the annual HSC reports) each involving analyses of construction fatality statistics over a five-year period (fatalities are always reported and investigated, thus ensuring consistent case details). In one case, 100 construction accident case studies were analysed (Health and Safety Executive 1978) and in the other all 739 fatalities in the five-year data collection period were included (Health and Safety Executive 1988).

Each study generally reported by very similar criteria, the activity or task type proximal to the accident event. In each study 'falls from height' accounted for approximately 50% of the fatalities and, including histories of sample accidents, there was much guidance relating to defining responsibilities, preventative action and improvements. Whilst these two sources have been important in isolation of hazardous incidences and activities from which a wealth of remedial measures has been proposed, current methods of analysis appear increasingly sophisticated. There is also a wealth of similar information from overseas, for example the National Institutes of Occupational Health in Denmark (e.g. Kines 2001), Finland (e.g. Niskanen 1986) and the USA (e.g. Hinze et al. 1988).

3.7.2 Summary table of inter-disciplinary knowledge sources

Previous literature reviews have revealed a variety of associations with accidents, either concerning individuals, or associated with work place and environment or with work organisational issues. Table 23 overviews some of the accident related findings. There are some conflicting reports, but they are listed here as examples of related research drawn upon for later site data methods development. Data have been obtained from a variety of individual publications and literature sources such as national HSE data, a comprehensive review of individual differences in an HSE

contract research report (Lawton and Parker, 1998) and a review of social theory and accidents (Dwyer and Raftrey 1991).

Individual differences		
Gender related issues	Males have a 20% higher risk of reportable injury, not explained by occupation / job characteristics	(Health and Safety Commission 2002b)
Age related issues	Accident rates for males are at their highest in the teens and early twenties	(Oborne 1987)
	Alternatively, accident rates for males are at their highest between the ages of 30 – 45 years	(Barsky and Dutta 1992)
	Males in 16-24 age group have a higher risk of work related injury than those older	(Health and Safety Commission 2002b)
Personality and intrinsic factors	Those who are low in openness, high in conscientiousness and high in agreeableness are less likely to be involved in accidents	(Clarke and Robertson 2001)
	There are inconsistent findings linking personality to accidents	(Lawton and Parker 1998a)
	Intelligence is not directly associated with accidents. However results may be mitigated by recruitment criteria or ameliorated by self-selection to more risky jobs	(Lawton and Parker 1998a)
Experience related issues	The acceptance of danger has some association with accident causation	(Dwyer and Raftrey 1991)
	A less positive attitude towards safety among employees is associated with higher accident rates	(Lawton and Parker 1998b)
	Inexperience, particularly among new recruits can raise propensity to accidents, and may account for higher accident rates in the younger age band	(World Health Organisation 1993)
	The rate of injury to workers within their first 6m with an employer is more than twice that of those employed for more than a year	(Health and Safety Commission 2002b)
	Training has been reported to provide desirable and no desirable effects upon reducing accidents	(Dwyer and Raftrey 1991)
Accident history	Stress is associated with a higher accident reporting rate and longer periods of lost time	(Lawton and Parker 1998b)
	Absence duration is greater among accident 'initiators' than where victims are perceived as 'passive' in accident causation	(Verhaegen 1993)
	Following major injuries employees have longer accident free periods than after minor injuries	(Laughery and Vaubel 1998)
	Employee behaviour is modified by prior accident experience. Intervals between accidents are greater with a recurrence of the same prior event/activity than between accidents presenting different features	(Laughery and Vaubel 1998)
	Workplace and task design	
Job content	Boredom and monotony have been associated with higher accident rates	(Dwyer and Raftrey 1991)
	Stress arising from poor person-environment fit has been associated with work accidents	(Lawton and Parker 1998b)
Environmental conditions	Greater sensitivity to environmental stressors is associated with higher accident incidence	(Melamed et al. 1989, cited by Lawton and Parker 1998b)
Payment / incentives	Work organisation	
	Financial incentives have been both refuted in accident link and found highly influential in reducing accident rates. Differences are thought to be related to the amount of risk taking that financial incentives induce	(Dwyer and Raftrey 1991)

Working time	There are conflicting reports among different industry types that extensive work hours are associated with accidents	(Dwyer and Raftrey 1991)
	A decline in work hours is associated with a decline in accident rates	(Dwyer and Raftrey 1991)
	There is no intrinsic link between day and night shifts and accidents	(Dwyer and Raftrey 1991)
	Accidents occur more frequently during the night shift than at other times	(Mathews et al. 2000)
	Exceeding the 8-hour day, 5 days/ 40 hour week is associated with higher accident rates	(Kossoris and Kohler 1947, cited by Center for Chemical Process Safety 1994)
Social support	An absence of 'work group integration' has been considered both responsible and not responsible for accidents	(Dwyer and Raftrey 1991)
Work organisation	Authoritarian management style is associated with higher accident rates.	(Dwyer and Raftrey 1991)
	Lack of or ineffective Trade Union's have been associated with higher accident rates	(Dwyer and Raftrey 1991)
	Autonomy contributes little to the production of accidents	(Dwyer and Raftrey 1991)
	There is a positive effect on lost time frequency rates from workforce empowerment, seniority within the workforce and an active role within top management	(Shannon 1998)
	Organisational issues	
	Construction injury frequency increases as firm size decreases	(McVittie et al. 1997)

Table 23. Example characteristics and conditions associated with accident events

3.8 Transferring accident causation models into practice

3.8.1.1 Criticisms of accident causation models

A criticism levied at accident causation models is that they can induce a struggle to fit the data range into a specified framework and inhibit 'free range thinking' (Kletz 1994). It should not be assumed that the development of an accident causation model is concomitant with the production of an accident investigation technique (Benner 1985). In a study of accident investigation procedures undertaken by seventeen US federal or industry representation bodies, Benner found that only two were able to specify use of a particular accident model. Most techniques used by the remainder were closely allied to accident causation models, but had combined model elements with in-house data collection techniques to create a practical 'investigative methodology'.

This suggests that, as an academic concept, accident study models do not automatically translate into efficient accident investigation methodologies. There may be a number of reasons for this (such as poor models, lack of knowledge at practitioner level or industry specific idiosyncrasies); the need to bridge the gap between theory and practice in accident investigation and analysis has been identified (O'Hare 2000). The practical aspects of accident investigation are reviewed in the following sections.

Hoyos and Zimolong, (1988, p. 29) note that 'the application of accident causation models in safety practice is a means to filter and control the organisation of data about accident risks and select appropriate measures to improve safety'. Given the historical perspective showing the progressive learning about the range of relevant factors in accident causation, 'filter' and 'control' suggest the risk of elimination of data with learning potential. Alternatively, the models may also give some structure and enhance the approaches used. A significant feature in identifying the range of latent factor conditions has been achieved by the incorporation of ergonomics / human factors assessments as part of the data collection process (Center for Chemical Process Safety 1994), yet this too has received a number of criticisms.

3.8.1.2 Criticisms of human factors /ergonomics approaches

Whilst the advantages of human factors / ergonomics assessments are embraced (as a means to identify contributory factors), the exact meaning and application of human factors and ergonomics appears to be a source of conflict. The Center for Chemical Process Safety (1994), attribute human factors /ergonomics to the use of design principals, matching the physical environment to the workplace layout and interface. The Health and Safety Executive (1999c), adopt a similar stance, but attribute different meaning to each word – ergonomics pertaining to physical fit between people and the things that they use, and human factors as the impact on safety and health behaviour arising from the job, the individual and the organisation. However, the International Ergonomics Association, in their definition (1.5.1), adopt interchangeable use of the terms ‘human factors’ and ‘ergonomics’ and reinforce that the approach and discipline is concerned with human interaction with the system.

Cross-reference to the headings collated from ergonomics texts in the first column in Table 15 and Table 16 may serve to debunk some preconceptions pertaining to a narrow view of ergonomics /human factors, but not necessarily its science. Human factors assessments are criticised methodologically - for leaping from ‘tokens’ to ‘types’ without adequate breakdown and evaluation of the event sequence (Dekker 2002), or error identification (Center for Chemical Process Safety 1994), and for lack of consideration of latent conditions, such as regulatory weakness (Johnson 1999).

From an alternative perspective, the quality of ergonomics in diagnostic approaches is also criticised. Kennedy and Kirwan (1997), in their evaluation of 15 safety culture assessment methodologies (including MORT and Tripod, 3.9.2.2), identified that ergonomics was generally dealt with only in a ‘piece meal fashion’ and concluded that an inadequate ergonomics evaluation could give a very poor reflection of interactions between the system and user.

3.9 Accident investigation

The aim of accident investigation is expressed from two different perspectives. Firstly, the emphasis of accident investigation is described in terms of its eventual desirable outcome; the improved safety of the system (Barnett 1987), a typical outcome being ‘judicious intervention strategies’ (Shappell and Wiegmann 1997).

The second perspective is that accident investigation, additionally, is a means to learn from past incidents in order to generate improvements (Redmill and Rajan 1997, Kontogiannis et al. 2000).

Whilst the authors with the 'desirable outcome' perspective may feel that learning from past incidents is implicit within their descriptions, the nature of learning is an important point as this concerns the types of accidents studied, the techniques used to gather information and the nature of evaluation and interpretation.

3.9.1 Accident types and consequences

A commonly accepted view is that major accidents are relatively rare events, representing the 'tip of an iceberg', yet for every major or lost time accident there are greater number of events with minor consequences, and yet more with no visible injury or damage (Heinrich et al. 1980). There has been some opposition to this viewpoint; Saloniemi and Oksanen (1998), (in analysis of Finnish fatality data 1977-1991) report increased fatalities on construction sites as cubic metres under construction decline and as accident frequency declines and proposed that the chain from minor to major accidents was unclear. Nevertheless, while the variables in their sample also incorporated number of employees, working hours and unemployment rate, there was no information relating context of the construction projects studied (build type, timeliness, environmental conditions etc.), which may have revealed important contributory information.

The Health and Safety Executive (1997b), adopts the traditional approach of relationship between major / lost time, minor and non-injury events and report a ratio of approximately 1:7:189. They conclude that the accident consequence (ill health, injury, damage) is often a matter of chance; investigation of near-miss events is urged (Health and Safety Executive 1997b). The more frequently occurring events could otherwise be more serious and, although not all risks lead to serious consequences, such events represent control failure and thus learning potential.

There are requirements to report major injury types, work related absences over 3 days and certain types of occupational ill health and dangerous occurrences (Health and Safety Executive 1999b). However, investigation of more minor events may have

less association with guilt, anxiety and produce a more candid history (Redmill and Rajan 1997). Different techniques and analyses are used in investigation of major and minor incidents and these are each discussed.

3.9.2 Major accident - assessment techniques

The investigations of major accidents in high-tech high-risk industries have been a key source of learning and intervention in the understanding of accident causation. Specific legislation has been developed to specify organisational responsibilities. In the petrochemical industries, responsibilities are defined by the Control of Major Accident Hazards Regulations 1999 (COMAH, formerly the Control of Industrial Major Hazards (CIMAH) Regulations 1984,) (Health and Safety Executive 1999c). As major hazard installations (sites with dangerous substances above specified quantities) they are required to detail emergency plans and include presentation of a 'safety case' (defining the safety of the installation, Reason 1997). These principles have also been adopted by other high risk industries and techniques used in Probabilistic Safety Assessment (PSA) and Human Reliability Assessment (HRA) are employed (Kirwan 1995). The assessments and development of different techniques have also provided much of the knowledge base concerning human error identification, prediction and risk reduction measures. Some of the methods also serve or have been used in development of accident investigations techniques.

3.9.2.1 Human error assessment techniques

An abundance of human error identification methods exist (Stanton and Baber 1996). A general feature of these measures is that they typically require task analysis (Kirwan 1994), the consideration of known events around a task (Johnson 1999) and expert judgement to determine predicted error types (Stanton and Baber 1996). Criticisms levied at human error assessment techniques are for their lack of consideration of physiological or intrinsic factors of the individual, (Shappell and Wiegmann 1997), for their lack of representation of the external environment and for variable reliability in judgement / predictions (Stanton and Baber 1996). Human error assessment is also used outside the major incident prediction scenario (in evaluation of human-machine interface for example), but further description is beyond the remit of this thesis. Nevertheless, solutions to shortcomings in human error assessment can be found in the assessment of systems issues and factors influencing performance.

3.9.2.2 System assessment techniques

Response to the limited focus on Human error has been in the development of methods that embrace the systems approach to accident causation and collect data on the range of latent factor ‘conditions’. Many event diagnostic approaches have been developed for application in particular industries; some are also used as HRA or as safety culture assessment tools. These methods incorporate a range of the systems issues relevant to the industry type; examples of some used in accident investigation include: -

Nuclear industry -	Management Oversight and Risk Tree (MORT) (Johnson, 1980) Safety through Organisational Learning (SOL) (Fahlbruch and Wilpert 1997)
Petroleum / shipping	Tripod –BETA described by (Reason 1997)
Chemical	Sequentially Timed Events Plotting procedure (STEP) (Hendrick and Benner 1987, cited by Center for Chemical Process Safety 1994)

Table 24. Example diagnostic approaches used in evaluation of systems failure

There are common features to many of the approaches; the need for training in use of the techniques, the need for task analysis and the use of expert judgement in risk determination (for example Kirwan 1994, Hoyos and Zimolong 1988, Center for Chemical Process Safety 1994). Another feature is of their presentation for use by industry professionals; the methods have also been developed iteratively through their use in field trials (in some cases over many years, Center for Chemical Process Safety 1994).

3.9.3 Major incident - data representation

3.9.3.1 Use of analytic trees

Software packages have been created to facilitate the diagnostic process using many of the system assessment techniques (Tripod – BETA for example, Reason, 1997). These may also adopt the more traditional approach of data representation by the use of analytic trees. Analytic trees include ‘event trees’, that identify error potential and possible operator recovery modes from a basic initiating event (Kirwan 1994), and ‘fault trees’ which employ a top down approach in the identification of sub-ordinate causal events (Hoyos and Zimolong 1988). These types of analytic trees typically employ a range of flow lines and symbols to distinguish interdependencies in event sequences in accident causation. Essentially, the aim is to identify the ‘root causes’,

the underlying factors or sequences in accident causation (Center for Chemical Process Safety 1994).

The 'tree' layout style is favoured for its visual representation (especially one that is well understood by engineers), for its potential to expose alternative events that might have happened (Johnson 1999) and to model error recovery and to identify barriers (or barrier failures) along the flow lines that would influence the end event (Kontogiannis et al. 2000). Analytic trees have been used for some time in many PSA/ HRA approaches. The subjective modelling used in predictive quantification techniques can also be enhanced through use of the analytic tree. The layout would guide expert judgement or ranking of importance in the process of comparing and verifying accident causation probability predictions pre and post event (Kirchsteiger 1998).

Shortcomings in the use of fault trees are that they record only a particular case, not system functionality (Rasmussen 1997). They do not model uncertainty or borderline human performance that can be both successful and unsuccessful, (Hoyos and Zimolong 1988), or compensatory (Rasmussen 1997). Neither do they necessarily provide temporal information in the event representation (Johnson 1996). They have also been used extensively in well-structured industrial process plants (with well defined tasks), rather than in less structured situations (such as workshops and construction) (Hoyos and Zimolong 1988). The quality of quantification will inevitably reflect the quality of the source qualitative information (Center for Chemical Process Safety, 1994), and this will be determined by the nature of data collection and analysis.

3.9.3.2 Accident mapping

Svedung and Rasmussen (2002) recently presented a hybrid representation, tracing the analytic tree through to decision makers at the extra-organisational level. Whilst the analytic tree follows the traditional fault tree sequence, the process progressively links with decision makers (identified as part of the risk management process) whose decisions, under normal conditions, have influenced outcome.

3.9.3.3 Tabular representation

An alternative approach was adopted by Taylor-Adams et al. (1999), who presented the investigation of a medical accident by identification of triggering factors between active and latent failures. Taylor-Adams et al. (1999), proposed this technique as the medical circumstances included a number of forms of 'correct' styles of treatment (making task analysis very difficult), situations where medical practitioners rarely work within the constraints of defined protocols and where there are no safety case requirements. They anticipated that the benefits of qualitative analyses would pave the way for more systematic assessments in the future.

3.9.4 Minor accidents - assessment and analysis

The root cause analysis system is concerned with detailed investigations of accidents with major consequences and is, by necessity, resource intensive (Center for Chemical Process Safety 1994). In contrast, investigations of more minor events generate different types and depths of data; traditionally these are more plentiful and compiled for epidemiological style analysis (revealing frequencies and incidences among the sample). Software packages can be purchased (or developed in-house) to assist with analyses and solution generation. The collection and analysis of data is bounded by the impact of those involved in the process of investigation, the methods used, their analysis, and solution generation (Barnett 1987).

3.9.4.1 Accident investigation – documentation

A range of forms, checklists and questionnaires are generally employed to record data. The advantages of these techniques are that they enable quantification of results and increase objectivity and standardisation (Hoyos and Zimolong 1988). They may also assist analysts from forgetting the range of factors (Fahlbruch and Wilpert 1997) and also facilitate the respondents history through recognition rather than the need to recall contributory factors (Hoyos and Zimolong 1988).

In contrast, there are also a number of disadvantages in the use of these techniques. The style of the materials may encourage only superficial investigation, such as focusing on what rather than why an event happened (Center for Chemical Process Safety 1994). Forms are generally modelled on the 'unsafe act – unsafe condition' dichotomy (active factors, Sanders and McCormick 1992), which is not very useful

for the design of improvements (Rasmussen 1997). Accidents may also be incompletely reported (Hoyos and Zimolong 1988) or the materials too inflexible or constraining to capture the subtleties and nuances of events (Barnett 1987, Fahlbruch and Wilpert 1997). The distribution of items may also adversely affect data collection, as points at the beginning tend to be chosen more than those at the end (Sheahy 1979), or because the detail of a particular item might lead to over-estimation of the causal relevance. Alternatively, if a cause is not listed on the checklist, it is likely that it will be missed (Fischhoff et al. 1978) and undermine the quality of investigation.

3.9.4.2 Accident investigation – observation and interview

Observation and interview are also used as data collection methods, and often in combination with the data collection forms and questionnaires (Barnett 1987). For near-miss incidents, the use of ‘critical incident technique’ (recollection of a dangerous situation or successful recovery to avoid an accident) can provide useful information from which to direct remedial action (Hoyos and Zimolong 1988). Where an accident has already occurred, interview should occur as soon as possible after the event for accurate recollection (Barnett 1987). The interviewer should also have, or have access to domain knowledge of the technical aspects of the system (Barnett 1987, Dekker 2002) and be mindful of inter-personal issues of interviewing technique. Such issues include avoiding judgemental comments, pressuring or rushing the witness in anyway, suggesting answers or avoiding questions by assuming prior knowledge of answers (US Department of Energy 1999). Whether or not confidentiality can be assured should be discussed and understood at the outset.

3.9.4.3 Accident investigation – current practice

The practice of accident investigation in the construction industry has been found to be poor (Gyi et al., 1999), but from a more general perspective many issues surrounding accident investigation have been summarised in a recent HSE contract research report:

In a general industry interview study (a range of 100 companies) of the nature and quality of accident investigations (Human Reliability Associates 2001) found that depth of investigation ranged from an event record only (at the most basic level) through to use of photographs,

statements, reconstruction (at intermediate level) to time line or analytic tree modelling (at the most structured level). Values and attitudes of the person driving the investigation (see also 3.9.5) exerted considerable influence over the process, but a robust and structured investigation style served to mitigate adverse effects.

The use of a structured approach to accident investigation tended to increase with company size. Most companies veered towards traditional (active factors) approaches to investigation and although they often did not distinguish between immediate and underlying causes, this didn't necessarily preclude the generation of system based remedial action. For remedial action companies undertaking basic level investigation were more likely to recommend training and raising of awareness, whereas those undertaking more intermediate level investigation changed equipment and procedures. Only 24% of the sample revised risk assessments and this was greatest in companies employing the most structured level of investigation. Results also indicated little training in accident investigation, and for those that had received training it was often incorporated within general 'health and safety training' or was more related to accident recording. (Human Reliability Associates 2001).

3.9.4.4 Problems associated with the collection of accident histories

There is a natural tendency (at any level in the organisation) to avoid blame, accusations of wrongdoing or incompetence (Woodcock 1995, DeJoy 1994). Accident involved personnel may prefer to associate their accidents with bad luck (DeJoy 1994) or be selective in recollection of events, choosing to omit seemingly unrelated or unimportant actions or events (Barnett 1987). There may be social factors at play too; the accident history may be devised to protect a group member (Woodcock 1995), or reflect the nature of social interactions between supervisors and subordinates (DeJoy 1994).

3.9.5 Cause attribution and hindsight bias

A range of different factors influences the perception of causation and the process of decision-making; bias and hindsight are the main areas of concern because of their potential for impact upon the depth and quality of investigation.

3.9.5.1 Role differences in attributing cause

Attribution to internal factors (intrinsic faults of the individual) is more likely the greater the administrative distance from the event (although supervisors with task experience are less internalised (DeJoy 1994). This is especially so among those with supervisory or decision making roles, who are in themselves influenced by the safety culture and attitude towards methods and level of search, perceptions of root causes etc. (DeJoy 1994, Woodcock and Smiley 1998). Attribution of cause is also affected by the investigators professional training (Svenson et al. 1999), whether the investigators role is 'adaptive' or 'defensive' (Wong and Weiner 1981), and by fear of economic implications in proposing solutions (Woodcock 1995). Repeatability, inter- and intra-analyst judgement, may not always be consistent or as objective as it might be (Stanton and Baber, 1996); in trying to avoid bias in one area it may inadvertently be created it in another (Woodcock 1995). Holding stereotype views of interviewees will also affect the interviewer / respondent relationship and likely produce different results (Loosemore and Tan 2000).

3.9.5.2 Event types in attributing cause

The type of event, the history of accidents affecting the task, or the accident history of the worker can influence the attribution of cause; where the event is more severe internal attribution is more likely than with a minor event (Woodcock, 1995). Causation attribution also depends on the stability of the event – consistent and repeatable conditions are more likely to invite change than temporary states or conditions (DeJoy 1994).

3.9.5.3 Bias and hindsight in accident investigation

Bias in information search can result from preconceptions among those with responsibilities for accident investigation. The reporting process is a series of filters, each of which may progressively contribute to bias / unwarranted selectivity in the transmission of injury related information (Webb et al. 1989).

Bias is especially apparent where there is a blame style approach (Dekker 2002), although the reasons behind this may be quite subtle. Attention and action can focus on well-defined hazards – ‘decoy phenomena’, while other problems are missed (Department of Health 2000, Rasmussen 1990). Some accidents are not acknowledged as abnormal, especially if they commonly occur and become integrated within the pattern (or ‘script’) of work (Woodcock 1995); this is one of the reasons why minor or near-miss accidents are particularly vulnerable to being overlooked (DeJoy 1994). Accidents are also often seen as one-off rare events and the lack of remedial action will not necessarily impede operations until the next ‘rare’ event (Woodcock 1995).

Dekker (2002) reports that hindsight encourages the creation of a logical sequence of events from information that was complex (and possibly unknown at the time of event unfolding), fragmented and with a background in its own right. This can also enable the investigator to ‘cherry-pick’ information from within the sequence to highlight particular themes (such as ‘hurrying’), that were not necessarily there in the linear sequence of the event.

What might have been perceived as normal or safe operations, may only in hindsight be identified as incorrect; the progressive development of latent conditions can create accidents that would have been considered ‘impossible’ at their creation (Wagenaar and Groeneweg 1987). Hindsight reveals what the ideal actions and sequence of events should have been, but does not identify why people did what they did and why they deviated from accepted or instructed practice. What are seen as choices in hindsight may not have appeared so at the time (Dekker 2002).

3.9.5.4 Resolving cause attribution and hindsight bias

Solutions to some of the problems concerning the integrity of interpretation will be met by cross-disciplinary teamwork in accident investigation (Svedung and Rasmussen 2002). Teams should include experienced operatives (Kontogiannis et al. 2000) and experts with different professional training - whose joint analyses should provide insightful coverage of systems interactions (Svenson et al. 1999). Solutions to any linguistic problems, such as natural language v.s. a profession’s vernacular, must also be resolved (Johnson 1996).

In order to interpolate the varied perspectives arising from the contributing data sources a process of triangulation may be used (Denzin 1970, Dekker 2002). Comparing data from one source with that of another, and incorporating different combinations of methods to secure an in-depth understanding is a process called triangulation. The outcome may serve to reinforce or question findings. Triangulation is an alternative to validation (Denzin and Lincoln 1998) and an especially useful tool where circumstances are unique and not repeatable.

3.10 Overview of main issues in accident investigation

Evaluation of the literature has revealed a number of differences in the nature of investigation into major and minor accidents. Data acquired from investigation of fatalities appears to have been useful for the large-scale epidemiological studies, but near miss / minor incident investigation is less emotive and a valuable information source when there is the potential for more serious outcomes.

The accident investigation techniques used, for both minor and major incidents, appear to have drawbacks. These included adverse influences from the style and content of the materials used and potential for adverse influences from those responsible for data collection and analysis. Techniques used in major accident investigation have been validated yet appear to be directed towards specific industry types and depend upon detailed knowledge of work practices and procedures and robust qualitative information. Use of multiple methods and cross-disciplinary input offer solutions to some of these problems.

Data representation, especially for major accidents, typically involves the development of an analytic tree which (where required) facilitates the quantitative analyses of accident probability associated with safety case development. Analytic trees appear less appropriate for representation of more subtle situations, especially where there is less control or proceduralisation. Alternative styles of representation have been adopted, eg. free text tabular representation of active and latent factors where a number of correct actions are possible. Alternatively, accident mapping, a variant of the analytic tree method, identifies the dynamic events in accident causation and traces these back to 'normal' extra-organisational conditions.

3.11 Construction industry accident models

There are few models of accident causation in the construction industry and little evidence as yet (beyond the source publication), that indicates the value, appropriateness and subsequent usability by those outside the originator research group. Literature review of accident causation models revealed the progressive research that has lead to the current level of understanding. This was summarised in section 3.6 and a table to encapsulate the main issues in a systems approach to accident modelling was devised (Table 22).

Evaluation of the intricacies of accident investigation has also revealed the many ways that data collection and analysis can impact conclusions made and subsequent remedial action. To represent both the systems approach and the data collection methods, the table was revised (Table 25).

Systems approach	Accident investigation	Key points
IDENTIFY Managerial, organisational and extra-organisational influences	<ul style="list-style-type: none">• Explore the range of influences and conditions that impact human performance• Explore compatibility of barrier / control interventions for user & process	AVOID over concentration on individual fallibilities AVOID the many forms of 'blame' AVOID technocentrism
IDENTIFY latent conditions independent of the accident sequence		
IDENTIFY types rather than tokens		
IDENTIFY the influence of dynamic states upon subsequent performance and adaptations		
	Explore using multiple methods and cross-disciplinary analysis	

Table 25. Overview of the systems approach and data collection methods

In order to explore whether the construction models might be used in the research, each was evaluated against the criteria devised for the systems approach and understanding of factors that impact data collection and analysis (data representation styles are unknown and are not included in this analysis). Five models were selected – one (3.11.1) derived from an HSE contract research report, two from peer reviewed journals (3.11.3 and 3.11.4) and the remaining two from conference proceedings.

Strengths, intermediate value and weaknesses were identified for each model using the criteria of the systems approach. Whilst this evaluation served the knowledge

elicitation process, it did not necessarily reflect the original intention or intended detail of the models. All best efforts have been made in giving a fair representation on the basis of the information documented.

3.11.1 Alternative model of accident causation

The work of Whittington et al. (1992) in their research into management, organisational and human factors in the construction industry, provided a key information source for the identification of accident causal factors. Their research entailed detailed analysis of industry reports of thirty reportable accidents and (to compensate for inadequate detail) was supplemented by interviews with Safety Officers for the companies concerned.

Headquarter issues
<ul style="list-style-type: none"> • <u>Poor selection /control of subcontractors & workers</u> • <u>Inadequate safety training of site managers / supervisors</u> • <u>Failure to consider safety in design of build, plant, PPE etc.</u> • <u>Poor plant maintenance systems</u> • Failure to learn from past incidents • <u>Other HQ factor (such as policy)</u>
Site Management issues
<ul style="list-style-type: none"> • <u>Lack of hazard recognition</u> • <u>Failure to set up and communicate safe system of work (SSW)</u> • <u>Failure to set up SSW for permanent and temporary works</u> • <u>Provision of wrong equipment</u> • <u>Failure to act on earlier safety incident</u> • <u>Failure to supervise subcontractors and employees</u> • <u>Failure to ensure training / authority to undertake task</u> • <u>Poor control of multiple / linked tasks</u> • Other site management issue
Individual Factors.
<ul style="list-style-type: none"> • Unsafe acts • (from exceptional pressures such as time delays etc., habitual violations and inadequate SSW) • Miscommunications between operatives • Using own initiative without skills / training • Other individual factor
Key - <u> </u> = most commonly linked. <u> </u> = second most commonly linked

Table 26. Example failures identified in accident data analysis

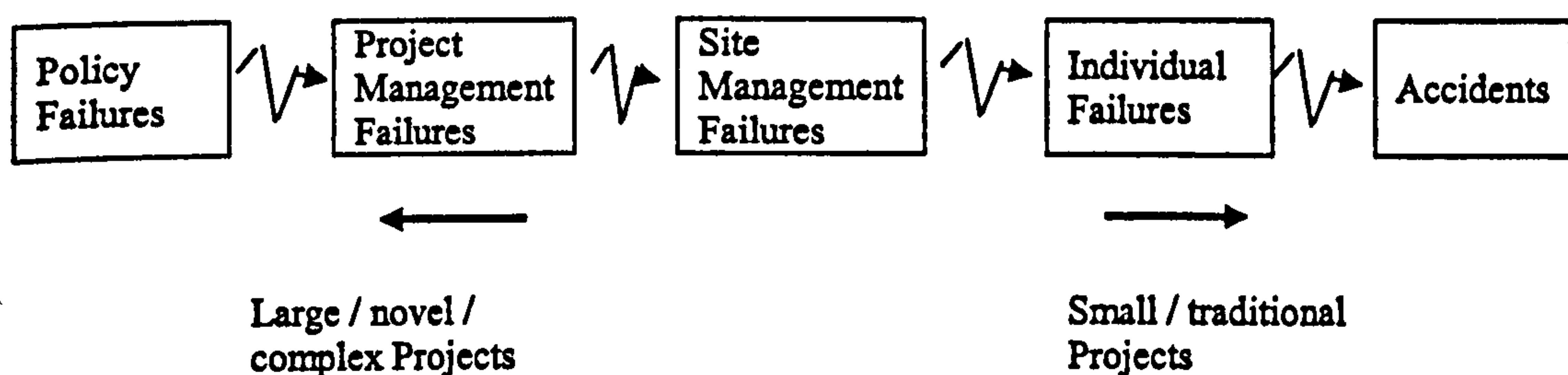
Findings indicated that the construction industry placed overwhelming importance upon the perpetration of unsafe acts by individuals as accident causal factors. However the Whittington et al. (1992) data evaluation (using an adapted HRA / analytic tree human factors orientated approach) identified three groups of causal or contributing factors – Headquarter issues, Site Management issues and Individual

Factors. Considering each accident in turn they identified 3 –15 causes (or possible causes) per accident (212 in total), distributed in a ratio 1:2:1. Head quarter factors were found to influence site factors, which in turn influenced other site factors and individual factors. The types of issues incorporated under each heading are given in Table 26 and those factors more often linked to other factors are underlined.

Based on these findings Whittington et al. (1992) suggested an ‘alternative model of accident causation’ showing the propagation of an accident. The model contains four main stages (Figure 8).

- Company policy level – inadequacies in policies for training, procurement methods etc.
- Project management level – inadequate planning or choice of construction methods
- Site management level – poor communication, supervision and work segregation
- Individual level – use of wrong equipment, violations

Although not annotated they also proposed that there would also be client influences at the commissioning stage.



(Whittington et al. 1992)

Figure 8. Alternative model of accident causation

3.11.1.1 Model evaluation

In comparison with the main issues identified in the review of systems issues, data collection and analysis the strengths and weaknesses of this approach are annotated:

Systems approach		Key points		Weakness	
IDENTIFY Managerial, organisational and extra-organisational influences	✓	Explore the range of influences and conditions that impact human performance	x/✓	AVOID over concentration on individual fallibilities	✓
IDENTIFY latent conditions independent of the accident sequence	x				
IDENTIFY types rather than tokens	x?		Explore compatibility of barrier / control interventions for user & process	x	AVOID the many forms of 'blame'
IDENTIFY the influence of dynamic states upon subsequent performance and adaptations	x	AVOID technocentrism			x/✓
		Explore using multiple methods and cross-disciplinary analysis			

The **strengths** of this approach are in the isolation of latent factors through to organisational, managerial and (inferred) extra-organisational issues. There is not undue attention focused upon individual fallibilities and blame directed at individuals is for the most part avoided.

There are aspects that have received **intermediate or uncertain address** too. Some psychosocial factors are identified although there seems to be little perspective of the accidents in the context of the work situation at the time of the accident (workload, work scheduling, personnel availabilities, the range of psychosocial issues, environmental conditions, for example). Analysis is not overwhelmingly technocentric, yet the accident is seen only as final act in sequential events of construction activities. Training, supervision and communication etc. are identified, but their emphasis appears construction activity related ('constructocentric') rather than orientated towards or reflecting personal and social needs of personnel. Findings are not listed by 'type', but by phase of generation. This is helpful in deflecting blame from 'active factors', but has not distinguished 'types' – there are failures in common at site management and headquarter stages.

The **weaknesses** in the approach are that latent conditions have not been identified independently of the analytic tree accident trajectory. These would have served in exploration of a more comprehensive range of contributory factors and might have reflected the interacting dynamic states within which the accident event evolved.

There are no histories from injured parties – accounts are from Safety Officers and incident records. As such this carries the potential for bias and offers no insight into compatibility of control interventions for the user and process, where they exist.

3.11.1.2 Further work

Whittington et al. (1992) used their data sample and results as a foundation upon which to search more widely and explore the factors affecting safety management and impact from the client on the construction process. They extended their interview survey to include views from Project and Site Managers and from subcontractors (These were reported earlier 3.6.5.2).

3.11.2 The distractions theory of accident causation

Hinze (1996) proposed ‘The distractions theory of accident causation’. The components of this entail the plotting of injury probability against the probability of achieving a particular work task, according to whether distractions arise from either physical or mental sources (Figure 9).

The extent to which a worker is focused upon (distracted by) unsafe physical conditions is a determinant of whether they reduce their productivity to accommodate this. The cross reference between the two is used to argue that productivity and safe working are not jointly achievable if the worker is distracted by a hazard – if safe work conditions are chosen, then the worker will not be distracted and the work will be relatively safe and productive.

Mental diversions are different issues or concerns that can occupy the mind, such as domestic, social or family problems – greater focus on mental distraction diverts attention from the work task and compromises productivity. Safety and productivity are not compromised by mental distraction provided they are not related to physical work hazards. Supervisors and managers must observe for these types of mental distraction, and remove the worker from site, or reassign, where safety might be compromised.

The conclusion to the distraction theory is that productivity will be compromised if the worker is distracted, but if the distraction is a physical hazard, focusing upon it will improve safety.

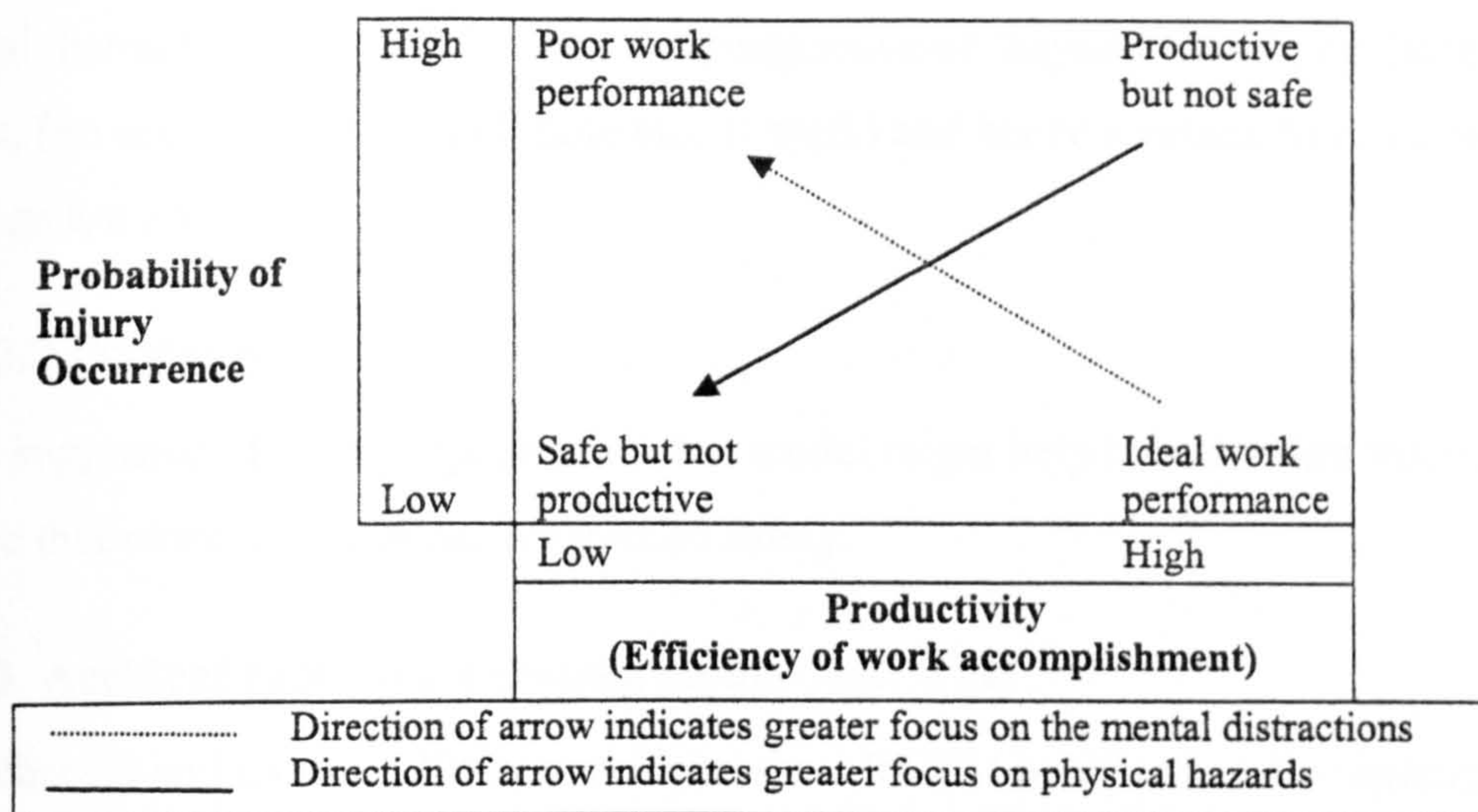


Figure 9. The Distractions Theory

3.11.2.1 Model evaluation

In comparison with the main issues identified in the review of systems issues, data collection and analysis the strengths and weaknesses of this approach are annotated:

Systems approach		Key points		Weakness	
IDENTIFY Managerial, organisational and extra-organisational influences	x	Explore the range of influences and conditions that impact human performance	x?	AVOID over concentration on individual fallibilities	x
IDENTIFY latent conditions independent of the accident sequence	x				
IDENTIFY types rather than tokens	x	Explore compatibility of barrier / control interventions for user & process	x	AVOID the many forms of 'blame'	x?
IDENTIFY the influence of dynamic states upon subsequent performance and adaptations	x				
		Explore using multiple methods and cross-disciplinary analysis			

There are almost **no strengths** to this model. The impression is that work hazards are seen as harmful to performance and productivity and should be removed, but this is also contradicted by a suggestion that the hazard keeps the worker alert.

The **weaknesses** are that the model is entirely focused upon unsafe acts and unsafe conditions and none of the systems approaches are used. Hazards are identified, but these in no way represent the range of conditions that affect human performance.

Mental distraction is seen only from the perspective of ‘beyond work’ psychosocial issues, (no mention of social climate etc. at work) and hence a reason to remove or reassign a worker.

3.11.2.2 Further work

None suggested. It was proposed that this model might help construction managers ensure that work activities are performed safely.

3.11.3 Accident root causes tracing model (ARCTM)

Abdelhamid and Everett (2000) developed the ARCTM in order to tailor existing accident causation models and human error theories to the needs of the construction industry. ARCTM was developed as a working model to assist an investigator in identification of the conditions at the time of an accident and in identification of antecedent human behaviour. Three case studies (including loss control narrative and investigator appraisal of accident causation) of highway construction accidents were used to demonstrate the approach. The main concept is that accidents occur due to one of three reasons; these are reported in Table 27 with examples extracted from the paper. An abridged reproduction of the model is presented in Figure 10.

Failure to identify an unsafe condition (workplace layout / location, tools, equipment, materials)
<ul style="list-style-type: none"> • Due to management in/actions (PPE provision, poorly maintained workplace and equipment / tools OR through initiating exposure to occupational hygiene/ health problems) • Due to (co)worker unsafe acts (social / management pressures, sabotage, fatigue, intoxication, disregarding housekeeping, horseplay and working without authority) • Non-human cause (systems, equipment / tools failure, Acts of God) • Natural part of initial site conditions (uneven terrain, concealed hazards)
Deciding to proceed in the presence of an unsafe condition
<ul style="list-style-type: none"> • Unsafe condition not identified (lack of knowledge /experience, misinformation, habitual violation, human factors violation) • Unsafe condition identified and work continues (as above and attitude / risk perception issue)
Deciding to act unsafe regardless of the initial conditions
<ul style="list-style-type: none"> • No – refer to unsafe condition • Yes – social / management pressures, habitual violation, lack of knowledge experience

Table 27. ARCTM failure types

Corrective actions entail redress in the areas of ‘worker training’, ‘worker attitudes’ or ‘management procedures’. Those workers without sufficient training / knowledge should not be expected to identify unsafe work conditions. Resolution of attitude problems are necessary for trained workers who chose to work unsafe. Management

should remove unsafe conditions proactively and reinforce the importance of worker safety.

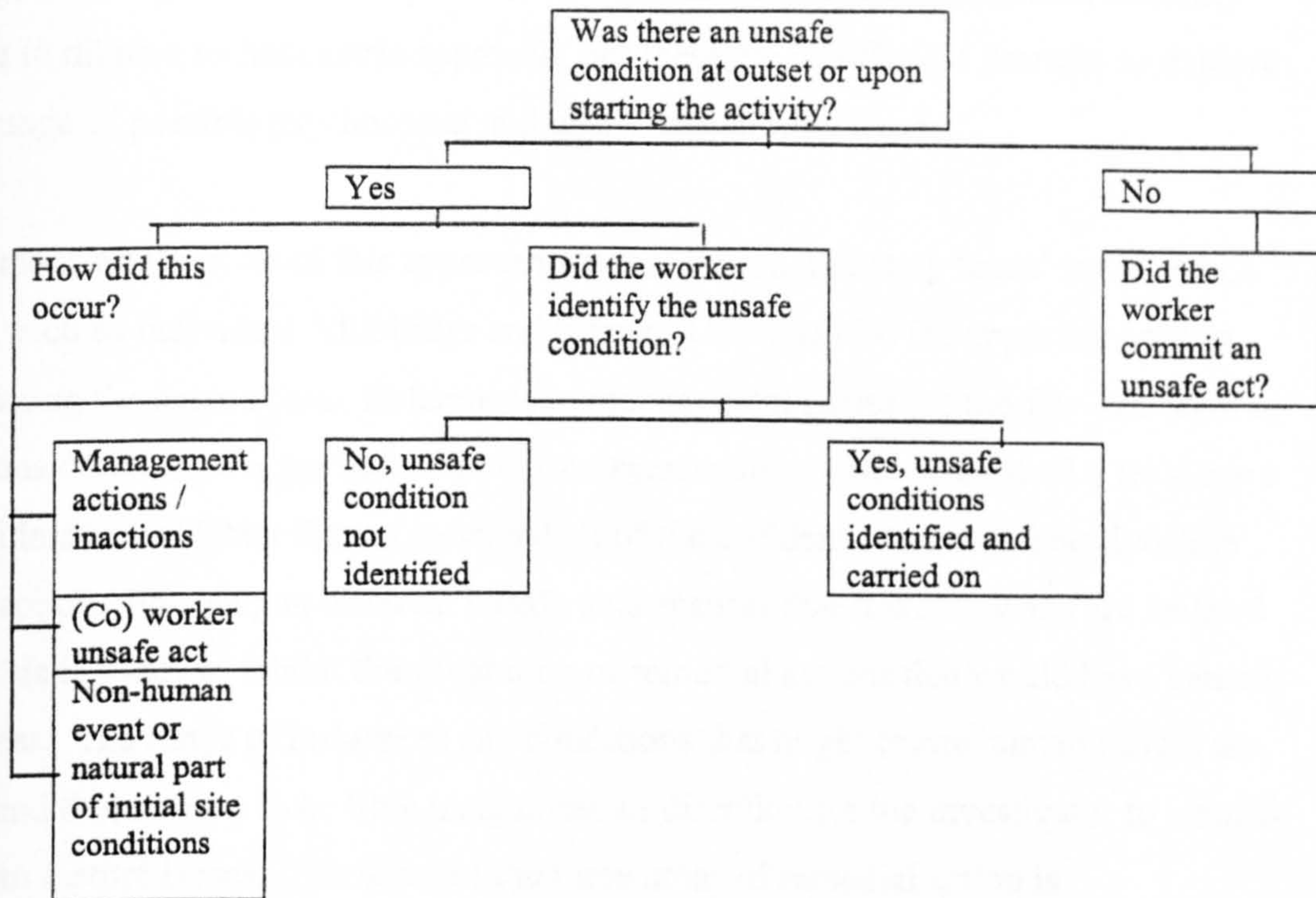


Figure 10. ARCTM Model (abridged version)

3.11.3.1 Model evaluation

In comparison with the main issues identified in the review of systems issues, data collection and analysis the strengths and weaknesses of this approach are annotated:

Systems approach		Key points		Weakness	
IDENTIFY Managerial, organisational and extra-organisational influences	x?	Explore the range of influences and conditions that impact human performance	x	AVOID over concentration on individual fallibilities	x
IDENTIFY latent conditions independent of the accident sequence	x				
IDENTIFY types rather than tokens	x?	Explore compatibility of barrier / control interventions for user & process	x?	AVOID the many forms of 'blame'	x
IDENTIFY the influence of dynamic states upon subsequent performance and adaptations	x			AVOID technocentrism	x?
		Explore using multiple methods and cross-disciplinary analysis			

There are few strengths to this model. As a model / investigative tool there are references to 'management issues' which is good, but no method of exploring the nature of these. Reference to possible peer pressures, tool and equipment usability serve to dilute a technocentric approach, but these are insufficient prompts to explore the range of possible psychosocial and user-compatibility issues.

The main weaknesses of this approach are that it predominately focus' upon unsafe acts, such as individual fallibilities and blame. This was also the approach used in collecting the source data. References to management issues are too few and there is no consideration of organisational / extra-organisational influences at all – let alone a consideration of latent factors independent of the accident event and their dynamic interaction. Focus upon different unsafe acts ensures that 'token' events are isolated and this is likely to inhibit the generation of remedial actions that would have generic address. The range of influences and conditions that might create human failure are few and there seems to be little insight into or direction for the investigator to identify human factors issues. The focus of the three areas of remedial action is predominately directed towards behaviour change or an undefined management intervention which, given the confines of the investigation process, is likely to be severely under informed.

3.11.3.2 Further work

Upon publication of the Abdelhamid paper, discussions were presented by Gibb et al. (2001), and Suraji and Duff (2001). These authors commented upon the narrow range of investigation and recorded the ongoing work of the Loughborough University and UMIST research groups.

3.11.4 Constraint response model of accident causation

Suraji et al. (2001), propose the constraints-response model of accident causation. Their model traces the construction project from participants at the project conception phase through to project and construction management, subcontractors and operatives (19 classes in total). It is the interdependencies of successive decision-making and action through the process (the constraints and responses) that generates the conditions under which an accident can occur. The model is reproduced in Figure 11.

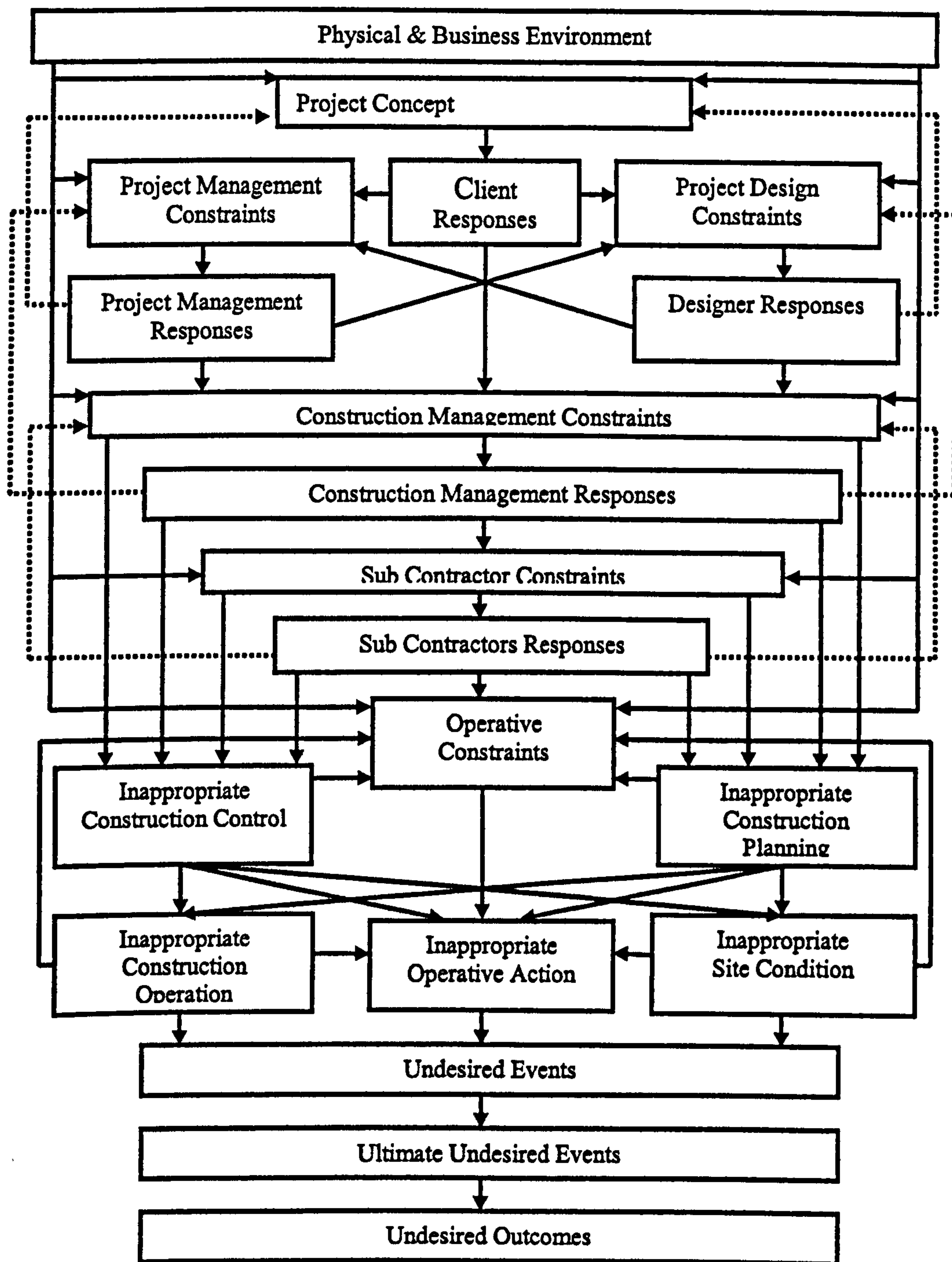


Figure 11. The Constraint- Response Model of accident causation

Examples of the issues attributed to each of the classes are repeated in Table 28 below.

Distal factors	
Project conception constraints	Client responses
<ul style="list-style-type: none"> • Difficulties obtaining funding • New business strategy • Planning constraints • Environmental legislation 	<ul style="list-style-type: none"> • Reduced project budget • Add new project criteria • Change project objectives • Accelerate design or construction of project
Project design constraints	Designer response
<ul style="list-style-type: none"> • Modified technical requirement of the constructed facility • Accelerated design programme • Inadequate design budget • Conflict of objectives or demands of other projects 	<ul style="list-style-type: none"> • Increase design complexity • Sublet part of the design process • Reduce design resources • Reduce quality of components
Project management constraints	Project management response
<ul style="list-style-type: none"> • Late delivery of design detail • Limited availability of suitable contractors • Lack of appropriate project experience 	<ul style="list-style-type: none"> • Increased time pressure on design team • Inadequate contractor pre-qualification • Inadequate budget for supervision of construction procedures • Inadequate attention to risk management
Construction management constraint	Construction management response
<ul style="list-style-type: none"> • Short programme timescale • Design variations • Designs difficult to construct safely • Labour skill shortage 	<ul style="list-style-type: none"> • Adjust level of supervision • Fail to supply safety equipment • Revise or accelerate construction programme • Fail to investigate subcontractor methods
Subcontractor constraints	Subcontractor response
<ul style="list-style-type: none"> • Cash flow problems • Pressure from other contractors for resources • Lack of relevant experience 	<ul style="list-style-type: none"> • Slow down work • Reallocate resources to another site • Recruit untrained operatives
Proximal factors	
Operative constraints	Inappropriate construction planning
<ul style="list-style-type: none"> • Social or domestic pressure • Physical disability • Lack of skill or familiarity with process • Peer pressure to conform 	<ul style="list-style-type: none"> • Inadequate method statements • Inadequate structural design for temporary structures • Inadequate site layout plan • Inadequate site investigation
Inappropriate construction control	Inappropriate site condition
<ul style="list-style-type: none"> • Inadequate control of plant or equipment operation • Inadequate supervision of operative work • Inadequate control or protection of weather effects • Inadequate control of the stability of temporary structures 	<ul style="list-style-type: none"> • Unsuitable existing topography • Unsuitable weather or climatic conditions • Inappropriate ground conditions • Unacceptably noisy or crowded surrounding site
Inappropriate construction operation	Inappropriate operative action
<ul style="list-style-type: none"> • Improper construction procedure • Improper plant or equipment operation • Inadequate illumination or poor lighting • Untrained or inexperienced workforce 	<ul style="list-style-type: none"> • Carelessness • Failure to adopt standard procedures • Improper or inadequate use of PPE • Failure to follow instructions

Accident event	
Undesired event (affecting)	Ultimate undesired event
Structure • Equipment / plant • Ground Service • Material or component • Facility Operatives or other personnel	<ul style="list-style-type: none"> • Fall • Struck • Scaffolding collapse • Excavator overturn
Undesired outcome	
Minor injury • Major injury • Fatality Minor damage • Major damage • Destruction	

Table 28. Example factors of the Constraint- Response Model

Through analysis of 500 records of HSE Inspector construction accident investigations, the researchers validated the proximal factors in accident causation by frequency of citation. These results are reproduced in Table 29; the findings for ‘inappropriate construction operation’ (cited in 88% of accidents) are listed separately.

Proximal factor	Accidents caused by proximal factors %*		%
Inappropriate construction planning	28.8	/	Breach of regulation / code of practice 54.6
			Access/egress defective / unsuitable 18.8
			Inadequate safety facilities 15.4
			Improper construction procedure 15
Inappropriate construction control	16.6	/	Defective equipment /vehicle 9.8
			Inadequate safety warnings / precautions 6.8
			Inadequate work platform / no guard rails 6.6
			Untrained / inexperienced workforce 6
Inappropriate construction operation	88	/	Improper plant / equipment operation 4.2
			Improper instruction to operatives 3.6
			Inadequate working tools / instruments 3.6
			Inadequate temporary structure 3.4
Inappropriate condition	6	/	Defective services 3.2
			Unsuitable plant / equipment 2.6
			Inadequate communication / co-ordination 2.2
Inappropriate operative action	29.8		

* total exceeds 100% due to multiple factors for each event

Table 29. Constraint- Response Model - proximal factors

The authors assume that inspectors report the most influential factors in accidents that they investigate. While they do not comment on the percentage attributed to breach of regulation / code of practice, they remark that the low frequency of ‘inappropriate construction control’ may be explained, in part, by the HSE Inspectors focus upon legal requirements rather than uncovering all the contributory factors. It was expected that Loughborough University / UMIST collaborative work on this research project might aid in redressing the balance.

3.11.4.1 Model evaluation

In comparison with the main issues identified in the review of systems issues, data collection and analysis the strengths and weaknesses of this approach are annotated:

Systems approach		Key points		Weakness	
IDENTIFY Managerial, organisational and extra-organisational influences	✓	Explore the range of influences and conditions that impact human performance	x	AVOID over concentration on individual fallibilities	x?
IDENTIFY latent conditions independent of the accident sequence	x				
IDENTIFY types rather than tokens	x	Explore compatibility of barrier / control interventions for user & process	x?	AVOID the many forms of 'blame'	x?
IDENTIFY the influence of dynamic states upon subsequent performance and adaptations	✓				
		Explore using multiple methods and cross-disciplinary analysis			

The **strengths** of this approach is that the full range of managerial, organisational and extra-organisational factors have been identified; the example constraints and responses suggest numerous ways in which failure can occur. The model has been developed by construction specialists; the depth of understanding and perspective of this unique working environment appears extensive. The nature of successive constraints and responses gives a clear impression of the dynamic nature of the process and the factors that affect performance and adaptations of each player. An important and novel feature of this model is that constraints and responses operate in each direction, showing interdependencies across all levels of the construction process.

There is **intermediate or uncertain value** in decomposition by 'constraints' and 'responses'. Cognitive mechanisms or information processing systems are used in error classifications, yet the terms here are used to describe the dynamic nature of the decision making process – in what is essentially a 'generic' management role. Indeed it could alternatively be argued that bifurcating information 'in and out' (constraints and reposonses) at each phase (or by each decision maker) serves only to create a very dense model of what are, essentially, interacting players making management decisions sequentially in the flow of a build process.

However, the constraints – responses offer very good illustrative example ‘tokens’ for each stage of the construction process, but classification by project player (or phase) has both positive and negative points. On the one hand it is deflecting blame from ‘active factors’, but it also masks opportunities to distinguish the main event ‘types’. On this latter point for example, considering the pre-site classes ‘Project conception constraints, Client responses, Project design constraints and Designer response’, ‘types’ generated from the examples given might alternatively be described as: -

- Funding (budget, procurement)
- Planning (needs analysis, managing criteria conflicts)
- Scheduling (time management)
- Policy (legislatory, local government, business strategy)
- Design (technical requirements, complexity, quality issues).

Generation of ‘types’ in this manner could be pursued through the remaining 15 classes, using the given ‘tokens’ and generating further types as the work nature changes. Classification by ‘token’ has perhaps made the model far more complicated than need be. Ironically some ‘types’ are given in free text introducing each set of constraints or responses (for example the ‘construction management responses’ are described as dealing with managerial, organizational, technical and operational aspects), yet the emphasis of these is on their introduction to the ‘tokens’ examples.

A weakness in the model is the classification by the use of abstract nouns (constraint/ response/ failure/ management) rather than concrete nouns that have no judgement associated with them. This is especially prevalent during the distal factor phases. The classes ‘project management’, ‘construction management’, ‘subcontractors’ are also proper nouns, thus identification by process stage / player instead of event types (concrete noun), leaves the opportunity for the direction of blame at those named in the project lifecycle. It does not describe the condition that has failed.

Re-classification by ‘types’ would likely enable exploration of the key points listed in Table 28, but it is not easy to identify these issues using the current failure orientated approach. In terms of whether the approach is technocentric, the model is certainly

‘constructocentric’ – entirely orientated towards the construction process itself; it is not possible to explore the conditions that influence human performance.

Proximal factors are dominated by the adjectives inappropriate, inadequate etc., These describe the sample, but offer no insight as to the quality of the lacking features. By representing the token events in terms of failure; the assumption is that problem resolution would be the antithesis – a black and white approach to correct or incorrect. For example, there may be an ‘improper construction procedure’ (in the class inappropriate construction operation), yet if the procedure were ‘proper’ would this necessarily be appropriate for the user and would it have prevented the accident?

There is no sense of the positive features that may have been affected at the proximal level to abate or reduce accident severity – this may have been achieved by exploration of the types of human error (operative action) rather than the process interaction with which they were associated. The model does not identify latent conditions independent of the accident, thus the focus is entirely based upon failures that occur in the dynamic situations and phases that interact in the accident trajectory.

3.11.4.2 Further work

The researchers noted the potential for bias (affecting the classification frequencies) as an outcome of the nature of HSE inspector investigations. It was expected that collaborative work on this research project might serve in validation of the distal factors of the model.

3.11.5 The modified loss causation model (MLCM)

Using a modified ‘Loss causation model’ (Bird and Germain 1990), Goh and Chua (2002) developed the Modified Loss Causation Model for classification of 140 construction fatalities. This uses the domino sequential chain approach (p.33), but replaces the first domino ‘lack of control’ with SMS (safety management system) (Figure 12); ‘lack of control’ is redirected to supervision and rule enforcement. Addressing SMS, as the final stage in each accident investigation, is intended to deflect blame from individuals / conditions towards organisational responsibilities. ‘Situational variables’ iterate the need to consider each aspect within the specific context of the accident situation and type of work being undertaken. The accident event is divided into ‘breakdown event’ (the loss of control of energy) and ‘incident’

(victim contact with source energy), to ensure greater precision in subsequent generation of preventative measures.

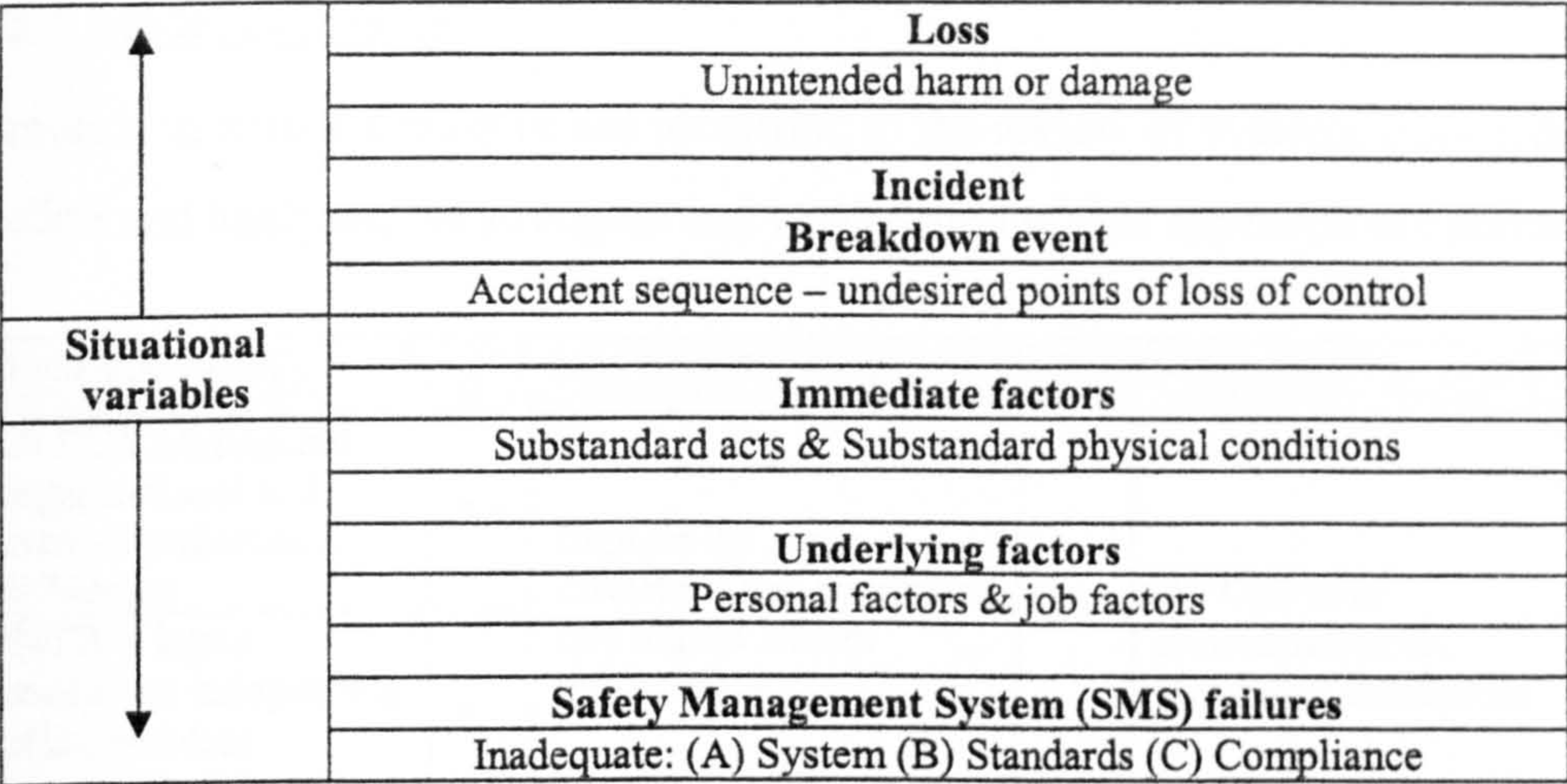


Figure 12. The Modified Loss Causation Model

Types of incident / breakdown events
<ul style="list-style-type: none"> Fall of person Struck by falling object Caught in or between objects Over-exertion / strenuous movements Exposure to hazard Collapse / fall of object Loss of balance Uncontrolled plant
Types of sub-standard physical conditions
<ul style="list-style-type: none"> Substandard plant/ machinery/ equipment/ tools Substandard construction material Substandard structures / parts of structure Substandard work environment
Types of substandard act
<ul style="list-style-type: none"> Extraneous Acts Improper equipment usage Inappropriate response to emergency Omission of basic safety measures Spatial error Improper work procedure
Types of job factors
<ul style="list-style-type: none"> Factors relating to designers Factors relating to operatives Factors relating to project management / corporate Factors relating to site management
Types of personal factors
<ul style="list-style-type: none"> Lack of knowledge / skill Mental / psychological factors Improper motivation Physical / physiological factors
Types of SMS failures
<ul style="list-style-type: none"> Safety policy Safe work practices Safety training In-house rules & regulations Evaluation, control and selection of subcontractors Maintenance regime Control of hazardous products Occupational health programme Safety inspection group meetings

Table 30. Main headings of MLCM taxonomy (abridged version)

A construction taxonomy was developed for use with the model to enable statistical analysis for description of distribution within the sample. Examples are reproduced in Table 30. The authors note a greater range of human error classifications, but selected

those that were observable behaviours (more objective and direct) and which were within the resources and expertise of the construction industry.

3.11.5.1 Model evaluation

In comparison with the main issues identified in the review of systems issues, data collection and analysis, the strengths and weaknesses of this approach are annotated:

Systems approach		Key points		Weakness	
IDENTIFY Managerial, organisational and extra-organisational influences	?✓	Explore the range of influences and conditions that impact human performance	x	AVOID over concentration on individual fallibilities	x?
IDENTIFY latent conditions independent of the accident sequence	x				
IDENTIFY types rather than tokens	x?	Explore compatibility of barrier / control interventions for user & process	x?	AVOID the many forms of 'blame'	x?
IDENTIFY the influence of dynamic states upon subsequent performance and adaptations	✓				
		Explore using multiple methods and cross-disciplinary analysis			

The **strengths** of this approach are that specification of ‘situational variables’ is intended to ensure that each accident is seen in the context of its own dynamics. Developed by construction specialists, there are a number of examples providing insight into the failure types that might occur within the construction industry.

There is **intermediate or uncertain value** in the final level of exploration (SMS). This may fulfil some of the managerial influences, but not necessarily the organisational or extra-organisational influences. SMS may tie into the accident trajectory and be very worthwhile areas to address but they do not necessarily address the full range of influences and conditions that impact human performance. A desire to avoid focus upon individual fallibilities / blame has been described; yet this is not apparent in the examples given for ‘substandard acts, job factors and personal factors’. Findings are not listed by ‘type’, but by phase of generation. This is helpful in deflecting blame from ‘active factors’, but has not isolated the ‘types’ of failures (the selection, design, maintenance, and use of equipment, materials and tools for example) that are common across all phases.

Weaknesses of the model (reflecting the intermediate values described above) are that the range of influences and conditions that impact human performance are not identified. Barriers / control measures are mentioned, but there is only scant reference to their (sub) standardness and it is not clear how this might be evaluated. As such the approach is almost entirely technocentric (constructocentric) and latent conditions are not identified independent of the accident sequence. The limited selection of human error classifications (observable behaviours and within the construction industry expertise) has rendered the evaluation of 'substandard acts' vulnerable to problems associated with causal attribution and hindsight bias.

3.11.5.2 Further work

The paper is part of ongoing work into construction accident causation. Currently there are no further publications.

3.11.6 Summary of findings concerning construction accident models

None of the models, alone, were suitable for the research yet many had positive points that could be drawn into the method development. Likewise a number of intermediate issues or aspects with weak value arose. Table 31 has been developed to synthesise the findings of all the models evaluated.

Strengths	Intermediate	Weaknesses
There is good <u>representation</u> of project concept and extra-organisational factors →	<u>Representation</u> of possible failures at any project phase deflects blame from accident players, but definition by proper noun makes this vulnerable to blame →	Latent conditions do not appear to be identified independent of the accident event
The <u>dynamic states</u> and variables contributing to each accident sequence is clearly identified →	The ' <u>constructocentric</u> ' approaches ensure that failures in the build process are identified, but not from the perspective of user needs →	A requirement to address the 'safety management system' in the accident sequence does not ensure that influences and conditions that impact human performance are addressed
		Psychosocial aspects and user-compatibilities are poorly addressed
		'Token' events are categorised by process phase or person "responsible" for their generation – not by 'type' –
There are excellent examples of construction specific ' <u>token</u> ' events →	Influences and conditions that impact human performance are randomly indicated, but lack completeness, clarity or categorisation →	Categorisation by judgemental, abstract noun, 'token' events (failure or unsafeness of person, barrier or control) perpetuates blame style approaches to accident investigation
		Attempts to evaluate observable 'human error' according to expertise already within the industry is vulnerable to bias and narrow attribution

Table 31. Strengths and weaknesses of construction accident models

The transfer of accident models into practice has been criticised (3.8.1.1). It was decided therefore to identify the strengths highlighted in both the systems approach and construction industry models as a reference point upon which to chose or develop the study investigation techniques (Table 32). These are drawn upon later for Phase Two of the research – Site based data collection.

Systems approach	Accident investigation	Construction model Strengths	Key points
IDENTIFY Managerial, organisational and extra-organisational influences	<ul style="list-style-type: none">EXPLORE the range of influences and conditions that impact human performanceEXPLORE compatibility of barrier / control interventions for user & process	EXPLORE <u>representation</u> of project concept and extra-organisational factors	AVOID over concentration on individual fallibilities AVOID the many forms of 'blame' AVOID 'constructo-centrism'
IDENTIFY latent conditions independent of the accident sequence		EXPLORE The <u>dynamic states</u> and variables contributing to each accident sequence	
IDENTIFY types rather than tokens		EXPLORE examples of construction specific ' <u>token</u> ' events	
IDENTIFY the influence of dynamic states upon subsequent performance and adaptations			
Explore using multiple methods and cross-disciplinary analysis			

Table 32. Overview of systems approach integrated with construction model strengths

3.12 Summary of the literature review

The literature review was undertaken in three sections. The first two sections explored knowledge sources concerning accident causation and the practicalities of accident investigation; this information was then used to evaluate construction accident models.

The review initially revealed the variety in historical and inter-disciplinarian understanding of the terms 'accident' and 'cause'. Early accident modelling showed that ideas about causation were fragmented; interested disciplines (e.g. psychologists, engineers) had identified failure types within their areas of expertise, but these were seen in isolation. However, as understanding increased, this changed and the concept of the multi-factorial event evolved. In parallel with these developments, advances in epidemiological analyses also revealed ever more comprehensive trends and patterns among the accident data sources.

The final representation of accident modelling was in the derivation of the systems approach. The mainstay here is that failure is often an outcome of the culture and management of an organisation. Accident initiating factors are either 'active failures' (errors effected at the front line) or 'latent failures' (effected by organisational and extra-organisational decisions). An important facet of latent failures is in their impact on defences independently of the active failure pathway, and in their contributory effect upon human performance, rather than directly causal in the accident sequence. In the systems approach the consideration of factors that meet both technical and human needs is paramount.

Construction accident models were evaluated against the criteria of the systems approach and a range of strengths and weaknesses were identified. The strengths of the models were in the representation of the construction process (including many examples of failure types throughout the project lifecycle and identification of the dynamic nature of the work). However, common omissions included failure to identify latent conditions independently of the accident event, various guises of blaming individuals, and poor representation of factors that affect human performance.

Appraisal of the construction accident models provided only intermittent or scant detail about data sources and it was possible only to make cursory observations about this in the evaluation process. Nevertheless, the review provided a firm foundation upon which develop the methodology and methods for data collection, interpretation and representation in the subsequent stages of the research.

Accident models have been criticised for their lack of transferability into the development of accident investigation techniques. The review revealed a range of assessment and data representation techniques; each had particular idiosyncrasies, varying according to the accident type and accident severity. Criticisms were levied at techniques used for all event types. For the more comprehensive diagnostic assessment techniques, criticisms included shortcomings in the interpretation and integrity of ergonomics approaches. Even where simpler assessment methods (such as questionnaires, checklists or interviews) were used, problems with their style and content were apparent. The impact of personnel involved in accident investigation

was especially important; reflected in poor accident investigation skills and problems with investigator bias and attribution of cause. The need to adopt multiple methods and cross-disciplinary intervention was identified as desirable in combating such problems.

3.13 Critique of the literature review

As a representation of the multi-factorial event, the Domino Theory (Heinrich and Granniss, 1959) was an early model showing the sequential development of accident antecedent events (Table 12). However, different disciplinary approaches (psychological / behavioural and engineering), and greater understanding of systems theories, appeared to have heralded divergence from the 'domino' baseline model.

Review of the contributions from inter-disciplinary knowledge sources indicated that the engineering approaches promote the use of physical and behavioural defences to control hazards and harmful energy transfer (3.5.3). This is the ethos of the revised domino modelling approach (e.g., (Bird and Germain 1990, United States Department of Labor. Mine Safety and Health Administration 1990). An example of the latter (Figure 3) showed that (prior to harmful energy release) accident antecedent events were indirect causes (unsafe acts and unsafe conditions) and basic causes (such shortcomings in policies, personal factors, work conditions etc.).

Whilst the 'basic causes' have an affinity with systems issues in accident causation, the perpetuated reference to 'unsafe acts and unsafe conditions' is an aspect that contrasts the full complement of developments made in the systems approaches and by psychological and behavioural sciences. Here, these terms are rejected for their leading terminology, their association with blame upon individuals and for their narrow representation of factors that affect human performance in accident causation. The isolation of active and latent factors in systems approaches is also distinct from the (domino derivative) sequential modelling approaches, in that latent conditions can influence defences independently of the accident trajectory.

The weaknesses identified in the construction accident models suggest prominence of the engineering approaches and that knowledge from the psychological / behavioural approaches has not been fully accommodated. The construction models showed that

attempts have been made to address human behavioural aspects, suggesting that these aspects have either not been completely understood, or were incorrectly interpreted.

The shortcomings may also reflect cultural differences between the two disciplines. Literature review showed that the engineering approaches were heavily criticised, but there was no comparable rejection of the psychological / behavioural approaches. Whilst further literature review might redress this imbalance, the information available at this stage does suggest that the psychological / behavioural disciplines have a tradition of being more critical in their approach, whereas the engineering disciplines are more receptive and less challenging of new interventions. Whilst there are merits in each approach, this may offer some explanation for the acceptance of poor interpretations of human behaviour and systems within the engineering approach. On the other hand, the development of models specifically for the construction industry is comparatively recent (compared with the longstanding generic accident modelling) and greater input over time might redress this imbalance.

The review also revealed that the prominence and contribution of different disciplines appears to have progressed at different rates. Engineering approaches appeared to be the mainstay of early accident modelling. The emergent understandings of the range of factors that affect human performance and human error have since brought the psychological and behavioural approaches to the forefront. Human error appears to have evolved from its early task based connotations; the 'new' approaches to human error champion address of underlying circumstances. This also indicates a change in the meaning of 'human error', as the term now implies address of wider systems issues too.

Nevertheless, examples of these 'underlying circumstances' in the human error approaches, at times, appeared to offer little in the way of categorisation upon which to direct further enquiry. The understanding of systems issues in accident causation has previously been promoted through use of ergonomics methods (e.g. Carter and Corlett 1983). It was through assimilation of a range of ergonomics approaches that a classification was generated to group the examples of underlying circumstances. This classification was used as a framework for the systems approach to construction accident investigation.

4 PHASE ONE – INFORMATION SEARCH

The phasic approach was introduced in (1.1.3) and the section for Phase One is reproduced in Figure 13. Phase One was concerned with establishing industrial contacts and generating the information that was necessary to proceed with the accident studies. The baseline literature review that was undertaken at the project outset revealed a lack of up-to-date and ‘unbiased’ information concerning accident causality. The FOCUS data base material, collected by the HSE, was directed towards enforcement action (Suraji and Duff, 2000) and the Whittington et al. (1992) research, although an excellent resource, predated the CDM legislative interventions. In addition there was little apparent input from construction workers, outside of safety or management roles.

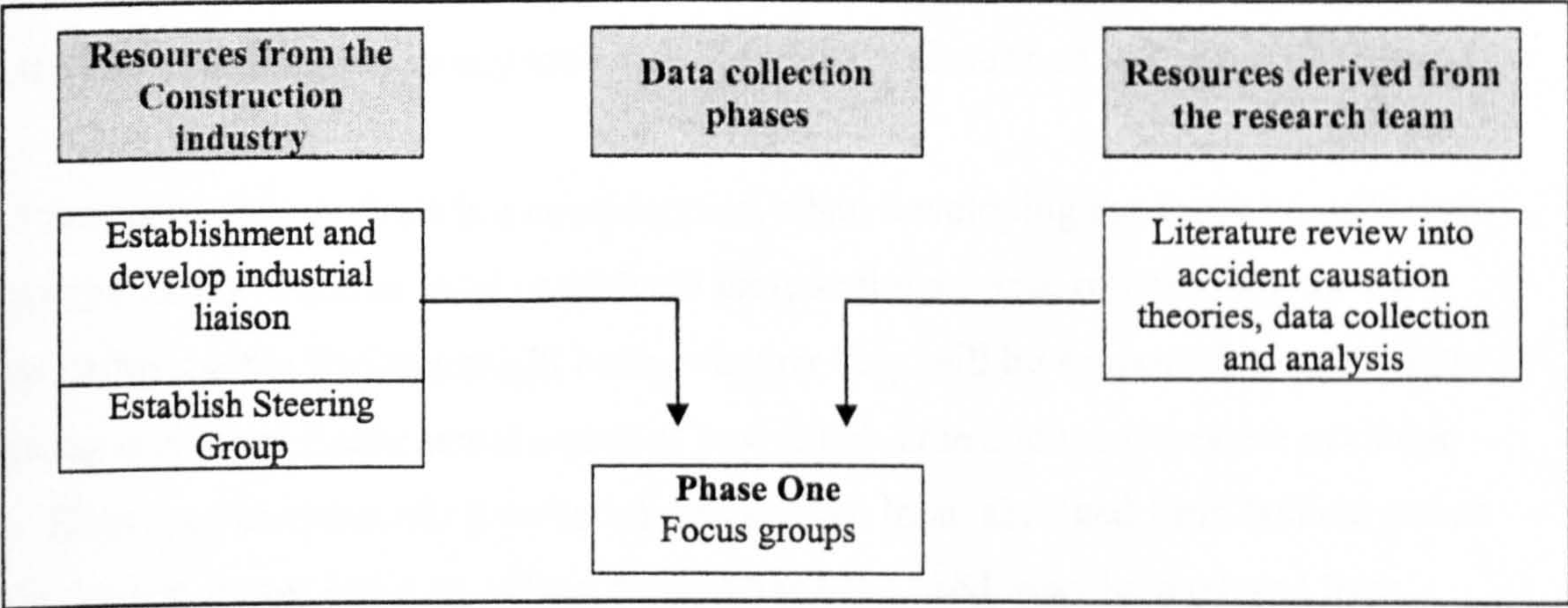


Figure 13. Phase One of the research

4.1 Methodology

Critical incident technique (3.9.4.2) has been used to explore near-miss events / recovery actions, but the one to one approach was not feasible given the time scale, resources and site access available. An alternative and more realistic approach was to use focus groups as a method to access a wider range of people and their perceptions of accident causation. Focus groups are commonly used in market research, social science and human factors research (Bruseberg and McDonagh-Philip 2002).

4.1.1 The nature of focus groups

A focus group is a style of group interview whereby the data obtained arises from the interaction and discourse generated from within the group (Morgan 1997). Topics are supplied by the researcher, who acts as 'moderator' for the discussions. Criteria for selecting focus group participants vary and depend on the nature of the area of enquiry. Participants may be selected by random sample or, where specific areas need to be explored, participants may be recruited from carefully selected categories (defined as segmentation).

The level of moderation is determined to some extent by the desire for session control; low-structured sessions may comprise general discussion around one or two discussion themes, whereas the discussion may be more structured (or become progressively more structured in a 'funnel' style of approach) accommodating up to four or five discussion themes. Under these conditions the moderator undertakes a more dominant role, but in any case should facilitate discussion rather than interview.

The nature of data analysis is a consideration when developing the focus group's style (Krueger 1998). Factors to be considered include the purpose of obtaining the data, what influence the findings might have, whether they will be supported by other data sources, and more fundamental issues of how much time and resources are available etc. Data may be transcribed verbatim, transcribed in an abridged form (salient points and relevant quotes only) or, where no tape has been used, may be analysed from written session notes, or even from memory. The style of analysis can be equally variable but usually incorporates encoding by topic or by some form of content analysis (typically frequency of iteration or semantics, Stewart and Shamdasani 1990).

Some caution in interpretation of focus group findings is required. For example, participants may generate a level of conformity and acquiescence within a group and this can result in the suppression or generation of extremity of opinion that might not necessarily be felt in private. Alternatively, the researcher, albeit unconsciously, may direct discussion into an area unimportant to participants, or indeed achieve this through data interpretation. However, whilst it is recognised that there are inherent weaknesses within the focus group technique, the dedicated discussion upon a

specified topic and access to the unique insights of group participants, offers a source of information and data that might otherwise be unavailable with more traditional approaches.

4.1.2 Aims and objectives

The aim of the focus groups was to consult a range of different employee groups in the construction sector, exploring where failure occurs and why accidents still happen. The objectives of the focus groups were to:

- (a) Learn more about perspectives or viewpoints held within different construction disciplines and groups
- (b) Supplement information available through existing published work.
- (c) Review information from foundation resources used at the project outset (Suraji et al. 2001, and Whittington et al. 1992) to enable refinement and enhancement of the study strategy and investigation protocol for the accident studies

4.1.3 Development of the discussion material

In order to meet the focus group aims and fulfil the first objective (a) it was necessary to identify and classify from the Whittington et al. and Suraji et al. research, possible areas of 'failure occurrence'. Effort was then directed at establishing a way in which these could be presented succinctly to the focus group participants.

4.1.3.1 Whittington et al. 1992

Whittington et al. (1992) identified three main groups of causal or contributing factors in their accident investigations (3.11.1). The first being 'Factors relating to the injured party or to his immediate work colleagues', the second 'Factors related to site management' and the third is 'Factors related to headquarter responsibilities'. The first two factors continue to be relevant features and are duplicated in the Suraji et al. research. However, the third factor, although including aspects such as problems with selection/control of subcontractors/workforce and failure to consider safety implications of building design, plant design or PPE, fails to thoroughly address the current complexities of project development, planning and financing. These are in part a consequence of the new legislation and also reflect the sphere of business development since the 1992 publication.

4.1.3.2 Suraji et al. 2001

Suraji et al. described up to 19 different construction phases where failure might occur (3.11.4). They noted the distinction between proximal (active) and distal factors in accident causation, whereby proximal factors are those that have a direct impact upon an event occurrence and distal factors are the constraints and responses which occur outside an event area, predominately in the conceptual development of the project. Conceptual development includes, for example, the nature of the client, financial procurement, and design and planning; these include factors which have been subject to legislative change since the Whittington research.

4.1.3.3 Isolating discussion areas

In either case, the content was either insufficient or too detailed for the focus group discussions. An alternative framework was developed for the discussion topic areas, based on HSG65, Successful Health and Safety Management (Health and Safety Executive 1997b) and (in the context of human failings of accidents) HSG48, Reducing Error and Influencing Behaviour (Health and Safety Executive 1999d). These isolate three distinct areas upon which much of Suraji and Whittington's causation factors or phases could be superimposed. These are (1) Management and organisational factors (to identify underlying causes), (2) Job and (3) Personal factors (to identify immediate causes).

Looking at these data in combination, it was apparent that all 'Factors related to injured party or to immediate work colleagues', 'Factors related to site management' (Whittington et al. 1992) and 'proximal factors' (Suraji et al. 2001) are included within the three HSE headings (1997). Some of the 'distal factors' (Suraji et al. 2001) or 'factors relating to headquarter responsibilities' (Whittington et al. 1992) are included in 'Management and organisational factors' (HSE 1997) - thus outstanding issues concerning project, concept, design and procurement issues, needed to be addressed separately.

This analysis resulted in the development of four discussion areas for the focus groups. After determining the most appropriate language style (3.9.5.4) with a construction specialist, aspects from the foundation resources were categorised for focus group discussion thus:-

Discussion Area One	- Project concept, design and procurement
Discussion Area Two	- Work organisation and management
Discussion Area Three	- Task factors
Discussion Area Four	- Individual factors

4.1.4 Choice of participants

Groupings of potential participants were devised to offer comprehensive representation of the different employment strata / responsibilities within the industry. Assistance with accessing appropriate focus group members was provided by industrial collaborators from the research Steering Group.

Six groups were scheduled (Table 33). A further ‘mixed discipline group’ was also undertaken as a pilot study. Minimal changes were made subsequent to the pilot and the data from these participants have been included as an additional group. An earlier pilot focus group was undertaken with Loughborough University Civil Engineering undergraduates. The research style was considerably refined following the undertaking of this focus group and these data have been excluded from the analysis.

Group	Employment	Target participants
One	Client team	Clients or client representative, Architect, Engineer (Structural / Civil or Mechanical / Electrical), Financial Manager, Project Manager or Design Manager and a Planning Supervisor
Two	Senior managers	From General and specialist contractor firms representing civil engineering, major building or the residential sectors and from small and large projects
Three	Site Managers	
Four	Operatives large site	Tradesmen or general operatives
Five	Operatives small site	
Six	Safety professionals	Industrial safety professionals and Construction Enforcement Officers
Seven	Mixed group (pilot)	A mixed discipline group (trades and professionals)

Table 33. Focus group categories

The composition of two groups varied from that intended, mostly due to the practicalities of recruiting participants. Group One comprised a mix of Planning Supervisors and Health and Safety Specialists; Group Three comprised a mix of those in general supervisory and managerial roles and those with health and safety responsibilities. All groups had between 5 – 7 participants.

The seven groups took place between February and June 2000. The ‘safety professional’ group was undertaken at Loughborough University campus, whereas all others were undertaken at a convenient location nationally for the participants.

4.1.5 Information for participants

Participants were provided with a briefing sheet describing the nature of focus groups and brief details of the research. Participants were advised that all identifiable information would be confidential to the researchers and that analysis would prevent the attribution of findings to any one individual. At the outset of each focus group overhead transparencies were used to provide a short presentation of the research and focus group discussion areas.

To clarify and distinguish the four discussion headings (4.1.3.3) examples were provided under each heading in order to enhance participant understanding and prompt discussion; examples were developed with the assistance of a construction specialist. Each of the four discussion areas (and examples in brackets) was presented on a flip chart sheet; the text is repeated below in Table 34 to Table 37.

With each theme participants were asked to consider where failure occurs and why accidents still happen?

- | |
|--|
| <ul style="list-style-type: none">• Client background (skills and experience of the client)• Selection of design team (Designers giving consideration to practicalities of construction?)• Procurement of contractors (What role do price and safety play in selection?)• Safety considerations (Safety in construction considered?)• Allocation of resources (Financial – where the money is spent)• Legislation (Enhances or hinders?)• Strategic design considerations (Choices of site, appropriate building design) |
|--|

Table 34. Project Concept, Design and Procurement

- | |
|--|
| <ul style="list-style-type: none">• Project management and supervision (Style, degree of input and instruction from management and supervisors)• Managing change (Handling of any design modifications of work in progress)• Work scheduling (Time pressures, overlap of operative / trades)• Resources (Availability of contractors, suitable skills of contractors)• Safety considerations (Risk of injury assessed, safety managed appropriately)• Site layout and logistics (Safe access routes, placement of essential services) |
|--|

Table 35. Work Organisation and Management

<ul style="list-style-type: none"> • Tools and equipment (Appropriate selection, maintenance) • Adequacy and use of procedures/method statements (Appropriate?) • Is safety considered? • Training in task and health and safety skills (Appropriate?) • Work load / time constraints (Time pressure upon individuals and/or groups) • Environmental conditions (Weather, out of hours work) • Design of task or working area (Layout of immediate area, is safety and access considered?)

Table 36. Task Factors

<ul style="list-style-type: none"> • Experience and competence of <u>all</u> employees • Safety considerations (Safety behaviour, attitude to risk) • Personality influences • Health status and fitness for work • Conformity (Company ethos, pressure to comply)

Table 37. Individual Factors

4.1.6 Data collection tools

Audio recordings were made of each focus group to permit subsequent transcription (and have since been destroyed). A questionnaire was administered at the end of each session (Appendix 1), and incorporated two elements. Firstly, in open question style, participants had the opportunity to reiterate aspects from the discussions which were important to them or which they were not comfortable to talk about publicly.

Secondly, using five point rating scales, participants were asked to consider what might contribute to accidents. A number of possible factors were proposed (again drawing upon aspects under the four discussion headings) and participants were asked to provide a rated response. Possible answers ranged from agreement with either ‘not at all’ to ‘to a very large degree’. All questionnaires were submitted anonymously.

4.1.7 Procedure

Each group was scheduled to last 1½ hours. A sample agenda is shown in Table 38. The time allocations were used flexibly as severance of discussion at an allocated time point would have been inappropriate. The four main headings were presented in reverse order for the two ‘operative’ groups. This was done to ensure the discussion could develop from a starting topic with which all participants were familiar.

Time	Topic	Time allowance
15.05	- Introduce / overview the nature of the project	10
15.10	- Round table introductions (name and discipline)	5
15.20	- Project concept, design and procurement	15
15.35	- Work organisation and management	15
15.50	- Task factors	15
16.05	- Individual factors	15
16.20	- Questionnaire	10
16.30	- Finish	

Table 38. Sample focus group agenda

At the beginning of the time allocation for each discussion area, a brief explanation of the intended meaning was provided by the researchers. Participants were encouraged to draw any related aspects into their discussions, even if these were supplementary to the points on the prompt sheets. Having introduced the discussion points, and once discussion had been generated among participants, the researchers took a passive role - interjecting only if conversation faltered, if meaning was lost or if the discussion strayed beyond the enquiry area.

4.1.8 Analysis

An abridged transcription was made from each audiotape. The transcriptions recorded the main points made as each participant spoke. This included a number of quotes where these were clear, and salient points. There were incidents where the tape was inaudible (due to interference, mumbling etc.) and short tracts had to be omitted. Given that most of the surrounding speech / speakers were audible, this is considered to have had a negligible effect on the results.

To facilitate interpretation of the transcriptions, intermediate analyses were undertaken which involved summarisation of all text into short bullet point statements. These were a subjective interpretation by the researcher of the main points of what the speaker was saying. This enabled significant points to be extracted and permitted later comparison and categorisation of information according to the discussion area headings and sub-headings.

The analysis aimed to identify:-

- The nature and range of the discussion data
- Differences between opinions of each group or among participants

- Whether any of the prompts were omitted from conversation by participants
- If additional and unexpected aspects were introduced into the discussion

4.2 Results - Focus group data

Sections 4.2.1 - 4.2.4 present the main points from the focus group discussions. It is the nature of this style of group discussion that participants engage in relatively free speech with minimal intervention from the moderators. Whilst this was a desirable feature (to enable exploration of a wide range of opinions), it also meant that some points appeared somewhat ambiguous, vague or were described with varied or outdated terminology.

In reproducing the essence of the conversations, no judgement is made on whether the material is right or wrong. It is possible that in some respects focus group participants may be factually incorrect or hold opinions with which others disagree.

4.2.1 Project Concept, Design and Procurement

4.2.1.1 Client background

Responses from participants concerning client background were for the most part negative although there were some positive comments concerning particular client sectors. An example of this is that many positive comments were made with respect to the larger high-tech organisations such as the Petro-chemical, oil, nuclear and (to a certain extent) retail industries. Such organisations were reported to have a responsible attitude towards construction safety and to anticipate costing for this at the project concept stage.

An overview of the data more generally indicated that clients are considered to vary in their commitment to health and safety. Many criticisms were directed at client ignorance in certain areas of the process, such as their legislative responsibilities under CDM, the contractor's responsibilities and the practical implications of any build or design changes they request. It was commented that the process of contracting out had diminished client skills and experience.

Clients (especially large and wealthy clients) were at times described as arrogant risk takers with little interest in the build process. The decisions of many were portrayed as frequently being determined by the lowest price tender, avoiding being accountable for a legislative breach and maintaining a high public profile (e.g. environmental issues, or general public safety being a high priority, but not the welfare of construction workers).

There were also reports of considerable time pressure from clients and a perpetual urge to trim construction times. To achieve this there is increasing pressure to undertake weekend / night work. Concurrently, clients are reported to be reluctant to provide the desired site area or access – again to avoid inconvenience to the general public. It was reported that one client had even repealed any time flexibility for poor weather conditions.

The general opinion seemed to be that client pressures and inflexibility caused time and output pressure, and induced a compromise of safe working methods. Some clients are reportedly unaware of the potential cost benefits of safety innovations, and never request guidance on safety at the tender stage. An additional loss due to the client pressures is that opportunity for project improvement and design revisions are lost.

4.2.1.2 Strategic design considerations

Strategic design was subject to a number of different criticisms. Firstly, an increased desire for aesthetic qualities was generally seen to inhibit ease of building, which in itself induced safety hazards. Designers reportedly use outdated plans as a template from which to develop each 'prototype', with this seen as ensuring continuity of the same accident types. A number of comments were made concerning the fallibility of design and the problems that are induced when having to work around incorrect drawings. Design changes are frequent and costly and incorrect drawings were described as having adverse implications for construction operatives later on in the process. It was suggested that some clients inappropriately see safety as a separate 'bolt on' issue.

A new development, although described still as a rarity, is the use of pre-finished components. There were mixed views on this. It was understood that designers positively encourage off-site fabrication and that there are great benefits in this, especially to compensate for a lack of available skills on-site and to make a faster, more buildable and safer structure. It was also reported however, that pre-fabrication often does not account for continuously developing prototypes (referring to the development of all new structures). It was argued that manufacturers need pressure to revise products and, in an example concerning design revision of timber trusses, the manufacturers were reported to have ignored requests for design improvements.

Clients were heavily criticised for not leading design innovation, either through the procurement process (it was claimed that Quantity Surveyors can ruin designers' innovation), or as a consequence of the range of problems described above. A number of comments indicated that Contractors have had to drive design innovations; it was reported that these needed further development (especially for every day tasks) yet costs for this have to be accommodated by the contractors rather than by the client.

It was felt that time and financial pressures from the client impede appropriate opportunities for review or audit of designs yet, were this possible, it would permit deferral of responsibility back to the client for revision (instead of contractors having to accommodate this late in the process). Design audit is also inhibited by the absence of a convenient and stylised pro forma. It was suggested that the process is also hampered by inconsistencies in the tendering procedures and that on occasions the construction phase Health and Safety Plan (2.5.4) can be ready even before the pre-tender is put out.

When discussing the range of different funding and management styles there was a general rejection of traditional methods where price and speed of construction directed the process. Likewise the style of 'Construction Management' and fragmentation of different parts of the contract to different contractors was also viewed unfavourably as it was reported that control is lost and safety compromised. Alternative methods such as 'Design and Build' and PFI (Private Finance Initiative)

were more popular as these foster a contractor: client alliance and encourage practical design review.

4.2.1.3 Allocation of resources

Participants felt that clients are reluctant to pay for outsourcing their responsibilities and in this context they are not acquiring the necessary information they need to fulfil their duties. It was reported that clients (and mostly their lawyers), make the money in construction, with price their priority in important decisions such as contractor appointment or apportioning appropriate arrangements for safety. Building cost benefit analyses are being used to address the safety case, yet despite this, time is lost during client: contractor price wrangling, and this can negate or induce additional problems to the process.

A further suggestion from the focus groups was that cost incentives mean that longstanding 'fixed' client: contractor relationships are diminishing and that there may be some pressure to attribute 'competence' to the lowest tenderers. This loss of fixed client: contractor relationships means that the knowledge of client requirements (that contractors may have developed over previous projects) is lost, as is the continuity of established team working. Although clients are required to consider safety in tenders they receive, this was reportedly not necessarily the case; it was felt that inbuilt safety costing in a tender had led to both loss and acceptance of contracts.

4.2.1.4 Selection of contractors

It was reported that the selection process is generally a paper-based exercise and some documentation, used universally, is approximately fifteen years old. Participants felt that it was inappropriate that contractors should be judged purely on a questionnaire basis, as this in itself may only be a judgement of ability to complete a pre-qualification questionnaire, rather than an adequate assessment of competence. It was also noted that contractors are burdened with multiple tender applications and that, within this, each competency assessment requires more and more time.

Another part of the tendering process is the submission of the Health and Safety Plan. There were comments that this is generated more to impress the client than to be used as a working tool, and contains meaningless generic statements about hazards. There were concerns that any tender including a price for safety indicates to the client that it

has been considered, but that the client may not appraise the actual content of this. The safety plan is developed by the contractor's Contracts Manager and there were reservations about the depth of safety knowledge held by this role.

All contractors in the process, both principal contractors and sub-contractors, have to submit tenders. General thoughts among participants were that principal contractors are more safety aware than sub-contractors and that sub-contractors often have a poor safety culture and do not adequately price safety. It was reported that there is considerable competitor pressure for contract work, yet skilled trades are difficult to find (especially in London).

4.2.1.5 Safety considerations

Although it was reported that commercial incentives influence the drive to consider health and safety, it was also noted that such competition may positively influence the development of new initiatives. Safety has a price, but it can be the cheaper option. An example given of this was in the use of netting for roof work, which is reported to enable greater productivity and performance among workers no longer fearful of falling or restricted to certain weather conditions.

On the other hand it was reported that a 'top down' culture drives attitudes towards safety, yet clients are not necessarily offering this commitment and were reported to have ignored contractors' safety requests. It was said that while accident costs can be considerably greater than profit margin, it appears to be the fear of prosecution that acts as the main driver to influence safety considerations. The industry was described as having an adversarial culture, where blame and lack of acknowledgement of individual responsibility persisted.

It was indicated that certain client team members, such as Quantity Surveyors, Designers or Structural Engineers do not have adequate training to appreciate their impact upon people. Likewise, it was recounted that in some cases Quantity Surveyors and Local Authority Planning Committees have openly rejected their contribution towards safety, yet these disciplines (by involvement in contractor selection or approving safer designs) were also seen as influential in their potential impact upon construction safety.

4.2.1.6 Client team

The client team can comprise any number of professionals (depending on build-type and site size) and many comments were made about them. At times these were directed towards a specific discipline, whereas for others generalised comments were made. The terms Designer and Architect appeared to be have used interchangeably at times. As a formal distinction cannot be discerned, the reporting below reflects the general themes generated by participants under the description 'Designer'.

A number of comments were made about Designers acting in an 'insular' manner, not communicating appropriately, consulting other disciplines nor forming part of a team with others on a project. As part of a 'design team' it was reported that although the Designer is responsible for informing a client of their need to appoint a Planning Supervisor, many are in fact ignorant of the Planning Supervisor function. Likewise, it was reported that Designers do not give adequate consideration to contractor utility needs at the project outset or to how the contractor will tackle site, build and maintenance logistics – they are removed from site reality. It was claimed that Designers never supply hazard information and that this can negatively affect the Method Statement quality. It was reported that inevitably these misrepresentations cause client: contractor conflict and the 'novation' of a Designer (client imposed rather than a chosen appointment) causes problems for principal contractors.

Although it was acknowledged that designers can be good at designing out risk, it was reported that although they are starting to understand safety matters, they have little understanding of health related issues. It was thought that Designers do not necessarily associate their undertaking of their design as influencing accident causation. However, when they specifically try to incorporate safety features there can be overcompensation, and the induction of awkward working conditions for operatives.

From a scheduling perspective, designers were seen as unprepared for work commencement and absent from sites - seemingly a designer can take between two and three weeks to revise a drawing thus delaying the start (or progress) for all concerned. There were reports of inadequate site investigation by designers and that their work had to be double-checked at contract outset. If it is possible to defer the

cost of designer oversight back to the client, then cheap alternatives may be sought by them to cover their misrepresentations; alternatively the contractor has to cover oversights in any misrepresented drawings and this has time and money implications. In summary a statement made by one participant was that 'the term Architect is a euphemism for continuous experimentation'.

It was also pointed out that design is not just about the design team and that this is a loosely used term and many people don't actually know that they are designers. Contractors often act as designers, but do not necessarily see themselves as such or appreciate their (legislative) responsibilities in this respect. It was reported that at times design inadequacies might be resolved through the Site Manager and that in-house design revisions might be preferred for their practicality. There were suggestions that designers might agree with design changes generated in this manner, if only they could be encouraged to come to the site to see for themselves.

More generally, some participants considered that contractors were seen as being too 'nice' or accommodating to clients – contractors never ask for extra time or help from clients and are instrumental in urging early completion in order to obtain competitive advantage for future work. Although it was seen that clients may capitalise on this, contractors too were portrayed as being able to take advantage of clients.

Of the other representations in a client team, specific note was made regarding the role of the Planning Supervisor. There were reports that Planning Supervisors vary in performance and contribution to a project. Clients, Contractors, Designers and Architects were often considered ignorant of Planning Supervisors' functions and as such these professionals are under-resourced and under-used. The Planning Supervisor can inappropriately be appointed after a job has already gone to tender, or even after site work has started, and is thus too late to do anything useful. From an alternative negative perspective, it was suggested that some Planning Supervisors are appointed only to protect the client and in this capacity they do not enhance the project.

There were other criticisms of the influence of the client team. It was suggested that the client team is led by accountants and that, knowing nothing about safety, they base

their decisions entirely upon the outcomes of key performance indicators – this was not deemed to reflect adequate and comprehensive information of the construction process and progress.

4.2.1.7 Legislation

The CDM Regulations were seen as poorly understood or incorrectly addressed by clients and designers. The legislative requirements are treated as a paper exercise and create an additional role that clients have had to assume from what were traditionally viewed as contractor responsibilities.

The loss of prescriptive legislation was rued by some (as this renders the client decisions more difficult), yet conversely, another participant inferred that the level of prescriptive legislation is inversely related to level of management. It was reported that changes would only occur when Senior Managers start to be prosecuted. The fear of prosecution was indicated as a driving force and that more authority and endorsement from the HSE would be welcome.

4.2.2 Work Organisation and Management

4.2.2.1 Project management and supervision

Within this subsection, Method Statements (2.5.4) procedures and general planning issues were the main topics of discussion. There were a number of issues concerning the quality, development and use of Method Statements. It was felt that Method Statements, to a certain extent, reflect the variable quality of information provided by the client or designer. In the same way, the Method Statement quality is also vulnerable to deterioration when highly technical information is the subject matter.

A number of discussions concerned the content of Method Statements. Firstly, it was thought that although Method Statements may provide a task breakdown (although the task analyses may be inadequately considered) they do not necessarily provide adequate procedural information. Method Statements are reportedly mistaken for risk assessments and were criticised for accommodating rather than addressing risk control.

It was said that there is often little variation in Method Statement content and they were portrayed as an 'office' based exercise, prepared by someone at safety / management level. A shortcoming of this was that there is rarely consultation with the operatives doing the work and consequently inadequate appreciation of, or understanding of, the demands of their work and the relative discomfort that may arise from the recommended PPE. The process of developing the Method Statement was portrayed as a ritualistic paperwork exercise resulting in material that does not necessarily reflect practice. In addition, much of the material was reportedly generic and often boring, too long and not of an appropriate language style for the end user.

As a consequence of these problems it was argued that operatives do not necessarily see, read or understand the method statements. The non-use or over-looking of procedures was described as habitual practice, but elsewhere was at times said to be due to operators looking for shortcuts or to make financial gain. Additionally it was acknowledged that non adherence to procedures may lead to dismissal and that where there is a lack of formal procedures, this creates an inability to maintain discipline. In spite of misgivings among the participants, it was thought however, that poor Method Statements are tolerated and accepted, and that use in their current state is perpetuated by all concerned.

Participants also spoke about the problems associated with planning, and noted that the parameters for work scheduling always change and may in fact be obsolete even within about three weeks of a project start. Various causes were suggested, such as lack of preparation by contractors / sub-contractors for an immediate start and the difficulties associated with dealing with fragmented 'packages' of work. Changes to work in progress also contributed to planning problems and these might be modifications in areas such as design, scheduling, as a result of transport & delivery problems, or as a result of weather conditions.

The consequences of planning problems were described as trade overlap (and loss of work sequence), work back log and the generation of time pressure – all of which were felt to contribute to risk circumstances. It was generally indicated that greater attention is now being given to planning, but that client commitment (to a longer programme for example) is required.

Allied to the problems with planning, some participants spoke about difficulties associated with maintenance activities, noting that maintenance operatives are not 'site-wise' and that their increased vulnerability in one-off visits to the site is not accounted for in planning, safety or design.

Supervisory aspects were drawn into the planning category whereby it was felt that, if dismissal is being considered (for poor performance perhaps), the possibility of inadequate planning is not regarded as a contributory factor. There were reports that fear for job security inhibits reporting of problems and that there are cases where the under-reporting of accidents is actually condoned by supervisory staff.

4.2.2.2 Work scheduling

Time pressure within work scheduling was mentioned frequently. Example causes cited for this are pressure from earlier contractors in the chain and pressure from Site Managers upon operatives. Additional causative factors mentioned are the pursuit of competitive advantage between different contractors seeking to ingratiate themselves to clients, or from a 'team-like' competition generated by managers of different contractor gangs working side by side on a site.

The time pressure of work scheduling was described as having effects upon two interacting factors – work performance and the skill base of contractors. To accommodate the time pressure in work scheduling it was indicated that unskilled labour and poor subcontractors are sometimes appointed. During a contract there were reports of time pressure, perhaps as a result of having to incorporate unexpected work, which is then detrimental to work in progress.

It was indicated, however, that nearing the end of a contract, performance and quality of work can suffer in particular – with participants citing negative effects such as short cuts, resulting from increased work intensity and trade overlap. There were concerns from operatives that they are not appropriately consulted concerning the scheduling of trade overlap. Although this was recognised as a Site Manager responsibility, the lack of appropriate consultation resulted in loss of work sequence and even the re-doing of work on occasions.

4.2.2.3 Resources

A number of criticisms were made regarding the move from direct labour towards lengthy chains of sub-contractors. As Principal Contractors employ less of their own employees, this has inevitably led to a greater demand upon the use of sub-contractor firms. Although it was recognised that some contractors work to a very high standard, that this can be compromised (when poor subcontractors are appointed), especially due to price/ time pressure, or as a result of a lack of good planning by the Site Agent (Manager). It was noted that the appointment of sub-contractors is generally price led and thus competitors undercut; this creates pressure to drop standards to be competitive, or to appoint less qualified / young people or immigrant labour. Sub-contractors are reported to invariably have inadequate supplies of safety equipment and this can have negative implications for the PPE stock levels of Principal Contractors!

The negative consequences of sub-contracting were described as working purely in a price motivated manner, to perform a task. This leads to the taking of short-cuts, inadequate or non-use of Method Statements and results in increased hazards to all on site. Sub-contractors, and especially those most distal in the chain from Principal Contractors, were seen as distanced from responsibility and ignorant of and not committed to the team work of the site. Sub-contractors reportedly make inadequate design revisions or may even walk out if site conditions are inadequate. Overseeing supervision of sub-contractors also appears to be a considerable problem. Firstly, this was described from the perspective of inadequate supervision from their own immediate employers, which had a negative affect upon safe working practice and performance. Secondly, the logistical problems experienced by Site Managers were also noted, especially in the difficulties they experience in co-ordinating and overseeing lengthy chains of sub-contractors.

Additional negative comments on this theme, were that specialist contractors are very expensive and at times are bought in to undertake tasks which could be undertaken as effectively and more time efficiently by the Principal Contractor operatives (had their skills been recognised). The sub-contracting system reportedly promotes the overlooking of the range of skills and experience that may already be available among site personnel. The advantages of direct labour (over sub-contractor labour) were

described as project dedication, better teamwork, a better safety attitude and better overall housekeeping. Other than being retained in continued employment, however, these advantages were not necessarily perceived by the operatives themselves; feedback on good performance appeared to be provided solely through their continued employment.

Skill availability was reported as a considerable problem for the industry. This affects recruitment and retention of competent Sub-contractors, Site Managers, Foremen, and Tradesmen – a problem worse in London. Problems in more rural areas were also cited, however, as it was indicated that in some areas a quota of local labour must be employed and this too does not necessarily provide the competent personnel required.

The consequences of these skill shortages were that people (without site specific experience) are appointed in trade, supervisory and management positions. These personnel may not necessarily have worked their way through the system and were not thought to have the range of knowledge of the industry necessary to work efficiently and to support the project.

At operative level, this means that at times new employees cannot be left unattended and that in the absence of even the most basic common-sense, considerable pressure is put upon gang leaders to undertake and supervise the work of the operatives. There were a number of criticisms that training certificates do not necessarily infer competence at operative level, yet are endorsed at management level. To fulfil the quota of required personnel, it was reported that agency staff are frequently used. The use of agency staff received a number of criticisms, predominantly due to their lack of commitment to the site and for not working according to work methods specified in their training. It was also reported that, due to difficulties in filling a quota, personnel with health problems are employed and create a risk to themselves and an additional burden to colleagues who have to 'look-out' for them.

The loss of a consistent complete team (both at management and site level) was rued, as work teams continuously disband and reform at each new site. With this is a loss of interaction, experience and common purpose among the group, which was felt in some cases to contribute to accidents.

4.2.2.4 Safety considerations

A number of positive comments were made about the improvement in safety culture in the industry over recent years, and all participants appreciated this. It was noted, however, that the effectiveness of any initiative is dependant upon the interaction of superiors with subordinates. The success of such top down commitment was reported to depend heavily upon the attitude of the Project or Site Manager and of the foremen or team / gang leaders. Similarly, the personality of the Safety Manager / Advisor was seen as carrying considerable influence, with positive outcomes being dependent upon the status and respect commanded by an individual.

Inhibitors to effective safety culture were that management on site is generally seen as reactive rather than pro-active. Time pressure plays a considerable part in work methods chosen and although it was reported that people may be committed to safety, they do not necessarily feel a concurrent pressure to comply with specified work procedures. It was reported that 'trades' are over-ridingly concerned about time and do not appreciate concern given to their safety. It was also indicated that unsafe work could be scheduled for the weekend when safety personnel are absent and unable to intervene. There were reports that personnel at an intermediate management level have conflicting responsibilities, which included facilitating maximum earnings by the operatives and achieving acceptable or even accelerated performance of the work. As such, safety was at times portrayed as a competing priority at site level with lower level supervisory grades described as being prepared to take risk on behalf of their men, as it is they who are likely to be disciplined should an accident occur and regardless of who is hurt. Some worst case scenarios recounted included suppression of the reporting of risk circumstances as it was believed that, should an accident or injury occur, some protection would be afforded to the employer if the risk circumstances had previously been 'unknown'!

On a more individual level, it was indicated that the traditional 'blame culture' shows signs of receding, but that there are still cases where individuals are blamed if procedures are violated. Procedural violations were seen as insidious and tolerated, and reflect a wider malaise on site. If dismissal results, this would only ensure that any problems are exported elsewhere.

Although safety arrangements reportedly receive more thorough consideration for the bigger jobs, negative comments were still made indicating that safety considerations can result in a loss of a contract (during the tendering process), can increase work load and that safety standards can be compromised by shortcuts. However, participants noted that accidents may be more common in one-off or small jobs and that the importance of near misses are undervalued. Concern was expressed that HSE are not providing enough guidance to the industry.

Specific criticisms were made regarding the risk assessment and accident reporting processes. It was stressed that risk assessments can be confused with Method Statements and that, in any case, risk assessments are at times of little value. Faults in preparation were described as inadequate attention to hierarchy of control, inadequate consideration of maintenance issues and, at times, over-specification of risk circumstances (which can inhibit consideration of broader factors). Problems were also attributed to the use of generic risk assessments, which do not include operative consultation and which are of more use as a bargaining tool to impress clients.

There were also criticisms of the accident reporting systems, in that some participants felt that they are prohibitive and that the recording of remedial action can appear very trivial. It was suggested that the loss of the accident book prohibits the review of previous accidents, a feature that had been valued previously.

There were conflicting opinions about the ratio between Safety Advisors and operatives, and of the value of Safety Advisors at each site - it was suggested that people can actually behave less responsibly where there is an on-site Safety Advisor. The Safety Advisor role was generally reported positively and it was felt that support would be given to operatives should they have any safety concerns. It was noted that, to make a stand, a certain amount of self confidence is needed by operatives and that this is how some less experienced / familiar operatives can be influenced to work in an unsafe manner. Some conflict was described, namely in that Site Agents don't necessarily "think safety" and that there can be occasions where they do not always incorporate safety as part of their work.

A number of participants in the focus groups indicated that they perceived that the state of housekeeping on a site closely reflected the site safety culture and the attitude of the Project / Site Manager / Site Agent. Good housekeeping was seen to reflect the 'state of affairs' for a number of site issues and this is impressive to a client.

Conversely it was recounted that working in a poorly maintained site has a negative effect on safety attitude and can contribute towards accidents. One group indicated that any problems should be resolved by disciplinary action or monitoring and that management should instigate this.

4.2.2.5 Site layout and transport

There were conflicting reports about site layout plans. Although it was acknowledged that they can be well done, there were a number of comments indicating that the provision of "laid out area" has decreased and that this impedes work processes. Problems with access were reported more, in that there can be inadequate access to a task area and that, on occasions, haul roads have to be used to compensate or to accommodate all who need to use a particular area. In themselves, uncontrolled transport issues were seen as able to dilute good control measures which may be present elsewhere. There were reports of work load pressure upon Banksmen and concerns about lack of supervision or induction for lorry drivers.

4.2.2.6 Job roles at work organisation level

A number of comments were made about the influence of different 'job roles' at organisational level that can impact upon safety. Where possible these are summarised here, although there has been some difficulty in compiling this due to the range of different job titles used and due to the number of references made in the focus group discussions to 'management' (given that for each group this may in fact have described different disciplines). Reference to Site Managers includes comments attributed to Site Agents.

Concerning Project Managers, it was reported that, while having a heavy workload, there may be shortcomings in their communication skills and level or appropriateness of experience. Project Managers were described on one occasion as insulated from enforcement action yet, on another occasion, were also described as being able to exert a powerful influence on safety performance.

When discussing Site Managers it was indicated that, as they are able to find employment outside the industry, competent Site Managers are hard to find. At best their responsibilities were described as including resolving design inadequacies, accommodating the consideration of trade overlap and of identifying and dealing with incompetent operatives. However, it was also suggested that Site Managers are not necessarily aware of safety standards and that they vary in their commitment to safety. This can be reflected in the level of instruction provided and in the amount of time pressure put upon tasks. It was also reported that Site Managers may or may not be prepared to delay work for safety equipment to arrive and that some can overlook or condone the taking of shortcuts.

As well as Site Managers, it was also reported that there is insufficient availability of competent Foremen. In the past, Foremen were described as powerful and knowledgeable, but it was considered that this role is for the most part now obsolete. It was suggested that 'Managers' may now replace foremen. Alternatively, operatives can nominally carry the 'foreman' or 'supervisor' title, but they do not necessarily have the skill base or role clarity of their predecessors. It was reported that pressure to fill a 'foreman' role can result in under-qualified people being promoted and that the impact of this results in inadequate work 'set-up', which in turn can lead to time pressure, the taking of short-cuts and inappropriate supervision. It was reported that about 20% of foremen just have a nominal role and that they do not provide the leadership required.

Overall, comments pertaining to 'managers' mostly reflected their positions regarding competence and their knowledge. Managers were perceived as lacking adequate construction knowledge and experience, which was seen to impact negatively upon accountability and construction health and safety.

The final role mentioned was that of Trade Union representatives. There were few comments, but there was some indication of costs inhibiting the amount of time that could be committed to safety matters. On the other hand it was also reported that bad Union advice can lead to accidents, yet Trade Union representatives have no accountability in this respect.

4.2.3 Task factors

4.2.3.1 Tools, equipment and materials

The selection of correct tools, materials and equipment received a number of comments with these appearing to be influenced by availability and work scheduling factors. Although it was generally acknowledged that, where provided by the Principal Contractor, the tools are often good and new to each site, it was indicated, however, that their selection is too cost motivated and that they are not always freely available. This may be because equipment is shared too widely between gangs, because loaned equipment is removed immediately after use (but prior to task completion), or because work scheduling is lost and the right tools are unavailable at time of need. It was indicated that this might lead to the taking of short-cuts or to the use of inappropriate equipment, especially if there is time pressure on the task. Cost implications were seen by some as inhibiting to the selection of preferred equipment. Safety equipment was in some cases seen to impede work efficiency. Work efficiency was also compromised by late delivery of materials as this can also induce time pressure upon the work.

It was described, however, that equipment is not always of a good quality and that there are problems with the selection of the correct capacity tooling and that there is not always provision of adequate maintenance (directed to lifting equipment). Overall, it was suggested that the health implications of using old and poorly maintained equipment is under-appreciated. There were some concerns about the unknown quality of equipment that is used by sub-contractors and of the use of multi-functional equipment. One example relevant to sub-contractor tool use was that to compensate for unknown site circumstances, they are known to bring their largest capacity equipment to site, and proceed with using this although the equipment may in fact be too large for the task.

Along with tools, equipment and material, participants also discussed the personal protective equipment (PPE) that is used whilst performing tasks. Availability and use of PPE was reported to vary widely. The impression gained was that for larger companies there are plentiful supplies, but for smaller companies availability is limited and in some cases operatives are even expected to provide their own PPE.

It was acknowledged that non-use of correct PPE does occur and, although this is more likely to happen at the week-end, use was seen as an individual's responsibility. It was indicated that those advocating the use of PPE do not adequately appreciate the practicalities and negative influence upon performance from its wear. For example, a considerable loss of mobility through using PPE was described; helmets are said to be disliked as they impede vision and fall off unless secured by ear muffs, and goggles are greatly inferior to visors (as they induce sweating and work is frequently interrupted to clean them), but that in either case vision can be impaired by surface scratching.

4.2.3.2 Task supervision and communication

Inadequacies were reported with both supervision and communication across the different disciplines at task level, and these were seen as contributing towards accident potential. Participants described different experiences of supervision, with contradictory observations that there is both more and less supervision nowadays. It was generally indicated that there is more supervision on larger sites, but that where this is lacking, poor practice and performance can result. The lack of supervision of lorry drivers and sub-contractors was mentioned a number of times. Particular reference was made to small groups undertaking a high rate of small jobs, who are less likely to be formally managed as their supervisors may cover many different sites. As such, safety behaviour may only be concurrent to the time of the Supervisor's visit. Participants explained that if an adverse event occurs and dismissal follows this only exports the unresolved problems elsewhere.

At site level, the efficiency of supervision was seen to deteriorate with a rise in the volume of sub-contractor labour, yet where supervision was regarded as good, sub-contractors would conform to standard. There were indications, however, that some task requests are inappropriate and that these relate to problems with communication. Communication was discussed as inadequate both with a same status team, and hierarchically through different grades. Within this there were indications that adequate consultation and liaison at trade level is lacking and that it is misleading to assume that absence of reporting of problems automatically indicates that all is well.

4.2.3.3 Task, techniques and safety factors

Small jobs, isolated work or short term contracts were seen as those where little forethought is given, and with safety factors more likely to be considered on an ad hoc basis or at an individual level only. It was noted that setting up safely, waiting for arrival of and use of safety equipment can take longer than the job itself and that duration of exposure to a 'risk' influences an individual's choice of safe working methods.

More generally, working methods were described by some as outdated, but that there is resistance to or ignorance of 'new developments'. Additionally improvisation or short-cuts in work methods are seen as contributory to the causes of accidents. The system for introducing and using risk assessments was seen as not working and (as described earlier concerning procedures and method statements) there is generalised ignorance at operative level. It was indicated by some, however, that operatives should look out for each other and that any wrong doing should be challenged and resolved at this level. On the other hand it was suggested that near misses are under reported, but there were feelings among some participants that even when 'incidents' are reported, they may be discarded or 'lost' higher up the hierarchy.

4.2.3.4 Training in task and health and safety skills

A number of different criticisms about training were mentioned and the first of these concerned induction. Comments on induction were that they can be overly long and repetitive of base-line information common to all sites (such as PPE). It was reported that they are inconsistently provided (lorry drivers especially were thought not to receive induction) and that they do not necessarily provide the 'appropriate' site-specific information. It was indicated that people become blasé about inductions and that in any case they are not evaluated and have no expected outcome.

Participants reported that induction and tool-box talks are confused and that tool-box talks can become obsolete. When discussing training in more general terms alternative problems were recounted, especially as it was indicated that training is often inappropriately seen as a response to all problems. The provision of training for young people was seen as inadequate (in terms of a lack of appropriate

apprenticeships), as was the use of multi-skill training. It was indicated that the consequences of the loss of apprenticeships would be felt considerably in approximately 15 years time.

Generally, for training content, it was mentioned that not all understood the terminology used and that agency staff especially perceived training as a waste of time. It was indicated that there is a shortage of courses, that training is not provided consistently (no manual handling training for labourers for example) and that it is the larger sites that provide more training opportunities.

The use of a trainer unknown to the trainees appeared to be criticised (and understood to be due to their lack of understanding / empathy of specific work problems). Additionally, the training content was also criticised (especially at task level), whereby it was considered by some that too much time is spent on office based theory (again much of which is repetitive common-core material) with insufficient time spent on practical field skills.

The lack of practical field skills was thought especially important. In this respect problems were mentioned with one day training courses that provide a certificate of competence. The certificated person is apparently not evaluated for competence, yet is still expected to display a wide range of skills from a very early stage. In any case it was also reported that working without the correct certification is permitted, but that learning on the job in this manner may convey the wrong techniques.

4.2.3.5 Work load and time constraints

The scheduling of workload appeared to be influenced considerably by the revised work patterns and long hours culture that is now prevalent in the industry. Although it was recognised that long hours are well rewarded financially, this is invariably disruptive to domestic life and can routinely entail early morning starts. This, coupled with the additional culture of travelling large distances for work, was discussed as having a negative effect on decision-making and productivity, and that the resulting fatigue could compromise safety.

Focus group participants reported that there has been an increase in the introduction of weekend, night and block work by clients. It was suggested that Management staff at the week-end may be unfamiliar with workload and that there can be omission of PPE or tolerance of unsafe work practices (especially whilst the Safety Advisor is absent) during this time period. The effects of revised work scheduling were particularly reported in the undertaking of retail work, whereby changing shopping patterns have made Sunday one of the busiest days (a day which was previously considered a quiet time). This has lead to increased night work, which in itself was felt to cause a loss of alertness, carelessness and permit double shifting.

Time pressure was repeatedly mentioned in relation to the undertaking of tasks. Various causes were noted and (in no particular order as many of these factors are mentioned elsewhere in the chapter) these include having to accommodate operative turnover, the availability of, and need to, inspect equipment, the use of (some) safety equipment, access to the site, poor work set-up prior to task commencement, waiting for sub-contractors to undertake fixed fee jobs, interruptions whilst working, the need to make bonus payments, inflexibility in work organisation, and the pressure to meet deadlines. The effect of time pressure was cited as corner cutting, the use of unsafe work practices and having to exert considerable extra effort to accommodate previous time losses.

4.2.3.6 Financial considerations

The implications of payment methods upon performance, quality and efficiency were mentioned on numerous occasions. It was indicated that pay is directly related to the work undertaken and that expectation of payment leads the choice of work methods. There are reportedly no longer any fixed wages for trades people, as all work is now target or bonus related. Financial expectations are high and exceeding the work target and increasing bonus related pay is considered essential for income and the prime incentive for operatives. Bonus pay may be safety-related, but it seemed that most often bonus pay is solely related to task performance.

A range of adverse consequences of these payment methods were presented in the discussions and these include poor working practices, ignoring procedures, increased risk taking and unsafe improvisation, time pressure, and consequent inhibition of

constructive decision making. It was indicated that there may be a financial penalty if a job is difficult or slow to complete and that any mistakes have to be resolved within the company's or individual's own time.

Participants variously reported that on the one hand pay is not related to qualifications or experience, but that on the other, pay may be increased after learning new skills (with some companies). It was commented that there is a reliance on young employees and that this is reflected in a low basic wage.

4.2.3.7 Environmental conditions

Poor environmental conditions were raised as a factor which can impede work for operatives. It was suggested that, where work has to continue in bad weather, this can induce risk-taking to finish tasks hastily. It was suggested that some operatives, such as pipe layers and scaffolders, may be more vulnerable in wind / rain conditions. The effects of heat fatigue also need to be considered (the need for special consideration during the religious fasting that occurs during Ramadan was noted). Isolated operatives were also described as being at greater risk if they have no means of calling for assistance should an adverse event occur. It was reported that bad weather affects morale and especially as some clients can stipulate that there will be no schedule revision in these circumstances.

4.2.3.8 Design of task area

While it was said within the focus groups that safety is considered in the task layout, there were also indications that there are some space restrictions (perhaps through the use of safety equipment, through inadequate scaffold set-up or other working 'at height' problems) and that these can introduce awkwardness or reduce stability.

4.2.3.9 Job roles at task level

There was consensus that there are insufficient competent and experienced trades people in the industry and that this has consequences not only in loss of task skills but in safety awareness too. There was some indication that different trades perceive safety guidelines differently, and that scaffolders and steel erectors are more likely to over-ride safety rules.

Clarity of job role received varied comments and different participants saw this in both a positive and negative light. Firstly, for speed, jobs are reportedly more fragmented nowadays and this can inhibit use of the full range of operative skills. However, fragmentation was also seen in a favourable light as certainty and role clarity of just doing specific jobs was valued as well. Overload was noted too in the context of Banksmen, who simultaneously have to assist with additional duties while doing their task, which was felt to inhibit the efficiency of their role in the safe movement of transport.

4.2.4 Individual factors

4.2.4.1 Age, attributes and experience

The discussions indicated that there is increased reliance on young and inexperienced employees on sites and there is particular concern about early responsibility and use of dangerous equipment by young workers. Young people were described as more safety conscious and seen as more likely to follow work instructions, but were reported to experience a high accident rate, especially within their first week of appointment. It was said that construction does not attract high calibre school leavers and formerly, prior to the last construction slump, there were older and more experienced workers, but they are now seen less commonly.

It was argued that young and inexperienced workers are present across all grades. Young people in authority were described as possibly having good organisational skills, but having low safety motivation – it was also described that those in authority, and inexperienced with safety management, can sometimes be perceived as not caring. At operative level, there was a certain amount of concern about the impact of inexperienced people on site, and especially about the lack of even the most basic common sense among newcomers. There were also references to lack of concentration and carelessness. It was reported that it is generally possible to establish whether a new person to site is ‘any good’ within approximately one hour, but that because of manpower shortages those less able have to be tolerated – creating supervision and safety-related problems.

The verification of ‘experience’ seems especially difficult and it was discussed that there are problems with people with inadequate skills presenting themselves as a

skilled trades person. Concern was also voiced about the appointment of trades people from outside the industry and reservations about the transferability of their skills onto site. When discussed, the use of the CSCS card (2.5.6), to provide a record of qualification and experience, appeared to be welcomed at trade level. It was understood however, from remarks made, that experience and skill is not necessarily perceived as particularly valued and that there can be some feelings of marginalisation among long standing employees. This was experienced in lack of recognition in pay and in having to assume a housekeeping / 'nannying' role to others brought onto site.

Although experienced workers were described as having fewer accidents, experience was also seen to have a negative side. The range of problems associated with experience were noted as work fatigue, over-familiarity and over-confidence, complacency, omission of or low safety awareness, and difficulties in changing work techniques.

It was variously described that site and work experience may either increase or diminish the likelihood of risk taking at work. It was said that a gang leader or charge hand may be more likely to get injured than new starter, but that this happens because they take risks on their behalf. Alternatively, the repeated successful undertaking of a risky activity was also thought to encourage perpetuation. Additionally, the commitment attributed to an employer through long service may also induce employees to take risks that they might otherwise avoid. By virtue of their short appointment time, maintenance staff and sub –contractors were described as tending to be more ignorant of site risks. Ultimately, inadequate knowledge and training were said to contribute towards risk misperception and apathy, and these were seen as accident causes. A number of comments were made by participants, which revealed the presence of a fatalistic approach to accidents – with luck and chance seen to have a considerable contributory role.

4.2.4.2 Competency issues

Where competency and the issues of certification were discussed by participants, a number indicated that that 'competency' lacked clear definition. Moreover, competency needs to be relevant to site conditions / equipment used and cannot be inferred just by certification. There was concern among some that too much emphasis

is placed upon certification as, for 'managers', this implies competence of workers and defers responsibility from themselves. In other cases, the misrepresentation of competence (deliberate or not) by people wishing to join the site was considered detrimental as this had supervision implications and also impedes ability of the gang to meet their bonus. There was concern too about spurious attribution of competence when convenient (i.e. when a particular task needed doing in a hurry) as it was indicated that proceeding without certification may result in lack of 'cover'.

4.2.4.3 Attitudes and conformity

Attitudes among personnel were variously described. There were a number of reports of pressure to conform, such that jobs must be done at any cost and although there is nominal commitment to safety, complacency breeds complacency, and people do not feel a pressure to comply. There was indication too of peer pressure to maintain work pace, especially in the context of achieving the bonus. It was also indicated that a degree of self-confidence and authority is needed to reject pressure to conform, but that once stated it is accepted. On the other hand it was also mentioned that fear of the consequences can inhibit operatives from complaining and, as such, violations remain insidious and tolerated.

4.2.4.4 Health status and fitness for work

One concern highlighted by the focus groups was the next day effect upon individuals of high alcohol intake. This was discussed as being connected with life-style factors associated with the industry, such as site distance from home, long hours and early work starts. More broadly, varying views and differing perspectives of general health status were noted. It was indicated by some that a lot of men are (or through work hardening) become quite capable of doing the jobs they are requested to do and that ability to do a task is evidence enough that they are adequately fit. On the other hand, there were also concerns that there are considerable health problems among construction workers, and that operatives are at risk of work related injury and, if affected, may continue to work with inadequate health status despite this. It was reported that light work may be possible for injured employees, but that dismissal is sometimes the alternative.

The general impression from participants was that ill health and health-related issues (especially slowly developing health issues) are under-appreciated in the industry and

that an increase in the extent of litigious action is anticipated in the future. In this context, the suspicion was raised that some work injured personnel might be securing appointment with larger companies in anticipation of making a future compensation claim.

The skills shortage was described as leading to the appointment of people with health problems and there were concerns about inadequacies in verification of health status – especially for sub-contractors. It was reported that health screening is increasing, but that there are major difficulties with this, given the turnover and mobility of personnel in the industry. The terms health screening, medical screening and health surveillance appeared to be used interchangeably by some participants and it was apparent that the distinction is not appreciated. Where content of health screening was mentioned, this was described in terms of drug and alcohol testing, whereas a more comprehensive ‘health assessment’ reportedly occurs only for confined space workers.

4.2.4.5 Exclusion of discussion themes

Few aspects of the discussion area prompts were left un-addressed. A notable exception was ‘site selection’ as a ‘strategic design consideration’ (Figure 14). This was discussed by only one group, but restricted to raising the point that wealthy clients would be willing to pay more to ‘make good’ poor site choices, as ‘location’ was an over-riding factor in their decision making. Likewise, there was little discussion relating to site layout issues.

4.3 Questionnaire results

As an element of the focus groups meetings, participants were asked to consider the contribution of different factors to construction industry accidents. This helped to isolate viewpoints by each different group. A five-point rating scale was used and the mean responses from each focus group are presented in Figure 14 - Figure 17.

4.3.1 Project concept, design and procurement

The graphical representation in Figure 14 shows that for the first three factors there is a visible continuity of responses among each group, although strength of feeling varies. For the first factor, ‘inexperienced client’, those that considered that there was a greater contribution were those in a senior role, either as a Senior Manager, Safety,

Mixed group or Safety role. In contrast this factor was considered less important by the site-based personnel – Site Managers and operatives (large and small sites).

These patterns of responses were similar when considering the contribution of 'unsuitable contractors' and of 'inadequate identification and assessment of risk', but for these factors the mean results from the responses of Site Managers indicated that they felt that the contribution of these factors was greater. Likewise for the operative group, strength of feeling concerning the contribution of these factors is increased.

The pattern of responses changes with the final four factors. Responses from Senior Managers indicated that they had considered the previous three factors important 'to a large degree', however 'inappropriate allocation of finance', a function likely to be under their control, was judged as less significant by them. In contrast, out of all the factors in this section, this was rated most highly by the operative groups.

'Choice of site' was rated least important by all respondents, and particularly by those working at site level - Site Managers and Operatives (large and small sites). This pattern was repeated for the final two factors 'technical faults in building design' and non-compliance with legislation', although these rose in significance, again for the non site-based personnel.

4.3.2 Work Organisation and Management

Figure 15 shows that the response patterns among participant groups, although not necessarily strength of feeling, were very similar for the first three factors. Although 'PPE deficiency' was considered the least important of these, results indicate that 'inadequate planning' and 'lack of safe systems' were seen as relevant to failure. Senior Manager, Safety, mixed and Site manager groups rated these factors as being of greater contribution than the operative groups.

The pattern changes for 'inadequate response to previous incidents' and, although the safety and mixed groups continued to see this as influencing 'to a large degree', the senior managers, client team and site manager groups were less strong in their agreement. 'Poor supervision of operatives' was noted as contributing towards accidents between 'to some degree' and 'to a very large degree', but strength of

feeling was least among the mixed and two operative groups. For the next factor 'lack of feedback on work performance', opinion was less strong, with operative groups continuing to rate this only 'to some degree' as did the Site Manager client team groups. Lack of training was rated as contributing 'to a large degree' by almost all participant groups, yet opinion was contrasting again when considering the influence of 'poor health and safety culture' and the site based personnel attributed least contribution of this among the different groups.

4.3.3 Task factors

Again, a similar pattern of responses was obtained across groups, excluding the mixed groups, who varied in opinion (by indicating a lesser contribution for poor tools and equipment) (Figure 16). When considering 'high workload of personnel', this factor was considered by all to at least influence accident causation 'to some degree', yet the opinions of the two operative groups appeared to be very different for this factor. Strength of feeling was greatest among the large site operative and safety groups, yet least by the small site operative groups. Opinion was similar among all groups for the middle three factors, yet 'missing or unclear instructions' appeared to illicit a much stronger response from the operative groups.

4.3.4 Individual factors

There was most variety in ratings among groups when considering individual factors (Figure 17), and there was a very similar pattern of responses from all groups. The least important factors appeared to be individual medical problems, and to a certain extent, the effects of monotony and boredom. In contrast, attitude to risk was considered to be important 'to a large degree' by all participants, as was (although responses were somewhat less consistent) 'failure to recognise danger or carelessness on the part of the employee'. All considered 'Tiredness' important at least 'to a slight degree'. High ratings were also given for 'low skill and competence levels' and 'the demands of the job are not familiar', with the operative groups providing some of the greatest strength of these responses.

4.4 Discussion of questionnaire data

The data (mean scores and standard deviation) for the rating scale responses are reproduced in Appendix 2. An overview of this indicates that variation of opinion

was higher among the mixed and site based groups (especially the operatives – large and small sites).

All factors presented were recognised as contributory to accidents to some degree among the different focus group participants. This recognition might have been expected for task or individual aspects, but it is perhaps surprising that factors determined earlier in the project lifecycle were rated so strongly. Researchers often argue that issues such as these are neglected as causal factors in accidents.

Differences in opinion between the groups are much greater when considering factors related to the first two discussion themes, 'project concept, design and procurement' and 'work organisation and management'. This was especially so concerning contractor suitability, client experience, health and safety culture, legislative compliance and availability of safe systems. Senior Manager and Safety professionals have consistently attributed a larger contribution of these factors to accident causality, whereas site based personnel (especially operatives) rated the least contributions. This was a theme among many of the group responses.

Whilst the questionnaire results have generated material that supports the focus group findings, it is felt that data from the rating scales should be interpreted with caution. The results may reflect the degree to which participants considered themselves to be associated with the subject area, the extent of their prior experience and their confidence in expressing an opinion upon such issues. It is also possible that the results have been influenced by norms among groups routinely used to completing such questionnaires.

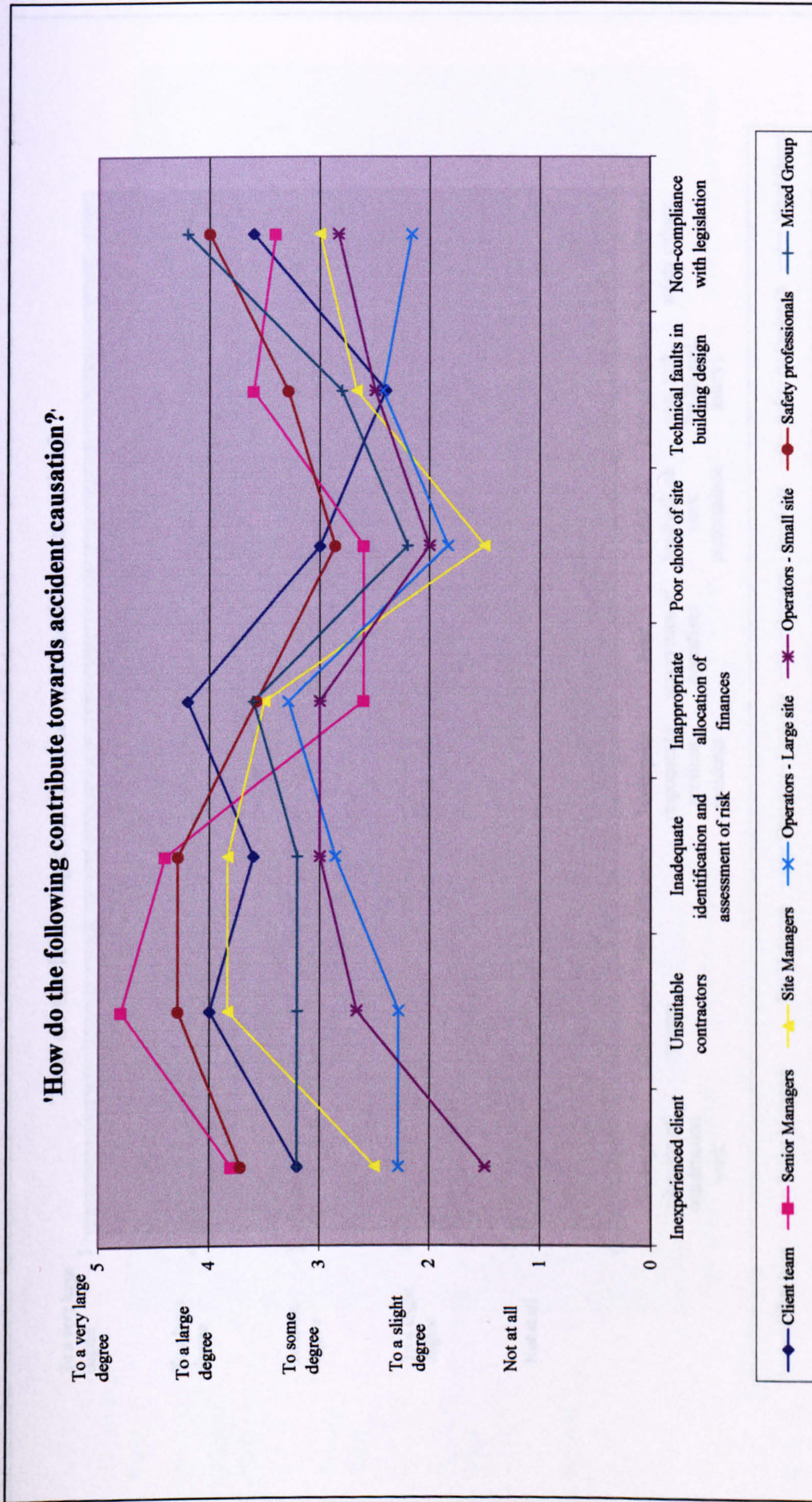


Figure 14. Project concept, design and procurement – Mean responses

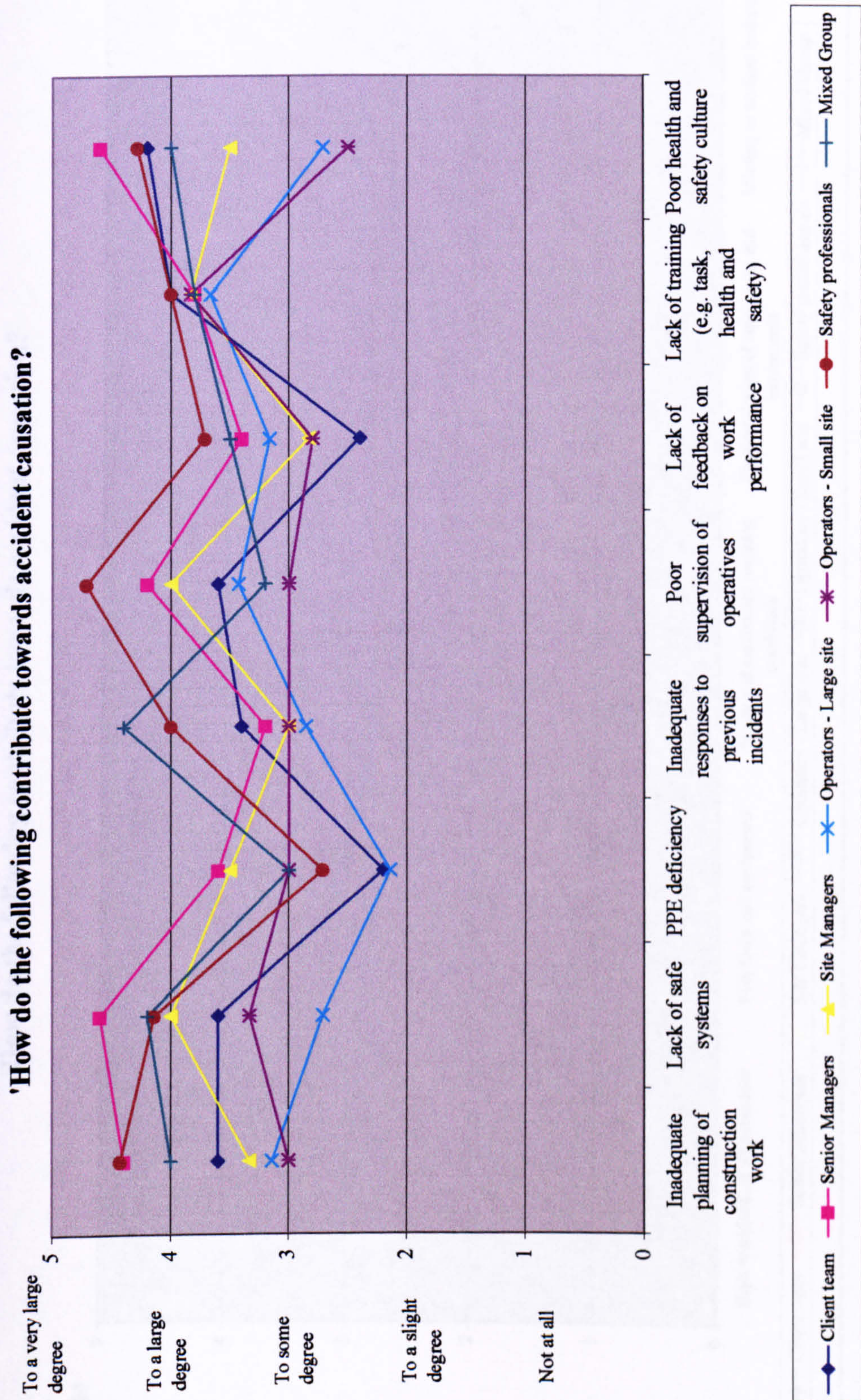


Figure 15. Work organisation and management – Mean responses

'How do the following contribute towards accident causation?

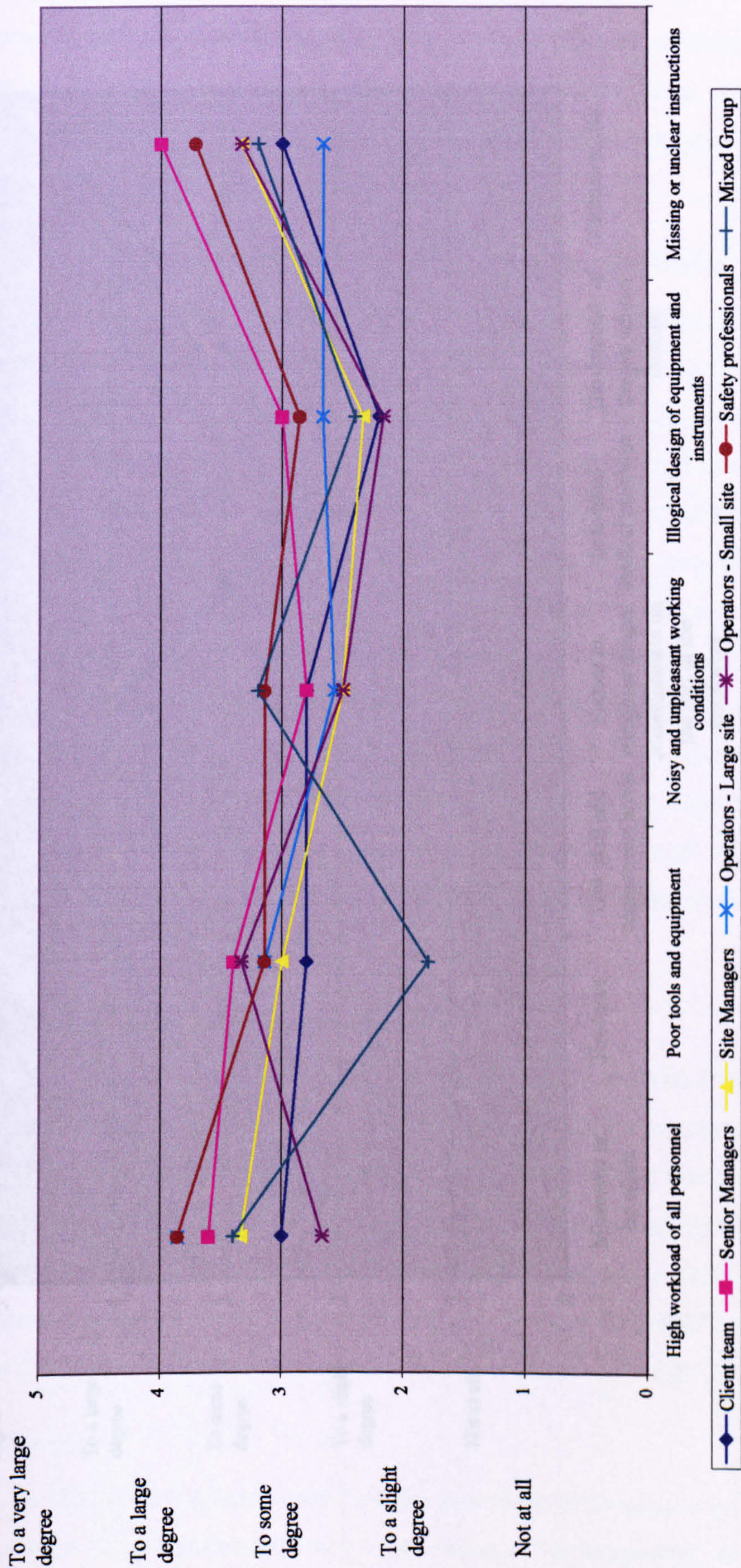


Figure 16. Task factors – Mean responses

'How do the following contribute towards accident causation?'

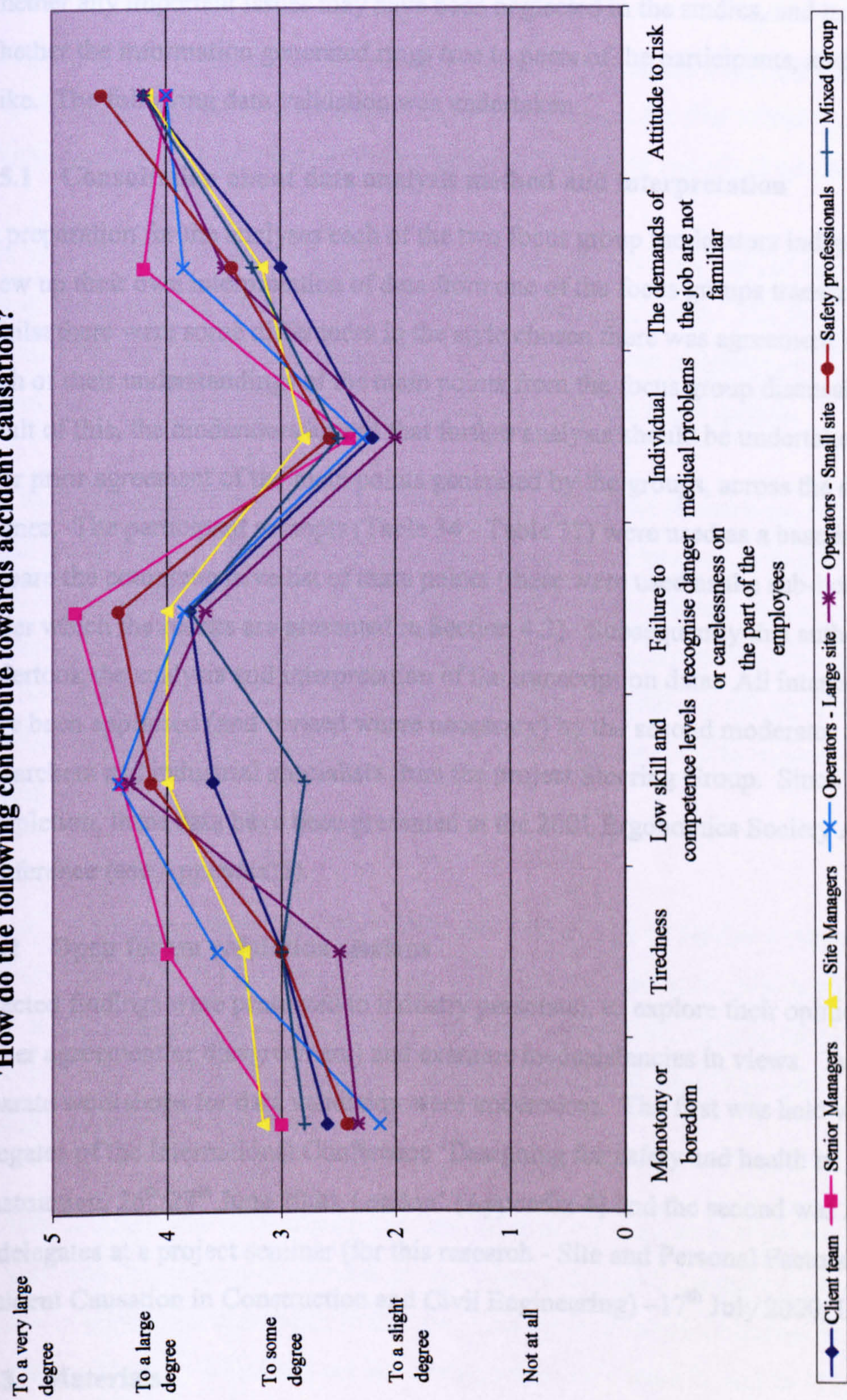


Figure 17. Individual factors – Mean responses

4.5 Data validation

An important element of the focus group methodology was data validation, to assess whether any important issues may have been neglected in the studies, and to test whether the information generated rings true to peers of the participants, and experts alike. The following data validation was undertaken

4.5.1 Consultation about data analysis method and interpretation

In preparation for the analyses each of the two focus group moderators independently drew up their own interpretation of data from one of the focus groups transcriptions. Whilst there were some differences in the style chosen there was agreement between each of their understandings of the main points from the focus group discussion. As a result of this, the moderators agreed that further analysis should be undertaken only after prior agreement of the main points generated by the groups, across the discussion themes. The participant prompts (Table 34 - Table 37) were used as a baseline to prepare the comprehensive list of main points (these were used as the sub-headings under which the results are presented in Section 4.2). Subsequently this author undertook the analysis and interpretation of the transcription data. All interpretations have been appraised (and revised where necessary) by the second moderator and by researchers and industrial specialists from the project Steering Group. Since completion, these data have been presented at the 2001 Ergonomics Society Annual Conference (see Appendix 5).

4.5.2 Open forum validation sessions

Selected findings were presented to industry personnel, to explore their opinions (either agreement or disagreement) and examine inconsistencies in views. Two separate workshops for data validation were undertaken. The first was held with 22 delegates of the International Conference 'Designing for safety and health in construction, 26th/27th June 2000, London' (Appendix 4) and the second was held with 21 delegates at a project seminar (for this research - Site and Personal Factors in Accident Causation in Construction and Civil Engineering) - 17th July 2000, London.

4.5.3 Materials

Material for validation was generated from the first three discussion areas (project concept, design and procurement; work organisation and management, and task

factors). Material generated from 'individual factors', although considered important, was excluded in order to concentrate the validation discussion into construction specific areas, rather than aspects which might equally apply in any employment area.

From the 'Project concept, design and procurement' discussion data, four categories were identified and these were presented for discussion at the first validation session. The categories were (a) Design (b) Innovation (c) Planning and (d) Communication.

For the second validation session, two aspects were drawn from each of the 'work organisation and management' and 'task factor' discussion areas. The themes, (a) Method statements (b) Work scheduling (c) Supervision and training and (d) Payment issues, had each been subject to considerable debate in the focus groups.

For each category, sample statements were generated by the researchers, from the focus group data, and were stylised to reflect what was understood during data analysis and to provoke a response from participants (these statements are repeated Appendix 3). As such, the statements provided were more provocative in style than any original statements, but this was deliberate. The rationale for this style was carefully described to participants to avoid misunderstanding and to encourage co-operation.

4.5.4 Validation method

At each validation session, participants divided into groups to discuss statements provided for one of the categories. At the first validation session, participants self-selected their category for discussion. At the second validation session participants were allocated to a discussion group, to ensure equal distribution of people (but with allocation on an ad hoc basis).

All sample statements were presented to the validation groups as a whole prior to dividing into the category discussion groups, after which each category discussion group was given their statements to discuss. Groups were asked to discuss the statements for a 30 – 40 minute period, during which they were invited to respond to the following questions:

- ‘ 1. Do you agree with the statements?
2. Provide a brief explanation for your responses (aim to list ~ 5 key points)
3. If you disagree with a statement, why do you think other groups within the industry hold this view?’

Participants were asked to prepare their responses on a flip-chart sheet and to give a brief presentation of their material to the other groups, after which the remaining seminar participants were also invited to comment. Responses from these presentations and comments from the sessions are reproduced in Appendix 3.

4.5.5 Validation results

Many of the responses generated by validation participants were similar to the responses provided by the original focus group participants. This was expected and reinforces the interpretation of material already obtained. New information came to light however and three continuous themes were apparent within this.

Firstly, although validation participants indicated that there are shortfalls in performance of some clients or professional disciplines, they reported that it is inappropriate to generalise or lump together poor performance. A number of references were made to how difficult many jobs are (such as Planning, Designing, being a Site Manager or Foreman), that conflicting demands can make decision making difficult for personnel in these sectors, and that this should be appreciated during any criticism.

The importance or relevance of communication within many of the discussion areas (and not just in the ‘communication’ discussion of first validation session) was also highlighted. There was indication that lack of inter-disciplinary work and sharing of knowledge are considerable drawbacks in the effectiveness of auditing, risk assessment and the development of training and method statements. Related to this was the suggestion that there can be a ‘loss of face’ in requesting assistance or acknowledging shortcomings and that this may inhibit communications too.

Finally, validation participants described a range of important training inadequacies. Training inadequacies for apprenticeships were openly discussed, but there were also indications that training (and especially in health and safety issues) was lacking for other disciplines too.

4.6 Summary of the focus group studies

Division of the focus group findings into the four discussion themes ensured that a broad range of information was obtained. At the 'Project Concept, Design and Procurement' stage the influences seemed to stem from failings arising from the actions of clients and their representatives, such as designers and architects. Typical problems included ignorance of legislative responsibilities and safety innovations, perpetual cost cutting, the exertion of undue time pressures, poor design management and bureaucratic burdens during the early project phases.

When discussing 'Work Organisation and Management', the quality of method statements, procedures and general planning issues appeared to be significant concerns. There were also problems with work scheduling, whereby frequent revision of project time lines generated trade overlap (and loss of work sequence), work back log, the taking of short-cuts, and the generation of time pressure. Role and appointment issues were also described, especially in relation to sub-contracting and site supervision.

Task factors concerned the provision, quality and usability of tools and equipment, materials and PPE. Participants were also concerned about failures in the provision of appropriate training and in only selective adoption of safe working practices. Work load and time pressures, revised work patterns and long hours culture were reported to be prevalent in the industry and there was concern about the affect upon performance from the resultant fatigue. There were also concerns about effects upon safety, performance and work quality arising from the widespread use of target and bonus related pay.

Issues relating to individual workers mostly concerned age, experience, attitude and health related aspects. There were particular concerns about increased reliance on young employees on sites and their inexperience in dealing with dangerous situations. Even experienced workers were vulnerable, yet for different reasons such as work fatigue, over-familiarity and over-confidence or complacency. It was suggested that construction workers have many under-current health problems and there should be an expectation of increased litigious action in the future.

4.7 Critique of the focus group studies

The range and depth of information provided a huge amount of information and was fundamental for later methods development (5.2.1.5). However, there were also a number of limitations with the focus groups studies. There were inconsistencies in the formation of two of the groups and, especially for client team, there was no representation from designers or other client team professionals. A consequence of this is that it affected the balance and role representation desired and is likely to have influenced the results. Likewise, the constitution of the Site Manager team was also subject to last minute changes and it is felt that, although the discussions were interesting, that the data collection from Site Managers may not be a good representation of the views held by Site Managers in the industry. It was anticipated that this problem would be redressed within the subsequent stages of the research.

In more general terms, the focus group data reflected only the information participants were comfortable to divulge at the time of the groups. This being in front of the other focus group participants and also the two moderators. Participants from the Senior Manager, Site Manager and Operative (small site) groups all knew each other prior to their focus group, and for the others all participants knew at least one other attendee. Whilst conversation might be generated more easily among people they know, it may also mean that participants are less willing to challenge 'group norm' or established thoughts on a topic. The nature of group dynamics is such that it is also possible for one member to dominate conversation and present a biased view that absorbs the discussion time allowance. Whilst the group moderators were alert to this, it should be noted that other participants might not challenge other's viewpoints and misrepresentation might not be apparent in the analysis. Additionally, it cannot be assumed that their feelings are representative of all in the industry, only that employees with a range of relevant experience and knowledge have generated these data.

Differences in opinion were encountered, although these often seemed to be among participants rather than typical to any particular group. Some groups concentrated on particular areas (perhaps reflecting their own experiences), but overall a range of data were obtained. The research enquiry concerns the range of opinion rather than

spurious attribution by group, as such all data have been presented, for the most part, by discussion areas.

5 PHASE TWO – METHODOLOGY FOR ACCIDENT STUDIES

Phase Two concerned site based accident studies. In order to proceed with these it was first necessary to develop the data collection methods, establish access to construction accidents, acquire ethical approval and develop a sampling strategy, (see Figure 18). The review of the literature presented in Chapter Three had identified desirable features of methods in accident modelling and the range of generic and construction specific issues that need to be considered (3.7 and 3.11.6). Table 23 also introduced a range of accident associations that warranted address in the exploratory methods. A range of accident investigation techniques were available, yet these were variably appropriate according to accident type, resources, training in technique and task decomposition etc. (3.9.1 and 3.9.4). Diverse methods of accident data representation were identified, yet these too differed according to the work situations studied and level of control exerted (3.10).

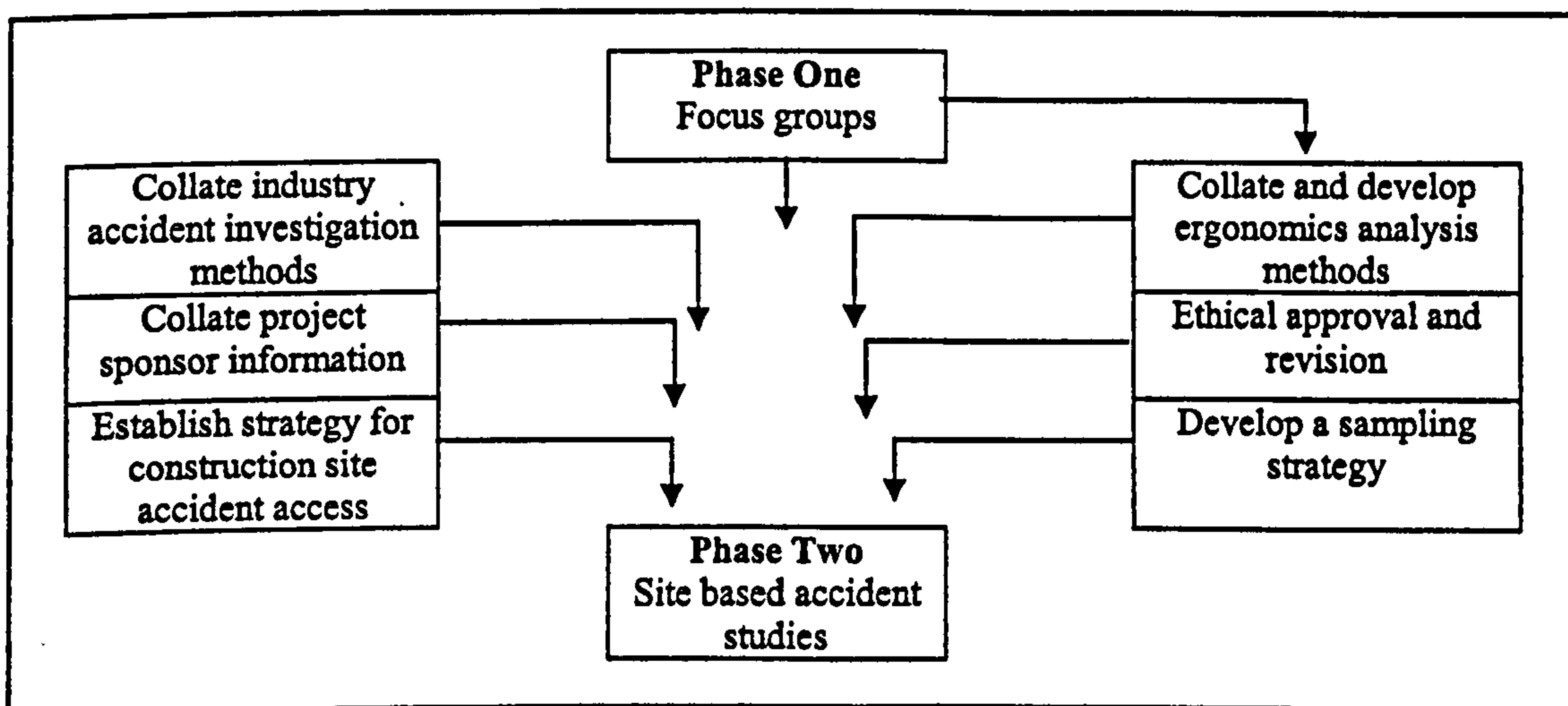


Figure 18. Phase Two of the research

In developing the sampling strategy, the research also had to operate within the constraints of the accident types actually available for inclusion. Given policy change within the HSE just prior to commencement of data collection (1.1.6), access to incidents of more serious consequence was very restricted. It was agreed with the Steering Group that near misses and accidents with risk potential for more serious outcome would accommodate this shortfall. As such, the approach was devised to address the range of near miss, minor and major accidents.

5.1 Aims and objectives

The aim of the site based data collection was to gather information on the range of active factors and latent conditions through the study of accidents and identify the most effective way to present the data. In order to achieve this the objectives were to:

- (a) Appraise and adopt advantageous features from existing generic and construction industry accident investigation methods
- (b) Identify information from ergonomics and construction industry resources that might enrich data collection
- (c) Develop accident study techniques for data collection
- (d) Use of multiple data collection methods to facilitate evaluation and avoid problems of bias and causal attribution
- (e) Ensure that the methods and techniques did not compromise ethical practice
- (f) Ensure that the accident study sample was representative of the accident profile within the construction industry
- (g) Identify the most effective methods for data representation

5.2 Appraisal of available data collection techniques

Literature review had revealed the range of latent conditions that affect performance (3.5.3.3) and that these issues are the foundation of an ergonomics approach in evaluation of interacting factors in the workplace (3.6.1). These methods however are not generally adapted for the construction industry, neither are they necessarily useful in identification of accident active factors. There are existing accident investigation techniques (3.9.2.2), yet these require certain conditions and a number of shortcomings have been reported (3.8.1.2). To identify what methods might be useful, an evaluation of general accident investigation techniques and those used in the construction industry were appraised.

Having isolated the framework of ergonomics assessment methods and desirable features from construction industry accident investigation methods, it was necessary then to integrate the construction specific information needs. A number of different resources were consulted and evaluated to see what information might usefully be extracted or be supportive in the development of construction specific methods

development. These included information supplied by the research partners and project sponsor and findings from the focus groups.

5.2.1 Appraisal of existing accident investigation techniques

A number of accident investigation resources (e.g. Canadian Centre for Occupational Health and Safety 1998, Health and Safety Executive 1997b, United States Department of Labor 2000, US Department of Energy 1999) and software packages (Norton Waugh Management Software 2000, EQE International 2000) were evaluated. Whilst these offered some helpful information, there were a number of shortcomings – mostly because these usually aimed at those with little background knowledge or because they were too proceduralised or constraining for use as an exploratory tool. These methods were not adopted.

5.2.1.1 Appraisal of ergonomics assessment techniques

Earlier development (for the focus group discussion themes) created an approach that accommodated the concept and development of the project, the work organisation and management, task design and individual factors (4.1.3.3). These were based upon ergonomics approaches and models of accident causation and provided an extensive network within which to explore perceptions of failure and accident causation.

Having ascertained the range of aspects that needed to be considered, a variety of practical assessment tools were consulted as a guide for developing question style and content within the main factors of interest (Institute for Occupational Ergonomics 1998a, Finnish Institute of Occupational Health 1989 and McAtamney and Corlett 1992). These were employed as a framework upon which to integrate construction specific enquiry in methods development.

5.2.1.2 Appraisal of construction industry accident investigation techniques

Construction companies, who had volunteered assistance with the research, were asked to supply the materials that they use for accident investigation purposes. Fourteen out of the 26 construction companies approached volunteered the accident investigation tools used in their own workplaces. These were all in questionnaire format and in many cases were used concurrently with data analysis software packages (not seen). There was much commonality of enquiry among the

questionnaires. The range of factors included in these tools is summarised in Table 39.

Area of enquiry	Example aspects addressed	Frequency
General details	Date, address, location, nature of project	14
Biographic details	Name, age, address, employer, occupation, experience	14
Injury details	Type, location, severity, treatment, absence	14
About the accident	Description and cause of the accident	14
	Unsafe acts or violations of expected practice	12
	Unsafe conditions such as organisational or job factors	7
	Estimated recurrence probability	2
	Recorded provision of training, induction or toolbox talks	3
Declaration / witnesses	Details / statements for accident history and form completion	14
Recommendations	Recording of actions taken to prevent recurrence	13
Reporting	Whether notifiable under RIDDOR 1995	9
Property / plant damage	Source, condition and estimated damage costs	9
Follow-up	Later review of recommendations and progress	5
Supporting documentation	Accident area sketch / photo or supplementary explanation for immediate causes	5

Table 39. Content appraisal of construction industry accident investigation tools

In this appraisal it is acknowledged that each of the accident investigation tools has been developed for use in work circumstances specific to the source company (which may have varied among contributors). Additionally, it is not known what background or accident investigation skills the reporter would be expected to possess, whether these tools may be used concurrently with additional documentation (which was not supplied) or whether these tools may be the precursor to a later and more detailed investigation method. Nonetheless, among the materials provided, the impression was that where subjective assessment is required during the accident investigation, attention to failures or violations by individuals received greater attention than those where indirect causes, such as unsafe conditions, may have been a contributory factor in the accident event. Unsafe conditions, where proposed, required address of such areas as the nature of the work and supervision, whether the correct tools and materials were employed and also more general comments concerning the work environment and conditions.

Whilst the evaluation was a worthwhile exercise, these methods did not embrace the breadth of search criteria (latent conditions, factors affecting performance and the four assessment areas identified during focus group development (Project concept design

and procurement, work organisation and management, task and individual factors). The focus of industry methods was predominately upon identification of 'unsafe', 'failure' etc. which invites the investigator to commence search with a biased judgement (3.5.3.2). These failings are common to reports concerning generic accident investigation tools (3.9.4.4). Advantageous features of the industry techniques was in the recording of 'active causal factors' and some of the base line data surrounding the task, site and build circumstances.

5.2.1.3 Appraisal of information supplied by the research partners

Analysis of the HSE focus database (Suraji and Duff 2000, but work in progress at the time of access) generated numerous examples of failure 'tokens' (Table 28) which were drawn upon to ensure the depth and range of exploration – where failure might occur and where assessment was required.

5.2.1.4 Appraisal of information supplied by the project sponsor

Earlier work undertaken by the project sponsor generated a series of notes concerning 'Intelligence needs' in accident investigation (HSE, Personal correspondence, 2000) and these provided a rich source of prompts for data collection and for indication of the areas where assessment was required. Whilst the complete list of notes is not reproduced here, the main themes were:

Client	- Construction and business history
Site	- Size, value, project timeliness and employee welfare and consultation arrangements
Accidents	- Incidences, causes and consequences
Supplier	- Data relating to provision of labour, services, plant and equipment
Work activity	- Task activity, work environment and nature of work groups
Person	- Biographic details, employment history, health history and work pattern on the day of the accident
Employer	- Size and trading history, health and safety arrangements
Planning	- Employment history, nature of interaction with site and client,
Supervisor	specialist skills
& Designers	

5.2.1.5 Appraisal of focus group findings

Findings from the focus group analysis were used to generate areas of enquiry, and were either complementary or supplementary to the resource materials described above. An essential outcome of the focus group analysis was that participants were encouraged to recount experiences of 'failure' under any circumstances; indirectly an opportunity to explore beyond boundaries of what is accepted 'best practice'.

An additional strength of the focus group findings was that the strategy for discussion points and analysis had already been developed from an ergonomics model of accident causation, with input from construction resources available at the time of development. This meant that data were already available across the range of enquiry areas in ergonomics assessment. The findings also contained considerable detail and practical examples of incidences where failure might occur. The richness of this information was essential in developing the questions themselves, within the ergonomics framework. For example, from an extract from the Phase One results

"....specialist contractors are very expensive and at times are bought in to undertake tasks which could be undertaken as effectively and more time efficiently by the Principal Contractor operatives (had their skills been recognised)"

.....was developed into the question 'Were any of the Sub Contractor skills available among your own operatives?' (Proforma 4 -- section 4.6.8). Development of the data collection techniques is discussed further in 5.3.

5.2.2 Evaluation and integration of the resource range

Evaluation of the range of materials described above showed that there were merits within each that could be drawn upon for the methods development. The accident investigation methods contributed from industry had the most straightforward style for baseline data collection concerning the accident event, yet materials supplied by the project sponsor and from the focus database analysis provided the most thorough resource upon which to identify general search needs concerning the site and build. The ergonomics analysis, as well as providing the framework for technique development, also provided the most comprehensive methods for the collection of data concerning the task and work situation. The focus group findings were the only

resource to accommodate the main areas of concern among construction practitioners and these supplied the core information for the question contents.

	Industrial resources	Project sponsor materials	Focus group findings	Ergonomics analysis methods
Baseline data to describe site and build	*	**	*	-
Baseline data of the accident / incident	**	**	-	√
Task activity and active factor identification	**	**	**	**
Techniques of comprehensive assessment of interacting factors in the work	*	*	*	**

Key: ** = comprehensive information sources * = valuable contributory materials

Table 40. Value of resources used in development of accident study materials

An appraisal of the perceived merits of the different data collection methods is shown in Table 40. Whilst each aspect had unique strengths, use of these methods in combination ensured that a range of enquiry methods was adopted. Although there was a certain amount of overlap, it ensured that important issues (perhaps beyond the experience of the researchers or normal remit of any of those working in the resource areas) were not excluded.

5.3 Development of site based data collection techniques

Having established the relative merits of each of the chosen resources, the next stage of the work was to develop the techniques for use in data collection of accidents. This entailed reaffirmation of the enquiry needs (primarily from focus group findings, the largest data source), and determination of different data collection methods that would ensure thoroughness and permit triangulation (3.9.5.4).

5.3.1 Reaffirmation of the enquiry needs

The focus group findings had been reported upon according to the four original search terms – Project, concept, design and procurement; Work organisation and Management; Task factors and individual factors. Whilst the findings were a valuable resource, the information appeared scattered ('token events'), often repeated and it was not always easy to categorise into the original search terms.

There were broad-spectrum information requirements, but generation of data collection techniques directly from these results would have carried over duplication and added additional burden to an already demanding range of search criteria. The problem with the focus group search terms was that they had close allegiance with a project timeline, yet there were many recurring themes throughout (as noted in evaluation of the Suraji and Duff model, 3.11.4.1). Review of the focus group results with a more flexible approach permitted isolation and re-categorisation of these recurring themes and adoption of new search terms unique to the construction industry.

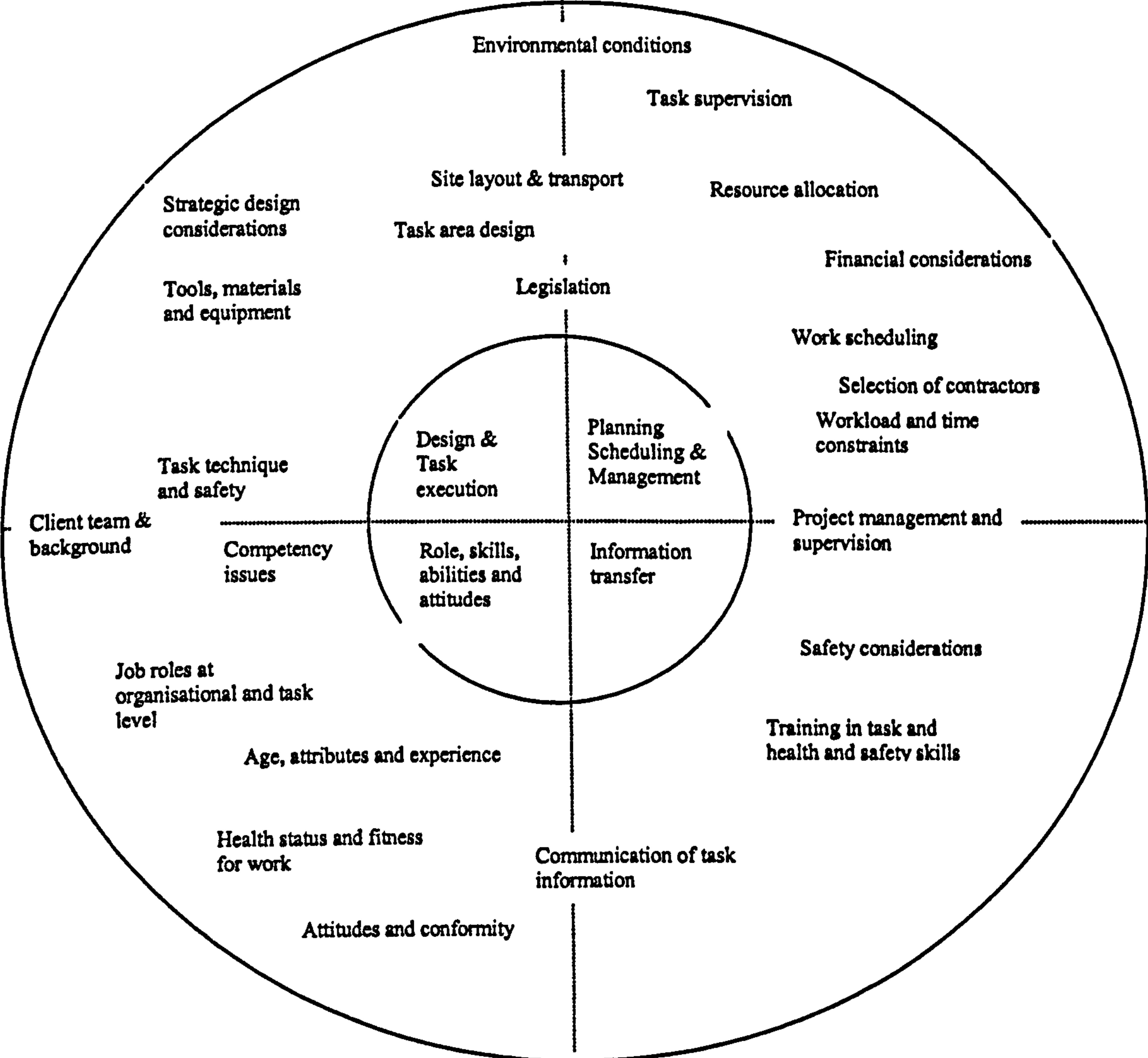


Figure 19. Developing search terms for the accident study methods

By undertaking a secondary analysis of the findings (in exclusion of the original anchor headings), four new themes were derived – Design and Task execution;

Planning, Scheduling and Management; Information transfer and Role, skills, abilities and attitudes. These new headings are repeated in the inner quadrant of Figure 19. The sub-headings from the focus group analysis findings are closely positioned to the revised search term in the outer quadrant. Overlapping or proximity to a border between the search terms indicates enquiry in common among the new search terms.

Although closely related to the original categories used in the focus group development and analysis, these new search terms gave a more succinct and representative overview of the findings in a construction specific context. Re-organisation generated some overlap or common enquiry, but this reinforced the research needs and avoided the fragmentation associated with the search terms used for the focus groups. More importantly, these had been derived from a multi-disciplinary source and it was thus anticipated that the search terms would likely be relevant in some manner to any individual in the industry. The next step was to determine which information to obtain from whom.

5.4 Generating materials to fulfil information needs

Much of the information requirements, not only about the accident but also about the complete background to the work and site itself, were aspects requiring specialist input from site personnel. Some of these information requirements were fixed data (giving a profile of the construction site and nature of the accident) yet subjective opinions relating to the accident and factors affecting performance were also required. An interview administered questionnaire format was chosen as the optimum method to collect these data; a series of different questionnaire “proformas” were developed and these were used as both data recording forms and as a framework for semi-structured interviews.

Whilst the value of the semi-structured interview was acknowledged, it was also felt that in isolation sole reliance on information provided by site personnel might ultimately reflect only the experiences or group norms among those included in discussion (3.9.5.4). To promote the use of multiple methods in data collection and to avoid bias, additional resources entailed supplementary data collection by the visiting researcher (5.4.3) and later review with construction and ergonomics specialists on the research team (8.1.2.1).

5.4.1 Recording accident details and descriptive site data

Information needs were varied, as it was important to acquire a summary of the accident, the work situation and the nature of the build type and phase of construction. These data were to be used for summarising the range of accidents and sites included in the research and were also necessary for accident sampling strategy purposes (5.6). Data requirements were developed from the resources provided by the project sponsor, and a construction specialist on the research team provided further guidance on content and terminology. It was the intention that any personnel with the relevant knowledge might complete the form (among site personnel or the research team) and that this would not be part of the interviews 'in confidence'. The accident notification form is reproduced as Proforma 1 in Appendix 6.

5.4.2 Gathering subjective opinions from site personnel

The main aim in the development of the study techniques for subjective data collection was to exploit the approach used in an ergonomics workplace assessment and use this as a framework upon which to integrate construction specific information needs. Objectives of this approach were that:

- That the methods should be readily transferable across a range of accident and site situations.

Different site management structures, build types and stages of build indicated that a broad spectrum of information would be obtained. This meant that the methods should be suitably open and adaptable to incorporate this

- The methods should be appropriate to the role and responsibilities of the interviewee

It was anticipated that job roles and responsibilities of interviewees would vary between accidents and sites.

Beyond the fixed data information needs (Proforma 1) the methods then needed to gain information about the accident and to acquire information from the perspective of the interviewee in relation to the revised search criteria

- The enquiries should be non-confrontational and encourage the interviewee to discuss issues openly and without inhibition.

It was anticipated that there might be some resistance to participation, given fears of blame and lack of any precedent of this type of research in the construction industry. The semi-structured interview content and style was developed so that issues readily identifiable and of greater familiarity to the interviewees were discussed first.

- The semi-structured interview should be conductable within a 30-minute period.

It was felt that this would provide sufficient time for a full discussion, but would not be unduly taxing or remove the interviewee from their work situation for too long a time period. Goodwill and continued good relations with industry were vital for success of the research.

Three further Proformas were developed as data collection tools for the accident studies and are also reproduced in full in Appendix 6. Each was used as a basis for the confidential semi-structured interviews. Proformas 2 and 4 were for data collection about the work situation and the main elements of enquiry are summarised below in Table 41.

	Proforma 2 Accident involved interviews	Proforma 4 Management / Supervision / Safety advisor Interviews
	<ul style="list-style-type: none"> • Comments on accident cause and remedial action → 	
	<ul style="list-style-type: none"> • Task details <ul style="list-style-type: none"> - Skill, training and experience issues - Interruptions &/or task overload - Known risks (such as chemical, electrical hazards) - Solitary or gang work 	<ul style="list-style-type: none"> - Opinions on task content and difficulties
Design and task related		<ul style="list-style-type: none"> • Managing design revisions <ul style="list-style-type: none"> - Management of redesign - Problem solving issues
	<ul style="list-style-type: none"> • PPE <ul style="list-style-type: none"> - Provision, care and training - Usability comments 	
	<ul style="list-style-type: none"> • Environment <ul style="list-style-type: none"> - Site conditions (such as light, noise, wet) - Compensatory measures 	
	<ul style="list-style-type: none"> • Workspace Interaction <ul style="list-style-type: none"> - Space and movement issues - Housekeeping - Comments on tools and equipment 	
	<ul style="list-style-type: none"> • Work scheduling <ul style="list-style-type: none"> - task work : rest issues 	<ul style="list-style-type: none"> - Managing delays and changes - Availability of skilled workers
Planning, Scheduling and management	<ul style="list-style-type: none"> • Work organisation <ul style="list-style-type: none"> - Interaction / overlap with other trades - Personnel availability - Presence of production targets - Consultation and communication issues 	<ul style="list-style-type: none"> - Assessing competency - Liaison and communication - Planning teamwork - Dealing with productivity pressures - Interacting with sub-contractors - Provision of training - Health and safety responsibilities
	<ul style="list-style-type: none"> • Work pace <ul style="list-style-type: none"> - Determinants of work rate 	<ul style="list-style-type: none"> - Motivation of employees - Managing time pressure
	<ul style="list-style-type: none"> • Target / payment issues <ul style="list-style-type: none"> - Method of payment - Use of incentives 	<ul style="list-style-type: none"> - Opinions on conflict to safe working
	<ul style="list-style-type: none"> • Supervision / Management <ul style="list-style-type: none"> - Opinion on adequacy of supervision - Communication issues 	<ul style="list-style-type: none"> - Retrospective opinion relating to accident
	Welfare - - Break and facility comments	
Information transfer	<ul style="list-style-type: none"> • Procedures / method statements / risk assessments / training <ul style="list-style-type: none"> - Knowledge of documentation & content - Perception and use of these 	<ul style="list-style-type: none"> - Preparation of documents - Consultation and communication issues - Dissemination of information - Review and evaluation of materials
		<ul style="list-style-type: none"> • Training provision <ul style="list-style-type: none"> - Nature of induction, - Provision of task training & tool box talks

Table 41. Enquiry areas for site based data collection of the work situation

- Proforma 2 - collected data from those undertaking the work activity when the accident occurred. These 'accident involved' interviewees included any injured party or co-worker.
- Proforma 4 – collected data from those with a supervisory, managerial or safety role. Whilst the questions are different from those in Proforma 2, they address the same search themes, but with questions relevant to their job roles.

A final proforma was also used for data collection, obtaining information concerning the final search term – Role, skills, abilities and attitudes. This, Proforma 3, was used universally for all interviewees, and obtained information concerning accommodation and travel arrangements; working hours, holiday and sick pay arrangements, accident history (accident victim only), employment and training history, health related issues (accident victim only), and individual perceptions of their work. Interviewees were asked to supplement any of the issues raised in the semi-structured interview with additional comment. They were also asked to complete a 5-point rating scale devised to measure work stress, social support and job satisfaction (Symonds et al. 1996). The scale end points were marked – 1 – completely disagree and 5 – completely agree.

Whilst a broad span of information was requested within Proforma 3, this was one area where it was felt inappropriate to collect the full set of information raised as concern issues by focus group participants. For example, items excluded were alcohol effects and risk taking behaviour; these items were considered sensitive issues and inappropriate for an already dense information search in the time available.

5.4.3 Timing an accident study

Previous research had indicated that immediacy in response for accident investigation was desirable (3.9.4.2), yet the possibility of such a response became increasingly unlikely with the dearth in notifications (5.7.1). Nonetheless, much of the information requirements of the semi-structured interviews were not time dependant.

Additionally, all accidents were already subject to their own company accident investigation and it was possible to incorporate this record into the data collection process. As a pilot study, accident study 001 was undertaken 8 weeks after the accident event (5.4.5), yet the clarity and integrity of information indicated that flexibility in the timing of an accident study would be acceptable. Thus all accident studies were conducted within eight weeks from the event.

5.4.4 Data collection by the visiting researcher

Supplementary data collection included (where possible or appropriate) ergonomics analysis of tools, equipment or machinery, the work and/or accident event area and analysis of any supporting documentation (such as risk assessment or method

statement for the accident task). Data were collected by the visiting researcher, who had longstanding experience of interviewing (3.9.4.2), knowledge of occupational health and safety and of ergonomics assessment during fieldwork.

5.4.5 Pilot study and iterative review of techniques

The first accident study (accident 001) was undertaken as a pilot study. This was successful and generated much information that was thought to be useful for analysis. However, it was anticipated that an iterative review of study methods would be required at the early stages of data collection as the researchers became more familiar with the process in general; whilst it was felt that the methods were comprehensive, there were concerns that unexpected issues might arise during site visits and that the study methods should be adapted to collect this information. The questionnaires were reviewed after accidents 004 (April 2001), 012 (June 2001) and 036 (September 2001). It had been the intention to continue iterative development, but as the data collection schedule had to be adapted (5.7) this became unfeasible.

	April 2001	June 2001	September 2001
Proforma 1	Addition of questions to collect history of accident victims direct employer or appointer & place in SC chain	-	-
Proforma 2	Work organisation enquiry developed to enquire about consultation and access to the Safety Committee	Additional enquiry about post accident remedial action, PPE and use of procedures	Additional enquiry about the interviewee's job description, tool use and individual purchasing criteria
Proforma 3	Additional questions to enhance enquiry about employment and training history	Additional enquiry about holiday and sickness absence	Additional enquiry about job security and Trade Union membership
Proforma 4	Additional questions relating to management of team and contractor workers. Inclusion of Safety Advisor within interview process	-	Additional enquiry about ensuring health and employment status of new employees and of purchasing criteria in obtaining PPE

Table 42. Nature of revisions to study data collection techniques

None of the original enquiries were deleted, merely added to. Some information requests were moved between different questionnaires (if it was felt that the enquiry could be better addressed at a more appropriate stage of the semi-structured interview) and the grammar was revised to facilitate comprehension. In exception to this, where information requests were revised, this is recorded in Table 42.

5.5 Ethical issues and their impact upon data collection methods

Although the accident studies were not scheduled to commence until August 2000 (and in practice started five months later), an early and 'preliminary' application was made to the Loughborough University Ethical Advisory Committee in November 1999. The researchers foresaw a number of unusual and significant possible problems and an early application and meeting with representatives of the Ethical Advisory Committee, in January 2000, provided an opportunity to explore these (Appendix 10). The potential problems hinged upon issues surrounding confidentiality and the recognition that there may be circumstances where the study method could not be manipulated to guarantee this. This would also have implications elsewhere and the main areas of concern are described below.

- Gaining participant consent and their right to withdraw from the study
- Compiling and storing data anonymously
- Avoiding litigious / potential subpoena cases
- Determining researcher action in discovering ongoing risk circumstances and participant refusal to notify a responsible person

Supplementary advice was also sought from the project sponsor and the Steering Group. Consent forms identifying our separateness from HSE inspector work, addressing our commitment to confidentiality (but not over-riding our 'legal obligations') were developed and a data storage system was devised to separate signed and anonymous data. It was the intention that interviewees should be unidentifiable in the evaluation and the final report. All materials were recorded by month, year and day of the week only, to avoid identification by date.

In practice, the methods were not universally acceptable to participants and those advising them. Fundamental issues (and unanticipated by the research team) were the provision of a signature on the consent form and the potential of breached confidentiality if ongoing (and unreported) risk circumstances were identified. 'Signaturism' carries a heavy weighting of responsibility and is discussed in 7.5.3.5. Safety Advisors in industry pointed out that employees do not have an option on whether to report risk circumstances (Great Britain Parliament 1974, S7(b)) and detail

indicating circumstances where confidentiality might need to be breached was removed. Following further review with the Ethical Advisory Committee, a simpler style and use of the consent form was developed and separate data storage was not required (Appendix 10). Prior to interview, the participant provided verbal affirmation of understanding of the nature of the study and the researcher signed the ‘consent’. This was successfully instigated into practice from Accident 008 onwards.

5.6 Development of a sampling strategy

A sampling strategy was devised to ensure that accidents included would link to representation of existing construction accident and build type data, but that this should not restrict the desired exploratory approach. Whilst a range of different variables, describing the build details and incident details were collected (Proforma One -Appendix 6), it was decided that most of these data should describe rather than dictate the accident study sample. In spite of this, two aspects were outstanding and these were chosen as the foundation of the sampling strategy.

5.6.1 Representation of UK construction industry types

Firstly, and with advice from a construction specialist on the research team, it was felt that the accident sites should be broadly representative of the profile of UK construction. Four categories of construction build types were defined and the recommended sampling among each are given in Table 43. N=100 represents that spread of the entire sample and within that, N=40, are the relative proportions reported in this thesis.

Target distribution	Construction types			
	Engineering Construction	Rail & Civil Engineering	Major Building	Residential
N=100	7	14	43	36
N=40	3	6	17	14
Percent	7%	14%	43%	36%
Ratio	1	2	6	5

Table 43. Construction profile sampling strategy

5.6.2 Representation of UK construction accident types

The second aspect of the sampling strategy was that the studies should cover a broad range of accidents and incidents – especially those types of events indicated in HSE statistics of fatalities, major injuries and absences of over three days (NB: this

preparatory period pre-dated the combined RIDDOR / SWI statistics now instigated by the HSE (2.2.2)). Data available at the time of development (Health and Safety Executive 2000) reported summary RIDDOR statistics of the three accident consequences for the four-year period 1997/97 – 1999/00 (provisional). Figures were summed for each category and causal factor within the four-year period, and the percentage representation within each is repeated in Table 44.

	RIDDOR fatalities 4year %	RIDDOR major injuries 4y %	RIDDOR over 3 day injuries 4y%
Falls from a height (all levels)	55	38	13.6
Injured while handling, lifting or carrying	0.3	8	34
Slips, trips and falls on same level	0	19	17
Struck by moving (+ flying / falling) object	15	19	19
Struck by moving vehicle	9	3	2
Contact with electricity or electrical discharge	8	2	1
Trapped by something collapsing or overturning	5	1	0.5
Strike against something fixed or stationary	0.6	3	5
Contact with/by moving machinery	2.5	3	3
Other accident events types	4.4	4	4.9

(Health and Safety Executive 2000)

Table 44. Percentage representation of reportable injuries to construction industry workers for the time period 1996/7 – 1999/00 (provisional)

The first four rows were an important resource for the sampling strategy as the causal factors accounted for 19% - 55% of incidences for each of the injury types (shaded area denotes greatest incidence by injury type). The pattern of distribution among these data were used in ensuring a representative range of accidents for the research.

5.7 Constraints upon site based data collection

5.7.1 Difficulties with accident notifications

The early phase of the data collection period was encumbered by problems with the accident notification process. There appeared to be a habitual disregard in industry of accidents with non-calamitous consequences, resulting in difficulties persuading them to inform the research team of accidents with minimal outcome. There was also a change of scope (less major accidents and more minor / near-miss accidents) just before data collection started and, despite revised publicity, this may have contributed to the confusion.

5.7.2 Lack of balance in sector participation

The research was hampered by reluctance to participate by those in both the Engineering Construction and Residential sectors. There were some offers of assistance from each sector at the project outset, yet these either failed to materialise or potential participants received legal advice guiding them to avoid participation.

5.7.3 Barriers to data collection

Upon receipt of accident information (often from participating company's monthly statistics (5.8.1) many many attempts were made to obtain access for accident studies. The greatest barrier to participation was that accident involved personnel or their managers had moved on (to other sites) since notification. At times it was not possible to access sites if they were particularly busy (especially nearing the end of a contract). It was only rarely that studies were not pursued, perhaps because participants were unwilling or because an unescorted interview was not permitted. A few interviews were conducted under time pressure and it was not possible to complete the full semi-structured interview. Time pressure was for the most part due to their work commitments, although there were a few instances where the visit was obstructed (beyond the time required to collect 'active' factor data); in these instances little value was perceived, by the site facilitator, in later review of the work situation (the latent conditions). These cases were few, but the research was seen by some as just another "hare-brained student project"; this affected enthusiasm / commitment to the research and perceived credibility of the methods.

5.8 The accident study procedure

5.8.1 Notification of accidents to the research team

Offers of assistance with the accident study data collections were confirmed as part of the process of developing industrial liaison. Two strategies were devised in order to alert the researchers to the possibility of an accident occurrence. The first, and preferred, strategy was for persons (designated by the liasing company) to phone the researchers with accident details as soon as possible after the accident event. This was not successful and as a contingency plan a second strategy was employed, whereby contributing companies provided their accident summary records, thus permitting the researchers to select accidents appropriate to their needs. This method introduced a

greater time element into the process, but those selected still fell within the agreed sampling strategy.

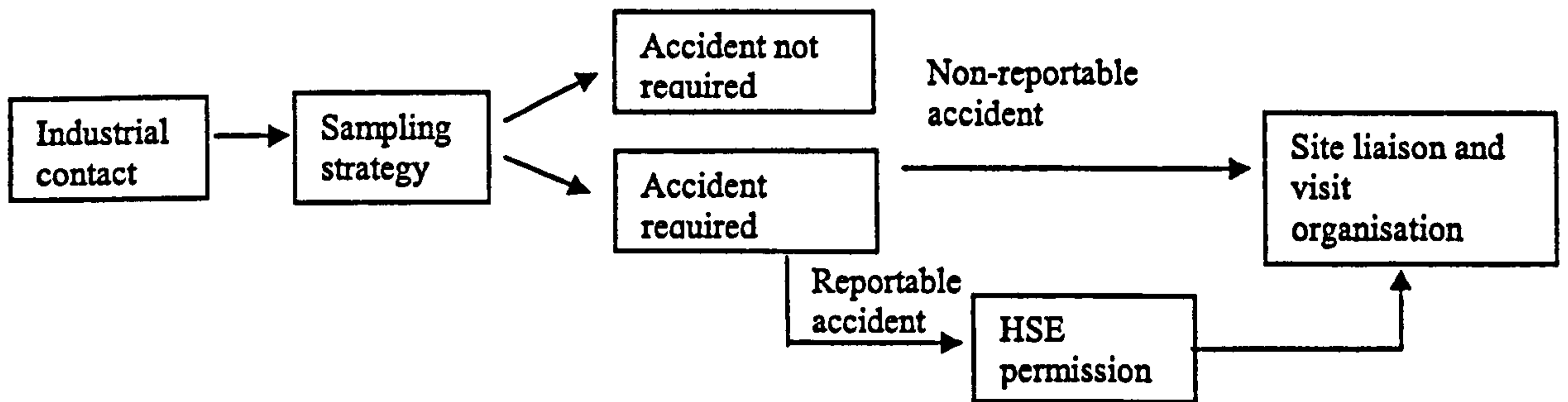


Figure 20. Accident selection process

Figure 20 shows the process adopted for selecting appropriate accidents for the research. When any reportable accident was selected, a representative of the HSE project management team reviewed the possibility of HSE Inspector action, before giving permission to proceed with the process of site liaison and visit organisation.

5.8.2 Site liaison and visit organisation

Each of the contributing companies provided a list of contacts (most commonly the Area Safety Advisors), with whom a first stage liaison was made to obtain the full details of the accident (for sampling strategy purposes) and site contact information. Arrangements for the site visit were made either via this contact person or directly from the researcher to the site contact. Discussion with the site contact included a description of the research, what the visit would entail and assurance that all findings would be reported anonymously. In turn, the discussion also ensured that the necessary research criteria existed; namely:

- That the HSE were not investigating the accident
- That the accident had occurred within the preceding two months
- That the accident victim and supervisor / manager were still on site and willing to participate in the research

It was also important to reinforce that the work was independent from HSE accident investigations and that all interviews would be undertaken in confidence. Where possible a briefing sheet was sent in advance of the visit (for circulation to those who

would be involved) describing the research and reinforcing the voluntary and confidential nature of information provided at interview.

5.8.3 Site based data collection

The process for undertaking an accident study during a site visit is described in Table 45 below. Despite revision of the three proformas, the additional search items added to rather than replaced information relating to the original data collection themes and results from all studies were included in the analysis.

On site assessment method			Additional researcher activities
1. Upon arrival review accident details with site contact person	Obtain / confirm baseline data including: <ul style="list-style-type: none"> • accident event information • contact details of personnel involved 	Proforma 1	Review and record accident details from the company records
2. Then review accident details with accident involved personnel	Obtain consent and interview relevant personnel, covering aspects such as:- <ul style="list-style-type: none"> • accident event information • work profile aspects • personal details 	Proforma 3 Proforma 2	Undertake task based ergonomics assessment (observation, weight / linear measurements as appropriate etc.)
3. Finally review accident details with supervisor / manager / safety advisor	Obtain consent and interview relevant personnel, covering aspects such as:- <ul style="list-style-type: none"> • accident event information • work profile aspects • personal details 	Proforma 3 Proforma 4	Evaluate risk assessment and method statements (removing copies off-site if possible)

Table 45. Practicalities of an accident study

5.9 Analysis and representation

It was difficult to identify the methods to be used for analysis – the accident range included near-miss events, minor and major accidents, and no one style appeared appropriate. Analytic trees (3.9.3.1), used for major accidents and appropriate for single events and where circumstances were fixed and controlled, were considered inappropriate given the volume of data and perpetual flux apparent within the industry. An alternative tabular style approach (3.9.3.3) has previously been used in the medical setting, where work situations are similarly dynamic and this was considered a more appropriate style for data representation.

With the much extended enquiry range (both active and latent conditions included) it was thought that findings would be greatly enriched and that the epidemiological style analysis traditionally used for minor accidents (3.9.4) may be appropriate.

Nevertheless, it was appreciated too that any such style of analysis only reflects the information from which it is derived (3.7.1). In order to generate categories that define the outcomes of both the active and latent conditions, it was thus necessary first to undertake qualitative analysis of the data.

Triangulation using multiple data sources (3.9.5.4) was a data collection objective at the outset and literature search surrounding these issues also introduced the concepts of qualitative research and naturalistic methods (Denzin and Lincoln 1998, Erlandson et al. 1993). Lincoln and Guba 1985, cited by Erlandson et al. 1993) reported that safeguards to ensure objectivity in research in effect serve as a barrier to prevent the researcher from exploring the most relevant aspects of the data. Qualitative research draws in information from many different sources in their natural settings (interview, case study, observation etc.) and according to the context of the enquiry. There are no set methods for data collection or analysis; the essence is that they should generate important insights and knowledge (Nelson et al. 1992). These principals of qualitative analysis were adopted as suitable methods for exploration of the findings.

Nevertheless, whilst this style of analysis precluded apparently 'objective' analysis through representation by volume or proportion of 'hits' relative to the rest of the data, it meant that analysis by 'insight and knowledge' lacked any structure. Many of the findings reiterated what were already longstanding problems in the construction sector (2.5.1 and 3.6.5.2). That the problems persist indicates some form of failure in the way that problems were previously identified or addressed. Traditionally, these issues would be addressed through safety management systems (SMS) and analysis using this approach was considered.

Safety management systems (SMS) were thought inadequate in their address to the range of latent factors in construction accident model evaluation (3.11.5.1), but as an isolated example this was not necessarily representative. Whittington et al. (1992) identified many improvements that could be made in construction safety management (3.6.5.2), yet these were grouped according to measures that could be taken within

companies, by clients and by extra-organisational sources. In summarising the construction accident models (Table 31), token events (although positive features on this occasion) categorised by project phase were seen as weaknesses, as they did not identify 'type' events (and thus offered no structure upon which to categorise findings).

A more promising approach was that of Hale et al. (1997) who in an extensive review of SMS and their audits, reported "arbitrary lists of topics clustered under convenient headings which vary from one instrument to another" (p. 122). Redressing this, they created a SMS framework and identified three levels to define decision-making and management activity within each phase of the life cycle:

- System structure– Principals and functions of SMS
 - adaptation to fit the culture of the organisation, activated when normal functioning fails
- Planning, organising and procedures – devising and formalising abstract principals into actions to be taken at execution
 - generation of safety manuals, setting out responsibilities, defining procedures, defining reporting lines, problem recognition [design reviews & accident statistics], solution choices [cost-benefit analyses], monitoring [auditing], contingency planning [first-aid]
- Execution – actions of those involved directly
 - recognition and control of hazards, hierarchy of control measures, correcting deviations from procedures

Hale et al. (1997) reported that these were loosely based on the 'skills, rules, knowledge' model of decision making (3.6.2.4) and, in the same measure, were proposed as 'abstractions' and not directly linked with organisational hierarchy. Nevertheless, although this approach offered a 'framework', the primary motive appeared to focus on hazard control and it did not appear to embrace the desired range of latent conditions (the importance of this shortcoming is discussed further in 9.2.1.18). As a result the SMS framework was not adopted for results categorisation.

An alternative measure was devised, cross-referencing the pre-focus group categories against the categories generated from their analysis. This provided the framework that was needed for categorisation of the results and is discussed further in 7.2.

In summary, therefore, analysis has created two styles of results:

1. A profile of the research sample, cross referencing data to the sampling strategy criteria and enquiry areas for site based data collection of the work situation (Table 41)
2. Representation and exploration of the results using qualitative methods of analysis and interpretation (7.1)

5.10 Summary of the methodological development

The methodological development incorporated the preparatory processes, from generation of the data collection techniques through to determining methods to collect, analyse and represent findings.

The preparatory process commenced by appraisal of a range of resources that might be used in building the data collection techniques. Ergonomics assessment methods provided the framework upon which information from construction specific resources (from the research partners, the project sponsor, through evaluation of construction industry accident investigation methods and from focus group findings) was integrated. These information needs were later distributed between a series of proformas; these were developed as data collection tools for use during site based semi-structured interview with accident involved personnel and those with a supervisory, managerial or safety role.

A sampling strategy was developed, so that accidents included in the research would be representative of the range of construction industry build types and of typical accident precursors. The accident study procedure addressed the way that accidents were notified to the research team, how site liaison was managed and the data

collection process during a site visit. There were also a number of preconditions, which were either fixed from the project outset, or were determined on the basis of the pilot study. These included exclusion of accidents subject to HSE investigation and the inclusion only of accidents that had occurred within the preceding two months. The methodological development continued during the early phases of data collection. This included supplementing the data collection range defined in the proformas and the generation of alternative methods to deal with difficulties that were being experienced with accident notifications and participation.

The final part of the methodological process entailed determining methods for data analysis and representation. A range of possible methods had been identified during literature review, but few offered comparable circumstances to those typified in the research. Alternative methods were devised and these are presented in the following two chapters.

A critique of the methodology is presented in the final chapter of the thesis (9.1).

6 PHASE TWO - PROFILE OF THE RESEARCH SAMPLE

Forty accident studies were undertaken on 24 different construction sites. The findings are reported according to the sampling strategy criteria (5.6) and also include supplementary details relating to the sites, build and accident conditions (Appendix 6).

6.1 Data representation

6.1.1 Description of industry types included in the sample

A comparison of the findings in relation to the sampling strategy is shown in Table 46. Whilst there is close representation of the suggested distribution, the research was hampered by two factors, namely reluctance to participate by those in both the Engineering Construction and Residential sectors (5.7.2).

	Engineering Construction (EC)		Rail and Civil Engineering		Major Building		Residential	
	total	ratio	total	ratio	total	ratio	total	ratio
Target	3	1	6	2	17	6	14	11
Result	1	-	6	2	22	7	11	4

Table 46. Distribution of the accidents studied

6.1.2 Description of the sample build and organisational data

Of those who did participate there was extensive variation in the nature of build and organisational details of sites, ranging from short contract work to major building projects being carried out over a number of years. All but 4 of the sites were brownfield sites.

Sites varied considerably in size, accommodating between 3-650 personnel (mean 168 people) and with build schedules of variable duration between 1 – 625 weeks (mean 231 weeks). Twenty-eight were running to time, one was ahead, yet 8 were behind schedule. Five of the sites were undertaking all phases of their work simultaneously, whereas 3 were in the ‘start’ phase (see Proforma 1, Appendix 6), 10 in the ‘middle’ phase, 9 between ‘middle’ and ‘end’ phases, 6 in the ‘end’ phase and 2 in the ‘after’ phase .

Five different principal contractors were represented, of which two each accommodated at least 15 of the accidents studied. The contract types were predominately 'Construction Management' (n=17), 'Design and Build' (n=7) and JCT² (n=7), with the remainder comprising a small number of unclassified or bespoke contracts. It was not possible to gain adequate detail relating to project value and company employee numbers, and this information is not reported.

6.1.2.1 Description of accident types included in the sample

Eleven of the 40 accidents were reportable under RIDDOR. Of these three were dangerous occurrences, seven resulted in absences of over 3 days and one was a major accident. The sample accidents are reported according to the HSE categorisation in Table 47 (revised to combine slips, trips and all falls data together)³. By excluding a distinction between level change in these data, some similarities in distribution exist to the percentage representation of national data (Table 44) – namely the predominance of accidents caused by slips, trips and falls (combining all level data), injury while handling, lifting or carrying and being struck by a moving (including a flying or falling) object. Given the problems experienced in gaining access to accidents for inclusion in the research (5.7) such similarities in distribution are considered fortuitous.

	Accidents reported	Total
Slips, trips and falls (all levels)	017, 023, 036, 037, 051, 053, 062, 064	8
Injured while handling, lifting or carrying	(005,007, 024)*, 033, 034, 038, 039, 050	8
Struck by moving (+ flying / falling) object	(005, 007, 024), 001, 004, 009, 019, 035, 061, 063	7
Strike against something fixed or stationary	006, 018, 021, 022, 025	5
Dangerous occurrences	003, 010, 011, 020	4
Contact with/by moving machinery	002, 012, 013	3
Trapped by something collapsing or overturning	060, 065	2
Other accident events types	008, 040	2
Contact with electricity or electrical discharge	052	1

* Difficult to ascertain correct category

Table 47. Distribution of accident types

² JCT = Joint Contracts Tribunal; a representative body of professional institutions and other industry bodies, charged with developing appropriate contracts for various types of construction procurement Duff, A. R. (2001).

³ The numbers refer to each accident studied. These are summarised in Table 52

6.1.2.2 Description of baseline incident conditions

A range of data was also obtained through Proforma 1 to summarise the conditions at the time of the accidents, including temporal representation of the data, summary of accident tasks or activities, the use of any tooling or equipment, the environmental conditions reported and level at which the accident occurred.

The temporal details, including month, weekday and accident time are summarised in Table 48. Data were obtained during all seasons and all study accidents had occurred only between the hours of 08.00 and 17.00.

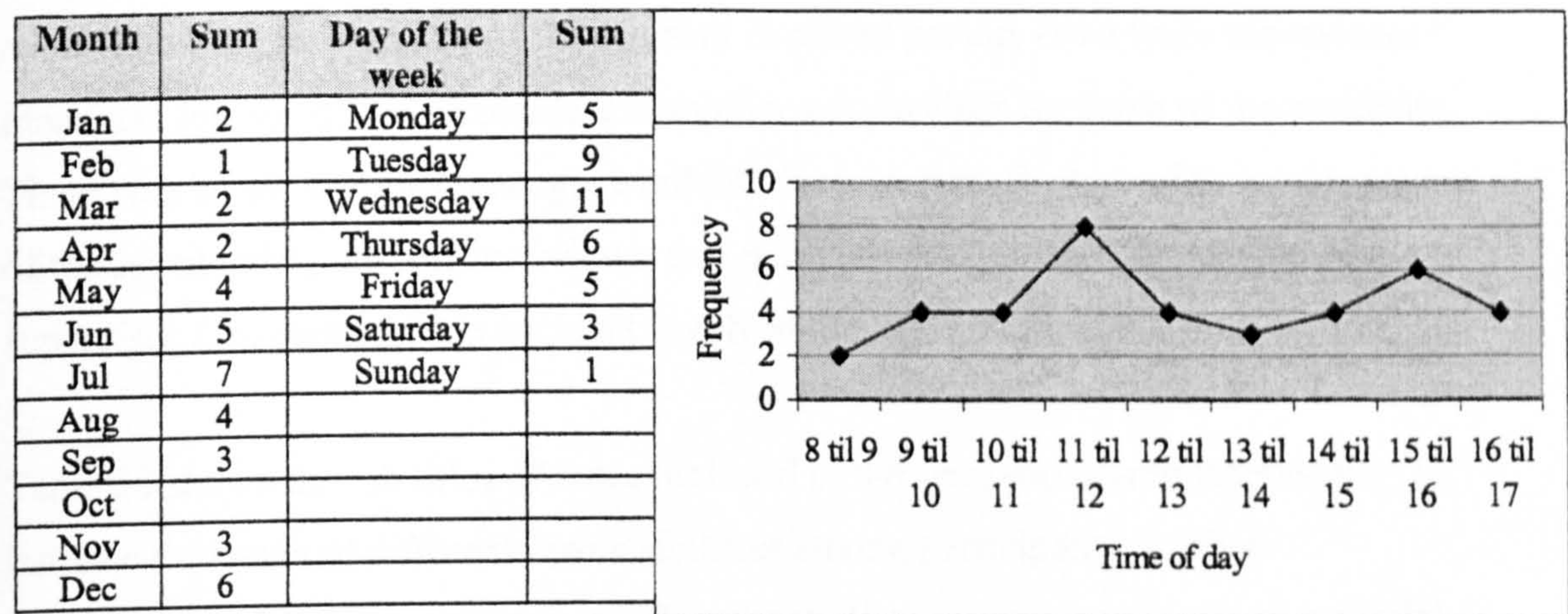


Table 48. Temporal details of accident sample

Additional summary details compare the incidences of tools, equipment and materials/structure that were involved in the accidents, with the nature of the task or activity being undertaken. These findings are reproduced in Table 49.

	Tools	Plant / equipment	Materials	Site / structure
Setting-up			034	
Task action	002, 003, 007, 013, 039, 065	008, 011, 038, 060	005, 009, 010, 033, 035, 040, 063	020, 024, 052, 061
Clear-up / maintenance		004, 012, 021		
Movement / transit	050	006, 017, 019, 022, 036, 037, 051, 062	001, 025	018, 023, 053, 064

Table 49. Description of task and activities within the accident sample

Fifteen of the accidents occurred indoors and of the remainder that occurred outdoors, adverse weather conditions (i.e. damp, wet or windy) were reported in seven of the accidents. Twenty seven of the accidents occurred at basement or ground level, with

the remainder occurring at higher levels – of these 3 accidents involved some form of level change.

6.2 Profile of participants included in the research

Forty semi-structured interviews were undertaken with accident involved witnesses (mean age 37, range 18-62, SD = 11.88). These included 38 who were directly involved in the accidents and two co-worker interviews; one accident was a dangerous occurrence with no immediate witness. A further forty-one semi-structured interviews were undertaken with supervisors, managers or safety personnel (mean age 43, range 23 – 62, SD = 10.56). Of these, 28 interviewees were directly responsible for supervision or management of the accident involved person - two were supervisors / managers for two of the accidents and another a supervisor for three of the accidents. There was no supervisor / manager available for interview for two of the accidents and of the seven safety advisor interviews, two were provided instead of the immediate supervisor / manager for the accident involved person.

Table 50 shows the job titles of those included in the semi-structured interviews. To indicate the range of different responsibilities among participants, further categorisation has been undertaken. This shows distinction according to managerial / supervisory responsibilities, either generally across site, or according to a specific section, location or task type. Operatives are distinguished according to whether they are general labourers or have undertaken a formal trade training.

Whilst accident involved interviewees (underlined) were mainly represented by operative grades, a small number of those in supervisory manager roles were also accident involved.

The client or principal contractor employee was 'actively' involved in 7 of the accidents, whereas sub-contractor employees were implicated in 25 and sub-sub contractors and agency staff were implicated in 7 accidents. Details concerning the nature of employment were often difficult to ascertain (7.6) and only cautious distinction between sub-contractor chains should be made.

(Total n=81)	Manager / Supervisor grades			Operative grades	
	Safety (n=10)	General site-based management (n=11)	Section managers / supervisors (n=26)	Trade (n=16)	Labour (n=18)
Job titles	Safety Advisor (x 3) Safety Manager Site Safety Manager Safety Officer Project HS&E Co-ordinator H&S Manager H&S Supervisor Group H&S Manager	General Manager Project Director Construction Manager Facilities Engineer Contracts Manager Project Manager (2) Site Manager Senior Supervisory Manager Assistant Surveyor Maintenance Inspector	Supervisor (3) Sole Trader Section Manager / General Foreman General Foreman Site Manager (4) Site Foreman Electrical Supervisor Senior Site Representative / Foreman Project co-ordinator Electrical Supervisor Mechanical Supervisor Site Supervisor Foreman Carpenter Scaffold Site Manager Foreman (2) Miner Groundwork Foreman Charge Hand Pipe Fitter Duct Worker Foreman Approved Electrician	Carpenter / Joiner Maintenance Fitter Carpenter Fitter / Glazer Floor Fitter Formwork Carpenter Driver Carpenter Scaffolder Bricklayer Plumber Pipe Fitter / Welder Approved Electrician Pipe Fitter Heating Engineer Bricklayer	Steel Fixer Decommissioning operative Panel Fixer Concrete Labourer Labourer Chain Boy Trainee Scaffolder Striking Labourer Ceiling Fixer Duct Work Engineer Fitters Mate Ground worker Leading Driver Labourer Labourer Ground worker Fitter Hod Carrier
Mean age (range)	43 (n=10) (range = 24 - 60)	41 (n=10) (range = 23 - 56)	43 (n=26) (range = 23 - 62) (SD = 10)	41 (n=16) (range = 26 - 60) (SD = 11)	34 (n=17) (range = 18 - 62) (SD = 13)
Duration on site (weeks)	75 (n=7) (range = 18-144) (SD = 53)	610 (n=7) (range = 32 - 3744) (SD = 1385)	85 (n=25) (range = 5-1560) (SD = 308)	37 (n=14) (range = 3-138) (SD = 41)	109 (n=17) (range = 7 - 156) (SD = 374)
Duration in role (months)	62 (n=7) (range = 11-264) (SD = 90)	30 (n=3) (range = 7-48) (SD = 21)	126 (n=2) (range =) (SD = 12-240)	169 (n=8) (range = 15-480) (SD = 165)	124 (n=11) (range = 9-480) (SD = 175)
Duration in industry (months)	257 (n=10) (range = 11-480) (SD = 177)	273 (n=11) (range = 384-72) (SD = 105)	303 (n=26) (range = 72-552) (SD = 123)	230 (n=16) (range = 66-492) (SD = 146)	139 (n=16) (range = 9-456) (SD = 151)
Duration with employer (months)	141 (n=10) (range = 11-420) (SD = 151)	73 (n=8) (range = 7-144) (SD = 66)	109 (n=25) (range = 2-240) (SD = 89)	24 (n=16) (range = 2.5-72) (SD = 18)	40 (n=17) (range = 2-456) (SD = 108)

(underline = accident involved interviewee)

Table 50. Job roles of participants included in the site-based interviews

6.3 Profile of accidents included in the research

Data summarising the main findings of the accidents are reproduced in Table 52; more comprehensive accident details are reported in Appendix 9 of the thesis. The information reproduced in the tables incorporates the main aspects reported by interviewees, or observations that were thought relevant to the accident by the researcher. The forty accident studies were assigned a number in sequence, but their assigned numbers are not chronological here. Other researchers also undertook accident studies during the data collection period, but these are not included in this thesis.

Data are reported according to the categorisation criteria developed following focus group analyses (5.3.1). Table 51 shows the tabular style used to present the information.

Depending on the accident circumstances and nature of the data obtained, the table has been amended for each accident, according to the relevance of information to report.

RESEARCH CATEGORIES	Accident number	
	ACTIVE FAILURES	
	SITE factors	
Design & task execution	<u>Task details</u>	
	<u>PPE</u>	
	<u>Environment</u>	
Planning Scheduling & Management	<u>Work scheduling</u>	
	<u>Work organisation</u>	
	<u>Work pace</u>	
	<u>Target / payment</u>	
	<u>Supervision</u>	
Information transfer	<u>Method statement and risk assessment</u>	
	<u>Skills and training</u>	
Individual factors	<u>Personal details</u>	
	Organisational factors	

Table 51. Criteria used to categorise data collected during accident studies

Three divisions are used to categorise the accident data:

- **Active failures** describe errors that occurred at or induced the accident event
- **Site factors** describe aspects of the work situation considered relevant to the accident.

These are aspects most analogous with proximal factors (Suraji et al. 2001), Site management issues and some headquarter issues (Whittington et al. 1992) or job factors (Health and Safety Executive 1997b)

- **Organisational factors** describe developmental, strategic or cultural aspects considered insidious to the accident event. These aspects are most analogous with distal factors (Suraji et al. 2001), some headquarter issues (Whittington et al. 1992) and organisational factors (Health and Safety Executive 1997b).

For succinctness a number of abbreviations are commonly used – these are described in the key below:

KEY

AI	Accident involved person
CAT	Cable avoidance tool
H&S	Health and safety
IP	Injured person
MH	Manual handling
MHOR	Manual Handling Operations Regulations
MS	Method Statement
PC	Principal contractor
PPE	Personal protective equipment
RA	Risk assessment
SC	Sub-contractor
TBT	Toolbox talk

Accident 001	A steel fixer operative was walking across top mats carrying a length of tying wire with the end dragging behind. The end snagged and when he pulled to release it, it sprang back and hit him in the eye		
Active failures	Slip of action		
SITE factors			
<u>Task details</u>	Poor material (quality / presentation for use/ weight/ storage / resolution of known problems)		Poor walking surface
<u>Environment</u>	Bad weather at time of accident. No shelter		
<u>PPE</u>	IP stated that gloves were incompatible with work task – not worn. [Since accident supplying own safety glasses]		
<u>Work scheduling</u>	IP worked 54 hours per week plus overtime		
<u>Work pace</u>	Perceptions of time pressure by all interviewees. IP reported pressure to do as much as possible		
<u>Method statement and risk assessment</u>	Accident activity excluded from MS / RA		
<u>Skills and training</u>	High dependence upon core skills (refresher and management supervisory skills apparently not happening)		
<u>Personal details</u>	Some dissatisfaction among mid-level management grades re. communication and work fulfilment		
Organisational factors	Indication of PC dissatisfaction with sub-contractors - Reports of slower reaction time with loss of direct labour		

Accident 002	A joiner was using a mitre saw to cut diagonal braces for cavity closure window frames. He raised the control handle of the saw and went to turn over the wood piece after making a cut. Unnoticed, the mitre saw guard had jammed with a wood fragment and the operative lacerated his hand.		
Active failures	Slip of action		
SITE factors			
<u>Task details</u>	Task technique was not reviewed or considered as an influencing factor in accident	IP perceived task as un-stimulating	
	Indication of poor manufacturer's instruction for bracing of window frames	Possible saw design & safety feature issues	
<u>Environment</u>	Preference for natural light for mitre saw work limited the available work 'window' period during winter months		
<u>PPE</u>	IP wore gloves because timber was wet	Unfamiliar with mitre saw and concurrent use of protective gloves	
<u>Work scheduling</u>	12hr work days for all interviewees		
<u>Work organisation</u>	Sudden additional workload - not known whether its management of had been agreed between Supervisor / Managers / joiners		
<u>Work pace</u>	Indication of time pressure - unexpected supply requests from other operatives and to stockpile in readiness for imminent loss of co-worker		
<u>Supervision</u>	Experienced personnel informally supervise own work	SC Manager workload appeared quite stressful	
<u>Method statement and risk assessment</u>	Inadequate address to task and risk in MS/RA		
<u>Skills and training</u>	Respect for previous skills / experience over-road supervision / training / TBTs / formal H&S mgmt measures		
Organisational factors	Poor / absent purchasing policy for the mitre saw		

Accident 003	An angle grinder was being used in a segregated radiological decontamination area and the filter of the extractor fan unit caught fire. The angle grinder and fire watch operatives were unaware of the fire development. In response to previous fires a fan filter screen was being used.
Active failures	None. Knowledge based mistake in design of work equipment and determination of task technique
SITE factors	
<u>Task details</u>	Operatives were unaware of fire – smoke was being extracted from the work area Other operators noted smoke before the fire alarm sounded – issues relating to smoke detector position Report of inability to obtain fan filter with adequate efficiency and made of non-flammable materials Fan filter screen had been created in-house without liaison with fan manufacturers
<u>PPE</u>	Fire watch activity was inhibited by full face respiratory protective equipment
<u>Method statement and risk assessment</u>	This was the third fire from this type of activity. The fire risk seemed inadequately and inappropriately addressed
<u>Skills and training</u>	Fire possibly accelerated by the fan use. Operatives were unfamiliar with operating fan switch in the event of fire
Organisational factors	Possible cost implications in purchasing range of tool requirements – all were to be disposed of upon work completion

Accident 004	A Scaffold was picking up steel wedges by a column that was being dismantled by a carpenter. The Scaffold needed access to the work area in order to erect a handrail. Whilst the carpenter was working, a loose steel pillar support fell onto the lower back of the nearby Scaffold.
Active failures	Not possible to confirm – Likely routine violations were – Carpenter (dismantling technique) + Scaffold (area access prior to work completion)
SITE factors	
<u>Task details</u>	Steel prop: formwork interdependency issues. Fastest removal method likely to destabilise structural integrity Design of steel prop and steel wedges appeared rudimentary + some rust at operational points Carpenter complained of lack of handhold area on work ladder
<u>Work scheduling</u>	Carpenter worked on a job and finish scheme + travelled 60 miles each way to work for a 49 hour week – possible time pressure
<u>Work organisation</u>	Trade overlap in accident area, but both employee groups felt justified in being there Scaffolders waiting and eager to access work areas – possible time pressure [but not perceived by interviewee]
<u>Work pace</u>	Carpenter worked on a price per column worked – possible time pressure implications, but not perceived by interviewee
<u>Supervision</u>	Both employee groups were ‘overseen’ by a Foreman, but otherwise organised their own work load and pace
<u>Method statement and risk assessment</u>	The carpenter stated that he had followed procedures – but this was contradicted by the scaffolders and Safety Adviser Scaffolders felt that the steel prop should be fixed top and bottom, but this was not reported by the Safety Adviser
<u>Personal details</u>	Carpenter had underlying musculoskeletal injury to back & elbow which he felt were work related
Organisational factors	Response to previous complaints (pre-accident) about work activity had been attributed to ‘trying to work too fast’

Accident 005	A panel fixer was working with his supervisor moving 9m x 140kg steel angles that had been delivered to the work area by FLT. Carrying an end each, and in the process of placing one on the ground, the IP caught his fingers beneath the steel angle and injured his finger.	
Active failures	Not possible to confirm – likely slip of action and routine violation of manual handling guidelines	
SITE factors		
Task details	The task was inappropriate for manual materials handling (MMH)	
Work organisation	Brick layers were standing waiting to access the work area – but this was not perceived as time pressure IP described lack of consultation / opportunity to contribute in decision making about work organisation	
Work pace	IP couldn't keep up with speed of taller and more experienced co-worker	
Supervision	Inadequate provision of MMH training and in realising that trainee needed more time to develop skills and opportunity to communicate	
Method statement and risk assessment	No manual handling assessment. Load greatly exceeded guide load in Manual Handling Operations Regulations MS detailed lifting aids but had no reference to the required techniques and operative interaction in their use	
Skills and training	MH trainer (also co-worker) 1ft taller than IP –a fundamental lack of understanding of a 2 person lift	IP had no experience of manoeuvring steel angles
Organisational factors	Impression that there was generally insufficient consultation / communication between Principal Contractor and sub-contractor Angle drawing and design were sub-sub contracted – possible loss of ownership, task understanding and responsibility	

Accident 006	A glazer was descending a scissor lift. In descending the platform, he mistakenly caught his wedding ring against a protruding bolt at the side of the handhold area. Not realising this he jumped down from the final step to the ground and sustained a finger laceration.	
Active failures	Slip of action	
SITE factors		
Task details	Poor design of equipment interface (including lack of handholds and design for access / egress). Last handhold situated 2.2m from the ground and thought relevant to need to jump off equipment Equipment design was not considered as a contributory factor in the accident.	
Method statement and risk assessment	None for the accident activity	
Organisational factors	Extruding bolt could also have caused a soft tissue injury (ring or not) – risk not identified by manufacturer / purchaser	

Accident 007	A floor fitter was working at the side of the road behind his van. With a craft knife he was cutting out the opening for a toilet pan from 4mm plywood. As he drew the knife towards him, the blade came out of the ply and lacerated his leg.	
Active failures	Slip of action or routine violation if task technique incorrect	
SITE factors		
Task details	Possible tool: material compatibility issue	Ad hoc provision of work surface for task activity
	IP had changed his technique for this cut – would not normally have stood behind the blade	
	Regularly changed blade indicated fluctuating efficiency during use – possibly difficult to anticipate how much force to apply on each cut	
Environment	Hot day – possible implications of handling force and grasp upon bare steel craft knife	
Work scheduling	IP felt that he was rushing and that it was this that caused the accident	
Supervision	Working alone. Peripatetic worker	
Method statement and risk assessment	None for this activity	
Skills and training	Task technique training provided on the job by a more experienced fitter	

Accident 008	A concrete labourer was securing a concrete clip to connect extension pipes for a concrete pouring operation. He had trouble compressing the clip, so was using his foot to try and secure it. For additional force he hit a scaffold pipe against his foot and injured it.	
Active failures	Exceptional violation under conflicting circumstances	
SITE factors		
Task details	Concrete clips were reported to vary in operational forces, and were especially difficult to use when contaminated with concrete residue	
Environment	A hot day thus concrete was setting at a faster rate	
Work pace	IP reported time pressure from the setting rate of the concrete and from the need to move the concrete lorry from a public access road	

Accident 009	A carpenter was cutting the steel banding of a bundle of ply, using a pair of nips. Although he thought he was standing out of the way, when he released the band it recoiled and lacerated his arm.	
Active failures	Routine violation if task technique incorrect	
SITE factors		
Task details	Interviewees gave varied reports on correct way to cut banding	
Work organisation	Indication of time pressure affecting the atmosphere on site – all interviewees experience it in different ways	
Supervision	Supervisor not aware that what technique IP had used nips to break the banding	
Skills and training	Task technique was not stipulated – at discretion of operative	
Organisational factors	Unknown criteria for choice of steel or nylon banding Safety adviser unaware of accident – opportunity for remedial actions lost	

Accident 010	Operatives on the 1 st floor were striking out a box next to a column. As the formwork was knocked out it fell down a level onto a board covering a floor aperture on the ground level. The materials went straight through and landed in the basement close to operatives working nearby.
Active failures	None. Knowledge based mistake in developing boarding criteria and task procedures
SITE factors	
Task details	Ply 'lying around', is used for covering holes – no apparent criteria for assessment of quality No specification of board dimensions to cover floor openings – ad hoc arrangement Advised that remedial action was to use double ply - no apparent criteria for assessment of durability or quality
Method statement and risk assessment	Advised that task technique for striking out would not be detailed Risk of ply damage had not been anticipated in the risk assessment Not known how subsequent risk assessment of double ply (remedial action) had been assessed
Organisational factors	Undercurrent feeling that sub-contractors do little proactively towards safety

Accident 011	A lorry loader driver was delivering scaffold poles to a site. As he was trying to manoeuvre the load towards the drop zone the lorry tipped over. The stabiliser feet (riggers) had been put down to the ground, but had not been extended before commencing the manoeuvre.
Active failures	Situational violation
SITE factors	
Task details	Report of restricted area for lorry parking – inadequate space for driver to move forward into preferred parking position. High level of load manipulation by crane required to reach drop off point and avoid adjacent public pathway. Reported restricted visibility One lorry wheel was on railway sleepers – possible contributory factor Lorry safety devices did not alert operator to instability and fall risk Lorry riggers required manual rather than hydraulic extension – possible relevance?
Work scheduling	Accident occurred at 13.30 – no indication of lunch / break in last 3hrs – still on morning workload. 'Time pressure' not perceived however Very long work hours for driver with indication of pressure to do overtime & to breach HGV driver rest allowances
Work organisation	Driver felt work area and access was tight, but continued with the job in any case
Method statement and risk assessment	Documentation apparently available, but driver unaware of materials
Skills and training	Criteria for use of riggers assumed to be within 'core' driver skills
Personal details	Driver quite unhappy overall with work conditions
Organisational factors	Site safety culture not perceived very highly by sub-contractor interviewees

Accident 012	Concrete pipes were being blown through (a wet foam ball is propelled inside the pipe with pressurised air) from 4 th floor to ground level at the end of the workday. An operative was astride the pipe and the force of expulsion threw him backwards onto a column.
Active failures	Exceptional violation
SITE factors	
<u>Task details</u>	Indication of restricted work area for the task
<u>Work scheduling</u>	Indication of opposing behaviour between operatives, resulting in injured operative being astride pipes only to correct actions of the other
<u>Work organisation</u>	Long hours of all concerned. IP at work 5hrs with no break preceding accident
<u>Work pace</u>	Not usual to have 2 people together at exit end – generally a one-person job. Distraction issues possible
<u>Supervision</u>	Interviewees gave different accounts of the accident - lack of team work /co-ordination apparent at and between levels on site
<u>Skills and training</u>	All operatives were trying to finish for the day – working job and finish
	Both operatives at ground level were inexperienced.
	Operatives untrained - experienced operatives not available for task
Organisational factors	Accident history appeared camouflaged due to fear of grassing

Accident 013	A carpenter, using a cordless drill, was putting up a new doorway in the walkway leading to the canteen entrance. Men were starting to arrive for their break – he twisted round to allow them to pass and accidentally drilled into his finger.
Active failures	Not possible to confirm. Likely slip of action or routine violation of cordoning off procedures
SITE factors	
<u>Task details</u>	Work area not cordoned off. Use of cordless drill may have induced different behaviour than work with an electric flex trip hazard
<u>Work pace</u>	Time pressure to complete job before canteen access required for work breaks
<u>Supervision</u>	Work was unsupervised. Reliance upon skills and operative experience to ensure safe work area
<u>Method statement and risk assessment</u>	None for this activity

Accident 017	A trainee Scaffolder was walking along, carrying four brick guards in each hand. He slipped on an electrical cable and twisted his ankle.
Active failures	Slip of action
SITE factors	
<u>Task details</u>	Power lines were lain in walkways and were not secured in position
	Power lines were black and of poor visibility
<u>Personal details</u>	IP appeared unhappy and isolated. Not helped by communication problems with Supervisor
Organisational factors	Habitual tolerance of power lines strewn over floor and indication of previous problems with the state of the floors

Accident 018	A Scaffolder was erecting a cantilever scaffold and lacerated his right forearm on a nail protruding from the concrete of a newly erected structure
Active failures	Slip of action
SITE factors	
Task details	Nails were not knocked off when shuttering was removed [leaving the nail hazards in the work area] IP working alone and reported handling of heavy items
Environment	Sunlight distraction / glare at time of accident
Work scheduling	11- 12 hr day for IP – IP rejected use of scaffold lifting aids due to additional time implications that would result from their use
Work pace	Work pacing – evidence of dissatisfaction with support labour (? Trainee) Trainee not qualified to climb scaffold and help IP
Supervision	Supervisor distracted him immediately prior to accident
Method statement and risk assessment	No procedures / instructions
Skills and training	‘Training’ seen as consequent of time on job (15y)
Organisational factors	Extruding nails from concrete appear to be an ongoing and accepted problem

Accident 019	A labourer was helping a carpenter to move a false work tower. He failed to remove a cantilever prop at the top and it became dislodged during the operation and fell ~3m hitting the IP on the left side of his back.
Active failures	Not possible to ascertain – likely routine violation
SITE factors	
Task details	Possible tower design issues – tolerance of movement with cantilevers attached and methods used to secure add on structure
Work organisation	An unplanned activity. The frames required earlier than expected – possible relevance?
Method statement and risk assessment	No apparent procedure for this activity
Skills and training	IP had no training in doing this task IP had a similar accident some months ago – but didn’t change his practice.
Personal details	IP had poor English – does this influence training / communication etc. provided?
Organisational factors	Safety culture issues – Possibly standard practice not to bother to take the cantilever off?

Accident 020	An operative was cutting off what he mistakenly believed to be a redundant gas pipe from an under-stairs cupboard during domestic refurbishment work. Using a petrol saw, there was a resultant 3ft flame and burns to under stairs and plasterboard.	
Active failures	Routine violation of procedures concerning gas supply work	
SITE factors		
<u>Task details</u>	Gas supply check not undertaken prior to task activity	Use of handsaw was seen as too lengthy an option for task activity
<u>Environment</u>	Large heavy tool for a relatively small task in awkward and cramped work conditions	
<u>Work scheduling</u>	Poor light levels in cupboard – visibility issues	
<u>Work organisation</u>	Task was unplanned/scheduled – ad hoc arrangement	
<u>Method statement and risk assessment</u>	Relatively new General Foreman – possibly relevant to communication and planning of accident task	
<u>Skills and training</u>	Operative, normally a brick layer, drafted in to labouring work to make up numbers	
	None available for task	
	Unclear history relating to access to information concerning gas supply	
	No formal training by IP in task or use of saw	
Organisational factors	Poor communication with gas supplier – muddled story re which houses were still live and which weren't	
Accident 021	A piece of wire was hanging over the top edge of a rail wagon and the works Manager climbed up to see if he could push it back in. He put out his hand to haul himself up and lacerated his hand on a metal slither extruding from the top rim of the wagon.	
Active failures	Slip of action	
SITE factors		
<u>Task details</u>	Reported that wagon apparently not designed for physical access. Only visual access anticipated	
<u>Work scheduling</u>	Apparent lack of handhold at the top of the ladder	
	IP had excessive working hours and infrequent days off	
	Described working under considerable time pressure.	
	Did time pressure encourage undertaking of unusual activities by Supervisory / Management staff	
<u>Method statement and risk assessment</u>	Task commonly undertaken, but excluded from MS / RA	
Organisational factors	Appeared that working under 'time pressure had become 'the norm' for work scheduling	

Accident 022	A ceiling fixer and workmate were pushing a trolley full of plasterboard along a scaffold gangway. There were communication problems about trolley manipulation and the IP sustained a hand laceration as the trolley knocked into exposed scaffolding nuts.
Active failures	Slip of action
SITE factors	
Task details	Scaffold design – possible design issues for scaffold nut position and criteria for cap use Plasterboard trolley design – two wheels were in fixed position – likely to have impacted upon manoeuvrability on narrow gangway Plasterboard trolley – no apparent handhold areas Scaffold and plasterboard design not considered influential in this accident
Work organisation	Indication of low level consultation in work organisation – liase on a job by job basis only
Work pace	One man absent on accident day – manpower shortage may have been relevant to accident
Target / payment	IP possibly on priced work – history not clear
Method statement and risk assessment	None for this activity
Skills and training	Lack of role clarity – IP felt he should not have had to push trolley as part of his job on this site Mixed accounts of provision of training in plaster trolley transport
Personal details	IP young and suffering long term back injury – no sickness absence pay
Organisational factors	Possible language problems with foreign workers – unwilling to tackle for fear of being accused of racism Remedial action seen as PC responsibility by SC – indication of lack of communal ownership in safety management

Accident 023	A duct Engineer was leaving work at the end of the day. As he reached the bottom of the stairs he slipped and fell on spilt oil that had been covered over with paper
Active failures	None. Situational violation of oil spill procedures
SITE factors	
Task details	Uncertainty re source of oil spill
Environment	Incorrect clearing up action had been taken after oil spill. Unable to ascertain reason H&S manager reported that ‘people’ are reluctant to report damage they have created for fear of being blamed
Personal details	Indication of significant work related health problems among duct worker – not apparently being managed Indication of job dissatisfaction related issues for IP

Accident 024	A fitters mate was sawing off the end from a threaded stud (from overhead ducting) after he had just put a brand new blade upon the saw. As he was cutting, the blade bounced and caught the top of his thumb and cut it.
Active failures	Routine violation of correct procedures
SITE factors	
<u>Task details</u>	Overhead work – comfort and performance issues Alternative and safer technique was known but this had not been communicated until the accident event.
<u>Environment</u>	Indication of tolerance of poor housekeeping
<u>Work scheduling</u>	Accident late in day – possible fatigue issues
<u>Work pace</u>	Work pace appears quite dependent upon others needing to use the work area
<u>Supervision</u>	IP seen as a skilled fitter – possibly an awkward phase as towards end of supervisory period but not finally ‘improved’ (trained)
<u>Method statement and risk assessment</u>	Documentation does not list the accident activity IP unaware of RA for the work task
<u>Skills and training</u>	IP indicated that he had been trained to use a hacksaw, but not technique to cut off the stud. IP had never been shown correct technique, but indicated that all colleagues worked in same manner Task considered a basic trade activity and within remit of core skills
<u>Personal details</u>	Dissatisfaction with welfare facilities

Accident 025	An Assistant Surveyor was inspecting some ongoing roofing work from an externally clad staircase. Roofing materials were around the ladder and as he descended a sharp piece of metal lacerated the back of his leg.
Active failures	None. Unable to confirm, but likely situational housekeeping violation
SITE factors	
<u>Environment</u>	Poor housekeeping reported of roofing company. Arrangements for ownership of a work area unknown
<u>Work scheduling</u>	Roofing company possibly working under time pressure or delay At least 11hr day for each interviewee. Culture of working through breaks
<u>Target / payment</u>	Financial compensation for work acceleration
<u>Personal details</u>	Young employee with high safety motivation, but feels there is lack of interest among his seniors and his concerns seem to be ignored Dissatisfaction with welfare facilities
Organisational factors	Possible disruption from multiple personnel at development stage (Architects / client /tenant) – programme rescheduled Timeline had been extended due to multiple design revisions Project Mgr performance monitored by re-active (rather than active) monitoring Client pressure upon work schedule – Project Mgr trying to juggle with this and worries of operative fatigue etc.

Accident 033	A ground worker was setting out key kerbs ready for laying. He was holding four in a row between his hands and as he placed them down he trapped and lacerated his finger between the blocks and the stone bed.
Active failures	Slip of action
SITE factors	
<u>Task details</u>	Poor handling technique and possibly inappropriate load (weight, dimensions, grasp) Accident blamed upon inattention; work technique not considered as an influencing factor
<u>PPE</u>	No gloves – poor for skin protection. Non-gloved work appeared to have advantages in comfort and speed Indication that glove size / fit / comfort is not satisfactory. Gloves not seen as the solution to this accident by IP
<u>Work scheduling</u>	Long hours + quite possibly working > 4hrs in afternoon without a break Very little holiday for either interviewee in past 12m – possible fatigue issues
<u>Work pace</u>	Possible time pressure – labourer had already laid concrete, but kerbs were not in position at the time ready for immediate laying
<u>Method statement and risk assessment</u>	Manual handling assessment and Method statement long and unwieldy IP unaware of MS / RA
<u>Skills and training</u>	High dependence upon gang cohesiveness for 'on the job training' & transfer of risk information – minimal else formally
Personal details	Fatalistic approach by interviewees to acquisition of superficial injuries and lacerations

Accident 034	Ductwork was stacked in two adjacent piles. A duct worker foreman was trying to removed one bit of duct from the inside of another. When he pulled hard his hand slipped on protective oil on the ducting and he sustained a laceration upon the raw edge of the adjoining duct pile
Active failures	Slip of action
SITE factors	
<u>Task details</u>	Ducting is manually transported around site. Double handling ++ as ducting is moved from drop off point to different storage points
<u>PPE</u>	Gloves not worn = possible issues relating to loss of dexterity and ability to make a pinch grasp
<u>Supervision</u>	IP saw himself as un-supervised / own manager, yet Project Mgr clearly saw him as being supervised – role and responsibility clarity issue
<u>Method statement and risk assessment</u>	IP had no knowledge of RA/MA. RA does not cover manual materials handling / movement – circumstances of accident task MS does not cover materials storage – circumstances of accident task MH RA does not identify the risk of laceration from the sharp duct ends – focus is entirely on musculoskeletal injury
<u>Skills and training</u>	No formal training for duct worker – all skills attained by observation over the years
Organisational factors	Long contractor chain – possible loss of information through the multiple series of people involved

Accident 035	A duct worker foreman was drilling, approximately at eye level, and swarf flew off into corner of eye. Goggles were not worn	
Active failures	Routine violation of goggles use	
SITE factors		
Task details	Hand drill – apparent lack of info from supplier.	
PPE	Goggles not worn for drilling task – IP did not think that they were necessary for this task	
Method statement and risk assessment	IP had no knowledge of RA/MA	RA indicates that goggles should be worn when using a hand drill
Skills and training	MS does not cover joining duct sections – circumstances of accident task Paperwork supplied by next SC in line – Possible issues relating to interaction / communication between them and his employer No formal training for duct worker – all skills attained by observation over the years Unsure of protocol for training / instruction for operatives concerning their own property (drill)	
Personal details	IP has had previous similar accidents + hospital treatment, but still no goggles / glasses (possible issues of familiarity / complacency)	
Organisational factors	Possible informal culture among duct gang of non-goggles use during drilling work	

Accident 036	A plumber was descending a tower scaffold. A harness that he had been wearing snagged on ceiling structures and when he released it he fell onto a metal rail of the scaffold and fractured his elbow.	
Active failures	Knowledge based mistake – dealing with an unfamiliar procedure	
SITE factors		
Task details	Indication of harness: scaffold tower incompatibility issues Trap design – process for design review and evaluation	Harness - design issues and entanglement risk
PPE	Building design – tight access space – architectural issues + correct choice of tower / raised platform for this work. IP took 1 ½ hours to find a harness – PPE availability and issues. Indication of harness hoarding Unaware the harness supported that some of his weight. Possible harness comfort issues	
Work scheduling	IP had worked previous 12d at 9hrs /day.	
Supervision	Supervisor had 18 –20 people to oversee	
Method statement and risk assessment	None for this activity	
Skills and training	Indication that TBTs only done as a consequence of previous failure, rather than as a result of RA	
Organisational factors	Rivalry between PC & SC ops and resentment re. ‘unequal treatment’	

Accident 037	A pipe fitter was walking along a corridor. There were a number of cables on the floor and these snagged around his left leg injuring his knee
Active failures	Unable to ascertain. Indication of routine violation concerning housekeeping
SITE factors	
Task details	Injury blamed on recurrence of an old injury
Environment	Report of poor lighting in corridor area Underlying poor housekeeping issues IP prepared to walk over top of strewn cabling – indication of acceptance of poor housekeeping among all individuals
Work scheduling	Long hours culture – 48hr week + overtime encouraged if living away from home
Organisational factors	Project behind schedule and impression of low morale among interviewees

Accident 038	A driver was preparing to hitch-up a fuel bowser. As he grasped the handle the jockey wheel gave way and he had to take the whole weight of load on his left arm, exacerbating an old shoulder injury
Active failures	None. Likely rule based mistake of previous user
SITE factors	
Task details	Jockey wheel / clamp design vulnerable to failure. No visible indication to IP that it had been incorrectly secured Difficult to ascertain stability of the product – free movement of contents inside bowser – heavy weight and unstable load
Work scheduling	Bowser movement was unscheduled work
Work organisation	No occupational health intervention pre or post injury for IP
Supervision	Supervisor and IP gave varied accounts of bowser handling frequency
Method statement and risk assessment	No manual handling or risk assessment for the task
Skills and training	Training had been provided, but task was perceived by IP as ‘common sense’
Personal details	Interviewees appear under stimulated and lacking in opportunities for development

Accident 039	A Maintenance Inspector was torquing bolts on a slewing ring of a gantry. The bolts were approximately 650mm high and he had to lean forward to reach and operate the torquing ratchet and multiplier. He experience back pain when he stood up.	
Active failures	Not possible to ascertain. Likely situational violation due to time component of the work	
SITE factors		
Task details	Task unfamiliarity - undertook task as was doing nothing else And could not leave work area unattended	
Environment	Working on rough ground, possibly wet and unprotected from wind.	
Work scheduling	Indication of time pressure -- work load related	
Work organisation	Trying to accommodate two absent / sick operatives	
Method statement and risk assessment	Inadequate manual handling assessment -- possibility that load / torque combination may been near upper limit of guidelines (MHOR) Indication of awkward postures to undertake task, but not identified on RA IP responsible for writing method statement for 'riggers', yet indicated that they "knew more than him"	
Skills and training	Task unfamiliarity by IP	
Personal details	Appeared to find work unstimulating and burdened with bureaucracy	

Accident 040	A general operative contaminated the inside of his work boots with concrete at the completion of a workday. Inadequately cleaned out, he sustained concrete burns to his feet upon next use of the same footwear	
Active failures	Not possible to confirm. Likely exceptional violation at time of contamination	
SITE factors		
Task details	Scaffold handrail had been erected as fall protection, but indication that the foot placement area was inadequate IP commented on lack of workspace Report of obstructed vision to work area -- possible lack of control during cement pour	
PPE	Wearing incorrect style of boots for task Mixed perceptions of who's responsibility it was to ensure that IP was wearing correct footwear	
Work scheduling	Long work day and no break for 4 - 5 hr prior to end of shift	Ganger man -- no holiday / sick in 12m. IP unpaid for any absence
Work organisation	Waiting for concrete delivery ++ reported during the day -- implication for time pressure and long work day	
Work pace	Ip appeared concerned about slowing gang down	
Target / payment	Preference among concrete gang for priced work	
Supervision	Implication from Site Mgr that PPE easy to get hold of if not worn, but this did not appear to have been perceived by IP IP saw ganger man as supervisor, but ganger man said supervisor not present -- lack of role clarity and responsibility	
Method statement and risk assessment	MS very generic -- instruction to wear 'safety boots' unhelpful in this situation	No risk assessment -- work was unplanned
Skills and training	Sub-contractor not involved in preparation of any of the documentation-- ownership issues	
	No task training for concrete gang Ganger man knew 'loads' of concrete burns cases -- impression of trivialisation and poor attitude to risk	

Accident 050	A labourer was carrying his work tools from one deck of scaffold to the next. A tool carrying pouch had been made from a cut-down flagon and this was slung over his back. He hurt his back as he twisted to pass through the scaffold aperture.	
Active failures	Rule based mistake in tools transport	
SITE factors		
<u>Task details</u>	Poorly designed transport method of moving hand tools around the site Normally a two person job – no assistance available at the time Scaffold aperture in the range of 950mm x 500mm – space restriction for physical access + for load manipulation	
<u>Environment</u>	Poor environment at the time of the accident – light low. Also IP cold and not warmed up for labour – first task at the beginning of the day	
<u>PPE</u>	Possible issues concerning the provision of warm clothing for employees	
<u>Work scheduling</u>	Long working week for all. IP no holiday in past year – paid in lieu – possible fatigue issues	
<u>Work pace</u>	Possible time pressure generated through supervisory style to ensure work acceleration	
<u>Method statement and risk assessment</u>	No MH assessment. Bucket 8kg when sample weight taken, but not assessed in the context of the environment or circumstances No procedures for carrying tools around site. Bucket was an ad hoc but accepted arrangement	
<u>Skills and training</u>	MH training not well perceived – leaflets only	
<u>Personal details</u>	IP newly appointed to this employer – possible influence in lack of request for help IP described job as very menial, didn't feel listened to by co-workers	
Organisational factors	SC firm not happy with housekeeping standard 'provided' by PC	

Accident 051	Repositioning a scaffold tower with a co-worker an Electrician was pulling it sideways and backwards. A manhole had been boarded over and, not seeing it, he tripped and injured his thumb as he fell.	
Active failures	Not possible to ascertain. Possibly slip of action	
SITE factors		
<u>Task details</u>	Possible issues of tower manoeuvrability and acceptable use over different depths of floor rise	
<u>Environment</u>	Poor lighting reported in the work area	Housekeeping – poor, but seen as a responsibility of the PC
<u>Work organisation</u>	Other trades were in the area at the time. Possible over lap of work location requirements	
<u>Supervision</u>	IP senior and seen as 'supervisory' in role – issues of supervision for experienced personnel	
<u>Personal details</u>	Immediate return to work with thumb immobilised. Replaced soiled dressings himself – possible impact on treatment quality & recovery	
Organisational factors	Reports of disharmony with other trades – housekeeping related Reported that the area would have been boarded if any members of public at risk, but that this care isn't taken for construction workers. Good ideas to prevent reoccurrence of the accident event (barriers) had not gone beyond the SC team – communication issue.	

Accident 052	A ground worker was digging for a temporary water main for site use. Although the area was surveyed with a CAT machine prior to excavations, a cable had been undetected. This was struck with the shovel and a short occurred.	
Active failures	Not possible to ascertain.	
SITE factors		
<u>Task details</u>	Unclear information about depth of CAT scanning capacity and recommended criteria for use	
<u>Environment</u>	Indication of different qualities of CATs supplied to site	
<u>Work scheduling</u>	Working in wet conditions	
<u>Target / payment</u>	Low amount of holiday both men + reports of pay in lieu	
<u>Method statement and risk assessment</u>	AI – considerable quantity of additional work outside site – possible fatigue issues	
<u>Skills and training</u>	Bonus for work acceleration provided	
	Shovelling by hand excluded from method statement	
	Lack of skills training both interviewees	
	Ground work reported as not a trade therefore have to train in-house	
Organisational factors	Electricity board did not have complete drawings of electrical services	

Accident 053	A pipe fitter descended a 3-rung scaffold to the ground. As he put his foot down to the ground he lost his footing on a broken brick underfoot and injured his ankle. The accident area was located by the site entrance and also housed the site stopcock and served as a brick storage area.	
Active failures	Slip of action	
SITE factors		
<u>Task details</u>	High access area – possible implications of locating services where brick rubble also likely to impact upon work areas	
<u>Environment</u>	Reports of inadequate space for storage, especially in winter when rained off and work cannot proceed	
<u>Work scheduling</u>	Report of site clear up initiated only when an empty skip arrived to accommodate waste	
<u>Work organisation</u>	Work was behind schedule – time pressure reported	
<u>Supervision</u>	Trade overlap – other trades working in same vicinity at time. IP needed to finish work to allow access for ceiling fitters	
	Experienced employee working unsupervised	

Accident 060	Four operatives were using two mechanical hoists to dismantle ceiling ducting while decommissioning a Plant Room. During descent the ducting snagged, unbalancing one of the hoists which fell onto and trapped the operating fitter.	
Active failures	Knowledge based mistake in determination of work technique	
SITE factors		
<u>Task details</u>	Plant room working area was cramped and restricted	No measures for assessing weight of ducting
	Activity was an unusual event and without precedent on technique	
<u>Environment</u>	Timber was used to reinforce hoist brakes – possible adverse impact on stability	
<u>Work scheduling</u>	Indication that work area messy during dismantling – possible adverse impact upon space availability	
<u>Supervision</u>	Work was delayed but this was not perceived as time pressure by the men	
<u>Skills and training</u>	IP felt that he self-supervised	Supervisor reported inadequate training in dealing with the different trades
	Experienced operatives, but inexperienced in this specific task	
	No formal training in use of hoist	
<u>Personal details</u>	IP unhappy with site welfare facilities and safety culture – little initiative / proactive improvement	

Accident 061	An Electrician, working at height on a telescopic boom, was cutting out old cable suspended on brackets at 4m intervals. One of the brackets gave way and cable slipped though and lacerated his hands. A portion of the cable had previously been joined and stabilised with a section of rebar.	
Active failures	Not possible to ascertain. Likely knowledge based mistake or routine violation if safe determination of task technique	
SITE factors		
<u>Task details</u>	Accident blamed on lack of brackets–lack of pre-task assessment / technique etc. not considered Unclear messages about whether this was planned / unplanned work Lack of earlier access to work area due to other trades in work area + use for storage	
<u>PPE</u>	Reported glove incompatibility with task demands. Not worn	
<u>Work scheduling</u>	10hr day IP and 11-12hr – Supervisor	
<u>Work organisation</u>	Time pressure as needed to mount new cable trays Activity was an additional task and was being undertaken late due to earlier lack of access to the work area	
<u>Supervision</u>	Task management by PC rather than SC and possible loss of ownership issues. Supervisor reportedly unaware of operatives actions	
<u>Method statement and risk assessment</u>	None for this activity	
<u>Skills and training</u>	No task training – reliance on core skills of original apprenticeship	
<u>Organisational factors</u>	Safety audit perceived to focus upon paper work / documentation – conditions leading to this type of accident possibly overlooked	

Accident 062	A heating Engineer was descending a scaffold tower. His boots were muddy and he slipped on the ladder and injured his knee
Active failures	Slip of action
SITE factors	
<u>Task details</u>	Reports of long-standing problems of muddy, poorly accessed and poorly maintained walkways No provision of boot scraping facilities – building structure (concrete) only other facility for boot cleaning
<u>Work scheduling</u>	Long hours – both interviewees – possible fatigue issues
<u>Personal details</u>	Dissatisfaction with welfare facilities
Organisational factors	Dissatisfaction with PC attitude to safety responsibility

Accident 063	A bricklayer was undertaking overhead work using a riveting gun, to insert a screw into a steel column. Steel fragments shredded off and into his eye.
Active failures	Routine violation concerning use of goggles
SITE factors	
<u>Task details</u>	IP found overhead work quite difficult, especially as force was also required to undertake task Work undertaken from a trestle table – possible restriction to choice of work position
<u>Environment</u>	Reported poor lighting and visibility to see screw hole
<u>PPE</u>	Eye protection not worn. Complaint that goggles steam up. IP wanted to buy own protective glasses
<u>Work organisation</u>	IP felt excluded from discussions about work organisation IP normally worked with son (alternating undertaking of tasks), but working alone of accident day
<u>Work pace</u>	Reports of constant experience of time pressure upon the work
<u>Target / payment</u>	Undertaking priced work – possible time pressure issues
<u>Method statement and risk assessment</u>	Risk assessment recorded need for eye protection, but noted incorrect tool type – possible issues relating to content and update frequency Method statement did not mention swarf from drilling or control measures for this IP unaware of either documentation
<u>Skills and training</u>	IP couldn't remember any task training in the 2 years since undertaking this task type

Accident 064	A charge hand pipe fitter tripped on an unmarked setting out point whilst walking along a passageway and exacerbated an old knee injury
Active failures	None. Likely knowledge based mistake at planning stage
SITE factors	
<u>Task details</u>	Setting out points protruded 40mm high x 100mm wide and were reported to be a frequent source of tripping Setting out points had previously been covered with traffic cones, but these were moved to facilitate equipment movement along access routes
<u>Environment</u>	Indication of poor ambient lighting in walkway
<u>Work scheduling</u>	Time delay in early setting out point placement and application of surrounding screed. Reports of setting out points being put down too early
<u>Personal details</u>	Dissatisfaction with welfare facilities IP had underlying musculoskeletal injury
Organisational factors	SC felt unable to take any remedial action other than to inform principal contractor

Accident 065	A hod carrier was lowering a hod full of bricks and sustained a finger injury as they fell out onto his hand
Active failures	Slip of action
SITE factors	
<u>Task details</u>	Possible brick transport issues – unclear why manual rather than mechanical lifting undertaken Carrying twelve bricks per hod - possible weight and load manipulation issues
<u>PPE</u>	Intermittent glove use by IP. Reports of problems in obtaining suitably durable and cheap gloves for brick handling work
<u>Method statement and risk assessment</u>	IP unaware of risk assessment for this activity
<u>Skills and training</u>	IP had never had any task training

Table 52. Summary of site based accident study data

6.4 Overview of accident specific results

An overview of the findings reported in Table 52 shows that there are a number of features that were common across the accidents studied. These are considered for each of the areas of analysis.

6.4.1 Active failures

The summary of active failure attribution is shown in Table 53. Whilst it was not possible to distinguish the area of active failures in five of the cases (possible attribution shown in brackets), the remainder reveal that the highest rate of incidences were likely to have occurred through some form of slip of action (32%), such as an unplanned or unintended action. Routine violations were afforded the second highest prevalence (20%) and reflected the many incidences of responses to time pressure, lack of clarity in correct working methods and dismissal of some safety rules (3.6.2.4). The range of violations (together comprising 32% of the sample) also included ‘situational’ and ‘exceptional’ incidents and these were thought to reflect the frequency of ‘unique’ work situations where improvisation in novel problem solving situations was required or where procedural compliance was seen as an inhibitor or barrier to effective task execution (Table 19). Mistakes in following rules or undertaking knowledge-based reasoning were also recorded.

ACTIVE FAILURES		
Skill –based errors	• Slips of action	001, 002, (005), 006, (007), (013), 017, 018, 021, 022, 033, 034, 051, 053, 062, 065
Mistakes	• Rule based mistakes • Knowledge based mistakes	038, 050 003, 010, 036, 060, (061), 064
Violations	• Routine violation • Situational violation • Exceptional violation	004, (005), (007), 009, (013), 019, 020, (023), 024, 035, 037, (061), 063 011, 025, 039 008, 012, 040

() = possible cause. Grey text = upstream causal factor

Table 53. Active failures within the accident study sample

6.4.2 Site factors

Analysis of site factors revealed a broad range of information across the accidents and within the four areas of enquiry. These data are outlined in Table 54. Overview of the findings revealed that, at the ‘Design and Task Execution’ stage, there were numerous issues concerning poor interface with the products, equipment and materials

used on site. Complementing this there were also issues relating to poor work design – perhaps through adoption of undesirable work techniques or the poor condition of facilities.

Issues relating to the 'Planning, Scheduling and Management' of the work featured strongly in the analyses and exposed a catalogue of problems relating to the management of manpower and the build schedule. Working hours were long and additionally compromised by inadequate breaks or time off for many interviewees. Working under some form of time pressure appeared routine, yet was taken for granted by many. Time pressure appeared to evolve from the need to accommodate fluctuations in workload, the need to vacate a work area for access by other trades people and as a result of some form of work acceleration incentive. Problems relating to manpower recruitment were also evident.

Communication and the nature of supervision were also identified as relevant aspects in accident causation, with especial problems concerning the nature of any supervisory intervention for experienced personnel. The data indicated that there was a high reliance upon core skills and little to distinguish role boundaries or formality in skills development. Information transfer, also in the form of risk assessment and method statement documentation, revealed a high level of bureaucracy, yet little real address to the tasks or events that were present in accident occurrence.

In describing the circumstances of their work conditions, individuals revealed a range of issues likely to contribute towards the low moral and apathy of personnel undertaking site work.

Individual factors	Information transfer	Planning Scheduling & Management	Design & task execution	Site factors		
				<u>Task details</u>	<ul style="list-style-type: none"> Materials problems Tool / equipment design problems Poor instructions Poor technique / task design Poor activity area and housekeeping Storage problems 	<ul style="list-style-type: none"> 001, 002, 009, 010, 060, 002, 003, 004, 005, 006, 007, 008, 010, 017, 019, 021, 022, 036, 037, 050, 051, 052, 060 002, 010, 035 002, 005, 007, 009, 012, 018, 020, 024, 033, 060, 061, 063, 064 003, 007, 011, 012, 013, 017, 018, 020, 022, 024, 025, 036, 037, 039, 040, 051, 053, 060, 062, 064 034, 053
				PPE	<ul style="list-style-type: none"> Task: PPE incompatibility PPE related problems 	<ul style="list-style-type: none"> 001, 002, 003, 033, 036, 040, 061, 063 033, 034, 035, 036, 065
				<u>Environment</u>	<ul style="list-style-type: none"> Weather extremes Poor lighting 	<ul style="list-style-type: none"> 001, 007, 008, 018, 050, 052, 062 002, 020, 037, 050, 051, 063, 064
				<u>Work scheduling</u>	<ul style="list-style-type: none"> Long working hours Inadequate breaks / time off 	<ul style="list-style-type: none"> 001, 002, 004, 011, 012, 018, 021, 025, 033, 036, 040, 061, 062 010, 012, 040, 050, 052
				<u>Work organisation</u>	<ul style="list-style-type: none"> Fluctuating workload Trade overlap Poor consultation /communication Manpower shortages Fitness for work issues 	<ul style="list-style-type: none"> 002, 019, 020, 037, 061 004, 005, 024, 033, 051, 053 005, 012, 020, 022, 050, 063 022, 039 037, 038
				<u>Work pace</u>	<ul style="list-style-type: none"> Time pressures upon pace Gang incompatibility 	<ul style="list-style-type: none"> 001, 002, 007, 008, 009, 013, 018, 021, 025, 033, 039, 040, 053, 061, 063 005
				<u>Target / payment</u>	<ul style="list-style-type: none"> Undertaking priced work Bonus / Job & finish No sickness absence pay 	<ul style="list-style-type: none"> 004, 063 004, 012, 052 022
				<u>Supervision</u>	<ul style="list-style-type: none"> Supervision of experienced personnel Numbers that supervisors oversee 	<ul style="list-style-type: none"> 002, 004, 007, 009, 013, 034, 051, 053, 060 036,
				<u>Method statement and risk assessment</u>	<ul style="list-style-type: none"> None / N/A Inappropriate detail Operatives unaware 	<ul style="list-style-type: none"> 006, 007, 008, 009, 013, 017, 018, 019, 020, 022, 023, 025, 036, 037, 038, 061 001, 002, 003,, 005, 021, 011, 024, 033, 034, 035, 036, 039, 040, 050, 052, 063 011, 024, 033, 034, 035, 063, 065
				<u>Skills and training</u>	<ul style="list-style-type: none"> Reliance on core skills Inadequate / Lack of training On the job training dependency 	<ul style="list-style-type: none"> 001, 002, 011, 018, 061 003, 005, 012, 019, 020, 065 007, 024, 033, 034, 035, 040, 052, 063
				<u>Personal details</u>	<ul style="list-style-type: none"> Work/ facilities dissatisfaction Communication / Language problems Underlying ill-health Fatalistic approach to accidents / injury 	<ul style="list-style-type: none"> 001, 002, 010, 024, 025, 037, 038, 039, 051, 060, 062, 064 019, 022, 051 022, 023, 051, 064 033, 035, 037

Table 54. Site factors within the accident study sample

6.4.3 Organisational factors

Analysis of organisational factors in the accident summaries revealed a number of incidences where latent conditions were readily identifiable at the site data collection phase. These findings are overviewed in Table 55.

The findings revealed one-off incidences where there had been a resultant negative impact and likely contribution to the accident event. These concerned the impact of design revisions to the work in progress and poor communications with external service providers. Additionally, there was only one clear incident where tight work scheduling was likely to have impacted upon the work and accident.

In spite of these sporadic attributions there were much more common accounts, less directed, but more indicative of cultural problems on site. These accounts especially concerned poor communications and relations between Principal and Sub-contractor groups and gave a strong indication of loss of ownership and responsibilities with lengthy contractor chains. A second, but equally important factor was the inappropriate response to earlier related problems and lost opportunity for problem resolution. The issues appeared related to lack of insight or possibly problems with informed decision-making by those in authority.

Organisational factors	<ul style="list-style-type: none"> • Friction between PC: SC relations / perception • Loss of ownership with long contractor chains • Purchasing: procurement issues • Inappropriate response to earlier problems • Time pressure in work scheduling accepted • Communication problems with external service providers • Impact from design revisions / client pressures 	<ul style="list-style-type: none"> • 001, 005, 010, 011, 022, 036, 050, 061, 062 • 005, 034, 040 • 002, 006, 003, • 003, 004, 009, 017, 018, 019, 051 • 021 • 020, 052 • 025
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Table 55. Organisational factors within the accident study sample

6.5 Critique of data representation and the accident specific analysis

The profile of data representation showed that although the range of accident types tallied well with those identified in the sampling strategy, it was not possible to study the number of accidents at residential and engineering construction sites as anticipated. A number of non-reportable accidents were included, yet these often had the potential for more serious outcomes (3.9.1). Accidents occurred not only during task activities, but also during clearing up, maintenance, movement and transit. There were peaks in accident timings and these appeared to coincide with the pre-lunch phase and mid to late afternoon.

The profile of the accident study results has revealed detailed information relating to conditions that are contributory in accident causation. Analysis of active failures revealed a high level of slips and violations. Many of these show clear association with failings revealed within the site data analysis – such as task related problems or failures with organisation of the build and site personnel. The site data collection also generated early findings relevant to failures at an organisational level (problems with site culture or in project development for example). The data are explored in greater depth in Phase Three of the research.

Whilst this style of analysis was comprehensive and succinct (compared with the qualitative analysis) there were a number of shortcomings in this approach:

- Introduction of researcher bias

Isolation of data thought to be specifically ‘related’ to the accident event proved difficult. In creating boundaries of what should or should not be included the researcher may have introduced bias into what is theoretically an ‘objective’ method of data representation and interpretation (5.9). Whilst the categories were chosen in good faith and for their known association with impact upon human performance, exclusion of the full range of supplementary or circumstantial information might have served only to reiterate or reinforce preconceptions of the range of factors to be considered in accident causation.

- Confined representation of latent conditions

Exclusion of the full complement of data (perhaps on the boundaries of ‘association’ with the accident) (see Appendix 9), curtailed the exploratory approach and resulted in the loss of enriched understanding of the climate on site or within the organisation - essentially the latent conditions.

- Restrictions caused by categorisation

The categories site and organisational factors were felt to be reasonable representations of the categories in the source research materials (Suraji et al. 2001, Whittington et al. 1992 and Health and Safety Executive 1997b). In practice however,

it was difficult to identify the point of initiation of findings or the junction between organisational and site event (3.8.1.1).

- Irregular access to data

Some detail or information sources were easier to access than others, yet this is not apparent in this style of representation. There was limited access to the accident event area (for researcher assessment) and people in more senior positions with latent factor knowledge. Additionally, up to two months following the incident, interviewees could not always distinguish actual accident related circumstances from other conditions at the time.

7 PHASE TWO - QUALITATIVE ANALYSIS

This chapter introduces the methods and rationale for the qualitative analysis. The generation of a style for data presentation is described and, adopting triangulation techniques, findings from all resources are presented.

7.1 Issues to be considered in results categorisation

Revision of the focus group search terms into the new construction specific search criteria provided an efficient anchor upon which to re-categorise the enquiry needs (see Figure 19). Duplication and fragmentation was reduced and development of data collection techniques was facilitated. Nevertheless, a cost in using this more succinct approach was that the time-line element inherent to the original search terms (Project, concept, design and procurement; Work organisation and Management; Task factors and individual factors) appeared masked. Whilst it was more straightforward to distinguish the types of failures that had occurred, the time of failure generation was not immediately apparent. In order to identify causal factors in construction accidents, it was important to try to distinguish not only the nature of the failures that had led the 'adverse event', but also to try to isolate the project phases where failure may have been generated. These two forms of distinction were vital for isolating areas of concern and for directing further work into latent factor follow-up (Phase Three).

7.2 Solution to categorisation of project data

To illustrate the application of this technique, Table 56 overviews how the findings were categorised. Findings have been generated as a result of the information supplied during the semi-structured interviews and by researcher observation during the site work. The technique used to extract findings from the accident study reports is described in Appendix 9.

Both the focus group and construction specific sets of search criteria are shown below and cross-reference between each permits categorisation according to the nature of the failure and perceived phase of failure generation. Flexibility in use of this approach was essential. Failures, on occasion, appeared to have been generated in more than one phase; this may have been genuine or possibly a conclusion resulting from lack of researcher knowledge or incomplete information. In spite of the shortcomings in this

technique, the advantages of this style of representation lie in the reintroduction of a time element lost in the development of construction specific search terms.

Phase of generation →	Failures concerning Project Concept Design & Procurement (PCDP)	Failures concerning Work organisation & Management	Failures concerning Task execution
Failure category ↓			
Design & task execution <ul style="list-style-type: none"> - Site plan - Design details - Materials - Equipment - Tools - PPE 	Development of building plan, the design development and site layout	Transfer and management of build requirements	Provision of necessary hardware or material effects for the work
Planning Scheduling & Management <ul style="list-style-type: none"> - Project timeline - Appointment of personnel - Scheduling the work - Provision of work area 	Definition and organisation of necessary construction skills	Management and co-ordination of site personnel	Provision of conditions for site occupation and task activities
Information transfer <ul style="list-style-type: none"> - With off-site personnel - Method statements - Risk assessments - On site instruction 	Determining and communicating criteria for build and personnel requirements	Developing and communicating means to assess and define safe practice	Measures to communicate instruction and guidance on safe practice
Individual factors <ul style="list-style-type: none"> - Roles - Skills - Abilities - Attitudes 	Identification of role, factors influencing development and maintenance of skills, individual capabilities and performance, and attitudes towards work and safe performance.		

Table 56. Categorisation of site data findings

7.2.1 Rationale for the reporting of findings

A distinction between immediate causal events (active factors) and findings of a more circumstantial nature (including latent factors) are not made. The reasons for this are three fold:

- Firstly, the aim of undertaking the accident studies was to adopt an exploratory systems approach to identify causal factors in accidents. Whilst the accidents selected for study were seen as broadly representative of construction accident types, it was essential to ensure that findings would reveal the generic nature of the contributory failings (latent conditions) in construction sector accidents. The forty accident studies were essentially a ‘vehicle’ with which to explore the causal failings and risk factors, rather than to serve as an end in themselves.

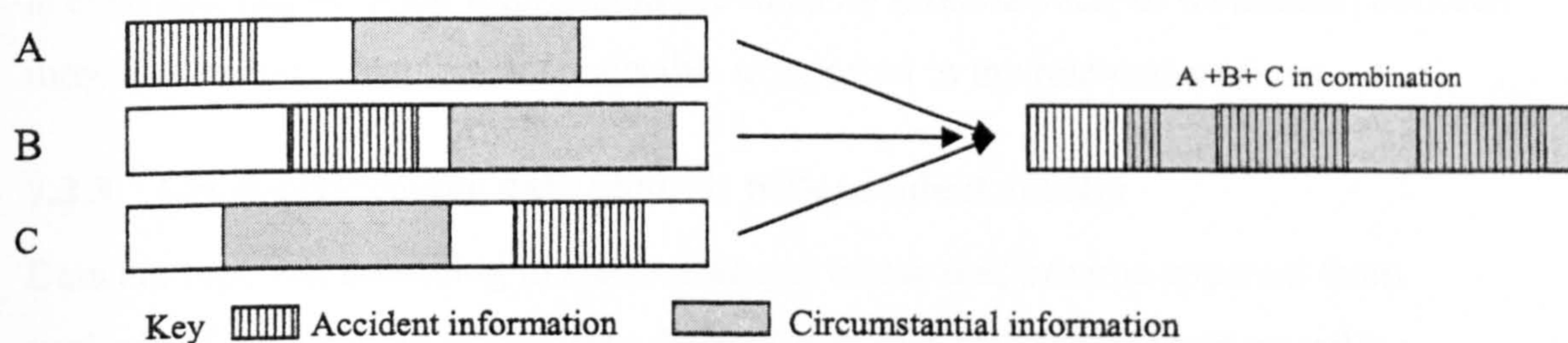


Figure 21. The benefits of combining ‘accident’ and circumstantial information

- Secondly, focus upon the adverse event in isolation would have limited the data source upon which to interpret the nature of failures. In some cases interviewees found accident focused discussions quite emotive (which may have resulted in censoring the information they were prepared to provide), yet were happy to discuss more general issues about their work. By pooling the data across all accidents it was possible to enrich isolated findings ‘directly’ related to the accident, by incorporating information provided without restraint or emotional duress (Figure 21).
- Thirdly, it was rarely a clear-cut exercise to distinguish accident active causal factors from the general factors affecting performance (6.5). By trying to enforce such boundaries, there was a danger of replicating the existing approach (and perceived failings) used within the industry for accident investigation.

This general nature of the data interpretation is redressed somewhat in the process of identifying areas where deeper exploration of accident latent factors would be appropriate – this process was introduced earlier (5.4) and is addressed again in Phase Three.

7.2.2 Arrangement of interviewee responses

It had been anticipated that responses would be generated per interview role. However, the reality was that interviewees were from a range of backgrounds – in age, skill and experience, and this was not possible. In a number of cases the injured party held a supervisory / managerial role; additionally the supervisory / managerial interviewees spanned personnel with a great range of responsibilities – from ganger man through to senior site management staff. Whilst this has excluded presentation of findings by job role, it has provided a number of interesting perspectives. Where there is clear contrast between information provided by interviewees, or distinction between interviewee and researcher accounts this is reported in the relevant sections.

7.2.3 Cross-referencing data analysis with accident studies

Data are reported according to the themes and issues that became apparent from analysis of the accident study data. Information was for the most part raised by interviewees during the semi-structured interview process, but this information was also supplemented by opportunistic discussions and researcher observations during site visits. Captions of the types of comments made during semi-structured interviews are included to illustrate the source of some of the interpretations.

Where possible, the findings in sections 7.3 - 7.6 are cross –referenced to the number of the accident study from whence it was derived.

A count of the referenced accident studies alone does not indicate relative importance, merely a clear attribution of information to a particular accident study. Comparative information may also have been available in other studies, but was not obtained, perhaps because of lack of knowledge by the interviewee or researcher, because the interviewee chose not to discuss certain issues (or was a poor historian) or because access was restricted.

7.3 Results according to Design and Task Execution factors

Design and Task Execution encompassed aspects vital to the physical process of the build. At the Project Concept Design & Procurement (PCDP) phase, this incorporated factors that are relevant to the build scheduling, the design of the build, the layout of the site itself and aspects related to procurement. At the level of work organisation

and management, this concerned the provision and management of supplies and the liaison of information concerning the task and PCDP phases. Finally, at a task-based level this concerned the tools, equipment and materials necessary to progress the work, tasks and work techniques, and the PPE designated for site work.

7.3.1 Design and Task Execution : PCDP phase failures

<div> <div>Failure generation</div> <div>↓</div> </div> <div> <div>Phase</div> <div>→</div> </div>	Project Concept Design & Procurement	Work Organisation & Management	Task
Design & execution			
Planning Scheduling & Management			
Information Transfer (MS, RA, induction etc.)			
Role, skills, abilities and attitudes			

7.3.1.1 Build scheduling

Interviewees reported that a considerable amount of build scheduling problems arose from numerous revisions or extensions to the project timeline (009, 025). Possible reasons for this were repeated client or architect requests for design revisions – with especial problems when there was opposition among those responsible for design choices, and with the numerous architect instructions (both formal and informal) subsequently generated.

... We’ve had over a thousand Architect instructions on this site because of disagreements within the outside design team. A good design should normally have no more than 300. The changes were for a range of reasons the area was not properly designed in the first place; the design didn’t work or they had changed their mind from the original specification

This had implications for the management of the site, including scheduling of all resources (such as supplies for task execution, labour provision and sub-contractor service providers).

7.3.1.2 Detail and design of the structure

Little of the data collected during site accident studies showed immediate problems with the design and build of the structure (although this issue is reviewed later by construction specialists, 8.1.2.1). However, aspects related to failures in the design of the structure were more concerned with uncertainty or lack of any clear specification

of responsibilities; this was especially apparent in the design of structures for temporary works.

In accidents 010 and 051, for example, there was no specification for boarding (both quality and dimensions) to cover holes in the ground. In a similar situation, the extent to which scaffolding should be designed (even to the point of determining whether scaffold clip covers should be used) appeared to be an arbitrary arrangement lacking any clear specification or boundaries of responsibilities (017, 022).

A second and related failing was the lack of fine detail of design, which ultimately had implications for the safety, complexity and duration of the task (002, 004, 018, 035). In accident 004, for example it was suggested by an interviewee that the steel prop that fell onto an operative should have been secured to the ground at the base plate, yet it was unclear to the researcher whether this should be conveyed in the design drawings, in task procedures (such as method statements) or be inherent to the skills of the operative responsible for erecting the structure.

Alternative examples indicated that there is also a certain level of acceptance or 'blindness' to longstanding design problems. On accident 018, for example, protruding nails were accepted as an unfortunate consequence of removing shuttering yet the potential for injury from these was severe. Alternatively, in accident 035 it was indicated that two alternatives were available for joining ducting -TEC screws or pot rivets. It was reported by some interviewees that there might be considerable time savings in choosing one of these methods in preference to the other. However, random comments were also made about equipment cost and TEC gun safety, yet it was not clear to the researcher that the possible drawbacks had been explored in any depth and the possible advantages of alternative working methods remained unexploited

7.3.1.3 Detail and design of the site layout

It was reported that there are problems with the provision of adequate space in the site layout (002, 007, 011, 017, 025, 053, 062). In one case it was felt that the space allocation was hindered by commencement of the build prior to the completion of demolition – resulting in a number of later reorganisations of site layout to

accommodate the changing plan of the build. General reports indicated that inadequate space affected the allocation of ground room for workshop placement, for footpaths, for storage (especially in winter when work is rained off), for parking provision and also adequate space in transport routes. It was reported that the impact of this was in constricted space for vehicle manoeuvrability and access to drop off points – ultimately affecting the ease of receiving deliveries and subsequent need for double handling of the deliveries.

Interviewees also reported problems concerning the provision of incomplete drawings from external services such as the electricity board – a common problem with live lines often unmarked and hazardous during ground work (052). Problems in transport between different levels was described, indicating such things as narrow routes for lorry access or lack of lifting equipment to hoist smaller items between levels (011, 050).

7.3.2 Design and Task Execution : WO & M phase failures

<div> <div>Failure generation</div> <div>↓</div> </div>	Phase	Project Concept	Work	Task
		Design & Procurement	Organisation & Management	
Design & execution				
Planning Scheduling & Management				
Information Transfer (MS, RA, induction etc.)				
Role, skills, abilities and attitudes				

7.3.2.1 Procurement of hardware

Interviewees reported the adverse effects of managing with insufficient quantities or having to work with incorrect materials or equipment because of cost restrictions (004, 017, 038, 062). In one case it was felt that there was a considerable increase in manual materials handling due to inadequate crane time allowances – managed informally with cash payment for assistance from other suitably equipped contractors on site.

7.3.2.2 Managing the provision of task resources

Shortages in the supply of materials and equipment to site were reported and for the most part these comments were provided by interviewees in a supervisory / managerial or safety role. The supply inadequacies included missing, late or incorrect

deliveries and also the delivery of materials where pre-fabrication had not been undertaken, but was expected (022, 036, 040). Interviewees reported trying to work around or re-jig work to accommodate this, but inevitably time was lost in standing around if re-organisation was not possible (040).

7.3.3 Design and Task Execution : Task phase failures

<div> <div>Failure generation</div> <div>↓</div> </div>	Phase	Project Concept Design & Procurement	Work Organisation & Management	Task
	→			
Design & execution				
Planning Scheduling & Management				
Information Transfer (MS, RA, induction etc.)				
Role, skills, abilities and attitudes				

7.3.3.1 Tool qualities

An assortment of tools was described in the accident studies, ranging from simple hand tools through to more sophisticated or powered tooling.

Shortcomings in function or performance were reported by interviewees (002, 052) yet observation indicated a much greater range of problems relating to the tool design. A number of the tools appeared basic with few features to enhance performance or interaction. Typical failings included poor texture and grip characteristics of the handhold areas, pressure points at the face of skin contact and, for powered tools, frequent use of single finger trigger operation (001, 007, 035, 065). Some tools also appeared quite weighty, especially for the circumstances of their use – for example the petrol saw and torque multipliers used in accidents 020 and 039 each weighed 11.5kg and 8.9kg. Tools had also been personalised (by the addition of padding / tape on handles) and, especially where bladed tools were used, a high rate of unprotected handling of the cutting edge was required of the user in order to change blades (007) or to remove obstructions (002). The variable function affecting dependability of performance was also noted with the use of the CAT scanner (052).

Interviewees described behaviour whereby they had to make do or work around tool related issues. This included non-cordoning off of a work area when using (non-flexed) battery powered tools (013). Trying to save time also seemed to be an issue in tool use for three of the accidents (020, 033, 050).

... A Curb lifter is available but by the time you go and get it it's easier to use two people at each end ...

...The saw was quite a heavy and bulky tool for cutting the pipes, but a handsaw would have taken forever ...

Interesting comments were made about criteria for tool purchasing. The self-employed often provided their own tools, although it was also reported that self-purchase was sometimes a matter of choice due to the poor quality and condition of those supplied (013). In describing criteria that lead their purchase choice interviewees most commonly described a 'middle of the road' price range (013, 051) and choice by manufacturer (035).

... Tools in the £15-40 price range are all pretty much the same ...

Interviewees were often unable to recount any other criteria for tool purchase and in only one case was the tool performance - non-rusting - referred to as a purchasing criteria (018). Interviewees obtained their tools from a specialist supplier or through mail order catalogues (018, 051). Tool pricing was a concern for many, especially when the tools were vulnerable to theft, or had a short life-span (003, 061). Some interviewees had received training in use and care of their tooling, but rarely since initial or apprenticeship training (061). Others felt that they had just picked it up as they went along (020, 022, 035, 065) or relied solely on suppliers information (038). Instructions were sometimes unread and considered unwieldy (002).

7.3.3.2 Material qualities

Materials, the base products used for the build development were identified as problematic in ten of the accident studies and of these eight were directly indicated in the adverse incident. Findings included a description of variability in the quality of materials; in accident 001 it was reported

... When the coils of tying wire are heated in the vat (annealing process) the ones at the top don't get heated so much – this makes them stiffer and more springy ... you cant really tell what its going to be like until you start to use it ...

Shortcomings in the way the material was presented for use was also noted for many of the materials identified here. Sharp or abrasive materials were reported (009, 065);

in accident 009 for example the steel banding is hazardous even after cutting, as the sharp ends remain and can cause trips or cuts if it is not properly secured. Cut hazards were also reported in the use of ducting, with the hazard enhanced by slipperiness from the protective oil coating (034). Weight related issues were indicated in five of the accidents (001, 005, 018, 022, 033), yet whilst interviewees made occasional comments about the failings, there seemed to be generalised acceptance of this type of handling within their work tasks and many were unaware of the weight of the materials they were handling - if this information was available.

... There were ten steel angles to be unloaded from the forklift truck onto the storage point on the floor... with a man at each end we expected to take about 20 minutes to do this...

This report from accident 005 for example belies the fact that each angle was 9m x 140kg each. Whilst this was an extreme case, the presentation of materials also appeared likely to impede good handling practice – perhaps through slipperiness of the product (described above) or inadequate contact area for grasp or purchase (001, 033) .

Interviewees were also concerned about the limited information from manufacturers concerning use of the product (002, 013, 022) and of the possibility of contamination of manually handled products by rat urine (001, risk factor for Weil's disease).

7.3.3.3 Equipment qualities

Equipment, including machinery or plant brought onto site, were identified as problematic in sixteen of the accident studies and in all cases were directly indicated in the adverse incident. Failures relating to equipment included adverse effects resulting from inadequacies in dimensions for user anthropometrics or at the point of user interface. These problems were also confounded by shortcomings in equipment maintenance, performance and safety related features.

A main issue concerning inadequacies in the physical dimensions of the products was that user interaction, such as physical or visual access, was hampered. In three cases this related to laddered access equipment. For example, in accident 006, it was reported that a jump was required to descend the scissor lift, and researcher

observation of the work equipment showed that there were no distinct handholds on this equipment to guide the user in this action.

... We're taught to come down the scissor lift steps backwards, but the last step is about 2ft from the ground, so you have to jump the last bit
...

Observation showed that the safety cage on top of the scissor lift offered the most convenient points to make a grasp (at 2.2m from the ground), yet the fixing bolts at 'grasp' point were exposed, compromising the only handhold area. With similar restrictions, it was also reported during the study of accident 021 that the length of ladder attached to the side of the rail wagon inhibited access when working at a depth of less than ground level or if any physical rather than just visual access was required at the top of the wagon. No further handholds were available. Elsewhere the use of split or cut down ladders was also reported (025).

The final example, commented upon spontaneously in three of the accident studies (yet only immediately relevant for accident 050), concerns the small size of the access hole between different scaffold levels. The width generally determined by the distance across two scaffold boards side by side (500mm); an example measurement gave the aperture as 500mm (width) x 950mm (long). With the ladder fixed within this, the actual access area in front of the ladder was approximately 750mm.

In a similar context, problems were also reported concerning the use of scaffold towers. Issues concerned the difficulties experienced in achieving a desirable scaffold and handrail height for the task requirements – given the fixed heights of the rise inserts available (036, 062).

The researcher observed and recorded general comments relating to awkward postures, such as over-reaching to gain access (039). Problems were also observed with load instability, such as fuel moving freely within the container of a fuel bower (038) and the difficulties that were experienced in choosing the correct equipment for the task (060) and in usability factors for the manual movement of loads (022, 060).

... I had a full trolley of plasterboard and was wheeling it along the gangway with help from a foreign labourer. There were communication

problems. If the other man could have understood “stop pushing” instantly it probably would have helped prevent it – not 100% though.

This comment from accident 022 for example shows that for the most part the accident was blamed upon communication issues, yet researcher observation of the plasterboard trolley and accident area indicated that the accident had happened at a bend in the route. The plasterboard trolley had rotating wheels at only one end (the other end having fixed forward facing wheels) and while it was not known which end of the trolley was leading, difficulties in manoeuvring a full load were anticipated. Incompatibility of equipment with the build structure was also reported in accident 036, whereby the depth of the M&E configuration in the ceiling space (ducting and services) inhibited handrail erection (and safe working practice) upon the access tower.

Equipment maintenance was recorded in three other accidents and these related especially to steel parts (such as scaffold clips, concrete pipe clamps and extendable steel props) (008, 018 and 004). Weathering and concrete were reported as the main contaminants and although ‘regular cleaning and maintenance programmes’ were in place, problems with rust and working with equipment in poor condition appeared to add to the physical efforts required in use and manipulation. In contrast, many interviewees spoke positively about the condition of other equipment hired onto or provided on site for their use.

Performance related aspects concerned shortcomings in interaction between parts or structures and also in the interface presented to the users. In accident 004 for example, in removing the shuttering from the column, it was possible for the operative to commence dismantling of the column braces prior to removal of the support props – resulting in a destabilised structure. Whilst it is acknowledged that there are other temporal and procedural issues within this accident study the loss of stability was not visually apparent to those working in the area. Lack of feedback (such as visual, auditory or tactile information to the user) concerning safe state of the equipment was also relevant in other accidents (019, 038).

Usability issues were also reported in accident 011, where the interviewee reported a wide range of lorry types that he might use in his work. There were common features

however, such as the crane controls, but the description of the operation of these indicated that the operational design contravened population stereotype behaviour (pushing the lever down raised the crane and vice versa). It was also reported that inbuilt safety features did not accommodate the accident event.

7.3.3.4 Personal protective equipment (PPE)

Whilst not formally within the physical process of the build, issues concerning PPE are included here as essential equipment for task execution. Use of (at the very least) a safety helmet, high visibility-vest and safety boots was mandatory on all sites visited, with supplementary use of protective eyewear, gloves, harnesses and respiratory protective equipment (RPE), depending on task types. Adverse comments were made about the PPE in twenty-six of the accident studies and were for the most part incorporated within four topic areas – poor fit and comfort; inappropriateness for task type; poor quality, care or condition; and aspects relating to cost and provision.

Reports concerning the safety helmet focused upon inadequacies of fit and comfort (005, 020, 024, 052, 063, 064). The complaints concerned lack of lining / foam padding, insecurity (due to lack of a chinstrap), poor ventilation (especially in summer) and being too small. Interviewees recounted that the helmets were regularly dislodged or fell off (005, 063), induced headaches (024) and interfered with the work upon looking up (023, 024). Many interviewees accepted or were resigned to wearing a safety helmets, but at times these were described as a necessary evil. However, it was also reported that they were not always needed, with interviewees showing frustration at the lack of flexibility concerning whether the helmet should be worn (022, 052, 064).

... With the hat you're more likely to hit your head, as you don't account for the extra height when walking underneath different structures ...

As with the safety helmets, there were a number of complaints about comfort and fit in the discussion of work gloves (001, 005, 033), with operatives describing not wearing them as they interfered with their ability to operate their tools and the speed with which they could undertake their work (052). Operatives reported inadequate supplies (necessitating ongoing use of worn out gloves), inadequate durability, and lack of a suitable size range or quality for their work tasks (017, 018, 040, 052, 062).

There were reports that they always got lost with constant putting on and pulling off (061, 062), whilst others for example reported that 'the gloves had been left in the van or a bag'; there seemed little incentive to wear them.

Interviewees discussed the use of fall arrest harnesses in only a small number of accident studies (only specified trades require use of this type of PPE), yet among those who were in a position to comment, there was a consensus of criticisms about the equipment (004, 006, 017, 018, 036). These included complaints about comfort and fit (especially in use over 30 minutes), concerns about restriction of mobility and inadequate supplies (leading to harness hoarding among site operatives). Interviewees were also worried that the 2-metre lanyard length was inadequate and that they would experience physical damage from the harness itself if they fell. As with the other PPE, harness use was seen as a necessary evil, but given the task disruption impracticalities of hooking on all the time, all interviewees felt that they should be permitted greater discretion on whether to wear the fall arrest equipment.

Fewer comments were made about the remaining PPE. The main complaints about protective eyewear were that goggles steam up and despite the apparent 'common sense' of wearing this equipment, some interviewees continued to avoid their use, in one case due to the added effect of poor lighting on their work (020, 034, 035, 063). Only two comments were provided about Respiratory protective equipment (RPE), and in each case the equipment used was very different (003, 060). Nonetheless the problems reported related to fatigue or to task compatibility problems.

There were random complaints about having to wear the high-visibility vest, mostly focused upon the obstruction they created in accessing tools worn on a waist belt (004, 008, 009) and also due to lack of fabric breathability and the discomfort they generated in hot weather (004, 008, 009).

Lack of an adequate range of PPE, for comfort and for all different environmental conditions, was also reported (019, 025, 037, 051). A number of interviewees reported receiving no training in the care of their PPE (018, 020, 024, 025, 034, 052), some felt that use and care was 'down to the individual' or not necessary as they had used it for a very long time.

In comparison to the complaints recorded about the PPE itself, further comments were generated relating to purchasing and PPE management issues. Many interviewees reported having to buy their own protective footwear and in one case another reported purchasing his own protective eyewear.

Reports from the Supervisor / Manager interviews revealed that their perception of PPE and its availability was quite different from those in operative grades. They perceived full access for all to a range of PPE and that it would even be provided on loan to the self-employed (053). Some reported working with glove manufacturers to trial new products, or in the case of the new short peaked hat tried them themselves to assess the product. These interviewees were concerned about the lack of care shown to PPE, with many reports of finding new and expensive PPE treated badly, left lying around or improperly cared for, precluding re-use (036). Ordering and choice of PPE was in a number of cases an exclusive function of 'Head Office' (061) although in other cases supervisor / manager interviewees were involved. Only a few had tried ordering new styles – their decision mostly led by recommendation or observation of use by other construction teams or by selection from a supply catalogue (040, 050, 051, 062, 063).

7.3.3.5 Task technique

Only limited comment can be offered on issues relating to task technique, as it was only in a small number of cases that it was still possible to see the accident event task. Almost all findings are observations of the researcher – the only hazards relating to task technique offered by interviewees related to risk factors of cement burns (033, 040) or the revision of work techniques when working alone rather than a more usual two man team arrangement (050, 063).

Nonetheless, where technique was described or re-enacted there were a number of physical interactions where risk factors for musculoskeletal injury were observed. These included forceful grips and awkward wrist postures and manipulations (001, 007), and load handling with a broad span hand grasp (033). Interviewees also reported commencing heavy physical work whilst cold and without a warm-up period (050). There was a high reliance upon brute force for many of the work activities observed. In one reconstruction, an operative demonstrated his technique for using a

mitre saw; this involved reaching repeatedly across the body midline to manipulate the wood pieces. Alone, the repetition rate of this task was considered insufficient as a risk factor for musculoskeletal injury, yet the very nature of the technique did involve passing the hand in front of blade and obscuring visual access (002).

From a broader perspective, communication problems were also observed where there was physical distance between a group of co-workers. Examples included liaison of concrete pour between different levels (012) or negotiating the desired delivery quantity when the exit was at some distance from the flow control source (040).

7.3.4 Summary of results according to design and task execution factors

Phase of generation →	Failures concerning Project Concept Design & Procurement	Failures concerning Work Organisation & Management	Failures concerning Task Execution
Failure category			
Design & task execution - Survey land - Site plan - Architecture - Detail - Materials - Equipment - Tools - PPE	<u>Development of build plan, site and design</u> • Build scheduling • Detail and design of the structure • Detail and design of the site layout	<u>Transfer and management of build requirements</u> • Procurement of hardware • Managing the provision of task resources	<u>Provision of necessary hardware for the work</u> • Tools • Materials • Equipment • Task technique • Relating to PPE

Table 57. Summary of results according to design and task execution factors

The results were few when reporting the PCDP and work organisation phases, as only a small number of interviewees could provide information with a direct link to these developmental and management phases. Nonetheless, clear issues arising from the analyses indicated three main areas of concern.

Firstly, the fluctuations that occur at developmental level (in planning, procurement, work scheduling etc.) had considerable impact on site organisational matters. This resulted in those in intermediary positions working in a perpetual state of flux; apparently having to effect the build development by reaction to prevailing circumstances rather than being able to generate and freely move the work forward according to the work programme. (See review and recommendations 9.2.1.1)

Related to developmental problems, a second feature concerned shortcomings in design of the site layout, with apparent inadequacies in space allocation for both planned interactions and to accommodate the fluctuating circumstances of work in progress. (See review and recommendations 9.2.1.2)

A third feature was the apparent lack in designation of responsibilities to manage procurement and task resource inadequacies. This was perpetuated once products were on site; some temporary works lacked clear design specifications and innovation in tooling or working methods was instigated at the discretion of the individual undertaking the task at site level. Inadequacies were described in tooling, equipment and materials, yet there was still no real criteria for identifying and delineating where the responsibilities lay for exploring and managing solutions. (See review and recommendations 9.2.1.5).

‘Task based’ aspects of the work were strongly represented in this section. This was expected, given the volume of semi-structured interviews, with operatives, yet appraisal of the findings shows that interviewees only in a limited number of cases offered critical review of these task-based failures themselves; for the most part the report and appraisal of failures was noted by the researcher during the site visits.

Across all areas covered – tools, materials, equipment and PPE - there were common failings, which were expressed in lack of intuitive design and poor interface for human interaction. These failings include poor contact points for ease of grasp, manipulation and manoeuvrability. Exposed surfaces were at times inherently harmful and appeared to inhibit safe and comfortable use. Some products were often weighty, of rudimentary design and awkward dimensions, and required considerable brute force for the task circumstances. Tool purchasing criteria, for the self-employed, was determined mostly by retail price, with apparently little appraisal of product qualities. Whilst incompatibility with PPE was cited as a problem during tool, material and equipment use, the very nature of the PPE used and incompatibility for comfortable use appeared to be a source of distress for many.

7.4 Results according to Planning, Scheduling and Management factors

Planning, scheduling and management encompassed aspects essential to the process of setting up and running the site – making the design and task execution phase possible. At the PCDP phase, this concerned issues relating to contracts development and the appointment of contractor teams to do the work. At the work organisation and management level, this concerned the appointment and management of personnel undertaking the work. Finally, at task level this concerned the provision of the area where the work was being undertaken and of the surrounding areas serving these work areas.

7.4.1 **Planning, Scheduling and Management : PCDP phase failures**

Failure generation ↓	Phase →	Project Concept	Work	Task
		Design & Procurement	Organisation & Management	
Design & execution				
Planning Scheduling & Management				
Information Transfer (MS, RA, induction etc.)				
Role, skills, abilities and attitudes				

7.4.1.1 Appointment of sub-contractors

Time pressure within the site schedule was often reported (001, 002, 003, 009, 053) and concerns about the financial penalties of project over-run were a burden for those in a managerial position (025, 061). Sub-contracting of the work was a feature on all sites visited and was also the method of obtaining the necessary labour and skill range in Construction Management. Sub-contractors were appointed as in-house skills and resources were kept to a bare minimum or were unavailable (002, 003, 004, 005, 011, 019, 038, 052, 064, 065). Given the fluctuating needs of skill and labour requirements in the industry, use of sub-contractor labour was seen as cheaper than retaining permanent employees on full pay.

Where possible, sites often retained a list of tried and tested sub-contractor groups that they would invite to tender for work. Nonetheless there were a number of comments regretting the loss of a directly employed workforce (001, 004, 021). Typically these general concerns emanated from interviews with principal contractor employees and

concerned problems with the performance and supervision of sub-contractors on site (004, 010). Performance losses were perceived as a loss in speed of 'reaction time' when something needed to be done (001) and lacking initiative or spontaneous action when a need arose (010, 025).

... The sub-contractors are working in isolation; they just consider themselves rather than the rest of the site ...

There were also concerns about the lack of control in appointment of contract labourers, the appointment of people who were unknown to their supervisor / manager and who possibly were involved in double shifting or second jobs outside the industry (021).

The supervisory problems that were reported concerned loss of control with lengthy sub-contractor chains (034) and complaints that sub-contractors do not project manage or address safety issues well (010, 025). In accident 051, for example, the researcher identified that liaison through a chain of four different sub-contractors was required in order to arrange for a work area to be cleared so that another could start.

Reports from sub-contractor interviewees, however, provided a different perspective on these issues. Whilst there were similar reports of working in 'isolation' there were supplementary comments concerning lack of consultation and communication from the principal contractor (005, 011, 038, 062, 064). Complaints related to lack of daily meetings with sub-contractor supervisors and increasing over-ride of formal communication channels the greater the time spent on site (005). Where liaison did occur, it was reported that this was often in isolation for principal contractor workers, or other teams on site, and that it was purely 'task' orientated (038, 062).

... It's frustrating managing practical matters with the principal contractor. You get left to your own devices and the managers wash their hands of you ...

A few sub-contractor interviewees also felt that principal contractor operatives were treated more leniently than those of the sub-contractor and that double standards were in operation (036, 062).

7.4.1.2 Defining contractor responsibilities

Some reports, from both principal contractor and sub-contractor interviewees, related to lack of clarity or ownership of responsibilities, especially (although not exclusively) in construction management (010, 050, 062, 064). The examples concerned clouded responsibilities for issues such as housekeeping, making decisions about site safety requirements and allocation of operative tasks (050, 061, 064). Whilst it was reported that construction managers try to encourage contractors to communicate between themselves (010), it appeared that (for those concerned) this was at times perceived as disregard by management of their responsibilities. Another concern offered by a principal contractor employee was that foremen for sub-contractors are working foremen – undertaking tasks in addition to their supervisory duties. Normally the principal contractor would provide some supervision, and although this does not happen with construction management, sub-contractors did not make alternative arrangements and this has contributed to supervisory failures (010).

7.4.1.3 Ownership of proactive safety behaviour

There appeared to be a lack of clarity and ownership of the responsibility to be proactive in safety, and failure to take initiative and put ideas into practice (017, 022). A small number saw taking action on safety issues as the responsibility of the visiting safety adviser (051). Alternative comments identified a perception by sub-contractor interviewees of a lack of responsibility among big companies (064), yet a contrasting perception from the principal contractor viewpoint was that sub-contractor groups had inadequate insight into the thoroughness of safety management in practice (002).

... If it's a cut it's our fault and he gets a pair of gloves, if it's a trip its not our fault as others supply the workplace ...

Where action was taken, the level of intervention varied between different employers. For example 'regular safety meetings' took place monthly for one employer (004), whereas another undertook this four times a year on a Friday afternoon (050).

Complaints about construction management were prevalent, as the purely 'management' role was seen as removing the principal contractor from responsibility for initiative and action (062, 064). In accident 050, for example, the sub-contractor group felt that the erection of safety barriers (rather than a board over a hole in the

ground) would have been a more appropriate safety measure, yet felt that a decision and action such as this was not within the remit of their responsibilities on site.

7.4.2 Planning, Scheduling and Management: WO& M phase failures

<div> <div>Failure generation</div> <div>↓</div> </div>	Phase	Project Concept	Work	Task
		Design & Procurement	Organisation & Management	
Design & execution				
Planning Scheduling & Management				
Information Transfer (MS, RA, induction etc.)				
Role, skills, abilities and attitudes				

7.4.2.1 Labour supply and appointment

Many Supervisor / manager interviewees reported problems with labour supply, in both volume and quality of workers. It was reported that selection sometimes depended on who was available rather than being able to make an appointment by choice (003, 012, 020, 022, 023, 037, 062); a ‘lack of strong young men’ willing to enter the industry was rued (012). A contact list of ‘good men’ was often maintained and where possible appointments were made from this (009); poor availability of labour appeared especially acute in the larger cities. Interviewees also reported that they were required to appoint a designated quota of labour from the ‘local’ population. At times they felt that this resulted in men undertaking tasks for which they were insufficiently qualified or experienced (003, 037).

Managing absenteeism was also a problem and there were a number of reports where trades and operatives would be moved around and have to take on work outside their normal area of expertise when necessary (020, 022, 023, 038, 039). There were complaints that the multi-skilled ‘modern day’ apprentices were lacking in work experience and at times were ‘more of a hindrance than a help’ (063).

7.4.2.2 Determination of competence

Members of the Major Contractors Group ran all the sites included in the research and it was their policy that appointees at trade level should be holders of a CSCS card (2.5.6). The company Head Office occasionally made this verification (022, 060, 061), or otherwise it was undertaken on site. Nonetheless, supervisor / manager

interviewees, when asked how they determined competence of new appointees on site, reported an additional range of practical methods. These included review of where they had worked before or obtaining an opinion of them from a previous employer (019, 036). Alternatively, they reached a decision by talking with them at induction (019) or by watching and reviewing the men once they had started work – an impression that would often be reached within the first few hours work on site and at most up to a week or two trial (017, 019, 020, 033, 037, 063). A principal contractor interviewee indicated that it was the responsibility of the sub-contractor to ensure appointment of competent personnel (022).

7.4.2.3 Identification and surveillance of fitness for work

Supervisor / manager interviewees were asked to describe arrangements for pre-placement health screening. A number of interviewees were unaware of such a system (063), although others reported that health requirements were stipulated for working in confined spaces (038, 062). Otherwise, there appeared not to be any formal arrangements, although it was indicated that decision about fitness for work would be made by the safety officer, contracts manager or director (040, 050, 060), or would dealt with by whoever provided the site induction (040, 050).

Interviewees reported health surveillance as the provision of an annual medical (036, 051, 061) or access to a discounted gym (037).

7.4.2.4 Supervision of experienced and inexperienced operatives

Operative interviewees reported considerable self-reliance when describing ‘supervision’ of their work, with many informally managing themselves and their own workload (002, 007, 009, 013, 018, 022, 023, 061). This appeared to be especially the case with the self-employed or of those undertaking a particular task type in the long-term (023). Supervision was reported (by both the operatives and managers / supervisors alike) as inappropriate for experienced men – many of whom might have taken a supervisory role themselves on other sites or under different circumstances (002, 004, 013, 052, 053).

Problems appeared to arise when experienced operatives undertook tasks which were 'one-offs' and with which they were unfamiliar - such as covering labourers' work due to manpower shortages (012, 020, 021, 039, 060, 061).

Issues relating to inexperience were also observed by the researcher (although were rarely reported as problems by the interviewees themselves) and concerned the young, or operatives with only a few weeks or months construction experience. Typically, they described worries about not being able to keep up with a fast work pace (005, 012, 040) and appeared reluctant to request assistance or a break when needed (040, 050).

In putting together a team of workers, supervisor / manager interviewees aimed to avoid disruption of established gangs, where there was often strong cohesion, perhaps through family groups working together or a history of longstanding co-working (002, 005, 034, 050). Where teams had to be made up they would aim to mix experienced with inexperienced employees, although this was not always possible (012, 019).

7.4.2.5 Establishing working hours

Interviewees in many of the accident studies reported long working hours (001, 002, 003, 004, 005, 011, 019, 021, 022, 023, 025, 033, 036, 037, 050, 061, 064). The mean working hours of each employee group are shown in Table 58. Weekend work was undertaken by many interviewees and appeared to be accepted practice – in one case seen as a beneficial method to spread the workload over seven days rather than five (061).

Many employees worked in excess of 40 hours / week and working hours, on average, were greater among those in a safety / managerial or supervisory roles (005, 020, 023, 061, 062, 064). Whilst safety and managerial staff appeared less likely to undertake 'overtime', they also described additional working hours as being an inherent part of their workload – perhaps undertaking paper work from home at the week-end or, and especially the case for managerial staff, feeling the need to be on site whilst their operatives were working (064). Few described their additional hours as overtime as they felt that such a schedule was inherent to their appointment and salary agreements.

	Interviewees on site (Total n=77)					
	Safety (n=9)	Management (n=9)	Supervisory (n=16)	Ganger (n=8)	Trade (n=16)	Labour (n=17)*
Mean designated hours / week + (range)	48 (38 ½ - 66)	52 (39 ½ - 75)	47 (39 - 63)	47 (42 ½ - 50)	43 (37 - 50)	43 (37 ½ - 69)
Occasional overtime (O/T) + (numbers able to specify weekly overtime hours)	4 (n=2)	4 (n=1)	14 (n=4)	6 (n=1)	9 (n=2)	15 (n=5)
Mean hours of OT / week (where specified)	17	6	11	12	7	11
Mean total hours / week	52	53	50	43	45	46

* data missing for two operatives.

Table 58. Working hours according to job role

Interviewees in the operative or supervisory grades saw overtime as distinct from their formal working hours; in two cases operatives undertook supplementary work outside the site. In a number of cases interviewees felt that overtime was pressed upon them and something that they could not decline (011, 025, 040, 050, 060); another also suggested that undertaking overtime was habitual rather than something that he really needed to do (013). One interviewee described the ability to undertake up to 30hrs overtime per week, before his pay incentive was reduced (021).

Interviewees also reported the requirement for considerable flexibility in working hours, if this was dictated by the process (a concrete pour for example) (011, 012, 040). Flexibility meant that the provision of breaks was not always honoured. Lengthy work periods without rest were reported (especially in the afternoon) - interviewees both accepted (021) or showed dissatisfaction with this arrangement (011, 012, 021, 022, ,023, 024, 025, 033, 040). On other occasions, however, interviewees were happy to forfeit their break in order to complete work and leave earlier at the end of the day (004, 012, 034, 037, 064).

A number of interviewees also reported long travel distances to work, with greatest duration (of 1 ½ hours or more) especially on the return trip (002, 004, 007, 009, 020, 021, 022, 040, 052, 053, 065). A number of interviewees arose and commenced work travel between 04.45 and 06.00, to arrive on site at any time from 06.45.

Reports also varied when interviewees described their arrangements for sickness and holiday pay and these data are reproduced in Table 59 and Table 60. A number of respondents reported that where they had taken sick leave, that they had not been paid

for this. The greatest number describing this were among the labourer group of interviewees; it was reported that this was a disincentive to take rest in the case of minor illness (034). Unpaid holiday was also reported by those in both labour and trade positions; time taken by these operatives varied considerably. For those who received paid holiday, those at labour, trade and ganger man grades took the least time off on average, with a number taking little or no time at all (018, 033, 040, 050, 053). There were reports of taking pay in lieu of holiday (050, 052).

	Received sick pay	Did not receive sick pay	Received SSP*
Safety (n=2)	2		
Managerial (n=3)	6		1
Supervisory (n=12)	9	2	1
Ganger (n=8)	5	3	
Trade (n=3)	2		1
Labour (n=11)	4	6	1

* Statutory sick pay

Table 59. Payment for sickness absences

	Received holiday pay	Mean paid duration in days (+range)	Unpaid
Safety (n=3)	3	25 (20-35)	
Managerial (n=70)	7	22.6 (15-30)	
Supervisory (n=12)	12	19.75 (13-30)	
Ganger (n=5)	5	14 (6-29)	
Trade (n=8)	5 & 3 no	19 (15-25)	26.7 (5-60)
Labour (n=12)	6 & 6 no	13 (0-22)	21 (0 – 40)

Table 60. Payment for holiday absences

7.4.2.6 Time pressures upon workload

Interviewees reported the effects of a tight build schedule on the management of their workload. Weekend, late evening or night work was sometimes reported as a method to accommodate this (021, 061).

Whilst the formal build schedule was pre-determined, interviewees also reported problems with accommodating unscheduled work (040), although at times unscheduled work was undertaken spontaneously perhaps because the tasks would be required anyway at a later date, because labour shortages were anticipated or ‘to gain time’ (002, 021, 020).

Interviewees described a variety of influences that affected the timing of their work such as delays to check site conditions prior to safely proceeding with a task (060) or delays from the process and access to site (008, 009).

... I had to be quick because the concrete was setting and because the lorry was blocking the road outside for the delivery ...

Time pressure from being 'rained off' was reported (009) and interviewees also described time pressures arising from shortages or late deliveries of materials, equipment or supplies (009, 062). Whilst there was labour shortage through covering sick leave (039), other problems generated from the very presence of other operatives were also described. These included pressures to complete work and vacate an area for access by another trade group, to make materials and equipment available for others that needed it (002, 004, 012, 019), the need to clear up or work around the debris or unfinished work that others had left (018, 025, 050) and slowness induced by another labourer or trainee (018).

A competitive element to time pressure was occasionally described and appeared to be applied to two aspects of work. Firstly this was reported among individuals undertaking priced work and needing to get as much done as possible (005, 013, 061, 063). The second element appeared to have more of a leadership element with reports of competition between different work teams or from initiation by a Site Manager or sub-contractor foreman (001, 005, 050, 063).

... The Charge Hand wants a surge of work first thing in the morning.
The work's not behind, its just his character ...

An important element of the issues described in this section was that interviewees often did not always perceive the situations and circumstances described above as time pressure (002, 004, 005, 007, 011, 012, 039, 060, 63). There appeared to be a generalised acceptance of these circumstances as the norm and that they had to accommodate the ever fluctuating circumstances affecting their work programme.

7.4.2.7 Monitoring performance and providing motivation

Some supervisor and manager interviewees described a range of techniques that they used to encourage performance and to provide motivation for the operatives. The variable methods of liaison were described. Some recounted the need to maintain a good relation with the operatives and included discussion, encouragement and asking the men about their work (019, 022, 050, 061, 063). Others felt that their own manner or rushed pace of working would act as a motivator (017, 064).

A range of practical techniques was also described. One principal contractor interviewee had adopted a scheme of providing a monthly prize (£100) to the best sub-contractor team (judged upon their management procedures, safety performance and adherence to method statements and risk assessments). (025). Where poor performance or unsafe work was observed sites reported various disciplinary measures such as work supervision and warnings prior to dismissal.

Across sites, motivational methods included financial incentives to make the target dates (025, 064) 'job and knock'⁴ (especially on Fridays and week-end work 004, 012, 020, 023, 034, 037, 052) and increased hours or double shifting (025). Fear of redundancy was mooted as a motivator in one discussion (051).

... We did job and knock as the site really wanted to get the work done
...

Whilst it was reported that extra speed was not wanted (as this would make the work unsafe 020, 065), it was otherwise indicated that safe practice would be maintained because of the supervisor's request for it and by his presence (062, 064). Job and knock was not seen to compromise safe practice (020) and in one case it was indicated that the absence of sick pay was an incentive to work safely (051).

One interviewee reported getting a 'pat on the back' for good work (037).

⁴ Term employed in the industry to describe 'job and finish' – the ability to go home as soon as the work is finished.

7.4.2.8 Pay and remuneration

Most interviewees received either salaried (for permanent employees) or fixed wage payments. Fixed wage payments were most common among interviewees at operative level and on-site for a transient period only. Only two operative interviewees received priced work payments (004, 063), yet it appeared that the pay for a number of managers or supervisors from smaller sub-contractors may have been interlinked with the fixed price of the work contract and performance bonuses for work completion (025, 034). When describing payment preferences, interviewees for the most part indicated a preference for a fixed wage (009, 019, 018, 020, 021, 022, 033, 036, 038, 050, 060, 061).

... At 31 I'm getting too old for priced work now ...

... There's less stress and you don't have to take so many risks to earn more ...

Some of the interviewees would have preferred priced work, however, because of the increased earning capacity that this method brings (004, 005, 023, 040, 052) and one reported that priced work was more likely at the week-ends (061).

... It would be very hard to get a bonus on this type of site, but I can go faster on house building work as it doesn't have to be perfect ...

Reasons for rejecting priced work included a conflict with safe working practice (002, 011, 013, 022, 025, 036, 037, 063); those in a safety role especially reported this. The competition between teams and a need to reach a production target were also reasons for rejecting priced work (020, 034, 064).

A small number of alternative payment methods were also described, such as a share of the bonus scheme for finishing work quickly or for working through the rain (034, 052). One interviewee received a loyalty bonus of time off equivalent to 4 weeks sickness absence per year (064).

7.4.2.9 Provision of welfare facilities

Response was mixed when describing the provision of welfare facilities. Many were happy with the facilities, but a number of operative interviewees showed dissatisfaction. Most complaints concerned the provision of insufficient numbers and location of toilets (022, 025, 060, 061, 064), and their dirty and smelly condition (022,

024, 062, 064). Shortcomings in provision of washing facilities were also described, including inadequacies in water pressure or the provision of grit soap (005, 006, 009), and a lack of shower facilities (011, 025, 037, 052). Whilst complaints about changing room provision were fewer (009, 037), there was concern about lack of security with reports of lockers broken into (065).

Complaints about provision for food and drink were few; a single complaint about access to fresh drinking water (008). All others concerned the pressures upon use of the canteen at break times, with queuing reducing break allowances and lack of space resulting in some having to eat in the changing rooms (023, 052, 039, 064).

7.4.2.10 Documenting accident events

Further analysis of company accident investigation forms (see 5.2.1.2) was not undertaken. However, the baseline documentation provided for many of the accidents studied were a mix of company forms (similar to those in 5.2.1.2) used either alone, and /or with forms used by the appointing contractor (in the case of a sub-contractor employee accident). Some of these were also used in combination with forms defined by regulatory requirements. These included the F2508 (for the RIDDOR incidents) and, the ‘accident book’ record BI 510 (as required by the Social Security (Claims and Payments) Regulations 1979). Aspects to be completed are reproduced in Table 61; as with the evaluation of construction industry accident investigation techniques (5.2.1.2), these did not embrace the range of search criteria (latent conditions and factors affecting performance through the project lifecycle).

	F2508	BI 510
Name of reporter and company	✓	✓
Incident record (time, location)	✓	✓
Injured person details	✓	✓
Injury details	✓	✓
Accident / dangerous occurrence kind (predetermined RIDDOR categories)	✓	
Description of what happened	✓	✓
- detail substance, equipment, precursor events, actions of others & describe remedial action	✓	

Table 61. Accident record forms to fulfil regulatory requirements

7.4.2.11 Managing accident investigation

Where possible, site accident reports were collated with descriptions of accident causes provided by interviewees to the researcher. Whilst in most cases the main

elements of the accident were documented, there were also anomalies of information. At times, accident involved interviewees were unfamiliar with the recorded description or their own account of events showed some disparity with the detail documented (013, 037). Accident records were also used as a forum to document complaints or requests for improvement to work circumstances (062).

... Slipped on inside of scaffold, fell and twisted left knee. Mud on boots caused slip. Designated footpath was asked for in H&S meeting. Item 15 in minutes ...

In a number of cases, it appeared that the person making the report had become involved only after the accident event and did not comprehensively document the accident details. The researcher felt that possible reasons for this included lack of space on the accident report form or because those involved had been reluctant to describe their own or others inappropriate behaviour or technique (008, 012, 022, 036, 060, 061). Whether they had completed the report or not, supervisor / manager interviewees were not always aware of the techniques or work circumstances of the accident involved interviewee (009, 061).

Interviewees descriptions of accident causes to the researcher for the most part fell into three categories. The first category (described both by supervisor / manager and accident involved interviewees) was that the accident was often seen as a 'pure chance' event (009, 033, 036) and that risks in techniques or work area (002, 009) were not perceived. A fatalistic approach was observed on a number of occasions; for example, interviewees were quite dismissive of the risk of skin damage in the manual handling of materials or in working with cement (004, 033, 053, 040) and had an expectation of higher risk working conditions in the housing sector (020).

The second category encompassed attribution of blame; generally this was directed at 'accident involved' interviewees, although there was one incidence directed at 'site control' (020). Typically the responses encompassed a range of sentiments that related to behaviour type failures, such as over-familiarity (002), carelessness (019, 024) complacency (022), negligence (024), rushing (024), lack of concentration and judgement (002, 011, 022, 24) or distraction (013, 022, 033, 037). There was one

incidence blamed upon recurrence of an old injury, thought to have been undisclosed by the victim at start on site (037).

Where relevant, some of the areas of blame were provided in the context of poor work technique, such as incorrect use of task equipment (011, 012, 013), working alone when two people would have made the task easier (018, 061) or incorrect use of PPE (040).

... He probably wasn't watching what he was doing; he was in a group and probably chatting ...

The third category of attribution concerned failures related to 'task related' aspects, such a poor machine design (002), or problems in the handling of materials (002, 005). Interviewees also expressed concern relating to poor condition of the work area (011).

7.4.2.12 Identification of accident remedial action

Responses to the accident events varied. Many interviewees reported no action at all (017, 035). Different reasons were given for lack of action, including the accident incorporating accepted hazards and being an unquestioned part of the job (009, 033, 034, 050), the job being a one-off or just temporary work (036, 060, 061), and that any intervention would have taken longer to do than the job itself (061). Interviewees also reported that remedial action would not be necessary because they were already following site rules (004, 022, 036), or because action was outside their remit and the responsibility of the principal contractor (022, 051, 064).

Where action was taken, this was applied in a number of different ways. One measure was to review and provide or reinforce guidance on work behaviour, such as advising people to get extra help when needed (039, 050), or to use better and less hazardous task techniques (019, 023, 024). For other accidents, the response was to reiterate the need to use PPE (033, 039, 063, 065), to advise improved housekeeping in the work area (025, 053, 062) or to install traffic cones over walkway obstructions (064).

Where remedial action was directed towards the generation of new ideas, these concerned the development and instigation of more robust procedures (020), and the consideration of new or safer equipment designs (012, 038).

7.4.2.13 Providing opportunities for operative consultation and communication

Operative grade interviewees reported variable opportunities for consultation and communication about work organisation and safety related issues. Some were involved in a discussion only concerning their own tasks (018), whereas a number of other respondents reported being 'told' and not being part of any consultation at all (010, 012, 022, 050, 052, 060, 061).

Other interviewees were included in discussions about work organisation, but not about safety, (020, 025, 052, 063) or vice versa (024, 037, 061, 063). Whilst one interviewee would have like much greater involvement, most interviewees felt that they could initiate discussions or make suggestions if they wanted to. Many spoke favourably about positive developments in 'health and safety' over recent years, yet there were also reported incidences of inaction in response to concerns raised about inadequacies in the provision of facilities (002), and of the quality and safe use of work materials and equipment (001, 004, 025). Complaints also related to general working conditions, in most cases concerning the condition of the site working areas, walkways and footpaths, in terms of poor housekeeping and trip hazards from protruding structures and uneven or poorly maintained surfaces (002, 004, 017, 025, 050, 051, 061, 064).

Interviewees often had positive suggestions or recounted experience in previous work (often abroad) of possible solutions to their problems. These related to improvements in tooling, equipment or materials design (001, 009, 018, 052), yet none of these ideas had been communicated to others.

... The tying wire comes in a 25kg roll here, but in Germany they come in small cartons which is much better ...

... When I was working in the Bahamas they used to have proper nips for cutting steel banding, but I haven't seen them here ...

... The sun bounces off the concrete and causes a lot of glare – perhaps adding some colour to the mix would reduce this? ...

7.4.3 Planning, Scheduling and Management : Task phase failures

Failure generation ↓	Phase →		Task
	Project Concept Design & Procurement	Work Organisation & Management	
Design & execution			
Planning Scheduling & Management			
Information Transfer (MS, RA, induction etc.)			
Role, skills, abilities and attitudes			

7.4.3.1 Ground, floor or foot placement areas

Interviewees reported many situations where the conditions ‘underfoot’ were a contributor or risk factor for accidents and these concerned the task and service areas (001, 017, 022, 037, 051, 052, 062, 063, 064). Common problems reported were raised structures on the walking surface that created trip hazards – typically the extent of the rise was often low enough not to be seen easily, yet significant enough for a trip to occur. In accidents 017, 037, 051 and 064 for example, the trip hazards were electrical cables, ply board used as a temporary manhole cover and setting out points – These structures were coloured either black, (steel) grey or brown and at most would have stood less than 50mm proud of the floor / ground surface.

... If the points had been marked or coloured then I could have seen them better, but they are steel discs, which is like a camouflage...

In other areas, the rise was much higher or more obviously precarious for walking over, such as working on or over rebars or upon loose ground or brick rubble (001, 053). The condition of traffic routes and walkways also received a high number of reports of problems (051).

... There is always brick dust, which is a slip hazard, but when block work is cut the debris is like roller-balls under your feet ...

Complaints focused upon partial obstruction of access areas or footpaths, with debris, deliveries or traffic cones for example (017, 062, 064) and of the shared access of pedestrian and traffic routes (062). Allied to the concerns about pedestrian access, was the impact that the condition of the floor or ground had upon the safe movement

or stability of mobile equipment, such as lorries, hoists or scaffold towers (011, 050, 060). Surface hazards such as spilt oil, mud, cement or wetness were also reported (022, 040, 052, 062).

7.4.3.2 Workspace provision

In addition to the reported problems at ground or foot placement level, there were also reports concerning the remainder of the workspace. These included constraints upon the space available for movement and manipulation activities (002, 003, 012, 020, 060) and inadequate work height or inappropriate work surfaces for materials or equipment placement (007, 039). Associated with space limitations were the presence of structures, such as scaffold cross-membering and protruding structures that impeded free movement (018, 036, 050).

7.4.3.3 Housekeeping

Poor housekeeping was reported by many interviewees, and they recounted the general problems of dust and lack of clearing up by others (002, 022, 023, 024, 050, 051, 061). Allocation of responsibility for clearing up was seen variably as something they would expect other gangs (who had created the problem) or the Principal Contractor to undertake – at worst work gangs were reported to push rubbish to one side or delay their work schedule in order to clear up after others (024, 051, 053, 064). Alternatively, it was felt that the weekly delivery of an empty skip that ultimately prompted a clear up – its predecessor being too full to take any more material long before it was exchanged. One interviewee, however, felt that he was less careful when the work area was overly tidy.

7.4.3.4 Environmental conditions

Whilst many operative interviewees cited poor weather (eg. cold, wet or windy) as one of the worst parts of their job (7.6.1.8), they rarely appeared to see this as having any direct implication to performance or accident risk factors. Accident involved interviewees were asked for opinions on adverse environmental conditions and where this was provided interviewees spoke about lighting conditions and dusty working conditions. There was one report of distracting glare from sunlight reflecting upon concrete (018), but all other reports concerned poor background lighting or inadequacy of daylight in terms of availability and task illuminance (002, 037, 050,

051, 063, 064). Too much dust was reported during general clear-up (008) and by interviewees involved in duct work.

7.4.3.5 Organisation of tasks between different trades or operatives

Many operatives appeared to organise their own task workload and three main aspects were reported to impact upon this task activity. The first of these was the occasional need to accommodate unplanned work – perhaps as a consequence of fluctuations elsewhere on site such as shortages in labour or resources (002, 019). In accident 002, for example, a stock of window braces was being made up because extra bricklayers had unexpectedly been appointed to site (using the existing supply of cavity closures) and because shortage of carpenter labour was anticipated in the next few days.

The second factor that impacted upon undertaking of tasks was the need to accommodate the space requirements of other workers. Some reported that space and scheduling provision was adequate for each group, whereas others indicated some form of ‘trade overlap’ in the work area (004, 005, 013, 023, 024, 025, 036, 051, 052, 053, 060).

... Most jobs are fast track programmes and you end up working on top of one another ...

The descriptions provided by interviewees indicated that this was an accepted and normal part of their work, yet the impressions of the researcher were that this affected ease of access and induced operatives to speed up if others were waiting for them to finish or indeed if they wished to gain first access to an area (005, 023, 024).

The third aspect that impacted upon undertaking of tasks concerned generosity and a desire to help others (and not necessarily within their own gang) when assistance was required. This took the form of helping others in their use or movement of equipment (012, 019, 039) and in helping older workers with strenuous activities (034). Not all offers were quite so altruistic, however, as there was also a report from a supervisor who chose taking ‘the risk’ himself as a measure to avoid having to do any ‘paperwork’ (021).

7.4.4 Summary of results according to Planning, Scheduling and Management factors

The results in this section were fewest when reporting failures at the PCDP phase, yet they echoed the failings of clear specifications and designation of responsibilities, which were also apparent at the Design and Task Execution level.

Phase of generation	Failures concerning Project Concept Design & Procurement	Failures concerning Work Organisation & Management	Failures concerning Task Execution
Failure category			
Planning Scheduling & Management - Project timeline - Appointment of personnel - Scheduling the work	<u>Defining and organising labour supply</u> <ul style="list-style-type: none"> Factors affecting sub-contractor appointment Factors affecting distinction of contractor responsibilities Ownership of proactive safety behaviour 	<u>Managing and co-ordinating site personnel</u> <ul style="list-style-type: none"> Labour appointment Determination of competence Identification and surveillance of work fitness Supervision of experienced and inexperienced operatives Establishing working hours Time pressure upon workload Monitoring performance and providing motivation Pay and remuneration Provision of welfare facilities Documenting and undertaking accident investigation and determining remedial action Providing opportunities for operative consultation and communication 	<u>Provision of suitable task conditions</u> <ul style="list-style-type: none"> Ground, floor or foot placement areas Workspace provision Housekeeping Environmental conditions Affecting operative task organisation (trade overlap)

Table 62. Summary of results according to Planning, Scheduling and Management factors

In the context of Planning, Scheduling and Management (PSM), the discrepancy revealed isolation between different contractor groups and little real sense of 'community' on site. This appeared especially apparent between the principal and sub-contractor groups, and appeared to be linked to losses in communication, consultation and co-operation that were formerly apparent with greater levels of direct labour employment patterns. Allocation of responsibilities and authority among contractors on site was unclear, with resulting feelings of exclusion, loss of belonging, ownership and goodwill, and of undercurrent frustration with others on site.

An overwhelming proportion of the findings in this section were related to aspects concerning work organisation and management of sites. Firstly, and in spite of formal methods for verification of the skills and abilities of new starters to site, an informal assessment process appeared to be running in parallel. This may have reflected a lack of confidence in the fidelity of the formal scheme or poor change management with its introduction. Nonetheless, with underlying restrictions in supply of the desired labour and skill range, a two-fold assessment process was apparent and burdensome for those in supervisory positions.

Whilst issues surrounding appointment criteria revealed duplication in formal and informal procedures for skills verification, there was a contrasting dearth of occupational health assessment (either pre-placement or as part of a health surveillance programme) and this was a second area of concern. Where attempts were made at pre-placement health assessment, these appeared to be unregulated and were undertaken by personnel without the competencies to make informed decisions. A few attempts were made at health surveillance, but it was not possible to determine the occupational relatedness of these interventions.

Lack of, or poor, regulation also emerged as the third area of failure in organisation and management of task operations. Whilst supervisors reported the need to observe and oversee the work of new operatives on site, their oversight rapidly declined once new appointees capabilities had been observed and 'approved'. Supervision for these 'approved' operatives appeared almost obsolete and they worked in relative freedom, with high decision latitude and autonomy. Whilst this freedom was welcomed at both supervisory and operative grades, problems (directly associated with some of the

accidents) emerged when new or unusual work was required. It appeared that there was quite an unsympathetic and traditional hierarchy for young and inexperienced operatives to reach 'approved' status; for any operatives, task-based learning appeared consequential to time on site or time spent working alongside others. Given the very nature of the work, novel circumstances and work conditions were frequent, yet there appeared to be little endorsement or presence of a learning culture to promote skills development during working time on site.

Similarly, some at operative grade perceived opportunities for consultation and communication, but this was largely informal and there was little sense of ownership, respect or response to the system when available. Contrasting with the poor learning and consultation culture, the impetus and priority on site was for the most part uniquely directed toward build progression. Whilst the fundamental need for work progress was not questioned, it appeared that lack of regulation, already attributed to skills development, was also apparent in more fundamental aspect of work organisation across the industry.

Temporal issues such as long working hours and overtime culture, which coupled with possible financial impediments to full holiday and sick leave, inhibited opportunities for rest, relaxation and recovery. Closely related to problems with working time, the motivational measures (often related to job and finish type arrangements or provision of bonus payments for work acceleration and completion) appeared likely to additionally confound opportunities for rest and safety in working methods.

There was a lack of insight into the possible health and safety impacts of these motivational methods. A habitual acceptance or blindness to the nature of adversity in the industry was the final area of concern. This was represented not only in working time arrangements, but also in the lack of perception of pressures upon working time, the lack of perception of the impact of trade overlap in work areas and the lack of perception concerning the impact of the condition of welfare, work and transit areas upon performance, safety and comfort of personnel.

Habitual acceptance was also apparent in the management of accident investigation and remedial action. There was multiplicity in form completion among principal and

sub contractors, and forms provided by regulatory authorities did little to encourage deeper or reflective accident investigation. Blame orientated culture and superficial site investigation of accident causal factors was common and essentially very little was done in remedial action that impacted upon or challenged the status quo.

7.5 Results by information transfer factors

Information transfer was largely concerned with determining and communicating criteria for safe development of the build. At the PCDP phase, this concerned liaison and communication in the pre-site stage of the work, whilst the work organisation and management phase concerned the techniques used to assess and communicate the details of the work plan, process and safety requirements. Consideration of information transfer at task-based level concerned issues relating to the induction and training of site personnel.

7.5.1 Information Transfer factors : PCDP phase failures

<div> <div>Failure generation</div> <div>↓</div> </div>	Phase	Project Concept	Work	Task
		Design & Procurement	Organisation & Management	
Design & execution				
Planning Scheduling & Management				
Information Transfer (MS, RA, induction etc.)				
Role, skills, abilities and attitudes				

7.5.1.1 Pre-contract information

Interviewees in sub-contractor roles reported problems that arose from late provision of design guidelines from the principal contractor (009). Provision of incorrect drawings or information from utility services (such as underground supplies) was also reported, resulting in the need for further liaison and revision later in the build process (009, 020, 052). The researcher also gained the impression that pre-contract materials (including method statements or confirmation of health and safety arrangements) were, at times, styled primarily to demonstrate an ‘intention of good practice’ in order to curry favour in the competition to gain the work contract.

7.5.2 Information Transfer factors : WO & M phase failures

Failure generation ↓	Phase →	Project Concept	Work	Task
		Design & Procurement	Organisation & Management	
Design & execution				
Planning Scheduling & Management				
Information Transfer (MS, RA, induction etc.)				
Role, skills, abilities and attitudes				

7.5.2.1 Risk assessments

There were no risk assessments for many of the accident studies (006, 007, 008, 009, 012, 017, 019, 018, 020, 021, 023, 024, 052, 036, 037, 038, 040, 050, 054, 061, 065). Most commonly, this was because the accident activity was seen as a core skill of the person undertaking the task (001, 002, 033, 061) or because the accident did not occur during a task activity (Table 49). Where risk assessments did exist, the hazards that contributed to the accident events were often excluded (002, 012, 034, 039, 052, 061), or control measures were not enforced (035).

Where possible, the risk assessments were evaluated by the researcher and a range of shortcomings were noted. Typically, there was insufficient detail to reflect operative practice during the task; generic risk assessments of repeated activities were commonplace, but breadth of application seemed to date these quickly and render them less well to the unique circumstances of site, task and work conditions (052, 063). In one circumstance, the risk assessor was directed to identify risks only if there was a ‘significant risk’ of injury (034). Additional failures were that alternative risks to the accident event had been identified (061) or, often in the case of handling or manipulations, human interaction had not been identified (033, 039, 055).

Various presentation styles were used and commonly these constituted a questionnaire type form inviting tick box responses, a range of prescribed questions and answers that could be selected at will by the assessor, or boxed areas for the addition of free text responses. Assessment of these revealed problems with style and presentation – at times quite complex sentence or language styles (034), scoring systems without easily identifiable meaning (005, 034) and comments with inadequate detail such as “Use the correct PPE” (063).

In a number of the accident studies, interviewees (mostly operatives) were unaware of the existence of the risk assessments (012, 022, 033, 034, 035, 052, 060, 061, 063).

7.5.2.2 Method statements

There were no method statements for many of the accident studies (006, 007, 008, 009, 017, 018, 019, 020, 021, 023, 033, 034, 036, 037, 038, 050, 051, 061, 062) and most commonly this was because the accident event did not fall within the process description for the section of the build being undertaken (i.e., walking around and preparation type activities) (062, 064, Table 49). Where the method statements did exist, many operative interviewees were unaware of them, or did not recall any procedures or instructions for their work (011, 012, 022, 033, 034, 035, 052, 060, 063).

The method statements were often married with or used alongside a risk assessment. Where it was possible to review the content and style of the document, a number of recurring adverse features were observed. Firstly, the content of the method statements was mainly concerned with the necessary sequence of steps from which to develop the process from initial to end stages. Whilst the process was often carefully structured, there was at times little or inadequate detail of the tasks that were required, skill requirements and the human interaction necessary to achieve the activity (001, 002, 005, 024, 035, 039, 040, 063). In accident 005, for example, the work sequence and lifting equipment required to lift the steel angles up and into the building was recorded, yet there was no description of the human interaction that was required to load or unload the angles between the different handling equipment.

It is of course possible that the manual lift in accident 005 was not a planned activity and this is the second area of concern; that the method statements are invariably prepared well in advance of the time at which they become effective, or are generic documents for repeated application to same type situations (009, 010). In either case, the content describes a best case scenario, yet is isolated to the prevailing circumstances at the time of task execution, such as access to an area, or equipment and tooling availability etc., at the very least. As such, the document appeared to serve well as a tool to develop or schedule a part of the build process, but was

invariably redundant or un-applicable at the time of actual application. Nonetheless, the documents were used as an audit tool to confirm safe work methods (011, 022).

Method statements varied in length, at times a single sheet (038, 040), although a number were very long – up to 20 pages and with multiple process steps (44 in one case, 039). Reading or reading out the method statement was often used as a training medium. In some cases, the language style and sentence construction was complex and of a regimented style; this was considered by the researcher to be inappropriate for low skill readers or for those with a low span of concentration (001, 033, 039).

Preparation of the method statement was generally undertaken by someone in a 'management' position, such as Contracts Manager (001, 009, 013, 050), Project / Construction Manager (002, 005, 009), Facilities Manager (003), Civil Engineer (004), or Site / General Manager (009, 011). Often they were developed from existing method statements or from generic materials, provided by a safety consultant (039, 040) or based on a style devised by the site principal contractors. Interviewees on site were occasionally consulted or involved in preparation of the method statements, although this appeared to be less common with those co-working at operative grades (001, 022, 040) or by sub sub-contractors in the chain. Where interviewees were able to comment upon the preparatory process, they reported that the documents were often prepared before site work began (022, 050) and that there was often inadequate information available at the project outset (009, 022) or there were time constraints in preparation time due to inter-contractor competition for the contract (033).

7.5.2.3 Ownership of provision of information transfer

Information transfer also included the provision of toolbox talks, induction and on the job task training. Provision and receipt of information transfer among sub-contractor groups varied and it was quite difficult to identify the systems in operation. Principal contractors seemed to provide toolbox talks at some sites. At other sites, however, each of the sub-contractor chains were expected to provide their own specialist training or toolbox talks (010, 020, 050, 062), but might occasionally be drawn into the arrangements of the next contractor in the contract chain (034).

Uptake of training varied among interviewees, both in frequency and range of training undertaken. The impression was that principal contractors at some of the larger sites accommodated sub-contractor employees, at a cost, into their own CSCS training schemes (013, 022). The CSCS training schemes were available elsewhere too, but often it appeared that the costs were born by individuals (especially those self-employed) and that this was prohibitive for some (004, 033).

7.5.3 Information Transfer Factors : Task phase failures

<div> <div>Failure generation</div> <div>↓</div> </div>	Phase →	Project Concept Design & Procurement	Work Organisation & Management	Task
Design & execution				
Planning Scheduling & Management				
Information Transfer (MS, RA, induction etc.)				
Role, skills, abilities and attitudes				

7.5.3.1 Styles of training provision

Paper-based training methods were regularly used as a mode for conveying information – these included booklets or leaflets on general health and safety information (033), manual handling training techniques (017, 050), site inductions, toolbox talks (062), and method statements and risk assessments. Where paper-based methods were used, it was reported that interviewees would either be given the material to read themselves, or that this would be read out to them (often during induction).

Interaction or use of supplementary training media (such as video, pictorial means or case histories), seemed infrequent (53) and there were concerns that the training messages were lost because of selection of inappropriate interface styles for the target audience (025). Interviewees who held supervisory positions, which included training provision, commented on the lack of training that they had received to undertake their own role - citing needs of their own for training in safety and management, and in the provision of toolbox talks and inductions (001, 040, 052).

7.5.3.2 Site induction

Both positive and negative comments were received about site inductions. Positive reports concerned the value of induction to introduce information unique to the site and also to inform newcomers about necessary emergency and health and safety information (040, 052, 064). On the other hand, other interviewees reported that site inductions offered no value (009, 022, 023, 025, 034, 037, 040, 050, 051, 052), citing reasons such as 'it's all common sense' (002, 036, 038), that 'they're not attention grabbing' (018, 038 052) and that 'they tell you what you already know' (005, 034). Others found them a time consuming formality to enter site (006, 036), appropriate for specialist sites only (061) and complained that they covered issues (such as drug / alcohol) that those running the inductions were not qualified to make a judgement upon (040).

Interviewees reported a variety of different styles of induction, ranging from a single sheet bullet point list of information through to mixed media including a range of video presentation, discussion, pictorial and paper based methods. When describing any preferences for presentation style, interviewees both liked (019) and disliked (064) the video methods, but were less keen when they had to read information themselves (051). In interviewees' experience, inductions varied in length from thirty minutes up to two days on some of the larger aeronautical or petro-chemical sites; for some, induction was one of their only sources of safety training (034).

Induction was both perceived (017, 061), and not acknowledged (024), as a training method. Issues such as Weil's disease, needle-stick injuries, fire and muster points were commonly remembered contents (017, 018, 051), yet others found the induction was too long or difficult to take in (017, 019). Some reported that the contents were not appropriate for their work, such as those undertaking delivery driving or who were specialist tradesmen (002, 011, 018).

... They're not any value when you've had so many – I just need to know if site varies from others. They're not really to do with scaffolders work, yet they always get the blame and into trouble...

7.5.3.3 Toolbox talks

Many of the operative interviewees received toolbox talks and there was varying perception of the value of these. Positive comments were received, although it was acknowledged that it was difficult to try to make these stimulating for longstanding employees (036). More negative reports concerned inability to remember the topics that had been addressed in toolbox talk training (040, 062), the use of toolbox talks as methods of controlling misdemeanours (such as going home early) or as a reprimand of some type of failure or accident (022, 036).

7.5.3.4 On the job learning

Interviewees also reported that their task skills were developed by less formal (and un-assessed) methods, such as practical experience alone (005, 020, 040, 060), or on the job learning.

... I do this job six days a week, and you can't get any more trained than that ...

... I haven't had any training – it's just something you pick up isn't it ...

On the job training was undertaken by many interviewees and was the sole method of skills development for those whose work was not a formally recognised trade, such as ground working (052), ceiling fixing and duct working (022, 024, 034) (although it was reported that efforts were being made to develop an NVQ system for duct workers). Interviewees from these groups felt that their expertise was underestimated (022, 052) and that they were dependent upon the ability and goodwill of their co-workers or supervisors in learning the necessary skills (009, 022).

7.5.3.5 Transferring training into practice

There was a range of favourable and negative comments surrounding training provision and a number of concerns were reported by interviewees and observed by the researcher. Many interviewees reported no especial training for undertaking the accident event task (009, 017, 019, 020, 022, 024, 034, 035, 038, 040). In some cases this was because the accident had occurred during non-task activities, such as movement around site, or because they had previously gained their task skills through a variety of formal and informal methods.

Evaluation of the training related issues by the researcher revealed a number of additional issues relevant to construction industry practice and the accident events. The first of these relates to different perceptions between those in operative and those in supervisory / managerial roles as to what constitutes training. In a number of cases, the supervisor / manager reported that training (such as toolbox talks, induction, task technique) had been provided to the accident involved personnel, but discussions with the supposed recipients often revealed that they did not perceive this (017, 020, 022, 040, 061). Informal site based instruction or toolbox talks were least likely to be perceived as training (065).

... I've never had any safety training ... (later) ... I had a toolbox talk this morning 'How to walk safely on site' – it was OK ...

A second feature concerns mistrust or trivialisation of training; with comments implying that it is a method to comply with health and safety rules rather than as a method of skills transfer (020, 038). In accident 005, for example, it was reported that the supervisor provided manual handling training to the accident involved interviewee, after which they then proceeded with the manual lift in spite of severe load and mismatch of team handlers. Some interviewees acknowledged receipt of toolbox talks in the three months preceding the semi-structured interview, but were unable to remember what these covered (040, 062). Alternatively, there were reports of working safely when the safety advisor was around, yet instructions to resume 'normal' practice when they left (023).

A third feature observed by the researcher was that although some type of training may have occurred, this often did not address the initiating activity of the accident. These included manual handling (such as pushing and manipulation of equipment) (022, 038, 050) and housekeeping (062). There were mixed reports about too little (023) and too much training (012, 022) and also some mixed comments indicating confusion or uncertainty about defining correct task techniques (004, 012, 024).

A final feature concerning all 'information transfer' issues was the value interpreted from obtaining a 'trainees' signature. In many instances, interviewees reported 'signing for it' after receiving some type of information (001, 005, 009, 025, 050, 051, 061, 062). Interviewees described this as a foundation upon which to reprimand rule

breaking (037) or as a disclaimer of responsibility by those in authority (004, 005, 009).

7.5.4 Summary of results according to Information Transfer factors

The results for this section were dispersed across each of the PCDP, Work Organisation and Management and task phases with findings in common across all levels.

Phase of generation	Failures concerning Project Concept Design & Procurement	Failures concerning Work organisation & Management	Failures concerning Task Execution
Failure category			
Information transfer <ul style="list-style-type: none"> - Client - Off-site personnel - MS - RA - TBT - Induction 	<u>Determining criteria for build and personnel requirements</u> <ul style="list-style-type: none"> • Factors affecting contract, design and development of work schedule 	<u>Developing means to assess and define safe practice</u> <ul style="list-style-type: none"> • Risk assessment • Method statement • Ownership of training provision 	<u>Communicating instruction and guidance on safe practice</u> <ul style="list-style-type: none"> • Styles of training provision • Site induction • Toolbox talks • Transferring training into practice • On the job learning

Table 63. Summary of results according to Information Transfer factors

There were anomalies in the way that information transfer was interpreted and used. At PCDP phase, late provision of information apparently constrained the development of risk assessments and method statements, yet at this pre-site stage the documentation (essentially developed and used as a competitive tool to gain contractual work) preceded the point of application by a time period often of many weeks or months. In addition, the level of detail varied among the documentation that was included in the research. Even where there was some indication of the task elements necessary to effect the process, the delineation of what were inherent core skills of the operative and what instruction needed to be detailed was unclear and a source of confusion. Risk assessments were more likely to be applicable to task elements of the work process, yet invariably accidents did not occur during a task activity – setting-up, transit and clearing up the work situation received little coverage in either document, yet were heavily represented in the accident incidences.

Method statements, often developed from generic materials, were essentially a 'best case' or even Utopian transcript of anticipated practice during sections of the build process. At the time of application, however, they did not necessarily reflect the prevailing circumstances at the time of work enactment. Those at task level rarely perceived them as working documents, yet their value as an instructional / training tool was seen as a fundamental component of safety management.

Written materials were process orientated and appeared to have insufficient address to operator activities that would be required to achieve this. This may reflect indiscriminate allocation to 'core skills', but the lack of detail describing task technique and skill requirements indicated poor insight into the human interaction necessary for the work.

Those in senior roles on site mostly prepared risk assessments and method statements, yet they invariably appeared to have little practical involvement in the process tasks. As such, it appeared that any learning experience derived from document preparation was not applicable at a practical level. Conversely, at site level, those reading the documentation had little concept at all of any instruction in task techniques or procedures. The subsequent emphasis on signature collection (apparently inferring transfer of ownership and responsibility for work practice), appeared to offer little value - the direction, value and bureaucracy in using these types of information transfer as instructional measures is questioned.

In the context of practical information transfer through induction, on the job training and toolbox talks, ownership and responsibilities for their provision appeared blurred, especially for those greatest in distance from the principal contractor in the sub-contractor chain. There was little indication of training in training provision for site personnel yet reliance upon 'on the job learning' for skills development was considerable. For those apparently providing practical skills training there was no real sense that they perceived this as part of their work role. The style, presentation and language used in both practical and written modes of information transfer often appeared un-stimulating and inappropriate for a teaching medium.

7.6 Results by role, skills, abilities and attitudes

Throughout the semi-structured interviews various concerns relating to the different employee grades were reported. These, with observations of the researcher, relate to differences among interviewees’ roles, skills and attributes.

<div>Failure generation ↓</div>	Phase →	Project Concept Design & Procurement	Work Organisation & Management	Task
	Design & execution			
	Planning Scheduling & Management			
	Information Transfer (MS, RA, Induction etc.)			
	Role, skills, abilities and attitudes			

7.6.1.1 Role clarity of those in safety grades

Interviewees that held a safety, or health and safety role, had a variety of backgrounds and training, ranging from trade to professional positions. A range of different job titles was also noted.. When referring to this grade, site personnel used the term ‘safety officer’ most commonly, although the jobholders themselves used the term ‘advisor’ or ‘manager’ in preference. For those that were not called ‘manager’, one was concerned that this lowered his credibility (010). Interviewees had also undertaken a wide range of training, ranging from short courses of less than one week (such as safety for Supervisor training), courses lasting in the range of 20 days (such as NEBOSH Construction & Certificate training) and longer training to NEBOSH Diploma and degree levels. These data are reproduced in Table 64.

Job title	H&S Manager	H&S Supervisor	Safety Manager	Site Safety Manager	Safety Officer	Safety Advisor	Safety Advisor	Project HS&E Co- ordinator	Safety Advisor
Nature of safety training	1-4days	Safety for Supervisors course	NEBOSH Certificate 1978	NEBOSH general + construction	22 days	BSc Safety related degree	NEBOSH cert + Diploma in progress	NEBOSH Part 2	NEBOSH Diploma

Table 64. Employment and educational training of personnel in a safety role

The Safety role often appeared to be seen in the context of enforcement, policing or wet nursing (001, 009). Site personnel offered most comments, but the safety interviewees also acknowledged these problems.

... We were trying to get away without a handrail on the scaffold to save some time. We thought it was safe and were happy with it, but the main contractor saw us and told us off ... We just had to put our hands up to it and say we'd done it ...

The researcher observed incidences of dismissiveness, backchat or dispute with the safety adviser (010), and these interviewees at times perceiving themselves as 'worst enemies until something goes wrong' (036). Those in a safety role had varied perceptions of the value of their role. Most gave the impression that they provided a valuable and worthwhile contribution, but others indicated that their appointment was a second-choice option (away from an professional site position, such as Engineer) and something to which they were directed towards by their company rather than chose (005, 009).

7.6.1.2 Role clarity of those in supervisory / management grades

Whilst the breadth of responsibilities for interviewees within supervisory / managerial roles was quite wide, there were also a number of concerns particular to this group as a whole. One of the main issues that interviewees described concerned conflict, which appeared to arise from the responsibilities of their role between subordinates and with those in authority.

... I'm in the middle and the buck stops with me ...

It was reported that principal contractors handed over responsibility for work organisation to sub-contractor supervisors (052), yet continued to be in a position to offer instruction or direction to their operatives, which undermined or confused the arrangements for control (061). Elsewhere, interviewees reported poor liaison in establishing arrangements for work planning or organisation - such as identifying needs for materials, supplies or PPE (001, 061, 062, 064). This resulted in feelings of isolation or feeling distanced from the development and feedback loop.

The level of responsibility within the supervisor role varied quite considerably among interviewees. There were reports of onerous demands to oversee a large number of people (up to 20 in one report, 036), yet other supervisory arrangements were more informal. Some interviewees did not see themselves as having a supervisory role, or saw their position just as an informal arrangement with their employers (020, 034,

040). Promotion to a supervisory /management role from a skilled operative position was not always welcome (062).

In describing their supervisory style, interviewees at times described the need for quite a strict and authoritative approach in order to ensure that the work progressed (009, 020, 052) and that correct PPE was worn (040).

... I have to stand over and drive them - if you don't then they don't do it ...

... The lads just don't see the danger and therefore they need to be told and kept in line ...

Demands upon supervisors were confounded by various dissatisfactions, such as the need to assess and oversee the performance of new tradesmen (009), the concurrent demands of dealing with mobile phone calls – averaging 20-30 per day for one interviewee (002) and with long working hours.

Supervisory / manager interviewees described their responsibilities for 'health and safety', and any instructions and performance review that they received. Responses varied – only one interviewee reported all aspects within his employment contract (063) but the arrangements for others were less robust. Some interviewees reported no standards or instructions to follow at all (017, 019, 062), yet felt that health and safety responsibilities were part of their role, although not specified (023, 040). Others also reported nothing unique to their appointment, but felt that any site documentation (such as site rules, codes of practice, toolbox talks, scaffold register, method statements or risk assessments) were their instructions (025, 033, 036, 037, 038, 050, 052, 060, 062, 065). One interviewee had received an instructional folder from his safety advisor (061). The nature of any performance review (as in appraisal) received varied comments. Some interviewees reported 'none' (038, 050, 052), or reported regular liaison with their safety advisors (061), or reactive monitoring according to accident occurrences (017, 025, 062), or audit by the principal contractor (065).

Training among these interviewees in safety related matters varied and, unfortunately, many were unable to spontaneously provide details of training history and duration at

the time of interview. Although data were not fully available, the impression was that, of the 24 interviewees who responded, 17 had received some health and safety training in the preceding five years, whilst the remaining seven had received none, either in that time period, or at all. For those that had undertaken some training, the duration was in most cases between one and six days (22 days in one case); some saw the First Aid at Work certification as health and safety training. Only two interviewees felt that they had received training in human capabilities and performance – one through the ‘experience of life’ and the other through previous training in the armed forces.

7.6.1.3 Role clarity of those in operative grades

At operative level, the main issues concerned problems arising from poor delineation of task responsibilities. Task requirements appeared quite varied from site to site and the boundaries of labourer/trainee or labourer/semi-skilled/tradesman roles appeared flexible. Interviewees resented working interchangeably with less skilled and qualified workers (003, 023), and the resulting uncertainty affected the definition of task responsibilities, of core skill requirements, and the level at which task based training or supervision in task execution would be required (002, 018, 022, 024).

A number of interviewees reported general feelings of dissatisfaction (5.11.4.9). Typically these related to the impact upon their work through trying not to inconvenience the public (039, 051, 061) and comparable disparity in the provision of safe conditions for themselves and for the public (037). Additional sources of dissatisfaction for the interviewees included feelings of doing menial, poorly paid or undervalued work (018, 023, 050, 062).

... There's no thanks or acknowledgement from the company Directors. You risk your life all day and end up getting told off for smoking or not wearing a hard hat. It really knocks the wind out of your sails ...

There also appeared to be undercurrent of dissatisfaction between different employee groups. At times this was interlinked with dissatisfaction with the housekeeping of another trade, or was related to poor performance or behaviour of others that the interviewee felt had induced the accident event (004, 011). Interviewees reported that

communication beyond their own peer group was limited (037, 038) and that there was a certain amount of secular behaviour (020).

... It's the brickies versus the chippies and then M&E versus everybody else ...

There were also isolated reports of 'them and us' situations between operatives and managers (037). In spite of quite a bit of self-management among operative interviewees, they generally experienced good rapport with their immediate supervisors. Where there were problems these related to mumbled instructions (017) and pressures upon work pace and performance.

Additional friction was apparent in (non-grade dependent) employee groups, distinguished by age, language and literacy. Quite varied perceptions of young or trainee workers were offered. From one perspective they were seen to be more safety aware (022, 025), yet it was understood that inexperience, reluctance to complain, and the impression of being maligned by older and more experienced workers rendered them less likely to effect this knowledge (002, 005, 017, 020, 025).

Issues relating to language and literacy also arose in the accident studies – there were reports of communication problems due to non-English speaking co-workers in three of the accidents. It was reported that this affected communication of safe working practice (008, 019, 022), yet there was some reluctance to address this as an accident causal factor, for fear of being accused of racism. Communication problems through poor literacy were also described (and noted by the researcher during data collection, 012, 024), although there were few reports about the disadvantage of this. Where relevant, any disadvantage was accommodated by reading out or describing the instructional materials. One supervisor /manager interviewee reported using the induction process to confirm language and literacy skills (023).

Although not especially commented upon by interviewees, the researcher noted that a number of interviewees described themselves as self-employed, or as self-employed but somehow linked to a sub-contractor employer (009, 011, 065). It was very difficult to ascertain their employment pattern, but self-employment appeared to be more common among the operative interviewees. Given the difficulties in identifying

the nature of appointment, any likely link to their nature of employment could not be made.

Whilst operatives in trade positions had undertaken apprentice or City and Guilds trade training, supplementary training for them and others in labour positions was focused upon CSCS or 'ticket' based training for use of site plant or equipment. Many interviewees were unable to spontaneously provide details of training history duration at the time of interview. However, of the 31 who were able to provide some details it appeared that for ten to 13 of these interviewees, the toolbox talks and inductions were their only source of training.

7.6.1.4 Skills development by trade, apprentice and NVQ schemes

Interviewees reported a variety of baseline trade, apprentice and NVQ training schemes, generally undertaken as school leavers and supplemented with subsequent experience on the job (001, 002, 007, 011, 018, 022, 023, 051, 061). The styles and duration of these different types of training were quite varied, and appeared to involve a mix of college and/or practical based experiences.

Among the few trainee interviewees, a number of problems were reported. Scaffolders training, for example, was described as two to three block release sessions at a training centre, with examination after each subsequently permitting a certain level of unsupervised work. The formal training was supplemented with ongoing 'on the job' learning and supervisor assessment. Interviewees in a trainee role expressed concerns about the quality of 'on the job' learning, in the context of inconsistency of standards and lack of enthusiasm among the training providers (017, 023).

... The training involves labouring with scaffolding thrown in if they can be bothered ...

A range of titles was given to the various stages of trainee development (from 'mate' to 'improver' for example) and the rationale for determining promotion intervals appeared quite flexible, lacking formal time scheduling or criteria for decision making of skills achievement (017, 024). Employers and the self-employed each reported paying for these training schemes.

7.6.1.5 Skills development by CSCS training schemes

Interviewees reported CSCS training schemes between one and five days and typically these involved training for use of a particular piece of plant or equipment (e.g., scaffold tower, mobile equipment, fork lift truck) or for supplementary safety training for their trade or area of responsibility. This scheme, with each training and assessment session also referred to as a 'ticket', was well established on the sites visited and was used as a formal method by which to ascertain competence for workers to operate on site.

Some adverse comments relating to the CSCS scheme were described and primarily concerned an over-balance of time on classroom style instruction compared with the practical component of a training course. A novice user of a piece of motorised mobile equipment might complete and attend a day's training course for example, but interviewees expressed concern that the time spent on practical skills training for the 'ticket' did not provide sufficient experience with which to subsequently use that equipment unsupervised on site.

... The crane co-ordinator course I had was not training - it was just here's the form, fill it out and sign it ...

7.6.1.6 Individual capabilities

Interviewees variously reported both good and bad health. Where there were reports of underlying or treated health conditions these related to background musculoskeletal injuries (004, 013, 017, 021, 022, 023, 028, 029, 040, 060, 63,64), respiratory problems (023, 053), eye problems (023) and feelings of stress or anxiety (001, 025).

7.6.1.7 Attitudes towards safe practice

Interviewees reported a wide variety of comments in relation to perceptions of safety culture within the industry and these fell within two main themes. Firstly, and although there really wasn't any rejection among interviewees of the need to 'be safe', perception of what constituted safe and advantageous practice varied.

Some saw the prescription of 'safety measures' as detrimental to performance, by slowing the job down (060) and reducing earning potential (002, 017). There were

one-off reports that some special or new measures (such as risk assessments for young people or anti-vibration gloves) were 'over the top' (052). Others thought that safety measures introduced new risks (052, e.g., safety barriers creating trip hazards or harnesses hindering safe escape in emergency situations), and that the introduction of regulated safety had led to relinquishment of personal responsibility in determining safe working behaviour (021, 052).

... People lose their wits because of regulated safety ...

Others felt that some general safety measures were unnecessary. The blanket policies on all sites about the wearing of PPE (hard hat and harnesses especially) were frequently considered inappropriate to a range of work circumstances (023, 018). Interviewees inferred that this stipulation undermined their ability to make informed decisions (on the conditions of any given work situation) and was also an insulting intrusion into their otherwise high risk / high responsibility roles.

Use or non-use of PPE was reported by operative and supervisor / manager interviewees alike as one of the main indicators of safe practice (041); yet there was anger among operative interviewees that focus on this was at the expense of concentration on less visible but greater hazards (001, 062).

... We're forever getting told off by the principal contractor about things not done. It's over the top, like complaining about you taking your hat off if its in the way – They go on about minor things, but the major stuff is all down to money ...

Overall, comments about the site's safety culture were good, with many reports and appreciation of the greater emphasis on safety in the preceding five years.

Nonetheless, there were a few adverse comments indicating that safe practice was overridden by production pressures (025, 037) and that, despite what was said in induction, 'safety' was more for appearances sake than actual implementation (011, 060). Where interviewees provided positive feedback on safety culture this was at times judged against reactive measures, such as the occurrence and response to serious accidents (007, 063).

... I couldn't fault them – they took me to hospital when the accident happened ...

7.6.1.8 Attitudes affecting work motivation

As a conclusion to the semi-structured interviews, participants described the best and worst parts of their work. Comments varied both between groups and across the participant range.

At the safety grade, for example, interviewees reported promoting safe work practices (002, 013), seeing people work in a safe manner (004, 010, 036) and contribution to reduction of major accident rates (005) as the best aspects of their work. Whilst these types of comments were unique to this employee group, these interviewees also had comments in common with other grades. For example, social interaction with others on site was cited as a 'best parts of the work' by safety (001) and by the other employee grades too. At the supervisory / management level this was described as the benefits of working with people (002, 003, 009, 025, 020, 064), of companionship (051) and of being able to pass on their own good work skills (063). At the operative level, the best parts of social interaction were seen as socialising, working with friends, helping others and having a laugh (005, 011, 019, 062, 063, 065).

Variety was also seen as a 'best part of the work' by all grades and was interpreted in the context of 'situation' and work content. In the situational context variety was valued in freedom of movement around and across different sites, with the opportunity to work in the fresh air and appreciate open space (019, 023, 024 025, 037, 050). Concerning work content, interviewees welcomed opportunities to deal with new and challenging situations (002, 005, 007 020, 025, 060, 063). More detailed descriptions by interviewees showed that opportunities to use mental capacities and a sense of accomplishment were also important. At a supervisory / managerial level, opportunities for problem solving (038, 064), making decisions and being in control (019, 020, 037, 063, 064) were valued and, especially concerning operative grades too, accomplishment of quality work (012, 020, 022, 023, 051, 053, 060) with value to the end user was prized.

For interviewees at the supervisory / managerial grade, work completion according to projected target was especially important (002, 017, 022, 023, 025, 037, 040, 050, 052, 053, 061). Alternatively, among operative interviewees only, working in an

environment where they could organise their own work, without pressure or hassle, was seen as 'best parts of the job' (017, 023, 024, 040).

A few other 'best parts of the work' were mentioned, relating to 'rewards' of the work – such as being complemented for good work (060), receipt of payment (009, 040, 062), keeping fit (017, 065) and work breaks or going home at the end of the day (002, 004, 011, 012, 018, 019, 038, 052). Other interviewees, and from all grades, gave no particular description for the 'best parts of their work', but simply reported that they mostly enjoyed their work (008, 013, 024, 025, 033, 034, 036, 038, 040, 060, 061, 063, 064).

In contrast, interviewees also described the 'worst parts of their work'. Across all grades, but especially mentioned by operative interviewees, was poor environmental circumstances, such as bad weather - wet, cold, snow and wintry conditions (001, 002, 009, 011, 018, 020, 033, 036, 050, 062, 065), dirt and dust (008, 017, 023, 024) and poor underfoot conditions, such as mud and uneven ground (002, 011, 038). Operatives also described aspects related to work or task types that were the worst parts of their job, for instance use of particular types of equipment (063), demolition (060) or heavy / labouring work (009, 017, 022, 063). For a few the work was boring and mundane (004) and there were safety concerns about being pushed to do work that they were not qualified for (020).

There was greater commonality of responses by those in the safety / supervisory / managerial grades, although those in safety grades specifically mentioned the occurrence of accidents as the worst parts of their jobs (002, 004, 036). Problems with communication and liaison were frequently mentioned, affecting relations within own employer group and with principal and sub-contractor teams (005, 013, 038, 052, 053, 062). Whilst a couple of interviewees cited 'being busy' as an advantage of their work (002, 065), more reported work overload as a 'worst part of their work'. This was expressed in terms of too much work (025, 023, 065), pressure to complete work (003, 006, 050, 060, 063, 064, 065) and having to work to over-ambitious targets (038).

Supplementary to these pressures, the safety / supervisory / managerial interviewees reported insufficient resource to do their work, such as lack of materials (010, 061) and of the burden upon them to manage absenteeism (038), or poorly skilled operatives (002, 020, 021, 023, 025, 050, 061). Bureaucratic demands, such as dealing with dismissals (009, 022, 064), 'paperwork' and burdensome and lengthy safety inspections were additionally mentioned by supervisor / manager interviewees as the worst part of their work (002, 012, 037, 040).

Whilst some interviewees reported no worse parts of their work (011, 019, 040), among each interviewee group, travel and working hours were reported. One interviewee felt his work hours were too short (053), but there was otherwise considerable disdain for long work hours (009, 013, 025, 037), coupled with lengthy travel to and from work (002, 034, 053, 061).

For others, getting up and starting work was the worst part of their work (004, 017, 051, 019, 052). Several interviewees, across all supervisory, management and operative grades reported that they would not enter construction work if they had their chance again - computer based office work was seen as the optimum type of work by many.

7.6.1.9 Report on rated responses for stress, job satisfaction and social support

A number of the comments concerning best and worst part of the job were generated when people completed the rating scale for stress, job satisfaction and social support. The data (mean scores and standard deviation) for the rating scale responses are reproduced in Appendix 7 and in the chart in Figure 22.

Whilst qualitative analysis revealed many different opinions and experiences, the rated responses of employee groups (as a common voice) were surprisingly positive. The intermediate level (3), signifying neither complete agreement nor disagreement was (except for labourers) attributed to 'my job causes me worry – the labourer group tended to disagree with this statement.

Other points at level 3 or below were 'I enjoy my work' and 'I would recommend my job and place of work to a friend'. Supervisor respondents rated work enjoyment at 3,

whereas senior managers rated this as '2' (SD 0.69) – suggesting least agreement among these respondents.

Standard deviation had a pattern of being greater among all groups' responses for the final four statements, indicating a larger breadth of feeling (around the mean score) for these issues

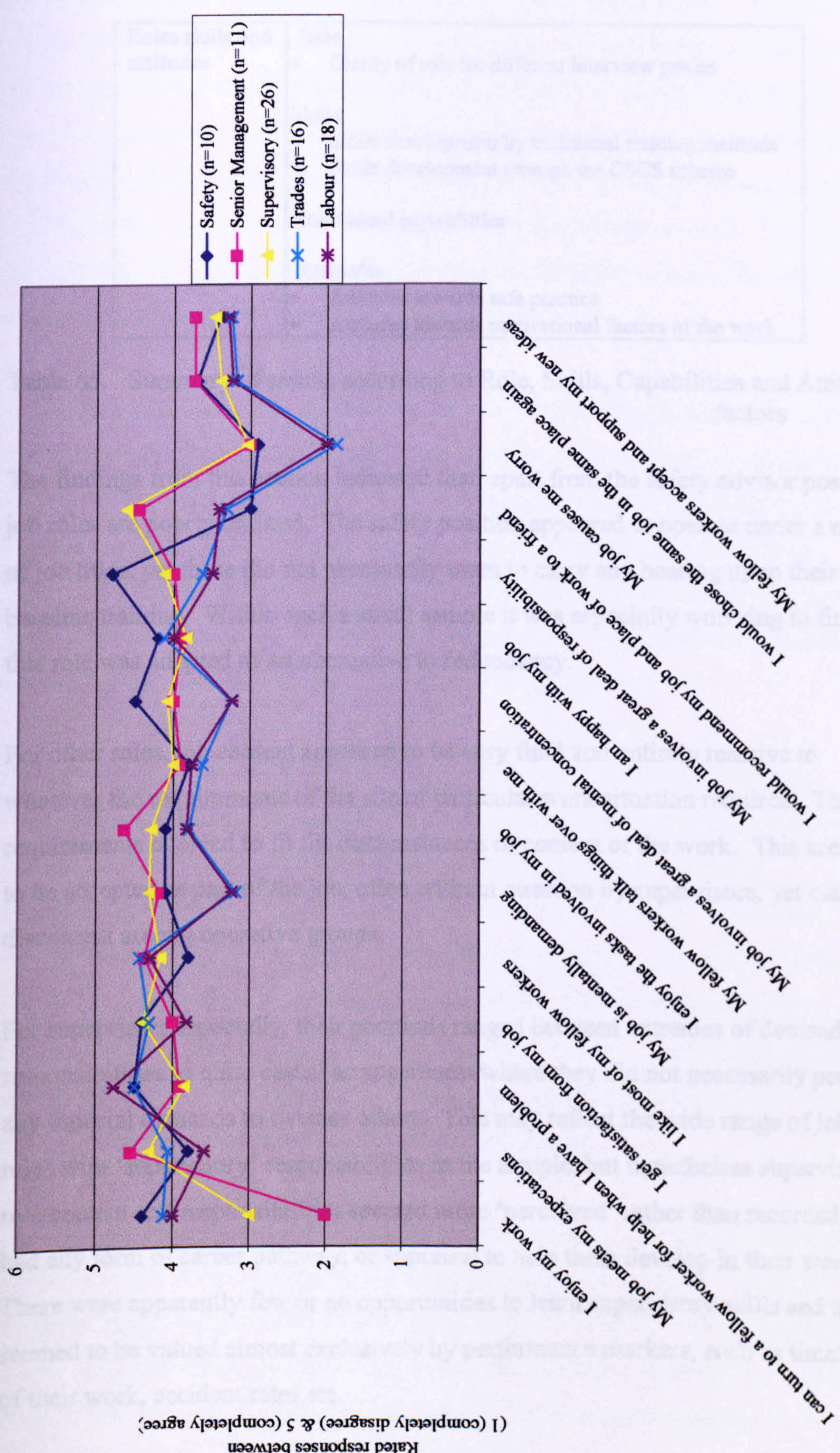


Figure 22. Rated responses for stress, job satisfaction and social support

7.6.2 Summary of results according to role, skill and attitude factors

Roles skills and attitudes	Role
	<ul style="list-style-type: none"> • Clarity of role for different interview grades
	Skills
	<ul style="list-style-type: none"> • Skills development by traditional training methods • Skills development through the CSCS scheme
	Individual capabilities
	Attitudes
	<ul style="list-style-type: none"> • Attitudes towards safe practice
	<ul style="list-style-type: none"> • Attitudes towards motivational factors of the work

Table 65. Summary of results according to Role, Skills, Capabilities and Attitude factors

The findings from this section indicated that, apart from the safety advisor position, job roles are poorly defined. The safety position appeared to operate under a myriad of job titles, yet these did not necessarily seem to carry any bearing upon their baseline training. Within such a small sample it was especially worrying to find that this role was adopted as an alternative to redundancy.

For other roles, job content appeared to be very fluid and entirely reactive to whatever the requirements of the site of particular work situation required. The job requirements evolved to fit the circumstances or context of the work. This seemed to be accepted as part of the job, often without question by supervisors, yet caused discontent among operative groups.

For supervisors especially, their positions ranged between extremes of demanding responsibilities to quite casual arrangements where they did not necessarily perceive any especial demands to oversee others. This may reflect the wide range of job roles with 'supervisory' responsibilities in the sample, but nonetheless supervisor role content and responsibilities seemed more 'perceived' rather than recorded. Few had any form of career pathway, or appraisal to help them develop in their work. There were apparently few or no opportunities to learn supervisory skills and they seemed to be valued almost exclusively by performance markers, such as timeliness of their work, accident rates etc.

At operative level, training history seemed very varied. Some were entirely reliant upon inductions or toolbox talks as their only training opportunities. Where formal skills' training was provided, there was concern about the disproportionate amount of time spent on theory, compared with practical skills development (7.6.1.5). Skill based learning (tickets) was invariably related to use of a particular piece of tooling or equipment – it is not known whether safe practice in set-up, maintenance and clearing away (i.e. many of the accident circumstances) was covered. That first-aid training was also seen as safety training supports the impressions of fatalism associated with many interviewee accounts.

In contrast to supervisors, operatives were less content with fluidity in their role and felt that their skills were not valued or respected as distinct from those without comparable skills or experience. There were incidences of considerable discontent and operatives seemed to receive little positive feedback on their performance. There were aspects from which they derived fulfilment and job satisfaction (doing a good job, companionship etc.), yet these appeared quite opportunistic rather than something that was desirable as a management initiative.

Information from operative interviewees gave two quite different pictures of behaviour and management style on site. On the one hand operatives appeared secular, with inter-trade rivalries and a rigid hierarchy that does little to accommodate special groups (young, non-British, poor literacy). Traditional management practices appeared to complement this, with a 'boot camp' mentality, encouraging petty rivalries between different trades and operating with heavy-handed disciplinarian methods. In contrast, others, and this includes representations among all roles, revealed disdain for this mindset and had a genuine desire to help others and to distance themselves from such antagonism.

Hand in hand with the traditional approach, many safety management practices also appeared dogmatic and inflexible. Non-use of safety equipment or PPE, albeit briefly at times, appeared to be perceived as deviant behaviour. Some responded by seeing what they could get away with without being caught, whereas many others found it oppressive and offensive to be ticked off like naughty schoolboys, in

circumstances when they had genuine reasons for such omissions. Objections to this style of safety management appeared credible.

One of the prime conflicts here was that agreement, sympathy for or sense of ownership for many site safety interventions was severely lacking. There seemed to be a tremendous contrast between perceptions of what safety interventions were warranted - between the site based and safety / managerial personnel. Other than resigned acceptance by some, many initiatives were seen as a management cop-out to doing something that might be more disruptive or expensive.

There were also many undercurrent health problems among operative interviewees and the provision of occupational health services appeared either incompetent or negligible.

7.7 Summary of qualitative site data

The summary sections for each failure category drew together the range of problems that had been identified across the project timeline. There were a number of main elements or common themes to the findings.

The early stages of the planning process were hampered by fluctuating inputs and ongoing revisions from designers and the client. This had broad reaching effects upon time scheduling and the quality of drawings or detail required later on site. Financial restrictions also appeared to be far reaching; affecting purchasing of materials, equipment and products used on site and the appointment of sub-contractors.

Co-operation and communication between principal and sub-contractors appeared poor. There were also numerous issues concerning the 'management and co-ordination of site personnel'. Findings suggested that these aspects were poorly conceived and appeared not to be 'managed' at all; problems appeared to focus upon lack of knowledge and an inadequate range of clear guidelines stipulating good practice (e.g. health related issues, providing supervision, monitoring performance and providing motivation, payment and working hours). Where there were specifications these were only cautiously adopted (e.g. in labour appointment

and competence determination) and operated in parallel with traditional and unregulated practices.

The training schemes received a mixed perception; much of the practical training appeared very casual and lacking in clear boundaries for development. The move towards 'ticketed' training often ensured that more people were authorised in use of particular tooling or equipment, but appeared to offer little in the way of task and skills development that fulfilled individual needs. Documentation, compiled for risk assessments and method statements, was used as training yet these materials had many style and content failings and appeared to offer little in the way of 'instruction' for operatives.

The common themes to the findings were that there was 'habitual blindness' among interviewees; many of the problems were accepted without question and intervention. There also appeared to be many instances of lack of clear specification or ownership of responsibilities, and this affected all phases from design, through to procurement and the roles of individuals. Even where there were specifications, the effectiveness of these were hampered by the lack of consideration of human interactions, and this affected layout, routes, the condition of the workspace and welfare facilities and much of the tooling, equipment and materials used on site.

Table 56 introduced the categorisation style for the site data findings and this has been amended (Table 66) to summarise the areas where failure was identified.

	Failures concerning Project Concept Design & Procurement	Failures concerning Work Organisation & Management	Failures concerning Task Execution
Design & task execution	<u>Development of the site and building plan and design</u> <ul style="list-style-type: none"> • Build scheduling • Detail and design of the structure • Detail and design of the site layout 	<u>Transfer and management of build requirements</u> <ul style="list-style-type: none"> • Procurement of hardware • Managing the provision of task resources 	<u>Provision of necessary hardware for the work</u> <ul style="list-style-type: none"> • Tools • Materials • Equipment • Task technique • Relating to PPE
Planning Scheduling & Management	<u>Defining and organising labour supply</u> <ul style="list-style-type: none"> • Factors affecting sub-contractor appointment • Factors affecting distinction of contractor responsibilities • Ownership of proactive safety behaviour 	<u>Managing and co-ordinating site personnel</u> <ul style="list-style-type: none"> • Labour appointment • Determination of competence • Identification and surveillance of work fitness • Supervision of experienced and inexperienced operatives • Establishing working hours • Time pressure upon workload • Monitoring performance and providing motivation • Pay and remuneration • Provision of welfare facilities • Documenting and undertaking accident investigation and determining remedial action • Providing opportunities for operative consultation and communication 	<u>Provision of suitable task conditions</u> <ul style="list-style-type: none"> • Ground, floor or foot placement areas • Workspace provision • Housekeeping • Environmental conditions • Affecting operative task organisation (trade overlap)
Information transfer	<u>Determining criteria for build and personnel requirements</u> <ul style="list-style-type: none"> • Factors affecting contract, design and development of work schedule 	<u>Developing means to assess and define safe practice</u> <ul style="list-style-type: none"> • Risk assessment • Method statement • Ownership of training provision 	<u>Communicating instruction and guidance on safe practice</u> <ul style="list-style-type: none"> • Styles of training provision • Site induction • Toolbox talks • Transferring training into practice • On the job learning
Roles skills, capabilities and attitudes	<u>Role</u> <ul style="list-style-type: none"> • Clarity of role for different interview grades <u>Skills</u> <ul style="list-style-type: none"> • Skills development by traditional training methods • Skills development through the CSCS scheme <u>Individual abilities</u> <u>Attitudes</u> <ul style="list-style-type: none"> • Attitudes towards safe practice Attitudes towards motivational factors of the work		

Table 66. Summary of qualitative site data findings

7.8 Critique of the qualitative site data analysis

In contrast to the shortcomings identified in analysis of 'accident specific' findings (6.5), the qualitative data analysis has provided much greater detail to support the core findings and how these issues affected different employee groups. Within this it has also revealed an impression of the site culture - the nature of interactions, intangible or invisible issues, which were not apparent in the more concise analysis. The style of cross-referencing the focus group enquiry themes with categories later derived from the analysis provided a useful anchor upon which to ensure that all aspects of enquiry were explored. It also ensured that the phase of generation in the project timeline was fully represented (Table 66).

The category 'Information Transfer' was essentially a means of conveying or communicating knowledge between 'Design and task execution' and 'Planning, scheduling and management'. Ideally, representation of these three categories would follow the style in Figure 23, where 'Information Transfer' is placed centrally (rather than following Planning, Scheduling and Management). The horizontal arrows represent progressive development for each category, and the oblique arrows represent the interaction between categories during the project timeline. However, this style of presentation was not adopted because much of the Planning, Scheduling and Management information needed to be introduced beforehand.

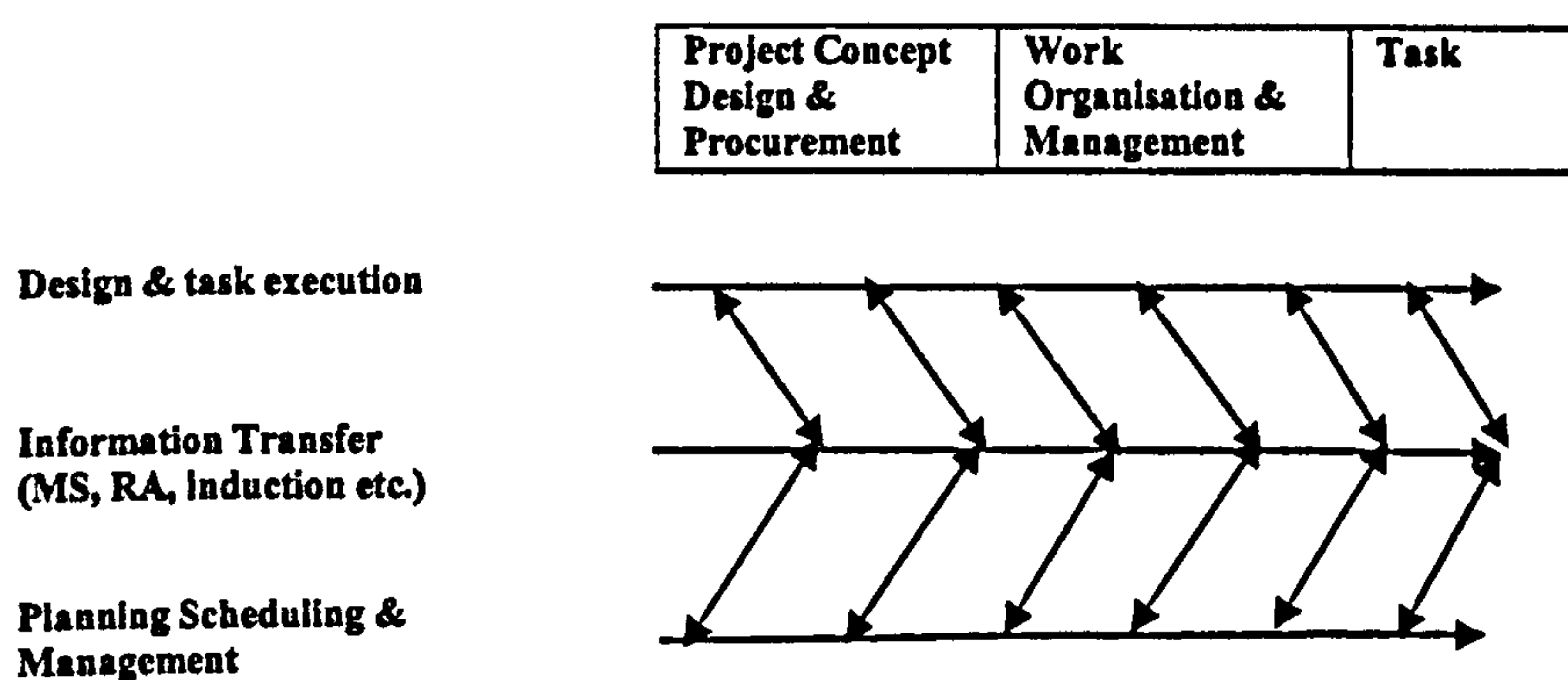


Figure 23. Information transfer – the central role

From a negative perspective, the categories did generate a certain amount of replication of information and at times it was difficult to allocate findings to a particular category. However, whilst not foolproof, they did permit isolation of

issues that arose and ensured that information was looked at from different perspectives. Although the analysis process was heavily dependent upon the subjective impressions of the researcher, this style of categorisation ensured that information relevant to all areas was considered. It was thought that this would minimise researcher bias (perhaps by inadvertent selection of information relating only to specific areas) and misdirected or inappropriate attribution of cause (3.9.5).

The multiple data collection methods generally fulfilled their objectives and created a wealth of data. However, it was unfortunate that it was not possible to proceed with the iterative development of proformas as expected (5.4.5). This meant that, although there was inclusion of new enquiry themes (Table 42), the later review or removal of unproductive questions was not undertaken. As such, the interviews, at times, took longer than anticipated.

The qualitative analysis has not identified the 'frequency of occurrence' that is the mainstay of epidemiological style analysis (although 'irregular access to data' (6.5) suggested that these data were in any case incomplete for this style of analysis). These 'frequency' data are traditionally important measures used to identify the extent of a problem and urgency of preventative measures. This practice is integral with the risk assessment process, yet it is important to consider whether these latent condition data fall into the 'risk' category and require comparable levels or urgency of action? Latent conditions are contributory in nature and not necessarily causal (Spurgeon and Young, 1980), (3.5.3.2). An alternative perspective is that these data reveal to the construction industry the nature of the problems, and that alternative means are required in the generation of remedial measures (9.3).

8 PHASE THREE – LATENT CONDITION FOLLOW-UP

Analysis and interpretation of the site data, Phase Two of the research, revealed a broad range of factors relevant to accident causation during site-based activities. By cross-referencing findings to the project phase of generation it was also possible to identify some of the organisational latent factors. These data, however, gave only occasional information concerning accident distal factors in the pre-site phase. Indeed many of the findings revealed failings outside the construction process itself – perhaps in the provision of ancillary services (provision of tools and equipment for example), or in related to regulation within the industry.

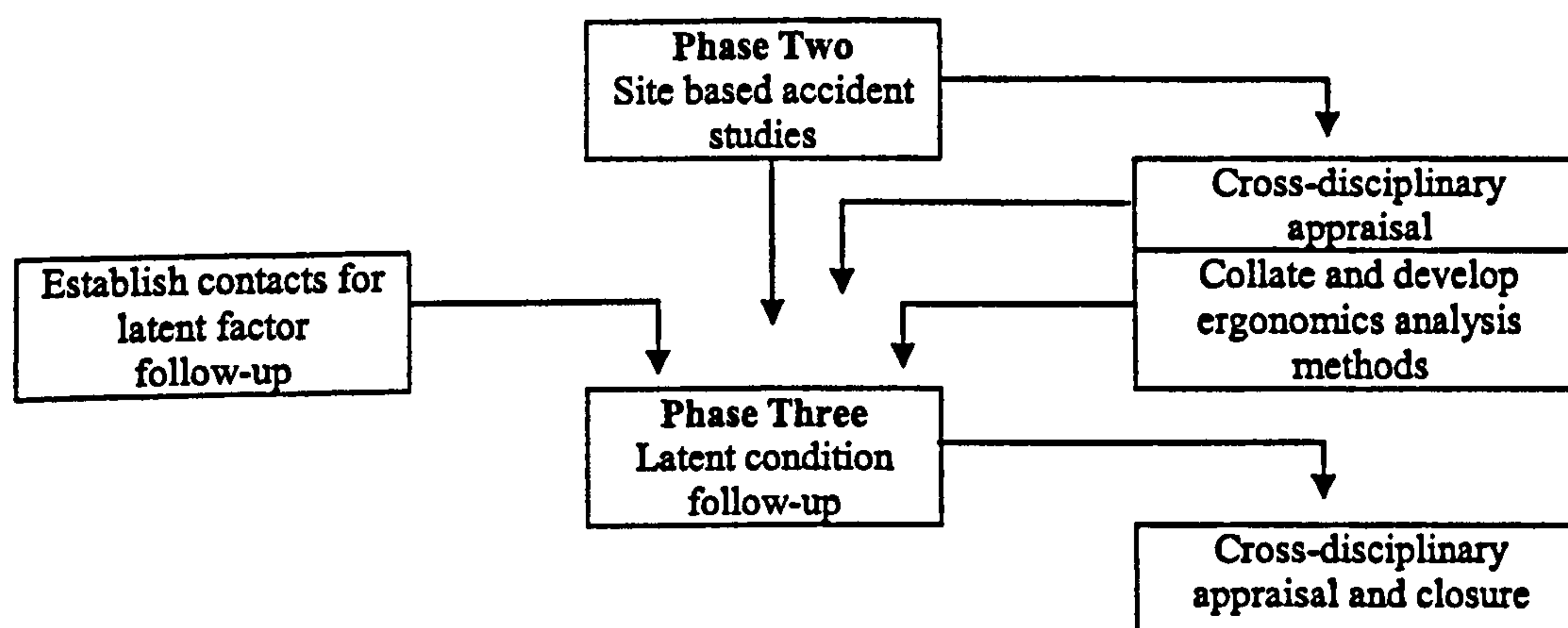


Figure 24. Phase Three of the research

Phase Three (Figure 24) of the research concerned the process of cross-disciplinary appraisal in identification of latent factors that warranted deeper exploration, development of the range of techniques used to acquire data, establishing further industry contacts and finally the methods adopted among the research team to validate the process.

8.1 Methodology

8.1.1 Aims and objectives

The aim of the latent condition follow-up was to explore issues that had emerged from the Phase Two analysis (either to reinforce or refute conclusions reached). It also aimed to reveal informational themes that might be more widely applicable, and especially across the accidents excluded from this more detailed analysis. In order to achieve this, the objectives were to:

- (a) Canvas opinions from both construction and ergonomics specialists concerning their perspectives of the most important factors to be pursued
- (b) Identify information from ergonomics and construction industry resources that might be used in the development of data collection techniques
- (c) Explore the latent conditions and range of alternative practices that might inform and enrich the data source
- (d) Identify the most effective methods for data representation

8.1.2 Technique used for accident study latent factor identification

8.1.2.1 Review by research team specialists

Accident summary reports (Appendix 9) were prepared for each of the accident studies. These included feedback of responses from interviewees, appraisal of procedural information and, where possible, photographs of the accident event work area (or current equivalent at the time of the site visit).

One each of the Construction and Ergonomics specialists on the research team appraised the contents of each report. This served two purposes:

- Construction specialists were able to verify interpretation by the Ergonomist researcher of the circumstances and terminology used to describe the accident. If relevant detail had been omitted, or if information was unclear, this process enabled them to highlight where clarification or supplementary information was needed to strengthen the report
- Construction and Ergonomics specialists were each able to identify the areas that they felt were most pertinent in accident causation. This information was later used to direct the accident study follow-up process

8.1.3 Research boundaries to latent conditions follow-up

The first thirty accidents (between 001 – 040) were selected for inclusion in the process of more detailed analysis. To accommodate the time and manpower available to pursue latent factors, each specialist was required to identify just two or three aspects that they felt had played an important contribution in the accident

event; this practice was agreed amongst the research team. Although the range of latent factors adopted for further research was reduced, it nonetheless channelled thoughts to consider the main issues.

8.1.4 Researcher criteria for evaluation of follow-up suggestions

Whilst specialists aimed to be succinct in their suggestions for follow-up, there were times when the range of suggestions (especially when construction and ergonomics specialists comments were combined) exceeded the 'two or three aspects' that might feasibly be explored. In order to select the nature and direction of the further exploration, the researcher undertook a process of cross-comparison of the suggestions made by each of the specialists. These data are reproduced at the end of each accident study report (Appendix 9). In order to identify which aspects to pursue, the following criteria were adopted:

Commonality of opinion

- Where each specialist had suggested the same aspect, this was most likely to be selected for further exploration

Anticipated feasibility of successful data collection

- Some suggestions were considered unlikely to be fruitful. Decision upon 'unlikelihood' was based upon existing knowledge of lack of access to the proposed interviewees
- Where the proposed enquiry and response had already been addressed as fully as possible as part of the accident study, the matter was not selected for reintroduction to the interviewees
- In some cases specialists' comments were indicative of their knowledge or suggestions for best practice under ideal circumstances. Whilst this provided a valuable learning resource it did not necessarily identify the follow-up route for the actual accident event
- Other suggestions proposed that interviewees should be asked why they had acted incompetently or with lack of insight. Experience from accident study interviews showed that such admissions were rare and that interviewee: interviewer conflict restricted openness of responses. Where an open enquiry could not be anticipated the suggestion was not pursued

- Some suggestions were of a personal nature (enquiries about the interviewee's domestic situation for example, which beyond the bounds of the research criteria), or were beyond recommended health and safety guidelines (use of back belts in manual handling, for example), or might breach an interviewee's confidentiality in discussion with others. Aspects such as these were not pursued

As an example of the latent factors selection process, the summary of the specialists' suggestions for accident 025 are reproduced in Table 67.

Accident 025: An Assistant Surveyor was descending a scaffold ladder and cut the back of his leg on sheet metal debris from roofing work	
Construction Specialist	Ergonomics Specialist
1. Housekeeping culture	1. Delegation of responsibilities for housekeeping
2. Sub-contractor viewpoint on safety culture	2. Criteria for sub-contractor appointment (quality and integrity of workmanship)
3. Risk assessment by client or Architect	

Table 67. Further exploration suggested by project specialists

In this example, each specialist proposed 'housekeeping'; this aspect was selected for follow-up, with the expectation that this information would be defined in the site policies of the Principal Contractor. A second proposed aspect was discussions with the sub-contractors about their perceptions of site safety culture; whilst it was known that they had been dismissed from site it was felt that this would also be a valuable enquiry and this aspect was selected for follow-up. Finally, risk assessment by the client or Architect, as part of the design activity, was identified and this aspect was also selected for follow up.

Criteria for sub-contractor appointment was the final aspect proposed by the specialists. 'Sub-contractor appointment' had already been discussed during the site visit and there was already indication that best efforts had made in appointment of competent personnel; this aspect was not pursued further. Whilst it was felt that further exploration of sub-contractor appointment would not likely reveal additional data for this specific accident study it was noted that that the issues of sub-

contractor appointment arose across a number of accident studies. In response to generation of specific and common concerns across accident studies, a range of follow-up methods was introduced.

8.1.4.1 Commonality of construction and ergonomist opinions

The same or similar responses from ergonomics and construction specialist were the trigger for selection of the suggested enquiry area to be pursued for further data collection. Whilst a different wording or source may have been offered by each discipline, there was commonality within suggestions for 24 of the 30 accidents (80%) included in this stage of the research.

8.1.5 Data collection methods

The need to explore pre-site or extra-site issues was identified at the outset of the data collection period, yet it was not clear until actual collection of accident study site data where these enquiries should be directed.

8.1.5.1 Generation of data collection techniques

During the resource appraisal and technique development phase for Phase Two (5.2, 5.3), it was apparent that latent factor follow-up would likely be directed towards personnel in positions 'upstream' in the project lifecycle. A further proforma, also incorporating roles and responsibilities laid down in the CDM Regulations (Health and Safety Commission 2001b), was developed for use in semi-structured interview with senior or off-site construction personnel (Appendix 8). From these resources, the client, planning supervisor and designer were anticipated as likely interviewees. It was intended that this proforma would be used in combination with Proforma 3 (as during the site data collection interviews, 5.4.2), although in practice, the prepared proforma was used only on a small number of occasions. The proforma had been developed for someone directly in the accident event 'chain', yet participant recruitment problems (8.1.6) meant that it was not appropriate when interviewees were outside the accident frame.

Many follow-up aspects concerned manufacturers or suppliers of machinery, tools and equipment; an existing data collection questionnaire for product and equipment evaluation was adopted for use in these circumstances (Institute for Occupational

Ergonomics 1998b, Appendix 8). For other interviews, questions were developed on an ad hoc basis (either prior to or during the interview) – to explore findings from accident study data or from ‘specialists’ comments. Interviews were less structured than those used during site data collection. A framework of discussion themes was generally prepared, but interviewees were encouraged to enlarge upon these as the interview evolved. The interviews with least structure were generally used for the more generic interviews.

8.1.6 The range of enquiry routes used in data collection

Most interviews were held at interviewees’ places of work (also one by e-mail/letter and four by telephone) and included one to one interviews and group discussions.

8.1.6.1 Accident specific data collection

Where there was a direct lead to individuals or specific companies in the follow-up factors chosen for each accident, all effort was made to proceed with this nature of enquiry. At times, however, this approach was not always possible (primarily because contacts did not wish to participate, or because they could not be contacted) and alternative ‘generic’ methods of latent factor data collection were sought.

8.1.6.2 Generic data collection

The process of exploring latent factors through ‘generic style assessment’ proved a valuable resource for the research. ‘Generic’ style exploration was undertaken with interviewees who were suitably qualified or experienced to be able to provide an informed opinion upon the subject matter, yet were not necessarily connected with any specific accident event. This style of latent condition exploration was undertaken under the following types of circumstances:

- Where accident studies revealed failures in common across a number of accidents
- Where accident study follow-up indicated that failure might stem from pan-industry issues (such as longstanding organisational problems or inappropriate guidelines, for example)

- Where it was not possible to follow the proposed enquiry routes for each accident study, whether through lack of access, or when contacts did not wish to participate in the research

These 'generic' interviews were conducted using either of two methods:

Generic specific data collection

'Generic specific' interviews were discussions that were directed at a specific area of enquiry

Generic collective data collection

'Generic collective' interviews were broad based discussions encompassing a range of enquiry areas.

The process of using these approaches is shown in Figure 25.

IDENTIFICATION OF DATA NEEDS

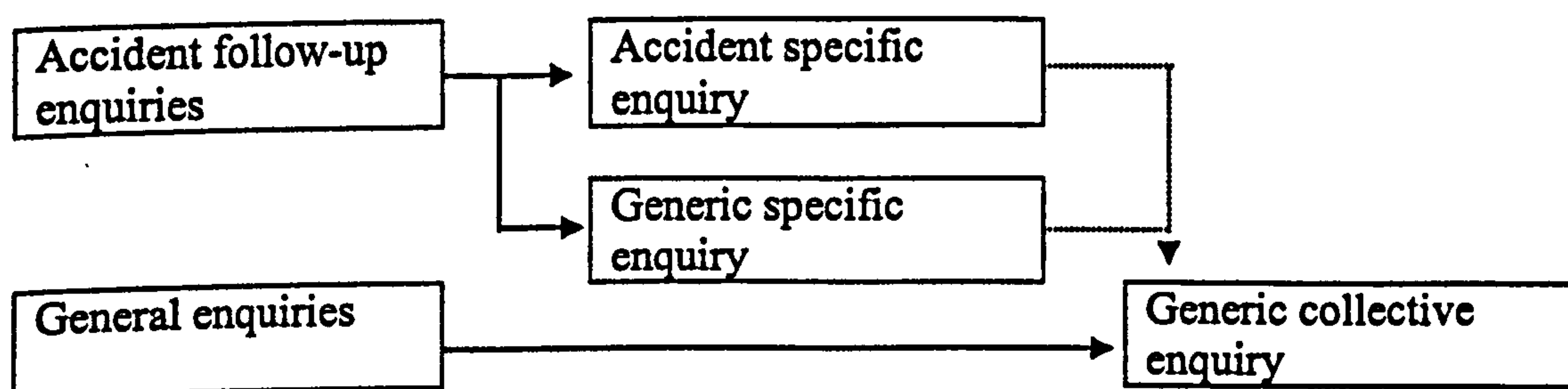


Figure 25. Process used to collect latent factor information

Use of published materials relating to enquiry areas were also used (publicity, fact sheets, instructions), and were appropriate for either of the generic data collection methods.

8.1.7 Analysis and representation

Data are presented in three different forms. Firstly the profile of the research sample reveals the follow-up areas that were pursued (8.2). The second form is tabular presentation of the findings, relevant to the enquiry areas for each accident (as in 6.3). The final form is the qualitative analysis of all findings (as in Chapter 7). Accident

specific enquiries revealed that the latent conditions were in themselves subject to latent conditions, and these data are combined (as in Figure 21) for presentation.

8.2 Profile of the research sample

Table 68 represents the nature of the latent factor analyses undertaken (shown in the context of the four enquiry areas). Whether data collection was successful or not (or not attempted) is also shown. This is also listed with each accident report in Appendix 9.

	Successful	Unsuccessful	Not attempted
Design & task execution	Design development & choices (002, 003, 005, 010, 011, 017, 024, 033, 035, 039) Ergonomist product evaluation (001, 007) Equipment/ Tool / PPE manufacturer (002, 003, 006, 008, 012, 022, 033, 035, 036, 038) Equipment / tool supplier (012, 036) Materials manufacturer (002, 034) Technical specialists (004, 005, 007, 009, 011, 017, 020, 021, 025, 036, 038, 040) Product procurement (033, 034) Other (009, 011, 019)	Design development & choices (001, 004, 005, 011, 022, 024, 025) Equipment/ Tool manufacturer (007, 008, 019, 021) Materials manufacturer (009) Task technical specialist (001, 008, 024) Product procurement (022)	Multiple personnel (001) Design development & choices (001, 003, 010, 018, 024) Equipment/ Tool manufacturer (002, 035, 038, 039) Materials manufacturer (018) Task technical specialist (034, 038) Product procurement (003, 038)
Planning Scheduling & Management	Housekeeping management (017, 018) Operative supervision (018, 019) Work scheduling (021) Fitness for work (037) Communication on site (038)	Co-ordination on/off site (004, 013, 020, 022) Work incentives (023) Housekeeping management (025) SC appointment issues (025)	Operative management / supervision (007, 013, 034, 035) Identification of working hours (011, 039) Communication on site (012, 023, 035) Housekeeping management (037)
Information transfer	Documentation issues (002, 004, 005, 013) Operative training (008, 011, 012, 017, 033, 035)	Documentation issues (010, 018, 019, 020, 021, 023, 025) Operative training (007, 020, 021)	Operative training (003, 006, 009, 010, 038, 040) Documentation issues (009, 038, 039)
Individual factors	Motivation issues (005) Professional training (017) Language / cultural issues (022)		Personal issues (021) Skills assessment (023)

Table 68. Overview of research pursuit for the follow-up proposed by specialists

8.3 Profile of latent conditions for the accident sample

Research questions generated from the construction and ergonomics specialists suggested areas of enquiry are reproduced in Table 69. As not all interviewees were traceable (or responded), the questions have been revised and developed to reflect the nearest equivalent given the eventual interview circumstances.

Where the interviewee name has been '~~struck-through~~' this indicates that a planned interview had been identified as desirable, but had not proved possible. As such, the data presented represents what could be achieved under the circumstances.

8.4 Validation of researcher findings

Upon completion of data collection, findings were discussed with the ergonomist and construction specialist. This was an opportunity for cross-disciplinary conference upon the results and for either to suggest any further exploration or clarification. It was also an opportunity to dispel bias by the researcher.

Accident 001		
Accident – Direct	Generic – specific	Generic – collective / Other
1) Structural Designer / Architect	2) Ergonomics evaluation of steel tying tools	
RESEARCH QUESTIONS		
<p>1) <i>Were rebar alternatives (fabricated off-site), such as welded mesh carpets or use of pre-cast concrete, considered in the design?</i> Designers may prescribe technical solutions, but the contractor would normally make the choice (such as use of pre-finished components) Issues relating to steel fixing were considered unlikely to be contained within transfer of residual hazard information to site Professional impact on ability to avoid accident recurrence were considered unlikely – control measures within site responsibilities</p> <p>2) <i>What tools and work techniques are used in the development of reinforced concrete structures (Ergonomics evaluation)</i> Site observation and sample evaluation of steel nips revealed risk factors for Work Related Upper Limb Disorders Automated rebar tying machines are available – criteria for purchase and use unknown</p>		

Accident 002		
Accident – Direct	Generic – specific	Generic – collective / Other
1) Mitre saw manufacturer 2) Cavity closure manufacturer	3) Architect 4) Site – risk management issues	
RESEARCH QUESTIONS		
<p>1) What thought did the manufacturer give to saw usability, maintenance and health and safety issues? Safety hazard review and failure analysis undertaken as part of product development in house + various methods to get product feedback about design issues Internal brake is not that important – all have to stop within 10 seconds (whether by brake / disc design / other means..) There is no maintenance schedule for the saw – not aware of wood slithers as an especial problem</p> <p>2) What are the arrangements for design development and design for interaction with the cavity closure window frame The manufacturers are extrusionists only they never supply direct to the builder – unusual for it to be cut and braced on site Use of the material is not a skilled construction activity – push fit parts</p> <p>3) What was the basis for the selection and construction of these window types in the design stage? This method of cavity closure was a ‘design innovation’ as avoided the need for scaffolding. Designer unaware of bracing requirements for window build Original design was revised for cost reasons, and accepted by the designer. The contractor chose this window type</p> <p>4) What were the issues surrounding risk assessment for the work Slither jamming saw implicated as joiners fault and not a saw shortcoming</p>		

Accident 003		
Accident - Direct	Generic - specific	Generic – collective / Other
1) Fan manufacturer	2) Design for decommission - current climate	
RESEARCH QUESTIONS		
<p>1) Why was this fan chosen and what are the normal operational limits? The ducting and grill connecting the fan to the work area were outside their remit of control. This was provided by the fan manufacturers employing contractor The fan is mobile unit is outside some of the static requirements for equipment in nuclear installations There was no user specification – this is down to the customer to specify Alarms had both a manual mute and manual reset function Unit can be left on for many hours / months ∴ the only time when people specifically have to interact with it is during filter change.</p> <p>2) How is design for decommission planned in the current designs of facilities Contractors have to provide a risk assessment for their work + appropriately training staff + PPE The nuclear industry have standard on specification of ventilation systems (including filter qualities) (Ergonomist) evaluation of documentation revealed a hazard checklist approach to risk assessment – control measures not listed for Designers use</p>		

Accident 004		
Accident - Direct	Generic - specific	Generic – collective / Other
Section Manager day-to-day co-ordination. Drawing of column operation & evaluation of MS / RA documentation	1) CITB- carpentry work	2) Temporary Works Designer
RESEARCH QUESTIONS1		
<p>1) What is the appropriate task technique and use of equipment MH of props is not covered in guidance. The Foreman or Supervisor should identify the necessary sequence of work Ideally the operative should tie the pipes with rope once he has released the pin that secures them (& before lowering them proper) Steel props are rarely use on a column as at 45°. There are few proprietary systems Designer designs them and then the Structural / Soil Engineer designs form and falsework. The design process stops at the support</p> <p>2) <i>What issues relating to the temporary works design might have influenced this accident?</i> The top of the steel prop should have had a connector to stop it dropping out A specific erections and dismantling procedure would have avoided this accident– but this is within a carpenter's core skill Engineering course notes wouldn't get to the level of detail about how to dismantle a column structure Dismantling should entail two ascents (one each for tie removal & spanner use), but its faster to do all at once</p>		

Accident 005		
Accident - Direct	Generic - specific	Generic – collective / Other
1) SC Safety Adviser Architect / frame designer 2) Planning Supervisor	3) Construction specialist	Health and safety Specialists
RESEARCH QUESTIONS		
<p>1) What arrangements are there for the undertaking of and provision of training in manual handling</p> <p>No enquiry into lifting and handling skills – capabilities judged by knowledge of previous task experience and competence</p> <p>Manual handling is normally outside of the training provision, but is covered using the HSE pictures during induction</p> <p>Accident history does not imply that manual handling is a problem. Operatives complain if the work is outside the norm of what they do</p> <p>Who was responsible for the detailed design of the steel work</p> <p>The work was sub-contracted for design of angle and capabilities. Very rare to have angles of this weight</p> <p>[NB: Steel frame designers perceived themselves as performance specifiers of the ‘design concept’, but the design of the angle and fix was a SC responsibility]</p> <p>2) What are the planning arrangements for materials movement and how is this developed into the method statement and risk assessment documentation</p> <p>It was not a Planning Supervisor decision to select the technical solutions. He would only have seen the MS for this action if it were an unusual design. aspect</p> <p>The overall responsibility was with the steel frame designers and their liaison with the SC</p> <p>Was not involved in the detailed working drawing – because it’s the designers’ role.</p> <p>3) What were the design alternatives for the steel angle</p> <p>Smaller sections could have been used but this would have additional cost & time implications</p> <p>The angle could have been designed so that it was not required at height but this would require more complex fitting and be more costly</p>		

Accident 006		
Accident - Direct	Generic - specific	Generic - collective / Other
Scissor lift manufacturer	1) A scissor lift manufacturer	
RESEARCH QUESTIONS		
1) What guidance is there for human interaction during the product design		
LOLER applies, but the employer still has a responsibility to identify the risk assessment for the work		
Design Engineering undertaken overseas – further information unavailable		
Sales personnel deal with hire companies and would liaise any feedback to product design engineers in the US.		

Accident 007		
Accident - Direct	Generic - specific	Generic - collective / Other
Craft knife manufacturer	A craft knife manufacturer	
1) Ergonomics assessment of task technique	1) CITB - appraisal of task content and technique	
2) Ergonomist assessment of the craft knife		
RESEARCH QUESTIONS		
<p>1) How might the task technique have influenced the accident event</p> <p>Board was lain upon road surface. The work area was stable but vulnerable to traffic interruptions The grasp compression force appeared considerable, causing finger blanching whilst making the knife cut [Ergonomist]</p> <p>A craft knife was the wrong tool for the job - A handsaw or jigsaw would be more appropriate. There are no guidelines to indicate which tool should be used (CITB,)</p> <p>2) How might the tool have contributed toward the accident</p> <p>The bare steel tool surface appeared to offer poor purchase qualities for grasp.</p> <p>It was considered that grasp force upon the tool would likely increase with any hand sweating - [NB: hot day for accident event]</p> <p>High rate of blade change required - repeated contact with exposed blades and possible uncertainty in task technique given fluctuating tool quality</p>		

Accident 008		
Accident - Direct	Generic - specific	Generic - collective / Other
1) Equipment maintenance / housekeeping	2) Training (CITB)	
Concrete pipe engineers	3) A concrete pipe system supplier and designer	
RESEARCH QUESTIONS		
<p>1) What are the responsibilities for housekeeping / maintenance concerning concrete works?</p> <p>Clips should be scrubbed with brush and water after each pour and checked weekly by the operatives. The pipes should be hosed off with high pressure water. Clips should occasionally be oiled - a supply surplus is kept on site. A safety clip is advised to keep the clamp shut, but this is under-used in the industry</p> <p>2) What is the training background for cement labourers?</p> <p>Cement workers are general operatives & are told what PPE to use and when</p> <p>3) Are manufacturers aware of the problems of concrete contamination of clips and do they offer alternative advice?</p> <p>The equipment can be kept clean with water or chipped off with a needle gun</p> <p>Not aware of innovation into low adhesion products. Trying to introduce lighter weight products for manual handling or boom mounting.</p> <p>Damaged equipment is replaced rather than repaired - commercial incentive</p> <p>Compression force to clamp shut is unknown [researcher unable to close clip during company visit]. Parent company (Europe based) expected to undertake any evaluation into human interface and interaction</p>		

Accident 009		
Accident - Direct	Generic - specific	Generic - collective / Other
Ply board supplier	1) Cutting tool guidelines (CTB) 2) BS5759 3) Chance encounter – manufacturer visit Timber and banding suppliers	
RESEARCH QUESTIONS		
1) What is the correct technique for removal of steel banding? There are bespoke wire cutters for safe removal of steel banding Gloves should be worn + it's a two person job		
2) BS 5759 : 1987 Specification for webbing load assemblies for use in surface transport Synthetic banding has variable qualities and can be weakened by wet, mechanical and chemical exposures		
3) What anecdotal evidence is available? A manufacturers in-house risk assessment revealed that nylon banding, with a strength capacity to 800kg, would reduce the risk of cuts and abrasions associated with steel banding		

Accident 010		
Accident - Direct	Generic - specific	Generic - collective / Other
1) Safety advice - Guidelines for ply use	2) Guidelines for ply qualities	2) Temporary works designer
RESEARCH QUESTIONS		
1) Has risk assessment revealed the need for an engineering assessment of ply cover qualities to seal holes in the floor ? It has been determined that a double ply board layer will be used in future and be secured in place		
2) Are calculations undertaken to determine correct ply board cover dimensions Ply deteriorates and becomes unusable after 6 months There is no research to identify hole diameter / density / loading capacities. A carpenter undertakes the work and scrap materials are often used (Design and build inhibits early Architectural input to solutions0		
3) How might There is no culture of calculating ply requirements; the technical ability is not on site Due to kinetic energy the formwork should have been caught before a drop of 3 metres People learn by experience. If the information was disseminated method statements could be upgraded		

Accident 011		
Accident - Direct	Generic - specific	Generic -- collective / Other
1) SC Health and Safety Manager Site manager--site layout	3) Lorry crane expert	
2) Lorry loader manufacturer		
RESEARCH QUESTIONS		
1) How are visiting SC opinions about safety managed on site? The SC had requested unique access to the accident work area, but the PC had denied this. The scaffold drop-off was unplanned work There were no daily meetings between the PC the SC - they had to 'anticipate' their role in putting up the build structure There was a monthly meeting for worker consultation & access to a safety representative on site		
2) How are safety feature developments determined and managed? There are a range of inter-locks and alarms to alert to misuse / overload. Manual outriggers are cheaper but becoming less common Non-extension of out-riggers is a widespread problem. There are moves to make this mandatory over the next 3 years (but met by some resistance in the industry) Manufacturers only occasionally hear about product related accidents or failure; perhaps if asked to repair damaged parts or to provide expert witness advice The finished vehicle has three separate manufacturers -- for the vehicle, bodywork and crane - customers may chose to buy and mount the crane themselves		
3) What issues are influencing the adoption of outrigger interlocks There are some issues concerning the specifications and applications of manual vs. hydraulic outriggers. Not all terrain / workspaces are suitable for use Customer demand leads UK suppliers to manage this -- but it needs to be taken on board by manufacturers internationally		

Accident 012		
Accident - Direct	Generic - specific	Generic -- collective / Other
1) Concrete pump training providers	2) CITB -- cement training (as Accident 008) 3) A concrete pump manufacturer A concrete pump supplier	
RESEARCH QUESTIONS		
1) What are the methods for providing training in concrete pump use? Training is provided by pump delivery driver / fitter (with subsequent supervision up to 4-5 hours if requested). Not aware of any refresher training provision The fitter / driver receives a minimum of a days training in safety awareness and concrete pump operation There is also an instruction booklet, but use of this is unknown Pump and equipment are manufactured in Europe -- they use different methods to pump screed overseas		
3) What are the different techniques for cleaning our concrete pipe Use of water and gravity is a preferable method to the use of compressed air for the blow down activity. Blow down can be undertaken from either end of the pipe Training is required to use compressed air, to ensure that it doesn't gather momentum Manufacturers provide the equipment and documentation but expect the purchaser and user to supply the training and related information		

Accident 013		
Accident - Direct	Generic - specific	Generic – collective / Other
1) Procedures for mains / battery tools Canteen Manager		2) Health and safety professionals
RESEARCH QUESTIONS		
1) What are the procedures for use of mains or battery powered tools? The procedures would be part of core skills training. Precautions would be required for the protection of trailing electrical cables		
2) What are the implications to work methods of new developments in tooling? Whatever new product comes on to site should be subject to the risk assessment process		

Accident 017		
Accident - Direct	Generic - specific	Generic – collective / Other
1) Policy for electrical cable management		Health and safety professionals
RESEARCH QUESTIONS		
1) Where do responsibilities for management of electrical cables lie? It is the suppliers brief to ensure that cables are not left in hazardous places Formwork, and the work itself, mean that securing cables to the ceiling is not always possible. All power sources are a common hazard The Electrical company have the responsibility to lay cables safely, but nobody really has responsibility to maintain the cable positions. Trip hazards are reviewed weekly Cable management is covered in induction -- including checking leads and plugs. Maintaining cable position comes within housekeeping responsibilities Prevention of trip hazards isn't especially contained in any training for supervisors / managers		

Accident 018		
Accident - Direct	Generic - specific	Generic – collective / Other
1) Scaffold manager Procedural information	2) CITB – Formwork striking	3) Temporary Works Designer
RESEARCH QUESTIONS		
<p>1) How is knocking off nails from concrete managed? Nothing is written down; its part of the carpentry work Carpenters are only responsible for fixing – its not up to them to strike Its automatic to send in a different gang to knock out the nails – there may be a bit of a time lapse</p> <p>2) What is best practice in striking formwork There should be a method statement and risk assessment. The MS should describe the technique for dismantling and nail removal Intervention may vary depending on whether the concrete will be the finished surface or not</p> <p>3) Are there alternative design practices to avoid the use of nails? It would be good practice to use a countersunk screw rather than nail on the shutter, but this takes longer A hammer can be kept on the work belt, whereas a screwdriver is vulnerable to theft Its not that common to re-use the shuttering</p>		

Accident 019		
Accident - Direct	Generic - specific	Generic – collective / Other
1) Scaffold manager Scaffold tower designer Review of procedures	2) CITB – Tower scaffold use	3) Language / cultural issues – Regulatory body
RESEARCH QUESTIONS		
<p>1) How might the accident have been avoided? The cantilever should have been removed when the boards were still on it The tower was being moved out of the way for other trades</p> <p>2) Is there a procedure stipulating frame condition prior to movement There are clear instructions indicating correct technique and order of dismantling – this should have been in the method statement Operatives should have been competent and trained, but people think its easy and just get on with it</p> <p>3) Are there any guidelines for managing language or cultural issues in the construction industry? Social inclusion, literacy and language are under review and the construction sector will take the lead in this The issues are currently under review (especially to guide Enforcement Officers) and should currently be managed as any other risk issue</p>		

Accident 020		
Accident - Direct	Generic - specific	Generic – collective / Other
Contracts Manager for info on Planning Supervisor, Training, history, MS/RA-development+ Gas board liaison	2) Health and Safety expert	
RESEARCH QUESTIONS		
<p>1) What should have been best practice and follow-up for this accident?</p> <p>The operative should first have uncapped the main and tested / sniffed – there could have been residual gas in the line or the supply could have been bypassed</p> <p>Both a petrol and handsaw might have generate sparks – an electric saw (readily available) would have been preferable</p> <p>Would expect that a MS/RA be developed if ≥100 supplies to do</p> <p>There have been previous problems with gas suppliers – One problem is that records are poor and they don't always know where the services are</p>		

Accident 021		
Accident - Direct	Generic - specific	Generic – collective / Other
Wagon design issues	2) Project Manager + Safety, Quality and Environment Manager	
RESEARCH QUESTIONS		
<p>1) How is the duration of work schedule determined?</p> <p>Possession times for track access are fixed and determination of work content within that time schedule is calculated upon knowledge from previous experience and of site conditions</p> <p>There is no proforma to identify how long a piece of work would take – flexibility is greatly reduced since loss of British Rail</p> <p>Are there any arrangements to monitor the duration of rail workers working time</p> <p>A 'smart card' is planned – this will monitor all workers hours per week</p> <p>2) How is risk assessed for wagon loading</p> <p>Wagon climbing would probably not have its own recorded risk assessment – there would be verbal instruction and the task would be incorporated within any generic documentation for digging and loading</p> <p>3) How might hazards be reduced to prevent accident recurrence</p> <p>A periscope might be feasible but there were reservations about whether that might be used</p> <p>If they had been consulted about the design a rounded wagon top would have been better</p>		

Accident 022		
Accident - Direct	Generic - specific	Generic – collective / other
Scaffolder—identify criteria for use of clip cover Plasterboard trolley purchasing criteria Role clarity—materials collection/transport	1) A plasterboard /trolley manufacturer	Language/cultural issues – (as accident 019) Regulatory body 2) Temporary Works Designer
RESEARCH QUESTIONS		
1) What guidance is provided for transportation and manual handling of plasterboard? There is no item weight on individual boards (a standard 8ft x 4ft board is 25kg. Weight given only per batch product and supply Plasterboard trolleys have two fixed wheels because this gives greater control (two men can push from one end if necessary) and it stops it rolling down an incline Handhold for pushing is the board itself Contractors can make-up trolleys themselves – welding together base materials + wheels The trolley can be driven from either end. (Tend to steer at front and person at back pushes, but individuals may choose otherwise). If working alone manipulate with rotating wheels at back Guidance in training is not to overload the trolley		
2) What is the criteria for using scaffold clips Positioning the clip to the outside of the access point is important Not sure if use of scaffold clip covering is part of Scaffold training and if there is use criteria		

Accident 023		
Accident - Direct	Generic - specific	Generic – collective / Other
Procedure for spillage clearance—Review of safety-culture incentives		Health and safety generic

Accident 024		
Accident - Direct	Generic - specific	Generic – collective / other
H&S Adviser—Ductwork designer	1) An M&E ductwork designer	
RESEARCH QUESTIONS		
1) Is there any way that this work activity could have been avoided? They can be left if they are not in the way, but it is preferable that they are flush with the ceiling surface A flexible wire rope gripper (+ nips to cut off the ends) would likely be a safer method The contractor makes the choice of whether to use a threaded rod or gripper – the duct designer would only have prepared the initial tender drawings This is not difficult work and no special training is required		
Is there a preferred technique or tool for cutting the threaded rods? It might be safer to use a small power tool to cut the rod. Not possible to cut pre-installation as has to be adjusted around other ceiling services Drawings would not help here as building tolerances are too great – any more careful measurements would be very timely and costly		

Accident 025		
Accident - Direct	Generic - specific	Generic – collective / other
Housekeeping arrangements – SC Appointment criteria Client / Architect and risk assessment activities		Senior Site Managers - generic

Accident 033		
Accident - Direct	Generic - specific	Generic – collective / other
1) Sub-contractor – general issues		
RESEARCH QUESTIONS		
<p>1) How do operatives learn how to handle and manipulate kerbs? Operatives all have 1 day Health and Safety Awareness training Training theory is provided by using *suppliers information *‘The essential Health and Safety Toolkit’ (HSE, 2002) Practical skills are taught in weekly TBTs and learnt from working alongside experienced operatives. Ground workers rarely have vocational training (ie. NVQ) The foreman is responsible for risk assessment and implementation of appropriate reduction measures</p> <p>Have you liaised with the kerb manufacturers about block deliveries and presentation? All products are delivered and packaged to optimise mechanical handling and mechanical movement of loads</p> <p>How is the provision of protective gloves managed? Gloves are selected from a supply catalogue. New styles have not been chosen – gloves do not protect from crush injuries</p>		

Accident 034		
Accident - Direct	Generic - specific	Generic - collective / other
1) Sub-contractor - Safety Adviser		
2) Ductwork designer		
RESEARCH QUESTIONS		
<p>1) What are the criteria for glove use during ducting work? People tend not to wear the gloves unless they are policed It is very difficult to obtain the necessary dexterity whilst wearing gloves - leather and canvas gloves are provided</p> <p>2) What are the alternative products that can be used for duct working? Almost all UK ducting is made of steel, although different products (such as mixed fibre composite materials) might be used overseas HVCA (heating and Ventilating Contractors Association) provide technical guidance on use of all products</p> <p>Are you involved in liaison concerning buildability, storage and handling Storage and handling are not part of the designers role although the designers risk assessment might alert to duct work sharp edges There is generally little other liaison - unless there is a particularly difficult work aspect Fitters have the best knowledge and ideas for better practice should come from them. Its presumptuous to impose a particular practice upon them</p>		

Accident 035		
Accident - Direct	Generic - specific	Generic - collective / other
1) SC Safety Adviser	3) Eye protection supplier	
2) Ductwork designer		
RESEARCH QUESTIONS		
<p>1) & 2) What are the control measures concerning swarf production? Swarf is a constant hazard and there are no tool alternatives (such as different drill types) to minimise the hazard Slower drilling and a sharper drill bit may reduce the hazard Unventilated goggles are uncomfortable, but dust gets through the holes or swarf drops from the hair into the eyes when they are removed New products would be selected from the suppliers catalogue - or the sales team would provide information on new products when ordering Ducting doesn't always need to be cut on site - it can be delivered ready for assembly (depending on application) There is no push fit ducting - fixing is either by pot rivet or drilling in screws - there is no tool that creates hole and pot rivets simultaneously It is expected that SC operatives are competent if this has been stated in the pre-tender questionnaire</p> <p>3) What might inhibit efficiency of protective eye wear The ventilation capacity is affected if goggles are designed to encompass accommodation of chemical, dust and gas hazards Recommended care involves washing with warm soapy water and anti-mist wipes. People don't look after them properly</p>		

Accident 036		
Accident - Direct	Generic - specific	Generic - collective / other
1) Supervisor	3) A Harness designer + a harness supplier	
2) Tower scaffold designer		
RESEARCH QUESTIONS		
<p>1) What were the circumstances requiring concurrent harness and scaffold tower use</p> <p>The ceiling structures inhibited erection of the specified handrail height on top of the tower</p>		
<p>2) How might the tower have been better employed in this accident activity?</p> <p>Adjustable handrails can be made up to accommodate ceiling structures, but these technically don't comply with handrail guidance – support from HSE invited</p> <p>Rental companies don't want to keep odd parts in stock –& therefore this restricts availability for sites. Minimum standard height increment is 0.5m</p> <p>A harness shouldn't be used if working at less than 4m in height</p> <p>The aperture size is dictated by a EU standard [details not available]</p>		
<p>3) What factors inhibit correct use of harnesses?</p> <p>A harness wearer needs instruction to fit and adjust the harness properly (at least 20 minutes). Its possible to put it on upside down and back to front</p> <p>Harnesses are not properly cared for and, in construction, are vulnerable to abrasion and wear</p> <p>People buy harnesses indiscriminately – they are not trained to select correctly</p>		

Accident 037		
Accident - Direct	Generic - specific	Generic - collective / other
1) Occupational Health arrangements		Health and safety specialists Industry OH publications
RESEARCH QUESTIONS		
<p>1) What are the occupational health arrangements for employees There is no formal system. Concerned that people are reluctant to reveal ill health in case asked to leave the site Health and Safety Adviser (also a first-aider) makes health related enquiries at induction. Annotates records to keep any information private Has never rejected an appointment on the basis of ill-health Attempts made at providing support in graded return to work post illness</p>		

Accident 038		
Accident - Direct	Generic - specific	Generic – collective / other
1) Accident communication	2) A jockey wheel mfr	
RESEARCH QUESTIONS		
1) Was there any circulation of information post-accident about lessons learnt? TBTs were undertaken locally, but there was no time to liaise with any other than immediate personnel The bowser manufacturers were not contacted as it was not a problem with their product		
2) What aspect of jockey wheel design could have reduced this accident? Less vulnerable jockey wheel designs are available, but purchase is customers led. More robust jockeys, incorporating design for human interaction are available & more commonly used overseas and by military services The equipment/plant is likely to have an EN/BS, but there is no standard for the jockey wheels. Damaged products can be replaced with poorly specified substitutes		
Accident 039		
Accident - Direct	Generic - specific	Generic – collective / other
1) Post- Accident communication		
RESEARCH QUESTIONS		
1) How was remedial action for the accident managed? The slewing ring was being used out of context – this was unorthodox and not planned by the manufacturers – advice was not sought from the manufacturers A hydraulic torquing wrench has now been bought to accommodate the high frequency of undertaking this activity There have been no changes in workload and absence management since the accident		
Accident 040		
Accident - Direct	Generic - specific	Generic – collective / other
		Health and Safety Specialists – responsibilities and ownership re PPE use

Table 69. Summary of latent condition accident study data

8.5 Techniques used for results categorisation

The tabular presentation of latent condition information shown in the last section answered the immediate research questions in relation to each accident but, in isolation, did not represent the findings in the context of the construction industry. In the same way, qualitative analysis of site findings (7) counter-balanced this and a similar style of analysis was used to explore the findings and identify the themes and common trends relevant to the industry.

8.5.1 Distinguishing accident direct and generic follow-up

Over forty follow-up interviews were held and these included a mix of individual or group discussions; many were able to provide information concerning more than one accident (recorded as generic specific or generic – collective interviews). The interview types are reproduced in Table 70, (categorised according to the data collection method used) together with abbreviations that are later used in the text.

Accident – direct	Generic – specific	Generic - collective
Structural Engineer (SE)	Temporary Works Designer (G-TWD)	Senior Site Managers (QS, Site Planner, Contracts Mgr, Project Manager (G-SSM)
Architect (A)	Ergonomist Analysis (self)	Plant suppliers (G-S)
Planning Supervisor (PS)	Ductwork Designer (G-DWD)	Architect (G-A)
Site Management staff *(~ x5)	Regulatory bodies (CITB, HSE specialists)	PPE Suppliers G-PPE)
Site Safety staff*(~ x7)	Scissor Lift Manufacturer (SLM)	Health and Safety Specialists (G-H&S)
Temporary Works Manager (TWM)	Plasterboard Trolley supplier (PTS)	Supply catalogues
Ductwork Designer (DWD)	Harness Designer (HM)	
Groundwork Contractor*	Jockey Wheel Manufacturer (JWM)	
Cavity closure manufacturer (CCM)	Concrete pump manufacturer (CPM)	
Extractor fan manufacturer (EFM)		
Lorry crane manufacturer (LCM)		
Scaffold tower manufacturer (STM)		

(* comments extracted from site data and reported by accident number)

Table 70. Profile of resources used in latent factor data collection

8.5.2 Categorisation of latent conditions

As a framework upon which to distinguish the findings, the methods of cross-referencing the development phase with the failure categories was re-employed. Further analysis of the information concerning the information source (accident direct or generic) (Table 70) revealed that the information also formed natural groupings

within the three development phases; these findings are reproduced in Table 71 and show the main information resources for the new categories.

Phase Resource	Project Concept Design and procurement	Work Organisation and Management	Task execution
Information sources	Designers and Planners	Managers and Suppliers	Ancillary designers*
Accident – direct	Architects Site Management staff (=) Site Safety staff Ductwork Designer (=)	Planning Supervisor Site Management staff (=) Temporary Works Manager Groundwork Contractor	Cavity closure manufacturer Extractor fan manufacturer Lorry crane manufacturer Scaffold tower manufacturer Mitre saw manufacturer
Generic – specific	Nuclear Installations Designer Temporary Works Designer Ductwork Designer (=)		Scissor Lift Manufacturer Plasterboard Trolley Designer /supplier Jockey Wheel Manufacturer Concrete pump manufacturer Harness Designer
Generic - collective	Senior Site Managers & Planners Architect Health and Safety Specialists	Plant suppliers PPE Suppliers	
		Other	
	Ergonomist Analysis, Regulatory bodies (CITB, HSE), Supply catalogues		

* Ancillary design denotes a common term adopted to encompass the designers of tools, equipment and materials used on site

Table 71. Distribution of interviewees included in latent factor work

Supplementary information was also available, 'other' and this was used to support or explore findings as appropriate. However, whilst it was relatively straightforward to categorise findings derived from the industry itself, this was less straightforward for information that had been generated outside the construction process. Information from suppliers and manufacturers, for example, whilst fundamental to the latent factor investigation, was a new resource to the research, revealing fresh information without an initiating prompt from construction related resources.

Development phases Failure categories ↓	Project Concept Design & Procurement	Work Organisation & Management	Task
Design & execution	Development of build plan and design	Transfer of management and build requirements	Provision of hardware and materials
Planning Scheduling & Management	Defining and organising contractors Factors affecting personnel management and task conditions		
Information Transfer (MS, RA, induction etc.)	Determining design requirements Assessing and defining safe practice		
Role, skills, abilities and attitudes	Role and skills development Shortcomings to optimum role execution		

Table 72. Categorisation of latent conditions

As a means to draw together and distinguish these new findings, the section headings were revised (Table 72). In contrast to the site data results, where many of the findings cross-referenced to 'Planning, scheduling and management' issues (and had no real route for further pursuit), findings here related primarily to the 'Design and task execution' category. This is reflected in the refashioning of the table.

8.5.3 Presentation style

At the beginning of each section the main points from site data qualitative analysis are reproduced in order to put the findings in context. Information source abbreviations (Table 70) are inserted into the text and denote relevant issues to their basis and reveal where conflict or contrasts arise. Some findings derive from second interviews with site based personnel and these are reported by accident number. As in Phase Two analysis (7.2.3), the volume of these annotations are not intended to represent strength of feeling, merely the range and commonality of experiences among respondents.

8.6 Development of build plan and design

Failure generation ↓	Phase →	Project Concept Design & Procurement	Work Organisation & Management	Task
Design & execution				
Planning Scheduling & Management				
Information Transfer (MS, RA, induction etc.)				
Role, skills, abilities and attitudes				

8.6.1 Build scheduling

Findings from site data collection

- Revisions to the project timeline adversely affected build scheduling

8.6.1.1 Factors affecting the development of project timelines

Determining a build schedule

Individual's knowledge and skills gained through previous experience appeared to be the primary resource for determining the build schedule and project timeline (021, G-SSM). Additional resources to supplement this included access to a book of 'Estimators Basic Data' (work study of construction operations) or use of computerised packages capable of calculating rates of construction operations (G-SSM). Whilst it was reported that work-study data eventually becomes learnt, any cross reference to this basic data eventually becomes obsolete, the computer package appeared to offer a broader range of advantages. For example, providing the client with cost estimates, facilitating calculation of task organisation and space allowances and assisting workload management where late or missing information occurred.

Build scheduling required a range of different allowances - time for architects and designers to prepare and deliver, time for materials such as plaster and concrete to cure, time to go through the sub-contractor tender and appointment process, time for inclement weather, time for closure and holidays and time to accommodate quiet periods (in residential areas for example).

Whatever the methods used in preparation of the build schedule, the arrangements and provision of any flexibility appeared vulnerable to the nature of relations with the client (021, G-A, G-SSM).

It appeared difficult for principal contractors to justify actual time requirements to the client. Clients traditionally stated their time requirements and there appeared to be an inevitable episode of bartering between the Principal Contractor and client in order to agree a build completion date. Interviewees felt that clients were poorly advised and that later repercussions of a tight time schedule might result in the taking of short-cuts by sub-contractors (G-SSM).

Build schedules were also revised because of sub-contractor tenders. If sub-contractor tender times varied from those originally scheduled, then re-evaluation of would be required. Interviewees felt that a quicker tender was generally provided where work was offered on a packaged or priced basis. (G-SSM). It was also reported that there are problems when the work programme gets out of line, as others working nearby may not be protected from hazards to which exposure was not expected (G-H&S).

Issues surrounding project timeline revision

The accommodation of late requests from clients (either to develop or revise their work) appeared relatively common for the architect interviewees (001, 002). For the most part this was sporadic, yet appeared to induce intermittent and considerable time pressure. Information derived from the 'generic architect' discussions revealed that 'architect instructions' (AIs) were for 'assumptions that haven't come to pass' (e.g.: a change in the lift supplier leading to shaft and motor room changes) and that otherwise their avoidance was preferable for project success. There were concerns too that this later information is missed out of the risk assessment process. The Generic Architect perspective was that AI requests more commonly derive from contractors, who use this method to increase time and financial allowances (G-A). However information from generic senior site manager interviewees completely contrasted with this; they reported that extension claims and design revisions derive from client requests 99% of the time!

8.6.2 Detail and design of the structure

Findings from site data collection

- Lack of clear specification of design responsibilities
- Lack of fine detail in design
- Acceptance or blindness to longstanding design problems

Reports and analysis of information from interviewees reinforced findings from site data collection concerning lack of specification of responsibilities and fine detail in design.

8.6.2.1 Designers' perspective

Designers assumed a role of providing initial tender drawings or performance specification (G-DWD, 001, 004, 005), yet the fine detail or prescription of technical solutions for these was attributed to the principal contractor or (more likely) the sub-

contractor chain. Designers were wary of providing excessively prescriptive measures, as building tolerances are too great and any more careful measurements would incur additional time and costs (G-DW).

8.6.2.2 Contractors' perspective

From the sub-contractor perspective, design ownership was seen as the domain of whoever had appointed them to undertake the work (005). Sub-contractors developed and undertook the portion of work that they had been contracted to undertake, yet at times had little knowledge about the context of application or interaction with other contractors. In accident 003 for example, where the fan was seen as a causal factor in the dangerous occurrence, the extract fan manufacturers were not involved in ducting and fire protection choices – these aspects were reported to be entirely within the remit of their employing contractor.

8.6.2.3 Use of proprietary products

Designer involvement also appeared reduced where there was standard use of proprietary products (002, 005). In accident 005, for example, the use of a proprietary cladding system appeared to have inferred the undertaking of a common activity and one in which the Planning Supervisor would not normally be involved (PS). Information about the unusually heavy angle weights appeared masked within the apparent 'standard' nature of the activity.

Alternative designs could have produced the angle in smaller sections, or the angle: cladding design could have been revised to avoid handling at height (G-CS, PS). These alternatives, however, would have introduced additional costs through the introduction of extra handling time or in the development and purchase of more complex fittings (005, G-CS). Design processes appeared to have had input from multiple personnel in accident 005 and safety measures appeared to have been directed at accommodating rather than challenging any design inappropriateness.

8.6.2.4 Lack of design

Problems with unclear ownership, boundaries of responsibility and poor liaison appeared to carry over from structural to temporary works design too. Many of these

issues relate to design for task compatibility of tools, equipment and materials used and are discussed later (8.8.1).

There commonly appeared to be lack of design or ad hoc arrangements for temporary structure design. In accident 010 for example, it was confirmed that the use of ply board as a hole covering had never been designed (010). Any decisions that might relate to the board diameter / density / loading capacities in any given situation would be determined by the carpenter.

...there is no culture of calculating ply requirements; the technical ability is not on site ...

Even where there had been ply board failure, remedial action perpetuated the exclusion of formal calculations or determination of board qualities (010). Ply board re-use was reported both as rare (G-TWD) and common practice (010) indicating very different experiences or perceptions for those with on- and off-site design responsibilities.

8.6.2.5 Drivers to lead innovation

It was proposed that there are a few lead architects who pioneer new practice or innovation; clients seek these qualities for landmark designs. Later, the novel practices often infiltrate into standard building practice within a few years (G-A). In spite of this, information in 8.6.2.1 and 8.6.2.2 revealed that choices for design alternative were often transferred or distributed among a number of different personnel in the build development and construction process. Responsibilities appeared blurred or diluted and opportunities for using products for more advantageous human interaction appeared to have been lost. Specialist advice has revealed that a number of design alternatives might have been appropriate for some of the accident scenarios. There was a strong preference for the introduction of more pre-fabricated materials on to site (G-CS), which was seen to improve quality and 'handlability' within controlled conditions (G-A). For example:-

- Use of pre-fabricated welded mesh carpets instead of individual tying of steel rebars (001)
- Use of alternative design and steel angles weights (005)
- Use of or pre-finished M&E structures (035)

The need for contractor involvement in off-site fabrication was acknowledged, in order to ensure continuity in knowledge of set-up, work phasing and planning etc. (G-A). Interviewees reported that costs were a significant influence upon the innovation choices made. It is not known what data are available to cross-tabulate costs of design innovation (such as time to devise, manufacture, integrate with build and schedule and train personnel) with those of more traditional methods.

8.6.3 Site layout

Findings from site data collection

- Inadequate space and traffic route provision
- Poor quality utility services drawings

Site layout related failures were commonly reported, yet few of the 'specific' follow-up interviews were successful in providing any general insight into the design and management issues involved. However, information was available concerning utilities supplies.

8.6.3.1 Provision of utility supplies

Problems were identified with the selection of appropriate locations to secure power cables (due to the nature of the work or temporary structures) (017). Even at the point of bringing services onto site, poor or inaccurate records from the Utilities services caused confused access and uncertainty (020). The Principal Contractor was described as responsible for the layout of temporary or portable services, with advice being sought from a Temporary Works Designer if an appropriately qualified person was not available on site. Positioning (to avoid snagging / damage of overhead cables or re-routing once interior walls have built) was one of the major problems – coupled with cabling straying into traffic routes and not being correctly repositioned or maintained in the desired position if movement had been necessary (G-SSM).

8.6.3.2 Barriers to efficient supply set-up

Both Generic Architect and Generic Senior Site Management interviewees recounted problems relating to liaison with Utility service providers and how client reluctance to establish an early contract can inhibit project progress. Utility service providers appeared unable to provide accurate drawings (especially water) and were unwilling to release information without full payment upfront. At times this entailed the

supplementary appointment of a labourer (and additional costs therein) to undertake a ground assessment and dig trial holes to assess ground conditions.

Architects and Principal contractors, not holding the service contracts, were unable to exert any influence other than to try and persuade the client to take action. This had a significant later impact upon preparedness for work and any subsequent time pressures. Generic Senior Site Management interviewees also felt that Utility services retained a 'Statutory Authority' mentality and did not behave as sub-contractors.

8.6.3.3 Space for welfare facilities

It was reported that some clients lack understanding of their responsibilities to provide space for personnel and welfare (G-H&S). There appeared to be some conflict concerning the provision of welfare facilities. Architects have to maximise clients profits, yet responsibility for provision of cabins etc., was attributed to the Principal Contractor. Within this, the Quantity Surveyor was also required to organise welfare facilities according to the sub-contractor tender submissions (G-A) and anticipated work schedules.

8.6.4 Contractual influences

Findings from site data collection

- None - New theme generated via latent factor data analysis

Interviewees had varied preferences for the different contract types commonly used. Findings are reported per information source, but at times appeared somewhat contradictory.

8.6.4.1 Partnered projects

Architect interviewees (002, G-A) both showed a preference for 'partnered' projects (Architects and contractors act as mutual contract holders), as it appeared to enhance an equal sense of ownership and performance on the project.

8.6.4.2 Perceptions of Design and Build contracts

Architect interviewees had different preferences for 'Design and Build' (although it was acknowledged that all contract types have good and bad points, G-A). For one, 'Design and Build' enhanced opportunities for the Architect & contractor to work together from

an early stage. This led to improved buildability and teamwork and avoided the contractor developing a lot of 'un-drawn design' upon their own initiative (002). The alternative viewpoint was that whilst such early liaison was desirable, this was only possible when the client was prepared to pay for this early collaboration (G-A). The Generic Architect interview revealed that the downside of 'Design and Build' was that Architect novation (meaning allocation without any negotiation) to the contractor resulted in 'dumbing down' of the design and stifled innovation. It was felt that minimising design by contractor led 'valued engineering', resulted in safety compromises (such as provision of harness hooks rather than full edge protection).

The training specialist felt that Architect driven projects were advantageous, and that 'Design and Build' was less preferable as site decisions were less skilled, informed and experienced. The Generic Temporary Works Designer supported this view, in that 'Design and Build' inhibits early Architectural input to solutions. From the perspective of senior site management interviewees, however, 'Design and Build' provided an exact specification with fewer variations. For them there was some control over the Architect and an opportunity to make the design practical or buildable. Invariably they acted informally as construction consultants to Architects and the client supports this input (G-SSM, G-A). The downside for them was that the risks in this style of management resulted in them having to assume responsibility for the design.

8.6.4.3 Perceptions of Construction Management contracts

The Generic Architect interviewee preferred Construction Management, as quality was enhanced with detailed performance requirements and drawings. Their work had to provide sufficient flexibility for contractors to input, to take ownership of the design and to determine how the design should be built. Disadvantages were that Construction Management forced the Architects to design in 'packages'. Designing in 'packages' was disliked – as it necessitated Architects to contract technical construction advice and resulted in lost control over the design risk assessment (G-A). Working in 'Packages' were also seen as a problem by the senior site management interviewees, as it encouraged sub-contractors to take on and struggle with work in which they might be inexperienced. There was also a regional perspective here – with a dearth of skills in some areas exacerbating the problems. There appeared to be no formal definition to identify the difference between a sub and packaging contractor (G-SSM).

8.6.4.4 Clients' perspective upon contract types

The Generic Architect interviewee felt that, from the clients' perspective, cost certainty was reduced with Construction Management. Alternatively, with design and build contracts, Architects have greater input into the design, which facilitates contractor costing and price certainty for the client. The greatest control would be obtained through a fixed price lump sum payment but this was felt to be disadvantageous, as the Architect would undertake considerably more work without the contractor on board (G-A).

8.6.4.5 Contractual essentials and barriers

Irrespective of contract types, interviewees felt that there was greatest advantage in close working relationships between designers and contractors - from the earliest stage possible. The impact of the client was seen as fundamental to later successes down stream.

Client failings were perceived as inability to pre-plan and listen to the contractor's advice, inability to make up their minds, inability to provide an Architect with sufficient time to complete their work before the contractor starts, disinterest in health and safety and ridiculous pressure to conform to ever tighter timescales (G-A, G-SSM). It was acknowledged that clients business' change and that this could affect their build requirements. There were reports too (from a business perspective) that designers felt pressured to tell client that they were coping, but that intervention from the HSE Enforcement Officers had a positive effect upon client: Architect: contractor liaisons (G-SSM, G-A). There were reports of considerable time pressures too for designers, as they also experienced tight timescales during client liaisons (001, 002).

'Compliance with the CDM Regulations' appeared to be the most commonly cited reference by interviewees. Only Architect interviewees spontaneously offered any critical appraisal of the legislation - indicating that its usability and guidance from the HSE was inadequate (002), and that contractors used it as a beating stick to constrain their work (G-A). Increased HSE presence and intervention on sites was urged (002, G-SSM), perhaps with a more informative and facilitative approach (G-A). There was also a call for acknowledgement and advice from the HSE on the influence of contract procurement on design and health and safety (G-A).

8.7 Transfer and management of build requirements

Failure generation ↓	Phase →	Project Concept Design & Procurement	Work Organisation & Management	Task
	Design & execution			
Planning Scheduling & Management				
Information Transfer (MS, RA, Induction etc.)				
Role, skills, abilities and attitudes				

8.7.1 **Procurement of hardware**

Findings from site data collection

- Cost restrictions resulted in insufficient quantities, materials or equipment

8.7.1.1 Ownership of procurement decisions

Architects appeared to expect that contractors would request design revisions, such as the introduction of cheaper or simpler build measures (002, G-A). Whilst designers appeared happy to consider alternatives (and revision to cut costs was also instigated by clients), they did not perceive hardware procurement as part of their role or within their control (001). From the Senior Site Manager perspective however, their own input was less if designers had made a specification perhaps for aesthetic or creative element of the work.

8.7.2 **Influences upon selection and purchasing criteria**

Findings from site data collection

- Purchasing criteria were vague and dominated by financial considerations

Analysis of interviewees’ reports indicated that, although product alternatives are available, some purchasers bought indiscriminately and were not trained to select and buy for user interaction or work application (G-PPE, G-PS); this appeared to affect all products used for task execution - ‘hardware’ items such as tools, equipment and materials and also PPE purchase too.

8.7.2.1 Financial considerations

Principal Contractors specified certain suppliers (for quality and delivery certainty), yet sub-contractors reportedly made their own price agreement and service arrangements (G-SSM). From the site perspective, problems centred on acquiring materials at the right time and their subsequent storage. This was less problematic with hired equipment such as plant, but problems were reported with manufacturers expecting storage either with the sub-contractor or on site even as soon as goods were ready and even prior to items being required. Items stored on site were vulnerable to damage. Payment would be required upon delivery, causing contractual problems if there had been programme revision and the build was behind schedule (G-SSM).

From the manufacturer's perspective, the influence of customer purchasing and a routine desire to obtain the cheapest products (sometimes contravening manufacturers or suppliers advice) was seen as the greatest influence on the quality (affecting comfort and task application) of products used in the industry (LCM, JWM, STM, HM). These purchasing arrangements meant that purchasers wanted multi-functional products (MSM), or alternatively, rarely bought anything but the bare minimum, missing out on opportunities for better quality or innovative designs (HM, JWM, PPE-S, HM).

Alternative designs were also available as a result of research and development commissioned by the military or emergency services. Learning from these examples was not transferred to commercial market and manufacturer interviewees felt that the customer led culture inhibited any such progress. Examples of improvements included harness development for female users and an innovative single action / all terrain jockey wheel (HM, PPE-S, JWM).

Incidences of non-use of available products were observed during the site data collection period. For example, it was clear from literature search that rebar tying guns and alternative (safer) craft knife designs are available. However, these alternatives were not observed during site visits - methods of introducing and trialing tools traditionally purchased by the self-employed are unknown. Impact at an organisational level was also apparent. In accident 003 for example, spark arrestor filters had been made up in-house to protect the extractor fan during the decommissioning activities, yet

it was apparent that a range of filter products were already available from the manufacturers (EFM). Whilst it cannot be ascertained that cost was the determinant of the development of the product on site, the possible influence of this and dissemination of information about product ranges may have influenced the choices made.

For larger equipment, manually operated components (as opposed to those fully automated) reduced purchase costs, yet may also have contributed to poor usability. In the case of the lorry crane for example, manufacturers revealed that upon servicing vehicles, it was not uncommon to discover manual outriggers jammed in their stowed position and clearly unused (LCM). Similar histories for hydraulic equipment are unknown, yet the researcher anticipated considerable physical burden and possible disincentive to use manually operated equipment that had deteriorated into this condition.

However, comments from site-based interviewees suggested that purchasing strategies did exist – with examples where service providers were required to provide products in a style to improve handling (033), strength and protected / minimised sharp edges (G-SSM). They reported that lengthy development and manufacturing times caused problems, especially where bespoke products were required for specific work activities (G-H&S).

8.7.2.2 Marketing strategies

Product manufacturers varied in approach to marketing. The more rudimentary or traditional product designs appeared to have received least innovation. Concrete adhesion to steel appeared to be a perennial problem yet there were no reports of research into lower adhesion products. Indeed there was commercial advantage in replacement, rather than repair of damaged products (CPM).

An alternative perspective was in marketing enhanced safety features of a product. In accident 002, for example, site personnel felt that mitre saw replacement with a similar product containing a disc brake was superior. Whilst acquisition of a newer generation product may well have achieved this (and the researcher did not undertake a detailed comparison of either product), it was not evident that the new disc stopping was necessarily superior to its predecessor. Latent condition data collection revealed that all

circulating blades must stop within a 10 second period (whether by brake / disc design /other means) and that many stopped within a 3 second period in any case (MSM).

Whilst it was reported that new products brought onto site should be subjected to risk assessment, the process to 'avoid or reduce risk' did not appear to easily translate into optimising use or performance (see also 9.2.1.18). There were also reports of reluctance among site foremen to change, apportioning a certain amount of rejection of new innovations to them (G-H&S).

8.7.2.3 Boundaries of hardware supply

It was suggested that sub-contractor purchasers have little detailed knowledge of the product range available (G-H&S). Interviewees described their PPE purchases with 'compliance' being a leading factor in purchase choices (036, G-SSM). Nonetheless whatever purchasing problems existed it was reported that sites do try to keep a full range of PPE stock and sizes on site, but problems in providing adequate storage and security affected the quality of what was purchased (G-SSM).

Interviewees described problems with product deliveries (G-SSM). These concerned delivery issues – with loss of control as a result of deferral of responsibility to sub-contractors and also due to restricted delivery times if in a residential area.

Manufacturing processes, with a desire to make all like items together, were also reported to have a negative affect on product availability.

Manufacturers also felt that supply was influenced by hire and supply companies, reporting that they were often unwilling to stock anything other than the most commonly used parts (STM).

Additionally, there were intermittent reports by manufacturers that some hire companies replaced damaged parts with a lower specification than the original product (JWM). Whilst it was not possible to verify this, a suggested reason was that repair and replacement of damaged parts was a source of revenue for Hire companies – for them an apparent disincentive to supply the industry with quality parts or products (STM).

8.7.2.4 Mixing brand products and components

Manufacturers provided mixed responses concerning the compatibility of their products with those of competitors. Responses ranged from little compatibility among PPE components (PPE-S), to an acceptance of interchange of detachable parts (harness lanyard and scaffold tubes for example (HM, STM) or where parts were subject to routine deterioration (saw blades for example, MSM).

Compatibility was seen as quite possible with other products, concrete parts for example (CPM), yet the manufacturer emphasised that this would not account for different qualities of parts offered by other manufacturers. In other cases, compatibility was inconsistent. In one case, the scaffold tower manufacturer reported deliberate development of their tubing to the same diameter of scaffold pipes – in order to permit interaction between the different products (STM). An alternative viewpoint was that commercial aspects limit interchangeability of scaffolding, ensuring consistent purchase and use of a manufacturer’s product at any one time (G-TWD).

8.8 Provision of Hardware and materials

Failure generation ↓	Phase →		Task
	Project Concept Design & Procurement	Work Organisation & Management	
Design & execution			
Planning Scheduling & Management			
Information Transfer (MS, RA, induction etc.)			
Role, skills, abilities and attitudes			

Analysis of site data revealed that there were many common problems among the range of tools, equipment, materials and PPE. This commonality is also apparent in latent condition data analysis and, in the light of this, findings in common are reviewed according to the term ‘product’.

8.8.1 **Compatibility for task purposes**

Findings from site data collection

- Poor compatibility for task purposes

8.8.1.1 Product qualities

Acquisition of products of an appropriate quality was reportedly subject to influence by the import of cheap, poorly specified and low quality products from Asia (HM, JWM). One of the issues apparently influencing this was where no standards or specifications existed for some parts. For example, it was reported that imported jockey wheels often bent easily and were not dimensionally true. The lack of specified standards or criteria meant that when these items were used as sub-components of a larger product (for which a standard was defined) the fidelity and overall quality was compromised.

Products without standards were subject to alternative influences however. From a design perspective, it was reported that harness buckle quality was unspecified in EU standards, yet there was some inference of this in related guidance which specified that that the buckle should not shear the webbing (HD). Lack of specification was also relevant in the use of raw materials on site. With ply board for example (and in spite of different perceptions of re-use, 8.6.2.4) there were indications that quality deteriorates over a period of months and that off-cuts or pieces of variable quality and strength were chosen for covering holes.

Manufacturers described a variety of measures to ensure durability and reliability of their products. Parts warranty was reported in some cases (MSM, LCM), and orders for replacement or repair were also used as measures to identify quality issues (CPM, STM).

8.8.1.2 Tool: Product compatibility

Temporary works typically involved the erection and dismantling of structures during the process of the build. Whilst there appeared to have been some innovation in user friendly fasteners for newly developed products such as cavity closure frames and scaffold towers (CCM, STM), the more traditional products, such as ductwork, scaffold and steel props / braces did not appear to have benefited from comparative design innovation.

An example of the impact of this can be seen in accident 004, with the discovery that dismantling of the column entailed two ascents (G-TWD). The first involved wedge removal and the second spanner use to undo the braces. It was commented that had the

operative used the formal dismantling procedure the operative would have tied the props with rope upon wedge release to keep the structure secure - but that in practice it was 'faster to do it all at once'. Researcher observation during the site visit had already identified that brace removal would probably automatically disengage the steel props without any intervention from the operative; the design and interaction of the different parts did not promote safe working practice. A natural desire to use the quickest or most convenient dismantling process – perhaps too the most logical method – resulted in an unstable structure and a work hazard.

It was also suggested that similar issues might also apply to scaffolding use (G-TWD). Whilst there is a range of proprietary systems, typical dismantling might also entail two ascents – the first to undo and remove scaffold clips and the second to undo and remove scaffold tie nuts. Whilst it is not known what Scaffolders dismantling preferences are, it appeared that this double ascent process was governed largely by the use of different tool types to operate the scaffold clip and tie nuts. Scaffolders interviewees had already revealed that they avoid changing tools whilst working at height (for balance and for fear of dropping them). The lack of interchangeability of tools for related product use and, possibly the physical burden of carrying a range of tool types, were considered by the researcher to increase the risks of time spent working and manipulating products at height.

8.8.1.3 Structure: Product compatibility

Structure: product incompatibility issues occurred in use of scaffold towers in areas of restricted headroom from interior ceiling structures (036). Manufacturers reported that minimum available height increments of scaffold frames were 500mm (STM). It is not known whether these minimum sizes were available on site, yet it is clear that optimum working platform height with the handrail had not been possible. Further exploration with the manufacturer revealed that there had been previous problems of this nature. In one case the company had been able to pioneer a solution (with support from an HSE Inspector), but the final design fell outside the formal handrail requirements (Health and Safety Executive, 2001). The company were willing to promote such solutions, but felt that endorsement or support from the HSE would be essential in such an endeavour.

A second incompatibility occurred with the use of the plasterboard trolley. It was reported that this item could be driven from either end, and that swivel wheels at one end only offered greater control (G-PTM/S). Demonstration revealed that any manipulation was possible in an open plan area, yet where manoeuvring was restricted to a narrower area (such as a scaffold gangway with direction changes) it was considered by the researcher that ease of manipulation would be greatly reduced – not withstanding the added burden of weight when fully loaded.

8.8.1.4 Environment: Product compatibility

There was a little general guidance on environmental factors relevant to products used. Equipment that might be vulnerable in windy conditions was variably provided either with (STM) or without (MLM) guidance on how to judge the severity of wind. Ground conditions were also discussed for use of the lorry crane. It was reported that there was no indication by the manufacturer of what might constitute suitable ground conditions (although this should be addressed in operator training). Appropriate counteractive measures included the use of outrigger 'slippers' (purchased as an optional extra), observation and knowledge of the ground condition; brick blocks were not thought suitable for outrigger support, but steel or wood (including railway sleepers) were considered appropriate (LCM).

8.8.1.5 PPE: Task compatibilities

It was felt that PPE was compromised by poor care and maintenance, with inadequate arrangements for cleaning and storage of PPE products and little insight into how products might degrade or deteriorate from exposure to various contaminants (PPE-S, HM). There were concerns too that PPE is not designed or properly issued (G-H&SS). Accident study examples include the inappropriateness of harness use whilst working at less than 4m from the ground (036), dexterity problems with poorly fitting gloves (034) and reduced comfort and ventilation problems during use of multi-purpose goggles (035). These problems tie in with findings from site data collection (7.3.3.4) and also expand upon the range of problems identified in the selection and purchasing among the range of products used on sites.

8.8.2 Compatibility for human interaction

Findings from site data collection

- **Products had poor compatibility for human interaction**

More detailed analysis and exploration of the way that tools, equipment or materials are used on site revealed that compatibility for human interaction was often poor. Findings reflect many of the failures already observed during site data collection.

8.8.2.1 Product: User specification

Manufacturer interviewees generally described few criteria for users of their products; where this was specified it related to user skill base (MSM, LCM), strength, and personal and anthropometric characteristics.

Some manufacturers indicated that users should be able bodied (MSM, STM, MLM, CPM). Others gave more information, indicating that they developed their products for mixed sex and/or mixed handed use (MSM, HM), whereas others felt that design was more likely oriented towards male users for some products (CPM, MLM), as in the case of rescue breathing apparatus (PPE-S). Alternatively others designed especially for female users, as in the case of harness design (HM) and in the designation of a handbrake operational force less than 60kg for jockey wheel products used more commonly by women (JWM).

Manufacturer interviewees derived from varied areas of responsibility and this may reflect the detail that they were able to provide; some were unsure, felt that user characteristics was the domain of their parent company (MLM, JWM) or that it was not possible to design for physical dimensions (CPM). Nonetheless, only the PPE supplier and mitre saw manufacturer were able to consider their products in the context of anthropometry, indicating that this was incorporated within the research and development process. The PPE supplier reported that products are selected for the average person in the UK; with approximately 90% of UK product users were in the M-L size range, with the remainder as S or XL. There were also concerns that products imported from overseas (such as the USA) were designed for their ethnicity and different body shape, but were not always appropriate for the UK market (PPE-S).

8.8.2.2 Product: Handhold design

Compatibility for manual interaction appeared limited in some cases; product designs were often basic and lacked many qualities that might enhance operation or performance. Basic hand tools, such as nips (001) and craft knives (007) are used universally throughout the industry yet, between them, ergonomics analysis revealed a range of undesirable features. Sample observations included poor grasp surfaces (exposed metal, inadequate purchase points) and, in the case of nips, excessive dimensions for handhold and manipulation. For both tools, task techniques included the repetitive and demanding application of forces and, in the case of nips, excessive forearm rotation to the extreme of joint ranges. These aspects were all felt to be risk factors for musculoskeletal injury.

Poor grasp surfaces also featured in some equipment designs, with handhold areas of exposed metal (004, 006, 022, 038) and, where handhold areas had been provided, dimensions were inappropriate for power grasp. With the jockey wheel handle, for example the handles were exposed steel and of a diameter of only 12 – 16mm; it was reported that handles for caravan use have a rubber surface, but that this is seen as an 'extra' in industrial use customers and will not pay for this (JWM). High force application was noted in the closure of concrete clips, yet a manufacturer was unable to indicate whether the forces had been measured or that any research had been undertaken in facilitating use for operative interaction (G-CPM).

8.8.2.3 Product: Movement and manipulation

Interaction, exertion and ease of manipulation appeared overlooked in use of larger items too. Examples of these relate to the use of manual outriggers and the issues already described in relation to the physical burden of interacting with poorly maintained products.

A second example concerned unwieldy design of the plasterboard trolley. The researcher considered that plasterboard trolley use on constricted passageways might be difficult, given the fixed forward facing wheels at one end (8.8.1.3). A confounding problem was the lack of recognition that the weight of transported plasterboards might have. Manufacturers guidance was 'not to overload the trolley' yet an example trolley had a 400kg capacity. Plaster boards were not marked with their weight (mean 25Kg

each) and it was felt that, fully laden and given site reports of the conditions of floor areas, trolley movement would be considerably more difficult. There were also reports that plasterboard trolleys might be made-up by contractors on site and, given the examples seen, there was little evidence to reveal design features to enhance user interactions.

Lack of knowledge concerning the weight of product materials had also been issues in accident 005 (handling 140kg steel angles) and accident 060 (dismantling steel ducting); from which there were issues concerning the nature of procedures and risk assessment (7.5.2) and determining contractor competency (7.4.1.1).

Interaction with products used in temporary works structures were also noted as areas of concern by the researcher. Restricted aperture size between level change on scaffolding and scaffold towers was noted on a number of site visits, and was directly relevant in accident 050 (IP injured carrying tools bucket on his back up a ladder). Interviewees confirmed that aperture width would generally be determined by the width of two scaffold boards (225mm x 2) (G-TWD, STM). In the case of the scaffold tower, this dimension was attributed to a 'EU standard' (specific details unknown), but in the case of scaffold erection this was at the discretion of the scaffolder. Interviewees were not aware of any research or particular direction for this size choice, but felt that the comparatively small aperture dimensions between level changes offered a certain amount of fall protection.

8.8.2.4 Product: Interface for perceptual characteristics

Accident data analysis indicated that there were some instances of inadequate visual, auditory or tactile cues to indicate whether the equipment was safely set up or not. These issues were apparent in accident 004 and, with accident 019 as a similar example, latent condition data collection revealed that accident avoidance would have been achieved by the following of procedures and method statement (TWM). Whilst the approaches and shortcomings of remedial action have already been evaluated (7.4.2.12), the nature of the cantilever fixing methods and apparent vulnerability of the design for inappropriate operative actions and for a commonly required situation is noted.

Manufacturers described measures inherent in their designs to provide 'positive feedback' during system set-up, with examples of auditory clicks for clamps, handles or triggers (MSM, CPM, STM), or changes in balance or resistance for winches or operational triggers (MSM, MLM). Others described such features as absent on basic grade equipment, but as an optional extra for higher grade products (LCM, JWM). The researcher considered that opportunities for annotating products with item weights or safe working loads were missed. Manufacturers reported that such detail could be painted on / moulded in (CPM), but for others the interchangeability of parts were a primary reason for avoiding this (MLM). There were no examples where design had been developed for simple visual inspection of structural integrity.

Latent factor analysis also revealed instances where poor design may have compromised usability, in the context of psychological processes involved in their use. The first of these concerned the extractor fan (003) whereby 'reset' for the alarm mute was a manual operation. The researcher considered that there was inherent system vulnerability in lack of accommodation for human failings (such as forgetfulness).

An alternative situation, but related to routine operation, concerned the contravention of population stereotype in lorry crane control direction (ie: control lever depression raised the crane and vice versa). Further exploration revealed that this had been introduced approximately 15 years earlier (in response to a fatality whereby an operative fell onto the controls and was crushed as he inadvertently instigating its downward movement) (LCM, crane specialist). Interviewees felt that this was a response generated from within the industry, possibly with guidance from the HSE, but was unlikely to have included any ergonomics advice. Current crane designs incorporate a variety of safety features, such as interlock devices and force fields (to stop the crane coming towards the operator). It is not known whether the incident could recur under current design conditions, or what design alternatives might be feasible to enhance crane safety and facilitate operability.

The final example of poor compatibility for psychological processes concerned harness use, which reportedly could be put on 'upside down and inside out'. In spite of the recommended 20-minute training, it appeared to the researcher a distinct possibility that

this would happen at some stage, if achievable within the tolerance of the equipment. Impact on comfort or product efficiency though such misuse is unknown.

8.8.2.5 Product: Hazard exposure

Exposure to sharp edges or abrasive surfaces appeared commonplace and the risks through interaction seemed little challenged by industry. Craft knife blade changing entailed handling of very sharp edges, as did working with cut ductwork (or its swarf) (034, 035) and steel banding (009).

The work materials generated similar hazards. With ductwork for example, it was reported that there are no tool alternatives to reduce swarf production and that, even when goggles are worn, (if they are ventilated) dust gets through the holes or swarf drops from the hair into the eyes when they are removed. Alternative ductwork products, such as glass fibre, or other synthetic products are available, yet sheet metal was reported to account for 99.9% of UK ductwork (G-DWD). In a related example, it was revealed that solutions to reduce risks of cuts and abrasions associated with steel banding (in securing palletised products) involved its replacement with nylon banding (to a strength capacity, up to 800kg) (G-CPM). This innovation was generated through a manufacturers own in-house risk assessment (CPM); the rationale for product choices and dissemination of information about alternative products in industry is unknown.

Design for chemical hazards appeared fundamental in PPE design (PPE-S), yet was not raised as an issue by other manufacturers. Some manufacturers did not identify any occupational hazards (CCM, STM), although some did report desirable behaviour such as avoiding electric cable or working on manhole covers (LCM). Deterioration through environmental contamination was mentioned; such as the possibility of harness webbing degradation, and heat exposure during hot works (HM). Two interviewees identified noise exposure. In the case of the mobile lift, however, it was felt that introduction of a silent racket winch might actually be associated with a greater risk of crush hazards.

8.8.2.6 Product: Maintenance

Product maintenance requirements varied according to the nature of the constituent materials and likely hazard exposure. Maintenance was not required for some products

(CCM), or alternatively, where the manufacturer did not specify a maintenance schedule, they indicated that users should follow legislative guidelines for maintenance (MLM).

Some manufacturers appeared keen to facilitate product usability by minimising maintenance requirements. Measures to achieve this included the provision of fixed price service and maintenance contracts for customers (LCM). Alternatively, although there was no maintenance schedule for the mitre saw (wood splinters were not seen as an especial problem), some internal parts were intentionally accessible (for blade changing etc.), yet full access to other inner mechanisms was deliberately restricted by compatibility only with non standard tooling (MSM).

Maintenance of less sophisticated products generally required more traditional cleaning methods. for example, it was reported that goggles should be cared for with warm soapy water and anti-mist wipes, but that there was general poor maintenance of PPE on site (PPE-S). There were varied reports on how concrete pipe equipment should be maintained. From a site perspective, the guidance was a weekly wash and scrub with water – using a hammer if necessary to break off resistant cement (TWM), whereas hire company guidance was to clean with water and chip off with a needle gun (G-PS). Visual inspection and lubrication were recommended for steel/ metal parts (TWM, TWD, STM).

8.8.3 Manufacturer design developments

Findings from site data collection

- None - New theme generated via latent factor data analysis

In spite of the many product shortcomings that were identified, manufacturers (to a varying degree) were involved in product improvements. From product and user trials and in response to customer feedback, manufacturers described a range of features that they had enhanced to improve usability and safety of their products and strength and integrity of materials (STM). Examples included variation in the design of load bearing shafts (JWM) redesign where parts might be omitted (STM), improved cable strengths (MLM) and greater use of simpler fixing methods.

Simpler fixing methods, such as push fit parts, spring loaded clips and reduced loading mechanisms between product parts had been devised. These were thought to reduce the volume of product parts and were seen as more straightforward and preferable because they minimised skill requirements for use (STM, CCM). These measures also reduced product weights; weight reduction and adaptation of dimensions or methods for improved handling were desirable features for other manufacturers too (CPM, PTS/M, MLM).

Design innovation to improve safety characteristics was also an important part of product development, including features such as safety interlocks to avoid unsafe use (LCM), and greater use of safety brakes (MLM, MSM). Some features, such as outrigger 'slippers' to distribute load, or harness waistcoats to facilitate correct donning mode were optional extras, and were reported to be vulnerable to customer purchasing criteria (LCM, HM, JWM).

Some features such as safety information labels or safety clips required identification by the user, yet there was concern among manufacturers that these features passed unseen or unused (MLM, CPM). For example, safety clips / pins for added security of concrete clips / pins had been developed; yet there were reports that these were rarely used (CPM, G-PS). Given the problems already observed with concrete adhesion and maintenance schedules for this type of equipment it does not seem surprising that the clips are not used. Measures for innovation, trial and development of the safety clips / pin are unknown.

Manufacturer interviewees also expressed concern about the extent of safety innovation that should be introduced into their products – given the possibility of refashioning or over-ride that might be undertaken by slowed or frustrated users and negative safety impact therein. Manufacturers also used a variety of training or informational materials to guide product users (8.10.2.3).

8.8.4 External factors influencing design

Findings from site data collection

- None - New theme generated via latent factor data analysis

8.8.4.1 Design ownership issues

Manufacturer interviewees indicated that there were at times a number of manufacturers responsible for significant portions of their final product. The lorry crane manufacturer, for example, revealed three separate manufacturers (for the vehicle, bodywork and crane) in creation of the final product; additionally, there was a further option whereby customers chose to buy and mount the crane themselves (LCM). Whilst it was clear that there were appropriate routes of consultation and communication for this process, the researcher felt that, as a general issue, final ownership of products created in this way might be challenged, or unclear.

This was the case in accident 038, where the site did not contact the bowser manufacturer about its jockey wheel failure, as this was not perceived as a fault with their product.

Another related aspect was the extent to which product designers specify use of their products. For example, the cavity closure manufacturer had originally intended to supply their product to site as a flat pack with the brace inbuilt (accident 002). However, ideas for supply of the completed product were withdrawn (to avoid potential for production faults and wastage) and responsibility for making up and choice of bracing method and material was transferred to the customer (CCM). Manufacturers were unaware that their products were being made up on site (rather than in a factory) and design ownership appeared blurred.

A final aspect concerned areas where opportunities for innovation might fall outside the usual remit of manufacturers' knowledge (e.g. qualities of nylon banding to replace steel banding, accident 009). Some manufacturer interviewees indicated that (with varying frequency) they employed external consultants, (MSM, LCM, CPM, STM, PPE-S), but it was not apparent that there was any leadership on these oblique type issues.

8.8.4.2 Overseas influences

Incidences of poor product quality and poor accommodation of UK user physical characteristics by overseas (generally US /European) manufacturers have already been discussed. In addition to this, there were concerns that, where alternative design

features (such as specific safety interlocks on lorry cranes or improved guarding or switches) were required, manufacturers internationally left management of this to UK suppliers (Crane specialist, CPM). At times, a number of manufacturer interviewees had little knowledge of the nature of design innovation measures that had been undertaken or were in development overseas (CPM, MLM). Additionally, the researcher perceived a certain degree of isolation from overseas parent companies (even from those in Europe), given their use of alternative materials, operational techniques or product choices (CPM, JWM). Nonetheless, there was some indication that the UK might benefit from evaluating the use of design alternatives used elsewhere.

8.8.4.3 Standards and specifications

Manufacturers and designers described a range of different resources that were employed in the determination of standards or specifications of their products. These included EN / TVV (German derivative) standards (MSM, CPM); trade standards (CCM, G-DWD) and/or general compliance under European Directives in the form of UK Regulations (PPE-S, MLM). A bespoke industrial standard was used in the nuclear industry. Although it was reported that the extractor fan was outside some of the static requirements for equipment in nuclear installations (EFM), any implications of this are unknown and were not explored by the researcher. In the case of the jockey wheel there was no standard, although it was reported that the German National Directive had been adopted elsewhere in Europe and Road Traffic Act 1981 compliance would apply in the UK.

Interviewees indicated some shortcomings in standards. One suggested that those preparing the standards were remote from, and lacked understanding of, the practical uses of products on site (MSM). There were also indications that some standards provided only a bare minimum criteria (such as a 100kg 'dummy' for harness drop testing) – the manufacturer in this case chose to undertake a wider range of independent testing with alternative dummy weights and dimensions (HM). Although not yet instigated, there were also concerns about the proposed implementation of mandatory use of lorry crane outriggers; worries concerned a mismatched 'idealistic' intent with a range of task circumstances whereby load, space and traffic conditions (for example) might impede facility of use (LCM).

8.8.5 Operative task technique

Findings from site data collection

- There was high reliance upon brute force
- Optimum performance was inhibited by interaction with products and physical distances on site

Through customer liaison, manufacturers gained a perspective of the types of failures or incorrect use (deliberate or inadvertent) that occurred with their products. Typically, manufacturers felt that their advice was contravened in a number of different ways:

- Taking shortcuts
 - non-use of brick ties with cavity closure frames (CCM)
 - non-deployment of outriggers with lorry cranes (LCM)
 - non-use of (metal-ended) end hoses for concrete pour (CPM)
 - omission of guards, boards, wheels on scaffold tower (STM)
- Use of incorrect fittings
 - incorrect use of nails to secure cavity closure frames (CCM)
- Use product incorrectly
 - safety hats on back to front (PPE-S)
 - respiratory protection masks incorrectly secured (PPE-S)
 - harnesses worn upside down and back to front (HM)
 - overloaded or unbalanced mobile lifts (MLM)

A range of technical specialists were consulted during latent factor data collection and their appraisal of accident data revealed that accident involved personnel had, at times, employed incorrect or inadvisable task techniques (G-TS, G-TWD, G-DWD, SM, H&SS). Specialist practitioners felt that there had been inappropriate tool selection for a number of the accidents (007, 009, 018, 020, 024). Failures included non-selection of bespoke tooling (004, 009); In accident 004, for example, it was reported that steel props are rarely used at a 45° angle and that there are few alternative proprietary systems for such an application. Nonetheless, site data revealed that alternatives do exist but availability may have been linked to supply issues. A second issue concerned non-selection of appropriately powered tooling. Failure in tool choices concerned

appropriateness for task hazards, be it to avoid undesirable operational forces of manipulations (007, 024) or tool: environment incompatibility (020).

Specialists also reported that improved task technique could have reduced accident risks. Desire for time efficiency was reported as a possible influence upon task technique. Speed (and sharpness) of ductwork drilling was considered a factor in swarf generation (G-DWD) (035), as was the choice of nails rather than countersunk screws as the speediest of shutter fixing methods (G-TWD) (018).

Adoption of incorrect working methods was also reported. The background to these incorrect choices at accident-involved level is not known, yet 'experts' opinions identified failures from their knowledge of product qualities (010, 020), or product: user interaction (019, 022). These findings are closely allied with risk assessment failures (such as testing methods to assess residual gas supply, 020), but also indicate a lack of understanding in procedure development (G-TWD, 010) and misplaced reliance upon procedural efficacy (G-TS, 019).

8.8.6 Summary of latent conditions according to design and task execution factors

Latent factor data explored and elaborated upon much of the information obtained within the site data phase 'Design and task execution' and also introduced additional factors (shown in bold, Table 73) that supported the analysis as a whole. Given the volume of information these are summarised according to work phase.

	Failures concerning Project Concept Design & Procurement	Failures concerning Work Organisation & Management	Failures concerning Task
Design & task execution	<u>Development of build plan and design</u> <ul style="list-style-type: none">• Build scheduling and timeline development• Detail and design of the structure• Detail and design of the site layout• Contractual types and preferences	<u>Transfer of management and build requirements</u> <ul style="list-style-type: none">• Procurement of hardware• Factors affecting selection and purchasing criteria	<u>Hardware and execution of the work</u> <ul style="list-style-type: none">• Compatibility for task purposes• Compatibility for human interaction• Factors affecting manufacturers design development• Task technique

Table 73. Summary of site latent conditions: Design and task execution

8.8.6.1 Development of build plan and design

Data relating to the developmental phase explored the background to the uncertainty experienced at site level as a result of build schedule revisions. Build scheduling appeared to be impacted by change or uncertainty from all directions – from alternative Sub-contractor timelines from those anticipated and as a result of client intervention. Bartering between the client and principal contractor appeared to be the main determinant of the agreed timeline. Whilst appraisal of materials used to develop build scheduling was not undertaken the bartering process appeared to over-ride or at least undermine the credibility of the calculations and skills involved in formulating a comprehensive programme. Data did not reveal the source of clients' advice in determining an adjusted build schedule.

Data revealed that there were quite different perceptions of the roles and responsibilities of architects and senior personnel within principal contractor (PC) groups. Architects were perceived as providers of the design concept, their responsibilities incorporating specification of performance and integrity of the build. Contractual influences determined the exact dynamics of their interaction and delineation of responsibilities, but the principal contractors (within their responsibilities of build management) were also afforded responsibilities for ascertaining fine detail and temporary works design for the build.

The distinction of responsibilities between the two groups appeared blurred and was often spread among a number of people (appearing to dilute rather than strengthen ownership for the design) or, when attributed to core skills, was not designed at all. This resulted in a loss of opportunities to integrate innovative practice for improved user and process performance. It appeared that the determination of this fine detail, or development of technical solutions, was perceived as less important or significant in input than the design as a whole. At times the PC responsibilities seemed quite casual arrangements, and there was an element of mothering vs. free spirited prodigy relationship between the two parties (“Architects wear a leather thong and carry a whip”!). The design fidelity of PC inputs received variable comments. Whilst their input was seen as essential the PC led design activities were openly afforded less esteem or credibility – more so a necessity to effect the build process and design objectives. The formalities of liaison, especially Architect Instructions, were very differently perceived among interviewees. They appeared especially burdensome for the PCs, in terms of time for liaison and integration of instructions.

The subtle dynamics between the designer and principal contractor groups found a common cause in mutual dissatisfaction and concerns about disruptive client influences on projects. Perspective was not gained from the project client, yet interviewees showed varied preferences for different contract types. Interviewee accounts appeared somewhat mixed, yet there was a clear preference for early and continuous collaboration between all parties. Acknowledgement and guidance from the HSE was also called for concerning the influence that contractual arrangements had on health and safety.

8.8.6.2 Transfer of management and build requirements

The latent factor data generated a considerable amount of material concerning the different range of products used in the industry and different perspectives on their development, procurement and use. Unfortunately interviewee groups were not large, but a number of issues of note emerged.

Detailed evaluation and observation of product design, use and performance reinforced site data collection findings – that design inadequacies inhibited interaction (for both

physical and psychological processing) and had a resultant undesirable impact upon usability and performance. There appeared to be three main influencers that impacted upon this outcome – those with procurement responsibilities, manufacturing responsibilities and also a number of independent external influencers. All aspects appeared to be undermined by themes in common; communication inadequacies and inadequate (or inconsistent) knowledge dissemination. These findings are summarised in Figure 26.

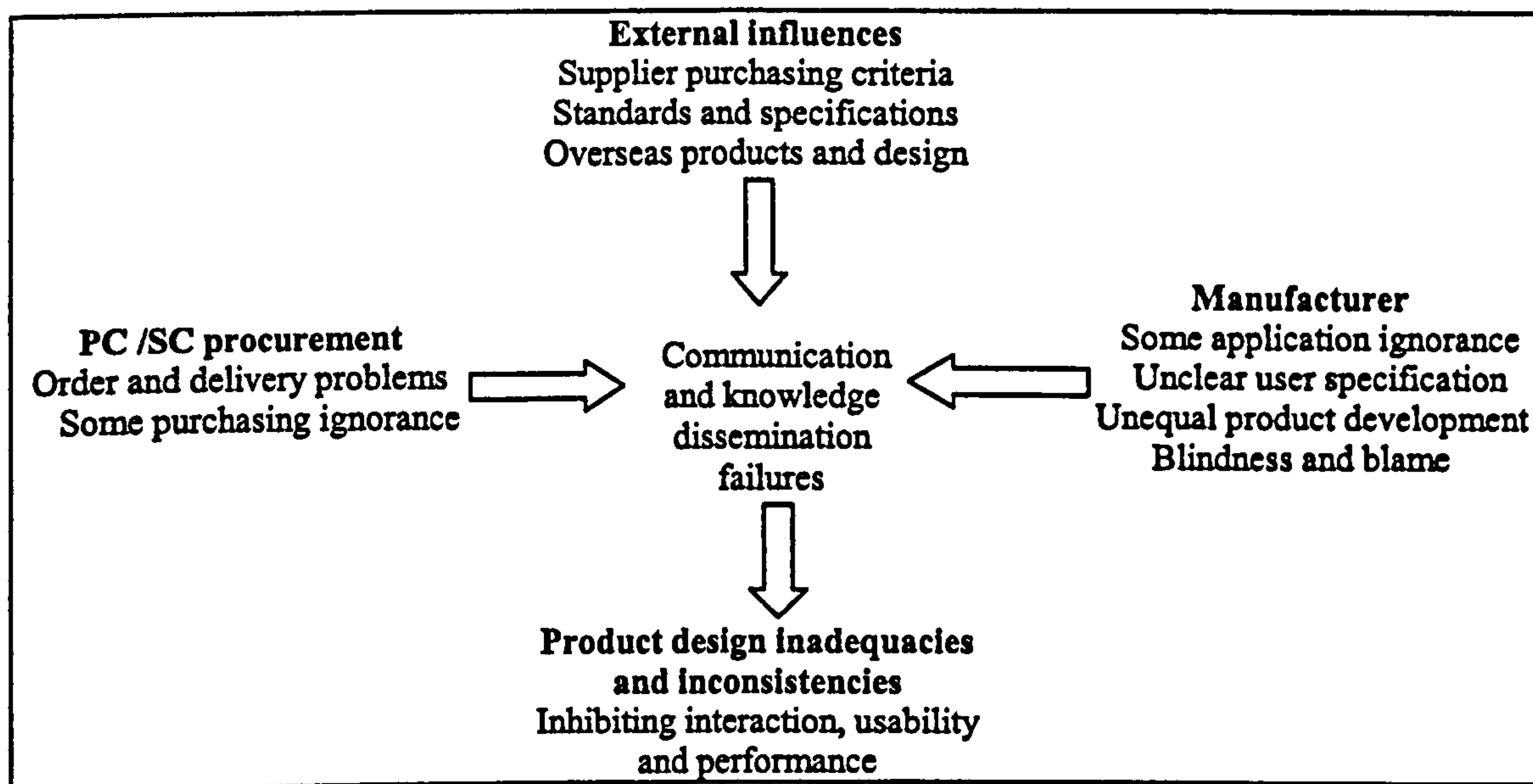


Figure 26. Constraints impacting on product development, purchase and use

Procurement issues essentially concerned activity undertaken at site level, either by the principal or sub-contractor. For those with a purchasing role their problems concerned timeliness of manufacturing, delivery and storage of products. A perspective on these issues was not obtained from manufacturers or suppliers. They did, however, express concerns that lack of knowledge and understanding resulted in indiscriminate purchasing and poorly considered use or task compatibility by those on site.

8.8.6.3 Hardware and execution of the work

Manufacturers gave varied responses and it was apparent that the drive and input into product improvement differed considerably among the sample group. Some appeared to have quite robust arrangements into product development, whereas for others (especially those making simpler products) deterioration and re-purchase were income generators and incentive for development was diminished. Development appeared

hindered by an apparent lack of knowledge of how products are used on site. Whilst some of the company's had sales representatives responsible for site liaison, overall this did not seem adequate to gain information about use, interaction and to become involved in problem management.

In combination with shortcomings in knowledge of application there was an impression too of failure to consider user specification in design. To a certain extent this may have reflected information available to the interviewee at the time of discussion, but nevertheless reports of design for human interaction (physiological and psychological processing) and for 'a range of users' were few. Where such action had been taken this was commonly directed at weight reduction and improved handability.

It was not possible to gain information from all manufacturers in the accident studies, but product evaluations and some comments indicated habitual acceptance and an apparent lack of regard to simple hazards. It was expected that the risks of cuts or abrasions, for example, would be controlled by the use of PPE. Where safety interventions had been implemented these were not always used on site. User trial of the products was very variable. There wasn't often any real sense of methods or strategy to use the trials as an opportunity to evaluate products in the context of user interaction, complimentary to evaluation of product qualities. Some safety related solutions had been generated but these did not always seem well communicated or were not considered in the light of usability or the nature of application observed on site. Manufacturers and specialist practitioners often saw adaptations or shortcuts with products as a user fault and rarely as an opportunity to explore product design and development. Indeed, misuse appeared to be a disincentive for manufacturers to explore and develop the products.

Manufacturer interviewees were not asked directly, but it was apparent during later analysis that many of the machinery shortfalls directly contravened the mandatory health and safety requirements of Annex 1 of the Machinery Directive (Great Britain Parliament 1992). Examples relevant to the failures or shortcomings observed include details for user-centred design, risk reduction, PPE compatibility, logical design or controls etc., yet this did not seem to have been identified by manufacturers or industry alike.

Whilst manufacturer innovations varied, they also had to operate within the confines of their business environment and standards and specifications. Standards and specifications were at times seen as rather dogmatic or idealist and there were some suggestions that those involved in their development were somewhat remote from practice. A dominant theme among all interviewees was of the overwhelming impact of customer purchasing power and how this limited the range and quality of products made available in the industry. Purchasers included site personnel, suppliers and other manufacturers. Manufacturers wanted to promote a number of innovative products yet were constrained by purchasing power and lack of direction or desire to introduce new products into the industry.

The impact of poor quality imports was a concern for interviewees, especially when integrated with their own products. For those with overseas parent companies there was an impression of the UK operating somewhat in isolation to the company whole. The parent manufacturer did not always accommodate UK design and user requirements. If any adaptation was required in order to fulfil UK criteria there were instances where features had to be added on to the completed product post-production. From an alternative perspective, however, it was felt that some overseas uses or innovations might be advantageous to the UK market, yet limitations in customer purchasing disabled their introduction.

8.9 Planning Scheduling & Management

Failure generation ↓	Phase →	Project Concept	Work	Task
		Design & Procurement	Organisation & Management	
Design & execution				
Planning Scheduling & Management				
Information Transfer (MS, RA, induction etc.)				
Role, skills, abilities and attitudes				

8.9.1 Recruiting and organising contractors

Findings from site data collection

- Lengthy sub-contractor chains led to loss of control and ownership
- Principal contractors experienced variable sub-contractor performance
- Sub-contractors experienced isolation from the principal contractor
- Responsibilities were poorly defined

8.9.1.1 Contractor appointment criteria

Interviewees reported that they regularly appointed those that have worked for them before (G-SSM, G-A). The advantages being knowledge of previous skills and experience and an ability to transfer learning and information previously gained.

For senior site managers the decision on whether to make a sub-contractor appointment was judged against a mix of criteria, with the project manager and client making the final appointment decisions. Essential qualities included price, ability to perform, 'safety' history (often accident records and RA/MS control strategies), quality and reputation from previous site (G-SSM). It was agreed that subjectivity was required in order to consider the tender in the context of labour requirements and skill supply etc. and the pressure upon those tendering to promise more than they could deliver (G-SSM).

8.9.1.2 Barriers to sub-contractor appointment

The constraints affecting senior site managers in their choices were pressures from clients. Clients were reported to require at least four tenders, yet contractors were frequently unable to amass the volume of sub-contractors who might feasibly be able to undertake the work. Clients were reported to consistently choose the lowest tender, with the expectation that the principal contractor would thus manage the safety of these appointees (7.4.1.3). Clients were reported to have no involvement with the subsequent appointment of sub-contractor chains.

Liaison problems and lack of continuity was reported from two perspectives – firstly in the development of a working relationship with a SC ‘front person’ ... who “evaporated” once the project was secured (G-SSM) – and secondly the lack of control and at times poor quality or understanding by those in the sub-sub-contractor chain – especially for those outside the specialist skills bracket (G-A).

8.9.2 Factors affecting personnel management and task conditions

Findings from site data collection (where relevant to latent factor data)

- Informal competence assessment ran in parallel with formal methods
- Lack of competent health assessment
- Little acknowledgement of the impact of long work hours and absence cover
- A range of concerns about inadequacies with supervision
- Frequent use of financial incentives
- Work area conditions reflected poor housekeeping

The majority of information relating to management and co-ordination of site personnel was collected during Phase Two of the research. Interviewees from the latent factor data collection phase offered supplementary data, which although not as expansive, enlarges upon earlier findings.

8.9.2.1 Skills and health related appointment criteria

Few interviewees within the latent factor data collection phase were able to comment upon appointment criteria of individuals. Data indicated that competence assessments were focused upon ‘ticket’ checks, but essentially capabilities were judged by knowledge of previous task experience and reputation of the sub-contractor firm (005).

There appeared to be little or no intervention to identify fitness for work, except where medical clearance was specified for certain work types (in confined spaces for example). An isolated incident of ‘screening’ for pre-placement ill health and graded return to work was reported, yet this well intended individual initiative appeared to be without the support of protocol or a competent practitioner (037).

8.9.2.2 General work organisation

One initiative, the development of a 'smart-card' system to monitor working hours, in the rail industry was reported, but little is known about the system, and degrees to which it will accommodate working and driving periods of employees (021).

Other accident follow-up discussions revealed that where workload and sickness absence cover had earlier been implicated in the accident study, there had been no remedial action to address these factors (039). Likewise, no allowances were made to accommodate sickness absence during planning and scheduling (G-SSM).

In discussing staffing levels, interviewees expressed especial concern about the inadequacy of supervision, especially among sub-contractors and where there were working supervisors (G-H&S). A range of different incentives (such as free breakfasts, prizes for good performance or good ideas), were employed to raise performance, motivation and the profile of health and safety. The importance of providing good welfare facilities was also acknowledged (G-H&S).

8.9.2.3 Housekeeping

Problems with housekeeping were reported in many of the accident studies and issues arising from latent factor data analysis revealed a number of factors that might have inhibited good management. Whilst standards existed, it was reported that actual effect would be whatever was accepted by those in seniority (G-H&S). Specification of clearing up frequencies was reported, yet this did not appear to infer any ongoing responsibility for maintaining steady state. With cable management for example, there was operative instruction for daily checking of leads and plugs, yet this did not extend to position management (to prevent trip hazards). Cable positioning became increasingly difficult as walls and doorways were erected (G-SSM), yet instruction on management and trip prevention was felt to be inherent within general housekeeping duties (017).

8.9.3 Summary of latent conditions according to Planning Scheduling and Management factors

Findings related to Planning Scheduling and Management were few at this stage of data collection and reflect completeness of the findings and analysis generated from site data analysis.

	Failures concerning Project Concept Design & Procurement	Failures concerning Work Organisation & Management	Failures concerning Task
Planning Scheduling & Management	<u>Recruiting and organising contractors</u> <ul style="list-style-type: none"> • Factors concerning contractor appointment <u>Factors affecting personnel management and task conditions</u> <ul style="list-style-type: none"> • Factors concerning skill and health in appointment • General work organisation issues • Housekeeping 		

There was much reiteration of earlier information – for example, reinforcing the combined ‘ticket’: subjective assessment competence determination, the lack of intervention or misguided efforts in health screening and surveillance, managers tolerance determining housekeeping standards, and supervision inadequacies especially among sub contractor groups. Data revealed that there were some inroads to monitor working hours, but this was only directed at rail work. Where cover of absent or unavailable operatives was pursued there appeared to have been little consideration of workload in accident causation. A resigned acceptance of working under these types of conditions was typical, combined with little apparent action into managing the resultant problems.

Issues surrounding contractor appointment were explored and, as with determining competency of individuals, the principal contractor had to employ a certain level of subjectivity in tender appraisal. The tendering process appeared to generate rapport with sub-contractors and generate ambitious promises that could not always be followed through in practice.

The tendering process also appeared to be adversely influenced by clients. A blanket requirement for a minimum number of tenders was felt to be unnecessarily ritualistic, especially in areas of specialist or skills shortage work. The process enforced the principal contractor to seek tenders from sub-contractors who were possibly unsuitable. Client’s reportedly over-rode principal contractors misgivings and routinely expected appointment of the cheapest sub-contractor. It was felt that clients lack understanding of possible safety outcomes of cost cutting, and had an unrealistic expectation that the principal contractor would manage the safety issues on site.

8.10 Information transfer

Failure generation ↓	Phase →	Project Concept Design & Procurement	Work Organisation & Management	Task
Design & execution				
Planning Scheduling & Management				
Information Transfer (MS, RA, induction etc.)				
Role, skills, abilities and attitudes				

8.10.1 Communication of design requirements

Findings from site data collection

- Principal contractors were late in providing sub-contractors with design guidelines
- Drawings from utility services was often incorrect
- Pre-contract health and safety documentation seemed to be biased towards tender acquisition rather than practice

8.10.1.1 Designer: Site liaison

Designers described the possibility of liaison conflicts during the development phase, especially if their work overlapped with others (e.g. architects), or if they were having to juggle conflicting client or tenant requirements (G-A).

Both designer and senior site manager interviewees expressed a desire for mutual involvement with the design from a very early stage (G-A, G-SSM). For designers this was an opportunity to liaise over methods of installation and task techniques etc. and was perceived to have a positive effect on quality assurance and health and safety. From the senior site manager perspective this enabled them to influence the designer to use simpler, quicker or more buildable methods from the outset.

Whilst there were complimentary goals the outcome of this liaison was differently perceived. From the designers' perspective necessary perhaps only if there was a particularly difficult work aspect (034) or if they felt that they had reached the boundaries of their responsibilities (001, 004, 005,024). Site visits traditionally were not undertaken by the original designer (unless essential or called for), although designer representatives might later be based on larger sites (G-A).

Site based interviewees gave an alternative perspective, describing a need for perpetual queries with designers and reaffirmation or revision of design because of inadequate or anomalous information at the outset, and late provision of information during the build schedule (G-SSM).

Designers were required to provide information for the health and safety file, including information relating to any 'residual risk' in the design. One instance, where a construction activity was considered a 'core skill', the provision of residual risk information was not thought appropriate (001). It is not known whether this was a widespread activity, but at times designers also appeared unaware of the nature of operatives' interaction in their use of products or in the building techniques used (002, 035). Opportunities to promote safer practice and performance were missed or were seen as the responsibility of the Contractor and outside the Designers role (001, 024).

The use of or introduction of 'new style' materials and designs was discussed and disparity between manufacturers anticipated uses or application of their products and actual use on site was noted. In accidents 002 and 039, for example, the cavity closure window frames and slewing ring were being fabricated or used in an entirely different context to that intended by the designers.

8.10.1.2 Manufacturer: Customer liaison

Manufacturers varied in the extent of liaison they had with customers. Arrangements varied from informal contacts to frequent and routine consultation with sites. The extent of liaison appeared influenced by the directness of contact with end users and this was absent, or least, in cases where intermediaries handled a manufacturers product as a component of a main product for the final customer (EFM, JWM).

Manufacturer interviewees were not always sure of the nature of product and user trial undertaken by their parent company (MLM), but descriptions otherwise reflected a range of different methods and levels of intervention used for evaluation. These included product reliability trials (LCM, MLM), simple trials with one or more potential end users (CCM, CPM, PPE-S), or multiple methods incorporating usability, hazard review and failure analysis (MSM).

Alternative methods of evaluation included demonstration to customers (STM, LCM) and evaluation of customer's in-house appraisal (EFM), feedback or complaints (HM, CPM). Whilst little of the follow-up data search addressed this from the perspective of the customer or end user, there were indications that consultation was not always undertaken or perceived and would have been welcomed (021). Some manufacturers who had access to end-users reported development of questionnaires (not evaluated by the researcher) to facilitate the end user appraisal process (MSM, PPE-S, CPM). Alternatively, lack of access to end-users was also associated with a lack of formal assessment methods (JWM).

8.10.1.3 Dissemination of accident related information

Interviewees generally had very little knowledge of construction industry accidents, except where there was some form of catastrophic failure (001, 002, G-A). There was a universal desire among all interviewees for access to a greater range of accident related information and dissemination of subsequent learning and knowledge gained. Whilst the HSE was proposed as one body to set up a database, it was also suggested that trade bodies and the Major Contractors Group might also be able to do more (G-A, G-H&S).

Manufacturers were dependant on customer liaisons to learn about product failure or accidents involving their products. There were concerns that, through misuse or adaptation, customers were damaging the products themselves (JWM, HM, EFM). Nonetheless many monitored product failures via customer liaison concerning damage, repair or warranty issues, and requests for spare parts (CPM, MSM, LCM, STM, MLM). Manufacturers knowledge about accidents was generally obtained through claims from insurers, where there was litigious action as a result of a reportable accident (CPM, MSM, STM, PPE-S), or if the company had been approached to provide expert witness advice in court cases (LCM, JWM, HM). Some manufacturers had no little or no knowledge of accidents with their products (038, JWM, CCM), or were concerned that they were over-exaggerated by the HSE (STM).

8.10.2 Assessing and defining safe practice

Findings from site data collection

- Documentation had many content and presentation inadequacies
- Documentation was often idealistic and incompatible with the work situation at the time of application
- Those involved with task execution had little involvement with documentation preparation
- Documentation was used as a training medium, but not perceived as such by the recipients
- Formal training was often 'ticket' orientated
- There was high dependence upon on-the-job learning, yet training provision was random and ill perceived

8.10.2.1 Risk assessments and method statements

Some designers acted as Planning Supervisors in the pre-contract stage (which included developing baseline risk assessments), and upon appointment of the principal contractor these were subsequently transferred. There were indications that preparation of this type of material for the Health and Safety file was an onerous task (001) and that the materials were at only a preliminary stage at the point of transfer. Designer's general guidelines for assessment of residual risk are unknown, but one example that was seen offered only a hazard checklist approach - in the absence of risk assessment guidelines or control measures (003).

Little further information was gained during latent condition data collection on the nature of site protocol to identify the need for development of risk assessment and method statements. In accident 020, for example, it was suggested that materials should have been developed if there had been ≥ 100 gas supplies to work on, but it is not known how such criteria is determined. Interviewees considered that generic documentation was appropriate in many cases, as was verbal instruction and attribution of responsibility to the operative's core skills (021, G-SSM).

A lack of resources was variably considered to inhibit the usefulness of materials; poor dissemination of learning from accidents was thought to inhibit the upgrading of method statements (010).

Additionally there appeared to be little insight into the range of failures (identified by the researcher) within the documentation and subsequent value that might be gained from them. The researcher gained a general impression of blanket faith in the efficacy of the materials and the systems in place to appraise them - by virtue of their existence. Even during latent condition interview, interviewees remained steadfast in their faith of the value of the documentation and the systems in which they operate. Where the documentation had existed it appeared to serve as a tool to absolve 'management' from responsibility, to endorse their sense of integrity in proactive planning and provision of task conditions, and transfer blame to accident involved personnel (002, 013, 018, 033).

8.10.2.2 Training related issues

The provision of training was considered important by all interviewees. A variety of methods (used either alone or in combination) were proposed, such as formal instruction (CPM, LCM, STM), demonstration (HM), videos, use of site based documentation, or materials from product manufacturers (G-H&S, 012, 033).

The methods chosen varied; manufacturers invariably provided paper-based materials, although had little or no control over the nature of their use (012). Interactive methods were more prevalent where there was direct access to site personnel, yet it appeared that provision of documentation such as risk assessments, method statements and supplier's information was felt to be a reasonable interpretation of 'training' (033). Where training needs arose that were beyond what was routinely provided, responsibility for identification and provision of additional instruction was apportioned to the foreman or supervisor (033).

Barriers to the provision of training were attributed to time pressures, from the general workload or as a consequence of using 'just in time' production methods (038, G-H&S). Whilst the CITB bursaries and raised profile of training were welcomed (G-H&S), there appeared to be little flexibility within the criteria to obtain funding. Training duration and the formal instruction: practical experience mix was specified; one manufacturer interviewee described being unable to 'stretch out' their training to fill the specified time period for the release of bursary funding (STM). This meant that their training was not endorsed with a 'ticket' and also suggested that more generally

(and however well intentioned) a desire to fulfil the CITB criteria might have disproportionate priority over desired training methods.

Manufacturers felt that instruction or training was either essential (LCM, CPM, STM) or unnecessary. Instances where it was considered inappropriate related to the product being a sub-component of a larger part resulting in manufacturers lack of knowledge about how the product would subsequently be applied (JWM). Similarly this was considered the case when hire companies were the main customer bases, indicating that it would not be possible to control the training that they subsequently provided (LCM).

Trainer's receipt of training skills was discussed (LCM), although it was not possible to obtain comprehensive details about their content, duration and frequency. In the case of hirers of concrete pump equipment, it was reported that drivers received a one day training course (including safety awareness and concrete pump use) – This would then render them responsible for provision of a safety manual, task training, plus supervised practice for the first few hours on site (if necessary). The researcher felt that although site practice could be supervised for the first few hours, this did not infer that any guidance would be provided in equipment clean up and dismantling upon work completion. Whilst it cannot be assumed that these aspects were relevant for accident 011, the potential for failure is apparent.

8.10.2.3 Provision of product information

Suppliers and hirers all offered some form of product associated leaflet, booklet or catalogue, ranging from single prompt sheets to large folders incorporating combined documents comprising a few hundred pages.

Even where instruction was not required product brochures were generally supplied nonetheless (CCM, JWM). Documentation was derived from a number of sources – either developed in house or (for the larger companies) developed by technical agencies (MSM, MLM). A number of manufacturers were concerned that, with intermediaries in the supply chain, that documentation was not distributed or taken advantage of on site (CPM, LCM, STM).

Varied routes were used to inform end users about the products. Larger contractors reported dissemination of in-house company advice or free product trial (G-SSM), but it is not known how widespread this practice is. Product manufacturers included in the research invariably spoke of a team of sales representatives or Engineers who advised end users on product choice and purchase, selection for task appropriateness and provision of training in use of their products (CCM, LCM, STM, MLM). In many cases they were able to liaise with site users, yet equally their end users were intermediaries such as trade suppliers, retail outlets or other manufacturers (LCM). In these cases they had no apparent control or influence over purchase choices or the guidance that ultimately was made to individual end users. The plant supplier indicated that they often dealt with repeat customers, who had little need for the provision of information about products. Where appropriate however they expected to offer telephone advice and a site visit (if necessary) to identify the most appropriate hire choice.

Product information was also provided by use of the flyers or catalogues. Although little information was obtained in relation to the use and dissemination of product flyers for the range of site hardware, it was clear (from site and latent condition data collection) that there was high dependence upon use of product catalogues for the purchase of PPE.

8.10.2.4 PPE related issues

The researcher noted two issues of concern, which were thought likely to have impacted upon the accessibility of optimum PPE products:-

The first of these concerned the methods used to identify market needs and the subsequent impact upon the catalogue sales range. This information was not obtained, but it was known that the catalogue did not include the full product range (PPE-S). Whilst it was acknowledged that it was impractical to include the entire product range in the catalogue, the methods for liaison and subsequent selection of desirable inclusions are unknown. An example of where an excluded product might have offered a positive impact on site, was a clip for holding gloves on the belt. This would seem a likely catalogue inclusion (assuming design appropriateness for the task and user), given the liaison with site personnel about product needs and the numerous reports of

lost, damaged or mislaid gloves – yet the clip was not catalogued; rationale for accommodating these types of viewpoints is unknown.

The second area of concern related to the lack of catalogue information on choosing products for user fit. This did not appear especially relevant for items sold according to retail sizing (such as shoes and garments), yet the researcher thought this especially relevant in glove purchasing (anticipating little comparative knowledge of hand sizing). Guidance on selection for appropriate hazards appeared strong, yet gloves were either sized or allocated for ‘male’ or ‘female’ use – there was no catalogued information concerning selection for a range of users and the benefits of appropriate fit. In accident 033, for example, alternative glove styles were not chosen ‘because they wouldn’t protect from crush injuries’; whilst this might be the case, the advantages in purchasing a range of different glove sizes appeared overlooked – as were the positive effects to dexterity and use compliance that might be gained through improved fit.

8.10.3 Summary of latent conditions according to Information Transfer factors

The principal contractor and designers unanimously welcomed early liaison at the project outset. For designers this enabled positive contribution towards quality assurance and health and safety issues, whereas for the Principal contractor involvement enabled assurance of simpler, quicker or more buildable methods.

	Failures concerning Project Concept Design & Procurement	Failures concerning Work Organisation & Management	Failures concerning Task
Information transfer	<u>Communication of design requirements</u> <ul style="list-style-type: none">• Liaison between designers, manufacturers and contractors• Factors concerning the assessment, definition and communication of safe practice		

Designers, in addition to their creative duties during the developmental phase, described pressures affecting their work. These included the preparation of risk assessments and multiple-liaison requirements - generated through client or tenant relationships and co-operation with other designers on the project. Designers generally appeared to assume an off-site role (although a designer representative may take up site residence on a large build), perceiving site liaison as necessary where there were work difficulties. From the site perspective however a continuous need for designer liaisons (because of

inconsistencies or late design deliveries), gave an impression of burden for site personnel having to perpetually hound designers for their information needs.

The term 'ancillary design' was employed as a common term to accommodate product manufacturers and suppliers and, whilst their perspective differed from those of designers responsible for the build process, there were findings in common. Data revealed incidences where products were used in a different way to that intended by the designer. Designers and ancillary designers were at times unaware of interaction with their products or of building techniques used. Although the designers' did not incorporate knowledge of task technique within their roles, attribution of this to core skill or principal contractor responsibility appeared to induce a chasm of understanding and missed opportunities for positive intervention in design and promotion of safe performance.

Mainly Engineers or sales representatives were responsible for manufacturers customer liaison. Whilst it was known that their role entailed the provision of guidance on product purchases, it was not possible to gauge whether they also dealt with appraisal of product failures or problems. In general, manufacturers intervention varied considerably; contact with end users was least where the manufacturer dealt with intermediaries, such as other manufacturers or where their customers were retailers. Product catalogues were used by many on site, especially for PPE purchases. Whilst analysis did not include a broad spectrum of documentation, the initial enquiry indicated that further detail concerning choices for catalogue content and conveying information on glove fit would be welcome.

'User trial' during product development took various guises, ranging from product reliability testing, to product demonstration, to small-scale user trails and also more detailed multiple methods. Some companies had developed in-house user appraisal systems, yet these were few. All companies (and for some these were the main methods) relied on reactive feedback to gain an impression of product performance - such as evaluation of complaints, damage, warranty or repeat orders etc.

There was a general feeling among manufacturers that customers' adaptations and misuse were behind many of the product related accidents. They relied upon a range of

alternative (and reactive) methods to learn about accidents involving their products – such as insurance claims, litigious action, or related cases where they were called to act as expert witnesses. Manufacturers and designers were concerned about the lack of resources to access information and learning outcome concerning non ‘headline’ construction accidents. Consequently they felt that because of this they were unable to revise or develop their work accordingly.

Findings from accident investigations were also felt to be important for improvement and development of documentation, such as risk assessments and method statements. Little beyond related findings of site data analysis were obtained. Information was scant, yet sufficient to highlight concern about the quality of designers’ resources for undertaking risk assessments.

Latent condition data collection did not clarify the types of situations where documentation should be prepared for site work, its level of detail or alternatively when verbal instruction or attribution to core skills might be more appropriate. Nonetheless the very existence of documentation induced great faith in the robustness of safety arrangements and operatives were seen to be at fault where accidents had occurred when such procedures had been in place.

As with site data collection, the provision of risk assessment and method statement documentation, and materials from manufacturers or suppliers, continued to be seen as a ‘training medium’. Manufacturers had no control over site dissemination of the materials, but were concerned that the information was not used. Manufacturers materials varied – some were lengthy and unwieldy, whereas others had developed shorter, pictorial guides for end users.

There was concern about time pressure from production exerting a negative affect on training provision. Full details of training content were not obtained, but indirectly it appeared that there might be conflict in preferred training content (customer funded) and a desire to fulfil the CITB training criteria (and hence eligibility for their training bursaries). The foreman or supervisor was relied upon to address skill development where there were no formal training methods.

8.11 Role, skills, abilities and attitudes

Failure generation ↓	Phase →		
	Project Concept Design & Procurement	Work Organisation & Management	Task
Design & execution			
Planning Scheduling & Management			
Information Transfer (MS, RA, induction etc.)			
Role, skills, abilities and attitudes			

8.11.1 Role and skills development

Findings from site data collection <ul style="list-style-type: none">• Many job roles and responsibilities are poorly defined• There were limited opportunities for task and skills development

8.11.1.1 Safety advisers: roles and skill development

Generic interview health and safety professionals described a varied range of personnel working in health and safety roles, with skills derived from both trade and professional roles. Practitioners obtained their safety based training, typically through a number of different methods, through NEBOSH (general or construction certificate or diploma level training), through Trade Union safety representative training (20 days), and through degree level training. Practical skills training was obtained by work across a number of different sites.

Whilst their responsibilities varied according to their skills and experience, it was expected that Safety Manager status would be equivalent to that of a Project Manager. Site Managers support was seen as essential for Safety Adviser’s motivation in their work. Nonetheless, there was reluctance to integrate the safety role with the site team, in order to ensure that any problems could be dealt with independently and that site personnel were not relieved of personal responsibility to address health and safety issues within their own work.

8.11.1.2 Architects and designers: roles and skill development

Interviewees indicated little or inconsistent formal skills development in health and safety issues and none had received any training in human capabilities and performance.

Whilst they had access to safety inductions, these were not always felt to be appropriate and, where professional training was specified (to obtain Chartership status, for example), safety related training was directed towards self-preservation rather than the impact of professional skills. Whilst there were expressions of interest (and instances of considerable study relating to safety related knowledge acquisition), such education for the most part appeared to be the consequence of personal preference and self-directed study (PS). Barriers to knowledge development were attributed to a number of factors, including:

- Working in professional isolation
- Emphasis on computer-based work (associated with diminishing site based experience)
- Unbalanced focus upon build quality rather than build process itself

Inadequate and late address to 'CDM' issues during the architects University training was also described; it was deemed inappropriate that design health and safety should be attributed as a contract law issue, rather than something that should be inherent throughout the entire educational period (G-A). Nevertheless, it was pointed out that health and safety issues are just one of many conflicting pressures for architects to accommodate. It was felt that Architects are easy targets for blame when accidents occurred, yet in reality they may not have made a final design decision or were one of a group who had been responsible (G-A).

It was not possible to obtain training details about the manufacturer designer skills range, but a number of disciplines were reported to influence the development process - Engineers (MSM, CCM, LCM, CPM, STM, PPE-S, MLM), technical specialists (HM, MSM, CCM, PPE-S) and sales and marketing personnel (MSM, STM).

8.11.1.3 Senior site management : roles and skill development

A range of different roles were incorporated into this interviewee group and it was not possible to obtain specific information about each professional group. Nonetheless the impression gained from this small group was of a variety of skills development routes. Interviewees described a mix of trade and site experience and higher or graduate level

education. For them, the emphasis was on essential understanding of the construction processes, sound technical knowledge and common sense in order to be effective.

8.11.2 Shortcomings affecting optimum role execution

Findings from site data collection

- There was high dependence upon core skills ability
- The supervisory role was extremely flexible and had to accommodate a broad range of responsibilities

8.11.2.1 Supervisors / managers

Larger companies were reported to have a range of in-house training schemes to provide line managers with safety training. Smaller firms, however, often had no access to comparable knowledge or health and safety advisers, and in these instances they would rely upon the foreman or site manager to undertake risk assessments and implement appropriate risk reduction measures (033, G-H&S). Problems attributed to this management style concerned lack of appropriate knowledge (G-H&S) and the impact of different tolerance levels and standard accepted by those 'at the coal face' (G-SSM).

8.11.2.2 Operatives

Latent condition data from those with direct site responsibilities revealed that, where formal procedures had been absent for the accident event, the skills of task execution were attributed to contractor and operative core skills (004, 013, 018). Even where operatives were without formal training it was expected that compliance with task execution instructions from those in charge should address this (008). It was pointed out that where the sub-contractor tender had stated that competent operatives would be provided, then it should not be unreasonable to expect this. Inflated views of own capabilities were thought to contribute towards ambitious pledges (018, 035).

The problem of skills shortage was acknowledged, as were the issues relating to language and literacy abilities (019). Whilst the current stance is that these should be managed as any other risk issue, 'social inclusion' issues were reported to be under review within the HSE and guidance would subsequently be provided to HSE Inspectors.

8.11.2.3 Designers

Interviewees with a design role identified reliance upon, and respect, for operative core skills. From a positive viewpoint they deemed it inappropriate for designers to impose a particular practice upon site-based personnel, given their superior knowledge and practical experience (G-DWD). The alternative perspective was that designers and manufacturers admitted to limited knowledge of practical build issues or actual task techniques (002, G-TWD, G-A). Control measures were perceived as the remit of site personnel (SE), with the expectation of PPE use often cited as one of the most likely control methods where risks remained (CCM). The researcher felt that this created barriers to designers understanding of their professional ability to avoid accident recurrence.

8.11.3 **Summary of latent conditions according to Role, Skills, Abilities and Attitudes**

Detailed information about training and skills development was obtained from only a small number of interviewees with active accident involvement. This lent a somewhat anecdotal bias to the findings, but where possible this was supported by comments from generic-collective interviewees.

	Failures concerning Project Concept Design & Procurement	Failures concerning Work Organisation & Management	Failures concerning Task
Role, skills, abilities and attitudes	<u>Role and skills development</u> <ul style="list-style-type: none">• Factors enhancing and constraining role development and execution		

Information relating to skills development varied for the professional groups included. For safety personnel and senior site managers the learning path was accommodated within a number of training schemes, varying from certificate courses through to diploma and degree level training. Some form of site position, either trade or office role, was often a precursor to such professional development and, for all, the value of site based learning and skills gained through experience on different sites was paramount.

Comparable detail of skills development for manufacturer designers was not obtained. Information relating to construction designers indicated that although their education

was University based, knowledge development of their professional impact upon health and safety appeared to depend upon self-directed study. There were instances where designers and ancillary designers had limited knowledge of build issues or task techniques. They gave the impression that risk control at task level was a site issue and beyond influence of their professional role.

As with site data analysis, skills shortage and sub-contractor operative capabilities were areas of concern. A level of expectation of core skill ability was common among the latent condition interviewees and, where this was lacking, the impression was that compliance with task instructions should accommodate those untrained. An absence of formal procedures meant that responsibilities for risk assessment and control fell to site managers or foremen, but there were concerns too about the negative influence from their lack of knowledge and different tolerance levels.

8.12 Summary of latent condition data

The summary sections for each failure category drew together the range of problems that had been identified across the project timeline. As with the qualitative site data analysis, there were a number of main elements and common themes to the findings. The findings both reinforced and extended understanding gained from the earlier site based data collection phase.

The fluidity in build scheduling and planning (impacted by accommodating multiple inputs from clients, designers and other contractors) was additionally hampered by lack of formal or respected criteria for devising timelines. Indeed, not only planning and scheduling work, but also the design activities undertaken by the principle contractor, appeared to be perceived quite casually and with little apparent respect. Responses from site based personnel and those such as designers based off site indicated many areas where roles were not distinguished or were poorly understood. The different contractual arrangements also appeared to have some impact in generating uncertainty or confusion between site and off-site personnel.

The influence of poor role clarity and understanding of others roles appeared widespread and this had repercussions in defining 'ownership' of work, designation of responsibilities and lost opportunities in the generation of improvements or solutions.

The lack of knowledge of others roles also meant that those in senior (especially off-site) positions had only variable perceptions of site needs, activities and core skills, upon which to develop or direct the work.

Lack of knowledge or understanding was also apparent in 'hardware' purchasing and in product development by manufacturers. The lack of knowledge concerned poor understanding of practical application for task purposes and poor understanding of the need to trial and specify products for human interaction and usability. This lack of knowledge was also apparent in purchasing products for site needs; the financial restrictions upon purchasing appeared to restrict the introduction of innovative or more user-centred products (where available) into the industry.

Site data analysis revealed many problems with 'habitual blindness' to longstanding problems and this was the case too among the manufacturer interviewees, when faced with misuse or revision of their products by site users. Opportunities for the generation of improvements or solutions to products used on site were often lost and it was noted that (where relevant) some of the equipment failings directly contravened the requirements of the Machinery Directive.

The development of a knowledge base was also hampered by inadequacies in communication or access to information of common interest to all parties. For example, the lack of any information about accident histories ensured that learning opportunities from previous events were, for the most part, lost.

An interesting perspective of the analysis concerned the latent conditions that impacted the manufacturers themselves. Standards and specifications appeared to be remote and did not always enhance practice. Where UK companies were part of an international branch the UK companies, at times, appeared to be working and adapting products in isolation. Opportunities to integrate innovative or alternative practice used elsewhere were lost and this appeared to derive from purchasing criteria and rigid adherence to traditional UK practice.

Table 66 summarised the findings for the Phase two analysis and this has been amended (Table 74) to amalgamate summaries from both the Phase two and Phase Three data findings.

	Failures concerning Project Concept Design & Procurement			Failures concerning Work Organisation & Management			Failures concerning Task	
	Site data	Latent condition follow-up	Site data	Latent condition follow-up	Site data	Latent condition follow-up		
	Development of build plan and design			Transfer of management and build requirements			Hardware and execution of the work	
Design & task execution	• Build scheduling	- factors affecting timeline development	• Procurement of hardware	- ownership of procurement decisions	• Tools	• Compatibility of products for task purposes - factors affecting qualities, inter-product environment and PPE interactions • Compatibilities of products for human interaction - factors concerning user specification, design for physical interaction and psychological processing. Hazard protection and maintenance • Manufacturers design developments • External factors influencing design - factors affecting design ownership - impact from overseas, standards and specifications		
	• Detail and design of the structure	- contractors and designers perspectives - using proprietary or innovative methods - absent design	• Management and provision of task resources	- financial restrictions - marketing strategies - limitations in supply - variations in product integrity	• Materials			
	• Detail and design of the site layout	- factors affecting provision and allocation of welfare services and utilities			• Equipment			
		• Contractual influences - Preferences, advantages and disadvantages of different management styles			• PPE			
					• Operative task technique			

	Failures concerning Project Concept Design & Procurement			Failures concerning Work Organisation & Management			Failures concerning Task execution		
	Site data		Latent condition follow-up	Site data		Latent condition follow-up	Site data		Latent condition follow-up
	<u>Defining and organising labour supply</u>			<u>Managing and co-ordinating site personnel</u>			<u>Provision of suitable task conditions</u>		
	<ul style="list-style-type: none"> • Factors affecting sub-contractor appointment • Factors affecting distinction of contractor responsibilities • Ownership of proactive safety behaviour 	<ul style="list-style-type: none"> - factors concerning contractor appointment 	<ul style="list-style-type: none"> • Labour appointment • Determination of competence • Identification and surveillance of work fitness • Supervision of experienced and inexperienced operatives • Establishing working hours • Time pressure upon workload • Monitoring performance and providing motivation • Pay and remuneration Provision of welfare facilities • Documenting and undertaking accident investigation and determining remedial action • Opportunities for operative consultation and communication 	<ul style="list-style-type: none"> - factors concerning skill and health in appointment - general work organisation issues 	<ul style="list-style-type: none"> • Ground, floor or foot placement areas • Workspace provision • Housekeeping • Environmental conditions • Affecting operative task organisation (trade overlap) 	<ul style="list-style-type: none"> - factors concerning housekeeping 			

Failures concerning Project Concept Design & Procurement			Failures concerning Work Organisation & Management		Failures concerning Task execution	
Site data	Latent condition follow-up	Site data	Latent condition follow-up	Site data	Latent condition follow-up	
	<u>Determining criteria for build and personnel requirements</u>		<u>Developing means to assess and define safe practice</u>	<u>Communicating instruction and guidance on safe practice</u>		
Information transfer	<ul style="list-style-type: none"> • Factors affecting contract, design and development of work schedule 	<ul style="list-style-type: none"> - factors affecting provision and allocation of welfare services and utilities - liaison between designers, manufacturers and contractors 	<ul style="list-style-type: none"> • Risk assessment • Method statement • Ownership of training provision 	<ul style="list-style-type: none"> - factors concerning the assessment, definition and communication of safe practice 	<ul style="list-style-type: none"> • Styles of training provision • Site induction • Toolbox talks • Transferring training into practice • On the job learning 	
Site data			Latent condition follow-up			
Roles skills and attitudes	<u>Role</u> <ul style="list-style-type: none"> • Clarity of role for different interview grades <u>Skills</u> <ul style="list-style-type: none"> • Skills development by traditional training methods • Skills development through the CSCS scheme <u>Individual abilities</u>					
	<u>Attitudes</u> <ul style="list-style-type: none"> • Attitudes towards safe practice • Attitudes towards motivational factors of the work 					

Table 74. Summary findings for site data and latent conditions

8.12.1 Transferability of information

Latent condition data collection incorporated analysis of only 30 of the 40 accidents included in the research. Suggestions for pursuit of further information for these accidents are reproduced below in Table 75.

	Suggested follow-up areas	Addressed	Excluded
Design & task execution	Site planning (53, 64)	✓✓	
	Good practice for setting-out points (64)		✓
	Temporary works design (50)	✓	
	Design and use of manholes (51)		✓
	Tooling qualities (52, 63)	✓✓	
	Equipment manufacturer (60)	✓	
	PPE suppliers (61, 63)	✓✓	
	Task techniques (61, 63)	✓✓	
	Brick transport methods (65)		✓
Planning Scheduling & Management	Housekeeping issues (51, 53, 62)	✓✓✓	
	PPE provision (50, 65)	✓✓	
	Task warm up arrangements (50)		✓
	Work organisation (52)	✓	
	Safety culture affects from corporate stability (62)		✓
Information transfer	Procedures and documentation issues (50, 52, 60, 61)	✓✓✓✓	
	Training issues (50, 60)	✓✓	

Table 75. Follow-up suggestions for the final ten accidents

Alongside, a comparison has been recorded indicating whether or not the enquiry type was addressed or excluded during the latent condition follow-up investigations. For the most part (81%) the issues were pursued, and this was the case especially where the enquiry was of a generic or non-specific nature. When the suggested follow-up was unique to the particular accident in question the issue was less likely to be addressed.

8.13 Critique of the latent condition data analysis

In contrast to the findings generated in the site data qualitative analysis, where findings were widespread across all categories (but concentrated upon management and co-ordination of site personnel), the latent condition findings were very much centred within the ‘design and task execution’ category. New information from the range of different interviewees also gave a perspective of the latent conditions within which they operated too.

New categories of information were generated within 'design and task execution' (shown in bold, Table 74), and for all existing categories new information was also generated. This was least for Planning, Scheduling and Management, Information Transfer and Role Skills Abilities and Attitude phases, where the information generally reiterated and reinforced earlier findings.

Arrangement or allocation of findings, according to the four failure categories, was less straightforward than in Phase Two of the research. An alternative style would have been to present findings according to their information sources (Table 71 'designers and planners', 'managers and suppliers' and 'ancillary designers'). However, this was not adopted, as presentation by role would not have permitted the (albeit somewhat awkward at times) cross-comparison of interviewee findings and different perspectives on similar themes. In addition, it was also felt that continued use of the failure categories would ensure that information relevant to all areas was considered and that this would minimise the potential for bias and inappropriate attribution of cause arising from researcher subjectivity (as for Phase Two, 7.8).

It had been anticipated that there would be greater interviewee representation from senior management, off-site personnel and clients. Recruitment difficulties meant that this was not possible for some of the desired follow-up areas (Table 68), yet the aspects that were pursued were nonetheless a genuine reflection of factors considered important by the construction and ergonomics specialists within the research team.

The data collection proforma (Appendix 8) that had been prepared in advance was of limited value. It was unwittingly quite a narrow interpretation of the range of latent conditions and job roles actually identified by specialists and subsequently selected for further exploration. Additionally, the proforma had been developed for someone directly in the accident event 'chain', rendering the proforma appropriate when interviewees were outside the accident frame. That latent condition follow-up would be directed so regularly at ancillary designers had not been anticipated, yet adoption of the existing product and evaluation proforma (Appendix 8) proved successful. That interviewees were not directly asked about their responsibilities (where relevant) under the Machinery Directive was unfortunate and would certainly be a valuable inclusion for any similar type of enquiry in the future.

Where accident specific interviews were not possible, the adoption of the 'generic' interviews meant that it was possible to gain opinions from personnel groups in a comparable role. Whilst these interviews were initially seen as a compromise option, it quickly became apparent that the absence of personal involvement was very much a positive feature. Interviewees discussed the accident scenario, or aspects that were relevant to the accident and the work circumstances, freely and without the need to defend any of their actions. As the discussions were not confined to any one particular accident, it also meant that interviewees were able draw upon relevant issues that affected their efficiency at work and which might not otherwise have arisen, had there been a more structured interview. This did not over-ride the value of information from 'accident specific' interviewees, but redefined the relative merits of each interview style.

In general, the data collection methods for this phase were more open and unstructured than for Phase Two of the research. This served the data collection purpose well, but meant that there was much less personal background information, as obtained by Proforma 3 (Appendix 6). As with the site data qualitative analysis, pursuit of 'frequency of occurrence' has not been the driver for this analysis (7.8), more so an exploration of the range of issues that emerged.

9 APPRAISAL, REVIEW AND RECOMMENDATIONS

This style of research is the first of its type in the construction industry, yet earlier construction research has revealed some of the same failure types (2.5.1) as those reported in this thesis. Previous recommendations have proposed a variety of practical interventions, and more general measures incorporating safety management and safety culture principles. New legislation has been developed and the industry is pioneering initiatives for quality and improvements. That accidents continue to occur in spite of these interventions suggests that accident causation is poorly understood, that failure types have not been adequately identified and that solution management has not been appropriately devised or directed.

To explore these issues 'appraisal, review and recommendations' is first divided into two sections (Figure 27), prior to drawing together the main issues for future work and conclusions.

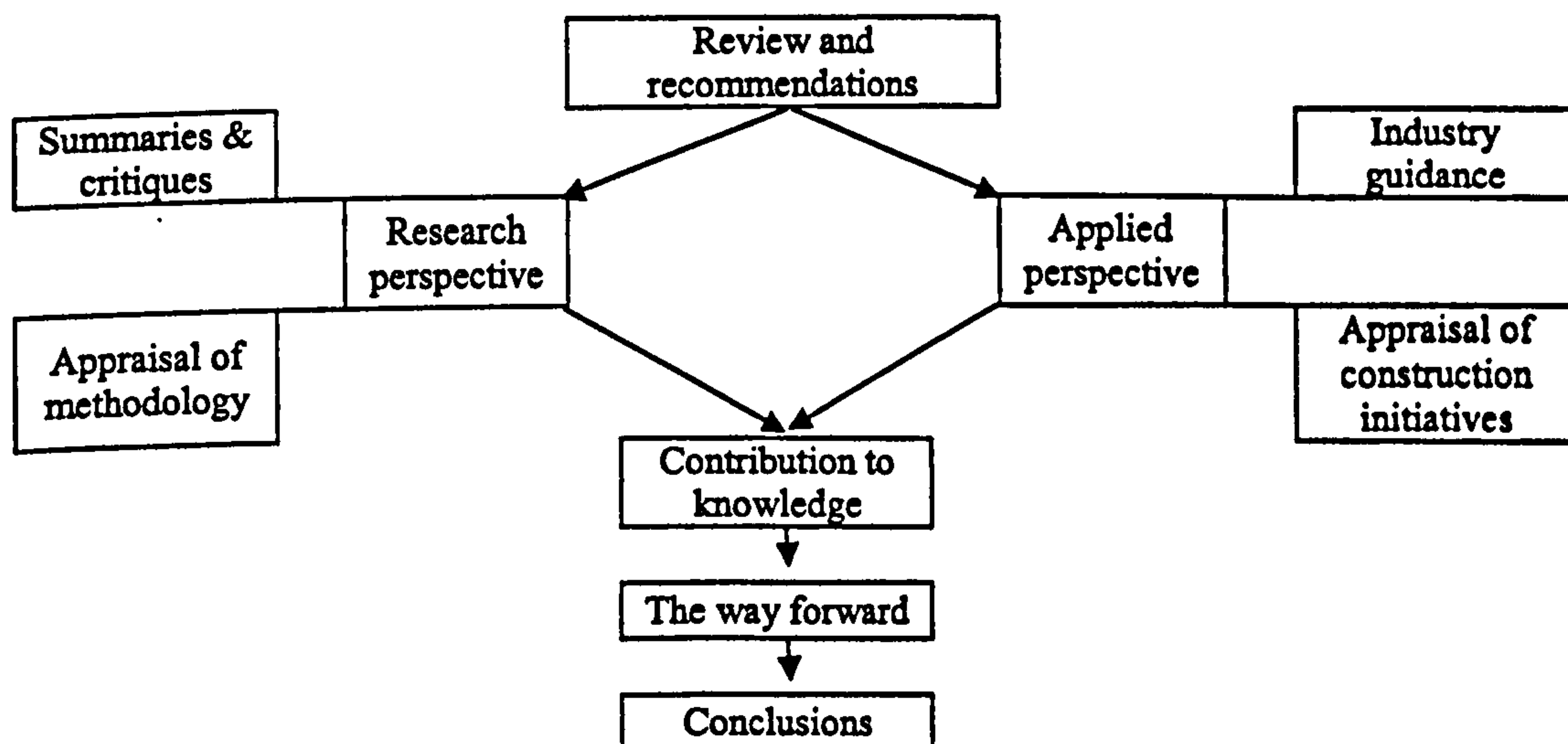


Figure 27. Content of review and recommendations

- Firstly, there is a review from the research perspective. This includes the main points from the summaries and critiques compiled during the research programme and appraisals of the methodology.
- Secondly, there is a review from an applied perspective. This includes summaries from the main findings from the Phase Two and Phase Three data interpretation, and proposes recommendations that industry might consider or adopt as improvement

measures. It also explores the findings in the context of interventions adopted by the construction industry

9.1 The research perspective

A summary was provided at the end of each chapter and a critique was undertaken following each stage of analysis and interpretation of findings. The main points from each are reproduced in 9.1.1.1 - 9.1.1.4 below. The research methodology has also been appraised using two further methods. Firstly, by application of the style of critical analysis used to evaluate the construction accident models, and secondly, by reappraisal of the construction accident models according to the criteria used for the systems approach and to classify data.

9.1.1 Summary and critique of the research programme

The aim of the research was to explore the nature of accident causation in the construction industry. The research programme incorporated, first, literature review and then three phases of data collection within the construction industry. This ensured that the methodology integrated reflective practice (the research based findings) with field data of current construction industry operations. The literature review and data collection phases served, each in succession, to inform development and direction of the subsequent phases of the research.

9.1.1.1 Literature review

Summary
<ul style="list-style-type: none"> • A range of inter-disciplinary understandings and contributions to accident causation knowledge was revealed. The progress of development of accident research was explored through evaluation of accident causation models. Approaches have developed from disparate fragmented attribution of accident causes, through understanding of their multi-factorial nature and finally systems approach to accident causation • Desirable features of the systems approach were isolated and, against these criteria, construction accident models were evaluated for their use in the research. None fulfilled the criteria identified for the systems approach, but advantageous features were isolated for later inclusion during Phase Two methods development
Critique
<ul style="list-style-type: none"> • There appeared to be disparity between the engineering and behavioural / psychological approaches to accident modelling. Engineering approaches faltered in their interpretation of systems theory; these failures concerned poor understanding of human performance, the use of leading terminology and a blame style approach • Construction models exhibited many of the engineering approach failures • Different disciplines appeared to have advanced in their contribution to accident causation understanding at different rates • Engineering and, more recently, behavioural / psychological approaches have dominated knowledge development. Nevertheless, an ergonomics approach was necessary to generate a framework for the systems approach

9.1.1.2 Phase One

Summary
<ul style="list-style-type: none">• This concerned information search from construction industry participants – gaining their perceptions of accident causation and the nature of failure.• It entailed seven focus groups with different construction disciplines. Using an ergonomics framework, discussion criteria for the research were devised from construction accident reference material. These addressed the nature of ‘Work Organisation and Management’, ‘Task factors’ and ‘Individual factors’. An additional theme was also introduced, ‘Project Concept, Design and Procurement’, to accommodate the developmental and design phases of a build project.• Findings from the focus group discussions provided a rich data source and were fundamental in devising the data collection techniques for Phase Two of the research.
Critique
<ul style="list-style-type: none">• The participants of two groups were poorly representative of their discipline, which may have influenced the depth of range of data obtained• Focus groups are vulnerable to the effects of group acquiescence and the introduction of bias from the opinions of dominant participants.• Validation from further construction participants both confirmed and expanded upon the findings. This suggested that findings were not necessarily representative of the industry as a whole, more so of a range of employees with the relevant experience and knowledge.

9.1.1.3 Phase Two

Summary
<ul style="list-style-type: none">• This concerned site based study of 40 construction accidents. A sampling strategy, devised to ensure appropriate representation of build and construction accident types, formed part of a detailed process of methodological development prior to data collection• Literature review of the accident investigation process had identified a range of data collection and representation techniques, but also indicated that the integrity of an investigation could be undermined by inadequacies in content, style and interpretation. Solutions to interpretation failures included cross-disciplinary appraisal, and triangulation of findings by the use of multiple data collection methods. These themes were integrated into the research methodology• To ensure adequate content and style, the methodological development process included assimilation of information from construction and ergonomics resources in the development of data collection techniques. Focus group findings were also included, but to generate a more succinct and construction specific categorisation, a new framework classification was devised – ‘Design and Task Execution’, ‘Planning, Scheduling and Management’, ‘Information transfer’ and ‘Role, Skills, Abilities and Attitudes’• Literature review had revealed a range of data representation methods, but none were considered appropriate. As an alternative, two styles of data analysis, interpretation and representation were generated. The first entailed isolation of active factors and latent factors ‘objectively’ considered relevant to the accident; the second entailed qualitative analysis of all accident study findings. Qualitative analysis was represented using the cross-referenced framework classifications that were developed pre and post focus group analysis.• Construction and ergonomics specialists evaluated accident studies; their findings were used to verify interpretations and inform Phase Three of the research

Critique
<ul style="list-style-type: none"> Analysis and evaluation of the strategy for Chapter 5, 'Development of the methodology for the accident studies', follows in 9.1.2.1
<ul style="list-style-type: none"> Isolation of factors 'objectively' related to the accident provided succinct and comprehensive data, but the shortcomings of this technique included the potential for researcher bias, confined representation of latent conditions, problems with categorisation and underplay of irregular access to data (6.5) Qualitative data analysis redressed many of the constraints introduced by the objective analysis, but shortcomings of the technique involved information duplication, researcher subjectivity and the management of interviews, at times, longer than anticipated.

9.1.1.4 Phase Three

Summary
<ul style="list-style-type: none"> This concerned exploration of selected latent conditions that had been identified from 30 of the accident studies Reviews from the research team specialists were used in determining the nature of follow-up and a strategy including both accident specific and generic interviews was devised. Data collection methods were devised from the construction, ergonomics and focus group resources and supplementary techniques, for use with interviewees in extra-organisational roles, were adopted Findings were validated by discussion with construction and ergonomics specialists and were analysed, interpreted and represented using the qualitative analysis style from Phase two
Critique
<ul style="list-style-type: none"> Representation of findings, using the same strategy as for site data, was less straightforward than before. However, it continued to permit cross-comparison of findings on similar themes from disparate sources There was little value in the pre-prepared data collection proformas. The use of alternative and less structured measures yielded important data but meant that a profile of participants was not obtained Generic interviews, initially a compromise, provided information of alternative but equally valuable merit for the research

9.1.2 Appraisal of the research methodology

The literature review evaluated the progressive development of the knowledge base concerning accident causation and isolated key features in modelling the systems approach (3.7). It also explored the nature of accident investigation and how common shortcomings might be avoided (3.8 & 3.9). The main points of each approach were summarised (Table 25) and, against both criteria, construction models were evaluated and their strengths isolated (3.11). In the light of the findings the table was revised, to represent the main features from all three areas of contribution (Table 32).

In order to appraise the research methodology a process, comparable to the evaluation of the construction accident models (reproduced below and based upon Table 32) was adopted, whereby strengths and weaknesses were isolated.

Systems approach		Accident investigation		Construction model Strengths		Key points	
IDENTIFY Managerial, organisational and extra-organisational influences	✓	<ul style="list-style-type: none">EXPLORE the range of influences and conditions that impact human performanceEXPLORE compatibility of barrier / control interventions for user & process	✓	EXPLORE <u>representation</u> of project concept and extra-organisational factors	✓	AVOID over concentration on individual fallibilities	✓
IDENTIFY latent conditions independent of the accident sequence	✓		EXPLORE The <u>dynamic states</u> and variables contributing to each accident sequence	✓	AVOID the many forms of 'blame'		✓
IDENTIFY types rather than tokens	✓		EXPLORE examples of construction specific ' <u>token</u> ' events	✓			
IDENTIFY the influence of dynamic states upon subsequent performance and adaptations	✓						?✓
Explore using multiple methods and cross-disciplinary analysis							

9.1.2.1 Methodology evaluation

The **strengths** of the methodology adopted in this research are that the criteria isolated from all three areas of contribution appear to have been met. In the context of investigation, multiple methods were adopted, not only in the use of different but complimentary techniques (interview, observation etc.), but also in the canvassing of opinions from different personnel on the same themes. This provided the opportunities for triangulation of results (Denzin 1970, Dekker 2002). There was cross-disciplinary intervention, firstly in devising a construction specific vernacular into the data collection methods (as proposed by Johnson 1996), and secondly in appraisal of findings from each data collection phase (as proposed by Svedung and Rasmussen 2002).

In the context of the systems approach, identification of the managerial, organisational and extra-organisational influences was achieved through data collection from managers, supervisors, and safety personnel during site visits, extending to senior site managers, designers, other off-site personnel, suppliers and ancillary designers, during latent condition follow-up. The representation of the project concept and extra-organisational factors in the construction models (Whittington et al. 1992, Suraji et al. 2001, Goh and Chua 2002) served in preparing for and identifying the range of issues to be addressed.

Latent conditions, independent of the accident sequence were identified and explored; this fulfils the criteria identified by (Reason 1995). The accident study methods, through use of the proformas (for semi-structured interviews) and assessment of documentation and tasks, ensured not only that antecedent events to the accident were explored, but also that the nature of the work and circumstances under normal conditions were assessed. The need to identify actions of decision makers under 'normal conditions' was identified by (Svedung and Rasmussen 2002).

The nature of latent conditions was initially distinguished through categorisation of disparate examples of 'types' and 'tokens' (Table 15, Redmill and Rajan 1997, Reason 1997, Health and Safety Executive 1999d, Svedung and Rasmussen, 2002), by using an ergonomics framework (based on Grey et al. 1987, Sanders and McCormick 1992, Finnish Institute of Occupational Health 1989, Institute for Occupational Ergonomics 1998a). The use of an ergonomics approach at each phase created commonality, avoided classification by 'token' examples, and ensured that interacting factors that affect human performance (rather than purely 'constructo-centric' issues) were identified.

Ergonomics classifications were used again in development of the focus group discussion themes (Health and Safety Executive 1997b, Health and Safety Executive 1999d), and in later interpretations of each data collection phase. Based upon focus group findings a revised framework classification (5.3.1) was devised to represent the construction specific 'token' events. The pre and post focus group classifications were used together in analysis for Phases Two and Three. This cross-comparison enabled identification of construction specific findings and interacting factors that affect performance, in the context of the time-line of a construction operation. This ensured that the dynamic states from the project concept and design, through to task execution were represented.

Whilst 'active factors' (Reason 1990b, Mathews et al. 2000), describing 'front-line' failures, were identified, they were evaluated in the context of what might have induced 'human failure' (Health and Safety Executive 1999d) rather than apportioning blame to individuals. The human failures included a range of error types and violations (6.4.1) which, when evaluated in the context of aspects of the work that might have induced them (Center for Chemical Process Safety 1994, Health and Safety Executive 1999d,

Mathews et al. 2000, Shappell and Wiegmann 1997, Table 17), often indicated the source as latent conditions.

There was intermediate success with the exploration of 'barrier and control interventions for the user and process'. For the most part this was successful, especially when the area of enquiry was a latent condition (e.g. nature of the risk assessment or planning the access of different trades to a work area). However, the belated or lack of access to an accident area meant that it was not always possible to gain a perspective of the accident event in the context of the control measures that had been in operation at the time.

9.1.2.2 Supplementary critique issues

Table 32 highlighted the necessary criteria for fulfilment of a construction centred systems approach and the use of data collection methods that would aid in the avoidance of bias and inappropriate attribution of cause. These describe the process or 'technical' aspect of the research, but little of the 'human centred' researcher influences.

Researcher subjectivity in results interpretation has already been identified within the critiques of qualitative analyses for the data collection phases (7.8 & 8.13). In addition to this is the researcher's evolution of knowledge and understanding of construction issues, during the 18-month data collection period for Phases Two and Three.

Little construction experience at the project outset may have had both positive and negative impacts. From a positive perspective the initial inexperience would have rendered the problems associated with causal attribution and bias unlikely. Examples that could have been avoided include 'scripting' (Woodcock 1995), professional preconceptions concerning the accident event and players (DeJoy 1994), or focus upon decoy phenomena (Department of Health 2000, Rasmussen 1990). Early stages of the construction 'learning curve' required the researcher to probe and explore issues that might otherwise have been overlooked by those with more experience, yet these simple enquiries regularly generated useful insights and understanding that formed an essential part of the analysis.

A more negative perspective of this is that information from early accident studies could have been missed, that might otherwise have been identified had a study been undertaken at a later stage. That construction specialists evaluated accident study findings was a mitigating factor. Additionally, the use of proformas during data collection also redressed such imbalance; their iterative development also permitted inclusion of supplementary enquiry themes as these became apparent (5.4.5).

9.1.2.3 Secondary appraisal of construction accident models

In appraisal of methods for use in the research, construction accident models were criticised for their lack of independent investigation of latent conditions, use of leading terminology and for adoption of a constructo-centric approach (Table 31). However, strengths were identified and, in order to accommodate these, the ergonomics methods used for the systems approach were revised. Cross-reference between the framework classifications of each (generated pre and post focus groups) was employed for qualitative data analysis (Table 56 & Table 72). A combined version of these tables summarised the findings for site data and latent conditions together (Table 74).

Terminology and technique varied between construction accident models, yet each identified areas of the construction process where failures occur. Tentative evaluations of the contents of the construction accident models have been undertaken in relation to the systems methodology that was devised. Causal factors identified in the construction accident models have been cross-referenced to the findings of the site and latent condition follow-up analyses (using an abridged version of Table 74).

Comparisons have been undertaken only very cautiously, as the style and language was quite different in some of the original sources. Detail also varied, according to the nature of the source materials used (i.e.: contract research report, journal papers and conference proceedings). Nevertheless, the comparison has enabled reinforcement of some of the assumptions made during the literature review – that the construction accident models did not embrace the systems approach. These results are shown in Table 76.

The comparisons represented in Table 76 are, for the most part concentrated in the areas of 'provision of suitable task conditions' and 'role skills, abilities and attitudes'. This was expected, given the emphases upon 'unsafe acts and unsafe conditions' typical of the

engineering approaches adopted by those modelling construction accidents (3.13). It was predominately the models of Suraji et al. (2001) and Whittington et al. (1992) which served in development of the focus group discussion themes and this is reflected here, in both spread (across all categories) and volume of factors that are compatible with the range used in the systems approach. Aspects identified by Goh and Chua (2002), although less plentiful in the source material, are also distributed widely.

Notable omissions from this cross-comparison are the absence of any reference at all to some of the findings identified in 'provision of necessary hardware for the work' and 'managing and co-ordinating site personnel'. Construction accident models were criticised for their lack of consideration of factors that affect human performance (Hinze 1996, Abdelhamid and Everett 2000, Suraji et al. 2001, Goh and Chua 2002). The absence of any reference to 'product: human compatibility' and of many of the aspects identified in 'managing and co-ordinating site personnel' reinforces this earlier observation. Expectance that use of safety management systems would accommodate and address these (often longstanding) problems in the construction industry has already been questioned in the literature review (3.11.5.1 and 5.9); again, this shortcoming appears to be reinforced here.

Some of the models gave good representation of organisational and extra-organisational factors (Whittington et al. 1992, Suraji et al. 2001). Some aspects that they identified were not addressed in the latent factor follow-up (such as 'environmental legislation', Suraji et al. 2001) and further work would be required to explore the relevancy of these issues. None of the construction accident models, however, suggested the influences of manufacturers and others in an ancillary design role (i.e. there were no cross-references to these aspects in 'provision of necessary hardware for the work') and this is a new finding from the research.

	Failures concerning Project Concept Design & Procurement	Failures concerning Work organisation & Management	Failures concerning Task execution
Design & task execution	<u>Development of the site and building plan and design</u> <ul style="list-style-type: none"> • Build scheduling * • Detail and design of the structure* * * • Detail and design of the site layout * • Contractual influences * 	<u>Transfer and management of build requirements</u> <ul style="list-style-type: none"> • Procurement of hardware * • Managing the provision of task resources * * * 	<u>Provision of necessary hardware for the work</u> <ul style="list-style-type: none"> • Tools* * * • Materials * • Equipment * * * • Task technique * * * * * • Relating to PPE * * * * • Product: task compatibility * * • Product: human compatibility • Manufacturers design developments • External factors affecting design
	<u>Defining and organising labour supply</u> <ul style="list-style-type: none"> • Factors affecting sub-contractor appointment* * * • Factors affecting distinction of contractor responsibilities* * * • Ownership of proactive safety behaviour* * * * 	<u>Managing and co-ordinating site personnel</u> <ul style="list-style-type: none"> • Labour appointment * • Determination of competence * • Identification and surveillance of work fitness * • Supervision of experienced and inexperienced operatives * * * * • Establishing working hours • Time pressure upon workload * * • Monitoring performance and providing motivation * • Pay and remuneration • Provision of welfare facilities • Documenting and undertaking accident investigation and determining remedial action * * • Providing opportunities for operative consultation and communication * * 	<u>Provision of suitable task conditions (general * * *)</u> <ul style="list-style-type: none"> • Ground, floor or foot placement areas * * • Workspace provision * * * * • Housekeeping • Environmental conditions * * * • Affecting operative task organisation (trade overlap) * *

Information transfer	<u>Determining criteria for build and personnel requirements</u> <ul style="list-style-type: none">• Factors affecting contract, design and development of work schedule **	<u>Developing means to assess and define safe practice</u> <ul style="list-style-type: none">• Risk assessment ****• Method statement ***• Ownership of training provision *	<u>Communicating instruction and guidance on safe practice (general ***)</u> <ul style="list-style-type: none">• Styles of training provision• Site induction *• Toolbox talks *• Transferring training into practice *• On the job learning										
Roles skills, abilities and attitudes	<u>Role</u> <ul style="list-style-type: none">• Clarity of role for different interview grades **** <u>Skills</u> <ul style="list-style-type: none">• Skills development by traditional training methods **• Skills development through the CSCS scheme <u>Individual abilities *</u> <u>Attitudes</u> <ul style="list-style-type: none">• Attitudes towards safe practice ****• Attitudes towards motivational factors of the work ***												
	<u>Key:</u> <table><tr><td>Alternative model of accident causation (Whittington et al., 1992)</td><td>*</td></tr><tr><td>The distractions theory of accident causation (Hinze, 1996)</td><td>*</td></tr><tr><td>Accident root causes tracing model (Abdelhamid and Everett, 2000)</td><td>*</td></tr><tr><td>Constraint response model of accident causation (Suraji et al., 2001)</td><td>*</td></tr><tr><td>Modified loss causation model (Goh and Chua, 2002)</td><td>*</td></tr></table>			Alternative model of accident causation (Whittington et al., 1992)	*	The distractions theory of accident causation (Hinze, 1996)	*	Accident root causes tracing model (Abdelhamid and Everett, 2000)	*	Constraint response model of accident causation (Suraji et al., 2001)	*	Modified loss causation model (Goh and Chua, 2002)	*
Alternative model of accident causation (Whittington et al., 1992)	*												
The distractions theory of accident causation (Hinze, 1996)	*												
Accident root causes tracing model (Abdelhamid and Everett, 2000)	*												
Constraint response model of accident causation (Suraji et al., 2001)	*												
Modified loss causation model (Goh and Chua, 2002)	*												

Table 76. Abridged summary of the site data and latent conditions findings with tentative annotation of the construction model attributes

9.2 The applied perspective

The data analysis and interpretation for each phase generated a huge amount of information and this section presents the findings in the context of their relevance for industry. This is presented in two sections. The first section summarises the main themes and proposes recommendations for industry, whereas the second section appraises the findings in the context of construction industry initiatives.

9.2.1 Review and recommendations – proposals for industry

The scope of this section is to review the nature of failures in construction and where needs lie, rather than generate pragmatic solutions to the myriad of problems that were identified. These are introduced mainly according to the framework categories generated as a result of the focus groups. These have been adapted slightly to avoid duplication and facilitate presentation.

9.2.1.1 Design and task execution: Build scheduling

The range of skills required to devise a build schedule and project timeline had little credibility, were treated informally and appeared to be decided by bartering between the client and principal contractor when trying to reach a final agreement.

From a managerial and organisational perspective (3.6.4 and 3.6.5) build scheduling also appeared to contradict the socio-technical systems approach, as it offered little ‘optimisation’ for users and had considerable impact upon time pressure (9.2.1.13) later during the build process. There is some analogy with the degree of ‘coupling’ in manufacturing production systems; build scheduling appeared to be a complex process and to be planned according to some of the tightly ‘coupled’ principles (Perrow 1999). Tight coupling often failed and a reactive, looser system, ensued. The scheduling appeared to become progressively ‘looser’ with each sub-contractor in the chain and as time from project initiation increased.

The industry is also trying to adopt some ‘just in time’ (JIT) efficiency measures (8.10.2.2) yet worked reactively (according to prevailing circumstances). This appeared to completely contrast the JIT philosophy (Myazaki 1992, Jackson and Martin 1996).

Recommendation

- Methods to devise and agree build scheduling and a project timeline need to be formalised and carry greater respect among co-disciplines
- Any variations to the formal agreement need to be justifiable. Competency requirements are necessary for anyone involved in re-scheduling. The instigator must also retain some responsibility of ownership over the impact that their revised calculations might have
- Scheduling according to rigid work study arrangements would appear inappropriate. A more loosely coupled build scheduling is required from the outset, to enable accommodation of delays and factors affecting sequence variability (Perrow 1999)
- Principles from the manufacturing sector may help in devising methods to decouple tasks, perhaps by the introduction of buffer zones (Konz 1992), alternative sequences, inbuilt time allowances etc. (Perrow 1999)
- Whether lean manufacturing techniques (such as JIT) can be inbuilt into this 'looser system' is unknown. Cross-disciplinary intervention (Svenson et al, 1999, 3.9.5.4), with construction and manufacturing systems expertise, may herald solution generation

9.2.1.2 Design and task execution: Design ownership and liaison issues

Lack of, or dispersed, design ownership was common; it was very difficult to gauge areas of responsibility. The culture of casual or non-recognition of design (when undertaken by principal contractors (PC), when left to operatives or when using proprietary products) trivialised the inputs of those without architect responsibility, and also ensured that there was no 'learning' or 'reporting' culture (Reason 1997, Table 20). Radically different perceptions between the architect and PC about architect instructions, site attendance, residual risk etc. suggested further safety culture communication failures .

Recommendation

- Non-Architect design would benefit from a strategy to formalise competency requirements, responsibility and ownership of interventions
- The industry needs to take measures to raise the profile of, and acknowledge the importance of all the non-Architect designers

- Measures to improve communication between off site and senior site personnel are required

9.2.1.3 Design and task execution: Contractual influences

Different disciplines had varied preferences for different types of contract. Styles appeared to offer a variety of benefits and drawbacks, and this had later impact upon sub-contractors appointment and time scheduling too. There were frequent requests for more guidance from the HSE concerning the health and safety ramifications of the varied contract styles.

Recommendation

- There is a need for improved consultation and authoritative guidance on the nature and impact of contract type and client intervention
- The industry and HSE need to improve communication channels so that needs such as these can be identified and managed

9.2.1.4 Design and task execution: Site layout and information requirements

Drawings of utility service layouts were inadequate. Site layout development appeared vulnerable to lack of consideration, or compromise in provision of process / user interaction space and facility needs. Problems appeared to result from lack of synchronicity with changes in build scheduling and resulted in much wastage (labour / resources etc.) later in the schedule. HSE guidance (Health and Safety Executive 2001) and construction information sheets define traffic route needs, but do not seem to address the much wider range of issues generated during the interviews. A range of welfare measures is described, but these do not cross-reference to provision for numbers of people on site (7.4.2.9).

Recommendation

- There is a need to formalise the range of aspects to be considered during the process of defining requirements for site layout.
- Development of the site layout should cross-reference to any ongoing changes in build scheduling, so that there is synchronised evolution of each
- Improved liaison with utility service providers is advisable to generate acceptable solutions to the drawing and service inadequacies

- More detailed guidelines specifying workspace dimensions and conditions for both process and human interaction are required
- Welfare requirements need to be defined according to numbers accessing them. If specifications for general workplace welfare facilities apply to the construction sector (Health and Safety Executive 1992), (e.g. numbers of toilets according to numbers on site), then this should be detailed in the industry guidance

9.2.1.5 Design and task execution: Product procurement and supply

Cost cutting, lack of synchronicity with the build schedule, blurred ownership of specification and varied purchasing arrangements between PC and sub-contractors (SC) resulted in hardware supply inadequacies. Middle management grades were able to operate only reactively to these circumstances – decision-making had not been decentralised (Reason 1997, Table 20), suggesting a safety culture failing.

There was little apparent hire or purchasing strategy to ensure that products with user centred design were targeted for site use; the self-employed received little or no guidance at all. Innovative products, with better user-centred design were sometimes available, but the customer led culture appeared to ensure that only basic quality and range products were made available.

Recommendation

- Aspects relating to quality and range of products provided by suppliers need further exploration
- Middle management personnel need greater authority and autonomy over the ordering, scheduling and purchasing of products
- The procedures for identifying product specification and purchasing need to be much clearer
- To enhance purchasing and determination of safe working practice the industry need skills, and guidance about how to evaluate usability and safety features in product purchasing
- Usability evaluation information also needs to be disseminated to retail outlets, suppliers and manufacturers

9.2.1.6 Design and task execution: Product design, compatibilities and user specification

Many products lacked intuitive design and had poor interface for human interaction and performance. Materials integrity and reliability (3.6.3.1) was sometimes poor.

Common hazards were often overlooked and were 'scripted' into every day activities (Woodcock 1995). The nature of product development by manufacturers was inconsistent - often poorly compatible for their construction industry work circumstances or for use with other products, and not developed or trialed in a user-centred manner. This was often worst for the less technical / expensive products - although this did not necessarily mean that they were used least on site.

Manufacturers were only variably able to specify a user profile for their products and at times had only limited understanding of their product use in practice or that design failures may initiate misuse. That 'standards and specifications' were accrued poor status suggests a lack of consultation and communication in their development and that safety cultural issues (Health and Safety Executive 1997b) extend into the extra-organisational context.

Many of the machinery shortfalls directly contravene the mandatory health and safety requirements of Annex 1 of the Machinery Directive (Great Britain Parliament 1992) (such as details for user-centred design, risk reduction, PPE compatibility, logical design or controls etc.). Non-'machinery' items had similar failures, but comparable guidelines were not found.

Recommendation

- There is need for widespread education and guidance on the employment and application of ergonomics principles to the industry, manufacturers and suppliers
- The construction industry needs to explore attitudes that contribute to scripted behaviour and devise and adopt remedial measures
- Industry information, guidance and liaison networks need to be developed and extended to manufacturers

- Manufacturers need to explore measures to integrate ergonomics into the development of their designs (e.g. Norris and Wilson 1997) and measures used for instruction
- The reasons for failure to identify and follow mandatory legislative guidance for product safety and design needs to be explored
- Solutions to manage the regulation: manufacturer: supplier: industry failures must be applicable for all products used in the industry

9.2.1.7 Design and task execution: Personal protective equipment (PPE)

Findings indicate that PPE was often uncomfortable, poorly cared for and that the range available for personnel was limited. There was much misunderstanding about range, fit and user-centred design and (as above) user specification was poorly defined.

The mandatory use of PPE appears to contrast with recommendations that it should be the last line of defence in control of hazards (2.5.4). Nevertheless, it is required where risk remains. Contrasting perceptions between senior and site personnel, on what those risks are, suggest a lack of consultation and communication on this issue (Health and Safety Executive 1996). The discontent may also reflect failure concerning psychosocial issues (3.6.4.1) and protest at lack of individual control and autonomy among those at site level (9.2.1.20).

Recommendation

- Manufacturers, suppliers and site need to improve their communication of what is really needed on site
- The PPE purchasing strategy needs review. Better quality products are required; purchasers and suppliers need greater knowledge about usability issues and the impact of restricted budgeting on quality and usability
- Provision of storage facilities, improved guidance for care and maintenance and definition of responsibilities is required for PPE
- Requirements for mandatory use of PPE need to be reviewed. This must include workforce consultation and representation in solution generation

- The culture of acknowledging and managing worker discontent needs to be reviewed. Opportunities for consultation and communication need to be enhanced and welcomed (Health and Safety Executive 1996)

9.2.1.8 Planning, scheduling and management: Sub-contractor appointment and identity

Inadequate quantity and quality of communication between principal contractors and sub-contractors fuelled feelings of frustration with each other in appointment and practice. Sub-contractors were compartmentalised, often isolated and responsibilities and ownership of safety decisions and safety training were blurred. These issues indicate safety culture failings (Health and Safety Executive 1997b, Table 20).

Recommendation

- The industry needs guidance / examples on good communication style. Communication channels need to be nurtured and sustained
- Current arrangements for appointment and liaison need to be evaluated. Distinction of responsibilities between contractors is necessary. They also need empowerment to challenge and enhance a denigrated role

9.2.1.9 Planning, scheduling and management: Labour appointment and determination of competence

The industry is hampered by skill and labour shortages. Designated competence assessment methods (CSCS) appear to run in parallel with informal 'gut reaction' evaluations. The CSCS scheme, as yet, is still in early days of introduction, but responses do suggest a lack of faith in its credibility (and see 9.2.1.19).

Recommendation

- The CITB (2.5.6) should verify the robustness of their standards for accreditation. Measures used in accrediting individuals to the CSCS standard require greater publicity to try to foster support

9.2.1.10 Planning, scheduling and management: Health status and fitness for work

This is not competently managed and is a longstanding problem in the construction industry. HSE have commissioned research into the feasibility of developing a

National Occupational Health Scheme for the Construction Industry (Amey Vectra Ltd 2001). This has widespread support and work is ongoing in this area.

9.2.1.11 Planning, scheduling and management: Operative supervision

Perspectives of appropriate management style varied between management and operative grades – this appeared to be concurrent with the degree of ‘coupling’ (9.2.1.1) in operation. Tight coupling and a top down management style defined the need for greater supervision, operative control and definition of ‘rule based behaviours’ (Rasmussen 1982, Table 17), yet ‘loose coupling’ at operational level, with high decision latitude (knowledge based behaviour), was necessary to deal with the dynamic and complex circumstances of the work. A desire for high control over and definition of practice is inappropriate (9.2.1.1). These issues suggest failures of an informed safety culture in relation to ‘flexibility and learning’ (Reason 1997, Table 20) and lack of insight into work design and organisational theories.

Recommendation

- The disparity of practice through the phases of management to operational hierarchy needs to be addressed.
- The industry should not try to constrain or control the flexible and dynamic work undertaken at operational level
- The industry should seek advice from industrial sectors where organisations have experience of developing and facilitating dynamic group work or teams working autonomously

9.2.1.12 Planning, scheduling and management: Working hours, pay and remuneration

The industry is not an excluded sector within the Working Time Regulations (Department of Trade and Industry 1998a), yet a long hours culture (especially in more senior grades), and flexibility in the taking of breaks was the norm. Supplementary hours were encouraged (evening and week-end work). Few were on priced work, yet there were a myriad of financial incentives (such as ‘Job and knock’ or bonus schemes) to ‘encourage’ work pace. Possible detriment to performance from extended work hours or time pressure was not acknowledged.

Recommendation

- The industry needs to define boundaries of good practice with regard to working hours, breaks, overtime and holidays
- Manipulation of working arrangements as a motivator / incentive is not acceptable
- Alternative means of work organisation and means to generate work fulfilment and motivation, such as those described in 9.2.1.11, should be explored

9.2.1.13 Planning, scheduling and management: Time pressures, trade overlap, performance and motivation

Build schedules with inadequate arrangements to accommodate 'adversity' were the root of many aspects concerning time pressure and trade overlap in a work area.

Various incentives were used to motivate personnel, with little apparent insight into the limiting mitigation that 'free choice' will have over poor task workload and interface (Center for Chemical Process Safety 1994). Management by competition between teams may have a number of sources – desire for first access to access a common work area, misplaced understanding of motivation .. or a sweepstake!

Recommendation

- Competition for access to a work area is a build scheduling problem (see 9.2.1.1)
- Alternative strategies for managing and generating better conditions for work teams are required (9.2.1.11)

9.2.1.14 Planning, scheduling and management: Welfare facilities

The provision of and condition of washing and changing facilities were often deemed inadequate (see 9.2.1.2).

Recommendation

- Arrangements for managing the condition of welfare facilities need to be reviewed

9.2.1.15 Planning, scheduling and management: Accident investigation

Only infrequently did accident records provide information beyond immediate active causal factors. Accident investigation is a poor method to gain information about latent conditions. 'Active' causal factor information suffered inaccuracies; records did not

always tally with the 'accident involved' person's recollection of the event and were vulnerable to selectivity in the information that was presented. These issues typify the problems of hindsight bias described by Woodcock (1995), DeJoy (1994) and Barnett (1987) in 3.9.4.4.

Documentation often offered only limited space to provide detail. Neither did it encourage more detailed exploration of latent conditions (3.9.4.1). Forms that fulfil regulatory requirements appear to endorse only superficial exploration (7.4.2.10), with categorisation by type of harmful energy transfer (e.g. 'struck by', 'fall' etc.). That accident records were used as a forum to register complaints indicates safety culture failures in communication (Health and Safety Executive 1997b).

It was only in a small number of cases that latent conditions were identified as accident causal factors. Otherwise, perception and attribution of cause typified the dated blame style approach (3.2.2, Heinrich and Granniss 1959). The varied 'unsafe acts' in the accident reports seem to have served as 'decoy phenomena' (Department of Health 2000, Rasmussen 1990), detracting attention from the range of other possible causal factors and certainly the majority of latent conditions.

Hindsight bias by those responsible for remedial action was common and the view that many accidents were pure chance rare events ensured that intervention with any great impact was avoided. The lack of remedial action for many events illustrated the degree to which adversity had become 'scripted' into and accepted as part of daily activities (Woodcock 1995, 3.9.5.3). Lack of remedial action is also associated with lack of ownership for safety decisions (9.2.1.8) and blind faith in site control measures (3.6.3.3).

There was no circulation and publication of the learning experienced from managing previous accident causation – suggesting further safety culture failures

Recommendation

- Alternative measures for accident investigation are required. This draws upon information described in (9.2.2.3) and possible solutions are proposed in (9.5)

- The need for measures to disseminate learning from accidents was proposed by Whittington et al. (1992), and this issue continues to remain outstanding
- Learning dissemination and communication must accommodate those providing supply and ancillary services to the industry and those with design and planning responsibilities

9.2.1.16 Planning, scheduling and management: Consultation and communication

Consultation and communication opportunities were available for those in operative grades, but there was little sense that they perceived that any real value would be acquired from their contributions. Information flow throughout an organisation is a fundamental principle of safety culture (Health and Safety Executive 1997b) and this suggests that communication channels are inadequately managed.

Recommendation

- The industry needs greater understanding of the value of consultation and communication
- The industry needs to fulfil its legislative requirement for consultation and communication (Health and Safety Executive 1996)

9.2.1.17 Planning, scheduling and management: Provision of suitable task conditions

Pedestrian routes, workspace, housekeeping, and environmental conditions were often inadequate and a source of distress to accident involved personnel. Conditions were variable among the sites visited. Whilst rarely identified with as accident causal factors within the industry, the lack of importance with which these conditions are attributed suggests that these conditions have become 'scripted' (Woodcock 1995, 3.9.5.3) as normal and are overlooked.

Recommendation

- The industry needs guidance and demonstration on what 'acceptable and good conditions' mean.
- The industry needs to explore, publicise and embrace solutions (beyond procedures or behaviour change) on how to deal with adverse conditions

9.2.1.18 Information transfer: Assessing and defining safe practice

Risk assessments and method statements were a bureaucratic burden, seemingly with very little impact at operational level yet useful for demonstrating intent to work with 'good practice'. Risk assessment was entirely directed towards identification, elimination and control of hazards, the failure of which would create 'active failures', leading to harm, and damage or productivity losses. Hazard control incorporated few latent conditions and, where included was heavily orientated towards local physical conditions only; there appeared to be no strategy for assessment and management of factors that affect performance.

The risk assessment and method statement documentation was entirely focused upon the construction process, 'constructocentric' (3.11.1.1), and hence many of the accident event activities (set-up, walking about) were not addressed. There was no apparent criterion for document preparation and style. That they existed was often a rationale for lack of post accident remedial action and their use typified the 'defences in depth' failures (Rasmussen 1997, Wagenaar 1990) described in 3.6.3.3.

Recommendation

- Determination of the circumstances where these documents are appropriate requires a clean sheet, cross-disciplinary and participatory approach
- Alternative measures are required to assess factors that affect performance – latent conditions, independently of the risk assessment process (see 9.4.1)
- Alternative approaches, styles and methods of generating materials must be considered
- Guidance will be required on the style and usability of whatever materials are finally chosen
- Training and education will be required for those with responsibilities for whatever measures are finally chosen – these must address user centred needs

9.2.1.19 Information transfer: Instruction, guidance on safe practice and skills development

Much of the various documentation used for 'assessing and defining safe practice' was inappropriate for instruction and training; they served more so as control measures for

site (Stanton and Baber 1996, Dekker 2002) and offered little in terms of user centeredness. On the job training appeared to lack structure, learning objectives or competent trainers, yet was the foundation learning source for many.

‘Training’ had ritualistic qualities, and appeared to be tied in with realising finances from the CITB bursary scheme. Training generally focused on the use of different pieces of equipment, and the application of this knowledge in the context of the works process was not clear or apparent in review of training for the accident activity. The skills of experienced personnel, in dealing with novel situations, appeared to lack a training strategy. That many site personnel rued the imbalance of theoretical: practical skills’ training suggests lack of evaluation of training needs effectiveness too. At worst, toolbox talks were used as disciplinary measures - behavioural control - which is inappropriate and gives a poor image of the value of training in the industry. Many of the training and procedural problems summarised by Reason (1997), Sanders and McCormick (1992) Center for Chemical Process Safety (1994) and Rasmussen (1997) in Table 19, epitomise the research findings.

Recommendation

- The CITB need to review whether the bursary scheme invites misappropriation of ‘training’
- Training needs much greater transferability to works processes. Fresh training needs analysis is required (a clean sheet, cross-disciplinary and participatory approach), giving priority to the development of user centred materials and methods – for personnel of all levels of experience
- On the job learning also needs revision. As a formal training method it needs a structured approach with proper learning objectives and acknowledgement and development of the ‘training providers’.
- Methods should be developed to evaluate efficiency of all training methods
- A network of consultation and communication, accessible by all personnel, is required, to canvas training opinions and needs requirements, to facilitate early, directed and user centred interventions

9.2.1.20 Roles, skills, abilities and attitudes

Job titles have subtly different meanings between different sites. Many roles are poorly defined and poorly understood throughout the hierarchy of the industry – especially between those on and off site. There is, nonetheless, tremendous reliance upon euphemistic ‘core skills’.

A high degree of flexibility is expected from those at site level. This receives resigned acceptance by supervisory staff; their role is highly reactive to circumstances, yet the problem solving, variety and authority this provides appears to offer them some element of job satisfaction. On the other hand, flexibility is sometimes deplored by trade and operative grades, for whom ownership and recognition for the quality of their work is almost entirely dependent upon the job satisfaction they perceive upon work completion. From a psychosocial perspective (3.6.4.1), their work is low status, inconsistently managed, undervalued and not ‘jointly optimised’ from a socio-technical system (Warr 1987) perspective. There appears to be no application or recognition of job characteristics or job design theories (Carayon and Lim 1999) and ‘work to rule’ and fierce defence of any tangible sense of autonomy and authority appears to be an understandable response. It is possible too that this may have some impact upon perception of site safety interventions (9.2.1.7).

Recommendation

- Measures to learn about the skill range and practices of construction industry professionals and trades are required
- The industry needs to investigate different styles of job design and look to alternative styles of work organisation, that might abate the negative aspects of the traditional management style (ties in with 9.2.1.11)
- The industry needs to understand the benefits of alternative organisational styles, learn from the experiences of other industries and undertake interventions as a cross-disciplinary and participatory intervention
- There is an urgent need for greater understanding of psychosocial issues, human capabilities and performance throughout the construction industry

9.2.1.21 Summary of proposals for industry

There were three recurring themes in 'appraisal, review and recommendations – proposals for industry'. Firstly, there were numerous incidences of poor consultation, communication and co-operation throughout the organisational and extra-organisational hierarchy, suggesting safety culture failures. There is tremendous potential for improvement through the application of ergonomics principles – reflecting a need for guidance, education and greater dissemination of this learning. Product manufacturers and suppliers for the construction industry need to be brought into the information and communication circle.

Secondly, organisational failures appear to arise from a strange dichotomy of practice. Planned at organisational levels with tight coupling and a high level of proceduralisation, rules and control - but contrasted with a need for flexibility and autonomy at site level. The numerous cases of 'defences in depth' and behavioural control suggest little insight or understanding of the benefits of alternative job and work design strategies.

The third theme accommodated the many cases of 'scripted' behaviour (also described as habitual blindness) where issues such as planning problems, role clarity problems, design problems, training problems etc. are just not seen by those within the industry, suppliers or manufacturers. There were many recommendations for a clean sheet, participatory approach in solution generation and many instances where guidance and example from other industries would be appropriate.

9.2.2 Overview of construction industry initiatives

The construction industry historically has a strong desire to improve performance and is in the process of a number of new initiatives (2.5). These are overviewed in the light of the research findings, to explore whether accident causation has been suitably addressed

9.2.2.1 'Rethinking Construction' initiatives

'Drivers for change' (Figure 2), such as 'leadership', 'commitment', 'quality' and 'commitment to people' all appear to accommodate many of the issues that have been identified in the research findings. That respect for people is isolated and that target

areas to accommodate a 'diverse workforce, site welfare, health, safety, lifelong learning and off-site welfare' (Respect for People Working Group 2000), is promising.

However, overview of the demonstration project initiatives (Table 6), and key performance indicators for both (including Table 7) give only limited impression of socio-technical approaches. Some benefit to personnel should arise through partnering and supply chain integration (i.e., from improved communication and co-operation), but it is not known to what extent are these user-centred in designs? The focus of 'Respect for people' initiatives is upon improving workplace conditions and personal development, but there is no suggestion of work organisational or job design changes, which appear to be the source of many of the latent conditions. A 'Hawthorne effect' may see some positive changes, but whether this is sustainable (3.6.3.3) remains to be seen.

9.2.2.2 General initiatives to improve health and safety

The ten-point strategy of the 'Revitalising Health and Safety' initiatives (2.5.3) appears to offer many opportunities to take positive remedial action for many of the failure types observed. The targets are general, however, and need to be seen in the context of legislative and construction specific initiatives that might facilitate their implementation.

9.2.2.3 General legislative initiatives

The legislative initiatives champion the risk assessment and risk management approach to prevent hazards and control risk (2.5.4). However, evaluation of this process (9.2.1.18) identified that latent conditions were not comprehensively addressed in risk assessment – or only so if they had the potential to become 'active' factors in accident causation. Strategies used in Safety Management Systems were deemed inappropriate for construction accident modelling (3.11.5.1) or as a framework for analysis and representation of the results (5.9), and comparison with the risk assessment process appears to reinforce this. Learning from earlier accident causation research has not been disseminated into assessment (comparable to risk assessment) of latent conditions. This would require assessment of factors that affect performance – 'performance assessment' – comparable to the risk assessment process.

'Revitalising Health and Safety' has arisen as a 25-year review of the Health and Safety at Work Act, 1974, (HASAWA) (Great Britain Parliament 1974) and this would seem to be a prime opportunity to reconsider the approaches of the HSE. As a topical example to the research and legislative review, Section 6(1)(a) states:

"It shall be the duty of any person who designs, manufactures, imports or supplies any article for use at work to ensure, so far as is reasonably practicable, that the article is so designed and constructed as to be safe and without risk to health when properly used"

Understanding of latent conditions and factors that affect performance suggest that 'safe and without risk to health' is not enough. That HASAWA, in isolation, would not bring about significant change to health and safety is not a new concept (Stubbs, 1992), but it is suggested that the anticipated benefits of the EC Framework and daughter Directives (2.5.4) are also limited in their influence upon accident prevention. The regulatory guidance and risk assessment process offer some redress but, given the research findings, seem to have had limited impact upon the full range of latent conditions outside the immediate health, safety, hazard and risk reduction arena.

9.2.2.4 Construction industry legislative initiatives

Overview of the distribution of findings from the research (Table 74) has helped in evaluation of the efficacy of the Construction, Design and Management Regulations (CDM), 1994 and Construction (Health, Safety and Welfare) Regulations 1996 (2.5.4). Despite the 'strategic approach to health and safety in project design, procurement, planning, preparation and execution', (Allan 2000), failures are apparent across all areas. That so many of the research findings concerned (1) poor liaison between contractors, manufacturers and suppliers and (2) work organisational issues, suggests that emphasis on the construction process alone is inappropriate.

A 'constructocentric' approach (lack of socio-technical principles) was heavily criticised in evaluation of construction accident models (3.11), and this problem appears to be replicated in the construction industry legislation. CDM, by identifying design and planning appears to address what would be considered 'root causes' in the

construction accident causation. In doing so it appears to give only scant attention to the social needs – management of people rather than the process.

9.3 Contribution to knowledge and directions for future work

This is the first type of research of its kind, undertaking detailed investigation of a range of construction accidents in order to identify causal factors. Previous construction accident research, by epidemiological style analyses or use of secondary data sources, has revealed a wealth of information but also identified that any shortcomings or bias in the data source are reflected in the quality of interpretations made (Suraji et al. 2001, Whittington et al. 1992).

Through systematic analysis of accident causation and construction accident modelling, key features of a systems approach for use in construction accident investigation were identified. Techniques were developed to acquire, analyse and represent details of active and latent factors. Findings were widespread; whilst often duplicating those from previous research, they also revealed that many of the unrecognised problems hailed from a lack of consideration of factors that affect human performance. Findings also revealed that manufacturers of construction products, although not previously acknowledged as construction accident extra-organisational latent conditions, are significant players in accident trajectories.

The data collection, analysis and representation techniques are as yet only in early stages of development. Nevertheless they provided baseline methods that served in the transfer of accident causation models into accident investigation techniques (Benner 1985). These would be enhanced by further development, the use of cross-disciplinary input, and iterative development to enhance the content and style. Future work might also incorporate the generation of alternative methods of data collection and analysis, in order to explore repeatability of the subjective impressions made by the researcher.

It was not possible to include the desired sample of housing and engineering construction accidents in this research. The profile of the research sample (6.1) also suggested that many accidents occurred in transit (rather than at task) and that there were time of day peaks. It is expected that the sample of 100 accidents might counterbalance under-representation of the two construction work areas and, with a

larger source of data, enable the creation of a more extensive profile to strengthen the research findings.

9.4 The way forward

Beyond the future work directly associated with the research methodology (above) , two areas were particularly isolated as routes for future research and intervention.

9.4.1 Integrating the accident investigation, risk and performance assessment processes

Findings from the literature review suggested many types of shortcomings in the process of accident investigation (3.9.5). To a certain extent these were apparent in evaluation of accident study accident records - at times incomplete data or a forum to blame or complain. Accident investigation did not appear to be a particularly efficient way to identify causal factors, especially latent conditions (9.2.1.15). Risk assessment appeared to address little more than 'active' factors in accident causation (9.2.1.18) and 'performance assessment' was identified as a necessary means to comprehensively identify latent conditions for accident prevention.

Figure 28, reproduces the model of organisational accident causation (Reason 1995) and, beneath it, compares the current and proposed assessment process. The risk assessment process concerns the control of hazards and is thus focused close to the point of 'defences'. The 'branches' generated from the risk assessment are there to illustrate that the hazards for a particular activity occur in the person /team, workplace and (less commonly) organisational issues. As the purpose of the risk assessment is to ensure that hazards are controlled, the branches represent following the traditional routes of risk assessment, in the prevention of unsafe acts (such as the provision of training) and unsafe conditions (such as environmental parameters etc.) that aid in mitigation of the risk.

The problem with this system is that, for many of the accidents, risk had not been identified and even where it had, isolation of aspects that could induce hazards did not adequately address the broad range of latent conditions in accident causation – especially where there was no task association. To address this, the proposed additional system to assess factors that might affect performance – 'performance assessment'

would provide comprehensive baseline data of latent conditions. Following the active and latent failure pathway in accident investigation would then enable access to a much wider source of information than is provided through the risk assessment process. Further research is required to explore the integration of accident investigation, performance and risk assessment information.

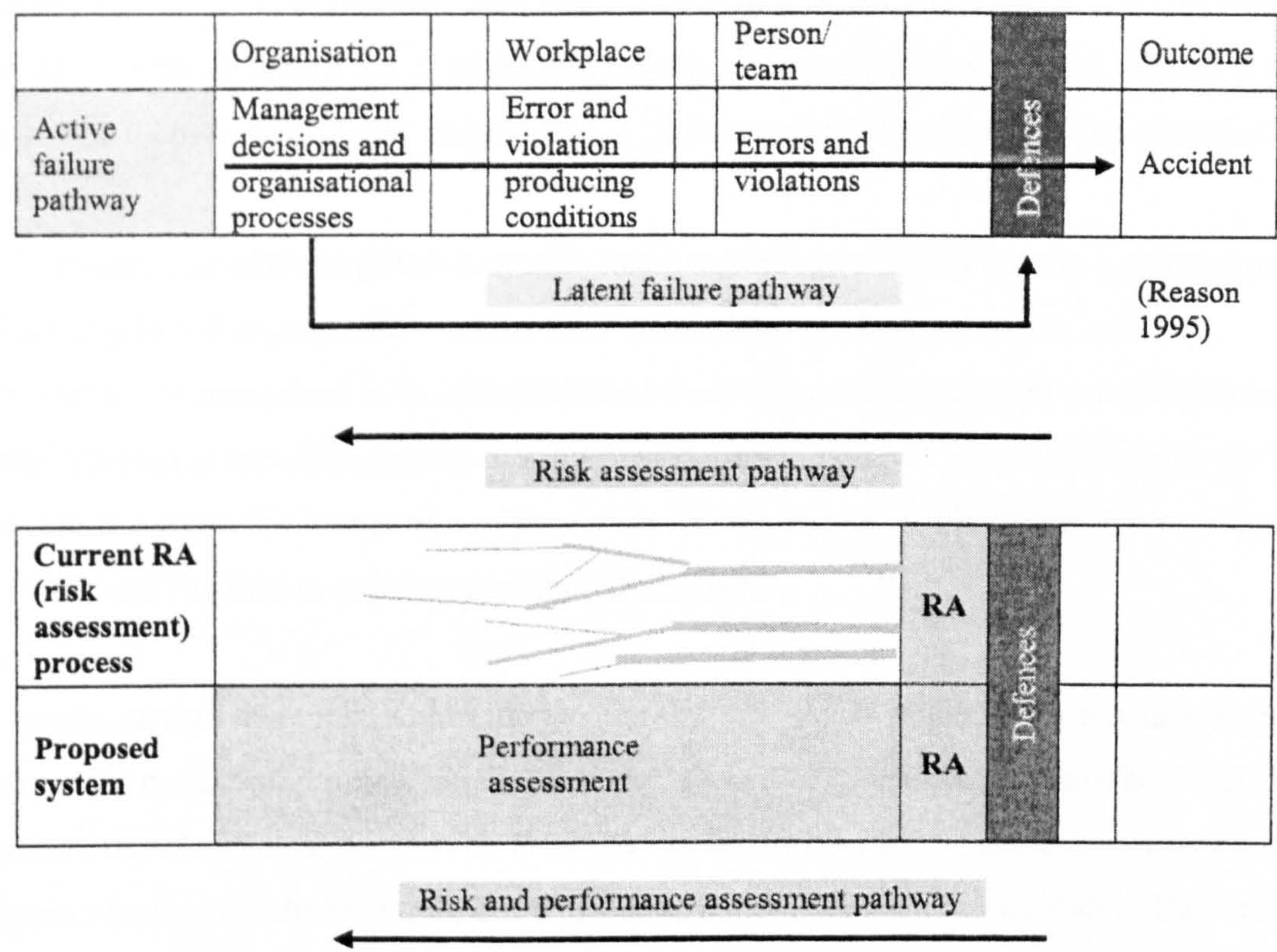


Figure 28. Current and proposed assessments to prevent accident causation

In representing dynamic accident data, Svedung and Rasmussen 2002, proposed tracing back the accident sequence to those at higher levels whose decisions, under ‘normal conditions’, had influenced outcome (3.9.3.2). These principles could also be applied to the ‘performance assessment’ as this would define the standards adopted for ‘normal conditions’ within an organisation. Consequently, this would entail a need to set standards for ‘performance assessment’ and ensure that competent personnel undertake assessment and evaluation. These are, in any case, baseline proposals of the research appraisal, review and recommendations (9.2.1). Many ‘performance standards’ could be extrapolated from existing CE /British Standard and HSE guidance or codes of practice – whether these would fulfil all aspects identified and be presented in an appropriate style should be the subject of further research.

9.4.2 Construction accident modelling

Appraisal of the construction accident models revealed numerous failures (3.11), essentially focused upon ‘constructocentrism’, poor categorisation and over-emphasis upon blame and unsafe acts. This appraisal was made possible by the evaluation of a much wider pool of pan-industry accident causation findings from which to cross-compare (3.5). This chapter, ‘appraisal, review and recommendations’, has revealed many instances where the construction industry had become insular and needed to look outside its own boundaries and capitalise upon learning experiences from elsewhere.

Consideration of these points suggests that a model specifically for the construction industry is not appropriate – whilst the construction process is unique, accident causation is concerned with identification of active and latent factors – and these are mainstream issues affecting all employment types. The need to model these to the life cycle and dynamic interaction of processes has already been identified (Rasmussen 1997) and fits into to existing accident modelling.

To ensure that the construction industry has future access to general information on accident causation it needs to remain in the arena of ‘organisational accidents’ and any future developments. Reason’s (1995) model of organisational accident causation has been relevant for the research, but extra-organisational issues (described in free-text by Reason 1995, were misleadingly under-represented. Reason’s model has been annotated to redress this (Figure 29).

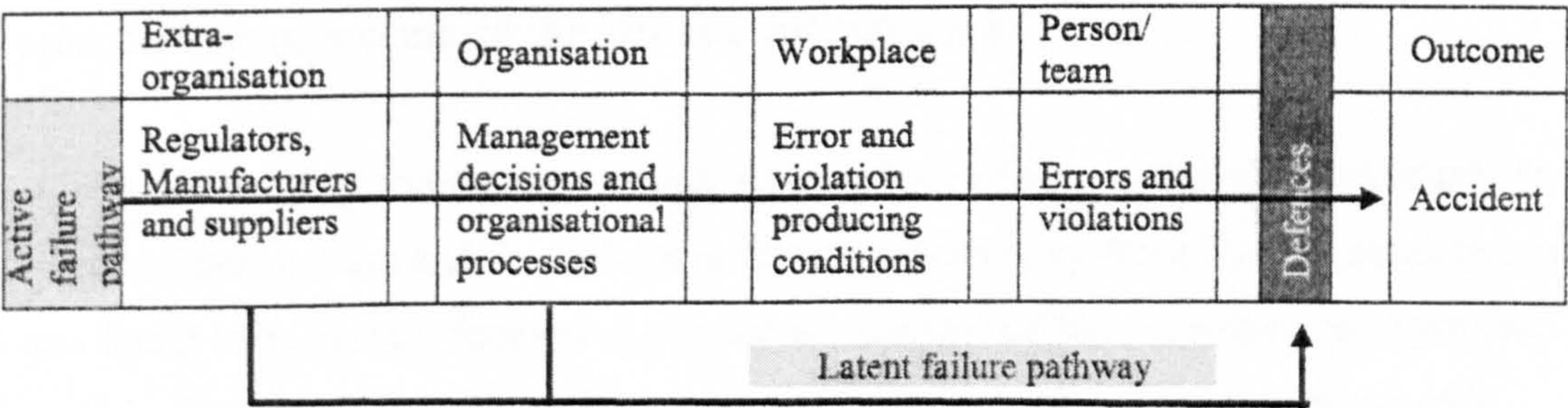


Figure 29. Revised model of accident causation

The challenge to the industry now is to generate comprehensive techniques, to ensure adequate address in the construction context, of active and latent failure pathways. The broad range of issues proposed in this thesis, such as the integrated accident

investigation, performance and risk assessment described in (9.4.1) and proposed development of the methodology (9.3) need to be drawn together for a more succinct assessment. These aspects would be need to be the subject of future work.

9.5 Conclusion

Findings show that accident causation in the construction industry is multi-factorial. As might be expected, there were many localised aspects such as the work tasks, work methods and physical conditions implicated in the accidents studied. Previous research has traced construction accident causation, using 'root cause' analysis, through to lack of 'health and safety' in design and planning, and these issues too continued to emerge during the accident studies included in this research.

However, that many of the findings revisit old ground from earlier research – issues such as design and organisation of site, equipment and PPE, supervision and training etc., suggests failure in previous remedial measures and initiatives. The wide scope of the analysis in this research, collecting data not only from site, but also about issues concerning the early project lifecycle or influences from extra-organisational factors, offered new perspectives on these old problems.

Exploration of the accident latent conditions revealed that an under-estimated and unexplored problem affecting the construction industry was the isolation of manufacturers and suppliers from the learning and information loop, which resulted in products with poor compatibility for user and task needs.

Within the industry, the main problems were the lack of a socio-technical approach, the organisational culture and the style of safety management systems. Safety management was found to be heavily focused upon risk assessment and hazard reduction measures; as such, the range of latent conditions were not comprehensively explored and only construction centred, 'constructocentric' failures were identified. The style of safety management complemented the traditional organisational culture – a rule based, highly proceduralised approach, with multiple and burdensome interventions to control both process and individuals. This completely contrasted needs and working methods at operational levels, where high decision latitude and autonomy was required to

accommodate the perpetual flux and unique circumstances that typified much of the working day.

There were incidences of considerable effort by the construction industry in trying to follow HSE legislative and regulatory guidance, yet this appeared to have played a hand in some of the problems experienced. Risk assessment is the foundation stone of health and safety management, yet appears to identify mainly 'active' factors that (when control fails) become hazards and hence risk factors for injury. In contrast, latent conditions in accident causation are a complex amalgamation of antecedent events and conditions. Degradation or impact upon performance may be more subtle than an 'active' event yet, unless latent conditions have the potential for an 'overt' association with the risk or hazard in accident occurrence, they appear to be given little attention. Safety management systems may be barking up the right accident 'tree' ... but only at the leaves!

Appraisal of the accident investigation process identified numerous problems and concluded that in its current state, this technique is not the most efficient way to explore accidents and especially latent conditions. Alternative methods, such as 'performance assessment', are required. Much of this information will be available within HSE 'guidance' or 'codes of practice', but further work will be necessary to adapt the style to inter-link with 'active' data collection methods and to ensure that the range of information is comprehensive.

The industry can help itself by benchmarking with industries that have moved away from the traditional organisational and safety management approaches. Instead of ever tighter controls it needs to embrace the flexibility and skills of those at the operational level and devise and engender different organisational methods to accommodate and nurture this. This, in any case, would be sympathetic with the current industry improvement initiatives. The additional challenge would be to devise changes that are compatible with management and contracting methods; the ultimate solution may well entail concomitant development of each to ensure compatibility.

A final cautionary note is that, despite its enormity, the industry appears quite insular. It is entrenched in the concepts of control and behavioural safety and quite possibly any

moves away from this may be a complete anathema to some; any intervention will need careful management, leadership, participatory processes and cross-disciplinary development.

10 REFERENCES

- ABDELHAMID, T. S. and EVERETT, J. G. 2000, Identifying root causes of construction accidents, *Journal of Construction Engineering and Management* 126(1): 52-60.
- ACSNI. 1993, *Study group on Human Factors 3rd report: Organising for Safety*. (Sudbury, Suffolk, HSE, Books).
- ADAMS, E. 1976, Accident causation and the management system, *Professional Safety*.
- ALLAN, T. 2000, Construction (Design and Management) Regulations 1994 (CDM) - The Regulatory Position. *Adding value through project management of CDM*, (London, Thomas Telford).89-93
- AMEY VECTRA LTD. 2001, *National Occupational Health Support Scheme for the Construction Industry: An initial feasibility study*.
- BAINBRIDGE, L. 1987, Ironies of Automation. In: Rasmussen, J., Duncan, K. and Leplat, J. *New Technology and Human Error*. (Chichester, Wiley): 271-283.
- BARNETT, M. L. 1987, Factors in the Investigation of human error in accident causation. In: J.A.Wise and A.Debons. *Information systems: Failure analysis*. (Berlin, Springer-Verlag): 79-83.
- BARSKY, I. and DUTTA, S. P. 1992, Age, shiftwork and industrial accidents - a longitudinal study. In: Kumar, S. *Advances in Industrial Ergonomics and Safety IV*. (London, Taylor and Francis): 113-120.
- BENNER, L. 1985, Rating accident models and investigation methodologies, *Journal of Safety Research* 16: 105-126.
- BIRD, F. 1974, *Management Guide to Loss Control*. (Atlanta), Institute Press.
- BIRD, F. E. and GERMAIN, G. L. 1990, *Practical Loss Control Leadership*. (Georgia, Det Norske Veritas).
- BREHMER, B. 1993, Cognitive aspects of safety. In: Wilpert, B. and Qvale, T. *Reliability and safety in Hazardous Work Systems: Approaches to Analysis and Design*. (Hove, Lawrence Erlbaum Associates): 23-42.
- BRIDGER, R. S. 1995, *Introduction to Ergonomics*. (New York, McGraw-Hill).
- BROWN, I. D. 1995, Accident reporting and analysis. In: Wilson, J. R. and Corlett, E. N. *Evaluation of Human Work; An ergonomics methodology*. (London, Taylor and Francis): 755 - 788.

BRUSEBERG, A. and MCDONAGH-PHILIP, D. 2002, Focus groups to support the industrial/ product designer: a review based on current literature and designers' feedback, *Applied Ergonomics* 33(1): 27-38.

BUCHANAN, D. 1998a, Strategic Organisational Issues. In: Di Martino, V. and Corlett, E. N. *Work Organisation and Ergonomics*. (Geneva, International Labour Office).

BUCHANAN, D. 1998b, Working together: Flexible work groups and multi-skilling. In: Di Martino, V. and Corlett, E. N. *Work Organisation and Ergonomics*. (Geneva, International Labour Office).

BUREAU OF LABOR STATISTICS. 2001, Census of Fatal Occupational Injuries, 1996-2001. <http://www.bls.gov/news.release/cfoi.t04.htm>.

CANADIAN CENTRE FOR OCCUPATIONAL HEALTH AND SAFETY. 1998. http://www.ccohs.ca/oshanswers/hsprograms/investig.html#_1_6.

CARAYON, P. and LIM, S.-Y. 1999, Psychosocial work factors. In: Karwowski, W. and Marras, W. S. *The Occupational Ergonomics Handbook*. (Boca Raton, CRC Press).

CARTER, F. A. and CORLETT, E. N. 1983, A model of the contribution of work stress to industrial accidents. *Proceedings of the 27th Annual Meeting of the Human Factors Society*, (Santa Monica, CA, Human Factors Societies).700-703

CENTER FOR CHEMICAL PROCESS SAFETY. 1994, *Guidelines for Preventing Human Error in Process Safety*. (New York, American institute of Chemical Engineers).

CITB. 2003, CITB grant scheme 2002/2003. <http://www.citb.org.uk>.

CLARKE, S. and ROBERTSON, I. 2001, Selecting for safety: Personality and accident involvement. *British Psychological Society Occupational Psychology Conference, January 2001*, (Winchester

COMMISSION OF THE EUROPEAN COMMUNITIES. 1992, COUNCIL DIRECTIVE 92/57/EEC of 24 June 1992 on the implementation of minimum safety and health requirements at temporary or mobile constructions sites (eighth individual Directive within the meaning of Article 16 (1) of Directive 89/391/EEC). (Luxembourg, The Council of the European Communities).

CORDINER, L., DAVIES, S., HAINES, H., HASLEGRAVE, C., HIDE, S. and WILSON, J. R. 1998, *Ergonomics Application in the Workplace. A distance learning course on the fundamentals and practice of ergonomics*. (Nottingham, Institute for Occupational Ergonomics, University of Nottingham).

CRONOR. 2002, *Management of Construction Safety*. (Kingston upon Thames, Cronor Publications Ltd).

- CSCS LTD. 2001, *Construction Skills Certificate Scheme Booklet. 7th Revision*, CSCS Ltd).
- DAVIES, N. V. and TEASDALE, P. 1994, *The costs to the British economy of work accidents and work-related ill-health*, HSE Books).
- DAVIS, R. M. 2001, BMJ bans accidents, *British Medical Journal*(322): 1320 - 1321.
- DEJOY, D. M. 1986, A behavioural-diagnostic model for fostering self-protective behaviour in the workplace. In: Karwoski, W. *Trend in Ergonomics / Human factors III*. (Amsterdam, Elsevier Science Publishers).
- DEJOY, D. M. 1994, Managing safety in the workplace: An attribution theory analysis and model, *Journal of Safety Research* 25(1): 3-17.
- DEKKER, S. W. A. 2002, Reconstructing human contributions to accidents: the new view on error and performance, *Journal of Safety Research* 33: 371-385.
- DENZIN, N. 1970, *The Research Act*. (Chicago, Aldine).
- DENZIN, N. K. and LINCOLN, Y. S. 1998, Introduction. Entering the field of qualitative research. In: Denzin, N. K. and Lincoln, Y. S. *Collecting and Interpreting Qualitative Materials*. (Thousand Oaks, Sage Publications): 1-34.
- DEPARTMENT OF HEALTH. 2000, *An organisation with a memory. Report of an expert group on learning from adverse events in the NHS. Chaired by the Chief Medical Officer*. (London, Her Majesty's Stationery Office).
- DEPARTMENT OF TRADE AND INDUSTRY. 1998a, *A Guide to the Working Time Regulations*. (Sudbury, Suffolk, Department of Trade and Industry / HSE Books).
- DEPARTMENT OF TRADE AND INDUSTRY. 1998b, *Rethinking Construction*. <http://www.dti.gov.uk/construction/rethink/index.htm>.
- DEPARTMENT OF TRADE AND INDUSTRY. 2002, *Construction Statistics Annual 2002 Edition*. (London, HMSO).
- DUFF, A. R., 2001, Description of JCT.
- DWYER, T. and RAFTREY, A. E. 1991, Industrial accidents are produced by social relations of work: A sociological theory of industrial accidents, *Applied Ergonomics* 22(3): 167-178.
- EASON, K. 1988, *Information Technology and Organisational Change*. (London, Taylor and Francis).
- EQE INTERNATIONAL. 2000, Tripod-Beta.
- ERLANDSON, D. A., HARRIS, E. L., SKIPPER, B. L. and ALLEN, S. D. 1993, *Doing Naturalistic Enquiry: A Guide to Methods*. (London, Sage).

EUROPEAN COMMISSION. 2000, *European codification system of the causes and circumstances of accidents at work*. (Luxembourg, Office for Official Publications of the European Communities).

FAHLBRUCH, B. and WILPERT, B. 1997, Event analysis as a problem solving process. In: Hale, A., Wilpert, B. and Freitag, M. *After the Event. From Accident to Organisational Learning*. (Oxford, Elsevier Science Ltd): 113-130.

FARMER, E. 1932, *The Causes of Accidents*. (London, Sir Isaac Pitman and Sons).

FARMER, E. and CHAMBERS, E. G. 1926, A psychological study of individual differences in accident liability (Industrial Fatigue Research Board Report no: 38). (London), Her Majesty's Stationery Office.

FERRY, T. S. 1988, *Modern Accident Investigation and Analysis, 2nd Edition*. (New York, John Wiley and Sons).

FEYER, A.-M., WILLIAMSON, A. M. and CAIRNS, D. R. 1997, The involvement of human behaviour in occupational accidents: errors in context, *Safety Science* 25(1-3): 55-65.

FINNISH INSTITUTE OF OCCUPATIONAL HEALTH, Ed. 1989, *Ergonomic workplace analysis*. (Helsinki, Finnish Institute of Occupational Health).

FISCHHOFF, B., SLOVIC, P. and LICHTENSTEIN, S. 1978, Fault trees: Sensitivity of estimated failures probabilities to problem representation, *Journal of Experimental Psychology* 4: 330-344.

GOH, Y. M. and CHUA, K. H. D. 2002, Identification of factors causing fatal construction accidents. *CIBW99 - 2002 Triennial Conference*. 69-75

GREAT BRITAIN PARLIAMENT. 1972, *Safety and Health at Work. Report of the Committee 1970-72. Cmd. 5034* (London, HMSO).

GREAT BRITAIN PARLIAMENT. 1974, *Health and Safety at Work etc.. Act*. (London, HMSO).

GREAT BRITAIN PARLIAMENT. 1992, *The Supply of Machinery (Safety) Regulations 1992, SI no. 3073*. (London, The Stationery Office Ltd).

GREEN, J. 1997, Accidents: The remnants of a modern classificatory system. In: Cooter, R. and Luckin, B. *Accidents in History: Injuries, fatalities and social relations*. (Amsterdam, Atlanta, Rodopi).

GREENWOOD, M. and WOODS, H. M. 1919, A report on the incidence of industrial accidents with special reference to multiple accidents, British Industrial Fatigue Board, No 4.

GREY, S. M., NORRIS, B. J. and WILSON, J. R. 1987, Ergonomics in the Electronic Retail Environment. (Slough), ICL (UK) Ltd.

GYI, D. E., GIBB, A. G. F. and HASLAM, R. A. 1999, The quality of accident and health data in the construction industry: interviews with senior managers, *Construction Management and Economics*, 17: 197-204.

HADDON, W. 1973, Energy damage and the ten year counter-measure strategies, *Human Factors* 15: 355-366.

HALE, A. R. and GLENDON, A. I. 1987, *Individual behaviour in the control of danger*. (Amsterdam, Elsevier).

HALE, A. R., HEMING, B. H. J., CARTHEY, J. and KIRWAN, B. 1997, Modelling of safety management systems, *Safety Science* 26(1/2): 121-140.

HANNA-KAISA, R. and MARKO, S. 2002, Perspectives on new occupational accident classification. *ORP'2002 Second International Conference on Occupational Risk Prevention, February 20th to 22nd, 2002*, (Gran Canaria Island

HEALTH AND SAFETY EXECUTIVE. 2000, *Key Facts Injuries in the Construction Industry 1996/97 to 1999/00 provisional*. (Bootle, Merseyside, Health and Safety Executive).

HEALTH AND SAFETY COMMISSION. 1995, *Managing Construction for Health and Safety: Construction (Design and Management) Regulations 1994. Approved Code of Practice L54*. (Sudbury, HSE Books).

HEALTH AND SAFETY COMMISSION. 2000, *Revitalising Health and Safety*, Department of the Environment Transport and the Regions,).

HEALTH AND SAFETY COMMISSION. 2001a, *Health and Safety Statistics 2000/01. Part 1: Statistics of workplace injury, gas safety, dangerous occurrences and enforcement action*. (Sudbury, HSE Books).

HEALTH AND SAFETY COMMISSION. 2001b, HSC Press Release C058:01 - 6 December 2001. Health and Safety Commission publishes revised ACOP and guidance on the Construction (Design and Management) Regulations 1994. <http://www.hse.gov.uk/press/c01058.htm>.

HEALTH AND SAFETY COMMISSION. 2001c, *Managing Health and Safety in Construction. Construction (Design and Management) Regulations 1994. Approved Code of practice and Guidance. HSG224.*, HSE Books).

HEALTH AND SAFETY COMMISSION. 2002a, Health and Safety Statistics Highlights 2001/02. <http://www.hse.gov.uk/statistics/overall/hssh0102.pdf>.

HEALTH AND SAFETY COMMISSION. 2002b, Levels and trends in workplace injury: Reported injuries and The labour force survey. <http://www.hse.gov.uk/statistics/2002/lfsfct01/pdf>.

HEALTH AND SAFETY EXECUTIVE. 1978, *One hundred fatal accidents in construction*. (London, HMSO).

HEALTH AND SAFETY EXECUTIVE. 1988, *Blackspot construction: A study of five years fatal accidents in the building and civil engineering industries*. (London, HMSO).

HEALTH AND SAFETY EXECUTIVE. 1992, *Workplace health, safety and welfare. Workplace (Health, safety and welfare) Regulations 1992. Approved Code of Practice and Guidance L24*. (Sudbury, Suffolk, HSE Books).

HEALTH AND SAFETY EXECUTIVE. 1996, *A Guide to the Health and Safety (Consultation with Employees) Regulations 1996. Guidance on Regulations L95*. (Sudbury, Suffolk, HSE Books).

HEALTH AND SAFETY EXECUTIVE. 1997a, *The costs of accidents at work (2nd edition)*. (Sudbury, Suffolk, HSE Books).

HEALTH AND SAFETY EXECUTIVE. 1997b, *Successful Health and Safety Management, HSG65*. (Sudbury, Suffolk, HSE Books).

HEALTH AND SAFETY EXECUTIVE. 1999a, *The costs to Britain of workplace accidents and work-related ill-health in 1995/96*, HSE Books).

HEALTH AND SAFETY EXECUTIVE. 1999b, *A Guide to the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995, L73*. (Sudbury, Suffolk, HSE Books).

HEALTH AND SAFETY EXECUTIVE. 1999c, *Major Hazard Sites and Safety Reports: What you need to know, C300*. (Sudbury, Suffolk, HSE Books).

HEALTH AND SAFETY EXECUTIVE. 1999d, *Reducing Error and Influencing Behaviour, HSG 48*. (Sudbury, Suffolk, HSE Books).

HEALTH AND SAFETY EXECUTIVE. 2000, *Rates of Workplace Injury: Europe and the USA*. <http://www.hse.gov.uk/statistics/pdf/eurocomp.pdf>.

HEALTH AND SAFETY EXECUTIVE. 2001, *Health and Safety in Construction. HSG 150 (rev)*. (Sudbury, Suffolk, HSE Books).

HEALTH AND SAFETY EXECUTIVE. 2002a, *Construction Tables 13a - 13f*. <http://www.hse.gov.uk/statistics/pdf/table13.pdf>.

HEALTH AND SAFETY EXECUTIVE. 2002b, *Health and Safety Executive*. <http://www.hse.gov.uk/statistics/pdf/rhscon.pdf>.

HEALTH AND SAFETY EXECUTIVE. 2002c, *Health and Safety Executive. Version 1.1*. <http://www.hse.gov.uk/statistics/pdf/rhscon.pdf>.

HEALTH AND SAFETY EXECUTIVE. 2002d, Statistics of fatal injuries 2001/02. <http://www.hse.gov.uk/statistics/overall/wkrftl.pdf>.

HEINRICH, H. W. and GRANNISS, E. R. 1959, *Industrial accident prevention, A scientific approach, 4th Edition*. (New York, McGraw-Hill Book Company Inc).

HEINRICH, H. W., PETERSEN, D. and ROOS, N. 1980, *Industrial accident prevention, A safety management approach, 5th Edition*. (New York, McGraw-Hill Book Company).

HELANDER, M., Ed. 1981, *Human factors / Ergonomics for Building and Construction*. (New York, John Wiley and Sons).

HENDRICK, K. and BENNER, L. 1987, *Investigating accidents with STEP*. (New York, Marcel Dekker).

HINZE, J. 1996, The distraction theory of accident causation. *Implementation of Safety and Health on Construction Sites. Proceedings of the First International Conference of CIB Working Commission W99*, (Lisbon, Portugal, A.A.Balkema).375-384

HINZE, J., PEDERSON, C. and FREDLEY, J. 1988, Identifying root causes of construction injuries, *Journal of Construction Engineering & Management* 124(1): 67-71.

HOYOS, C. G. and ZIMOLONG, B. 1988, *Occupational Safety and Accident Prevention: Behavioural strategies and methods*. (Amsterdam, Elsevier).

HUMAN RELIABILITY ASSOCIATES. 2001, *Accident Investigation - The drivers, methods and outcomes. CRR 344/2001*. (Sudbury, Suffolk, HSE Books).

INSTITUTE FOR OCCUPATIONAL ERGONOMICS, 1998a, Unpublished questionnaire of the Institute for Occupational Ergonomics. Nottingham, University of Nottingham

INSTITUTE FOR OCCUPATIONAL ERGONOMICS, 1998b, Unpublished work - Liaison with product manufacturers. University of Nottingham,

INTERNATIONAL LABOUR ORGANIZATION. 2002, Work-related fatalities reach 2 million annually. <http://www.ilo.org/public/english/bureau/inf/pr/2002/23.htm>.

INVESTORS IN PEOPLE. 2003, What is Investors in People. <http://www.investorsinpeople.co.uk/IIP/Internet/InvestorsinPeople/WhatisInvestorsinPeople/Default.htm>.

JACKSON, P. R. and MARTIN, R. 1996, Impact of just-in-time on job content, employee attitudes and well-being: a longitudinal study, *Ergonomics* 39(1): 1-16.

JOHNSON, C. W. 1996, Integrating human factors and systems engineering to reduce the risk of operator 'error', *Safety Science* 22(1-3): 195-214.

- JOHNSON, C. W. 1999, Vizualising the relationship between human error and organisational failure. *Proceedings of the 17th International Systems Safety Conference*
- JOHNSON, W. G. 1980, *MORT Safety Assurance Systems*. (New York, Marcel Dekker Inc.).
- KANTER, R. M. 1984, *The Change Masters*. (London, Allan and Unwin).
- KENNEDY, R. and KIRWAN, B. 1997, A review of methods for safety culture assessment: implications for ergonomics. In: S.A. Robertson. *Contemporary Ergonomics*. (London, Taylor and Francis): 289-294.
- KINES, P. 2001, Occupational injury risk assessment using injury severity odds ratio: Male falls from heights in the Danish Construction Industry, *Human and Ecological Risk Assessment* 7(7): 1929-1943.
- KIRCHSTEIGER, C. 1998, Absolute and relative ranking approaches for comparing and communicating industrial accidents, *Journal of Hazardous Materials* 59(1): 31-54.
- KIRWAN, B. 1994, *A Guide to Practical Human Reliability Assessment*. (London, Taylor and Francis).
- KIRWAN, B. 1995, Human reliability assessment. In: Wilson, J. R. and Corlett, E. N. *Evaluation of human work. A practical ergonomics methodology*. (London, Taylor and Francis): 931 -968.
- KJELLEN, U. 1983, *Analysis and Development of Corporate Practices for Accident Control*. (Stockholm, OARU, Royal Institute of Technology).
- KLETZ, T. A. 1994, *Learning from accidents, Second edition*. (Oxford, Butterworth Heinemann).
- KONINGSVELD, E. A. P. 1997, History and future of ergonomics in building and construction, *Ergonomics* 40: 1025-1034.
- KONTOGIANNIS, T., LEOPOULOS, V. and MARMARAS, N. 2000, A comparison of accident analysis techniques for safety critical man-machine systems, *International Journal of Industrial Ergonomics* 25: 327-347.
- KONZ, S. 1992, Macro-ergonomic guidelines for production planning. In: Helander, M. and Nagamachi, M. *Designing for Manufacturability: A systems approach to concurrent engineering and ergonomics*. (London, Taylor and Francis).
- KOORNEEF, F. and HALE, A. 1997, Learning from incidents at work. In: Felix Redmill and Jane Rajan. *Human Factors in Safety-Critical Systems*. (Oxford, Butterworth Heinemann).
- KOSSORIS, M. O. and KOHLER, R. F. 1947, *Hours of Work and Output*. (Washington DC, U.S. Government Printing Office).

KROEMER, K. H. E. and GRANDJEAN, E. 1997, *Fitting the Task to the Human*, 5th Edition. (London, Taylor and Francis).

KRUEGER, R. A. 1998, *Analyzing & reporting focus group results*. (Thousand Oaks, Sage).

LAUGHERY, K. R. and VAUBEL, K. P. 1998, The role of accident experiences on subsequent accident events. In: Feyer, A.-M. and Williamson, A. *Occupational Injury: Risk, Prevention and Intervention*. (London, Taylor and Francis).

LAWTON, R. and PARKER, D. 1998a, *Individual differences in accident liability: A review*, CRR 175. (Sudbury, Suffolk, HSE Books).

LAWTON, R. and PARKER, D. 1998b, Individual differences in accident liability: A review and integrative approach, *Human Factors* 40(4): 655-671.

LEATHER, P. J. 1987, Safety and accidents in the construction industry: A work design perspective, *Work and Stress* 1(2): 167-174.

LINCOLN, Y. S. and GUBA, E. G. 1985, *Naturalistic Enquiry*. (Beverly Hills, CA, Sage).

LOOSEMORE, M. and TAN, C. C. 2000, Occupational bias in construction management research, *Construction Management and Economics* 18: 757-766.

MARSHALL, A. 2000, IEA News, *Ergonomics* 43: 1939-1945.

MATHEWS, G., DAVIES, D. R., WESTERMAN, S. J. and STAMMERS, R. B. 2000, *Human Performance: Cognition, Stress and Individual Differences*. (Hove, Psychology Press).

MCATAMNEY, L. and CORLETT, E. N. 1992, *Reducing the Risks of Work Related Upper Limb Disorders; A Guide and Methods*. (Nottingham, The Institute for Occupational Ergonomics, University of Nottingham, UK).

MCDONALD, G. L. 1972, The Involvement of Tractor Design in Accidents. (St Lucia, USA), Dept. of Mechanical Engineering, University of Queensland.

MCDONALD, N. 1997, Deriving organisational principles for safety management systems from the analysis of aircraft ramp accidents. In: Hale, A., Wilpert, B. and Freitag, M. *After the Event. From Accident to Organisational Learning*. (Oxford, Elsevier Science Ltd): 95-112.

MCKENNA, F. P. 1988, What role should the concept of risk play in theories of accident involvement?, *Ergonomics* 31(4): 469-484.

MCVITTIE, D., BANIKIN, H. and BROCKLEBANK, W. 1997, The effects of firm size on injury frequency in construction, *Safety Science* 27(1): 19-23.

- MELAMED, S., LUZ, J., JUCHA, E. and GREEN, M. 1989, Ergonomic stress levels, personal characteristics, accident occurrence and sickness absence among factory workers, *Ergonomics* 32: 1101-1110.
- MINISTRY OF LABOUR. 1967, *Accidents in the Construction Industry*. (London, Her Majesty's Stationery Office).
- MORGAN, D. L. 1997, *Focus Groups as Qualitative Research*. (Thousand Oaks, Sage).
- MYAZAKI, S. 1992, Just-in-time manufacturing - past present and future. In: Helander, M. and Nagamachi, M. *Design for Manufacturability. A systems approach to concurrent engineering and ergonomics*. (London, Taylor and Francis): 257-268.
- NATIONAL OCCUPATIONAL RESEARCH AGENDA. 1999, Organisation of work. <http://www.cdc.gov/niosh/nrworg.html>.
- NELSON, C., TREICHLER, P. A. and GROSSBERG, L. 1992, Cultural studies. In: Grossberg, L., Nelson, C. and Treichler, P. A. *Cultural studies*. (New York, Routledge).
- NEWBOLD, E. M. 1927, Practical applications of the statistics of repeated event, *Journal of the Royal Statistical Society* 92: 487-535.
- NISKANEN, T. 1986, Preventative measures of fall accidents in the construction industry. In: W.Karwoski. *Trends in Ergonomics/ Human Factors III*. (Amsterdam, North-Holland): 1005-1013.
- NORMAN, D. A. 1981, Categorization of action slips, *Psychological Review* 88: 1-15.
- NORRIS, B. J. and WILSON, J. R. 1997, *Designing Safety into Products: Making ergonomics evaluation a part of the design process*. (Nottingham, Product Safety and Testing Group, Institute for Occupational Ergonomics, University of Nottingham).
- NORTON WAUGH MANAGEMENT SOFTWARE. 2000, Accident recording.
- OBORNE, D. J. 1987, *Ergonomics at Work, 2nd Edition*. (Chichester, John Wiley and Sons).
- O'HARE, D. 2000, The 'Wheel of misfortune': a taxonomic approach to human factors in accident investigation and analysis in aviation and other complex systems, *Ergonomics* 43(12): 2001-2019.
- O'HARE, D., WIGGINS, M., BATT, R. and MORRISON, D. 1994, Cognitive failure analysis for aircraft accident investigation, *Ergonomics* 37(11): 1855-1869.
- PERROW, C. 1999, *Normal accidents. Living with high-risk technologies*. (Princeton, New Jersey, Princeton University press).
- PHEASANT, S. 1991, *Ergonomics, Work and Health*. (Basingstoke, MacMillan Press Ltd).

POWELL, P., HALE, M., MARTIN, J. and SIMON, M. 1971, *2,000 Accidents*. (London, National Institute of Industrial Psychology).

RASMUSSEN, J. 1982, Human errors. A taxonomy for describing human malfunction in industrial installations, *Journal of Occupational Accidents* 4: 311-355.

RASMUSSEN, J. 1983, Skills, rules and knowledge: Signals, signs and symbols, and other distinctions in human performance models, *IEEE Transactions on Systems, Man and Cybernetics* 3: 257-268.

RASMUSSEN, J. 1990, Human error and the problem of causality in analysis of accidents. *Human Factors in Hazardous Situations. A Royal Society Discussion Meeting*, Clarendon Press)

RASMUSSEN, J. 1997, Risk management in a dynamic society: A modelling problem, *Safety Science* 27(2/3): 183-213.

REASON, J. 1990a, The contribution of latent human failures to the breakdown of complex systems. In: Broadbent, D. E., Reason, J. and Baddeley, A. *Human Factors in Hazardous Situations*. (Oxford, Clarendon Press): 27-36.

REASON, J. 1990b, *Human Error*. (Cambridge, Cambridge University Press).

REASON, J. 1995, A systems approach to organisational error, *Ergonomics* 38(8): 1708-1721.

REASON, J. 1997, *Managing the Risks of Organisational Accidents*. (Aldershot, Ashgate).

REDMILL, F. and RAJAN, J., Eds. 1997, *Human-factors in Safety-critical Systems*. (Oxford, Butterworth Heinemann).

REESE, C. D. 2001, *Accident / Incident Prevention Techniques*. (London, Taylor and Francis).

RESPECT FOR PEOPLE WORKING GROUP. 2000, A Commitment to People "Our Biggest Asset".

http://www.rethinkingconstruction.org/rc/publications/reports/rfp_report.pdf.

RETHINKING CONSTRUCTION. 2000, A commitment to people 'Our biggest asset'. A report from the Movement for Innovation's working group on Respect for People.

http://www.rethinkingconstruction.org/rc/publications/reports/rfp_report.pdf.

ROBERTSON, I. T., DUFF, A. R., MARSH, T. W., PHILLIPS, R. A., WEYMAN, A. K. and COOPER, M. D. 1999, *Improving safety on construction sites by changing personnel behaviour. Phase Two. Construction Research report 229/1999*. (Sudbury, Suffolk, HSE Books).

ROSPA. 2002, European Week for Safety and Health at Work. Alert: 'Safety under Stress'.
http://www.rosipa.org.uk/cmc/STORE/Occupational%20Safety/0_stress_files/stress.htm

SAFETY AND HEALTH AT WORK: REPORT OF THE COMMITTEE 1970-1972 (THE ROBENS REPORT). 1972. (London), Her Majesty's Stationery Office.

SALMINEN, S. and TALLBERG, T. 1996, Human errors in fatal and serious occupational accidents in Finland, *Ergonomics* 39: 980-988.

SALONIEMI, A. and OKSANEN, H. 1998, Accidents and fata laccidednts - some paradoxes, *Safety Science* 29: 59-66.

SANDERS, M. S. and MCCORMICK, E. J. 1992, *Human Factors in Engineering and Design, 7th Edition*. (New York, McGraw-Hill International Editions).

SASS, R. 1987, Accident causation theory as victim blaming. *20th Annual Conference of the Human Factors Association of Canada*, (Montreal, Quebec, Human Factors Association of Canada, Mississauga, Ontario.)

SHANNON, H. 1998, Workplace organisational factors and occupational accidents. In: Feyer, A.-M. and Williamson, A. *Occupational Injury: Risk, Prevention and Intervention*. (London, Taylor and Francis): 171-178.

SHAPPELL, S. A. and WIEGMANN, D. A. 1997, A human error approach to accident investigation: The taxonomy of unsafe operations, *International Journal of Aviation Psychology* 7(4): 269-291.

SHEAHY, J. E. 1979, Impact of theory of accident causation on intervention strategies. *Proceedings of the Human Factors Society - 23rd Annual Meeting*, (Santa Monica, CA, Human Factors Society).225-229

SHEPHERD, G. W., KAHLER, R. J. and CROSS, J. 2000, Crane fatalities - a taxonomic analysis, *Safety Science* 36: 83-93.

SMITH, M. J. 1981, Occupational stress: an overview of psychosocial factors. In: Salvendy, G. and Smith, M. J. *Machine pacing and occupational stress*. (London, Taylor and Francis).

SPURGEON, P. and YOUNG, K. M. 1980, The role of work analysis in the study of shipping accidents and the implementation of computer-based collision avoidance systems. In: Osborne, D. J. and Levis, J. A. *Human factors in Transport Research. Volume One*. (London, Academic Press): 49-57.

STANTON, N. and BABER, C. 1996, A systems approach to human error identification, *Safety Science* 22(1-3): 215-228.

STEWART, D. W. and SHAMDASANI, P. N. 1990, *Focus Groups : Theory and Practice*. (London, Sage).

STRANKS, J. 1996, *Safety Technology*. (London, Financial Times Pitman Publishing).

STRATEGIC FORUM FOR CONSTRUCTION. 2002, *Accelerating Change: A report by the Strategic Forum for Construction Chaired by Sir John Egan*, Rethinking Construction).

STUBBS, D. A. 1992, Ergonomics, health and safety: A function of management. In: Lovesey, E. J. *Contemporary Ergonomics 1992, Proceedings of the Ergonomics Society's 1992 Annual Conference*. (London, Taylor and Francis): 16-27.

SURAJI, A., DUFF, A. R. and PECKITT, S. J. 2001, Development of a causal model of construction accident causation, *Journal of Construction Engineering & Management* 127(4): 337-344.

SURRY, J. 1968, *Industrial Accident Research, A Human Engineering Appraisal*. (Toronto, Ontario, Ontario Government Publications Service).

SVEDUNG, I. and RASMUSSEN, J. 2002, Graphic representation of accident scenarios: mapping system structure and the causation of accidents, *Safety Science* 40(5): 397-417.

SVENSON, O., LEKBERG, A. and JOHANSSON, A. E. L. 1999, On perspective, expertise and differences in accident analyses: arguments for a multidisciplinary integrated approach, *Ergonomics* 42(11): 1561-1571.

SWAIN, A. and GUTTMAN, H. 1983, Handbook of human reliability analysis with emphasis on nuclear power plant applications (NUREG/CR-1278). (Washington DC), Nuclear Regulatory Commission.

SWAIN, A. D. 1963, A method for performing a human factors reliability analysis. Monograph SCR-685. (Albuquerque, NM.), Schandia National Laboratories.

SYMONDS, T. L., BURTON, A. K., TILLOTSON, K. M. and MAIN, C. J. 1996, Do attitudes and beliefs influence work loss due to low back trouble?, *Occupational Medicine* 46(1): 25-32.

TAYLOR-ADAMS, S., VINCENT, C. and STANHOPE, N. 1999, Applying human factors methods to the investigation and analysis of clinical adverse events, *Safety Science* 31: 143-159.

THE CONSULTANCY COMPANY LTD. 1997, *Evaluation of the Construction (Design and Management) Regulations (CDM) 1994, CRR 158*. (Sudbury, Suffolk, HSE Books).

THYGERSON, A. L. 1977, *Accidents and disasters, causes and countermeasures*. (Englewood Cliffs, New Jersey, Prentice-Hall, Inc.).

UNITED STATES DEPARTMENT OF LABOR. 2000, Accident investigation. <http://www.osha-slc.gov/SLTC/smallbusiness/sec6.html>.

UNITED STATES DEPARTMENT OF LABOR. MINE SAFETY AND HEALTH ADMINISTRATION. 1990, *Accident Prevention (Safety Manual no: 4)*. (Beckley, United States Department of Labor).

US DEPARTMENT OF ENERGY. 1999, *DOE Workbook. Conducting Accident investigation. Revision 2*. (Washington DC, US Department of Energy).

VERHAEGEN, P. 1993, Absenteeism, accidents and risk taking: A review ten years later, *Safety Science* 16(3-4): 359-366.

WAGENAAR, W. A. 1990, Risk evaluation and the causes of accidents. In: Borcharding, K., Larichev, O. I. and Messick, D. M. *Contemporary issues in decision Making*. (Amsterdam, North-Holland).

WAGENAAR, W. A. and GROENEWEG, J. 1987, Accidents at sea: Multiple causes and impossible consequences, *International Journal of Man-Machine Studies* 27: 587-598.

WAGENAAR, W. A., HUDSON, P. T. W. and REASON, J. T. 1990, Cognitive failures and accidents, *Applied Cognitive Psychology* 4(4): 273-294.

WARR, P. 1987, Job characteristics and mental health. In: Warr, P. *Psychology at Work, 3rd Edition*. (London, Penguin): 247-269.

WEBB, G. R., REDMAN, S., WILKINSON, C. and SANSON-FISHER, R. W. 1989, Filtering effects of reporting work injuries, *Accident Analysis and Prevention* 21: 115-123.

WHITTINGTON, C., LIVINGSTON, A. and LUCAS, D. A. 1992, *Research into Management, Organisational and Human Factors in the Construction Industry*. (London, HMSO).

WIEGMANN, D. A. and SHAPPELL, S. A. 1997, Human factors analysis of post-accident data: Applying theoretical taxonomies of human error, *International Journal of Aviation Psychology* 7(1): 67-81.

WILDE, G. J. S. 1982, The theory of risk homeostasis: implications for safety and health *Risk Analysis* 2: 209 - 225.

WILLIAMSON, A. and FEYER, A.-M. 1990, Behavioral epidemiology as a tool for accident research, *Journal of Occupational Accidents* 12: 207-222.

WILSON, J. R. and RAJAN, J. A. 1995, Human machine interfaces for system control. In: Wilson, J. R. and Corlett, E. N. *Evaluation of Human Work. A practical ergonomics methodology, 2nd Edition*. (London, Taylor and Francis): 357-405.

WONG, P. T. P. and WEINER, B. 1981, When people ask 'why' questions and the heuristics of attributional search, *Journal of Personality and Social Psychology* 40(4): 650-663.

WOODCOCK, K. 1989, Accidents and Injuries and Ergonomics: A review of theory and practice. *Proceedings of the Annual Conference of the Human Factors Association of Canada*.1-10

WOODCOCK, K. 1995, Bias in real-world accident cause-finding. In: A.C.Bittner and P.C.Champney. *Advances in Industrial Ergonomics and Safety VII*. (London, Taylor and Francis): 907-914.

WOODCOCK, K. and SMILEY, A. 1998, Organizational pressures and accident investigation. *Proceedings of the 30th Annual Conference of the Human Factors Association of Canada*, (Mississauga, Ontario.45-49

WORKING WELL TOGETHER. 2001, Turning Concern into Action. Construction summit - 27th February 2001. <http://wwt.uk.com/ConferenceDetail.asp>.

WORLD HEALTH ORGANISATION. 1993, Ageing and Work Capacity, Technical report no: 835. (Geneva), WHO.

ZIMMERMAN, C. L., ROSECRANCE, J. C., COOK, T. M. and SCHNEIDER, S. P. 2001, Construction. In: Karwoski, W. *International Encyclopaedia of Ergonomics and Human Factors*. (London, Taylor and Francis). One: 1486-1488.

ZUCKERMAN, M. and NEEB, M. 1980, Demographic influences in sensation seeking and expressions of sensation-seeking in religion, smoking and driving habits, *Personality and Individual Differences* 1: 197-206.