Exploring, evaluating and improving the development process for Military Load Carrying Equipment

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Exploring, evaluating and improving the development process for Military Load Carrying Equipment

by

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Abstract

This work sought to explore, evaluate and then improve the process of development for personal Military Load Carriage Equipment (MLCE), such as rucksacks. It was suspected that current MLCE had a number of user interaction deficiencies which should have been addressed during development. Three research questions were posed to determine: the influences on MLCE development, what needed improvement in MLCE development and how MLCE development could be improved.

The work was based on eight studies conducted in three phases: the first to explore MLCE development and the observed deficiencies, the second to evaluate MLCE development, and the third to improve it. The chosen research strategy was phenomenological, using a grounded theory methodology within which phenomena could emerge. Grounded theory approaches were adopted for this research because they were the best way in which to access the design domain. The research was framed within cycles of reflective action research to enable the researcher to re-orientate the enquiry to make the best use of the research opportunities that arose from the organisational context in which the research was sited.

An initial investigation into the development of in-service equipment was done via a comparative case study, using documentary analysis and interviews with authorities in the field. Through this investigation it became clear that MLCE development was based on heuristics and tacit knowledge of manufacturing techniques, and collaboration between professional groups, including: materials / manufacturing, human systems, project management and military personnel. Deficiencies within MLCE development, determined through the comparative study, were validated against current practice through a further case study and additional evaluations. A comparison of outputs from these studies was then reviewed in a grounded manner to gain a holistic understanding of MLCE development. The interaction and importance of the various influences on MLCE development was then better understood, in particular the inadequate understanding of MLCE user needs, and requirement specification.

To refine the possible avenues and target audience for an improvement of MLCE development stakeholder interviews were undertaken to develop a better understanding of how military user needs were gathered and applied. Following the interview survey, a tool was developed to analyse video and audio data of soldiers operating with MLCE on current operations. The tool was then reviewed by a panel of MLCE developers and stakeholders. The panel thought that the tool had a number of benefits to MLCE development: improving understanding of soldier environments, improved quality and reliability of information used in development, and as a conduit for concept evaluation. The research has provided a novel perspective on MLCE development, and provided a number of avenues upon which subsequent research could focus. The research has been able to make original contributions to understanding, albeit in a manner limited by the methodologies used.

Keywords: *grounded theory, development process, user needs, load carriage, soldiers, video design tools*

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Publications

The research in this thesis has been used to support the following publications:

The literature review (Chapter Three), **comparative and soft systems studies** (Studies 2 and 3, Chapter Five) were used as a part of; "The Dismounted Soldier, Mobile Asset or Burdened Workhorse?" Tutton, W.M., Sparks, E. (2005). Proceedings of the Land Warfare Conference 2005. Gold Coast, Australia.

And were published in; "Load Carriage UOR Literature Review" Humm, E., Tutton, W., Edwards, R. (2006). Dstl Report No.- CR19958 V0-1. UK Ministry of Defence. Dated 9 May 2006.

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Chapter 1: Introduction

This research was stimulated by the researcher's (a designer in the UK Ministry of Defence) experience of observing soldiers' problems with Military Load Carriage Equipment. Soldiers' problems and frustrations appeared to be influenced by the design of MLCE, prompting the question; could these problems have been addressed in development?

1.1 Chapter introduction, aims and objectives

The researcher, an industrial designer working in the UK Ministry of Defence's clothing and textile research establishment, noticed a number of problems soldiers had with using their Military Load Carriage Equipment (MLCE), an example of which is shown in Figure 1, which indicated the original design had not been effective. How the MLCE was designed also appeared to be unclear despite discussions with colleagues. These observations became the genesis of this study.

Figure 1. *Picture showing the UK's in-service 90 Pattern Personal Load Carriage Equipment (PLCE).*

This chapter aims to introduce the MLCE design domain and professional context in which the research was set.

Objectives:

1. To outline the reasons for starting the research and initial issues identified within the context of MLCE development.
2. To outline the professional context in which the researcher had to conduct the study.
3. To propose the initial research question and research aim.

1.2 Military Load Carriage Equipment (MLCE) design and development

How MLCE was designed and developed appeared to be ambiguous, despite many human factors investigations into the principles of load carriage in a military context, such as: Knapik et al. 1996, Tilbury-Davies and Hooper 1999, Lloyd and Cooke 2000, Martin 2001, and Bunting et al. 2001. It also appeared that MLCE design and development had not been investigated, to date, from a design perspective[1]. MLCE design and development was done, at the outset of the enquiry, by a group of UK MoD craft-trained designers and material specialists, who ensured a design could be manufactured. At the outset of the research the management of MLCE development in the UK was conducted in the same organisation as design and development. During the research this situation was changed and towards the end of the enquiry there were no longer any designers within the UK MoD. The MoD now commissioned and managed MLCE design being done by industry, rather than undertaking the design work itself. In addition, human factors evaluation of MLCE prototypes also had to be paid for, whether undertaken by internal UK MoD staff or by industry.

1.3 Starting the research

As stated, this research was started because the researcher noticed deficiencies within the design of the MLCE that was being used by UK Armed Forces personnel. Many of the deficiencies and frustrations observed appeared to be problems with interface between the user, the MLCE and other pieces of military equipment. For example; the interface of MLCE with helmets, combat body armours (CBAs) and weapon butts (Tutton 2000a). A solution to these problems could have been achieved in many different ways. Reflecting on civilian rucksack designs gave insights into possible solutions and provided further indication that the problems should have been more adequately addressed in the design of

[1] MLCE was determined as not having been investigated in the context of design studies by undertaking a number of keyword searches using the following keywords: MLCE – design, development, manufacture, specification and evaluation.

the MLCE. In addition, soldiers were buying civilian 'militarised' rucksacks to get better performance or an attempt to ameliorate back-injury problems (Tutton 2001). The question therefore arose:

'Could these issues be identified and tackled earlier in design, and so mitigated?'

This question needed some exploration before it could be framed as a research question. The initial aim of the study was to help improve the design of MLCE, or to improve the soldier's ability to use MLCE: while bearing and accessing loads to achieve military tasks.

Research approach

In order to answer the question above research would need to be systematic, rigorous, critical, reflexive, and communicable (Newbury 2001). Within MLCE design there were limited opportunities for research due to the infrequency of MLCE development in defence organisations. The researcher, as a civil servant, could access archive information and make use of the best opportunities for research into MLCE development through personal contacts which may not be accessible to other researchers. Access to the commercial environment and parallel load carriage development for civilian use was problematic, due to the competitive nature of the area. It should be stated, however, that the access gained by the researcher was greater for being a civil servant with existing relationships in the area. A pragmatic approach based on historical and available resources for case studies and expert views, was therefore chosen to provide an acceptable prospectus for gaining insight (Figure 2).

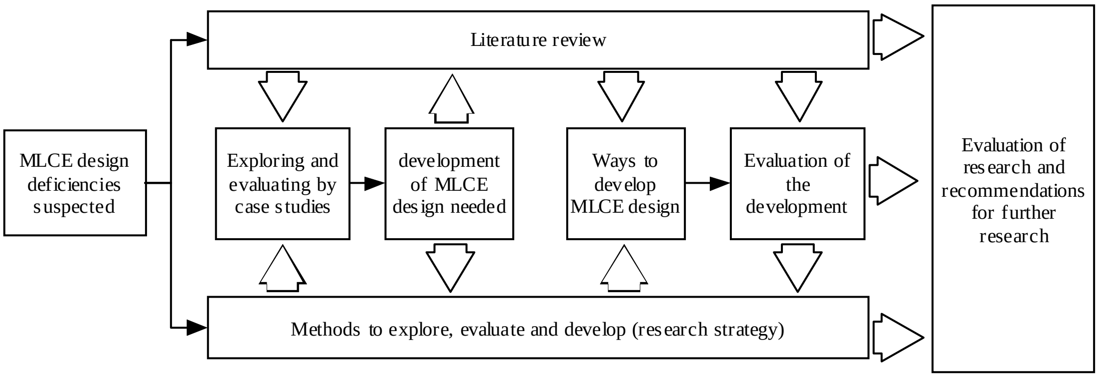

Figure 2. *Diagram showing the initial research approach.*

The initial stages in the research explored and evaluated MLCE design and development in relation to established approaches to design (representations from the literature) to set it in context. This allowed for MLCE development to be understood and enable comparison with civilian Load Carriage Systems (LCS) development. From the comparison one could determine whether MLCE design and development needed improving and, if so, how this could be achieved. The research into the improvement of MLCE design and development would depend on the resources available, as well as opportunities for making improvement. The last stage of the research would reflect and evaluate how suitable the research approach was for understanding MLCE design.

Who would benefit from the research?

This research was focused on issues and problems encountered during the design and development of MLCE and so would benefit those interested in improving the ability of military personnel to carry loads, such as:

- Military load carriage designers and developers
- Civilian load carriage designers and developers
- Those who are involved in MLCE design either as customers, stakeholders and professionals from areas such as human systems or acquisition
- Design researchers interested in exploring and evaluating little-understood design domains

This research was also intended, in part, to set MLCE design in a framework so that it could be discussed and understood by professionals involved in MLCE development. This research, therefore, may have consequences for the management of MLCE projects in providing a more transparent and robust evidence-based strategy or method.

The Researcher

The researcher, at the start of this research, was an industrial designer within the UK Ministry of Defence (UK MoD). Posts held within the UK MoD during the research included:

- Industrial Designer responsible for MLCE design and research at the UK MoD's Defence Clothing and Textile Agency, Research and Technology Division, Colchester.
- Science Desk Officer responsible for soldier related research programmes (including MLCE research) in UK MoD Headquarters, London.
- Senior Systems Analyst at UK MoD's Defence Science and Technology Laboratories (Dstl), Land Battlespace Systems Department, Fort Halstead.
- Ergonomist at the UK MoD's Defence Science and Technology Laboratories (Dstl), Human Systems Group, Porton Down.

In these various roles the researcher was a professional working with the various UK MoD organisations that were responsible for MLCE design and development. The research was, therefore, based in a changing professional and social context, in which the researcher had to work diplomatically with authorities in MLCE development to ensure the success of the research.

1.4 Structure of this thesis

This thesis is structured in four parts; each reflecting different phases that the 'research journey' has taken.

Part One – Enquiry Definition (Chapters 1 to 4). This initial part of the thesis provides the context and starting 'conditions' for the research which influenced and underpinned the successive phases along the research journey.

Part Two – Grounded Studies (Chapters 5 to 9). The second part contains the first iteration of the enquiry to explore MLCE design and development processes. This part of the thesis also includes an evaluation which was used to determine what needed improvement in MLCE development.

Part Three – Development Studies (Chapters 9 to 12). The third part includes work to determine how to improve the process of MLCE development. In particular this part covers the development and evaluation of a tool to improve the early stages of MLCE development.

Part Four – Outcomes (Chapter 13). The final part brings together the findings of the research and lays out the conclusions, implications and recommendations for further study.

Due to the evolving nature of the research journey, discussion of the research findings is reported within a number of chapters rather than in a separate discussion chapter. In order to aid the presentation of the research journey a research map was developed (Figure 3). The map will be used at particular points in the thesis to explain where the reader is in relation to the enquiry as a whole.

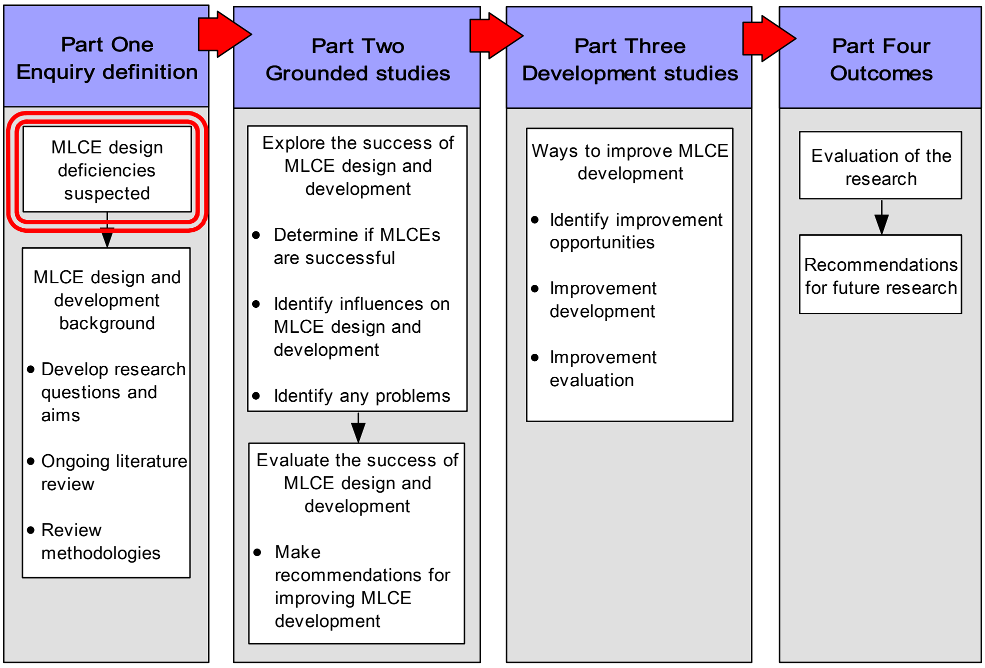

Figure 3. *Research map.*

The red double lined box, with curved corners, shows where in the reader is.

1.5 Chapter conclusions

This chapter has introduced MLCE design and development and the professional context in which the research was conducted.

Revisiting the chapter's objectives:

1. This chapter has outlined the reasons for starting the research and initial issues identified within the context of MLCE development.
2. The professional context in which the researcher had to conduct the research has been discussed and explained.
3. An initial research question and research aim have been identified in the context of the starting conditions for the research.

Key point to take forward:

1. The nature and issues which initiated the research in to MLCE design and development will be built on in the next chapter in the development of the initial research aim and question.

Chapter 2: Background

At the beginning of the project the researcher had been working in MLCE development for two years. In this time the researcher had noticed problems with MLCE during visits to military units on exercise in the UK and Norway. Noticing these problems stimulated further investigation during which a number of themes emerged, providing the initial context for the research.

2.1 Chapter introduction, aims and objectives

The aim of this chapter was to provide the starting context for the research into MLCE design, provide information on the scope of the research. Figure 4 situates the contents of this chapter on the research map.

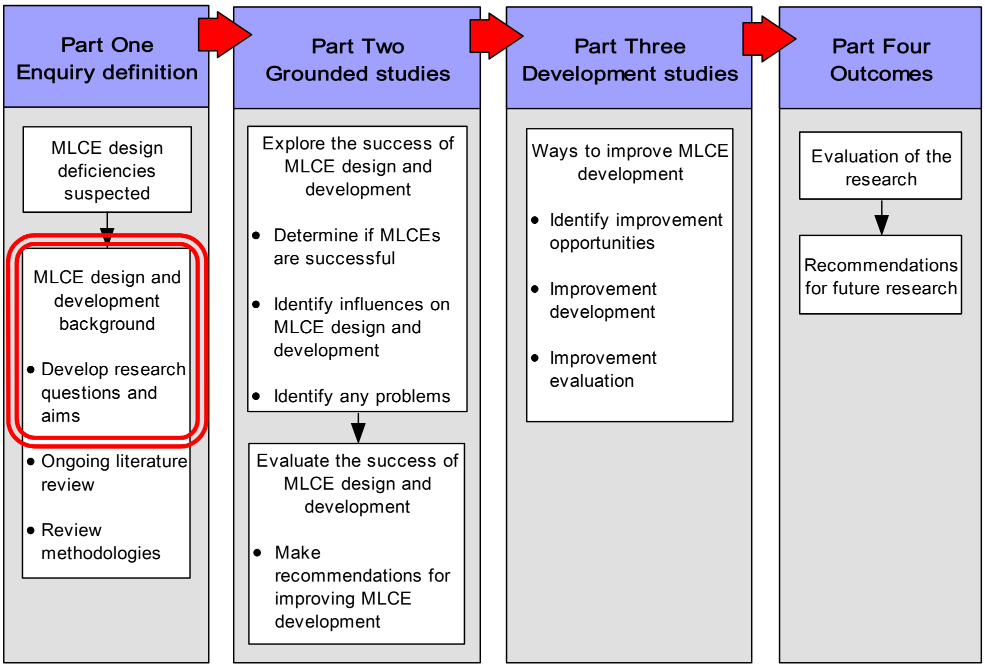

Figure 4. *Chapter 2 research map.*

Objectives:

1. To discuss the reasons for starting the research and outline some of the initial issues within the context of MLCE development.
2. To identify the starting boundaries for the research.
3. To develop the initial aims and objectives for the research to focus a literature review of the area.

2.2 The context of MLCE design

This section will outline the context of MLCE design, by discussing the need for MLCE and how this may impact on designing MLCE.

The need for soldiers to bear load

MLCE stems from a need for soldiers[2] to move items, for example food or weaponry and ammunition, from one place to another. How to carry items when moving around has been impacted by: the environment, the items to be moved, people's goals and the form of load bearing that was available (people, animals or vehicles). Soldiers must carry out a wide variety of military tasks in varying climates and terrains, and therefore need either flexible MLCE, or separate MLCE designed to be climate and or task specific. In defence organisations one flexible MLCE was the preferred option since providing more types of MLCE increases costs and may lead to availability problems. Whether current MLCE meets this requirement was uncertain at the outset of the research.

Issues with MLCE

Part of the reason for beginning this study was the researcher's observations that certain interface issues had not been embraced in an integrated manner (Chapter 1). This lack of integration appears to have led to a number of identifiable deficiencies in the MLCE, identified by observing and talking to military users, including:

i) Interface between rucksack and 'Belt Orders', issued and commercial combat waistcoats (otherwise known as assault vests) and patrol packs, and chest webbing.

ii) Interface of MLCE with helmets, Combat Body Armours (CBAs) and weapon butts (Tutton 2000a).

iii) Interface and easy access to radios and communications equipment (observed during a familiarisation visit to 1st Battalion Argyll and Sutherland Highlanders (1A&SH), while on a four-day exercise in Scotland, September 2000b).

[2] The UK's Armed Forces are comprised of both female and male soldiers. Throughout this study 'soldier' or 'soldiers' will be used to refer to both sexes. A soldier in the context of this study is a person with military training and skill who serves to conduct military operations on land.

iv) Lower back pain associated with heavy loads (observed during a familiarisation visit to Royal Marines Senior Command Course while on exercise at Sennybridge Training Area, December 2000c).

v) Skin rashes caused by MLCE during training and in high humidity environments (Tutton 2000d).

vi) Interface of MLCE with clothing (Tutton 2000c).

vii) Inability to load MLCE with unbalanced equipment such as Light Anti-Armour Weapons (LAWs) and Mortar Shells (Tutton 2001).

viii) Bulk and snag hazards of loads carried, especially on seated troops when carried in vehicles, (particularly Armoured Fighting Vehicles (AFVs) such as tanks and Armoured Personnel Carriers (APCs), ships and aircraft), and when moving in close terrain, such as woods or buildings (Tutton 2000a, Tutton 2000b and Tutton 2000c).

Figure 5 illustrates some of the above and with Figure 6 showing the imperfect interface between rucksacks and belt orders[3]. Alternatives to belt order which were more suitable for use with vehicles are shown in (Figures 7 and 8). Indeed (ii) and (viii) were identified as problems in an equipment compatibility study by Haisman (1975) and a history of military packs by Renbourn (1954), but had not been addressed by the introduction of new equipment shown in Figures 5 – 8 in the 1990s.

[3] Belt Order describes a load carriage system that uses a belt to attach a number of pouches to the user (shown in Figure 6 as the black MLCE), often used with a yoke (straps which go around the shoulders to stabilise the load carried in the pouches). In the British Army there are three orders describing the states of dress when using MLCE; marching (usually includes rucksack, day sack (otherwise known as a grab sack, usually carried in the rucksack), and belt order (Figure 6), patrol (day sack and belt order) and combat (belt order only). Belt order is also called webbing, after the web of straps and pouches that makes up the belt order. Webbing is also confusingly used to refer to chest rigs and waistcoat MLCEs which are also used for combat order (Figures 7 and 8).

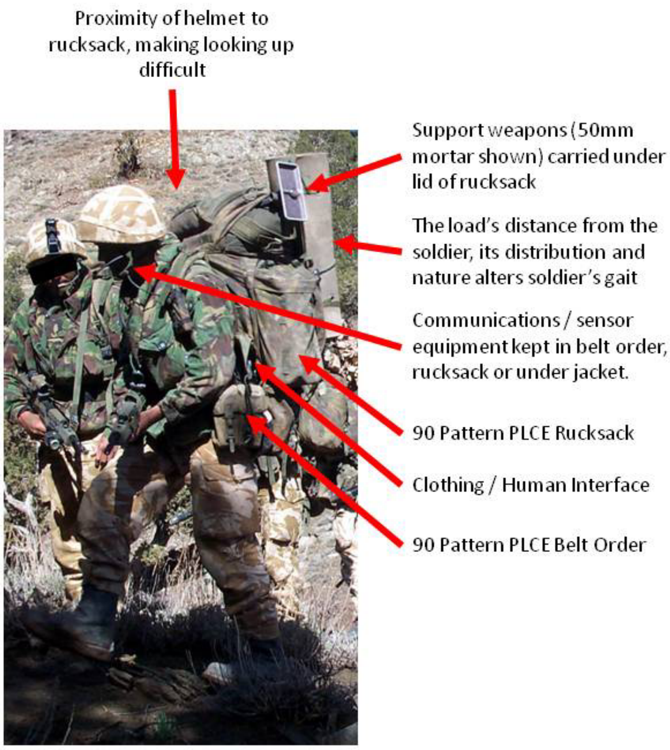

Figure 5. *Picture showing soldier carrying 90 Pattern Personal Load Carriage Equipment (PLCE) on operations in Afghanistan, illustrating some of the MLCE issues noted by the researcher during visits to Armed Forces units on exercise. © Crown Copyright*

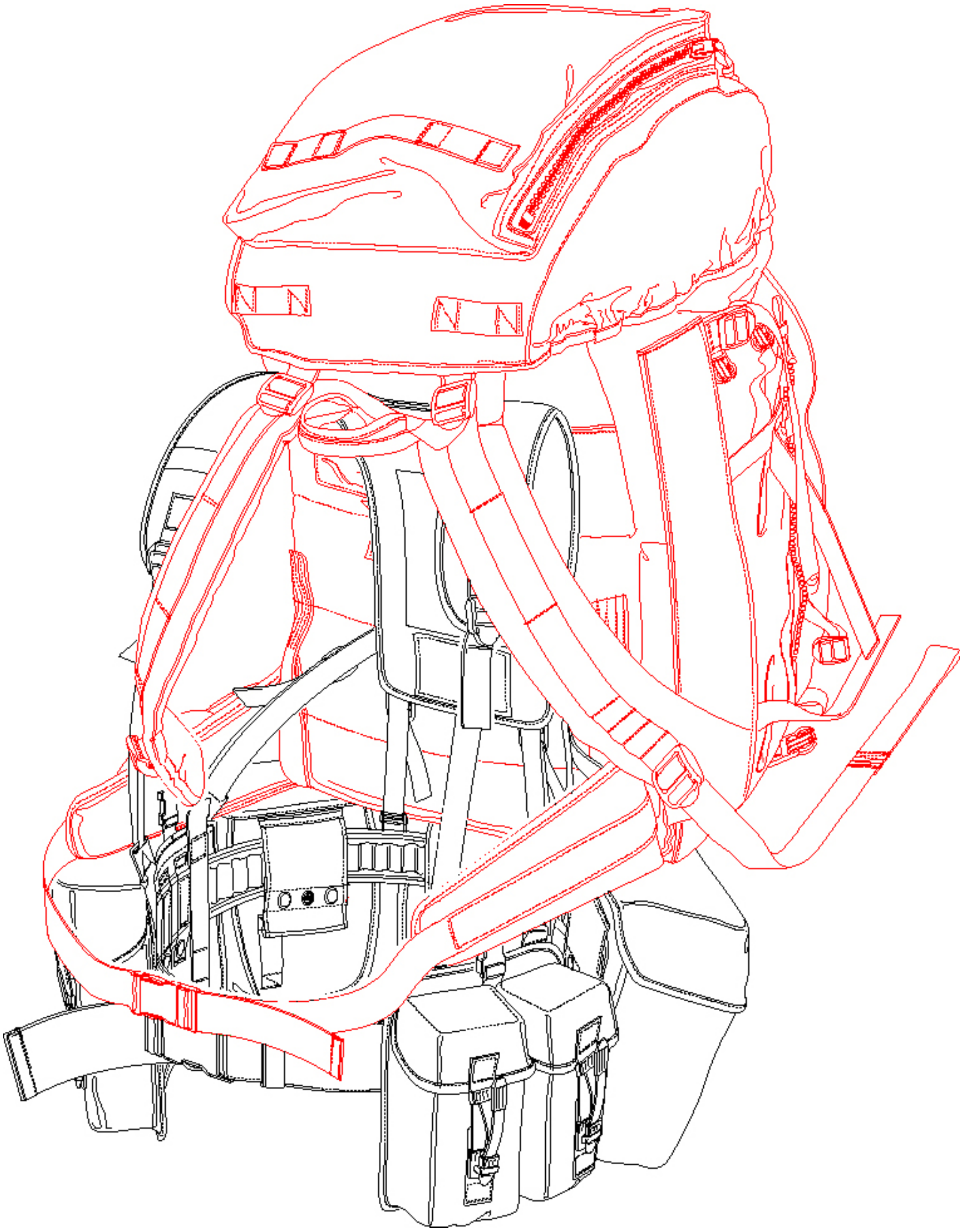

***Figure 6**. Diagram of 90 Pattern Personal Load Carrying Equipment (PLCE), showing the interface between belt order (in black) and the rucksack (in red). © Crown Copyright*

Figure 7. *Soldier wearing Chest Webbing style MLCE, © Crown Copyright.*

Figure 8. *Soldier wearing a Waistcoat-style MLCE, © Crown Copyright.*

Evolution of soldier's equipment

The deficiencies listed have been affected by many issues, including the continuing development of technological threats and counter-measure technology. These two developments have changed the role of the soldier and have necessitated the carrying of extra equipment (Tutton 2000c). Often there was a physiological or ergonomic penalty associated with new equipment which, until recently, the soldier has been able to bear. Gradual improvement of MLCE may not be able to provide a solution in the long term, due to loads being so high that they may not be mitigated by MLCE. Figure 9 illustrates the increases in the average marching load for soldiers since 1914. Deriving the weight[4] carried

[4] The *weight* of a military load is the force of gravity on it. In the context of this study *load* is not used to describe weight or forces acting on a body as it sometimes is in a scientific context, but to describe the characteristics (including weight, bulk and placement of load in relation to the bearer) associated with military

was difficult since different roles within a military organisation require soldiers to carry different equipment. Also different assumptions were made in each for example, the distances, climate and role the soldier was expected to be capable of changed, hence again making direct comparison difficult.

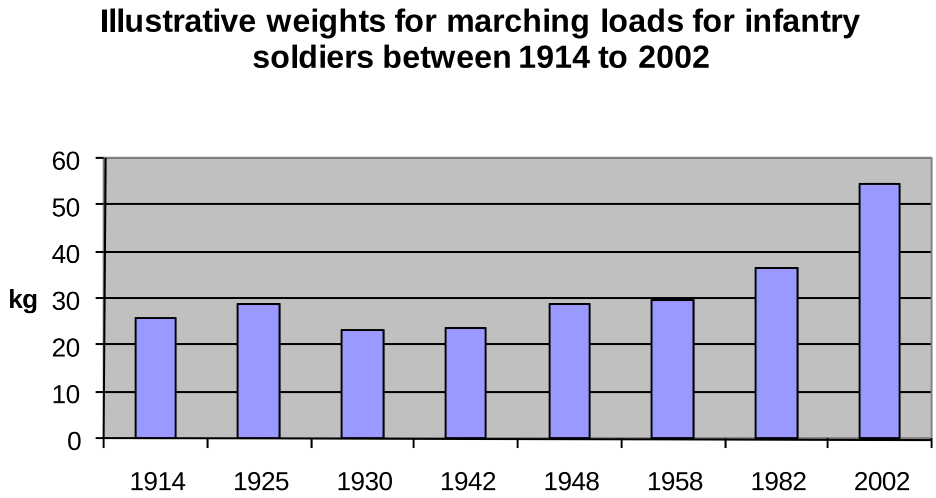

Figure 9. *Illustrative weights for Marching Order Weights since 1914. (Sources: Harding (2003) and Holt, J. S. (2003) CDO 21 – Tactical Agility for the Close Combat Companies, Internal MoD Memo.)*

The dip between 1925 and 1948 was due to the assumption, made in 1925, that soldiers would have a vehicle to offset some of the marching load. During the Second World War load states varied considerably, as did the availability of a vehicles such as the Bren Carrier (Jary 1986). Specially trained mountain troops during the same period did carry loads above 45.3 kg after considerable training (Harding 2003). The rise in the weight carried by the soldier has been subjectively linked to several factors including an increase in ammunition loads and personal equipment (nuclear chemical and biological (NBC) equipment for example) (Harding 2004).

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equipment which must be borne or conveyed by the soldier on foot. In scientific terms weight is expressed in Newtons (N) since it is a representation of the force of gravity on a military load's *mass. (Mass* is a measure of the amount of matter in a body.) Within the context of this study weight is used in the lay context and is expressed in kilograms (kg) which is the scientific measure of mass. This is done to keep the units presented in such a manner that the lay reader may get an impression of the quantities described.

Support weapons

The problem of determining accurate historical loads was compounded for soldiers using support weapons (Skinner 2000) who carry heavy weaponry, such as anti-tank weapons.

Methods of transport

As mentioned above a solution to excessive weights on the human body is to use an additional method of transport. Figure 10 from Lothian (1922) illustrates the range of additional modes of transport, such as animals and vehicles.

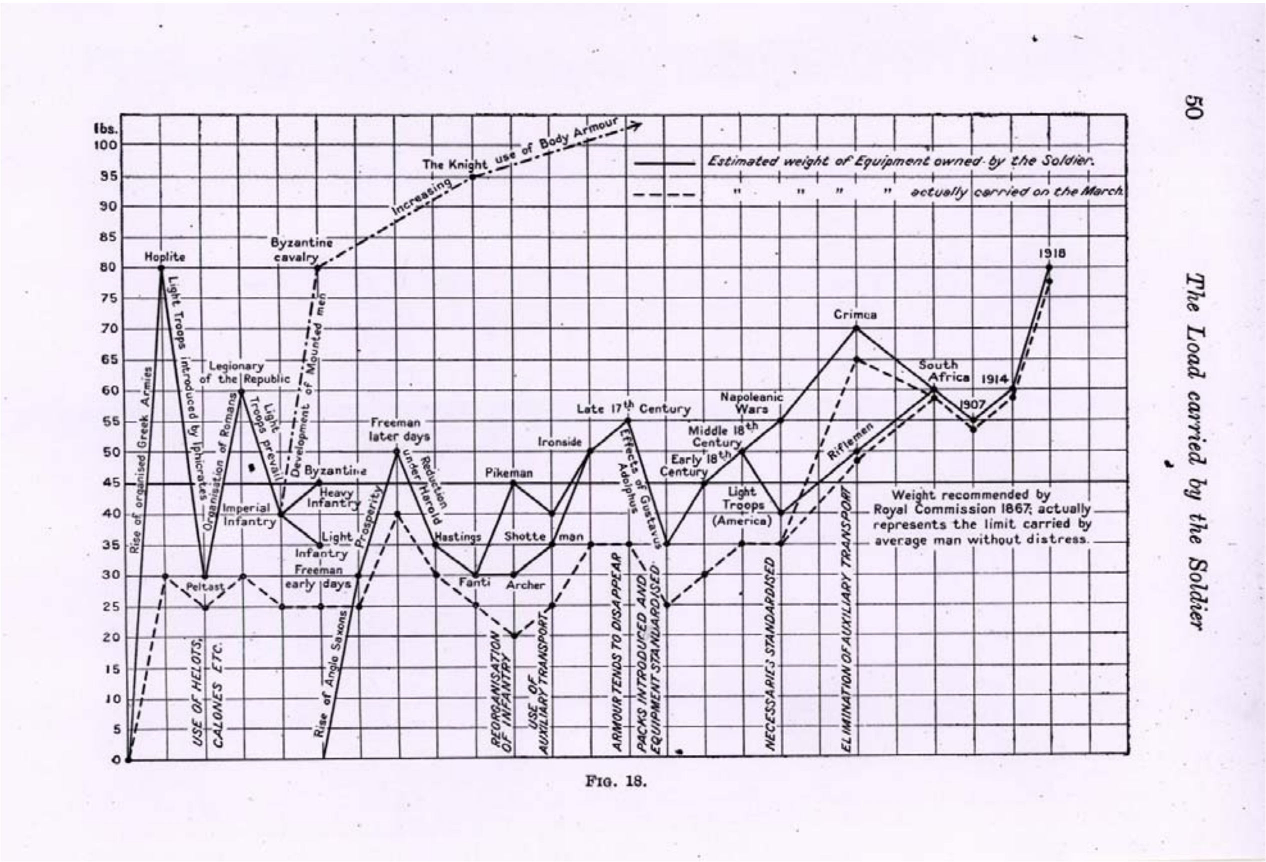

Figure 10. *'The Load Carried by the Soldier' From Major NV Lothian (1922), Royal Army Medical Corps, Army School of Hygiene, Advisory Committee Report No 1. © Crown Copyright*

It should be noted soldiers must be able to move to another location across complex terrain where a vehicle cannot be used in order to achieve mission success, which can be when MLCE is heavily relied upon.

Tactical influences on MLCE

Soldiers often need to move through complex and rough terrain for tactical reasons, whereas a civilian may be able to choose a more convenient route. MLCE makes this task easier and possible, when one considers the array of survival equipment, weaponry, communications and sensor equipment soldiers currently carry. The speed at which soldiers must be prepared to move also differs from civilians when operating on foot. Soldiers also must be able to remain agile; they must be able to climb, crawl and enter windows and so forth, while carrying equipment.

Differences between civilian and military users

Table 1 illustrates the differences between civilian and military users and the differences in modes of use.

Characteristics	Military User (UK Armed Forces)	Civilian User
Biophysical profile of user	17 to 55 years of age. Fitness varies from average to exceptionally fit. Used to prolonged periods of exertion. Used to high loads.	Any age. Any fitness level from very low to exceptionally fit. Unlikely to be used due to periods of prolonged exertion or high loads.
Load requirements	Up to 80kg – could be higher in certain instances, including radios, weapons tripods, ammunition as well as personal survival gear. Often carrying awkward and off-centre loads.	Up to 45kg, including photographic equipment as well as personal survival gear (i.e. food, sleeping bag, spare clothes.)
Operating environment	Must allow soldier to perform military tasks during day or night in all environments from the temperate regions, desert, mountains, arctic and jungle. Must be camouflaged, infra-red reflecting, be able to resist jagged and abrasive surfaces for long periods of time and industrial hazards.	Must allow user to perform activity in relative comfort. May be used in temperate climatic conditions, desert, mountainous and jungle conditions. Must be reasonably durable against general tear and abrasion.
Durations of use	Expected to last ten years. Can be used for six months before maintenance is possible.	Any length of time dependant on usage.
Special features	Convenient access to food/hydration, binoculars, compass and maps. Need for features that allow for the carriage of and quick access to: Radio antennas, skis, ammunition and so forth.	Convenient access to food, binoculars or cameras, compass and map. Occasionally need for carriage of and timely access to: ropes, ice axes, skis.
Speed used	Used at slow walking pace (patrolling, approach marches – must be silent and tactical). Must be able to sprint reasonable distance to gain cover, close with the enemy.	Varies between walking pace and running.
Interfacing	Must be usable within the confines of vehicles. Must also interface with radios, Weapons (stocks and sights) and clothing (including body armour and helmet).	Must fit inside cars. Must not interfere with clothing. Mountaineers need good interaction with helmets, harnesses and climbing racks.
Donning and doffing.	Must be quick to take off and put back on in tactical situation (that is silently and whilst lying down in cover). Must also be usable while mountaineering.	Must be easy to put on or remove. Most awkward position usually encountered whilst mountaineering where balance may be difficult.

Table 1. *A table comparing military and civilian use of load carriage, gathered from talking informally to military (soldiers) and civilian (mountain instructors) users.*

It was interesting to note from Table 1 the effect of a tactical environment on the use of MLCE. One must bear in mind that a soldier may only have one MLCE system, which may not be optimised for all the tasks he needs to do. The problem seemed to arise with the assumption that issued MLCE was fit for all military tasks.

Weight and its effect on the soldier

The weight of loads must have an impact on MLCE design, but did not seem to be sufficiently understood. In their survey after the Falklands Conflict, McCraig and Gooderson (1986) noted that soldiers' problems with MLCE were often associated with heavy weights. They also estimated that for the load (although as has been demonstrated this is difficult to determine) the average soldier was carrying about 70% of nude body weight. The accepted percentage at which soldiers can remain militarily effective historically (and physiologically) was between 30 to 40% of nude body weight (Harding 2004). The researcher has heard of similar anecdotal evidence from British Soldiers from Operations: JACANA (Afghanistan), TELIC 1 (Iraq) and HERRICK (Afghanistan). The US Army's experience was similar, having undertaken an extensive combat load survey during operations in Afghanistan (Dean 2003).

Human factors influences on MLCE

The physical limits of a soldier to bear weight and other such human factor influences were highly important to MLCE design and use. There was a large variety of human factors information on MLCE, but how this information and expertise was used to aid MLCE design was not clear at the outset. In the researcher's experience, only the most basic human factors information (or expertise) was used during MLCE design. Intuitively there was a need for human factors to better inform the design process. This was an area that needed further investigation.

Soldier satisfaction with MLCE

A factor which may be important in MLCE design, which has a human factors' quality, was soldier satisfaction with MLCE. Today the British soldier is regarded as a professional and used to a standard of living and freedom of choice that is similar to the rest of the population (Walker 2001), unlike previous generations of soldiers (Holmes 2002). Soldiers try to make their life in the field more like life at home and exercise consumer choice in order to do this. On the practical side, the researcher had observed that soldiers do have problems with personal equipment in terms of functionality, flexibility and durability (Tutton 2000). The researcher also noted that Officers and Senior Non-Commissioned Officers (SNCOs) regarded the purchase of civilian equipment as a positive attempt by soldiers to improve their combat effectiveness. Soldiers today are more affluent and empowered to supplement their personal equipment with products from the marketplace. Whether this has had an effect on altering the satisfaction with MLCE was uncertain.

Approaches to designing MLCE

In the civilian market designers must know their market well, understand individual consumers' desires and how consumers will use the product, so they can sell their designs to make profit. In the military arena the role of the designer was harder to identify. The 'user' or consumer was not the purchaser, as they generally are in the civilian arena. The approach of military organisations differed from the civilian arena in that there was a greater attention to cost, supply, and maintainability. There were clearly differences between the civilian and military approaches but what affect these had on the process of MLCE design was uncertain.

Differences between civilian and military design approaches

The differences between defence and civilian MLCE design practice were also not understood or documented. From the researcher's informal discussions with various companies, design practices varied depending on commercial pressures, a good example being seasonal demands. One observation by the researcher was that both commercial and military designers have difficulty in interpreting human systems information during the design process.

In summary

The factors influencing MLCE development from this limited review are summarised in Figure 11.

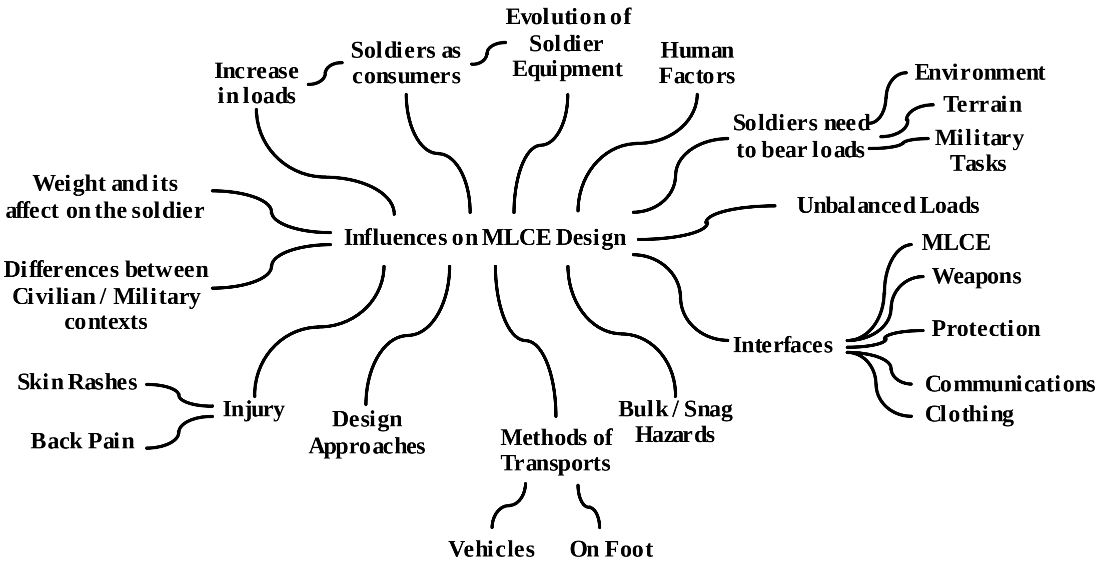

Figure 11. *Diagram showing the influences on MLCE design from the initial exploration of the area under study.*

2.3 Organisation and funding information

The approach to MLCE research within the UK MoD altered, along with organisational practices, during the period of this enquiry. This enquiry was to provide information and knowledge useful to the UK MoD's efforts in equipping British soldiers. The enquiry was focused on design processes, so detailed issues of procurement, manufacturing, costs and marketing were not discussed in depth.

Funding

The research was funded in the first five years by the UK MoD, the last two by Loughborough University, Department of Design and Technology. The research was carried out on a part-time basis, with no additional funding beyond the researcher's time.

2.4 Scope of research

The scope for the enquiry needed to be bounded to frame and direct the research. Initially this was done by conducting a literature review, which put structure on some of the thoughts and observations discussed in section 2.2. The review needed to look at the influences on MLCE design, reflecting on design within defence and civilian arenas since there may be much that could be learned from reflecting on the similarities and differences between them.

Focus on development

It was decided to focus on development processes, such as New Product Development (NPD) (Pugh 1991), within the context of MLCE, since it was unclear whether resources and opportunities would be available to investigate design activity in detail. Gaining access to MLCE development was thought to address aspects of design activity, and be of most relevance to the main sponsoring organisation (UK MoD). This was because the UK MoD began to outsource its MLCE design and development work in 2004 and was not conducting any MLCE development projects at the time of the early research (2002).

It was anticipated at the outset of the enquiry that it would follow three stages; exploring, evaluating and improving.

Exploring

The exploring phase of the research sought to understand what was happening and why through a literature review. The literature review helped identify what the next phase of research would need to focus on and how further research could be conducted.

Evaluating

The evaluating phase sought to understand how the influences affecting MLCE development, and see whether any improvements were needed. Since there was no possibility to look at contemporary cases at this stage in the evaluation, historical cases were used. The evaluation would check for common factors between the cases and compare the influences. Once an analysis of the cases had been done, then it was planned to propose how the improvement of MLCE development could be conducted within the resources available.

Improving

Improvement in the context of this research sought to define and, if required, to then improve MLCE development. Whether the resources for this part of the research would be available was uncertain at the start of the project. Obviously this phase of the research would be dependent of the recommendations of the earlier phases.

Figure 10 shows the research approach as was understood by the researcher while looking at the background context, and shows how the envisaged research methods fitted in to the three phases; exploring, evaluating and developing.

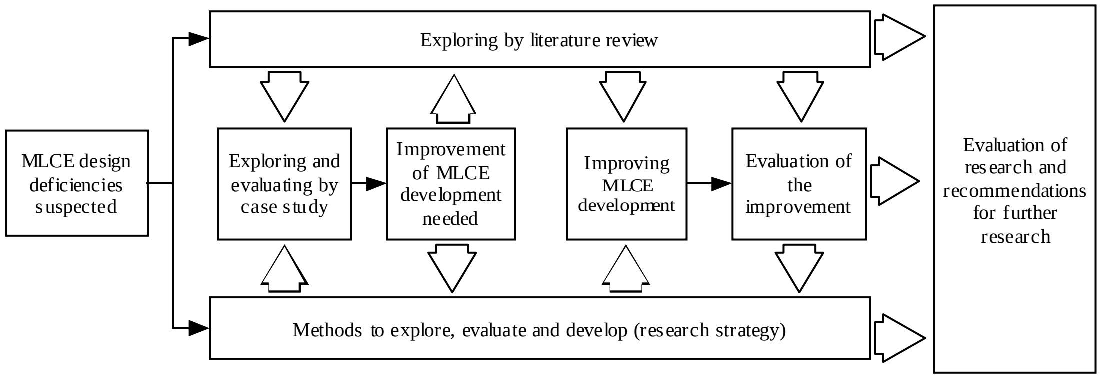

Figure 12. *Diagram showing the research approach in the early stages of the research, adapted from Figure 2.*

The research *aim* therefore was to; *explore, evaluate and then improve MLCE development.* From this statement the research's *objectives* were developed:

1. To understand the influences involved in MLCE development.
2. To understand how important these influences were in MLCE development.
3. To develop an understanding of how MLCE development can be improved.

2.5 Research questions

From the research *aim;* to explore, evaluate and then improve MLCE development, *research questions* were developed to provide a basis for the research:

1. What are the influences involved in MLCE development?
2. What needs improvement in MLCE development?
3. How can we improve MLCE development?

2.6 Chapter conclusions

This chapter has provided background information about the context of MLCE design, and why it was the area of study.

Revisiting the chapter's objectives:

1. This chapter has discussed the reasons for starting the research and outlined some of the initial issues within the context of MLCE development that were perceived at the beginning of the research.
2. This chapter has identified the starting boundaries for the research.
3. Additionally the initial aims and objectives for the research have been developed to focus a literature review of the area.

Key points to take forward:

1. In order to further focus the research a literature review was needed to define MLCE development and identify areas for research activity.
2. Also the research needed to be placed with a wider design context and determine the definitions to be used in the enquiry.
3. The literature review was also needed to look at the influences on MLCE design, reflecting on design within military and civilian arenas.

Chapter 3: A review of MLCE development literature

As highlighted at the end of the previous chapter there were areas which needed to be explored in order to focus the research. For example definitions used during the research needed to be considered in the context of design studies. The exploration of MLCE development was taken forward, from the last chapter, by a review of the existing literature.

3.1 Chapter introduction, aims and objectives

The literature review aimed to explore development processes and design activity in the literature that have relevance to MLCE. This review builds upon the contextual background presented in Chapters 1 and 2. It establishes the definitions and terminology to be used in the research. This review also provides a description of the state-of-the-art in MLCE development and highlights gaps in knowledge. Figure 13 shows this chapter's place in the research.

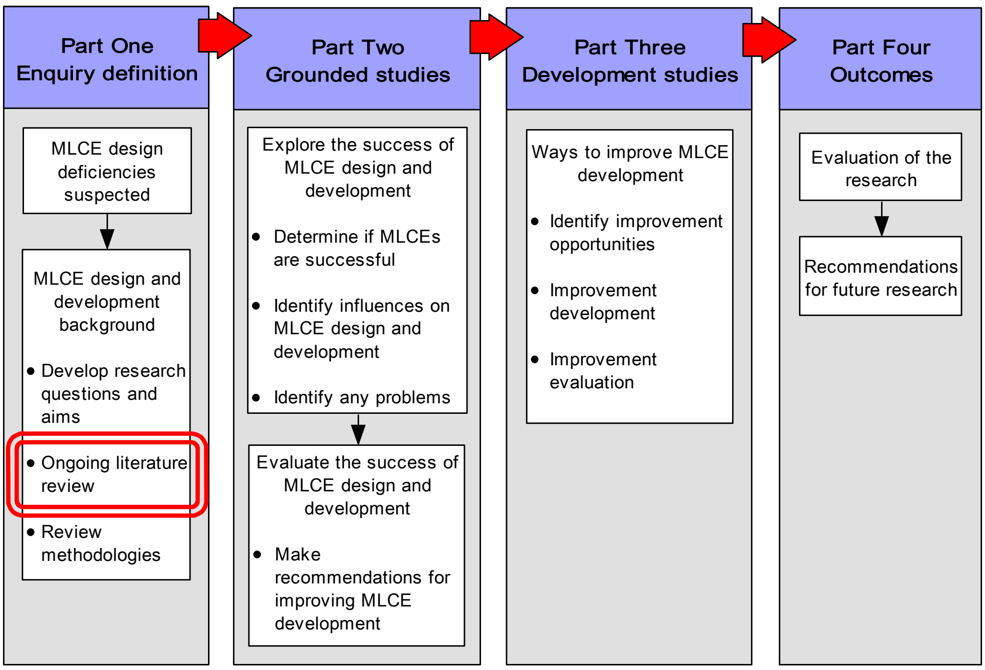

Figure 13. *Chapter 3 research map.*

Objectives:

1. Establish what the design processes and methods were used in MLCE development.
2. Identify gaps in knowledge which affect MLCE development.
3. Define the context for MLCE development in military and civilian organisations.
4. Gain an approach to understanding the performance of MLCE products.
5. Gain an appreciation of parallel areas of design and development which could provide insights when exploring, evaluating and developing MLCE products.

3.2 Method

The method used to undertake the literature review was to undertake a number of initial searches using a variety of key words based on the influences on MLCE identified in Chapter 2 (Figure 11). Key word searchers were conducted via the university's electronic resources, including: on-line journals, meta-searched material and internet sources. The researcher could access UK MoD archives as well as knowledge searches conducted in support of MLCE related projects. The researchers job also enabled him to network with other specialists in the area. Some documents were purchased from the British Library. Some of the information was restricted, with respect to national security or commercial aspects. This was dealt with by the researcher's use of UK MoD procedures for storage and handling such materials, and by making agreements about the use of material with providers. Once initial source documents were identified, the search was 'snowballed' by using the references in the source documents to identify further sources. To ensure the literature review was not too far reaching, it was decided to limit the search for information when no further useful information could be gathered on a given topic. The only instance where this became a problem was when trying to gather information on human sciences related to MLCE. In this instance there was a large quantity of information available, therefore, it was decided to get advice from specialists on which texts would be most useful. Records of the various searches conducted were collected in the researcher's note books and computer files. The literature review was continued throughout the research and is expanded in more detail in later chapters.

3.3 Design processes in the context of MLCE

The first aspect of the literature review was an exploration of the existing definitions of design and development, in order to be able to compare the findings from the research studies with generic models and clarify the terminology used in the research.

Definitions of Design

Design has been a source of debate for many years, its definition being one of the primary difficulties. Pye (1969) described design activity as the process of applying a principle and prescribing a particular embodiment to achieve a particular result. More recent texts concerning design have expanded on this definition; Lawson (1997), Cross (1995), Pugh (1991), and Roozenburg and Ekels (1995) all agree that design, to some extent, is concerned with problem solving. To an extent every person is a designer in that they effect the environment and artefacts around them. Cross (1995) further explains that all design activity is focused on a 'description' of the final artefact. So those involved in 'describing' the final artefact from marketing, human sciences, manufacturing and specialist designers (for example: industrial, mechanical and electrical engineers) collectively contribute to the design of products (Roozenburg and Cross 1991 and Ulrich and Eppinger 1995). Designers, however, must collect data from all areas, generate ideas and move towards a final artefact. Within MLCE locating the 'designer' was difficult, since a range of people with varying backgrounds were involved in design and moving it towards a final artefact. From this perspective the term *developer* is used to indicate someone who influences the MLCE's physical embodiment, regardless of background or role. Designers would be, therefore, included within the description of an MLCE developer, but are defined as the individual who described the form and embodiment of the final artefact.

Describing design activity

Understanding the two main paradigms (or models) describing design activity was an important step in understanding MLCE design processes (Visser 2006). These two paradigms are described in Table 2, adapted from Dorst and Dijkhuis (1996).

Item	**'Simon'**	**'Schön'**
designer	= information processor (in an objective reality)	= person constructing his / her reality
design problem	= ill-defined, unstructured	= essentially unique
design process	= a rational search process	= a reflective conversation
design knowledge	= knowledge of design procedures and 'scientific' laws	= artistry of design: when to apply which procedure / piece of knowledge

Table 2. *The rational problem-solving paradigm and the reflection in action paradigm.*

From this table one can see the differences between Simon and Schön's paradigms, which may be explained by the professional perspectives they are derived from: Simon – engineering and business management (Visser 2006), Schön – arts and asethetic design (Schön 1983). Simon's outline of design is overtly scientific and seems to define design as an 'analytic, partly formalisable, partly empirical, techable doctrine about the design process' (Cross 2007). Schön challenges this positivist view because of its focus on well-framed design problems, rather than the complex reality of professional practice. This lead to Schön's paradigm, called 'reflection-in-practice'. Dorst and Dijkhuis (1996) see both paradigms as having utility with one being appropriate for well-defined problems (Simon), the other working well for conceptual stages of the design process (Schön). Which would describe MLCE design is uncertain, although each paradigm may have relevance given the inputs needed to design successful MLCE[5]. Indeed Cross (2007) notes that the paradigms may not ultimately be conflicting, if one regards design as an interdisciplinary area, rather than as a science. Another view of design activity which was useful was to regard design as a complex interaction between the designer, problem and the materials used (Roozenburg and Dorst 1998).

[5] MLCE design was thought at the outset of the enquiry to be dependent on the use of craft knowledge to make design decisions (Schön), and to a degree the rational use of scientifically based human factors knowledge (Simon) at certain points during development.

In addition to Schön there are other perspectives that argue that creativity is not represented within scientfic / systematic representations of design, such as Coyne 2005 and Rittel and Webber 1973, which can make systematic definitions problematic. MLCE design could be regarded as ill-structured since it was initially considered a dynamic and complex activity. This avoided thinking of design as simply problem solving using application of knowledge to make a design or development decision. How design functions, in terms of proceedures or working towards a solution in this context needed defining.

Types of design processes

Many different types of design processes, both descriptive and prescriptive models (Van Aken 2005) have been established over the years for a variety of purposes. Whether descriptive or prescriptive models are used in MLCE design and development was not known at the outset of the research. In order to explore the MLCE domain an understanding of design and development process models would be needed; firstly to assist with evaluating how successful it might be, and secondly to help describe how it was conducted. From this perspective it was important for the models used to explore MLCE development to: i) be well regarded, ii) allow parallels from the military processes to be drawn, and iii) be flexible enough to allow for improvements in the process MLCE development if so required.

Cross (1995) distinguishes between descriptive models and prescriptive models for design. Descriptive models tended to present the design process as sequential stages, with instances of feedback showing iterative returns. Within different areas of design, for example engineering and architecture, there is some debate as to the balance of systematic analysis in design processes (Roozenburg 2002 and Coyne 2005). Some of these ‘systematic’ design systems have been criticised for not being adequate during real, complex problems (Joseph 1996 and Cross 1995). Joseph’s (1996) contention was that these processes fail because the design strategy they use, a paradigm of problem-solving (see Simon’s paradigm in Table 2), does not allow for the creative acts that go on outside of it. Also the use of a design process may alter one’s understanding of the situation one is trying to address. Prescriptive models identify stages in the design process which try to prompt the designer into adopting better ways to work. This may be an appropriate way to improve MLCE development if needed.

Are design processes useful for MLCE designers?

A study conducted by Austin et al. (2001) found that designers perceived that they perform better as a team[6] when they agree on and follow a process. It was clear from the study that, without a process to follow, some team members could become sidetracked and compromise team effort. Valkenberg and Dorst (1999) observed that design teams will approach different design problems using very different strategies and processes, when viewed from Schön's (1983) 'reflection practice' paradigm. Essentially the processes are not predictable using the reflection practice paradigm, and were a function of the behavioural interactions of the team. Whether design processes could be useful within the MLCE development was not clear from the literature. Certainly the researcher had experienced several different design approaches in MLCE development practice which seemed to be the result of social interaction and behaviours within the team. Whether these interactions and behaviours were dependent on design or development processes was uncertain. Part of the uncertainty was the difficulty in determining between design activity, design process and development process and how social interactions and behaviours were situated within them.

Product development process for MLCE

At this stage in the research, MLCE development was defined as a process that encompassed the activities that develop and bring a product (MLCE) to a state of readiness for use by soldiers, whereas design and design processes are a group of activities within product development which enable the product to be described and made ready for use. This definition was developed from: Otto and Wood (2001), Roozenburg and Ekels (1991), Pugh (1991), and Ulrich and Eppinger (2004) and British Standard 7000, all so called 'systematic' processes. While user aspects did not appear to be covered adequately by these processes, it is important to remember that the UK MoD extensively use engineering processes, such as these, which may influence MLCE development. For the purposes of this study Pugh's (1991) Total Design Activity Model was chosen to help look at MLCE development (Figure 14) despite the lack of detail on user aspects. The one area where the Total Design Activity Model may not represent MLCE development processes was the marketing and specification stages. The MoD did not explicitly undertake the marketing activity as outlined by Pugh (1991), but used operational requirements to frame the need for equipment. The UK MoD used a process call the Acquisition Management System (AMS)

[6] A team was defined as the specific people responsible for the development of the form of the MLCE product, that is designers, development managers, military advisors, ergonomists and materials specialists.

to manage development, including operational requirements. As a part of the AMS, during the research, the UK MoD also began to improve the incorporation of user-centred aspects within the engineering processes they currently used (see section 3.5). At the outset of the research MLCE had not, however, been developed via AMS processes. The Total Design Activity Model was used as a 'hand-rail' to explore and evaluate MLCE development, user-centred aspects were looked at by reflecting on the literature in section 3.5.

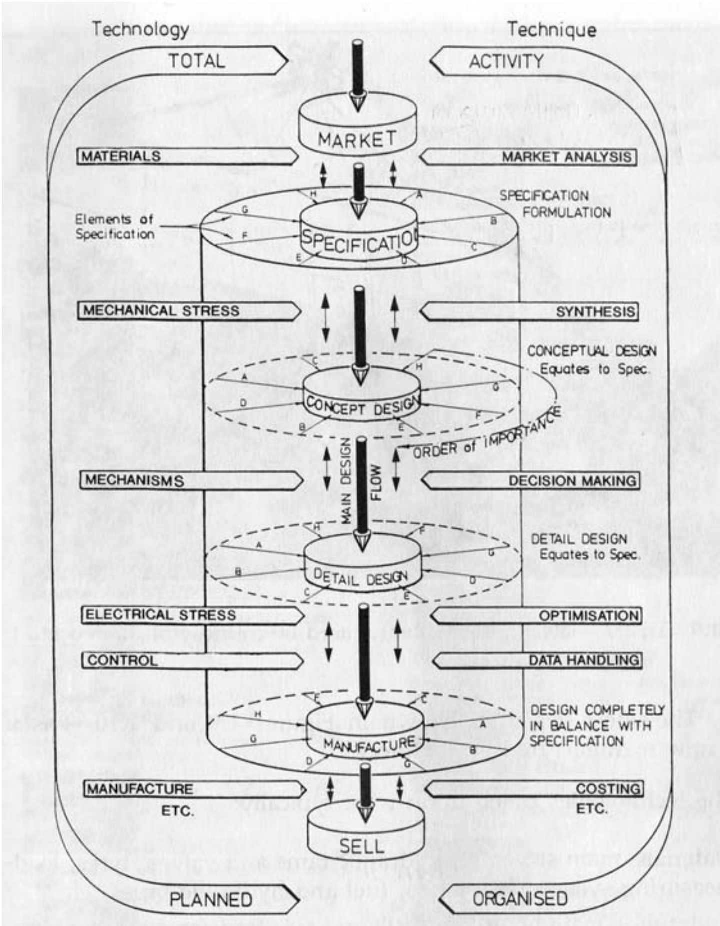

Figure 14. *Diagram of Pugh's (1991) Total Design Activity Model.*

Other representations such as Ulrich and Eppinger's (2004) Generic Product Development Process were too broad to give sufficient reference to enable an understanding of how MLCE design was conducted. They observe that engineering process models tend to be biased towards the elements that are better structured in the process, such as system and detail-level design. This means that conceptual or ill-structured problems were not addressed. In MLCE development this may be an issue; certainly aspects of MLCE design were difficult to quantify and model, such as suspension characteristics and interactions with the human body (Ren et al 2005). While characterisation of other aspects like centre of mass and affect on human physiological performance were possible, these were variable and hard to use, as has been experienced in other design domains (Darses and Wolff 2006). Over time it should be possible to translate this ambiguous and arguably qualitative data into usable quantitative design data.

The UK MoD's process for managing defence equipment (including MLCE) procurements requires the development of User Requirements (URs) and System Requirements (SRs), as shown in Figure 15.

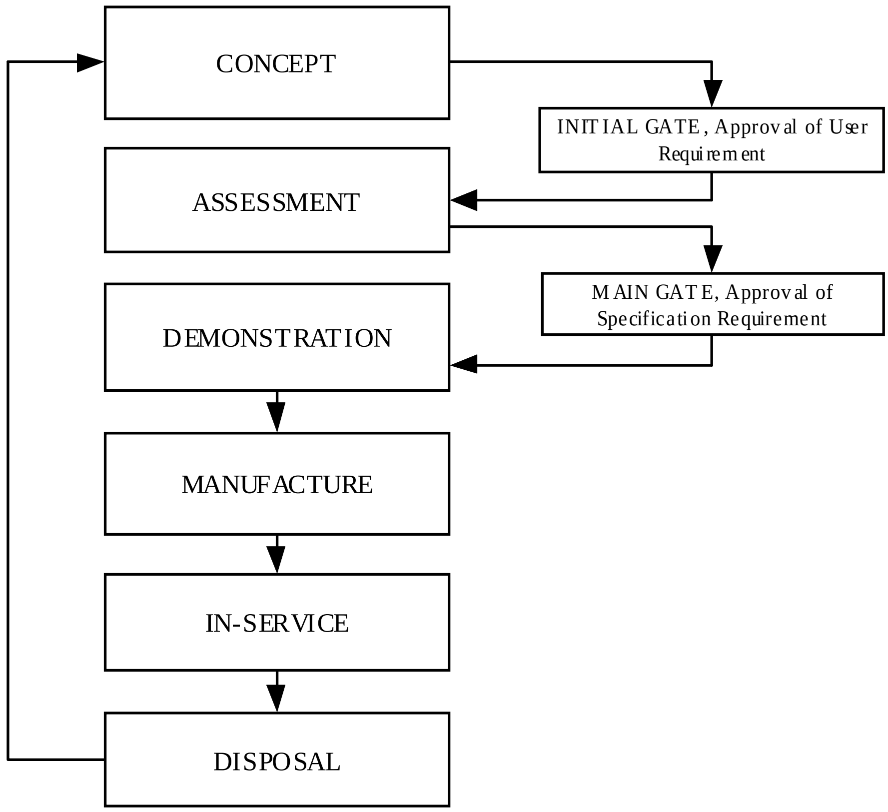

Figure 15. *Diagram of the Acquisition Management Systems CADMID Cycle.*

The URs and SRs were analogous of Pugh's (1991) Product Design Specification (PDS) and illustrated the similarities between the civilian and military arena. It is important to note that there was little detail of how user-centred aspects were dealt with, as with Pugh. It can be argued, however, that the defence arena (like the civilian) controls how users and stakeholders formulate requirements through the development process (Darlington and Culley 2004). This may be the case with MLCE projects; first, however, one must determine what, if any, development process was being used to develop the MLCE. Current

MLCE was developed using the previous UK MoD procurement process, the Downey Cycle, which was developed from the Downey Report (Downey 1969) (see Figure 16).

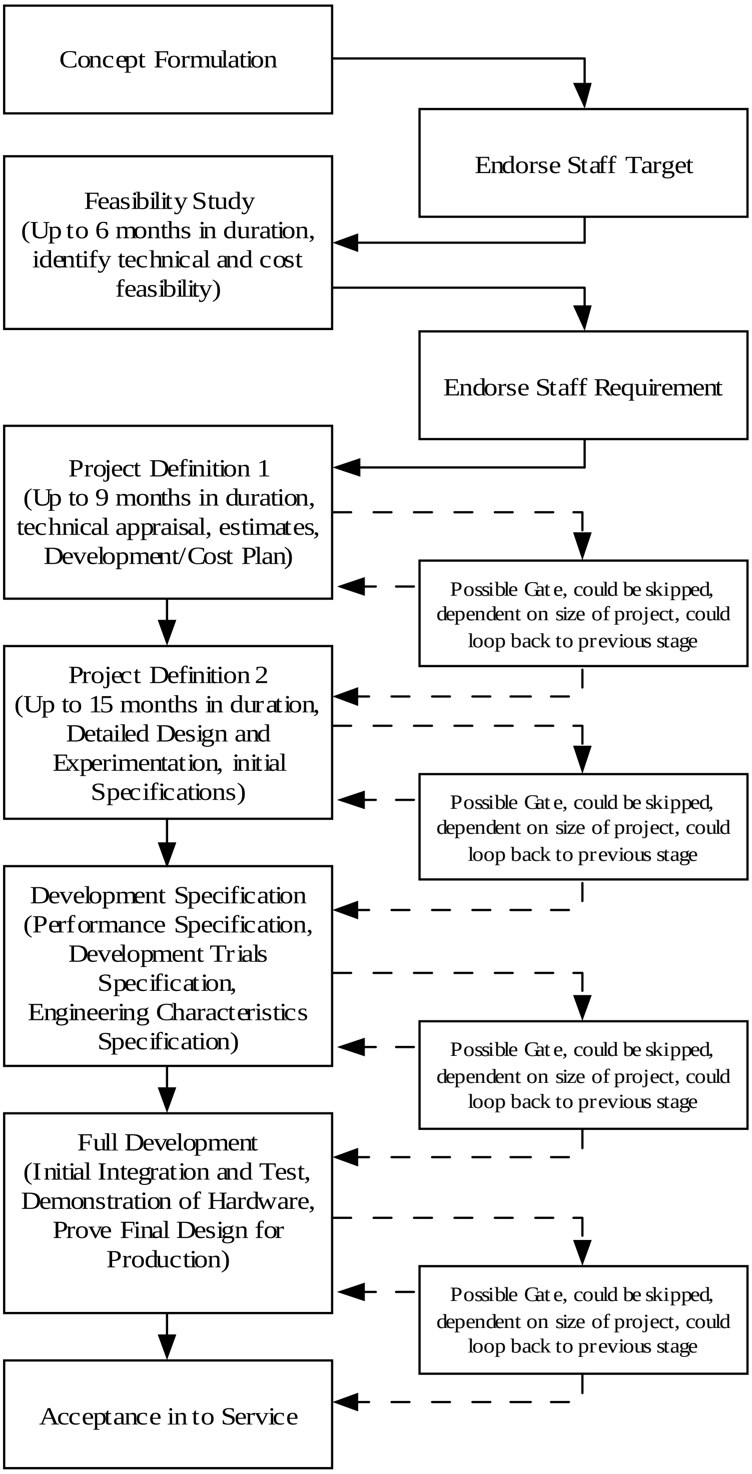

Figure 16. *Diagram of the Stages of the Downey Cycle. (Source; Tutton, W. (2005) Interview with R.W. Ruffles.)*

The Downey Cycle process is difficult to map on to product development processes (or PDPs) since it, like the AMS, was designed to apply to all projects and cover all types and aspects of defence procurement projects. One can identify parallel activities which enable comparison of the Total Design Activity Model, the AMS and the Downey Cycle (Figure 17). Figure 17 enables one to understand how design processes fit into organisational processes which influence MLCE design activity.

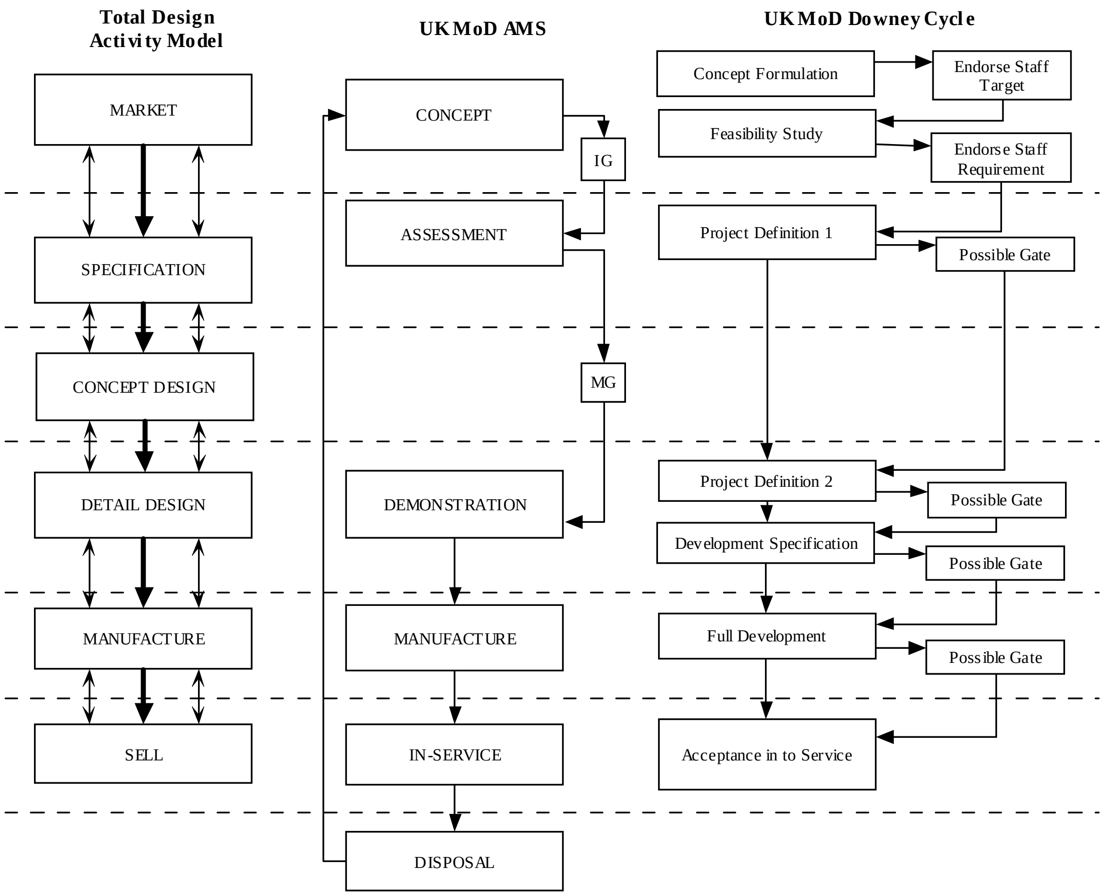

Figure 17. *The three development processes compared. Amalgamated from Figures 11, 12, and 13, showing the comparative equivalent stages in each process.*

The processes described above were called *generic processes* for the purposes of this study, since they were organisational and proscribed development activity in a broad manner. The differences between the generic processes were in how the initial need for a new product was articulated and when in the process the product solution became clear.

Different descriptions of design process in other areas of design

Design over the past hundred years or so has become increasingly professionalised, with an increased separation between those who design and those who make (Lawson 1980). MLCE development appeared to lack any clear distinction between those who design and make; the roles sometimes being undertaken by the same person. Those involved in MLCE development were regarded as professionals since they were paid to competently develop MLCE[7]. Additionally there were no professional groups for MLCE design as there were for architecture or engineering design. MLCE designers appeared to have most in common with industrial and garment designers in terms of thier approach to design and materials used.

Indutrial design processes

Industrial design, like MLCE development, seemed to have an interest in refining human interaction with products using a variety of materials and manufacturing technologies. Industrial design was defined as: a process that (separated from the means of production) synthesised contributory and conflicting factors into a three-dimensional concept capable of being reproduced by mechanical means (Heskett 1987). Industrial Design was further defined by Ulrich and Eppinger 2004 as a profession of design which concentrated on the form and user interaction of products. Ulrich and Eppinger (2004) noted that industrial design processes are adaptable and described them broadly in the following stages:

1. Investigation of customer needs
2. Conceptualisation
3. Preliminary refinement
4. Further refinement and final concept solution
5. Control drawings
6. Coordination with engineering, manufacturing and vendors.

These stages should not be interpreted as occurring in a sequential manner since they have utility across the product development activity (Ulrich and Eppinger 2004). Cross (1995) also noted that product development was moving towards industrial design engineering, thus

[7] A professional person was defined as; someone engaged in an activity as a paid occupation rather than as an amateur, and had impressive competence in a particular activity. Source: Oxford English Dictionary.

this representation of industrial design may not be accurate. Ulrich and Eppinger's (2004) stages appeared to have validity since MLCE design was concerned with human interface with products. Industrial design, however, differs from MLCE design in its relative separation from manufacture. Although initially aesthetics was thought less of an issue in MLCE development; it may be a determinant in how soldiers judge MLCE's fitness for purpose. Aesthetics was very relevant in the context of Civilian Load Carriage Equipment (LCE), where appearance can be critical in appealing to buyers.

Garment development processes

Garment development had a great deal in common with MLCE development with respect to its' closeness to materials and manufacturing technologies. Garment design processes were also broad but followed in a sequential sequence (McKelevey and Munslow 2003):

1. Design brief
2. Research
3. Design development
4. Prototype
5. Solution

Garment design is principally concerned with using textiles to form a three-dimensional product (a garment) which is intimate with the wearer (McKelevey and Munslow 2003), as was MLCE. Design practices used in garment design are similar to MLCE development in that they begin with a 2-D representation of the design, which is then translated into a pattern which is used to manufacture a prototype (Cooklin et al. 2006). MLCE products, like garments, were predominantly textile based, although they generally utilize more plastic mouldings and materials. Other design areas, within garment design, which have relevance to MLCE design were knitwear and bra design. Knitwear design uses specialist techniques in manufacture (Eckert et al 2000) and bra design is focused on the design of specific close-fitting garments (Hardaker and Fozzard 1997). They both share a similar element to MLCE in that they provide a 'structure' to a textile product. To show the similarities between MLCE and knitwear design process a realistic MLCE design flowchart was developed using the knitwear design process as a base (see Figure 18).

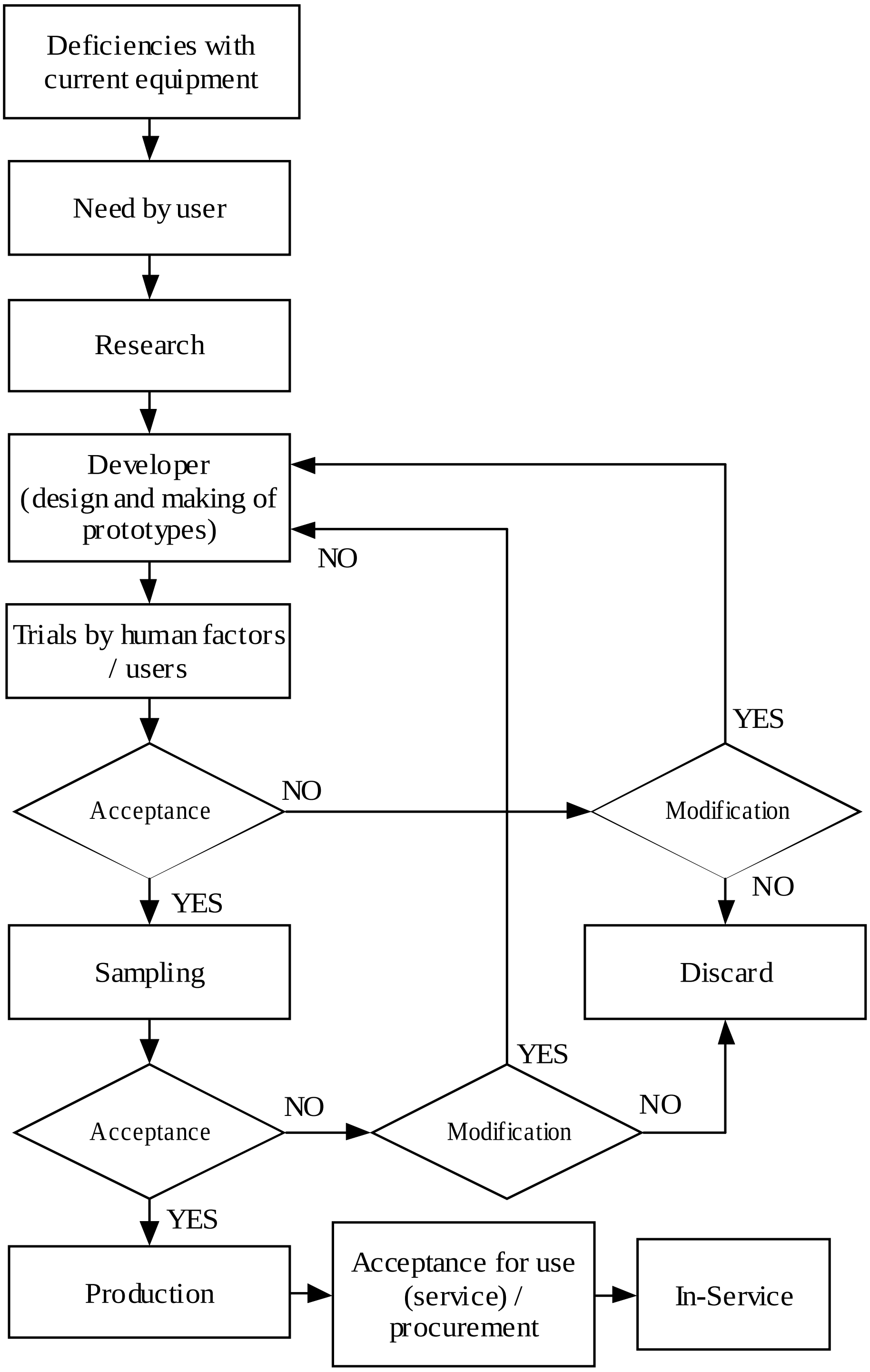

Figure 18. *MLCE design process adapted from Eckert et al. (2000) model of the knitwear design process.*

From Figure 18 it was clear that within the practice of MLCE and knitwear design there was high demand for feedback and iteration in design development. This differs from the stages of garment design that showed a separation of design development and prototyping. While this was perhaps a simplistic comparison and may not represent what actually happens, it was clear from looking at knitwear design processes (Eckert et al. 2000) that there may be significant interaction and dependence between stages in MLCE development. Hardaker and Fozzard (1997) also reported that there was significant feedback in bra design processes. Discussions with a civilian LCE firm also confirmed that they used a similar process, although they had considerably shorter timescales, market-based needs and use context.

This made the descriptions of MLCE, bra and knitwear design processes difficult to fit within the descriptions of generic or professional design processes. This was not to suggest they were not professional design processes, but they describe design activity in more detail than was expressed within generic and professional descriptions. Therefore, the design processes described within MLCE, knitwear and bra design processes, for the purposes of this study, were described as *specialised* design processes. This description was coherent with Heskett's (1987) description of industries such as textiles, book-making and cabinet-making reproduction of prototype models by craft methods, as was MLCE.

Figure 19 shows summaries of the design process discussed, within the three descriptions of design processes used for this enquiry.

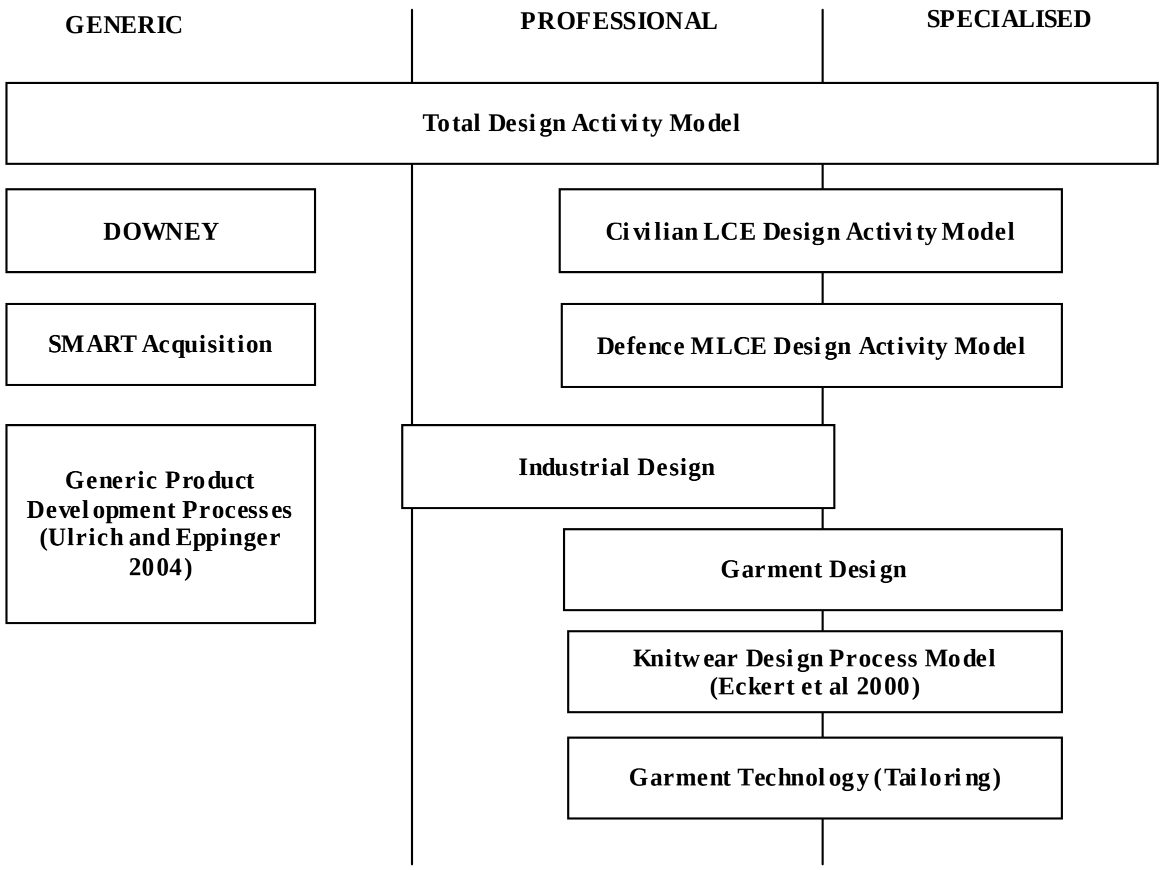

Figure 19. *A representation of design and development models in the context of generic, professional and specialised descriptions of design processes.*

From Figure 19 MLCE design was likely to be described as a specialised design process (the Defence MLCE Design Activity Model in Figure 18). This needed to be confirmed by further enquiry. If MLCE development did need improvement then understanding the design process was important if designers were to be supported in producing successful products (Eckert et al. 2000).

The performance product development processes

Development process performance included product performance and financial performance, as well as the output of effective products (Oliver et al. 2004). No evidence was found of this sort of performance data either within open literature or internal UK MoD records. The focus of this research was to address MLCE with respect to effective outputs from the process, rather than the efficient performance of the process. Since these aspects were linked, however, it was thought likely that some information on this subject would be needed to inform the enquiry.

3.4 Contextual influences on the process of MLCE development

This section discusses the influence of organisation, individual and team expertise on producing successful MLCE. The human science influences on MLCE design are discussed in section 3.4.

Defence organisation approaches to MLCE development

Defence organisations evolve MLCE and develop the next design from the previous one (Harding 2004). Martin (2002) was critical of MLCE design approaches and concluded that they were unscientifically designed and too reliant on small iterative changes to problems, which were only identified after large and expensive trials. This was an accusation which could only be confirmed by examining cases of MLCE development.

Risk of product failure – differences between civilian and military arenas

The risk to the user from product failure was an important factor in the product design of outdoor equipment (Ainslie et al. 2001) like MLCE. Most civilian users were able to manage the risk to themselves by a number of safety measures, for example seeking shelter in inclement weather. Soldiers may not be able to use the same safety measures and so must not have equipment fail during operations. MLCE failure may prevent soldiers from carrying the necessary equipment to sustain them in hostile conditions. An interesting area that has not been addressed within the literature to date was how users judge risk in the context of MLCE (Verral 2006).

Future MLCE development processes

In the future it was likely that defence organisations will source MLCE from civilian manufacturers. This could be simply the purchase of Commercial-Off-The-Shelf (COTS) MLCE, Modified-Off-The-Shelf (MOTS), or bespoke MLCE from civilian contractors. MacLeod and Lane (2001) highlight some of the problems of using COTS in a UK context, which in their opinion stemmed from a lack of planning and understanding of the usability issues with COTS. Whether this was the case with MLCE was uncertain, but a realistic possibility.

Functionality versus expectation – the market place

All users have expectations of equipment and products that it will; function well and that it will enable the user to undertake the desired task for which the equipment was designed (Norman 1988). The designer needs a good understanding of user expectations at the beginning of a design project in order to achieve a successful design. User expectations are often expressed in terms of the market in which the product exists. A *market*, in the civilian and arguably military context, was a set of actual and potential buyers of a product, buyers being analogous to customers or users and procurers (Kotler and Armstrong 1996). Defining a market was important in discussing military and civilian expectations for MLCE, since the market and marketing may have an effect on MLCE development.

The civilian outdoor market

Meeting the UK outdoor market's needs, of which commercially available (COTS) MLCE was a part, was an assemblage of small specialist companies, who had grown to prominence after the growth interest in the outdoors during the 1960s and 1970s (Parsons and Rose 2003). Parsons and Rose (2003) note that in the case of Karrimor, a prominent UK civilian manufacturer, that the market was a strong driver for designers. The skill to identify growing markets, an appreciation of market conditions and the flexibility was a critical element to Karrimor's success (Parsons and Rose 2003).

It was also important to note the differences between products for the outdoor market and military equipment. Within the civilian market load carrying equipment (LCE) was designed to be retailed and bought by individuals. Within the military arena in-service MLCE was designed to be bought by defence organisations, although some were privately purchased by soldiers (Shepherd et al. 2003 and Human Systems Group 2007). Soldiers actively exercise consumer choice by purchasing equipment if; i) they are not issued with something they want, ii) perceive that the issued equipment is deficient for the tasks they are trying to do, iii) or because of fashion.

Product life cycle

Another aspect which affects the development processes in civilian and defence organisations, is MLCE product life. Civilian manufacturers follow the demands of the civilian user and currently many users only need the products to last a relatively short time compared with a soldier's needs (3 years versus 10 years). This has an impact on the consequence of failure of the product.

Darlington and Culley's (2004) explanation of real customers, that is the end user, and 'virtual' customers, imagined or perceived customers who represent a class of users that might be satisfied by a product, was useful when thinking about customers of MLCE. It may be the case that military expectations were determined for a 'virtual' customer rather than the end user. In the military context expectations were often managed by using 'User Requirements' (see Figure 15). Having a good understanding of user requirements, however, was typically not handled well by large organisations, according to Pugh (1991), Holt (1989) and Busby (1998). Indeed, Holt (1989) paints a varying picture of user consultation across industry in Europe and the lack, in many organisations, of systematic gathering of user problems and needs. Handling user requirements, from private soldier to general officer, in defence organisations was affected to some extent by the hierarchical and social structure of the organisation (McKenna 2000, Kirke 2003, 2004a). Military culture and society may also lead to under-reporting of problems with personal equipment due to the social and organisational context (Shepherd et al. 2003), as can happen in the civilian context (Weyman and Boocock 2001). How user requirements (and expectations) were dealt with in MLCE development was open to debate, especially within the military community. Edmonds and Lawson (2001), however, have demonstrated that understanding user requirements was essential in developing appropriate equipment for carrying Police equipment. If user requirements do not reflect user expectations and allow functional needs to be adequately linked to expectation, then the resultant products may not meet user expectations and satisfaction (Gause and Weinberg 1989, Rouse 1991). Inclusion of this type of information was essential to translating user needs into a good product and gaining user acceptance.

Communication during design

Good communication was beneficial to design, allowing designers and other specialists to understand one another more effectively and efficiently (Lorenz 1990). Communication is a dynamic process, where one person affects the cognition of another (Chiu 2002) and can be difficult to achieve effectively. In design collaboration Chiu (2002) shows that communication problems manifest themselves in four ways: i) in the method of transmitting information, ii) in corruption or misinterpretation of the original information, iii) in their influence upon behaviour due to the relative importance of information, iv) by reaching the right people in an organisational hierarchy. Busby (1998) notes that these problems affect design tasks in organisations, that they are due to social interactions as much as individual cognitions and that they revolve around good handling of the feedback of information. Motivation for solving these feedback problems, Busby (1998) argues, is also problematic since feedback about safety and design goals is negative, intermittent, complex and only compelling after a major failure. While this may not be the case in all cases of feedback, these points may be relevant to the design of MLCE in defence organisations. Sonnenwald (1996) suggests that adopting guidelines during design projects may be one way to handle communication between team members. However, would this reduce or affect creative design? Russell et al. (1999) suggest that there were a number of factors involved, including how skilled designers are at using guidelines so that the guidelines do not impinge on their creativity.

MLCE development by teams

In the researcher's experience MLCE development was rarely an individual activity, but was one where many people were involved in a team including: clients, users, designers, human factor specialists and industrial partners. Working in teams on design problems is a complex activity. Petre (2004) noted that, in a survey of 12 engineering consultancies, successful teams embraced multi-disciplinary approaches and different ideas, technologies and perspectives to aid them in providing innovation. Key to these teams' successes was the active reflection they engaged with to improve practice and escape familiar thinking on problems. The researcher would agree with Brereton et al. (1996), Cross and Clayburn Cross (1996) and Radcliffe (1996) that social interaction within the team is important. McDonagh and Denton (2004) also highlight the different communication channels preferred by different professionals who interact with designers, who are 'imagers' rather than 'verbalisers'. This again is a phenomenon that the researcher recognises from working with different professionals on MLCE projects, where designers must try to communicate with professionals who often seemed to prefer written or verbal forms of communication to images or drawings. The process of design is also an important factor in enabling teams to work well, and was one that the team used to focus and prioritise activity (Stempfle and Badke-Schaub 2002). The researcher's own experience of this was limited since formalised design processes, either prescriptive or descriptive (see Section 2.4) are not used. Team activity is heavily reliant on the developers' knowledge of MLCE design.

Knowledge in the design of MLCE

MLCE knowledge is the facts, experiences and information known by a designer or those involved in design, which has relevance to MLCE development. Knowledge can only be embodied in a human being's understanding of the design domain (Friedman 2002). This was explained by Drucker (1999), and Davenport and Prusank (2000), who note the importance to industry of innovation and the importance of people creating knowledge by using information and learning by experience. This definition is consistent with the description of design activity described in Section 3.2 under *Describing design activity*, summarised in Table 3.

Item	**'Simon'**	**'Schön'**
MLCE domain (design) knowledge	= knowledge of MLCE design procedures and 'scientific' laws	= artistry of MLCE design: when to apply which procedure / piece of knowledge of MLCE development

Table 3. *The rational problem solving paradigm and the reflection in action paradigm summarised from Dorst and Dijkhuis (1996). Adapted from Table 2 in section 3.2.*

Table 3 illustrates that MLCE design may require knowledge of the procedures and information needed to conduct successful development, but also an appreciation of when to apply that knowledge. In the UK knowledge of MLCE (and an awareness of when to apply that knowledge) is resident in government designers which can also be the case within industry (Bertola and Teixeira 2002). The challenge was to harness this knowledge within the complex interactions of a design team formed between organisations. This was more pressing in the UK with the loss of MLCE expertise knowledge that occurred with the closure of the UK MoD clothing and textiles development research and development unit (Defence Clothing Research and Project Support (DC RPS)) in 2006.

Gaining knowledge

It is likely, in the future, that defence organisations will be reliant on industry for MLCE design. It was therefore appropriate to look at how civilian firms gain design knowledge. Parsons and Rose (2003) note that when producing a new civilian load carriage system for the market, designers are dependent on networking with others to gain knowledge as well as aid design activity. In the civilian arena, for example, Rose et al. (2007) report that the design of civilian LCE is thought to be reliant on individuals tacit knowledge of manufacturing processes learned through communities of practice. This may be the case with MLCE development.

With regard to gaining knowledge of how MLCE is used, there were thought to be differences between civilian and defence arenas. In the defence arena, a civilian, without military experience, works with military personnel in developing MLCE, paralleling the civilian LCE networking approach. Designers at Karrimor (a civilian firm) also actively participate in the activities of the end user (Parsons and Rose 2003, Rose et al. 2006) to gain knowledge of user activities. The same cannot be said of those civilians within defence organisations, however, due to health and safety issues. In the researcher's experience military users have limited confidence in equipment designed without heavy military involvement. Whether personal involvement in military activities is essential for MLCE designers was uncertain, as is whether this would enable knowledge of MLCE design. It is unlikely that providing information, rather than being involved with military activities, will help novice MLCE designers; they also needed support in identifying what they needed to know, as has been found in the civilian arena (Ahmed and Wallace 2004).

Design expertise in the context of MLCE

One way of obtaining a good solution to a design problem is to use experienced designers. However, a designer may only be experienced in one area of design and may not be empathetic towards other design areas; so, what is an experienced designer? The definition of expertise used by Popovic (2004) from Chi et al. (1982) is 'the possession of a large body of knowledge and procedural skills'. This is however, a limited definition of expertise since it does not embrace the determined practice and application needed to perform as an expert (Cross 2004). It has also been noted by Ho (2000) that experienced designers have quicker cognitive processes than novices and will reduce the number of concurrent actions being processed. While this may mean an expert is more efficient, Kavakli and Gero (2002) suggest that this may provide a reason for why novices are successful in creating novelty and innovation. This implies that one needs expert and novice designers within a design team. Ball et al. (2004) have noted that expert designers will often use a similar approach to novices when they find problems that are unfamiliar or resistant to the use of 'schema-based' approaches, upon which experienced designers often rely. Schema-based approaches rely upon the designer knowing how to solve a design problem using a known solution approach; these are more likely to be known by those experienced in design. The findings above were consistent with Cross and Clayburn Cross (1998), who argue that a distinction is needed between designers who are expert designers within a defined field, and those who have expertise in creative problem solving.

Expertise in defined design domains

Gunther and Ehrlenspiel (1998, 1999) have demonstrated that experienced designers have an advantage in well-defined problem domains. MLCE was regarded as a defined problem domain and so would benefit from expert designers within the design team. What was known about the domain of MLCE, however, was limited in the literature, partially due to the low numbers of employed MLCE designers and specific studies to ascertain expertise levels. This was interesting to note, since future MLCE development will be reliant on small numbers of designers, some of whom may not have much knowledge and experience of the domain.

Learning in the design process

Another aspect that was linked to the practice of team in MLCE design was the role of professional reflection and learning to improve the process of development. Popovic (2004) has begun to describe how designers build their knowledge, which may be relevant to building expertise in the context of MLCE. This was especially found in the case of intermediate designers who acquired knowledge and strategies as they progress through the design process. Design learning is concerned with the development of designers' knowledge and understanding, in order to produce successful design solutions (Archer and Roberts 1992). The way in which designers learn is affected by a number of different factors, which may be linked to their style of designing (Durling et al. 1996).

Designers prefer a teaching style that, according to Durling et al. (1996):

- Starts with the wider context and then explains detail
- Focuses on future possibilities and alternative view points
- Has a 'lightweight' structure allowing for guided exploration
- Often shows objective data, is logical and analytical, with examples (although about a third prefer subjectivity, a person-centred approach using value judgements)

By comparison, non-designers prefer teaching that begins with details and facts, and then explores wider issues, proceeding step by step. This was supported by Adams et al. (2003) who note that designers who engage in discussing wider design issues and the problem situation were generally more successful. This may have an influence on how MLCE designers work with others in the design team, and indeed how knowledge of MLCE design was improved. This distinction has been characterised by Cross's (1982) a 'designerly way of knowing', and illustrates designers' need for experiential learning (Lawson 2004). Lawson (2004) has also added to this by arguing that there are five stages to gaining design expertise:

1. Acquisition of design domain schemata (plans)
2. Development of a pool of precedent
3. Identification of guiding principles
4. Identification of situations with minimal analysis (e.g. quickly ascertaining how any given situation may affect design)
5. Building of design gambits or 'tricks' for use with design domain schemata

Of the five stages, precedent has not been discussed so far in this review. Lawson (2004) explains precedent as knowledge that enables the designer to affirm suitable design schemata of what works within the domain. These stages do fit well with Ho (2000), Popovic (2004), Cross and Cross (1998), Petre (2004), Cross (2004) Ball et al. (2004) and Petre et al.s' (2006) descriptions of design activity. Whether these stages applied to MLCE was not clear from the literature; the researcher, however, as the enquiry matured (subjectively) recognised his own knowledge growing through Lawson's five stages.

Innovation

Innovation was important in the context of commercial LCE manufacturing to produce different and marketable products. Innovation was difficult to define in the context of design, some indeed regard innovation as a separate area to design which involves insight, ideas and impact (Haywood 2003). Creativity was a related concept which was also a driving force in new product development and problem solving. Designers have varying approaches in how they use creativity in design work but often begin by a period of exploration followed by 'problem framing' (Dorst and Cross 2001). This enables the designer to identify a number of 'surprises' which interest them and enable them to reframe the problem and drive innovative aspects to the design project. From a design perspective this approach is central to enabling people to visualise innovation (Hoenle 2003). This approach is not confrontational, but complimentary in that innovation is a broader phenomenon with design playing a beneficial and central role. This view is supported by King (2003) who argues that in this context, design could be perceived in different ways, one of which is realisation of ideas into artefacts. In MLCE development this is an important distinction since MLCE design had been concerned the realisation of evolutionary ideas, rather than to stimulate creative ways to improve MLCE.

3.5 Human factor aspects of MLCE development

As outlined in Chapter 2, MLCE development was thought to be highly influenced by human factors[8] since bearing load has such an impact on human performance.

Perspectives on balancing influences in MLCE design

Balancing influences in MLCE development was dependent on the design problem situation, and deciding what balance was appropriate. Elliot et al. (1999), in a study of how companies communicate about different influences, note that those influences which were soft, intangible and difficult to specify were given lower customer priority, for example human factors. There was a lot of human systems information available on MLCE, but limited evidence as to how well it was used or represented in MLCE development.

Human systems in MLCE development

Human systems focus on human interaction with products has been credited with playing a role in ensuring better performance in military equipment design (Sanders and McCormick 1992, Archer 1999, Noyes 2001). An understanding of human systems, therefore, was of high importance when studying the interaction of the human with MLCE. The use of human systems helps to provide safe, efficient and comfortable products under normal or predictable conditions of use or misuse. The MLCE human machine interface (HMI) can be characterised as a manual system within Sanders and McCormick's (1992) three system

[8] Human factors and ergonomics were synonymous terms, therefore, within the context of this thesis both terms will be referred to as *human systems*. They both primarily look at the measurement and collection of data concerning the body's structure, system, function and behaviour in a given situation (Roebuck 1995). They also have strong methodological and academic links to anatomy, physiology, biomechanics, psychology and engineering practice.

classes, in that users of MLCE use their own physical energy as the power source for the system. Figure 20 shows how the MLCE human machine system can be represented.

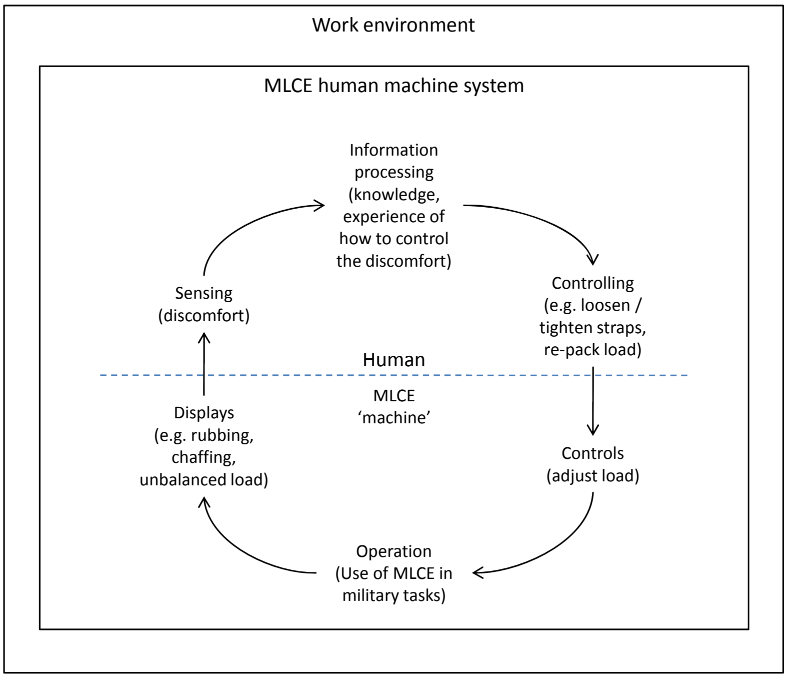

Figure 20. *The MLCE human machine system.*

From Figure 20 one can see that MLCE, in order to function well, has a number of dependencies between how the user decides when and how to adjust the MLCE 'machine'. The primary feedback mechanism (Sensing) to stimulate the user into making an adjustment (Controlling) was the discomfort caused by the MLCE (Displays[9]). User knowledge was also important in controlling the MLCE 'machine' since knowing how to adjust MLCE, for a novice user, can be a challenge. User experience was also important since experienced users will often sense minor discomforts early, so adjust the load to prevent greater discomforts later. How MLCE developers design the 'machine' was ambiguous at this stage in the research, but from the researcher's experience focuses on Controls and Operation stages in Figure 20, in order to affect Displays. How well MLCE development succeed in optomising MLCE to these aspects was in doubt, and a contributing factor to why the research was initated.

Haisman (1988) and Wheatley (2004) provide good starting points by listing the affect of MLCE on soldier performance from a human systems perspective, although the interaction

[9] Display is used in the sense of making a problem with MLCE noticeable to the user, rather than seeing the problem through a computer display. Source: Collins English Dictionary and Thesaurus (2006), HarperCollins Publishers.

between the factors was hard to determine. Figure 21 shows the human systems influences on personal load carriage adapted from Haisman (1988) (this perspective was strongly physiological).

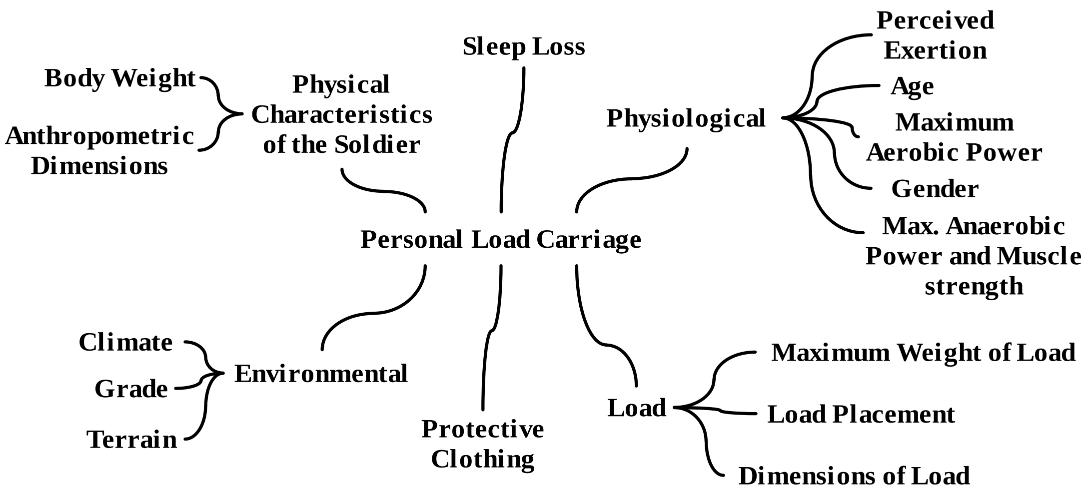

Figure 21. *Influences on Personal Load Carriage diagram adapted from Haisman (1988).*

Human systems within MLCE design

Kolnicker and Tolcott (1962) offer the most practical information for the designer, describing design factors or characteristics identified during the course of a number of studies, including work by Hunter and Turl (1952). The factors identified were good general guides for MLCE designers, but lack the detail to enable design. To investigate the use of human systems data in MLCE design a number of key texts were reviewed at the outset of the enquiry (see Appendix A). These revealed that human systems expertise was often used to understand single instances associated with the user / product interaction. This was also confirmed by later reviews (Vicary and Wood 2005, and Humm et al. 2007). Some areas were better provided with information than others. For example Hooper and Jones (2003) and Martin (2002) had successfully addressed interface design issues associated with pressure on the shoulders, which were linked with Rucksack Palsy (or brachial plexus syndrome; an injury associated with high loads, where the shoulder straps cause a traction injury of the nerve roots).

To explore how human factors were integrated into MLCE design, and to enable the researcher to begin to develop an awareness of research approaches, a short workshop was arranged to develop a human systems view of MLCE development (see Appendix B). The workshop (Study 1) was held with four human systems researchers undertaking MLCE research. The final view from the workshop is shown in Figure 22.

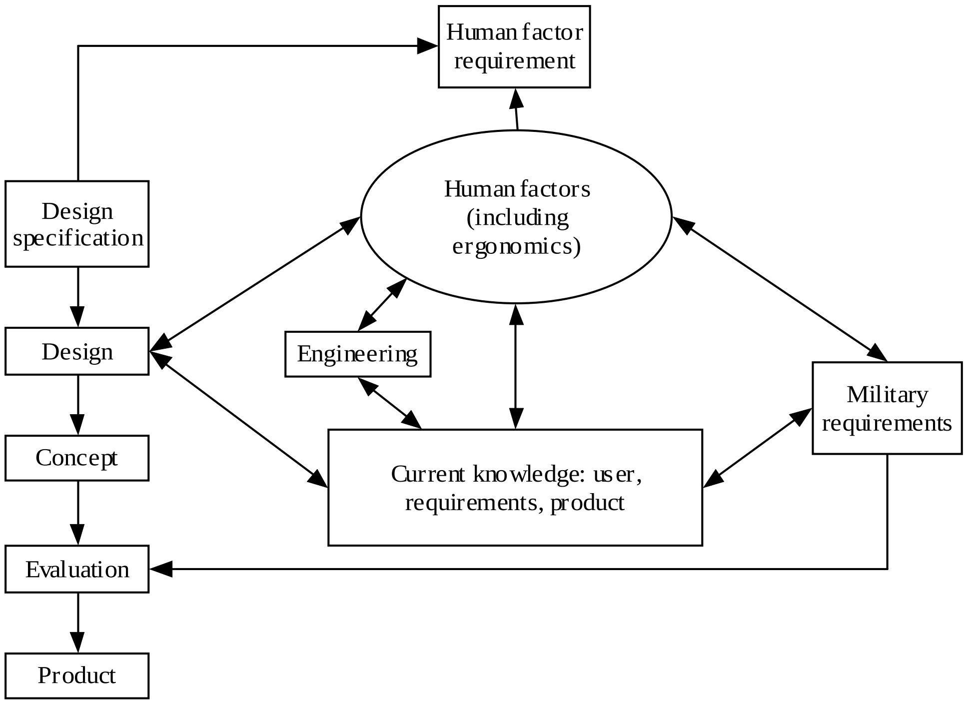

Figure 22. *MLCE human system researchers' view of MLCE development processes.*

The view had strong biases towards the role of human systems in MLCE development and did not seem to compare adequately with engineering representations of design (such as Otto and Wood (2001), Roozenburg and Ekels (1991), Pugh (1991), and Ulrich and Eppinger (2004)). There were also doubts about whether this was how human systems influenced MLCE development from the researcher's experience and the best-documented example of the role of human systems in MLCE development from Stevenson et al. (2004a), where the role was positive largely concerned with the evaluation of the outputs from the design activity. Figure 22 does, however, show how the other aspects may need to feed into design to produce a manufactured artefact, via human systems. In MLCE development all the elements in the diagram have a role in determining the performance characteristics of MLCE, represented by the 'Design specification' stage. Additionally, not all MLCE characteristics could be necessarily be represented in human systems terms given extant knowledge; particularly material characteristics related to suspension and stability. Human systems may help define the performance characteristics of MLCE before any explicit design activity, but it may not have a significant role during the design activity stages. After Study 1 the role of human systems in MLCE development remained awkward.

Limitations in human systems information for MLCE design

From the researcher's experience, MLCE designers were often interested in how altering one part of a design concept affects other parts of the design, and how this affects the user interface. Human systems were important in providing the designer with this casual information. An example is shown in Figure 23.

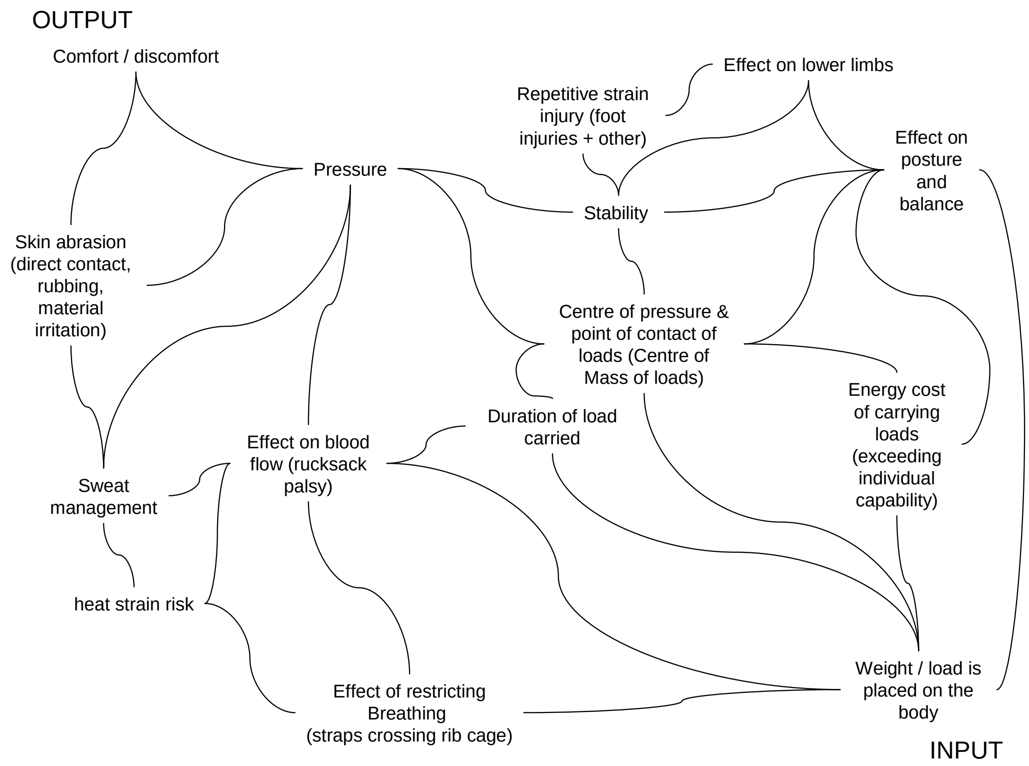

Figure 23. *Diagram showing simplistic linkages between putting load onto a human with the resultant influence on comfort and discomfort.*

Figure 23 shows how putting a load onto a user produces a number of related and integrated human factors aspects which then dictate user perceived comfort. Each aspect is variable depending on the user and the type of MLCE used. Some MLCEs for example, were very good at mitigating pressure for one user but might be very poor at allowing another user to carry the load in a balanced and stable manner.

The literature in this area was often not presented in an integrated manner, thus giving limited insights. Knapik et al. (2004) have presented the most integrated texts which were relevant to MLCE design. These texts detail most of the physiological, biomechanical and medical influences on MLCE, but lacked information on comfort and other human systems aspects which could be used in design. Harker and Eason (1984) suggest several barriers to embracing human systems within design, these were; i) insufficient human systems information, ii) insufficient human systems techniques, iii) an inadequate systems design philosophy or approach. Which of these were present in MLCE was not clear from the literature.

Stevenson et al. (2004) argue that physiological, biomechanical and perceptual approaches do not allow for a good understanding when undertaking MLCE design changes. They have developed an objective biomechanical approach, which during a recent iterative development has been successful in determining performance criteria and quantitative data useful to design. What was not clear from Stevenson et al. (2004), however, is how designers used the biomechanical, user information and trials information in the iterations of development. After the review it was still difficult to determine what influence one piece of human systems information had as opposed to another during MLCE design activity.

Gender aspects of MLCE Design

An important aspect in integrated human factors in MLCE was the gender of users; this is an area where there is been concern with the provision MLCE for female (Neely 1998, Gemmell 2002, Llewellyn 2002, Lewis and Dando 2006, Humm et al. 2006). Currently, within the UK MoD, female users use the standard 90 Pattern Personal Load Carriage Equipment (PLCE). However, within the civilian market and Canadian Defence Forces, LCE was available that has been designed with different hip and shoulder straps to suit female anatomy; around the pelvic girdle and shoulders.

Heavy loading and its affect on MLCE development

The impact of carrying heavy loads with MLCE, as discussed in Chapter 2, on the user can lead to temporary and chronic injury (Llewellyn 2002, Neely 1998, Knapik et al. 1996). Casual data on the prevalence of injury related to MLCE was unavailable however (Jones 2008). The soldier's load has increased over the past hundred years to around 70 – 80kg on current operations (see Appendix C). The degree to which MLCE can mitigate these high loads was thought to be limited. Jones and Hooper (2003) have shown that mitigating the impacts of load beyond the 40kg is difficult given current materials. Little information was found with regard to how military units dealt with manual handling regulations with respect to MLCE. Kroemer and Granjean (1997) quotes lifting data, adopted by the MoD in 1984, which gives a maximal (two-handed frontal) lift of 350N (35kg approximately).

Product quality related to user satisfaction

One human systems issue that the researcher had noticed in discussing equipment with soldiers was the perception that having good equipment enables them to undertake functional tasks. Taylor (1999) points out need for psychological effects to be considered as contributing to ‘functional’ constraints and user needs. Service personnel satisfaction with MLCE was an aspect of quality related not just to function, but also non-functional user satisfaction, for example appearance. The definition of quality used in this research was defined as being the product features that meet the needs of customers and provide satisfaction (Juran and Gryna 1988). Fox (1993) adds to this definition and applies it to the process and activities used to get the product to manufacture. Quality, therefore, not only affects manufacturing, but also has an impact on the user of the MLCE, since poorly designed equipment detrimentally affects the user’s confidence in the MLCE.

Training in MLCE use

Many products fail primarily because the user cannot interpret how to use them, according to Norman (1988). It is wrong to assume that within a military environment soldiers are trained to use their MLCE. Indeed, deficiencies in training of military personnel with personal equipment have been highlighted in Shepherd et al. (2003) with regard to breakages and poor Human Factors Engineering (HFE). Cooper (1993) lists three main reasons for new product failure from a broader perspective; i) poor market research, ii) technical problems and iii) bad timing. Whether these are reasons that can be applied to military MLCE was uncertain at the outset of the research.

User in the MLCE design

To what extent the end user, the soldier, was represented in MLCE development had not been found in the literature to date. From the researcher’s experience the end user was represented within the trialling of MLCE. If users are not well represented in design then it is important to understand the degree to which MLCE development met the tenets of better practice models for working with users in development. One well-known approach which may aid this situation, should it be appropriate, is User Centred Design (UCD) (Rubin 1994, Baber 2002 and Jordan 1998). A UCD approach includes user needs throughout the design process, to allow it to be built in to the system specification alongside other constraints and functional aspects (Stanton 1998). In order to achieve this, methods to capture user needs are required, as are techniques to evaluate any resultant concept (Rubin 1994).

Related to UCD was inclusive design, a design 'project' which looked to include people who were ignored or overlooked (Coleman 2006) in the use of mainstream products. Inclusive design was investigated because of its focus on designers understanding the user and preventing exclusion in product use (Keates et al. 2002 and Cassim et al. 2007). Whether or not MLCE development, in the UK or in other nations, was done in an inclusive or excluding manner was not know at this stage in the research, although some degree of exclusion was suspected by the researcher after seeing soldiers' frustration with some MLCE. An example of MLCE development, which involved users in development and appeared to be user-centred, was Stevenson et al. (2004a and 2004b), who put emphasis on objective evaluation, an important aspect of inclusive design (Coleman 2006).

Another concept that was pertinent to this aspect MLCE development was *usability*. Usability was defined as a function of personal interaction with a device rather than of being a feature of the device (Baber 2002 and Jordan 1998). Jordan (1998) lists some ways in which usability can aid design activity, which may be relevant to MLCE. Usability was an accepted concept in product design but remained difficult to apply in practice. BS EN ISO 13407: 1999 Human Centered design processes for interactive systems (British Standards 1999) appeared to be a good articulation of UCD. BS EN ISO 13407: 1999 also contains methods for UCD application during development processes, however, DD ISO/PAS 18152: 2003 (Ergonomics of human system interaction – Specification for the process assessment of human systems issues) (International Standards Office 2003) was more prescriptive. DD ISO/PAS 18152: 2003 recommended outcomes and practices (developed on from BS EN ISO 13407: 1999) that had a place in MLCE design activity since they were concerned with trading the extent to which usability was traded against other design criteria. The standard, however, falls short of providing guidance of an appropriate trade off for MLCE and so would have to be defined further on a case by case basis. And so before UCD can be adopted in the context of MLCE design, more information was needed to understand the information designers needed during design activity and how this may affect the design process.

Summary of influences

Figure 24 shows the influences on MLCE development, which the researcher has determined from the literature to date.

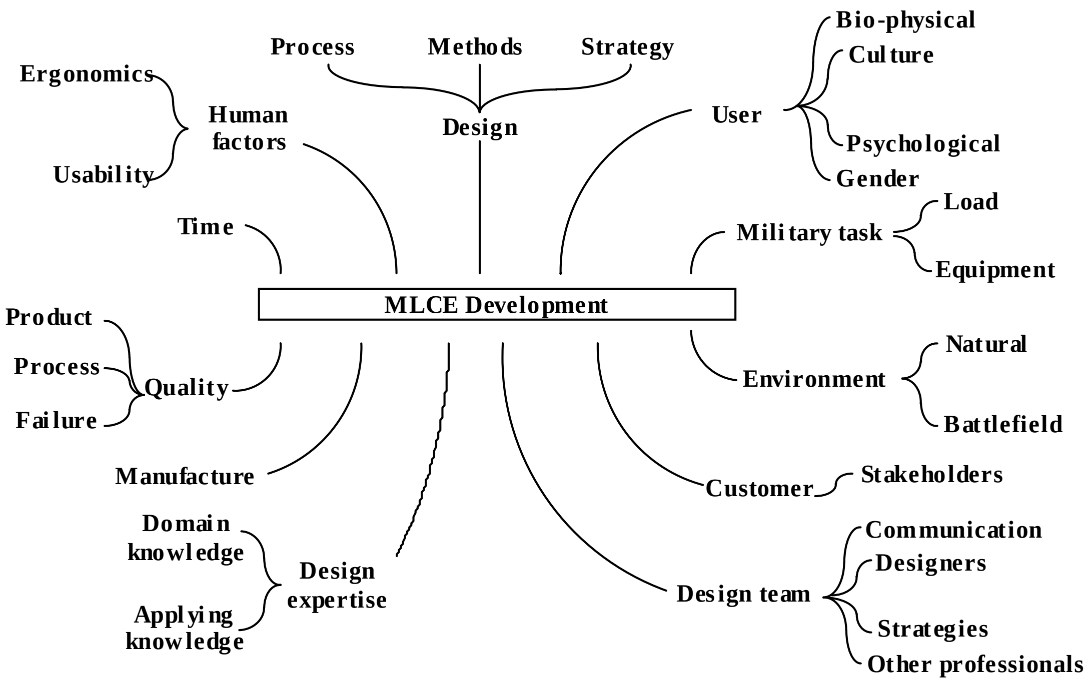

Figure 24. *Influences on MLCE development from the literature.*

Figure 24 could be regarded as an attempt towards a systematic description of the influences on MLCE development in the engineering design paradigm advocated by Simon (Visser 2006 and Cross 2007). The influences were useful in helping to explore the literature on various topics related to MLCE development, and illustrated the lack of specific information to build a more complex picture of the domain.

3.6 Design Methods in the context of MLCE

If MLCE development needed improving this was likely to be done through the development of a design method. This section outlines the researchers investigation of design methods in MLCE development.

The definition of design method, used in this research, is: any identifiable way of working including any procedures, techniques, aides or 'tools' within the context of designing (Cross 1995). Design methods are defined as tools used at specific points to support design activity, and therefore different to design processes (described in section 3.2). Roozenburg and Ekels (1991) define four characteristics for design methods: i) a specific way to proceed, ii) a reasoned procedure, iii) are able to be applied to other problems, iv) an observable use. They go on to add that design methods are not a guarantee of success and that they require knowledgeable application. Perhaps the most important stipulation that they make is that design methods are not *ad hoc* but a result of collective experience and insight. The implications are clear that before any specific tools or design process improvement could be sought, a reasoned case must be made.

Design process, design methods and design strategy

Design methods can be used within a design process to aid and support the transition through the various stages (Smyth 1998). They can also be used within a design strategy. Design strategies are the general plan of action for a design project and the sequence of activities which the designer or design team expect to use (Cross 1995). Design strategies are different from design processes however, which are descriptions or prescribed stages for design activity. Design strategies are to help manage the design process circumstances change during design activity. It was important to distinguish design processes from design strategies since the research may encounter cases where a strategy was used and design processes were not.

What design methods are used currently in MLCE development?

In order to answer this question a short review was undertaken of the tools used in MLCE development (see Appendix D). This showed that MLCE development was reliant on drawing and prototyping, with little use of information technology (IT) based design support. A possible explanation of this was that designers prefer tools which provide an immediate solution to a design issue they are looking at (Smyth 1998). A good example of this is the reticence of industry to use CAD systems, which were well used in the clothing industry, to manage MLCE patterns. This reticence could be due to the relatively high cost of buying and maintaining the specialist CAD systems for MLCE firms. MLCE, unlike clothing, often uses more engineered components for its back system (usually aluminium rods or injection-moulded plastics) which may also explain why designers prefer not to use clothing CAD systems, which do not deal well with engineered components.

User needs and design guidelines

While the tool review was not exhaustive there were examples from other areas which may have applicability. Tools that were alluded to under ‘user needs analyses’ are well known human system methods for understanding user needs. These are relatively well defined in the fields of interface design and assistive design which are orientated to the use of design guidelines (Poulson et al. 1996 and Bonner 2002). Guidelines varied widely from the unstructured and generic to emphatic guides which may not give the designer the context in which the advice sits (Russell et al. 1997). To date there is little in the manner of generic or emphatic design guidelines for MLCE. There is information which could form a guide such as Hunter and Turl (1952), Knapik (1994) and Jones (2005), but it is often contradictory and difficult to establish in a logical framework which one could then apply in design. Whether a guide was an appropriate improvement to the process of MLCE development remained to be proved.

User evaluation

The main tool used to date by developers to get advice and information about how users interact with MLCE, from the review, is user trialling. From the researcher’s discussions with designers from industry, MLCE development was very similar to product development in the outdoor and sportswear industry. Indeed soldiers’ perceptions and responses have been anecdotally similar to those of elite athletes (Harber 2007). The reliance on user trialling and testing is time consuming and costly given the iterations needed to undertake prototype development. In the outdoor industry, according to one well-established firm, trialling was kept to a minimum, only using highly experienced outdoors enthusiasts, ensuring products are well developed before they went on trial.

In summary

MLCE will always be a compromise between what is sound in human system terms and operationally necessity (Renbourn 1954 and Haisman 1988). The literature supports this statement, although it was important to improve our understanding during the enquiry, to enable the best compromise to be made. Evidence of the MLCE development was evident from the literature but often had to be inferred from other design areas, due to the lack of specific references to MLCE development in the literature. Overall, little has been written with regard to how MLCE was, or could be designed. These gaps in knowledge are summarised in Appendix E. Gaps in the literature were found where further clarification was needed in order to answer the research questions. How human systems qualities were represented in design requirements and how designers used human systems in design were also ambiguous. The review also concluded that not enough was known about user involvement in MLCE development.

3.7 Chapter conclusions

This chapter has presented the literature review undertaken to support this enquiry into MLCE development.

Revisiting the chapter's objectives:

1. Established what the design processes and methods may be used in MLCE development.
2. Identified gaps in knowledge which affect MLCE development.
3. Defined the context for MLCE development in military and civilian organisations.
4. Enabled an understanding of the performance of MLCE products.
5. Enabled an appreciation of parallel areas of design and development which could provide insights when exploring, evaluating and developing MLCE development.

Key points to take forward:

1. In order to progress the research a review of suitable research methods which could be used to answer the research questions.
2. The methodological review also needed to take into account the professional context of the research and opportunities available.

Chapter 4: Methodologies for exploring, evaluating and improving MLCE development

The literature review had explored the context of MLCE development; determining what was known about the field to begin research and highlighting large gaps in knowledge. With little known about the area, choice of which area to research was, in part, defined by limited resource and access to MLCE development activity. This chapter defines the possible research strategies and data collection methods given this starting position.

4.1 Chapter introduction, aims and objectives

The aim of this chapter was to consider research strategies and methods which could be used to answer the research questions[10]. Figure 25 shows this chapter's location in the research map.

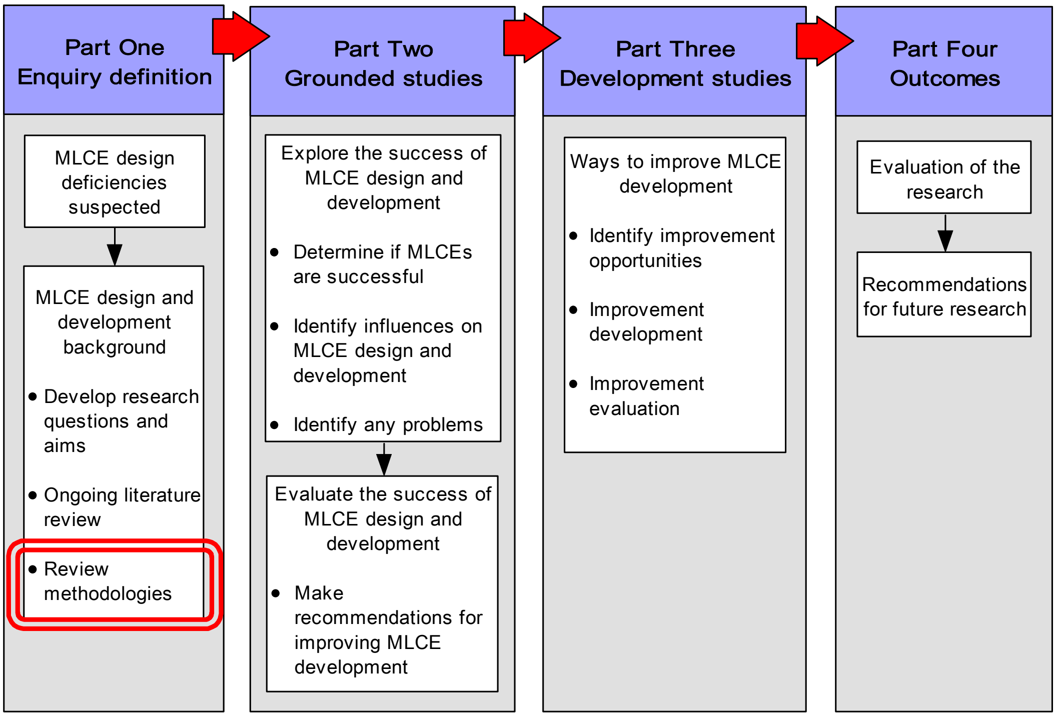

Figure 25. *Chapter 4 research map.*

[10] Research Questions:
RQ1. What are the influences involved in MLCE development?
RQ2. What needs improvement in MLCE development?
RQ3. How can we improve MLCE development?

Objectives:

1. Review and identify a suitable research strategy[11] to address the research questions.
2. Identify specific data collection methods[12] to be used in the overall research strategy.
3. Identify and acknowledge the limitations of the research strategy and methods.

4.2 Planning the research

To enable the enquiry to be rigorous[13] and 'fit-for-purpose' a review of generic research practices was undertaken. The purpose[14] and context of the enquiry determined methodology[15] selection and research design (Cohen et al. 2000). The review consisted of reading widely through a variety of references to gain sufficient understanding to enable an effective research design to be established (Bryman 2004). The findings from the review which influenced the research design are described in the following:

1. Theoretical background (section 4.2.1)
2. Context of the research (4.2.2)
3. Specific issues in planning the research (4.2.3)
4. Reviewed and selected methodologies (4.3)
5. Data collection methods and approaches (4.4)
6. Summary of chosen research strategy and methods (4.5)
7. Evaluation of the research (4.6)

[11] *Research strategy* may be defined as the general orientation or approach to the enquiry. Robson (1993) points out that a research strategy may be interpreted in many different ways, often as a simple description of the main methods being used so can be synonymous with 'methodology'. Bryman (2004) also uses 'qualitative' or 'quantitative research' as a descriptor for research strategies.
[12] *Methods* may be defined as the specific techniques or tools used to investigate a subject, in this case MLCE development (Robson 1993).
[13] Rigour was defined in this research as the correct optimum application of research methods (Newbury 1996).
[14] Robson (1993) classifies 'purpose of enquiry' in three categories: exploratory, descriptive and explanatory.
[15] *Methodology* was defined as being the system of data collection and analysis methods that were used as research tactics (methods of investigation) within a specific research discipline (Gray 2004).

4.2.1 Theoretical background

The theoretical hierarchy used to refine the research was epistemological[16] because it sought to determine what knowledge was legitimate and adequate in MLCE development. Epistemology provides a philosophical framework to underpin theoretical perspectives of the different research methodologies applied in different research disciplines (Bryman 2004). Figure 26 shows the generic theoretical framework that will be used for this research. It shows the hierarchical relationships between epistemology, theoretical perspectives, methodologies, and data collection methods.

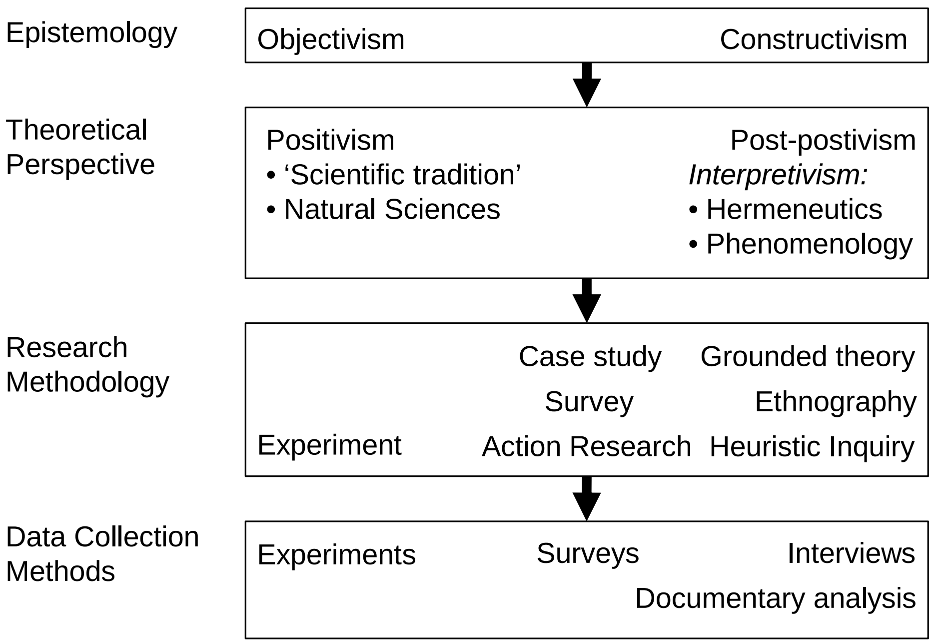

Figure 26. *Generic theoretical framework (adapted from Gray 2004).*

Theoretical perspectives and research methodologies will be discussed in section 4.3 and data collection methods in section 4.4. It was important to understand the links within the framework for the research strategy and methods to be systematically applied in an organised manner; to establish why and how a phenomenon occurs (Sekaran 1992 in Gray 2004 and Robson 1993). Selection of these methods, their use and coherency with the theoretical framework, are likely to be affected by the context of the enquiry.

4.2.2 Context of the research

[16] *Epistemology* is the philosophical discipline which tries to understand knowledge (Gray 2004).

The most immediate contextual characteristic for the research was MLCE development's place within the defence arena (see Chapters 1 and 2), which brought issues related to national security and commercial confidentiality. The defence arena also brought interaction with UK military organisations, who have considerable influence on the research done to support them. The context of the research is described as follows:

1. The purpose of the enquiry
2. Researcher experience
3. Access to data in a professional environment
4. Theoretical context of the research

The purpose of the enquiry

From the literature reviewed to date (see Chapter 3), it was clear that there had been limited exploration of the MLCE design domain from a design studies perspective. The research, therefore, needed to address all three purposes of enquiry: exploration, description and explanation (Robson 1993). The research was intended to find out what was happening, currently and historically, in MLCE development by seeking insights, describing and assessing the phenomena for the first time. An expected *sequence of enquiry* was developed to help understand how this could be achieved practically and to confirm the purpose of the research (Figure 27).

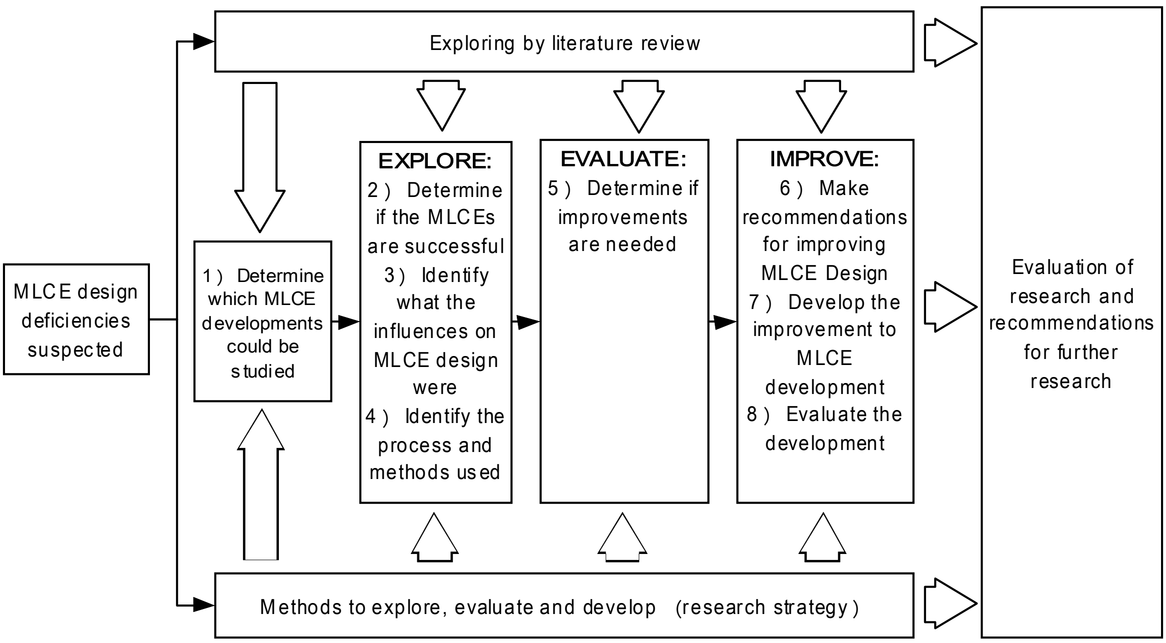

Figure 27. *Diagram showing the expected sequence of enquiry for the research adapted from Figure 10.*

Detailed objectives were developed from the sequence of enquiry and the main objectives listed in Chapter 2:

1. To investigate issues with military load carriage equipment in order to:
    a. Identify existing load carriage systems.
    b. Define what makes successful load carriage systems.
    c. Evaluate their success or otherwise.
    d. Understand the process by which they were designed.
    e. Define available processes that may be applicable to MLCE development.
    f. Evaluate the process and methods used which resulted in successful design.
    g. Identify what is likely to lead to successful MLCE.
2. To determine whether MLCE followed generic or specialised design processes (as defined in Chapter 3).
3. To find out if any improvements are needed and where they could fit into current design processes used in the military environment.
4. To identify and develop suitable improvements (e.g. design tools) to the development of MLCE.
5. To evaluate the improvements' strengths and weaknesses.

From the detailed objectives one can see a strong need for exploratory methods to describe MLCE design in reality (points 1, 2, 3 and 4). There was also a requirement for good comparative methods (points 1, 4, and 5).

Researcher expertise

An issue was the researcher's initial lack of experience in the majority of research techniques considered. Robson (1993) has argued that researchers who lack a background in research can successfully apply scientific techniques, and indeed may have specific knowledge and skills that suit the area they were studying. From this perspective the researcher was familiar with the defence arena and the military. The cautions that Robson (1993) gives, such as the need to learn during the enquiry, and a lack of familiarity with the theoretical models used in qualitative research, were factors in this enquiry. The researcher addressed these by seeking advice from others, as recommended by Robson, and by ensuring that preparation was thorough. If experience was a limitation then it was declared, and its impact determined.

Practice runs, with iterative reflection and methodology development, were used as standard practice to address experience issues.

Access to data in a professional environment

One of the constraints in formulating the research strategy was determining research methods which could flexibly access data (people and documents). Since there were no MLCE development projects underway at the outset of the research; early research phases were reliant on documentary sources and reactive to opportunities that arose for data collection. This was in part due to the lack of documented studies about MLCE development or design, knowledge of the MLCE design domain being vested in people (Friedman 2002). This was perhaps a characteristic of the private nature of design practice, in which designers to not tend to write about what they do or how they apply their knowledge. Access to documents and people was determined by the professional relationships that the researcher made. This was helped by the researcher's job as a civil servant, which provided contacts in the various organisations involved in MLCE development, including the military.

Ethics

Since this research was conducted in a social context it was important to base research on sound ethical principals. Ethics refers to the conduct of research according to a set of codes that ensure participants rights to privacy, dignity and safety (Robson 1993). Bryman (2004) outlines four ethical areas, which were used to inform the ethical conduct of each study:

1. Whether there is harm to participants
2. Whether there is a lack of informed consent
3. Whether there is an invasion of privacy
4. Whether deception is involved

In addition to the above, University Ethical Advisory Committee (EAC) guidance was used to consider the risks to participants in the research and whether formal ethical approval was required. In addition the researcher used the University EAC templates on participant information and consent; modifications were reviewed by the researcher's supervisors. Gaining consent was an important aspect in the design of the research, particularly in gaining informed consent from commercial designers by ensuring confidentiality and anonymity.

Reporting the findings of the research was also important to ensure that the information from participants was utilised. Another ethical aspect was ensuring that findings would be credible to participants and that the researcher interpreted participants' experience in a respectful manner. Participants were also made aware that they could withdraw from the research at any point.

Theoretical context of the research

The lack of a 'unified body' of theoretical knowledge relevant to design to guide researchers in methodology selection (Love 2002) opened the possibility of importing methods from other research areas not appropriate to design studies (Cross 2007) was an issue within the context of the research. The literature review had highlighted, however, that design could be regarded in a number of ways, the two dominant perspectives being those of Simon (Visser 2006) and Schön (1983). As noted in Chapter 3, Cross (2007) has argued that both paradigms; Simon's 'design as science' and Schön's 'reflective-practitioner', have a place within design studies, but that design, by its nature, is interdisciplinary (science and art). Design is also dependent on its social context (Lawson 1980 and Cross 2000), so MLCE development is; a domain of design practice dependent on a group of interacting specialists to realise a product. Looking at theoretical perspectives such as positivism[17], and post-positivism[18] from a social standpoint made the selection of a methodology more straightforward. It was clear that an experimental approach in the 'scientific tradition' was of limited value since control of social variables can be extremely difficult (Bryman 2004) and was likely to be so in MLCE development. There also appeared to be no theories about MLCE development which could be tested in a quantitative manner due to the lack of explicit knowledge about the MLCE design domain. In addition Cross et al. 1981, Cross 2007 and Dorst 2008 have noted that design has escaped positivist definition to date. This is not to say that a scientific-type approach could not be used in the future, just that the lack of knowledge about MLCE development made its use here unpractical and did not suit the exploratory and evaluative purposes of the research.

[17] The 'scientific tradition' was defined as research approaches which are routed in natural sciences disciplines, such as: empiricism (the use of observation to explore phenomena) and hypothetico-deductive method (the testing of a pre-defined theory tested using empirical data) (Gray 2004, Bowling 1997 and Bryman 2004).
[18] The *post-positivist paradigm* was a discipline of research, with its epistemological roots in induction; which is the derivation of theory from findings, rather than testing in the 'scientific tradition'.

It was decided, therefore, to use a post-positivist paradigm where a number of different methodologies might be used to meet the purpose of the enquiry; to explore, evaluate and improve MLCE development. From this view point the enquiry could be referred to as 'illuminative' (Gray 2004 and Robson 1993) since it was trying to understand the phenomena within MLCE development from a low knowledge base. In addition, the research was also thought to focus on design praxiology (the study of the practices and processes of design); one of Cross's (2007) three main categories of design research: people, processes and product. Due to the context of the research it was uncertain if this would be the only focus for the enquiry (given its opportunistic nature); it was doubtful that any quantifiable measures of MLCE development processes would be available.

4.2.3 Specific issues in planning the research

In planning the research, the researcher needed to be familiar with technical research issues that would impact on the adoption and use of methods in a disciplined manner (Newbury 2002).

The following research issues are discussed:

1. Validity
2. Reliability
3. Reflexivity

Validity and reliability

Important concepts in ensuring the research data collection and analysis were the related concepts of *validity* and *reliability* (Cohen et al. 2000 and Willig 2001). Validity and reliability can be applied to quantitative and qualitative research, although they may be applied differently depending on the methodology used. *Validity*, in this research, was defined as an indication that the findings were due to the identified causes rather than unseen phenomena (Robson 1993); and, that the research questions were being answered through the appropriate measurement instruments (Gray 2004). *Reliability* describes whether the research delivers the same result on different occasions (Gray 2004, Willig 2001 and Robson 1993). Cohen et al. 2000 suggest that reliability is a necessary pre-condition for validity, but that reliability alone does not give validity.

Establishing whether this research was reliable through repeated use of the methods to check that similar results emerge (Gray 2004) was difficult due to the limited number of cases of MLCE development. In qualitative research the social context of the phenomena being studied can also add complication (Bryman 2004, Gray 2004). Cohen et al. (2000) note that different researchers studying the same social setting may reach different, but equally valid, findings. In qualitative research, however, reliability can be regarded as the degree of fit between what researchers identify as data and what is occurring the natural setting (Bryman 2004). Reliability could be enhanced by looking across multiple cases to check that research methods can examine different cases of MLCE development.

Whether the term validity could be applied in the context of this research was also questionable; while peoples' accounts of a setting may differ, all accounts are equally valid and it is difficult for a researcher to be completely objective (Cohen et al. 2000). Hammersley and Atkinson (1995), therefore, suggest that qualitative researchers try to understand the accuracy of peoples' accounts rather than trying to address validity. From this perspective checking the accuracy of findings from the data impacted on the research's *internal validity* (the degree to which the explanation of an event can be sustained in the data). Internal validity was also partially addressed by using a number of MLCE cases to determine whether the findings were credible when compared. *External validity* was also important since the outputs from the research may need to be generalised to other MLCE development cases. The research methods, therefore, needed to be sensitive to whether the findings could be generalised to other MLCE settings. This was done by looking at different MLCE development cases and applying a consistent methodology. If the context of the research had altered during the research, the methodological directions of the research would need to be reviewed (Barbour 1999, 2001, Cohen et al. 2000). Matthews (2007) regarded generalising results as a particular concern when trying to locate design phenomena, in that results were reliant on the 'conformance', or likeness, of specific instances of design. This was an aspect that was addressed in the methodologies adopted by taking care when applying the findings to another MLCE development situation.

Reflexivity

An important component of reliability and validity was observer bias, or *reflexivity*. Concerns of reflexivity often refer to differences between accounts of a situation (for example: descriptions, analyses by the researcher) and the situation from which the accounts actually derive (Cohen et al. 2000). Reflexivity was also a strong concern in relation to qualitative strategies where the researcher was the principal conduit from the phenomenon to the research findings. The research methods countered reflexivity issues by maintaining an awareness of the researcher's impact on the practice of MLCE development in the cases studied, through open discussion with supervisors and by maintaining transparency in the research methods used (McQueen and Knussen 2006 and Willig 2001). Another way the initial MLCE development case studies controlled reflexivity was by the use of propositions (detailed in section 4.4). Propositions outlined the expected outputs from the research methods to examine whether the research methods were sensitive to the different MLCE developments cases.

4.3 Reviewed and selected methodologies

An objectivist approach had been rejected as not being appropriate to the research context (see section 4.2.2); the alternative was a constructivist approach[19], which moved the research towards interpretivism[20].

Adoption of interpretivism

This enquiry was focused on uncovering where MLCE design practice was undertaken, and by whom, in order to see if better MLCE could be developed. It was also likely that to understand the 'where' and 'whom' within MLCE design one would need to explore the phenomena through different people's constructed views of the phenomena, and so be interpretive in nature. In order to achieve this, it was important to look at people's experience of MLCE development to see if an understanding of the phenomena could emerge. Little was found in the literature to date on interpretivist approaches to design research through a key word search of 'interpretivism'. Interpretivism was a broad theoretical perspective within which there were a number of approaches including hermeneutics, phenomenology and ethnography (Gray 2004).

[19] *Constructivism* was defined as a philosophical approach which sought to construct meaning from interactions between people and the wider world (Gray 2004).
[20] *Interpretivism* was defined as an enquiry using culturally derived and historically situated interpretations of the social world (Crotty 1998).

4.3.1 Reviewed methodologies

A number of methodologies with different but related theoretical backgrounds were looked at to see whether they were appropriate to the enquiry.

Hermeneutics

Hermeneutics focuses on the importance of documentary data, and plays down the role of observed data when attempting to define people's understanding of phenomena (Ashworth in Smith 2003, McQueen and Knussen 2006). As a perspective it was regarded as theoretically complex and, therefore, unsuitable for this enquiry given the inexperience of the researcher. The possibility of a heuristic enquiry (Gray 2004) as an investigation into the researcher's experience of MLCE development was also explored, but dismissed due to the job changes during the research (see Chapter 1).

Phenomenology

Phenomenology is concerned with the ways in which humans gain knowledge of the world around them (Willig 2001, and Ashworth In Smith 2003) and could be applied to t pick up insights that have not previously been identified (Gray 2004). Love (1999) regarded phenomenological research as the best research methodology with which to explore design, particularly cognition, if exploring different people's positions on the phenomena, as this research was likely to do. Phenomenological research does, however, have limitations in that it is concerned with how phenomena present themselves to people and how people perceive the phenomena, rather than why phenomena occur. Love (1999) suggests that a constructivist approach must depend on other perspectives, post-positivist or scientific, to focus on specific aspects of design.

Ethnography

Ethnography, as a form of phenomenological research, was concerned with how people (researcher and participants) make sense of their environment (Cohen et al. 2000). Ethnography has links to cultural studies, social sciences and anthropology (Gray 2004) and gets its primary insights by the use of context specific studies often lasting some time (Hammersley and Atkinson 1995). Ethnography had been used in research into design and shown to be useful in eliciting the social aspects of design activity (Bucciarelli 1988 and Button 2000). Ethnography appeared to be well aligned with the purposes of this enquiry since it sought to interpret phenomena and peoples thoughts about a topic (Desai 2002).

Traditional ethnographic methods, however, took a long time and required considerable access to the phenomena (Robson 1993).

4.3.2 Selected methodology

Phenomenology was adopted as the most appropriate methodology since it could be used to describe, and access, how people experienced the world (Bird 2002). In addition, it appeared to have been considered by previous design researchers as a relevant approach to design research (Levy 1985, Schön 1988, Ward 1989, Buccarelli 1988, Galle 2002, Coyne et al. 2002, Cross 2007 and Matthews 2007).

Phenomenology can be applied in a number of ways using different research methods as the instruments of investigation (Gray 2004). The particular phenomenological research methodology adopted was *grounded theory,* defined as: 'discovered, developed and provisionally verified through systematic data collection and analysis of data pertaining to that phenomenon' (Strauss and Corbin 1998). Strauss and Corbin, however, state that grounded theory can be applied as a method or strategy. Grounded theory was hard to define in a particular research position since it has been used in both positivist and post-positivist approaches (Locke 2001). In this research it was used as a method to review the outcomes from the various exploratory studies to see what could be determined about MLCE development from the data. Generation of a grounded theory was started when initial context setting research had been completed.

Principal of grounded theory

Working from the basis of grounded theory, any initial ideas had to be put to one side while the research was conducted (see the paragraph below on *Initial Hypothesis*). To allow a grounded theory to develop, it was important to mitigate against reflexivity. This was due to the gaps in and reliability of the evidence which could be used to characterise MLCE development and its possible misinterpretation by the researcher. A method which helped to mitigate the impact of reflexivity was the use of the grounded theory 'process' of *coding* the data using a variety of pattern-seeking approaches (Willig 2001). This process provided links between the data and the 'grounded' findings of the research, which would help make the data transparent to check that the research methods were providing reliable and valid outputs. In addition this approach would assist in ensuring that the research methodology was being applied correctly and in a logical manner. The *coding paradigm* (Willig 2001), otherwise known as *axial coding* (Strauss and Corbin 1990), explicitly focused on aspects of ‘process’ and ‘change’ in the data. Axial coding was a useful technique which helped the support the rigour of the enquiry by providing a methodological ‘hand-rail’ by which the researcher could check the analysis of the data. Coding is often regarded as a time consuming activity, but in this instance was regarded as a necessity to make the enquiry function effectively.

The grounded theory ‘processes’

The process of grounded theory was not a formalised process, but a number of analytical building blocks (Willig 2001). The first block was coding which described instances of phenomena from the data called categories. The main principal of coding was that the researcher moves between the data and analysis, building confidence that the categories provide a good understanding of the complexity of the phenomena one was studying.

The next block, *theoretical sensitivity* was an analytic level activity during which the researcher asked questions to refine the construct the categories represent (Gray 2004). Allied to this block was *theoretical sampling*. Theoretical sampling involves collecting further data in the light of the determined categories to elaborate or challenge the developing construct. The last block was *theoretical saturation*, at which point further sampling or coding reinforces the categories one has developed. Recording of grounded theory activity was achieved through memo-writing which tracks the grounded theory ‘processes’ and the formulation of the categories.

These blocks continue through one’s research into a given area, during which time the researcher may pause to gain more data to enable the grounded theory development. It was from this perspective that the researcher used a case study[21] approach to explore MLCE development to begin gaining data to enable a grounded theory approach. Other studies were then used to provide a degree of triangulation[22] and enable the grounded theory process articulated above.

Limitations of grounded theory

Some grounded theory researchers have doubts about focusing on coding since they may limit theories to emerge from the data (Melia 1996 in Willig 2001, Gray 2004). They argue

[21] Case studies were empirical enquiries which investigate a specific instance of a ‘phenomenon in its context’ (Yin 1994).

[22] Triangulation entails using a number of methods or data sources to study phenomena (Bryman 2004).

that focused aspects, or *theoretical codes* (Glaser 1978), should be determined directly from the data. The researcher had no experience of a coded approach and was wary of subjecting the data to a framework that would suppress a grounded theory, but was willing to try the approach. Charmaz (1990 in Willig 2001), and Glaser and Strauss (cited in Dey 1999) have introduced the idea that a researcher constructs an organised view of the data, rather than placing an order on the data. From the researcher's perspective this was the preferred approach due to the different possible explanations for the phenomena which may be occurring in MLCE development. From the outset of this enquiry the research questions have attempted to organise and present 'a' view, rather than the 'only' view of the data.

Initial hypothesis

At the outset of the enquiry there was no preconceived idea of the phenomena acting within MLCE development, due to its relatively complex and undiscovered nature (Chapter 3). It is not unusual for researchers to have a competent understanding of the area being studied (Willig 2001), although having too strong a preconceived idea would question the application of a grounded theory approach. Grounding one's understanding of the literature on the phenomena and researcher experience was argued to be important by Silverman (1993) and Yin (1994); to enable corroboration of the findings uncovered by the methodology.

Methodology selection summary

The research methods adopted for this enquiry can be summarised as a simplistic diagram (Figure 28) showing the links between epistemological view, theoretical perspective, methodologies and methods adopted in the dotted bubbles.

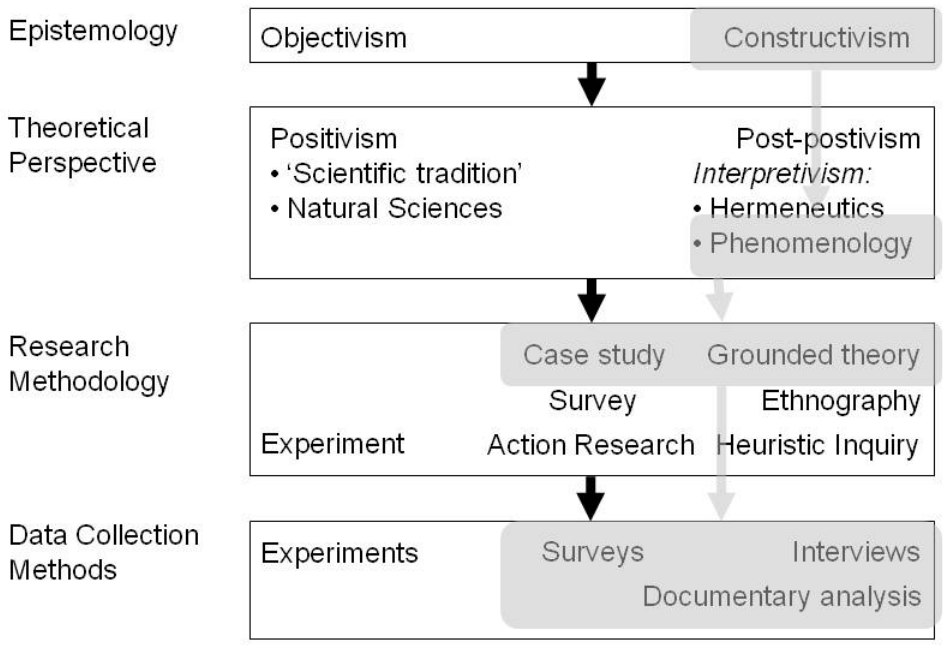

***Figure 28**. Enquiry elements overlaid on the generic theoretical framework (see Figure 26).*

The data collection methods for the enquiry were, therefore, scoped towards documentary analysis and interview techniques, the details of which are outlined in the next section.

4.4 Data collection methods

The following research methods were reviewed to determine whether they could be used to explore and evaluate MLCE development within a grounded research approach.

4.4.1 Documentary analysis

It was likely that some of the enquiry would rely upon information contained within documentary sources; documentary analysis was an important method to enable the research. Documentary analysis was defined as the systematic and objective identification and evaluation of evidence to determine facts and draw conclusions about events (Borg 1963 in Cohen et al. 2000). As such documentary analysis was strongly related to the study of the history of design and a relevant research approach in design studies (Margolin 1992). Documentary analysis could also be complimented by other techniques which were used to clarify points that do not lie in the documentary evidence. The documentary analysis approach for this study follows a typical structure (Chadwick 1978), as shown in Figure 29.

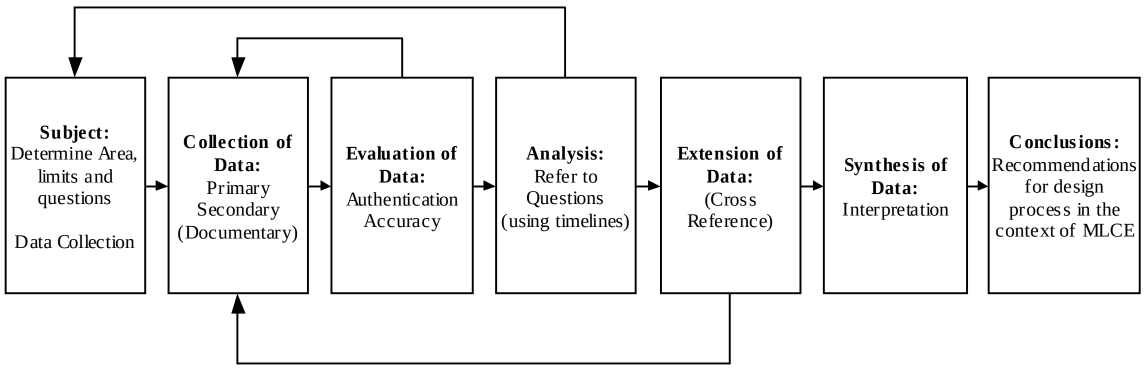

Figure 29. *Diagram showing the stages of documentary analysis adapted from Chadwick (1978).*

A technique that was considered as an alternative to documentary analysis (to undertake documentary analysis) was *content analysis*. It involves establishing categories and then determining the number of instances when those categories were used in a piece of text. Content analysis requires attention to validity, but Silverman (1993) points out that there is an unclear theoretical basis for the technique and that the results are often unoriginal. Gray (2004) also points out that content analysis requires an appropriate hypothetical standpoint prior to application which this enquiry lacked at the outset.

4.4.2 Interview techniques

Interviewing was used in a number of studies as a stand-alone method, and to supplement the documentary evidence. Interviewing was extensively used as a data-collection method because the data can be used in a number of ways, particularly within grounded theory paradigms (Willig 2001, Charmaz 2002). This research used semi-structured interviews, where questions are prepared beforehand but modified depending on the interviewee's responses. Semi-structured interviewing, therefore, enabled good linkage to the research questions through pre-planning, but was responsive to the interview circumstances. Open-interviewing and structured-interviewing were not used because they were optimised to only one these research needs. Structured interviewing, while arguably more reliable would not have allowed for insights to emerge from the interviews or allow a good rapport with interviewees. The challenge when undertaking interviewing was to provide scope for interviewees to express themselves and to trust the researcher (Gray 2004).

Limitations of interviewing

Interviewing does have its limitations which needed to be understood by the researcher who was a novice in research interviewing practice. Key to the challenges of using interviewing techniques was to define whether findings could be trusted relates to issues of reliability and validity (Gray 2004 and Cohen et al. 2000). The extent to which these two issues can be mitigated was limited. Reliability in how consistent the results were from interviewing was more difficult to manage, in particular to avoid researcher bias. This issue was addressed by the researcher practising their interviewing skills; by using a common guide containing sample questions and by checking the accuracy of participants' comments against documentary data.

Interviewing for this research

The intention was to use semi-structured interviews which could be done in one interview or over a series of sequential interviews following the pattern of interview suggested by Charmaz (2002) and Willig (2001): i) initial open ended questions, ii) intermediate questions, iii) ending detailed questions. The purpose of the interviews were to gain information missing from documentary evidence, and probe for insights relating to MLCE development.

4.4.3 Artefact evaluation

Much of the information about MLCE development can be found within documentary evidence. Evaluation of MLCE may be required as a research activity within the enquiry to understand design activity during development. Current evaluation methods for MLCE revolve around user trialling either in laboratories or in field trials which were outside the resources available to the study. Initial MLCE evaluations were also thought to be useful in understanding the link between design activity and user requirements. User requirements at this stage in the study were not the focus for the research, but could be achieved by using the following rucksack descriptors to characterise the rucksack as an artefact, derived from Vicary (2003) and from the researcher's experience:

- Description (picture and words)
- Cost
- Manufacturer
- Size (litres)
- Weight (grams)
- Gender specific
- Durability
- Main entry method
- Detachable day / assault pack
- Expansion valance (size)
- Compression / attachment ability
- No. of compartments
- No. side pockets
- Stowable back system
- Description of back system
- Back system qualities – General
- Back system qualities – Specific
- Ease of adjustment for user anthropometrics
- Interface with elements of the personal equipment system
- Interface with other military equipment and environment
- Materials: General use
- Materials: Specific use
- Maintenance

- Signature management
- Quality / Reliability
- Safety / Security Features
- Waterproofing
- Sizing
- Ergonomic factors
- Special features
- Grab / haul / parachute handles
- Competition
- Modifications during service
- Other information
- In Service Date (ISD)
- Out of Service Date (OSD)

Comparing these descriptors against the process of development can only happen at the end of the case study, since it requires a detailed understanding of the context of each case. This comparison could then be used to inform the conclusions of each case study.

4.4.4 Case study

Since there was no MLCE development being conducted in the UK in the early stages of the research, the researcher looked for methods which could enable understanding of people's experience of MCLE development. An approach that met the illuminative purpose of the early research, and the phenomenological paradigm, was a case study approach, since it could be used to: i) find out what is happening, ii) seek new insights, iii) ask questions, iv) assess phenomena in a new light (Robson 1993). Yin (1994) also noted that this form of enquiry was especially relevant when the boundaries between the phenomenon and context were blurred, as was the case with MLCE design. A case study approach by itself, however, was not suitable for exploring all the research issues. A case study approach was, therefore, part of a methodology which used other complimentary approaches and techniques to address all the research issues pertinent to the research questions. Research techniques and methods could then be employed within these approaches to provide a more complete picture, and provide an aspect of triangulation (Hakim 1987) to the findings.

Data sources strengths and weaknesses within the case study strategy were reviewed to determine their suitability for answering the case study questions (see Table 4).

Source of Evidence	Strengths	Weaknesses
Documentation (Letters, memoranda and agendas)	• stable – can be reviewed repeatedly • unobtrusive – not created as a result of the case study • written evidence – may contain exact names, references, and details of an event • broad coverage – long span of time, many events, and many settings	• retrievability – can be low • biased selectivity, if collection is incomplete • reporting bias – reflects (unknown) bias of author • access – may be deliberately blocked
Archival Records (Service / organisational records, charts, lists, survey data, personal records)	• (same as above for documentation) • precise and quantitative	• (same as above for documentation) • accessibility due to privacy reasons
Interviews	• targeted – focuses directly on case study topic • insightful – provides perceived causal inferences	• bias due to poorly constructed questions • response bias • inaccuracies due to poor recall • reflectivity – interviewee gives what interviewer wants to hear / interviewer may hear what they wanted to hear
Direct Observations	• reality – covers events in real time • contextual – covers context of event	• time-consuming • selectivity – unless broad coverage • reflectivity – event may proceed differently because it is being observed • cost – hours needed by human observers
Participant – Observation	• (same as above for direct observations) • insightful into interpersonal behaviour and motives	• (same as above for direct observations) • bias due to investigator's manipulation of events
Physical Artefacts	• insightful into cultural features • insightful into technical operations	• selectivity • availability

Table 4. *Six Sources of Evidence: Strengths and Weaknesses adapted from Yin (1994).*

Documentary and Archival Records had similar research methods so which was referred to as *documentary analysis* (see section 4.4.1).

Multi or single-case study approach

A single case would not have allowed the research questions to be fully explored from multiple points and so a comparative case study approach (Gray 2004) was looked at to see if similarities existed and if some aspect of replication could be generated. Replications were defined as the common threads between the cases which mutually support one another, analogous to experiment replication (Yin 1994). There were two types of replication; *literal replication* highlights issues in each case which were predicted to be similar, *theoretical replication* highlights issues which were predicted to be different from one another for particular reasons.

A comparative (case) study approach was adopted as the initial part of the research strategy to explore MLCE development; although some work was needed on the theoretical aspects of the research (see section 4.3.4).

Improving reliability in the comparative study

Because of the limited resources and availability of cases, ways to improve reliability needed to be determined. Improving the reliability of the comparative study approach was done by maintaining good case study notes and documentation (recommended by Yin 1994 and Gray 2000). Usually research strategies include data source collections;
i) the data, and ii) the researcher's report. In case study strategies these collections can become blurred and make triangulating data difficult. This is often due to the nature of the qualitative information being collected. The researcher mitigated this risk by keeping a bibliography of the documents being used in each case study. Yin (1994) suggests that reliability was improved by maintaining a good evidence chain and using multiple sources of evidence to guide data collection. The reliability of the findings was based upon the sources of data and good analysis technique, therefore, effort was put into making a link between the study's research questions to the evidence in the data.

The comparative study results were also compared with later studies to check whether there were common results (literal replication) and where gaps (theoretical replication) were between studies. This was also an opportunity to determine whether the results from one study or another were more robust, by critically looking at the evidence chain behind each finding across each study. The later studies also allowed the methods from the comparative study to be adapted for a single case study looking at a contemporary MLCE project thus further checking the robustness and reliability of the case study approach.

The methods used within the case study approach must be appropriately selected to gather data from the available sources. Now that a comparative study approach had been chosen as the initial part of the research strategy, one could start to develop the specific methods appropriate to the research by investigating the studies propositions, as mentioned in the previous section.

Propositions

Yin (1994: 21) in his description of case study methods uses ‘propositions’ as links between the research questions and where one can find information. Criteria for measuring the success of the study, linked to its purpose were used.

The initial propositions have been broken down by research question and were:

1. What are the influences involved in MLCE development?
    a. By looking at the product development of existing MLCE it is possible to understand how the resultant products were designed?
    b. Identify the factors which influenced the resultant product.
    c. How design decisions were made.
    d. It is also possible to see how success for MLCE is:
        1. Determined.
        2. Whether they met user needs during military tasks.
        3. How successful the designs were in-service.
    e. The design information needed to design MLCE will be identified.
    f. It is possible then to evaluate MLCE development and determine where there are deficiencies.

2. What needs to be improved in MLCE development?
    a. Areas where attention is needed to enable improvement are to be identified.
    b. It is possible to identify where designers had problems during the design process and other factors that affect the success of the final MLCE.
    c. There is a need for improvement in MLCE development either because:
        1. the product is deficient because of limited practice.
        2. The design decisions were made with insufficient evidence due to other pressures beyond the control of the design practitioners, e.g. time.
    d. Whether the use of design methods or tools would increase efficiency and effectiveness of MLCE development needs to be determined.
    e. If design tools are appropriate, places where they could be used as a support to good practice will be identified. The use and context of how the tool is used also needs to be understood.

3. How can we improve MLCE development?
    a. By establishing areas within MLCE development which will enable an improvement, recommendations can be made on how to improve these areas.
    b. By looking at MLCE it is possible to identify information which can be used to improve development.
    c. It is possible to begin to understand how designers design MLCE which gives an indication of how development might be improved.

Case study questions

The initial case study questions were derived from the research questions and propositions. It was important that the same questions were used for each case otherwise the results may be unbalanced and not allow for commonalities to emerge from the cases. If further cases became available it was possible to add questions. Tables 5, 6 and 7 show the links between the research questions, propositions and case study questions.

Research Questions	**Propositions**	**Case Study Questions**
1. What are the influences on MLCE development?	a. The elements which influence MLCE development can be categorised and their interfaces and relationships understood.	1. What are the aspects and factors which affect the process of New Product Development (NPD) (within an MLCE context)?
		2. What is the relative impact of each factor?
		3. What are the relationships and interfaces between these aspects and factors?
	b. By looking at the product development of existing MLCE it is possible to understand how the resultant products were designed.	4. Who were the designers/product developers?
		5. How was the product development conducted?
		6. How are design tools used within design process?
		7. Were there legislative issues of Health and Safety or Human Factor constraints?
	c. How design decisions were made.	8. Who took design decisions?
		9. How did those involved in the MLCE design process:
		10. Access and use design data?
		11. Make design decisions?
		12. Collaborate with other professionals?
		13. Use and access users?
		14. Are they experienced MLCE designers?
		15. Was there conflict between organisational decision making and design decision making, and was it a positive or negative influence?
		16. Who accepted the item for service?
	d. It is also possible to see how success for MLCE is:	
	i. determined	17. What were the success criteria?
		18. How was it tested or evaluated?
	ii. how successful the designs have been in-service	19. Have the MLCEs been successful during service according to the different stakeholders?
		20. Have the requirements changed during service?
	iii. whether they meet user needs during military tasks.	21. Were user needs identified at the beginning of the project?
		22. Were military tasks identified during the project?
		23. Was this information used?
	e. The design information needed to design MLCE will be identified.	24. What information did designers need?
		25. What information did they have?
		26. What information was not available?
		27. How did they use the information?
	f. It is possible then to evaluate MLCE development and determine where there are deficiencies.	28. By what criteria can one judge MLCE development to have been successful?
		29. Can one identify where there were areas of deficiency in MLCE development?

Table 5. *Initial starting case study questions linked via research questions and propositions, for Research Question One.*

Research Questions	Propositions	Case Study Questions
2. What needs improvement in MLCE development?	a. Areas where attention is needed to enable improvement will be identified.	30. By looking at deficiency areas, can one see where improvement is possible?
	b. There is a need for improvement in the process of NPD in the context of MLCE either because (for example):	
	i. the product is deficient because of limited practice	31. How is the product deficient because of limited practice?
		32. Was there something the designers did that lead to be deficiency, if so to what extent?
	ii. The design decisions were made with insufficient evidence due to other pressures beyond the control of the design practitioners, e.g. time.	33. Were there time constraints on the project?
		34. How efficient is MLCE development?
		35. How effective is MLCE development?
	d. Determination of what opportunities exist for increasing the efficiency of MLCE development.	36. What opportunities are there for increasing efficiency in MLCE development?
	e. Determination of what opportunities exist for increasing the effectiveness of MLCE development.	37. What opportunities are there for increasing effectiveness of MLCE development?

Table 6. *Initial starting case study questions linked via research questions and propositions, for Research Question Two.*

Research Questions	Propositions	Case Study Questions
3. How can we MLCE development?	a. Determination of a strategy and recommendations to improve MLCE development is possible.	38. What Strategy is appropriate given the resources available to improve MLCE development?
	b. Recommendations for how one can determine the success of any developments to MLCE developments are possible.	39. Therefore, MLCE design should be about producing:
		40. Effective
		41. Efficient
		42. Satisfying
		43. Products fit for the intended function (i.e. military task).
		44. Are the products effective, efficient and provide satisfaction to the users during military tasks?
		45. And does the MLCE design process enable this? (Is MLCE design effective, efficient, and satisfying? Total Quality Approach?)
	c. Organisational recommendations for how improvements in MLCE development can be used in UK Ministry of Defence equipment programmes.	46. What information is needed to enable the development of successful MLCE?

Table 7. *Initial starting case study questions linked via research questions and propositions, for Research Question Three.*

Types of case study approach

Choosing the type of case study approach required for the research was limited in part by the two cases available (detailed below in this section). There were two principle options; option

1 was a *pattern-matching* approach (Yin 1994) in that one was looking for data to corroborate that propositions one has made, option 2 was an *explanation-building* approach (Yin 1994), enabling the generation of hypotheses as one goes through the cases. If the data does not support a proposition, then one must review the proposition. If one takes the example of proposition RQ1.e. from Tables 7a:

RQ1.e. The design information needed to design MLCE will be identified.

If the proposition can be answered in Case Study 2 but not Case Study 1 for a predictable reason then the evidence supports a theoretical replication. If the case studies supported one another or if one could support the reasoning for the difference using another, third case, then one can support a literal replication. Replication was important since it improved the reliability of the findings, assuming the questions being asked were valid. It also provided an indication of where there may be points in the case study approach that needed more investigation or clarification. In option 2 the iterations allow reflection back on the case study questions and the altering of propositions linking with the research questions. This enabled one to answer aspects which may have been overlooked at the outset and begin to alter the propositions to allow one to begin to generate theoretical positions.

An explanation-building approach would be desirable, due to its compatibility with grounded theory and the illuminative paradigm of the context-setting research part of the research strategy. This approach requires iteration over a number of cases to allow theoretical positions to be revisited, as well as evidence to be looked at using different perspectives, although evidence was limited by the number of cases available. The principal difference between the two options was how they developed reliability through repeated use. From this perspective option 1 was a comparative study and so enabled better cross-case analysis for replication between cases to be observed. For option 2 to achieve this at least twice the number of cases to determine replication would be needed. This study used option 1 since there were insufficient cases to allow the context of MLCE design to be examined through option 2.

As further cases became available, they were used as single studies to improve the reliability of the findings of the option 1 approach.

On starting the research, two UK MoD MLCE projects were available which contained accessible data sources:

1. UK MoD's 90 Pattern rucksack
2. UK MoD's Airmesh rucksack

These cases were chosen not only because of the ease of access to the data needed for the study, but also because they offer the most recent and relevant examples of the design process of MLCE. Additionally, they were both familiar to the researcher and so an emphasis could be placed on the correct application of chosen research methods.

The product development of the US Army MOdular, Lightweight, Load carriage, Equipment (MOLLE) 2 was considered as a case, although gaining enough data on this product proved to be difficult. Commercial sensitivities prevented the use of civilian LCE cases.

Case Study One – 90 Pattern (Infantry) Rucksack Development

The 90 Pattern (Infantry) rucksack (Figure 30) is the standard UK Armed Forces Infantry Rucksack.

Figure 30. *90 Pattern rucksack, the two large side pouches detach to form a small day pack.*

Case Study Two – Airmesh rucksack development

The Airmesh rucksack (Figure 31) was developed for a specific role, but has been trialled by infantry troops and is widely liked. This rucksack is not on general issue. It was chosen as a case because access to the designers and evidence of its development was possible.

Figure 31. *The Airmesh rucksack.*

Four of the six sources of evidence in Table 12 were suitable for the two case studies. Of the sources available within the two cases each source had a corresponding research method associated with it, as shown below:

- Documentary – Documentary analysis
- Archival Records – Documentary analysis
- Interviews – Interview techniques
- Artefact – Rucksack evaluation matrix

Figure 32 shows how the sources of evidence fitted into the multi-case study.

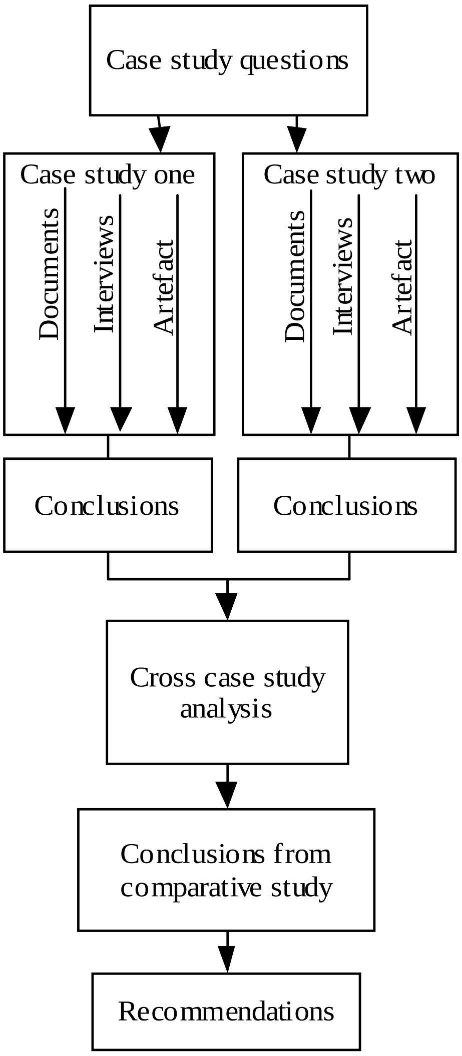

Figure 32. *Diagram showing how the sources of evidence fit in to the multi-case study approach.*

Cross case study analysis

Comparing outcomes from the research methods does have limitations, however, in that replicated findings between different methods do not necessarily indicate consistency or reliability unless they directly address the research questions (Cohen et al. 2001).

Cross-case analysis provides the final stage in answering the research questions and reporting out the case study results in a reliable manner. The cross-case analysis pooled the conclusions from the individual case studies to form the conclusions of the comparative study, as shown in Figure 32. It did this by reflecting on the individual conclusions for each case study together to form findings across the case studies. Aspects of agreement were noted and theoretical reasons declared if the findings differed between cases. This period in the comparative study approach helped address ambiguous issues in the findings and concerns of validity. It was also important for the cross-case study analysis to identify the best practices and support activities in MLCE design. This helped the identification of insights for adapting or adopting 'best practice' and supporting activities which could be addressed in further research stages. These were important if the third research question was to be effectively answered; was improvement to MLCE development appropriate?

Limitations of case-study approaches

There is some debate about the importance of generalising from results in case-study research designs (Bryman 2004). Yin (1994) and Bryman both caution about generalising from the findings of a case to other cases. A case can, however, be used as a revelatory case, when a phenomena which is previously unavailable is investigated (Bryman 2004). This enquiry was to some degree revelatory, so it was important to gain findings that could be generalised in order to improve MLCE development (RQ3). Additionally, there is a misconception that case-study approaches were loosely structured; partially because of the issues raised above (Cohen et al. 2000, Willig 2001 and Gray 2004). Willig points out that the converse was usually true, if the case study is well designed and conducted properly. The limitations of a case study approach vary, however, Nisbet and Watt's (1984, in Cohen et al. 2000) three main weaknesses were a good summary of Willig (2001) and Gray (2004):

1. Results can often not be generalised; they are specific to the case.
2. Results are not easy to cross check and hence may be selective, biased, personal and subjective.
3. Results are prone to problems of observer bias, despite attempts to address reflexivity.

The first limitation was of concern to this research since the results needed to be generalised between instances of MLCE development. This is not a concern, however, if the same questions were asked of each case and the common findings reported are found in all cases (Yin 1994). Also results should be not generalised beyond MLCE development. Willig (2001) noted that generalisations could be used, as they were here, to develop a broad understanding of similar areas. The second and third limitations would be addressed via rigorous application of the selected methods and approaches to address reflexivity (see section 4.2.3). Over reliance on triangulation was a concern (Silverman 2000) when considering how to address the second and third points. This was due to the problems that can occur when trying to aggregate data from multiple sources. If multiple points were used, this could lead to a confusing picture of the phenomena being studied; this was addressed by transparent reporting of research results.

Leading to a Pilot Study

In order to better understand how the identified methods could work together within the comparative study a *protocol*[23] was drawn up (see Appendix F). The protocol was then reviewed by the researcher's supervisors prior to conducting a pilot study[24], using the protocol, to ensure the approach was appropriate to the enquiry. Since there were not sufficient cases available within the context of MLCE, the pilot study could only do this by using one of the two cases available for the comparative study. It also allowed the researcher, to practice and learn the skills to use the comparative study techniques defined in the research strategy, the pilot study was also used to check the case study questions and their relation to the research questions. This was possible by using one case, as long as the single case's interfaces with other cases are looked at. Figure 33 shows how the data collection was achieved through the pilot study; the blue shaded boxes show what was included within the pilot study as it progressed from the case study questions up to the case conclusions.

[23] *Protocol*: the procedures for the comparative study.
[24] Pilot studies are an initial test or run through of an approach (Robson 1993).

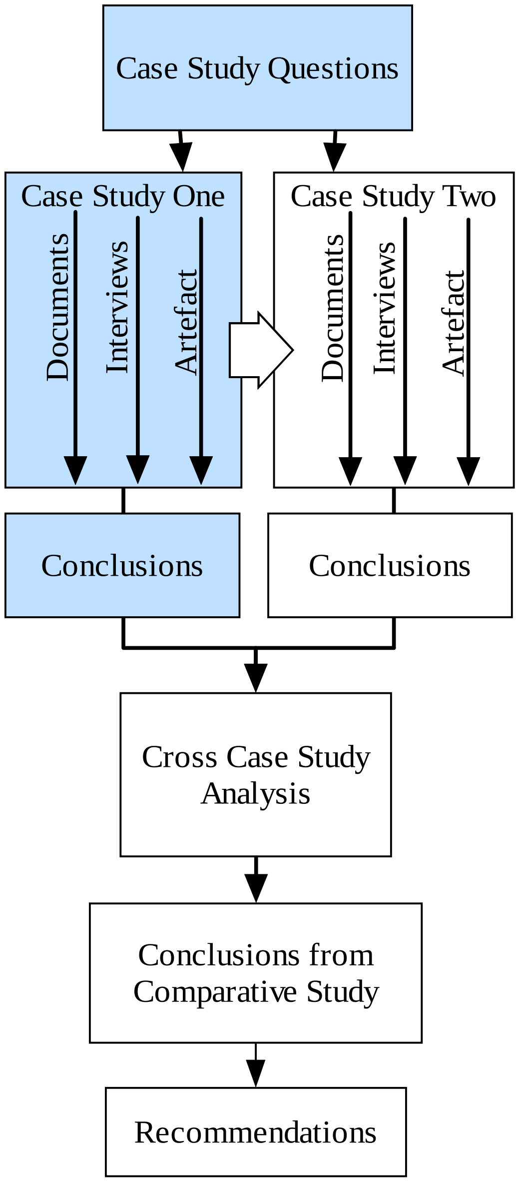

Figure 33. *Diagram of protocol for the comparative study pilot.*

The conduct and results from the pilot study are reported in Appendix G, and were used to provide initial sources for study 2 (see Chapter 5).

4.4.5 Action research

Another research approach used within design research is action research (Baynes 1982, Antill 1986, Walker 1986 and Swann 2002). Action research may be described as a methodology rather than a method, since usually uses a variety of specific research methods to observe the effects of the researcher and participants doing something (acting). It is included in this section because of the influence it had on the researcher's actions as a reflective tool, rather than as the principal approach. Action research was appealing for this enquiry due to its ability to enact change in a pragmatic and collaborative manner, as well as access design practice (Swann 2002). Action research was defined as joint action of the researcher and people involved the in MLCE development to solve a problem and generate new knowledge (Coghlan and Brannick 2001). To do this, cycles of research were undertaken which allow reflection and control of events. A theoretical cycle is shown in Figure 34; the cycles link at the end of each reflecting stage to loop via the planning stage in to another cycle of action and observation.

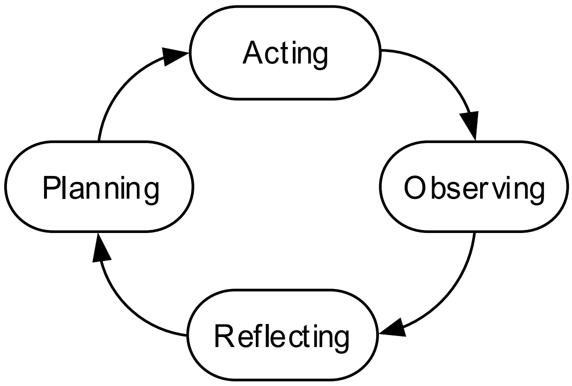

Figure 34. *Diagram showing Kurt Lewin's Action Research cycle, from McNiff (2001).*

As one can see from Figure 34, action research looks at how people learn, reflect on practice, and improve one's own and other people's practice (McNiff 2001). Action research is particularly applicable to this research since it enables insights from practitioners by reflecting on current techniques. Perhaps the best way to envisage action research may be as an 'intervention experiment' (Argyris and Schön 1991).

A level of control over the periods of action research was important to ensure that an enquiry was focusing on the right studies to answer the research questions. Action research was also thought useful in enabling improvements to MLCE development if the opportunity became available for collaborative research. A benefit of using action research was to support, if possible, the transition of research outputs to practice (which was one of the primary uses for action research). The transition to practice was dependent on the results of the research and whether practitioners were willing to participate (discussed in later chapters). Action research had been used within qualitative approaches (McNiff 2001, Coghlan and Brannick

2001, Flood 2001, Checkland 1991) allowing some relation to 'naturalistic enquiry' (Robson 1993), as a form of interpretative research (Gray 2004).

4.5 Confirmatory studies

Due to the use of historical cases in the comparative study (Studies 2 and 3) there was a need and opportunity to conduct confirmatory studies to check the relevance of the comparative study results in contemporary MLCE design. Due to little MLCE development being conducted in the UK defence arena, a number of studies sought to seek contemporary MLCE design information from the civilian arena. At these points additional research methods were adopted, appropriate to the research strategy and altering research context.

4.6 Evaluation of the research

It was important that the enquiry could be assessed in terms of its success in exploring, evaluating and improving MLCE development. This could only be done by evaluating the study's research methods' performance in answering not only the research questions but also the research's aims. This should be shown in how well the understanding of the MLCE development improves through the study, particularly in filling knowledge gaps highlighted by the literature review (Table 10). An assessment of whether the enquiry had added value to MLCE development was dependent on the outcome of the last phase of research and confidence in the conduct of the research.

4.7 Chapter conclusions

In conclusion, this chapter has considered the various research approaches which could be used to explore, evaluate and improve MLCE development. The research strategy for the first phase of the investigation was based on a grounded theory methodology, which met the purpose of the research to explore and evaluate MLCE development. The methodology contained a number of research methods including interviews and document analysis within a case study framework that were appropriate for exploring MLCE development given the starting context. This approach needed to be as flexible as possible since it was difficult to predict the context for the later stages of research; the enquiry being conducted over six years. The use of a grounded approach was also particularly appropriate to this enquiry; in a changing and adaptive professional design context. Action research phases were used to enable researcher refection and interaction with stakeholders in MLCE development. The first cycle is outlined in Figure 35.

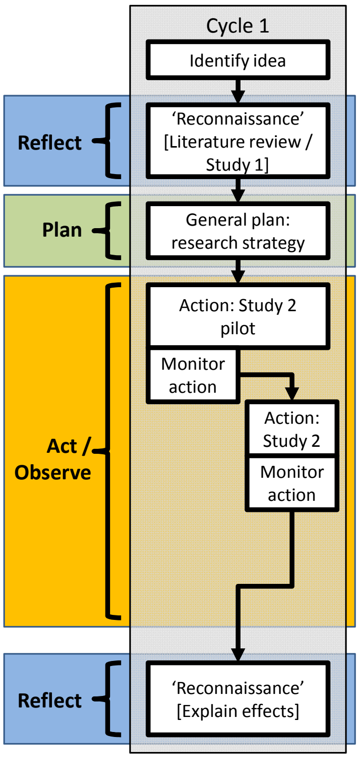

Figure 35. *Research Cycle 1 (adapted from Elliot, in McNiff 2001).*

This approach to action research had been designed to be flexible to allow for the inclusion of confirmatory studies which were difficult to plan for at the beginning of the enquiry.

Revisiting the chapter's objectives:

1. A phenomenological strategy consisting of a comparative study approach and other research methods has been determined as being appropriate to address the research questions.
2. The specific research methods which can be used to explore, evaluate and improve MLCE development have been identified.
3. Identification and acknowledgement of the limits and limitations of the research strategy and methods have been discussed.

Key points to take forward:

1. The methods for the initial stage of the research to explore MLCE development had been determined and now needed to be applied through a pilot study, followed by a comparative study of two MLCE development cases.

Chapter 5: Exploring MLCE development through a comparative study

Once the methods that could be used to answer the research questions had been identified, a comparative study of two recent MLCE developments was undertaken to initiate a grounded exploration of MLCE development. This was the first cycle in the research which would begin to inform the themes which had initiated the research and consolidate knowledge gathered through the literature review.

5.1 Chapter introduction, aims and objectives

This chapter describes the conduct and results of a comparative study using the case study approach (Chapter 4). The chapter includes the important lessons learned from the conduct of a pilot of the methods to be used in the comparative study (see Appendix G). The pilot had allowed the researcher to reflect on the limitations of the research techniques, as well as gain training and experience.

This chapter outlines the development and results of the comparative study of two cases of MLCE rucksack development. Figure 36 shows the comparative study within the research journey.

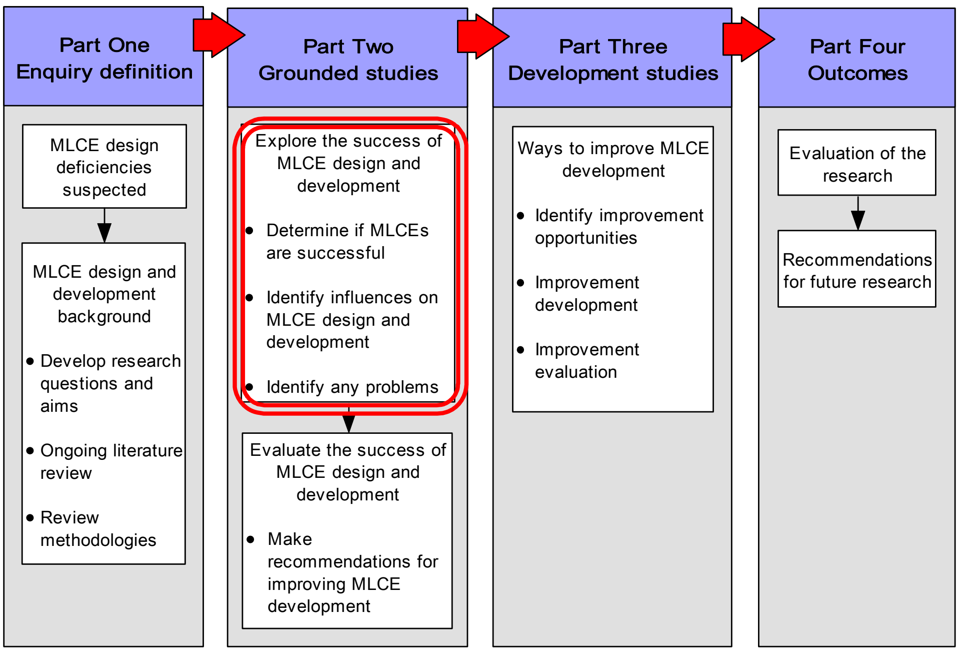

Figure 36. *Chapter 7 research map.*

Objectives:

1. Report on the conduct of the comparative study
2. Report on the results of the comparative study
3. Discuss the results and identify how the research can be taken forward to answer the research questions

5.2 Method for the comparative study

The methods used for the comparative study are outlined in Chapter 4, with the protocol in Appendix F. The study pilot is shown in Appendix G, with modifications outlined in the section below.

5.2.1 Modifications to the method during the comparative study

Once the results from the comparative cases started emerging (initially started in the pilot study) it became evident that the process definition approach did not enable a combined cross-case process definition to be identified. This was thought to be important since a cross-case process definition would aid in answering RQ2 and 3, and reflecting on contemporary cases of MLCE development. The solution to this was to generate a model of MLCE development which could be used and updated in discussions with MLCE developers.

Soft Systems Methodology (SSM)

The technique that was identified as being appropriate for combining cross-case process definitions and exploring the commonalities and differences between the two cases was Soft Systems Methodology (SSM). SSM was an established technique (Checkland 2002, Geras 2003, Flood 2001, Patching 1990, and Stevens et al. 1998) for putting complex and un-structured situations into elements which can be related to activities in the real world. SSM was useful in exploring a problem space and determining ‘virtual’ models which can be used to initiate discussion about the ‘real’ world. It was thought at this phase in the research that a way of engaging with stakeholders in action research could be aided by a suitable model of MLCE development. SSM was appropriate to this study due to its potential to structure the influences on MLCE design in each case and develop a common process model. SSM relies upon the application of ‘systems thinking’, a holistic approach to establishing relationships between elements in a systematic manner (Checkland 2002) and has been used to examine soldier issues as a part of theoretical systems research (Sparks 2006).

SSM usually follows a seven-stage methodology (Figure 37), however, only the first four stages were conducted during the comparative study. The last two stages of the methodology were associated with implementing change and action to redress a problem situation. These were addressed in later studies within the research through modification of the model.

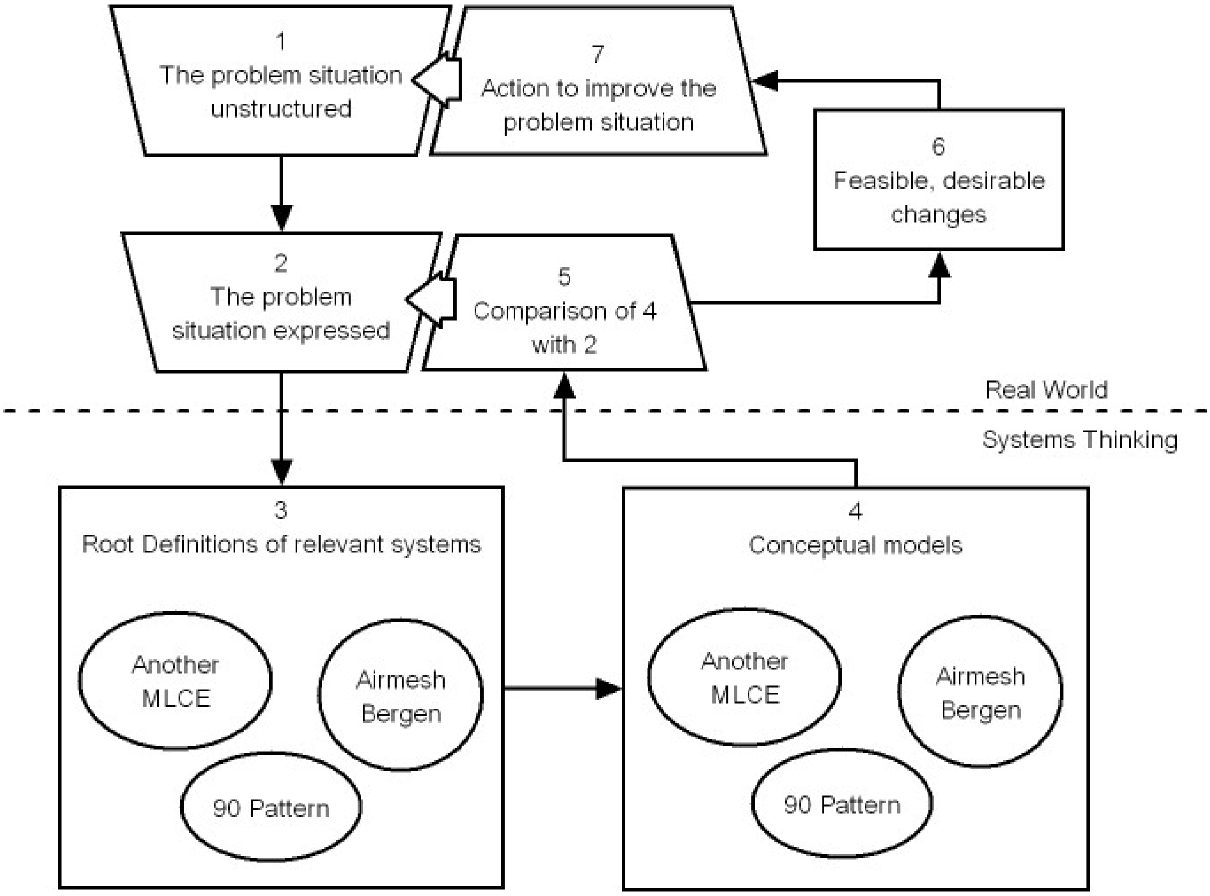

Figure 37. *Outline the Soft Systems Methodology (SSM) methodology used for this study (Checkland 2002).*

SSM was applied to each case from the comparative study (stage 2 in Figure 37) to produce an SSM view of each case (stage 3 in Figure 37). These cases were then combined to produce a researcher's model of MLCE development (SSM stage 4 in Figure 37) (see section 5.4). Stages 5 – 7 were conducted through later studies and were reported in the relevant chapter as new insights on the model were identified.

Modifications to the cross-case analysis method

These improvements were necessary to increase the reliability of the cross-case analysis. The cross-case analysis method was developed to improve the link between the research questions and evidence. This was because the answers were derived from case study summaries. Without the individual case study results and evidence the summaries lacked the information to link the findings to the data. In addition the findings were checked against evidence, and the knowledge gaps from the literature review to ensure there was a link. While this approach was more thorough than the initial protocol, it was limited in that it had to rely upon the quality of the available evidence.

The development of the cross-case analysis method was needed, in part, because of not testing it during the pilot study. Despite this, the necessity to amend the protocol was detected early in the analysis. Figure 38 provides a summary of the comparative study with the cross-case analysis modifications.

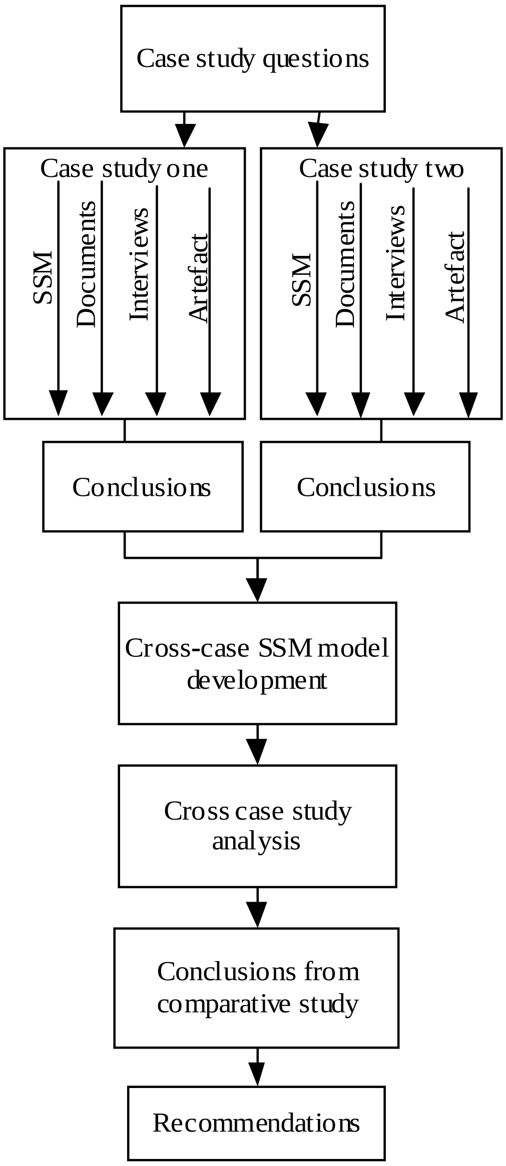

Figure 38. *Modified cross-case flowchart.*

The conduct of the case studies, including interview questions and individuals interviewed are detailed in Appendix H.

5.3 Results

The comparative study was conducted over several weeks, with interviews taking place when convenient times could be arranged with interviewees and the researcher's work commitments.

The detailed results from the individual case studies can be found in Appendix H, results from the individual case studies are shown in Annexes A and B in Appendix H respectively. The individual case study process diagrams and summary results are presented in this section to provide an indication of timescales and conduct of MLCE development. The literature review influences (shown in Figure 24) were used to show some of the main similarities and differences between the cases before looking at the cases by research question (Tables 1 to 3 in Annex C in Appendix H).

In order to report the two cases characteristics, a summary from the cross-case analysis and individual case study results were compared against illustrative factors such as: customers, design process, strengths and weaknesses (see Table 8). These factors provided ‘hand-rails’ or ways of organising the data by which to further explore the two cases. This was done to help sensitise the researcher to characteristics of the cases, in Strauss and Corbin’s (1998) phraseology; ‘move from the specific to the more general’, and allow the possible range of meanings emerge from the data in a phenomenological manner.

Illustrative Comparative Factors	90 Pattern	Airmesh Bergen	Comparison
Customer	3 Star Military (Lieutenant-General) UK MOD Headquarters Equipment Director (towards end of development)	Staff Level Equipment Capability Team – Mixed Military / Civilian (Below Colonel / Civil Service Middle Management)	*Red = no similarity.*
Design process	Iterative – long cycles of prototyping and HS assessment	Iterative – more de-risking done at the front end of the process	*Amber = some similarity but some notable difference*
Areas of deficiency	Timeliness > no clear goals > end of development was rushed	Timeliness was a minor issue	
	Little information for designers	Little information for designers	*Green = Similar instances in both cases*
	Evaluation could be better today with more systematic approach to ergonomics	Use of HS could have been better	
	Military got what was asked for – i.e. they almost designed the equipment	Military got what was asked for	
	Long-term problems with weight not tackled / need to understand the effect different MLCE solutions have of users	(Weight problems not addressed, although not a concern for this user group)	
Success in-service	Well liked in-service, although latterly showing problems with comfort and integration with other pieces of equipment	Thought to be well liked and used today, no reported deficiencies	
Strong Influences	Customer / stakeholders – the organisational structure and boundaries controlled the development, and the design approach to a large extend	Customer stakeholder involvement – requirements / little bureaucracy	
	Human Systems / usability – strong reliance on human factors assessments and field trials	Human Systems – new tools developed to assess new an innovative material	
	Manufacture – designers strongly focused on manufacturability and specification	Manufacture – designers strongly focused on manufacturability and specification	
	Quality – strong emphasis on the quality of the equipment	Quality – strong emphasis on the quality of the equipment	
Weak Influences	User – only understood for infantry	User needs – many suggestions of where the design started, which don't agree with archives	
	Military tasks – Not well understood, apart from general battlefield agility	User to check that the rucksack was fit for all tasks	
	Design – little or no evidence of using design methods	Design – little or no evidence of using design methods	

Table 8. *Table showing illustrative comparative factors between the two cases used in the comparative study.*

Individual case process definitions and timelines

The process definitions (Figures 39 to 40) are presented to show the output from each case which was used to base the cross-case model (Figure 44). Timelines were standard historical instruments to show the course of events towards a specific outcome. In the comparative study the timelines (Figures 41 to 43) were used to understand where pieces of evidence sat in the sequence of events leading to the production of the MLCE in each case. The timelines also helped identify evidence gaps and initiate searches for them. 90 Pattern was presented in two timelines: Figure 41 provided an overview timeline, and Figure 42 more detail around the key development period. The timelines also show the differences between the cases in how long it took to produce an effective product.

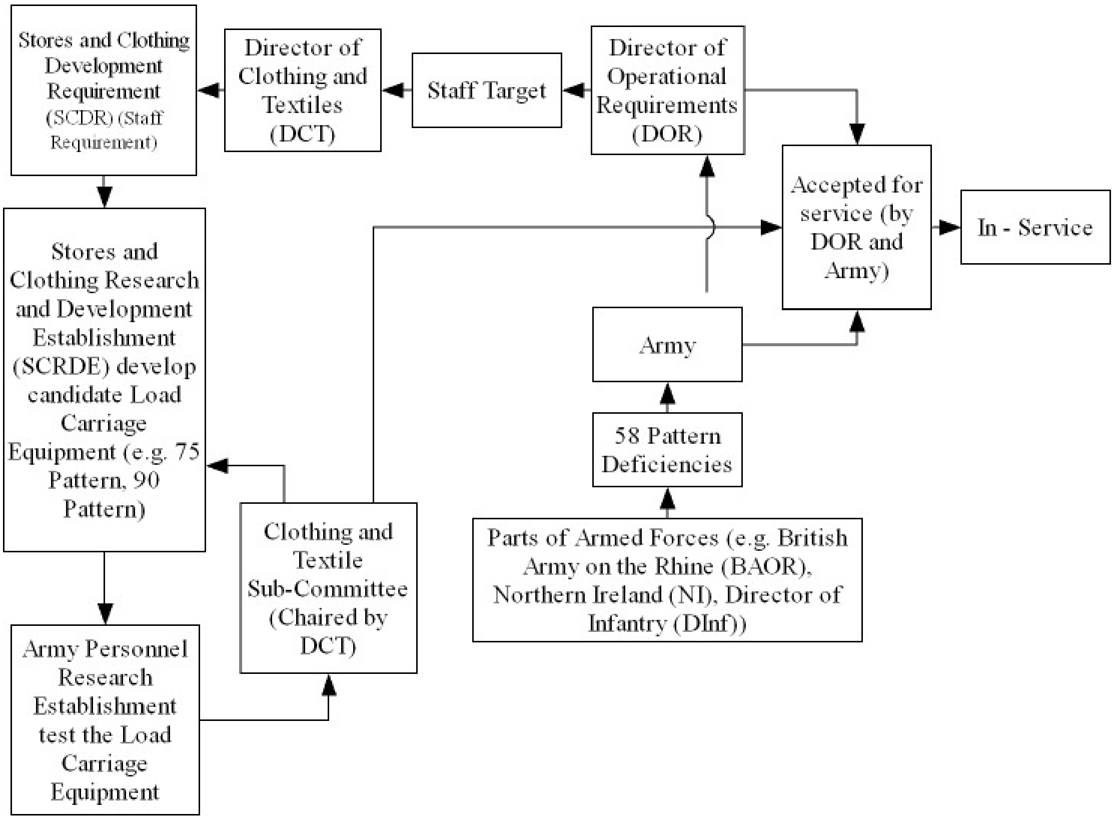

Figure 39. *90 Pattern process definition.*

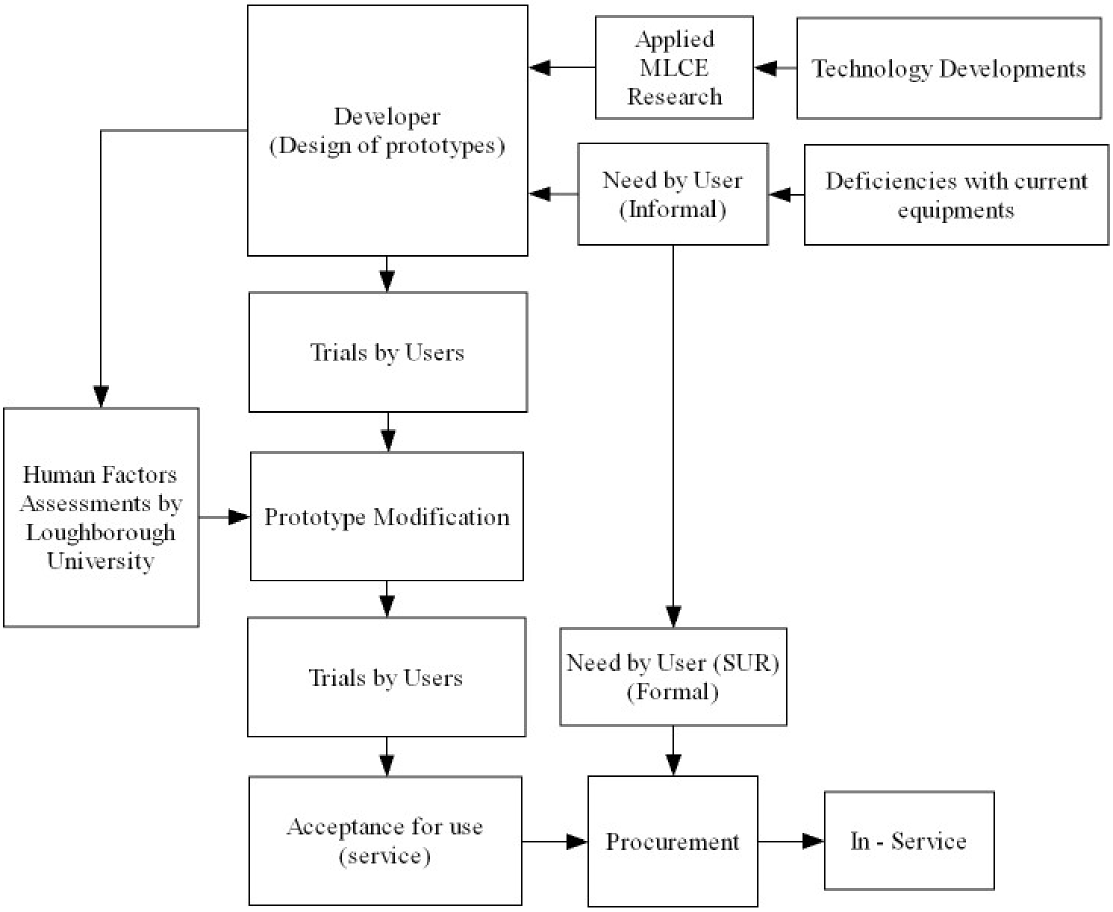

Figure 40. *Airmesh process definition.*

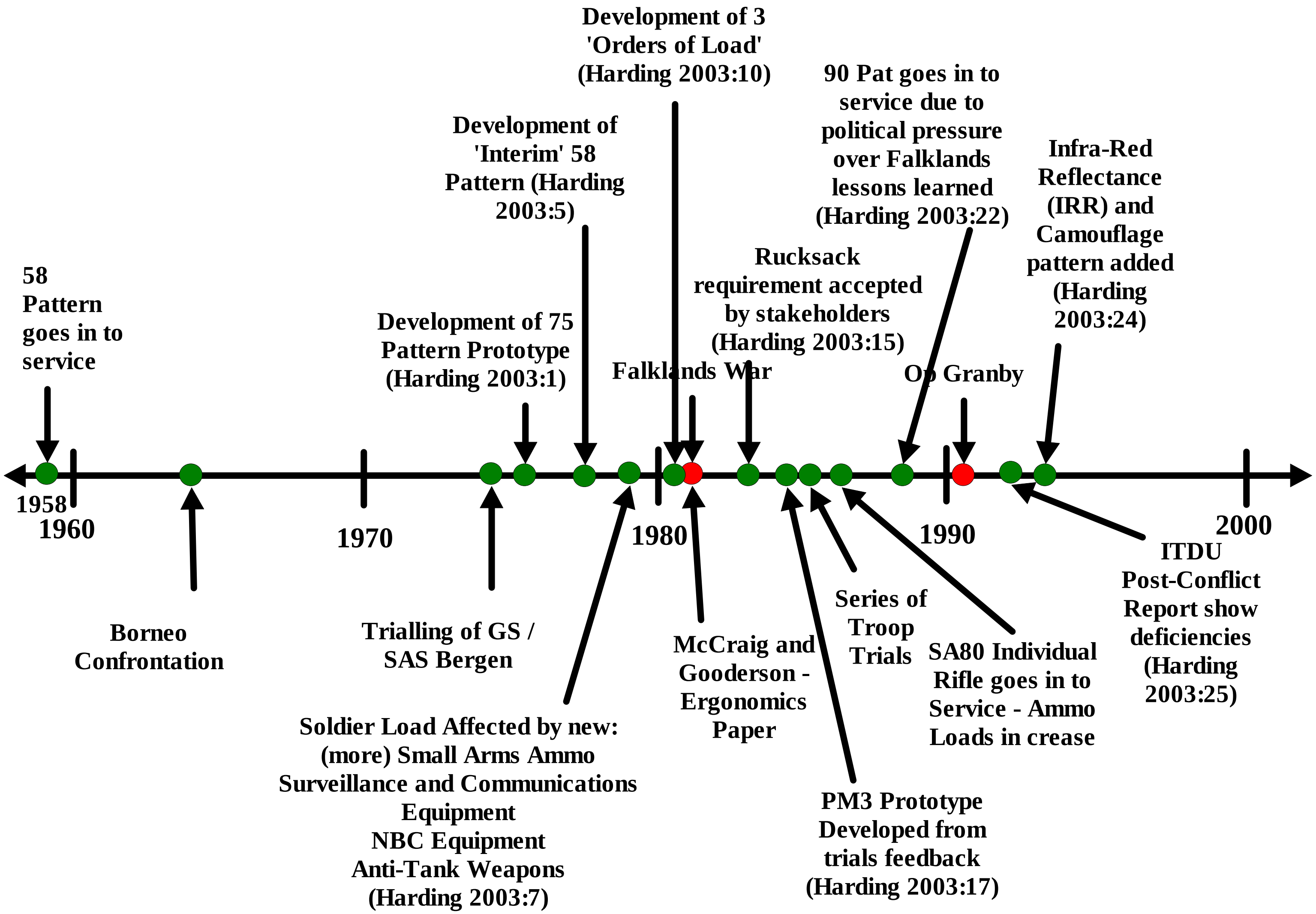

Figure 41. *90 Pattern timelines 1958 – 2000.*

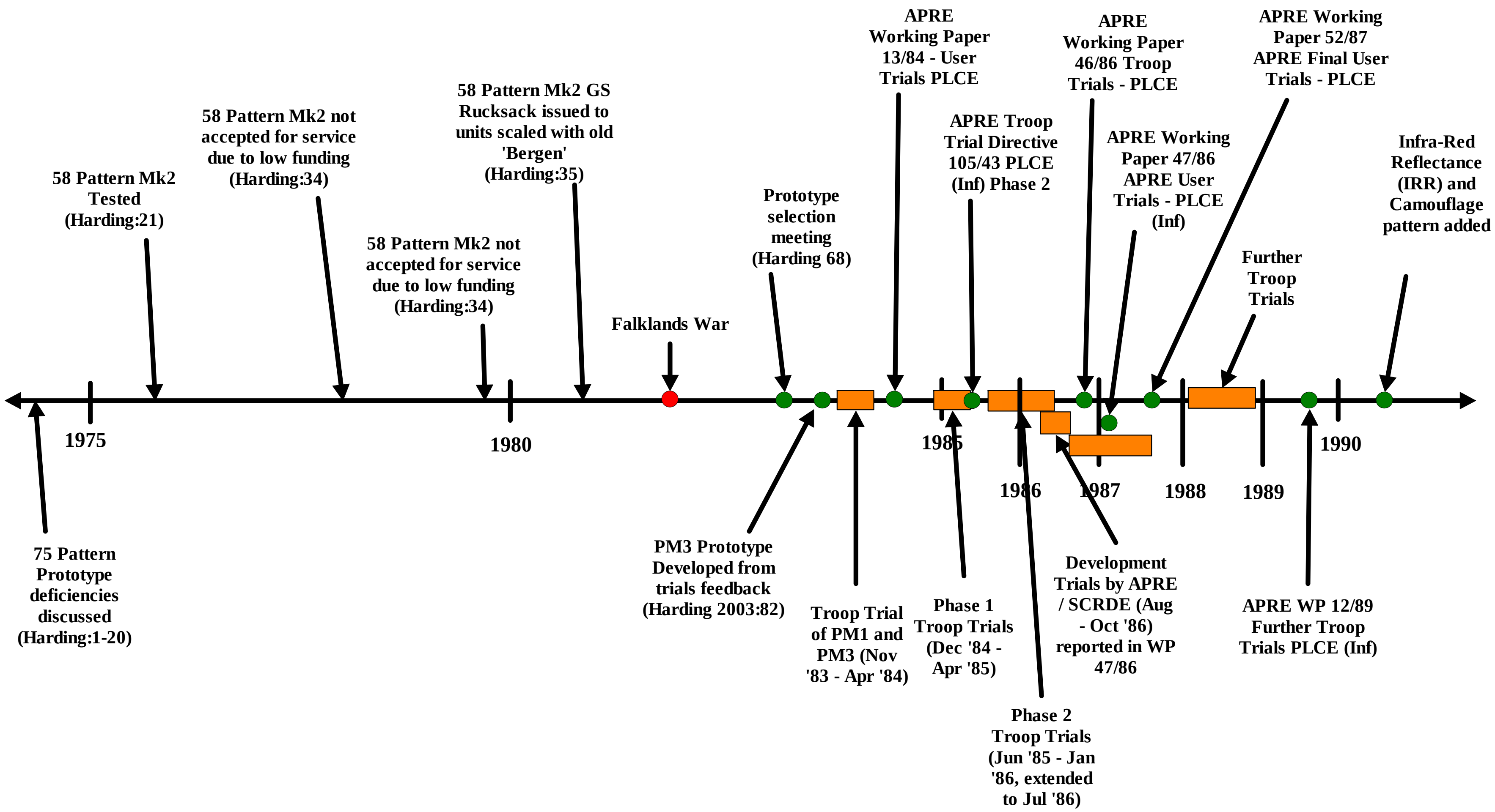

Figure 42. *90 Pattern timelines 1975 – 1990.*

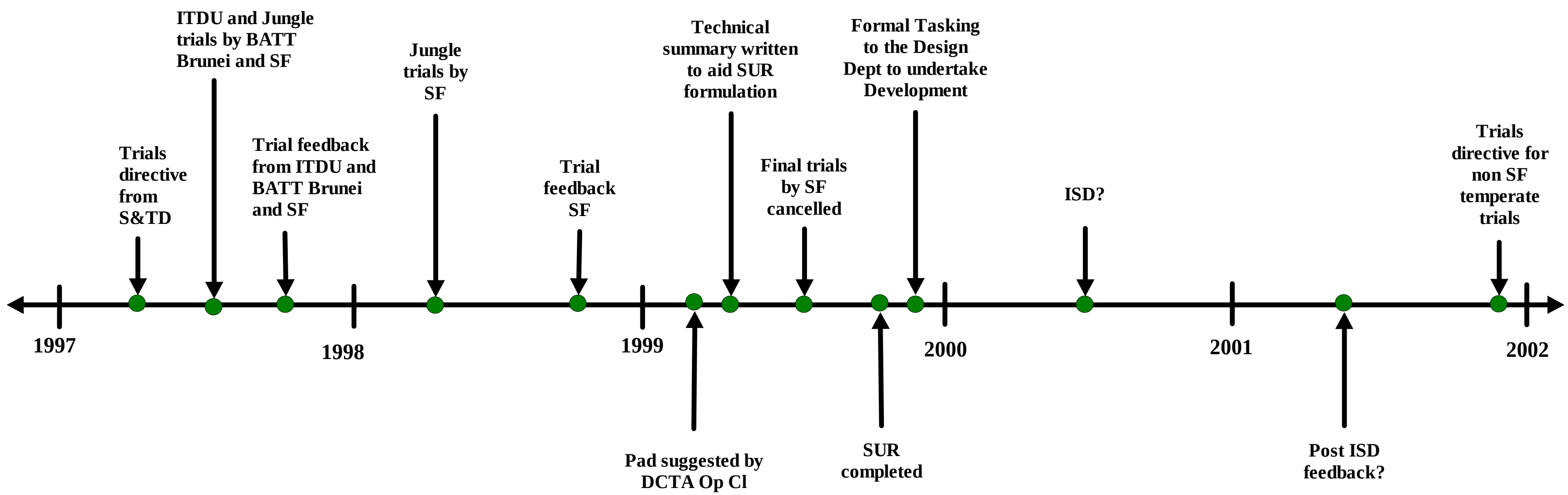

Figure 43. *Airmesh rucksack timeline.*

SSM Results – researcher's model of MLCE development

With the addition of SSM methods (see Section 5.3.1), it was possible to produce a view of the combined development processes (Figure 44). The model at this point in the research was only a theoretical representation of the MLCE development process. In due course the model needed to be compared with contemporary instances of MLCE development to establish it was a valid representation (SSM stage 5 in Figure 37).

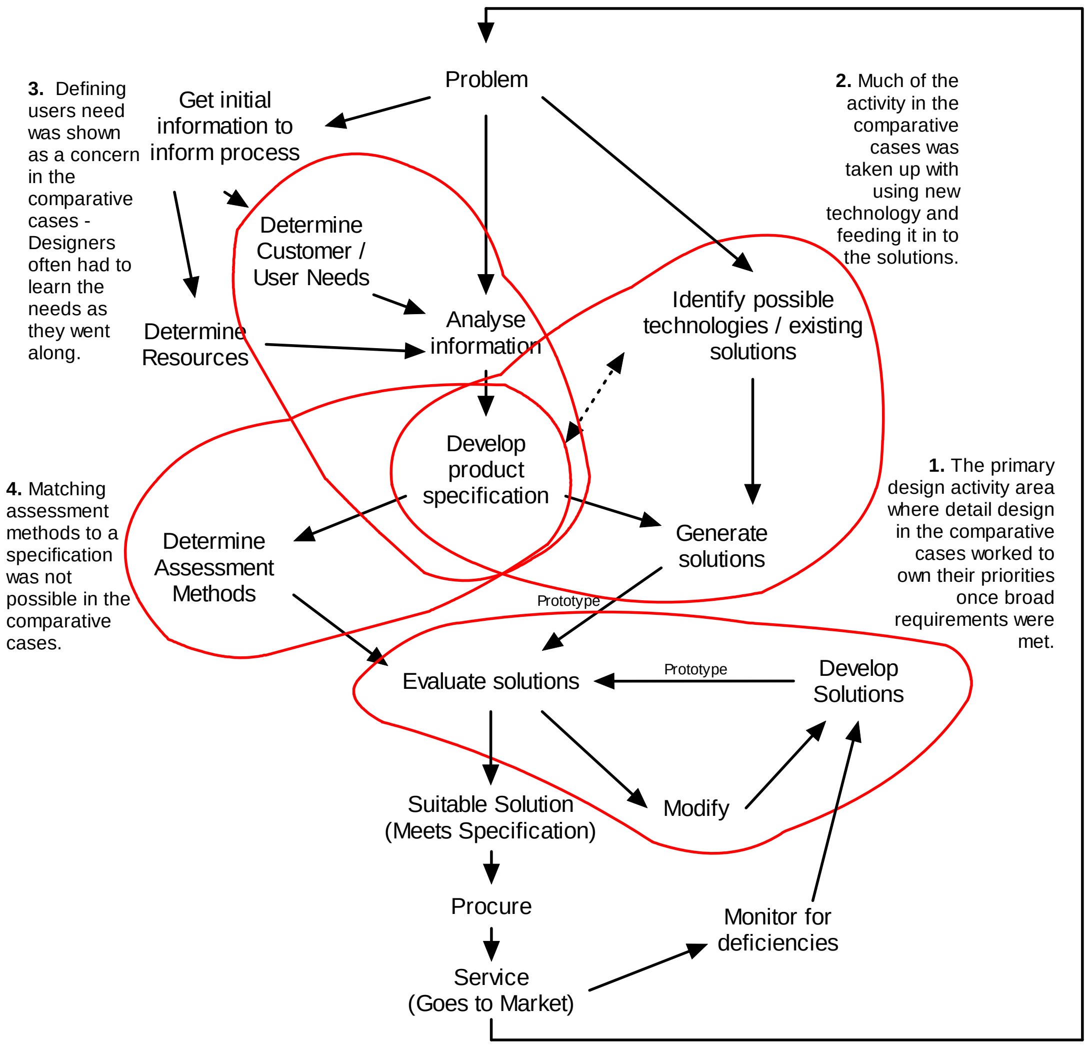

Figure 44. *Researcher's model of the MLCE development process based on historical data.*

The model shown in Figure 44 was used to enable the cross-case analysis and as an illustrative aid in discussing the results from the comparative study with stakeholders during later studies. In particular the four red outlined areas show the key findings as they applied to the development process.

5.4 Discussion

The comparative study was successful at providing illuminative insights into MLCE development; this has been possible by the characterisation of development, albeit in broad terms.

5.4.1 Comparison of cases

From the comparative study results it was clear that to date an evolutionary approach to MLCE development had been taken in both cases. The results from the two cases also show that different approaches to development could be taken, either of which can result in relatively successful MLCE. The difference in development approach between the cases was predictable given the different uses the two MLCEs were intended for and the organisational contexts which existed at the time of development.

The two cases were broadly similar despite the distinct user groups they were designed for; one was destined for a large varied group to be used during all tasks, the other for a small specialist user group for specific tasks. From this perspective none of the cross-case summaries were surprising and did highlight the need for MLCE development to be appropriate for the tasks being undertaken. It was also clear, however, from looking at these cases, that there was the possibility of improving the approach to MLCE development if the findings were compatible with contemporary cases.

Influences on MLCE Development

The influences on MLCE development in the comparative study cases were consistent with the influences from the literature review. There were some minor alterations in how expertise was defined as the difference between the various professionals became more clearly understood. To call the expertise influence ‘Design expertise’, as represented in Figure 21, did not show the expertise applied by development managers and human systems specialists. Changes to the influences on MLCE development are shown in red in Figure 45.

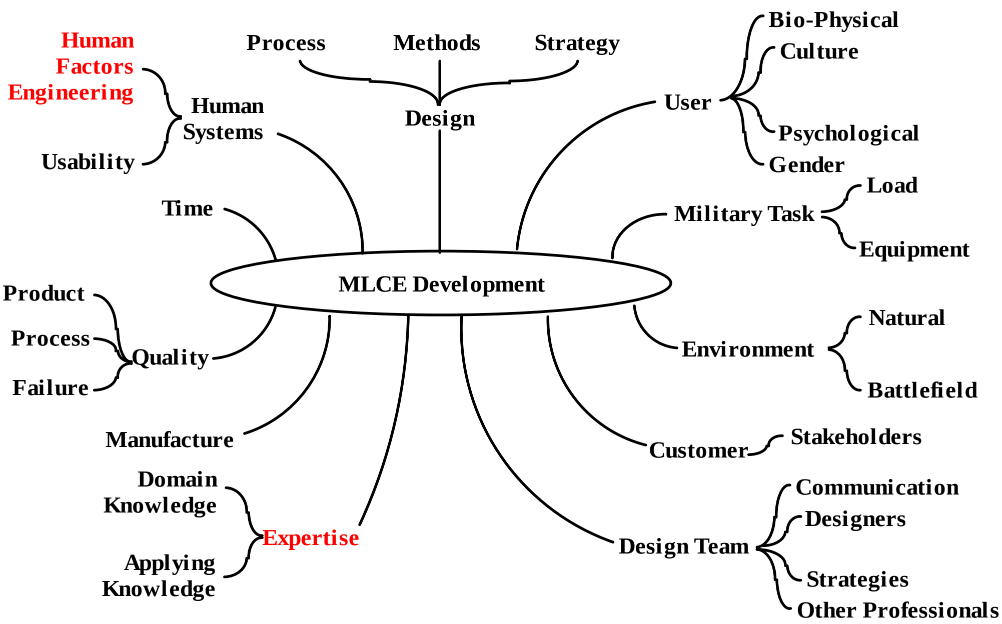

Figure 45. *Influences on MLCE development modified from Figure 24.*

Figure 45 as a representation does not show the interactions between the influences, or their relative importance. The approach in the comparative study was designed to explore the influences rather than to determine the interactions between influences in detail. Patterns of interactions did begin to emerge when one looked at the cross-case analysis presented in Tables 1 to 3 (in Appendix H) and 8.

The influences represented in Table 8 indicated that the influences were broadly similar for both cases. The main differences in influences being:

i) The level and nature of organisational constraint

ii) The way in which human systems expertise was used in development

Table 8 also shows how the cases compared, for example that the customers were different, explaining in part the differences in organisational constraints. Also the cases follow a similar development process with some differences in design approach, particularly their use of human systems expertise. The deficiencies noted in Table 8 show that the problems experienced were shared across both cases, and show that these might be enduring issues for MLCE design. This was determined in follow-on studies where experienced practitioners were able to give their own judgement of the influences on, and deficiencies in, contemporary cases.

Affect on design activity

Looking at the results from Tables 1 to 3 in Appendix H, the interaction of influences has a clear effect on the process of development, although it was difficult to get detailed insight into how they affected design activity. The results from the individual case study reports (Appendix H) show that this is because of a lack of evidence, so only broad conclusions could be drawn. What this illustrated was a lack of a clear design strategy and process and that the approach to the user needs was confusing. What could not be said, however, based on the evidence from the comparative study (even if these were contemporary cases), was how improvement to the MLCE development would affect design activity and result in better MLCE. From the literature review there was evidence to suggest that designers who use systematic approaches to design are more successful (Petre 2004). So determining what the development process is remained important, particularly if the representation was ultimately used by practitioners in the field. Therefore, the issues discussed above were likely to be key in answering Research Question Two and Three and needed to be addressed in follow-on studies.

Systematic approaches

Looking at the development approaches used in the comparative study it is clear that those involved used scientific approaches pragmatically. The approaches used, however, could not be described as systematic since the working stages were not clearly defined or transparent (Cross 1995). The main conclusion from looking at the results was that a more systematic approach may improve the effectiveness of MLCE development. A benefit of a systematic approach would be to improved communication during development.

Porter and Porter (1999) note three main communication issues, two of which were found in the comparative study:

1. Communication of ergonomics information at an inappropriate time; during the 90 Pattern development there were long delays as the user requirement was debated.

2. Communication difficulties within the design team; there is no clear linkage from the different user needs to the assessment approach during the 90 Pattern development.

Although there was no evidence of the third communication issue; 'communication of information and data in an inappropriate form, by ergonomists', within the comparative study, there was a lack in some instances of human systems information being used, when otherwise it might have been expected.

Additionally a systematic approach would enable an audit trial for the fitness for use and purpose of a developed MLCE, which was not evident in either case. In both cases there seems to be a partial understanding of how users perform, which may not allow the final MLCE solution[25] to be as effective as it might be. If a systematic approach to developing an MLCE solution is well handled then users' performance should be optimised and result in increased combat effectiveness.

The Researcher's Model (Figure 37) was an initial version of a systematic approach, since it picked the working stages apart from the comparative study cases, making them more transparent. The Model had been developed with knowledge of systematic design processes from engineering (Cross 1995, Roozenburg and Ekels 1995, Pugh 1991 and Ulrich and Eppinger 2004), clothing and apparel technology (Hardaker and Fozzard 1997, McKelevey and Munslow 2003, Eckert et al. 2000), and defence (Downey 1969 and UK MoD 2005). The model offered a way to compare other MLCE processes and provided a discursive tool to help establish common references, and so may address the communication issues discussed above. The model shows that the number of steps in historical cases of MLCE development was high and interrelated.

Development of product specification

The high number of early steps in the model that were orientated towards requirement capture was thought to have a strong influence on the later steps. This was contrary to the findings from the comparative study, where only some of these steps were

[25] This is certainly the case for 90 Pattern PLCE, which is showing optimisation problems, particularly for female soldiers.

evident. To mitigate the possibility that the model was inaccurate, it was shown to UK MoD development officers who agreed that these were the early stages from their perspective. They also added that the steps in practice were not clearly defined and that they often had to undertake the steps concurrently. For the development officers the key step was 'develop product specification', since it represents the synthesis of the previous stages and the conduit for managing the later stages. They were also clear that current MLCE development practice in the UK MoD began with a detailed written statement of user need. In discussion it became clear that this process could be problematic and heavily reliant on expertise within the UK MoD development office (finding repeated in Chapter 7).

Users within MLCE development

The comments above and the first steps in the model raised the question: how should user need be determined? In the military context user needs and expectations are often managed by using 'user requirements' within the defence procurement process (The Smart Requirements Model – UK MoD 1999). A good understanding of user requirements, however, is typically not handled well in the civilian arena, according to Pugh (1991), Holt (1989) and Busby (1998). Military culture may lead to under-reporting of problems which may have an influence on user requirements (Shepherd et al. 2003), as can happen in the civilian context (Weyman and Boocock 2001). The comparative study shows that in the past handling of user requirements was not done well. Looking at 90 Pattern development it was clear that part of the problem was the large number of different military users, including; Combat Arms (CA), Combat Support (CS), and Combat Service Support (CSS). 90 Pattern was designed to meet the needs of all of these user groups, although the tasks and roles they undertake, as well as their equipments, varied widely. It may be that this was a case of assuming that 90 Pattern was satisfactory for all users. Whether this was the case was uncertain, although the documentary evidence intimated it due to the varied debate about the needs in military publications about MLCE requirements. It was also clear that requirements did not consider future theatres of operations and future equipment coming into service in either of the two cases.

One way to focus on soldiers' requirements may be to adopt a User Centred Design (UCD) approach (Rubin 1994, Baber 2002, Jordan 1998). UCD includes individual user requirements throughout the design process to allow requirements to be built in to the system specification (Human Factors Engineering – HFE) along side other constraints and functional aspects (Stanton 1998). In order to achieve this, methods to capture user requirements are needed, as are techniques to evaluate any resultant concept (Rubin 1994). Barriers to this are: i) insufficient human factors information, ii) insufficient human factor techniques, iii) an inadequate systems design philosophy or approach (Harker and Eason 1984). Which of these are present in MLCE was not clear, although all three are to some extent factors from looking at the results of the comparative study. Arguably, however, UCD may have too specific a focus on individual needs which may skew a requirements capture away from the need of soldiers to act as a group during military operations. This is particularly important with the needs of military units changing when operating in the modern phenomenon of a three-block war[26].

What may be a problem in the future if military organisations manage, rather than conduct, MLCE design themselves is that they may rely on commercial designers who have little experience of designing MLCE. It will be necessary to get designers up to speed with how to design MLCE and to get 'under the skin' of the soldier system so they can appreciate users' needs and use of MLCE.

Human systems during the development process

Each case was different in how they used human systems expertise to support MLCE development (Table 9). Human systems expertise, however, although useful at different points, was a relatively low priority compared with other aspects of the projects (Table 1 in Appendix H). Human systems could be used in almost every stage of the researcher's model; as well as during evaluation trials and assessing candidate technologies. Areas that occur within the comparative study where human systems were arguably most useful, and could be useful in future MLCE projects, are shown in Table 9.

[26] A *Three Block War* describes military units having to operate in three different ways within an urban environment, peace keeping in the first city block, peace enforcement in the second, and warfighting in the third.

Human Systems Role in MLCE development	**Linkage to design**
Evaluating technologies / existing solutions	– detailed component design information
Evidence-based specifications	– key design requirements for capture within a Product Development Specification (PDS) (Pugh 1991)
Assessment methods for possible solutions	– support to design decision making
Establishing deficiencies after introduction to service	– comfort / durability problems during first years of service

Table 9. *Examples of how human systems expertise could be used in the researcher's model of MLCE development.*

The areas in Table 9 have been selected from the comparative study. Determining where human systems expertise could aid MLCE development most effectively needed clarification so that the results of the comparative case study could be built upon. From the comparative study it was clear that human systems had a strong role in the evaluation of a product after a prototype had been designed (Table 9). There are evaluation methodologies which looked at modelling soldier activities within a framework (North Atlantic Treaty Organisation 2005a). This framework was not focused on design or development, however, and so it was perceived that MLCE human systems knowledge was probably not well reflected within the framework. There was commonly accepted evaluation methodology for MLCE (North Atlantic Treaty Organisation 2005b) based on Canadian research which provides a framework for how human systems expertise and information could feed into MLCE development activity through iterative evaluations. The North Atlantic Treaty Organisation (NATO) (2005b) methodology was designed to aid in design development using standardised test methods to allow exchange of information between nations. The extent to which the methodology represented all the influences which affect MLCE development or test MLCE against a detailed requirement was not clear; however, it is a good step towards helping designers successfully address the human-related influences within MLCE development.

5.4.2 Answering the Research Questions

The comparative study has been successful in exploring some of the answers to the research questions but further research was required to answer them with more confidence. Since the results were based on historical information the findings are not a reliable indicator for modern instances of MLCE development. Table 10 shows the eleven informally prioritised influences on MLCE development from the comparative study.

Research Questions	**Research Answer Notes**	**Follow on research**
Research Question One		
What are the influences involved in MLCE development?	The following influences have been evident from the comparative study (See Table 14 and Figure 22):	
1.	Time	The historical results of the comparative study need to be confirmed by looking at contemporary cases.
2.	Human systems	
3.	Design – methods, strategies, processes	
4.	User	
5.	Military task	
6.	Environment	
7.	Customer	
8.	Design team	
9.	Expertise	
10.	Manufacture	
11.	Quality	

Table 10. *Contribution of the comparative study to Research Question One with an indication of follow-on research activity.*

The influences in Table 10 were difficult to put into a priority order due to the interdependence between them, but they are useful in challenging and testing the role influences played in both cases.

Research Question One

The comparative study has been useful in determining the influences on MLCE design which begins to identify an appropriate answer for Research Question One. The comparative study indicated that broad project pressures (like time and cost) seemed to influence design activities more than design orientated influences like the make up of the design team. This was thought to be due to the lack of evidence available to drive the detailed design activity being conducted in each case, and highlighted the need for further research.

The influences identified by the comparative study were thought to begin to provide some information to answer Research Questions Two and Three. It was thought that an understanding of the influences may give stakeholders, in combination with the Researcher's Model, a simple aide-memoire to some of the wider influences which affect MLCE development. Whether this would be of use to stakeholders had not been determined at this stage but offered a possible way to improve MLCE development if needed. This fitted with the findings of Research Question Two (Table 11, Research Answer Note No.3) and Research Question Three (Table 11, Research Answer Note No.9).

Research Questions	**Research Answer Notes**	**Follow on research**
Research Question Two		*(Green indicates there was good opportunity for follow on study, amber that there was existing information which can improve the process of MLCE development).*
What needs improvement in MLCE development?	The following aspects have been identified from the comparative study as being areas where development could be undertaken (See Table 19b):	These are historical results and need to be confirmed by looking at contemporary cases.
Note No. 1.	Formalised Human Systems (HS) support approach - flexible dependent on resources / problem situation - aid developers determine what HS support is needed.	This may be an area where considerable improvement may be possible.
Note No. 2.	Better requirement capture and handling approach - it is important to have auditable requirements which developers can challenge with users to look at the effect on technology on the requirement.	This area is arguably already addressed by a myriad of organisational guidance.
Note No. 3.	There must be an articulation of the process of MLCE development otherwise the various stakeholders: development managers / procurers, designers, users and Human Systems (HS) specialists will not have common reference by which to undertake development.	This is a possibility which could provide a benefit quickly if presented appropriately to the various stakeholders.

Table 11. *Contribution of the comparative study to Research Question Two with an indication of follow research activity.*

Again the information in Table 11, similarly to Table 10, needed the relevance to contemporary instances of MLCE development checking. Of the three areas for development summarised in Table 11, Research Answer Notes 1 and 3 have potential for being addressed in improving MLCE development. Research Answer Note 2, however, was arguably addressed by extensive organisational guidance and so further development work was not carried out. Once these areas for development had been explored in a modern context they needed to be checked with stakeholders to determine that the assumption was correct (see Chapter 8). Although the Research Answer Notes from Table 12 are summaries from Table 1 in Appendix H, Table 12 is an expression from the researcher's perspective of how these could be addressed in improving the process of development.

Research Questions	**Research Answer Notes**	**Stakeholders**	**Follow-on research**
Research Question Three			*(Green indicates there was good opportunity for follow-on study, amber that there was existing information which could improve development processes, red that the resources needed were beyond the means of this research).*
How can we develop the process of NPD in the context of MLCE?	The following are ideas for improving MLCE design following the comparative study:	The ideas would be useful for the following stakeholders*:	The following scoring indicates whether the ideas are appropriate for taking forward within the resources of this research.
Note No. 1	Designers tools	Designers	Look at specific areas where designers have gaps in their current toolset.
Note No. 2	Requirements – 'Getting under the skin of users'	Designers	Address how designers can become familiar with military user issues very quickly in an objective manner.
Note No. 3	Prototype assessments	Designers, development managers and users	Look at methods for objectively and scientifically assessing prototypes to inform MLCE development.
Note No. 4	Technology / Existing solutions assessments	Designers, development managers and users	Look at methods for objectively and scientifically assessing products / technology to inform MLCE development.
Note No. 5	Sub - component Guide	Designers and development managers	Look at how to collect successful instances of good MLCE design to inform design decision making and development management.
Note No. 6	Weight tools	Designers	Look at how weight can affect design decision making and give designers a better indication of how to mitigate high weight / bulk loads in design.
Note No. 7	Integrated human systems data capture	All	HS expertise required and funding for laboratory time.
Note No. 8	Human systems guide	Designers, development managers and users	HS expertise required to aid in formulation, some guidance available already (Humm et al 2006).
Note No. 9	Design process representation to enable design strategy / method formulation	All	Potential 'quick win' representation to enable discussions from stakeholders in MLCE projects.
Note No. 10	Military requirement capture guide	Designers and HS specialists	Military Requirements Managers in UK MOD expertise required
Note No. 11	Technical specification formulation guide	Development managers	Commercial sensitivities and changes to Research and Development (R&D) contracting make this problematic.
Note No. 12	Systematic approach	All	Expertise from all areas needed – ideally in a participatory project addressing most of the ideas above.
*Various stakeholders: Development managers, designers, users and human systems (HS) specialists			

Table 12. *Contribution of the comparative study to Research Question Three with an indication of possible improvements to MLCE development.*

The ideas presented in Table 12 were developed, in addition to Table 11, from the case study reports and discussions with human systems specialists and development managers. At this stage in the research the possibilities for improving development needed to be tempered by the requirements of current and future stakeholders involved in MLCE development.

5.4.3 Evaluation of the research approach and methods

The research method allowed a successful phenomenological exploration of MLCE development and enabled a model of the area to be generated. The nature of the documentary method used, however, meant that reflexive aspects were hard to mitigate due to a lack of evidence. The researcher found that a lot of information had been destroyed, with only key trials reports being held on file. However, the UK MoD's Army Historical Branch had many original records which made the study possible. The reflexivity of the method could have been improved if there were other researchers available to check the appropriateness of the sources used and conclusions drawn, as happens in traditional historical analysis.

Reflecting back on the research method selection in Chapter 4, if a technique like coding was employed in the comparative study the risk of failure would have been high. This was due to the relative inflexibility of the method and lack of balanced evidence needed to have confidence in the statistical output. The researcher also found immersion in the sources difficult while studying part-time, despite conducting the study during a period of leave.

Effectiveness of the comparative study

The effectiveness of the comparative study in providing answers to the Research Questions appeared to be sufficient in providing some interesting insights into MLCE development.

Research question and propositions from section 4.5	**Success of the comparative study in meeting the propositions**	**Possible research approaches**
Research Question One – What are the influences on MLCE development?	*(Green indicates that the proposition has been well met and no further research is intended, amber that some further research is needed, red that some insights are available but considerable work is needed).*	
a. By looking at the product development of existing MLCE it is possible to understand how the resultant products were designed?	The evidence trail for design is well documented and determining a process definition is possible in both cases.	
b. Identify the factors which influenced the resultant product.	Determining the influences which affected the resultant product is possible in a broad manner – clarify in a modern context.	Nominal Group Study, Delphi Technique.
c. How design decisions were made.	Yes at a project level relatively well, and to an extent how designers / HS specialists worked together to identify successful sub-components.	Survey or Interviews with practising designers.
d. It is also possible to see how success for MLCE is		
1. determined.	Clear criteria for the success of the MLCE don't appear to have been determined.	Interview with Development Managers.
2. how successful the designs have been in-service.	Evidence suggests that the designs have been successful in-service although deficiencies have been noted.	
3. whether they meet user needs during military tasks.	Deficiencies that have been recorded and the lack of detailed tasks being identified at the outset makes this hard to establish without better data.	Interview with development managers
e. The design information needed to design MLCE will be identified.	It is difficult to establish what information the designers needed in detail although some information is available, that is; sub-component success in use data.	Survey or interviews with practising designers.
f. It is possible then to evaluate the process of NPD and determine where there are deficiencies.	It is possible to identify some deficiencies based on current understanding of what constitutes good development processes – somewhat problematic since our understanding of 'good' development processes is also hard to define.	Survey or interviews with practising designers / Nominal Group Study or Delphi Technique.

Table 13. *Success of the comparative study in meeting propositions for Research Question One.*

Research Question and propositions from section 4.5	**Success of the comparative study in meeting the propositions**	**Possible research approaches**
Research Question Two - What needs improvement in MLCE development?	*(Green indicates that the proposition has been well met and no further research is intended, amber that some further research is needed, red that some insights are available but considerable work is needed)*	
a. Areas where attention is needed to enable improvement will be identified.	Areas for improvement can be determined from deficiencies (Proposition RQ1.f) – although this is based on historical information.	Survey or interviews with practising designers / Nominal Group Study or Delphi Technique.
b. It is possible to find where designers had problems during the design process and other factors that affect the success of the final MLCE.	Yes to an extent although designers are reticent to say they had any difficulties and problems in detailed design are not well documented.	Survey or interviews with practising designers.
c. There is a need for improvement in MLCE development either because:		
1. the product is deficient because of limited practice	There is little evidence of limited practice, although the organisational constraints of the time may have played a factor – the lack of data is a problem.	
2. The design decisions were made with insufficient evidence due to other pressures beyond the control of the design practitioners, e.g. time.	It is clear that organisational constraints and budgetary constraints were factors in both historical cases.	
d. Whether the use of design methods or tools would increase efficiency and effectiveness of MLCE development needs to be determined.	Reflecting on the development of human systems practice, organisational guidance and design tools there is room for improvement based on the historical cases.	Survey or interviews with practising designers / Nominal Group Study or Delphi Technique
e. If design tools are appropriate, places where they could be used as a support to good practice will be identified. The use and context of how the tool is used also needs to be understood.	These have been developed and outlined in Table 21. - Confirmatory work is required however to determine stakeholder requirements.	Survey or interviews with practising designers / Nominal Group Study or Delphi Technique

Table 14. *Success of the comparative study in meeting propositions for Research Question Two.*

Research Question and propositions from section 4.5	**Success of the comparative study in meeting the propositions**	**Possible research approaches**
Research Question Three – How can we improve MLCE development?	*(Green indicates that the proposition has been well met and no further research is intended, amber that some further research is needed, red that some insights are available but considerable work is needed).*	
a. By establishing areas within MLCE development which will enable an improvement, recommendations can be made on how to improve these areas.	These have been developed and outlined in Table 21. - Confirmatory work is required however to determine stakeholder requirements.	Survey or interviews with practising designers / Nominal Group Study or Delphi Technique.
b. By looking at MLCE development it is possible to identify information which can be used to improve MLCE development.	There are a number of areas where better information can be gained to improve our understanding of MLCE.	Nominal Group Study or Delphi Technique.
c. It is possible to begin to understand how designers design MLCE which gives an indication of how development might be improved.	Some insights have been gained but work remains to get contemporary insights as to how designers might improve MLCE development.	Nominal Group Study or Delphi Technique.

Table 15. *Success of the comparative study in meeting propositions for Research Question Three.*

Tables 13, 14 and 15 show that all but one of the propositions had been successfully explored and new insights gained. Tables 13, 14 and 15 also indicated that different research methods were needed to answer the propositions more fully. Most needed a group consensus to be determined using research methods such as interviews, surveys, Nominal Group Technique (NGT) or Delphi Technique (see section 4.7). (NGT was a similar method to Delphi Technique but had several procedural differences, defined in Chapter 7.)

From the comparative study there did seem that there were areas for improvement in MLCE development. These were tentative acknowledgements at this stage until contemporary instances of MLCE development were explored.

Knowledge gaps

The comparative study had also addressed some of the MLCE development knowledge gaps initially identified in literature review (summarised in Appendix I). The new knowledge appeared robust with regard to historical MLCE development but needed to be externally validated with instances contemporary instances of MLCE design, outlined in Chapter 7 and 8.

5.5 Chapter conclusions

This chapter has documented and discussed the development and results of the comparative study of two MLCE development cases.

Revisiting the chapter's objectives:

1. The conduct of the comparative study has been reported.
2. The results of the comparative study have been reported.
3. How the research can be taken forward to answer the research questions have been identified.

Key points to take forward:

1. The comparative study needed to be compared against a contemporary case of MLCE development to improve the generalisability of the findings thus far.
2. It was also desirable to seek an 'in-field' data to if design activity could be located.

Chapter 6: Exploring MLCE development through a contemporary case study

Towards the end of the comparative case study, the opportunity to corroborate the results against a contemporary MLCE development case became possible. This was done via a single-case study; based on documentary evidence and interviews. This opened the opportunity for more involvement with participants active in the area and further research.

6.1 Chapter introduction, aims and objectives

The comparative study (Study 2) was successful at providing insights into past UK MoD MLCE development projects; this however needed to be compared with contemporary case to see if practice had changed. Chapter 6 describes the conduct of an ‘in-field’ study (Study 4) which was undertaken to explore contemporary issues in MLCE development after the comparative study.

This chapter aims to discuss the methods and results for a study exploring and evaluating issues in contemporary MLCE development.

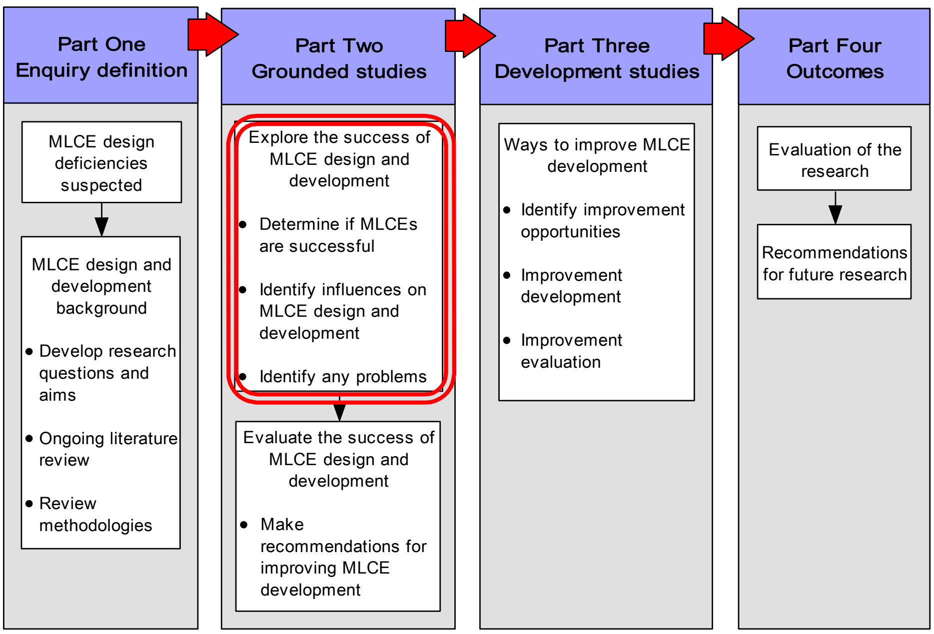

Figure 46. *Chapter 6 research map.*

The research map (Figure 46), is the same as for Chapter 5 since Study 4 was a part of the grounded studies exploring MLCE development.

Objectives:

1. To report on the conduct and results of the case study of contemporary MLCE development.
2. To discuss the results of the case study.
3. To determine how the research can be taken forward to answer the research questions.

6.2 Opportunities for research in a contemporary MLCE development case

Following the completion of the comparative study there was a need to gain more information about current issues in MLCE development to check the results of the historical comparative study. Initially the researcher had attempted to engage with civilian firms try to an initiate an observational study to explore contemporary insights in MLCE design. An observational study was, however, not possible due to commercial sensitivities that prevented access.

At this phase in the research, the opportunity for the researcher to be involved in a MLCE development for female soldiers in the British Army became available. The UK MoD’s development offices for MLCE, Defence Clothing Integrated Project Team (DCIPT), had asked the researcher’s employer, the Defence Science and Technology Laboratories (Dstl) to support the project. The researcher was then asked to contribute to a review of human systems literature related to MLCE design for females.

Becoming involved in the Female MLCE project required a review of the phenomenological approach outlined in Chapter 4 to see how this opportunity could be fitted into the research strategy. There was the chance, if appropriate methods could be found, to undertake some opportunistic studies if the researcher could establish a rapport with the stakeholders. In order to do this the researcher approached DCIPT (after some initial meetings) to ask if an observational study was possible, and, if not, if some short studies would be appropriate. Unfortunately due to the contractual sensitivities on the project observational research was not possible. There was the possibility of using the Female MLCE project as a single-case study of development, with the researcher being given access to some of the key documentation while at the development office.

The opportunity to undertake a single-case study and run a workshop as a contemporary study was the first step in the second cycle of the research. This is shown in Figure 47, which shows the single-case study in relation to the other research studies which had been conducted in Cycle 1.

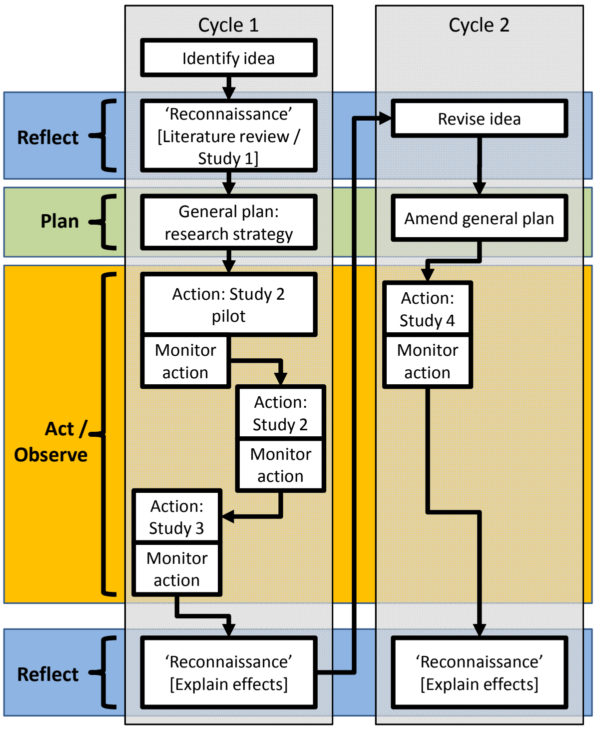

Figure 47. *Research cycles 1 to 2.*

6.3 Background to the Female MLCE Case Study

The Female MLCE development project was started in response to a perceived need by senior military managers to provide female soldiers with appropriate rucksacks. This was because of the in-service rucksack, 90 Pattern Infantry (Figure 30), caused discomfort, and possible injury, to female soldiers. Given the increase of gender-specific products in the civilian market it was felt that a better-fitting MLCE could be provided to female soldiers which did not cause discomfort. The project was treated as an urgent requirement and as such was expected to deliver results quickly and be handled sensitively due to interest by senior stakeholders. Due to its urgent nature, development was constrained to minimise the risk of producing a rucksack that would not fulfil military requirements or that would induce injury. This was done by limiting the design strategy to only re-designing the back system, but retaining the main rucksack compartment and lid, shown in Figure 30 (Chapter 4) of the in-service rucksack.

For commercial reasons DCIPT preferred contact with contractors on the project to go through them, this limited the opportunity for observational research. The Female MLCE project was studied from its conception up to the end of 2006, when the first trial was cancelled. The reasons for the cancellation are discussed in section 6.6.

6.4 Method

The method for the single-case study (Study 4) would be strongly affected by how easy it was to access data. Because of the researcher's involvement in the project and the good relationship with DCIPT, access to documentary evidence was good, although access to participants in the project was limited due to the sensitivities of the project. The challenge was therefore to find research methods that could gain valuable insights in this social and organisational context.

Appropriateness of approaches and methods within a grounded-theory paradigm

Methods that would be appropriate to study the Female MLCE project needed to be compatible with the grounded paradigm and phenomenological approach outlined in Chapter 4. Due to the assumption that more data would be available, methods such as *content analysis* were re-evaluated, although they were not appropriate for the comparative study. Content analysis has the advantage of not being reliant on the researcher for interpretation and so may have benefits when looking at reflexivity issues (McQueen and Knussen 2006). As a technique it was thought to be too resource-dependent and required access to more documents than would probably be available to provide a reliable output. Also content analysis was thought to take a long time to do unless a software package was used. Unfortunately neither of the above was available within the timescales or resources of the study, and so these techniques had to be discounted.

Research approaches

Due to the sensitivities on the project the most pragmatic approach which offered flexibility was to conduct the development study using a single case study approach (Stake 1994 in Willig 2001), with the Female MLCE project as the object of study. Since the Female MLCE project was a unique and arguably revelatory case this approach could be supported by research methods appropriate to the sensitivities mentioned in the sections above. However, there are some potential limitations of using a single case such as:

1. Misrepresentation of the case (confusion over its unique nature, and potential to provide novel insights).
2. High level of access to gain the evidence needed.

Both these limitations were from Yin (1994) and needed to be addressed before the single-case could be adopted as an approach and the methods with the approach could be determined. The first, misrepresentation of the case, could have been an issue due to the constraints placed on the project, but since the project was the only case available, it needed to be explored for potential insights. Indeed, the case was valuable to confirm some of the comparative study findings, given the organisational constraints of the Female MLCE project.

The second limitation, as has been discussed, was problematic, but given the researcher's role in the project, access to information and people was good if the appropriate methods were used to exploit the available data. It was also important to stress that building a good relationship with the DCIPT was also essential in gaining access beyond that usually allowed for a consultant. To this extent it was important to explain how information would be used in the study, and how DCIPT might get benefit from the research as a whole.

Research methods within the single-case study approach

There were two possible research approaches that could allow the single-case study to be successful given the constraints surrounding the project:

1. Use a single-case form of the case study approach used for the comparative study, and the methods used within it.

2. Determine a new approach, using alternative methods which would link to the Research Questions in a different way.

Advantages and disadvantages of modifying the methods within the comparative case study approach

The main constraint in establishing appropriate methods within the single case study approach was the linkage to the Research Questions. The case study questions for the comparative study were established with a link to the Research Questions using propositions (see Chapter 4). The problems encountered during the comparative study were not thought to impact the effectiveness of the case study questions, namely; gaps in evidence. It was thought possible with the Female MLCE project to get access to more complete information than for the comparative study. The documentary analysis method for gaining information and answering the case study questions could be applied largely unchanged. There would be a need to use interviewing to allow for the capture of information from the development managers in DCIPT.

Artefact analysis

The other source of data that was used for the comparative study was the rucksacks themselves. As it transpired, access to the artefacts being designed for the Female MLCE project was a problem since they remained with the industrial contractors until they went on trial. The researcher did manage to review the rucksacks after the trial was cancelled; therefore visual inspection of the rucksacks was possible and a basic evaluation carried out with feedback going to DCIPT. (Pictures of the prototypes are not included for confidentiality reasons.)

Account Study

A method which was an alternative or complimentary approach to the case study was an account study. Accounts in Cohen et al. (2000) are largely placed within the ethnographic paradigm or applied market research and seek to explain phenomena from the perspective of participants in complex situations. Market research uses diary panels as a data-gathering approach and requires participants to record information about their behaviour using diaries and video diaries (Crouch and Housden 1996, Desai 2002). Additionally, market research uses techniques such as interviews and story boards to elicit information about behavioural reactions to situations and products (Crouch and Housden 1996). An account protocol was worked up by the researcher (see Appendix J) and account templates were issued to participants, but ultimately it became problematic for people to complete their accounts due to work commitments.

Selected methods

Due to the timescales of the study it was decided to use the comparative study approach and methods within it due to the established linkages to the Research Questions through the Propositions. The Propositions were reviewed and found to be appropriate for the single-case study. The comparative study approach was also known to the researcher, who had confidence that it would produce a valid output in a phenomenological context. The outputs from other methods made this less certain since they may not have given any explanation as to what was happening on the project. Additionally the comparative-study approach provided a good way of comparing the single-case versus the cases in the comparative study.

6.5 Results

The single-case study was completed towards the end of the Female MLCE project. Several meetings with the DCIPT development manager were held during the project to keep abreast of project changes, and records of the meeting were kept in note form by the researcher.

The detailed results from the single-case study can be found in Appendix K, with the process definitions and timelines presented in this chapter.

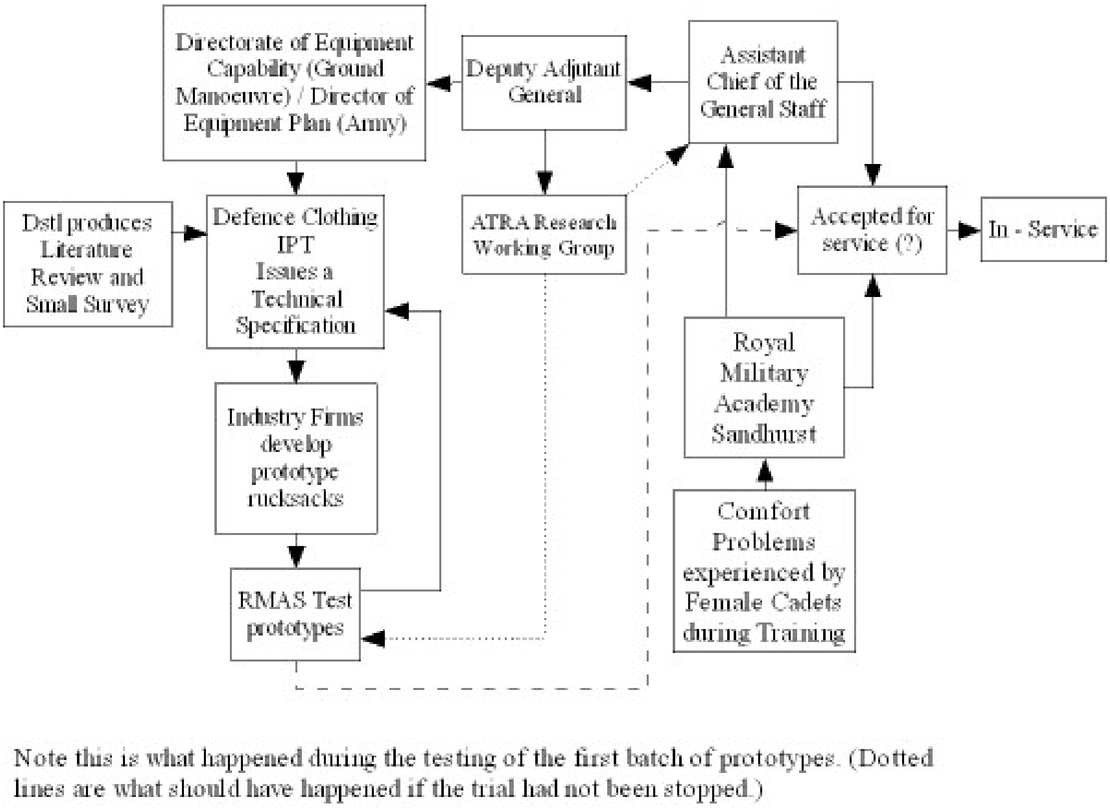

Figure 48. *Diagram for the process of development for the Female MLCE Project.*

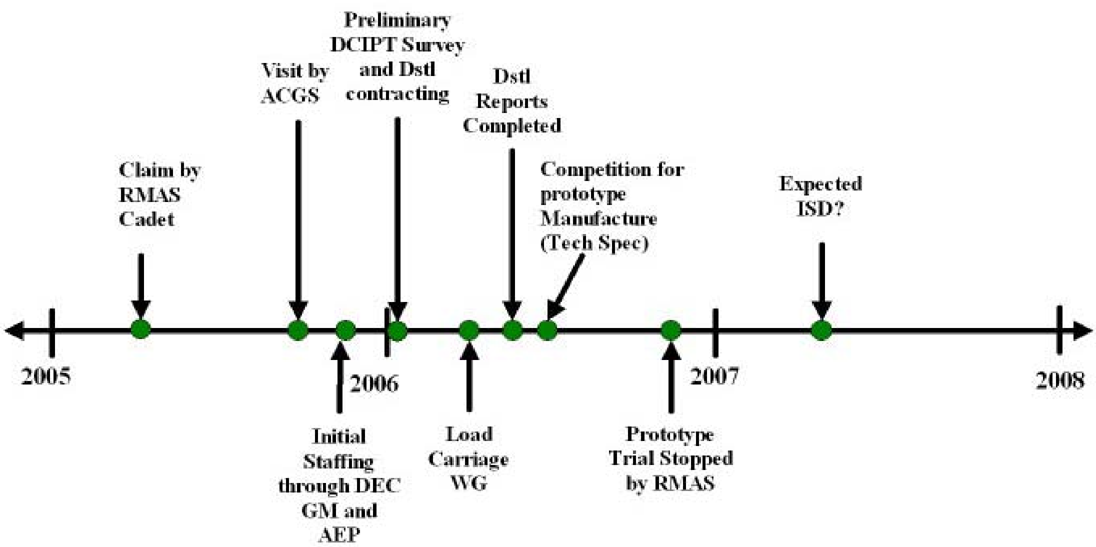

Figure 49 . *Timeline for Female MLCE project.*

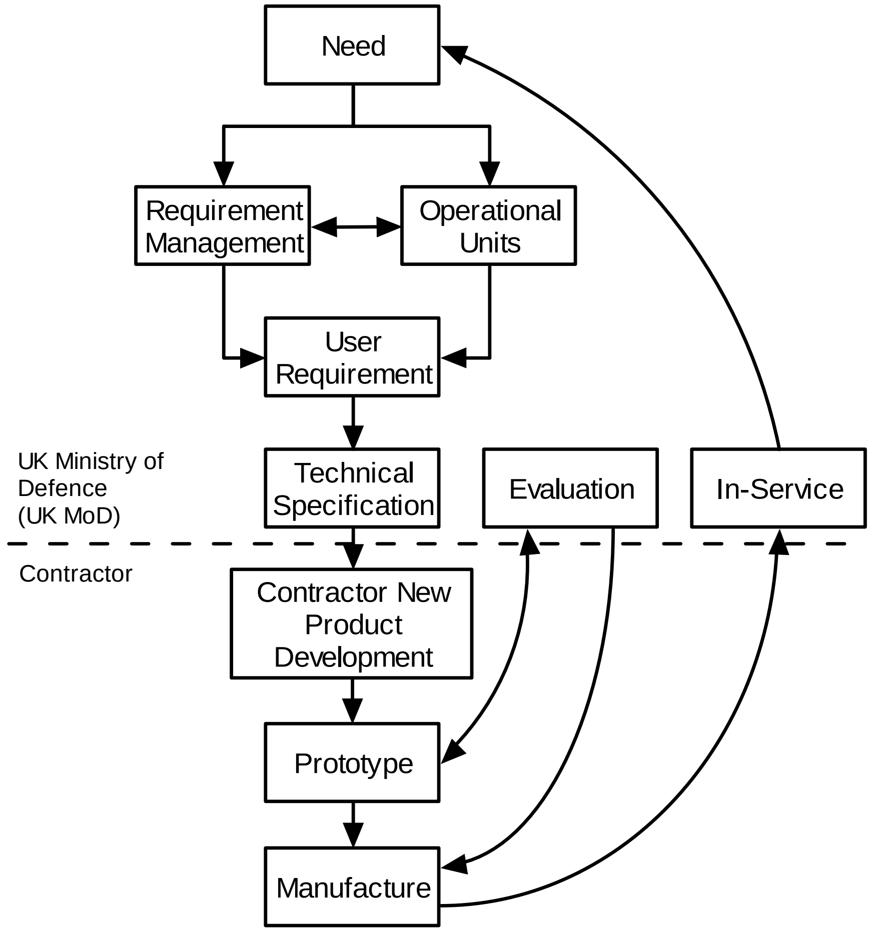

Figure 50. *Current defence procurement process for MLCE, developed from discussions with DCIPT.*

6.6 Discussion

The Female MLCE project highlighted some important lessons and issues related to the contemporary practice of MLCE development, most notably because (to date) it has not produced a successful design in the eyes of stakeholders.

The process definition diagram for the Female Load Carriage project shows the interactions between the various stakeholders in the development (Figure 48), and was useful for understanding the high-level organisational motives for the project. It was also useful in understanding the influence that senior stakeholders had in establishing the project boundaries. These boundaries, however, did not impact design activity apart from determining the speed with which the development was to be undertaken in the case, and trials conducted (since the trials were cancelled this did not take place). Trials appear to have been distinct from ergonomic inputs to prototype development but were intended as tests, confirming the prototypes did not cause injury.

As a part of trying to understand the interactions during the development, the researcher compared the process-definition diagram (Figure 48) versus the Researcher's Model (Figure 44). This helped to develop Figure 50, which DCIPT agreed was a good representation of the development approach they used for the project, since it showed the relationship between the firms undertaking the design work. The lack of iteration in Figure 50 was surprising, but was accounted for by the short time scales. It could be adequately modified by linking the 'Evaluations' box to the 'User Requirement' box and or 'Technical Specification' box, which would more adequately represent what happened on the project once the trials had failed.

Figure 49 outlines the main activities undertaken and shows the short development time (mainly conducted in 2006). Time was arguably the most important influence on this case because it drove decision-making on the project.

There were found to be four key influences which accounted for the limited effectiveness of the development to date, which were set in the context of the tight schedule for the project:

- Confusion of requirement
- Access to ergonomic knowledge and expertise
- Experience of MLCE design
- Knowledge of the military environment

Confusion of requirement

At a late stage in the development the trials were stopped due to the prototypes not interfacing with in-service 90 Pattern belt order. Essentially the 90 Pattern belt order conflicted with the large hip belts of the Female MLCE Project prototype rucksacks (they both need to sit on the waist and hips in order to function correctly). The decision by the trials unit to use 90 Pattern belt order was confusing since the Technical Specification (and User Requirement) stipulated that the prototypes were to be used with waistcoat load carriage, so freeing the hips to allow for better distribution of the load. This was thought to have been determined between DC IPT and the operational unit, as outlined in Figure 48, which shows the broad process which DC IPT follow for MLCE developments. The researcher, however, did find the need for the ultimate solution to be compatible with belt order in the minutes of a meeting at the outset of the project. As it turned out the users at the trials unit refused to use the waistcoat load carriage for certain tasks. This may point to a lack of definition of the User Requirements and limited capture of specific user needs, although this cannot be confirmed due to a lack of evidence. This raised whether the Technical Specification was the most effective way to seek innovative ideas from industry. Ryd’s (2004) study of design briefs as a carrier of customer information indicated that an evolving briefing process may be a better way to meet customer need and give designers an understanding of a project.

Application of ergonomics

The confusion above was linked to the application of ergonomics expertise in the development, which could be applied to determine accurate and detailed user needs information which could have been used to direct design activity. With the benefit of hindsight this was an easy assertion to make, but one which could have allowed the designers to come up with more appropriate solutions if identified earlier. It was encouraging that some human systems data was collected (the Dstl Reports) to explore the problem space (although this data was filtered by DCIPT to the designers). The development strategy was constrained at an early stage so that re-development of 90 Pattern belt order was not undertaken to allow its use with rucksacks. If re-development of the 90 Pattern belt order was to be undertaken it was arguable that the last two factors; experience of MLCE design, and knowledge of the military environment, may have proved a greater challenge to the project. The other deficiency with regard to ergonomics was the lack of prototype evaluation prior to limited user trials. Had this been done, in consultation with the user, then it would have provided an opportunity to ensure that the prototypes were fit for use and purpose.

User culture

An underlying influence which impacted the two factors above was user culture. Users are familiar with 90 Pattern belt order and are anecdotally known to prefer it for infantry tasks, since it allows them to adopt low profiles, move quickly and carry appropriate equipment. 90 Pattern belt order was issued to all soldiers and has been regarded by experienced users as sufficient for all soldiers, all of whom are taught infantry skills as a basic skill set. The decision to use waistcoats with the prototypes would not, in the eyes of some experienced users, allow female soldiers to adequately perform when undertaking infantry tasks. This was confirmed by the secondary evidence available, but does open the question as to how user culture affects user needs for MLCE development. In addition this highlights the need for objective ergonomics information gained by engagement with users, which can then be used to inform MLCE development approaches and design decision making.

Interlinking of factors

The four key factors outlined at the beginning of this section were interlinked, particularly the last two. Looking at *Experience of MLCE design* defined as the knowledge of what sub-components work in MLCE designs and how they relate to specific user needs. There were points in this case where guidance has been needed

by designers in understanding the user requirements and how user needs affected the MLCE solutions they were pursuing.
The need for guidance may point to either:

1. A lack of clarity in the expression of the user requirement in terms of specific user needs, thus requiring DC IPT to 'unpack' requirements.

2. Lack of *knowledge of the military environment* which may have allowed designers to 'unpack' the needs themselves.

The evidence was inconclusive concerning which of these reasons were the causes and it is possible that both are important in allowing the designers to develop appropriate solutions.

Comparison with the comparative-study cases
The development strategy to alter the back system was probably appropriate, given the short timescales. The confusion and lack of definition of user needs in the single case study limited the ability of the designers to produce effective solutions. The comparative study cases were broadly successful, despite limited user needs definition. The comparative study cases were dealing with evolution of MLCE, rather than what may be regarded in the single-case study as a radical departure from existing equipment. It was likely that in the single-case study the changes were too extreme a departure for some users and the lack of a participatory approach, which provided evidence that their concerns and needs were not represented in the proposed solution. This ideally would be explored with users, but was not possible due to access limitations and the failure of the trials.

The single-case study also differed from the others in that access to designers with a detailed knowledge of the military environment was limited due to the development approach. It could be argued that more information should have been released to the designers to inform their design activity. Whether this would have made a difference cannot be certain, particularly given the confusion over user needs which ultimately limited the solutions the designers could offer.

Emerging needs from DCIPT

As the study progressed, however, it became clear that there was a need for DC IPT to determine better ways of working with designers in the commercial arena. In particular DC IPT were concerned that civilian designers did not have the experience of military requirements which meant they had to invest much time in MLCE design themselves. This was a position that they believed would continue due to the increasing organisational pressure for competition that may prevent them from being so heavily involved. An additional pressure on DCIPT was the reliance on internal staff's expertise. One of the aspects that they were interested to monitor from this research was possible ways of educating new DCIPT staff (including military personnel) and designers new to UK MLCE development.

Answering the Research Questions

The case study was very useful in gaining more information to answer the three research questions.

Research Question One – What are the elements involved in the process of NPD in the context of MLCE?

The single-case study shows the importance of getting the beginning stages of the development project correct to prevent problems later in development. Table 20 outlines the main influences on the single case which had the greatest impact on the project, particularly at the outset. The influences on the single-case study shown in Table 20, although complex, were traced from the results and added nuances to our understanding of the influence on MLCE design. The priority of influences should not be regarded as authoritative because of the overlap and linkage between them, but rather as a guide to how this case progressed through development.

Research Questions	Prioritised influences	Follow-on research
Research Question One		
What are the influences involved in MLCE development?		
1.	User (culture)	Confirmation of these factors across a range of development projects
2.	Military task (user requirements)	
3.	Legislative (injury)	
4.	Time	
5.	Customer	
6.	Expertise	
7.	Human systems (ergonomics)	
8.	Design team	
9.	Environment	

Table 16. *Contribution of the single case study to Research Question One with an indication of follow-on research activity.*

It was also clear that listing influences in order of priority did not indicate or aid understanding because the data that sat behind them was not transparent. This made answering Research Question One difficult at this point, not least because this project had not been as successful as intended. What was clear was that research data from across a range of the other MLCE developments was needed to add some clarity to how influences interfaced and linked. Comparing Table 16 with the results from the comparative study (Table 10) revealed similar prioritisation of influences despite very different project contexts.

The single-case study had added a new influence in the concern over comfort of personnel and the mitigation of injury, which was not so strong in the comparative cases. This could be linked to an increased awareness of the ‘duty of care’ the UK MoD had to service personnel, and the necessity of ensuring the load carriage provided was fit for use by both genders.

Research Question Two – What needs improvement in MLCE development?

The single-case study provided additional insight in how to answer Research Question Two, most notably the perceived need for more support between the interface between the development managers (UK MoD) and industry (designers). A critical aspect of this according to DCIPT was improving the generation of the Technical Specification from a User Requirement (shown in Figure 50). As has been mentioned this was difficult even for an experienced development manager, but was also problematic if the User Requirement underpinning it was deficient.

On the industry side there was a need for better access to information, since they only had a technical specification to work to, and had limited access to the user environment.

Solutions to these problems were best summed up tentatively at this stage in the research, since they may only be problems associated with this project (Table 17).

Research Questions		**Follow-on research**
Research Question Two		*(Green indicates there was good opportunity for follow on study, amber that there was existing information which can improve the MLCE development, red that pursuing this avenue would be problematic).*
What needs improvement in MLCE development?		
1.	Increased understanding of user requirements – and their subsequent influence on MLCE development and design.	This area was arguably already addressed by a myriad of organisational guidance, but the latter aspect was poorly understood.
2.	Better use of ergonomic expertise to provide information to development management and design activity.	This may be an area where considerable improvement may be possible.
3.	Improve the knowledge of designers of the military environment.	This could be achieved not only by direct experience, but by better access to information.

Table 17. *Contribution of the single-case study to Research Question Two with an indication of follow-on research activity.*

Table 17 also began to explore where research might be best focused to answer Research Question Two. It was clear at this stage that Research Question One had to be answered using data across a range of MLCE developments to ensure that any improvements were correctly focused.

Evaluation of the research approach and methods

The use of a case-study approach to look at a single case of MLCE development was successful from a phenomenological perspective, in that new insights were discovered as well as confirmatory evidence of some of the findings from the comparative study. The effectiveness of the single-case study was judged to be sufficient, taking account of the sensitive nature of the project and issues raised during the development. The findings from the study were checked against the propositions from the comparative study approach and are shown in Tables 18, 19 and 20.

Research Question and propositions from section 4.5	**Success of the comparative study in meeting the propositions**	**Possible research approaches**
Research Question One - What are the influences involved in MLCE development?	*(Green indicates that the proposition has been well met and no further research was intended, amber that some further research was needed, red that some insights were available but considerable work was needed.)*	
a. By looking at the product development of existing MLCE is it possible to understand how the resultant products were designed?	The single-case study successfully characterised the process of MLCE design for this project which aids in answering this proposition at a high level.	
b. Identify the factors which influenced the resultant product.	An exploration of the influential factors has been possible, although further exploration is needed to ensure the identified ones are generalisable to other MLCE cases.	Action research, survey, or interview.
c. How design decisions were made.	Since access to designers was not possible this has been explored through secondary sources.	Survey or interviews (with practising designers).
d. It is also possible to see how success for MLCE is		
1. determined .	The study has been able to show how success for this project was determined and how it was intended to meet these targets.	Survey or interviews with stakeholders / action research.
2. how successful the designs have been in-service.	This has not been determined (to date) due to the failure of the trial although it has been possible see some aspects which lead to prototype failure.	Revisit the case study findings as information becomes available.
3. whether they meet user needs during military tasks.	This study was not able to interview users (due to the sensitivities of the project) but has been successfully explored through secondary sources and determined that some user needs were not met.	Revisit the case study findings as information becomes available.
e. The design information needed to design MLCE will be identified.	An exploration of the sources of information was possible, although the resource developed (the Dstl reports) have not been accessed by designers it was highly useful to the development managers.	Survey or interviews with practising designers / action research.
f. It is possible then to evaluate the process of NPD and determine where there are deficiencies.	It was possible to evaluate the process of NPD taken and to determine where there are areas for improvement, although these should be compared with other instances of MLCE development.	Survey or interviews with practising designers / action research.

Table 18. *Success of the single case study in meeting propositions for Research Question One.*

Research Question and propositions from section 4.5	**Success of the comparative study in meeting the propositions**	**Possible research approaches**
Research Question Two - What needs improvement MLCE development?	*(Green indicates that the proposition has been well met and no further research was intended, amber that some further research was needed, red that some insights were available but considerable work are needed.)*	
a. Areas where attention is needed to enable improvement will be identified.	These have been identified for this project rather than all MLCE projects.	
b. It is possible to find where designers had problems during the design process and other factors that affect the success of the final MLCE.	Areas where designers have had problems have been identified from the perspective of development managers. Access to designers was not possible due to commercial reasons.	Survey or interviews with practicing designers.
c. There is a need for improvement in MLCE development either because:		
1. the product is deficient because of limited practice.	This was not established from the study; there were strict limits on design activity and the level of innovation that designers could offer. Much of the development risk was placed on the UK MoD.	Survey or interviews with practising designers / action research.
2. The design decisions were made with insufficient evidence due to other pressures beyond the control of the design practitioners, e.g. time.	It was possible to explore this area linked to the proposition above, and there was evidence that many factors were beyond the control of the designers.	Survey or interviews with practising designers / action research.
d. Whether the use of design methods or tools would increase efficiency and effectiveness of the process of NPD in the context of MLCE needs to be determined.	It was not possible to determine this because of limited access to designers. There was an inferred need for better use of ergonomic tools to inform and aid the design decision-making process.	Survey or interviews with practising designers / action research.
e. If design tools are appropriate, places where they could be used as a support to good practice will be identified. The use and context of how the tool is used also needs to be understood.	A number of opportunities within the context of this project for a better use of design tools were determined.	Survey or interviews with practising designers / action research.

Table 19. *Success of the single-case study in meeting propositions for Research Question Two.*

Research Question and propositions from section 4.5	**Success of the comparative study in meeting the propositions**	**Possible research approaches**
Research Question Three – How can we improve MLCE development?	*(Green indicates that the proposition has been well met and no further research was intended, amber that some further research was needed, red that some insights were available but considerable work was needed.)*	
a. By establishing areas within the MLCE development which will enable an improvement, recommendations can be made on how to improve these areas.	This area was successfully explored with regard to improvement for this project.	Survey or interviews with practising designers / action research.
b. By looking at NPD in the context of MLCE it is possible to identify information which can be used to improve MLCE development.	This area was extensively explored through the researcher's involvement in the literature survey. It was not possible to determine what other information designers needed however.	Survey or interviews with practising designers / action research.
c. It is possible to begin to understand how designers design MLCE which gives an indication of how MLCE development might be improved.	This area was not extensively explored due to the lack of opportunity for observational research. It was possible to explore it through secondary sources however.	Survey or interviews with practising designers / action research.

Table 20. *Success of the single-case study in meeting propositions for Research Question Three.*

Tables 18, 19 and 20 show that the single-case study had been successful in contributing to answering the research questions in the context of this MLCE project. The majority of propositions were explored, some, due to limitations of access to participants in the development and project issues over the requirement, were not looked at in as much detail.

The single-case study provided a good base from which to further explore MLCE development using studies which were coherent with the phenomenological approach outlined in Chapter 4. Further cases were not available to explore MLCE development, therefore, other research approaches and methods had to be considered. Fortunately because of the relationship that had been built up during the single case study with DCIPT, they agreed to a workshop to explore MLCE development and to characterise the influences that affected it.

6.6 Chapter conclusions

This chapter has discussed the methods and results from studies exploring and evaluating issues in contemporary MLCE development.

Revisiting the chapter's objectives:

1. The conduct and results of a case study of contemporary MLCE development has been reported.
2. The results of the case study have been discussed.
3. How the research can be taken forward to answer the research questions has been outlined.

Key points to take forward:

1. It was necessary to confirm the findings of the case studies to build the reliability of the findings to date.
2. The influences on MLCE development were becoming better established through the studies, but the relative importance of the influences needed to be established to better answer RQ1.

Chapter 7: Exploring MLCE development through a nominal group workshop

In order to provide additional information to aid in developing a reliable picture of contemporary MLCE development, the researcher negotiated a small workshop with practitioners active in the area to explore the influences on MLCE development. This study helped to corroborate the results of the contemporary case study, prioritise the influence on MLCE development, and provide a firmer base for conclusions drawn from the grounded studies.

7.1 Chapter introduction, aims and objectives

Through working on the Female MLCE project (Study 4) there was the opportunity to gain information about the influences on MLCE design from the people involved in MLCE development through a one-day workshop. The workshop was hosted by DCIPT who enabled the participation of a current MLCE contractor.

This workshop study builds upon information from the comparative study and single case study to answer Research Questions 1 to 3 in that it looks at contemporary influences, gaps in knowledge, and what may need improvement in MLCE development. The approach taken did not critique the Female MLCE project, but took the opportunity to reflect on the practice of MLCE development and highlight any opportunities for improvement. This study's relation to previous research and place within the cycles of research is outlined in Figure 51.

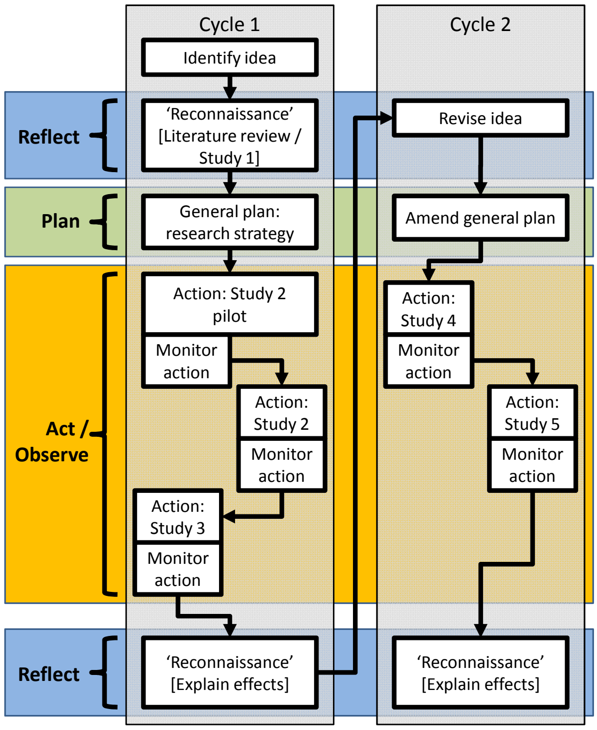

Figure 51. *Study 5 within the research cycles.*

This aim of this chapter is to report on the conduct of a workshop with practitioners involved in MLCE development to look at contemporary influences on MLCE development.

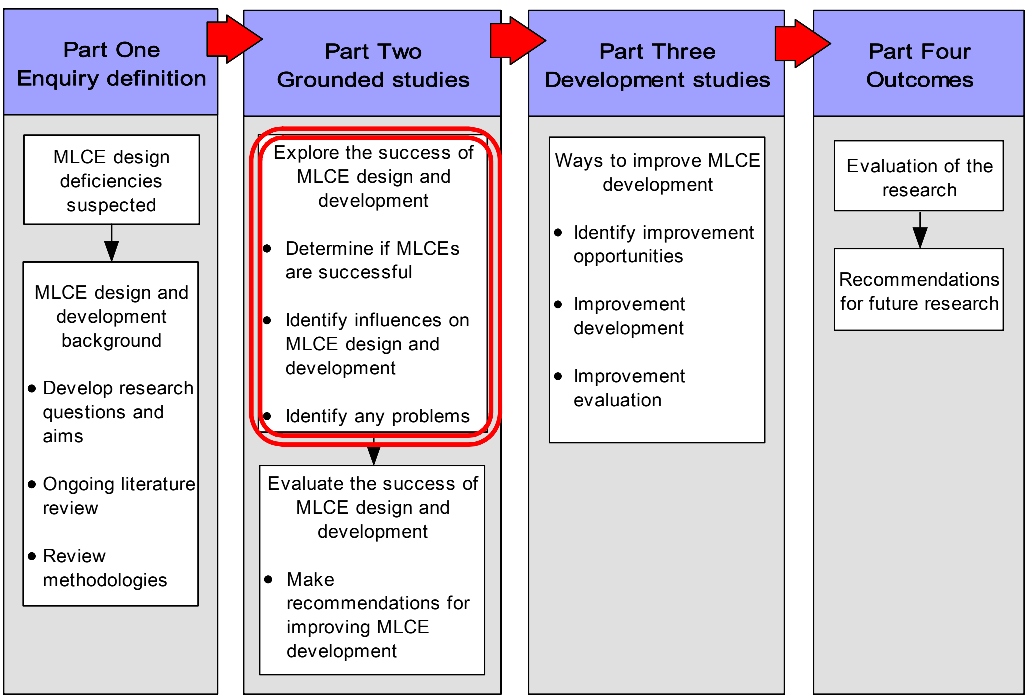

Figure 52. *Chapter 7 research map.*

Again the research map in Figure 52 for Chapter 7 is the same as Chapters 5 and 6, since it is a part of the grounded studies.

Objectives:

1. To report on the method, conduct and outputs of the workshop.
2. To discuss the output from the workshop.
3. To determine how the research can be taken forward from this study to answer the research questions.

7.2 Method

The method adopted for the study needed to:

- Fit within the research strategy
- Be simple for participants to engage in data capture
- Be dependent on minimal resources
- Build on existing understanding of knowledge about MLCE development in a systematic way

Selection of research method

Initially it was thought at the end of the comparative study that the Delphi Technique may have been used to gain a contemporary understanding of MLCE development (Chapter 4). The Delphi Technique was originally developed by the RAND Corporation during the 1960s to investigate a complex or ambiguous area with a structured process. The technique uses a panel of experts to develop a number of structured statements regarding the area being studied. The process occurs in three or more rounds and aims to achieve consensus amongst experts. The technique could have been useful in that it does not require experts to meet, but was constrained by the way in which information was given to the panel and how they could respond.

The Delphi Technique, however, requires an appropriate starting idea or context to stimulate debate and get participants interested. Data from Delphi sessions can also be very labour intensive to analyse, which adds to the time it takes to conduct a full Delphi study. Therefore a similar but shorter duration method, Nominal Group Technique (NGT) was identified as being an alternative. NGT was developed by

Delbecq and Van de Ven in 1968 (Rohrbaugh 1981), as a way of mitigating the biasing effect of dominant personalities in group 'brainstorming' and decision-making sessions. A nominal group was defined as a non-interacting group, although NGT was usually conducted face to face where interaction between participants was structured (MacPhail 2001), where as the Delphi technique was done remotely and anonymously. NGT has often been compared with Delphi and despite the differences in the time the two take to operate there was no conclusive evidence as to which is more accurate (Rohrbaugh 1981 and Rowe and Wright 1999). There were examples of NGT use in the medical arena (Raine et al 2004), education (O'Neil and Jackson 1983 and MacPhail 2001), information management (DeSanctis and Gallupe 1987 and Dowling and St. Louis 2000), and engineering (Beruvides 1995 and Duggan and Thachenkary 2003). Another advantage of NGT was that it is relatively easier to learn (Beruvides 1995) and did not require the resources and careful application which Delphi necessitates (Rowe and Wright 1999). Recently Dowling and St Louis (2000) have developed a method which follows the NGT stages but that can be done remotely by participants. This method, while interesting, was unsuitable since the appropriate software was unavailable and would take longer than a workshop session.

The NGT workshop envisaged for this study was to elicit problem solving strategies and ideas from the workshop participants and to explore and evaluate the process of development of MLCE. By using NGT in this way the combined ideas and consensus generated could be evaluated and consequently could accurately represent the combined judgement of the workshop participants (Duggan and Thachenkary 2003).

In summary, the benefits of NGT that make it appropriate to this study were:

- Speed of data capture
- Clear differentiation between idea generation and evaluation-enabling analysis of the data
- A 'brainstorming' effect that allows identification of more factors due to group interactions
- Participants encouraged to contribute

- Effects of group dynamics and researcher bias are kept to a low level by well-structured stages
- Ease of implementation by novice facilitators

The method used in the workshop followed the steps outlined in Rohrbaugh (1981), O'Neil and Jackson (1983) and Duggan and Thachenkary (2003) (Figure 53).

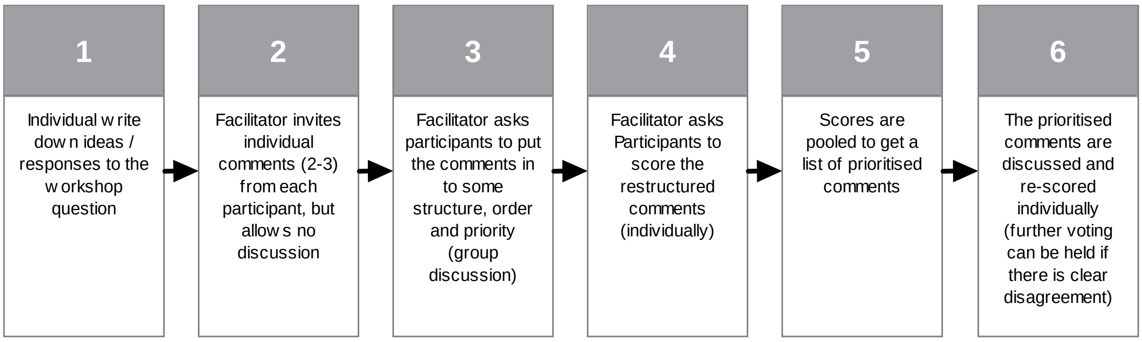

Figure 53. *Diagram showing Nominal Group Technique stages adopted for this study.*

NGT, as used in this study, could be viewed as a specific period of action research, since the stages of an action research (see Figure 30) mapped on to the process outlined in Figure 53:

- Planning – pre-NGT planning with DC IPT
- Acting / observing – NGT workshop
- Reflecting – post-workshop analysis, feedback provided and discussed with DCIPT

Selecting participants

NGT works best with 8 – 10 participants (O'Neil and Jackson 1983) to have a better chance of getting divergent ideas to stimulate discussions. The number of people involved in MLCE development was limited, but it was thought possible to get this number participants. The smallest number of participants was set at four participants representing each professional area involved in the development project:

- Designers
- Development managers

- Human scientists
- Military requirements managers (not able to attend)

Format for the workshop

The question the participants are asked to consider at the NGT Stage 1 was:

'Analyse and explore the way military load carriage is currently developed'

This was then explored and evaluated by following the stages of NGT in Figure 53. Evaluative issues were raised during the discussion phases of the workshop, where evaluative data was looked for. The Researcher's Model (see Figure 44, Chapter 5) was also introduced and comments collected on whether, after the consensus of NGT Stage 6, the representation was still correct. This evaluated the MLCE development process derived from earlier studies.

This approach was piloted with analysts familiar with the soldier environment before the workshop, using a simpler question to tease out some of the practicalities for the actual NGT workshop.

Data outputs

The data outputted from the workshop were:

1. Individual ideas and comments on the process of MLCE development (NGT Stages 1 and 2)
2. Notes on group two discussions (NGT Stages 4 and 6)
3. Scored participant comments (NGT Stages 5 and 6)
4. Comments on the detailed design process from the comparative case study

These outputs were qualitative and so analysis was done by comparing elements within and between the four outputs above. One of the most critical outputs was the third, the scored participant comments, since this contains the consensual agreement between the participants about the contemporary MLCE development.

7.3 Results

The panel consisted of five people (others having work commitments), each representing a different professional area of MLCE development; Development Manager (Government), Designer (Industry), Sales Manager (Industry), Ergonomist (Government) and Physiologist (Government). The meeting lasted four hours and was held in a quiet conference room at Defence Logistics Organisation (DLO) Caversfield, Oxfordshire.

Development of a prioritised ranked list

Construction of the prioritised ranked list of influences produced a good discussion about how the various influences on MLCE development interacted and were characterised (NGT Stage 3). The comments on the influences, despite being introduced by different people, were broadly accepted by the panel and were written up on a flip chart by the researcher (Figure 54). During the discussions the facilitator added detail that gave further clarification and definition to each comment, as directed by the participants.

Figure 55 shows the average scores of importance for the influences on MLCE development, Table 21 giving the total scores for each influence.

Figure 54. *Figure showing the brainstorming sheets used to record the influences on MLCE development at the NGT Workshop.*

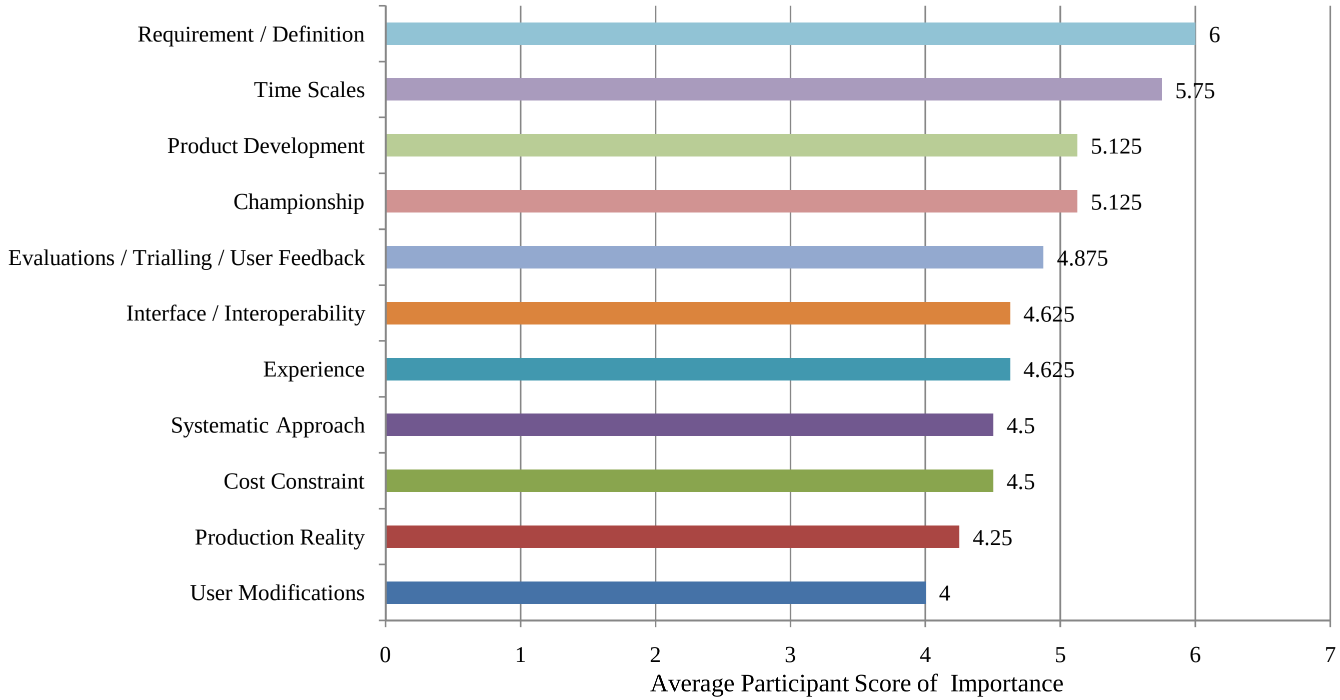

Figure 55. *Scoring of influences on MLCE Development by stakeholders at the Nominal Group Workshop.*

Comment Serial	Comment	Total Score	Average Score	Importance Ranking
A	Requirement / Definition	30.0	6.00	1
B	Cost Constraint	24.0	4.80	3
C	Time Scales	28.0	5.60	2
D	Championship	23.5	4.70	5
E	Product Development	23.5	4.70	5
F	Systematic Approach	21.0	4.20	9
G	Production Friendly	22.0	4.40	7
H	Evaluations / Trialling / User Feedback	22.5	4.50	6
I	Experience	21.5	4.30	8
J	Interface / Interoperability	20.5	4.10	10
K	User Modifications	20.0	4.00	11

Table 21. *Table showing results from the NGT workshop scoring.*

The following were the main insights from the workshop, based on the discussion of the results before and after scoring:

- Relatively few people had detailed knowledge of the whole development process represented in the Researcher's Model.
- There was broad agreement about the main areas of importance for MLCE development – 'requirement' was most important initially, but after this different aspects varied in importance in different stages through development.
- Cost was not a driver in initial product development – it was a strong driver later in development.
- Use of evaluations remains ambiguous – explained, to an extent, the varying use of human factors expertise in the comparative study and single-case study.
- A systematic approach was perceived by the three government participants to be essential for future MLCE development projects – but there was uncertainty as to how to achieve this approach.

Most important influence

The participants thought that *requirement* was undisputedly the most important influence on MLCE development (see Figure 55). Timescales were deemed to be next in importance, arguably because of their impact on prototype development. The placement of the other influences was as per the prioritised ranked order before the scoring, with the exceptions to this having a low level of consensus.

7.4 Discussion

Cost drivers in prototype development

The first issue raised during the discussion of the scoring (shown in Figure 46) was with regard to the level of consensus than the requirements of costing constraints. This was felt to have a lower consensus since costing constraints have a varying effect depending on the stage in the development process. Cost can be managed in a manner of ways by the MoD depending on the nature of the MLCE project, either by undertaking cost-neutral design alterations or alternative contractual arrangements.

It was argued by the non-government participants that the biggest driver on MLCE development was cost, although this was disputed by the designer and development manager present, hence the lower scores. Costing MLCE development was thought to be difficult and highly constrained by the contracting approach used by the customer. The point was made that often industry may be forced to 'make down to a cost', although in the initial product development it emerged that cost was regarded as a driver by designers. Subsequently the initial prototyping cost was felt to play a part in influencing design as the prototype(s) were developed and specified for manufacture. The influence of cost was felt to vary through the stages of development and it was a fine balance to avoid affecting the end design and creative thinking in a detrimental manner. Cost was also strongly related to the timescales of the development since cost and time constrained the number of iterations of prototypes conducted. It emerged that MLCE designing relies heavily on seeing a three-dimensional prototype to identify areas where improvements to the design can be made, and was essential to producing a good design. It was also mentioned that getting 'a good feeling' about the design was important in knowing whether the design was likely to be successful and that this was only really possible with a prototype, drawings being hard to interpret. The initial product development stage emerged as being important since the production of prototypes supported the other aspects of MLCE development.

Interface links

The interfaces between the comments were noted on the brainstorming sheets (Figure 54), in order to show how some could be linked or combined. The areas that were linked in this way fell into three areas of MLCE development:

- Evaluations

- Systematic approaches
- Interface / interoperability

These were all felt by the participants during the discussion to be important but were hard to define within MLCE development. The first two had a wide reaching effect on the whole development process:

Evaluations: This area was easier to characterise since it was understood that the nature of evaluations was dependent on the MLCE project being undertaken and contains aspects of ergonomic testing and user feedback as well as formal user acceptance trialling. This meant that evaluations were defined by the time and project resources and the goals in terms of whether the requirement requires a high level of design innovation or an evolution of an existing design. It was also felt that evaluations were often difficult to conduct due to the low priority given to them in MLCE defence procurements to date. There was also recognition that evaluations do not need to be hard to achieve and that they can demonstrate comfort and fit (fitness for use) relatively quickly. Interaction with the user and gaining good feedback was also highlighted as being critical not only to Evaluations in checking that the MLCE was fit for use and purpose, but also to the design activity. The designer present highlighted the importance of knowing how well certain design features worked so that they could be used in other MLCE developments.

Systematic Approaches: This area was the hardest to define because it has such wide influence throughout MLCE development, as shown in the first scoring in Figure 55 and Table 21. Participants thought the only way to get into some of the 'softer' issues (for example; comfort) addressed in MLCE development. How a systematic approach could be achieved was uncertain from the discussion, partially because of a lack of clear definition.
Interface and interoperability: The MLCE's interaction with people, equipment and the wider environment was characterised as having an influence throughout MLCE development. In the discussion it was mentioned that this area was closely related to defining the requirement, but also has to be dealt with in any design solution. There was no discussion of how to manage this area within MLCE development.

Derivation of requirement and link to technical specification

An interesting debate was over the definition of the requirement and the derivation from the requirement to a technical specification from which industry could work. It was raised that requirements often may not be forthcoming or well written and so there was an element of interpretation by civilian development managers and designers. The interpretation of the requirement was citied as enabling the generation of a suitable technical specification to help contracting with industry and enable the product development process. It was also mentioned that the interpretation was heavily reliant upon experience. The researcher asked whether industry received enough information from the requirement / technical specification to enable it to undertake product development. The broad answer was that industry did get enough information, although this was only possible due to good relationships between the personalities involved. The example of the Female MLCE project was given as an example of how informal regular meetings facilitated industry in developing prototypes (this concurred with the findings from the single-case study).

Championship in MLCE development

The next most important comment was felt to be the championship and leading of the development. This was a broad comment aimed at explaining that there was a need for ownership for MLCE developments. During the discussion it was explained that this could be exhibited at different levels, but that it was important for the project to have consistent contact and direction for it to be successful. It was also mentioned that this was very difficult to organise and undertake with the variety of approaches that the MoD had used over the past years.

Integration of design features

The importance of the comments beyond Production Friendly (Figure 55) proved more problematic, as the reasons why they were still important was harder to determine. They were known influences but the participants found it difficult to establish their importance beyond identifying their links to other comments, and so ascribed the best priority they could. User Modifications and Production Friendliness were thought to be important aspects with regard to how features on MLCE were treated in the development process. This lead to a discussion on how the MoD could integrate design features from different firms either by paying for the Intellectual Property Rights (IPR) or by making alternative contracting arrangements.

Concluding the workshop – improvements to MLCE development

To complete the workshop the researcher asked whether there was a need for more design-orientated guidance in industry, to see if there were any areas that were felt to need improvement in the MLCE development process. The answer from all participants was that any up-to-date information was useful, with information on load distribution being a key area of interest for industry. Establishing systems information was thought to be a priority for the MoD due to future projects trying to develop MLCE which would work with other equipment. With this goal in mind it was thought that determining wider systems interfaces for MLCE was important. Summary comments from the workshop:

- Interesting insights were discovered, particularly of the influence of cost on design and development
- Outcomes from the workshop should be compared with other views of MLCE development to see whether the findings are common to other nations and the civilian manufacturing market
- Good indications of how to take the research forward in two priority areas were:
    - Load Distribution
    - Systems (and interfaces) information

Note on second scoring

Due to the strong consensus and subsequent debate, the participants felt there was no need for a second scoring since they thought that the scores adequately represented their opinion.

Answering the research questions

The findings from the NGT study were compared to the findings from the previous studies to help answer the research questions. The information gained from the NGT study helped mainly in providing additional information to answer Research Question One, since it was concerned with understanding the influence on MLCE development rather than where improvement was needed. The NGT helped to provide a non-contextual view of MLCE development, since a pre-requisite for participation was that specific projects should not be discussed. This aided objectivity and reflexivity issues with previous studies and established the opportunity for better definition of the influences on MLCE design.

Evaluation of the research approach and methods

The group produced a strong consensus on the influences, but may not have mitigated all the effects of a group 'effect' in that only one person from each discipline was represented. The reticence of firms to undertake this type of workshop with other companies present also created a difficulty.

The following were the lessons learned from the NGT workshop:

- This method was difficult to set up and apply in this design context due to commercial sensitivities (industry were not willing to discuss these things while other firms were present).
- There are relatively few designers / developers working in MLCE development at the moment within the UK (there are more globally and within the civilian arena), therefore it was very difficult to get experienced developers to attend.

Next step from conducted studies

At this stage in the research five studies had been undertaken to explore MLCE development. In addition to the two case-study approach-based studies there had also been the opportunity for the researcher to explore MLCE development with stakeholders in an NGT workshop, thus representing a specific period of action research. This offered the opportunity to triangulate the findings from the three studies conducted. These five studies, however, did not offer quite enough information and evidence with which to adequately answer the research questions with confidence, because of the small number of stakeholders consulted. Additionally the cases studied to date were UK projects, and it was uncertain as to whether the same influences had affected other nations' MLCE projects.

There was a need therefore to validate aspects of the findings to ensure that the identified influences represented what happened in instances of MLCE development beyond the cases used. It was important that the findings from the conducted studies had sufficient *external validity* (see section 4.4 for a definition of validity) to be generalisable to most MLCE development projects, as implied by the research questions. The way forward from these studies was:

Research Question One – Establish an approach to confirm the definition of the influences and their relative importance by engagement with experienced stakeholders in MLCE development.

Research Questions Two and Three – In seeking to answer Research Question One, establish an approach for eliciting information from experienced stakeholders on their opinion of whether and how MLCE development could be improved.

The above approaches were thought, therefore, to improve the reliability of the workshop's findings.

7.5 Chapter conclusions

This chapter has reported on a workshop with practitioners to look at contemporary influences on MLCE development.

Revisiting the chapter's objectives:

1. This chapter has reported on the method, conduct and output from the workshop with MLCE development practitioners.
2. The workshop outputs have been discussed and findings outlined.
3. How the research can be taken forward to answer the research questions has been outlined.
4.

Key points to take forward:

1. To enable the results of the NGT workshop to be used in a generalised manner to look at other instances of MLCE development, it was important to seek the views of other practitioners in the field.
2. It was also important to clarify what might be perceived as needing improvement by others in the field.

Chapter 8: Investigation into contemporary views of MLCE development through a survey of expert practitioners

To give greater confidence in the reliability of the findings from the previous studies it was important to look at what the views were from other specialists in the area outside of the studies conducted to date. This provided the opportunity to canvass the views of MLCE practitioners in three other countries, all of whom had considerable experience of the area.

8.1 Chapter introduction, aims and objectives

This chapter describes a phenomenological study conducted to extend the exploration and evaluation of MLCE development with a survey of expert practitioners. Following the studies looking at contemporary MLCE development, discussed in studies four and five, there was a need to explore other instances of MLCE development (see Chapter 4).

This chapter aims to discuss the methods and results from the survey of expert practitioners in contemporary MLCE development.

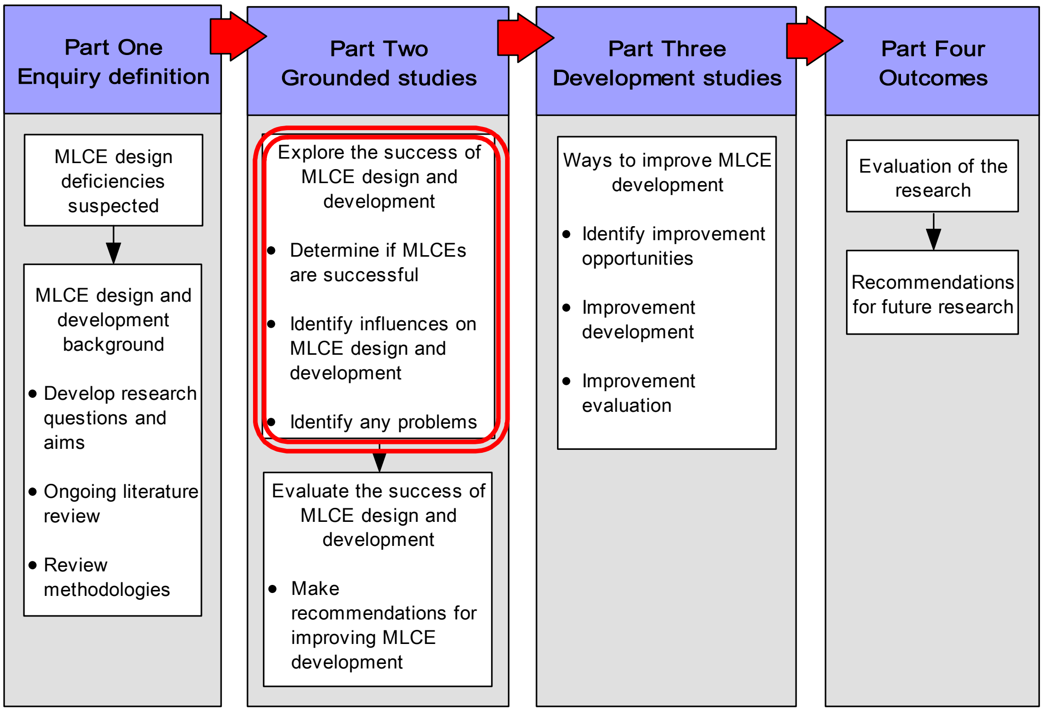

Figure 56. *Chapter 8 research map.*

The research map for Chapter 8 (Figure 56) is the same as for Chapters 5, 6 and 7, since it is a part of the grounded studies.

Objectives:

1. To report on the design, conduct and results of the survey
2. To discuss the results and determine how they could help answer the research questions

8.2 Opportunities for a contemporary priorities study

The aim of the study was to elicit information on current views of MLCE development from professionals in the field, and build a better understanding of the results of the previous phenomenological studies through triangulation.

Objectives of the survey:

a. To establish the relative importance of influences to answer Research Question One (What are the influences involved in MLCE development?)

b. To establish practitioners' current priorities for improving MLCE development (Research Question Two – What needs improvement in MLCE development?)

c. To establish potential avenues for how MLCE development could be improved (Research Question Three – How can we improve MLCE development?)

The first two objectives were the primary focus; to triangulate the results of the previous studies, and to understand practitioners' improvement needs. The last was to begin determining how MLCE development can be improved.

8.3 Method

A significant issue to take into account during the selection of an appropriate method to elicit current views on MLCE development was commercial and governmental sensitivities.

These both had affected the previous studies and meant that participants' identities had to be confidential throughout the study. It was important that the participants' positive and negative views were explored to elicit a group view. Differences between participants could be followed up to ensure that the reasons were understood.

Another constraint on the selection of an appropriate method for this study was the lack of resources to enable visits to a large group of geographically separated professionals. Approaches that brought people together in a workshop or seminar were discounted due to many of the professionals being based abroad. A method which could be facilitated by remote approaches such as email or telephone was important.

A number of methods were reviewed, including those in Chapter 4, which could be applied in the research; the most applicable to this study was a survey. Interviewing was also considered as the method for the study and as the method by which to gain the survey data. Interviewing was, however, discounted at an early point as a method for delivering a survey, or as a single approach. This was due to it being more effective to get the participants to score against a number of influences and provide their reasons for scoring in written form. This approach gave practitioners more time to consider the questions and mitigate possible interpretational problems when canvassing non-English speaking practitioners. Phone call interviewing was thought to be a possible method for querying a response if it was confusing. A survey is a detailed description of a population (and their views) (Sapsford 1999 in Gray 2004). The survey used an electronic questionnaire (a Microsoft Word document), allowing participants to give open answers. Surveys had the benefit of being potentially quick to deploy, require few facilities and were straightforward in gaining information (Willig 2001). Caution was applied, however, since their development and analysis can be far from straightforward or easy.

Limitations with a survey approach

There were limitations in using a survey in that the information generated could be broad in nature and rely on large-scale data collections (Cohen et al. 2004). These were mitigated by taking care in the survey design, data collection, analysis and population sampling. Another limitation of surveys related to exploring judgements, views and events where participant (and researcher) bias may distort results. These limitations were harder to mitigate in determining views on MLCE development, although participants were thought to be intelligent and motivated to give reasoned responses. The limitations were addressed by keeping the judgements made by participants simple, and by asking them to give their reasons, which could then be followed up by telephone after the survey if necessary.

There were two possible approaches to the survey:

> Method 1 – Offer a view of MLCE development (generated from previous studies) against which participants can react.
>
> Or:
>
> Method 2 – Use a questionnaire that does not refer to the categories explicitly but seeks to get information which could be used. (This was thought to be difficult to achieve since it would require a 'cold start' by participants.)

The data that would be produced by the two methods differ in terms of the transparency of the links from the existing studies to the participant views. Method 1 was clear in that it was explicit about the offered view that the participants were being asked to react to. Method 2 was less explicit and would require the participants to provide a lot of additional information to get insights that would enable a comparison between views. The approach chosen was Method 1, with the proviso that the participants had the opportunity to add open comments. Method 1 also had the advantage of providing clear linkage to previous studies and provided insights which could be used to address this study's objectives.

Developing the offered view

The construction of the offered view became important because it was the link between participant comments and what was learned about MLCE development to better answer the research questions. Participants may not agree with the offered view, or might feel that some of the nuances of MLCE development were missing; therefore, the offered view had to be carefully constructed. The offered view was generated from the Factors in MLCE development from Study 5. This enabled the Factors to be reviewed by more specialists in the field and linked directly to Research Question One.

Analysis of the comments was done by pattern matching from the textual responses of the participant. This approach required some coding of the words from the participants comments and was dependent on participants providing enough written information. The pattern matching was done against the Factors in MLCE development, with participants' insights noted against each Factor. This approach was similar to the coding approaches recommended by Strauss and Corbin (1998) discussed in Chapter 4. Initially, pattern matching was done by simple word coding, but was expanded as appropriate to include sentences or paragraphs given the context of the participant's response.

Biases

In the analysis of the survey data the relationship between a participant's background and their view of MLCE development was the interaction which was an important aspect in monitoring possible biases. This was due to the different backgrounds and working environments of the professionals working in government and industry. To aid managing this aspect the initial questions in the survey questionnaire were designed to determine the participant's role (i.e. designer, development manager, user (soldier/outdoor sports), human scientist or materials technologist). The resulting responses could then be considered versus the participant's background.

Back pocket Delphi study

Getting the professionals to score the influences was regarded as the development of a 'virtual' peer group, similar to the activities undertaken in Delphi Technique (see Chapter 4). Since the peer group were collectively reflecting on MLCE development, the study was also viewed as a specific instance of action research. It was thought possible, depending on the results of survey, to initiate Delphi Technique cycles to provide the some feedback on the results of the survey. A generic Delphi protocol was prepared but not used, due to the limited resources available to conduct the Delphi cycles and commitments of participants.

Development tools

One important aspect of the survey was asking participants how they would describe the Load Carriage System (LCS) development tools they used. (LCS, rather than MLCE, was used since this study was looking at civilian as well as military practice, so MLCE as a term may have been confusing to some civilian designers.) Asking questions related to development tools attempted to stimulate participants' thoughts to answer research questions related to strengths and weaknesses in the MLCE development. Looking at development tools was controversial since it was thought that this may be seen as an attempt by government to probe the weaknesses in civilian firms' development approaches, or to steal their secrets. In earlier studies, for example during the comparative study interviewing and the NGT workshop, participants had difficulty describing what tools or aids they used. Due to the sensitivities of asking about development tools it was decided to ask participants to list the top three strengths and weaknesses of MLCE development, leaving the wording and structure of responses to participants.

This approach was outlined to the MoD acquisition office responsible for MLCE development. The approach was well received since they were keen to determine where there may be room for improvement in the process of MLCE development, given recent problems.

The final survey questionnaire is at Appendix L.

8.4 Results

The survey was conducted over two months, with the deadline for contributions being extended to allow more participants to respond. A request for information was made through international collaboration agreements via the UK MoD's Technical Project Officer (TPO). Contact was made with civilian firms in different countries via the researcher's personal contacts or the firm's website. Table 22 shows the numbers of participants who responded to the survey.

Countries	Approached	Responded
UK	9	5
Canada	6	5
US	6	1
Others (NL, N, SWE)	3	0
TOTAL:	24	11

Table 22. *Number of participants approached and numbers who responded to the survey.*

The response rate to the survey was 45.8%.

The split between governmental and non-governmental participants was 45.5% and 54.5% respectively.

Table 23 shows how participants scored their roles in the organisations in which they worked.

	Participant										
Roles	**A**	**B**	**C**	**E**	**D**	**F**	**G**	**H**	**I**	**J**	**K**
Designer	3	3	2	1	6	3	3	6	1	2	2
Development Manager	1	6	1	1	6	6	3	6	1	4	4
Business Manager	2	6	2	1	5	2	6	5	1	4	4
User	4	6	4	2	6	6	1	6	4	3	5
Human Scientist	6	1	6	4	6	1	6	6	6	2	5
Materials Technologist	3	3	2	1	5	6	1	5	1	5	3

Table 23. *Participant role scoring, the grey columns indicate the industry participants.*

The participants scoring of the Factors is outlined in Figure 57, which showed that the Requirement was the most important Factor in MLCE develop, closely followed equally by Evaluations and Systematic Approaches.

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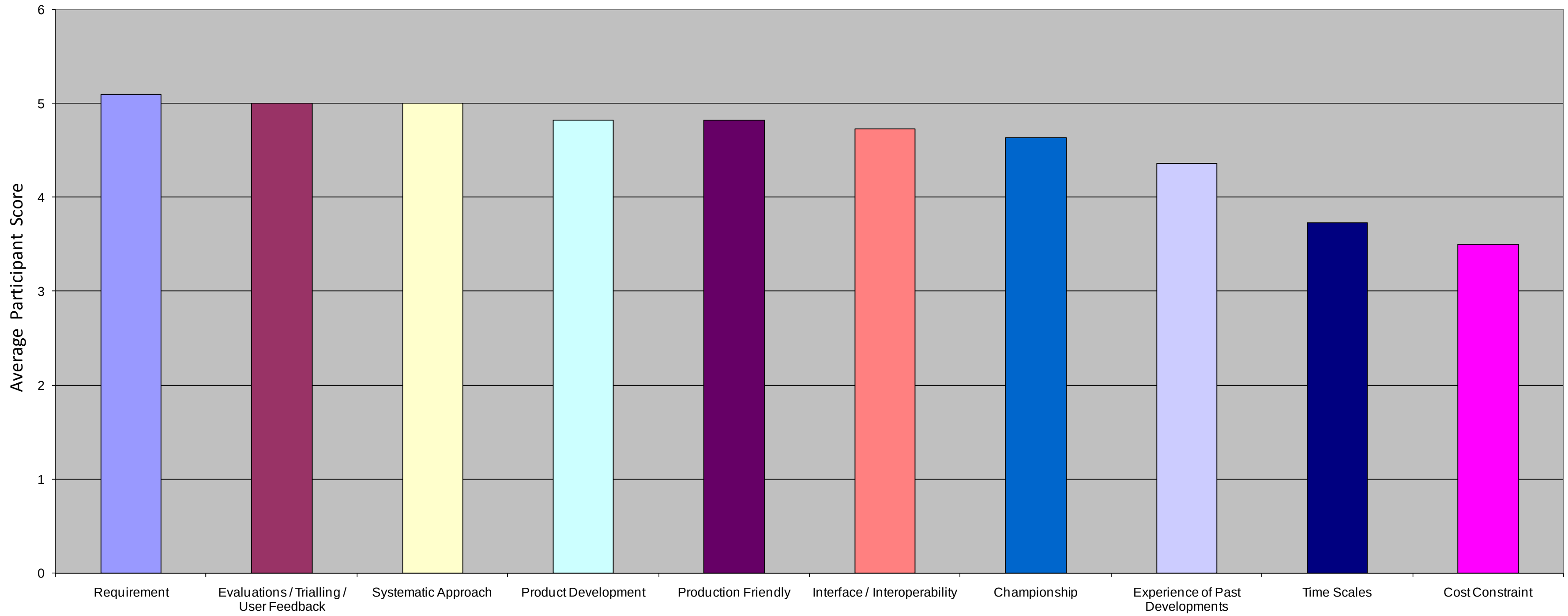

Figure 57. *Average scores for factors in MLCE development.*

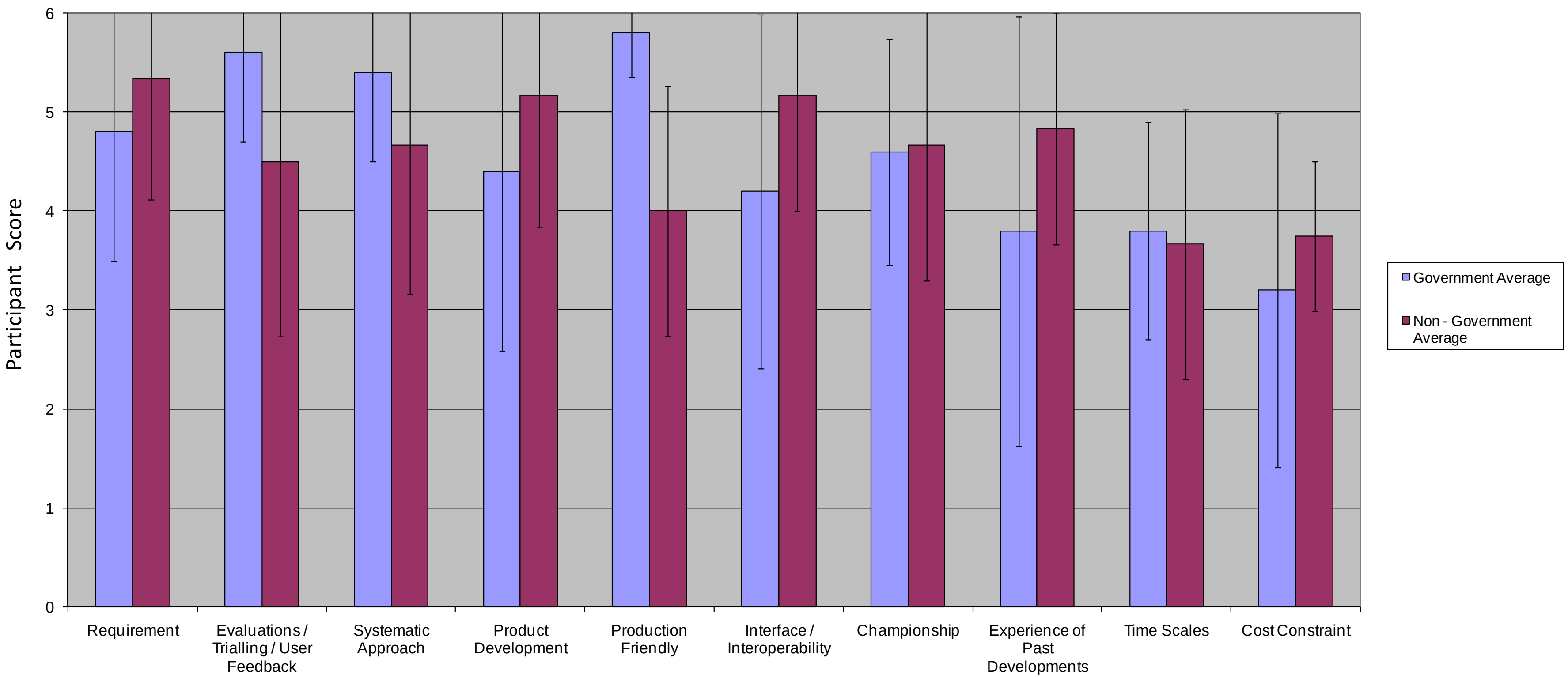

Figure 58. *Average scores for factors in MLCE development by government / non-government organisation.*

Figure 58 shows the differences between government and industry participants in scoring the Factors in MLCE development. Notable differences were in the importance of Production Friendly, Evaluations, and System Approaches versus government participants' emphasis on the importance of the Requirement, Product Development and Interface/Interoperability.

The comments on each Factor made by participants are summarised in Tables 24 and 25. Each Factor has been colour coded on the left to enable connections between Factors. For example in the Requirement row two comments are dark blue in colour which indicates they are linked to Systematic Approaches. The number in the coloured box indicates the number of participants who made the comment.

Table 26 provides a summary of comments, based upon the number of participants who made the same comments to give an indication of strong agreement on issues in MLCE development. In the survey the most commonly raised issue in was the necessity of developing MLCE as a system, with a concentration on how 'sub-systems' work together.

Factors in MLCE Development	**Participant comments from initial questionnaire** (**Key** – Each Factor has a colour assigned to it on the left, with comments on that comment in the row the right of the Factor, usually buff in colour. If a comment in a Factor's row is not coloured buff then it links to the Factor of the same colour. Numbers refer to the number of participants who raised the comment.)				
Requirement	3	2	2	1	1
(= Definition of military need)	Most requirements are written in vague or high level terminology – the essential requirements should be identified versus lower priority requirements (Military may not know what they want)	Needs to include information on weight, environment and life of the system to allow for appropriate materials tests, which should be done as 'ageing' tests (i.e. to represent use)	Effect of carrying heavy loads is not well understood, and indeed is not practised by some armies – different approaches need to be explored	Must look beyond the product to training, people, how it is maintained and so forth	Performance criteria are more valuable than 'hard' specifications which often lack an evidence base
Cost Constraint	2	2	1	1	1
(= Cost of end LCS and process of development)	Cost relating to design time and quality versus material and construction. Best value effects when one sees the benefits from good design (product) (i.e. cheap design may get short-term results, but may not in the long term) Cheap development = cheap (poor/inexperienced) designer	Cost is often used to constrain specification of a product – this may lead to poor construction and integration (comfort and use)	Better requirements would protect the product from cost constraints	Cost should not be important at the beginning of a project	Affordability should be presented, ideally as feature (function) versus cost
Time Scales	1	1	1	1	1
	Project timelines are altered by having different requirements and views	By the time requirements are articulated they may be time expired	People are discouraged if they wait too long for a new MLCE	Speed of development must be quick otherwise MLCE will be outdated by the time it arrives in-service	High tempo design iterations driven by the champion also enable successful development
Championship	4	3	2	1	1
(= Customer / owner who can champion the project at a high level)	Effective design meetings – communication? – 'Decisions should be made with the right people in the room'	Ideally integrated teams are needed – design, scientific, user (test team) and commercial teams	Trust (of specialists) is important to enable development	Getting the right champion(s) is essential – ideally with technically aware and good project management skills	Champions should understand the risk of failure of the product to perform and the risk of injury to the user even if it does perform
Product Development	2	2	2	1	1
(= Design of candidate prototypes)	Not many firms around to provide expertise in product development – (counter argument from one participant however)	Users should be involved in product development to build support	Ideally one should undertake a couple of iterations before production, using appropriate evaluations in each iteration	Product development is never wasted since it explores the solution space and allows early identification of inappropriate solutions	It may be best to undertake design and prototype manufacture in different organisations, although working concurrently in early development stages

Table 24. *Participant comments after completion of pattern-matching exercise, part A.*

Systematic Approach	5	3	3	1	1
(= Systematic development of LCS from the start of the project to when the LCS finishes service)	Development must be done as a system and look at how 'sub-systems' are developed / work together	Role of data in development – use of objective and subjective (human) data and applied baseline research	People (e.g. groups of people load carrying), training and logistics are infrequently addressed adequately	User training and expectations need to be addressed in development – especially with regard to fitting MLCE	Evidence base for specifications is needed
Production Friendly	2	1	1	1	1
(= Ensuring the candidate LCS are fit for manufacture)	Ease of production (and cost) should not be allowed to limit function or price (these are usually the priority – i.e. without function you won't want it, if it costs too much you won't buy it)	Evaluations are linked to production cost since they incur costs to development	Most designs can be produced, but at what cost?	Productionisation should be looked at in the later stages of development after it has been evaluated	Production staff should understand function of LCS to enable correct selection of materials
Evaluations / Trialling / User Feedback	3	1	1	1	1
(= Assessments at every stage of LCS development, from designer based tests to final user acceptance and safety trials)	Essential in ironing out problems with designs - can only be done in field since the more users involved the more the product is de-risked	Evidence must be provided to enable design alterations ideally from all areas involved in development and previous scientific work / assessments	People revert to natural comfort zones so testing early may result in early rejection of innovative solutions	You do not need to do every level of test at every stage, this should be strategically determined	The design team should not be involved in evaluations, but should be in the post evaluation review
Experience of Past Developments	3	2	2	2	1
(= Knowledge and awareness of the design decisions and development of previous LCS (successes and failures))	Technology (Materials) and task alter with each MLCE project so each project should be regarded as a new development	Knowledge of previous development may help avoid pitfalls	Experienced development teams may be best to re-develop or evolve a product, a fresh team may be more appropriate if innovation is needed	Product Knowledge is important to civilian products since each product is evolved every few years	Users must be eloquent about equipment weaknesses
Interface / Interoperability	2	2	1	1	1
(= How the interface of LCS with other equipments and platforms (e.g. vehicles) impacts development)	Early identification of interface problems is important to de-risk user conflicts, but should be addressed later in process	Interface problems are often known about, but often not addressed (e.g. Interface of assault orders with vehicles)	Interfaces must be identified in the requirement so that the function of the product is clear and can be tackled in development	Although interfaces in theory are not ideal and often cause problems, there is a lot of capacity for humans (users) to make MLCE work	Interfaces are also looked at as a part of civilian pack design

Table 25. *Participant comments after completion of pattern-matching exercise, part B.*

Number of participants supporting the statement	**Participant Comments**						
5	Development must be done as a system and look at how 'sub-systems' are developed / work together						
4	Effective design meetings – communication? – Decisions should be made with the right people in the room'						
3	Most requirements are written in vague or high level terminology – The essential requirements should be identified versus lower priority requirements (Military may not know what they want)	Ideally integrated teams are needed – design, scientific, user (test team) and commercial teams	Role of data in development – use of objective and subjective (human) data and applied baseline research	People (e.g. groups of people load carrying), training and logistics are infrequently addressed adequately	Evaluations are essential in ironing out problems with designs – can only be done in field since the more users involved the more the product is de-risked	Technology (materials) and task alter with each MLCE project so each project should be regarded as a new development	
2	Requirements need to include information on weight, environment and life of the system to allow for appropriate materials tests, which should be done as 'ageing' tests (i.e. to represent use)	Effect of carrying heavy loads is not well understood, and indeed is not practised by some armies – different approaches need to be explored	Best value effects when one sees the benefits from good design (product) (i.e. cheap design may get short-term results, but may not in the long term) Cheap development = cheap (poor) designer	Cost is often used to constrain specification of a product – this may lead to poor construction and integration (comfort and use)	Trust (of specialists) is important to enable development	Not many firms around to provide expertise in product development – (counter argument from one participant however)	Users should be involved in product development to build support
	Ideally one should undertake a couple of iterations before production, using appropriate evaluations in each iteration	Ease of production (and cost) should not be allowed to limit function or price (these are usually the priority – i.e. without function you won't want it, if it costs too much you won't buy it)	Knowledge of previous development may help avoid pitfalls	Experienced development teams may be best to re-develop or evolve a product, a fresh team may be more appropriate if innovation is needed	Product knowledge is important to civilian products since each product is evolved every few years	Early identification of interface problems is important to de-risk user conflicts, but should be addressed later in process	Interface problems are often known about, but often not addressed (e.g. Interface of assault orders with vehicles)

Table 26. *Level of participant agreement by number of duplicate comments.*

8.5 Discussion

The level of response to the survey was good with just under half of respondents replying, with common comments being made by different participants independently of each other. The method was successful in producing new insights which were either previously not known, or anecdotal; however, the sample was small.

Analysis of the survey results was broken down into three areas:

- Participant roles
- Factors on MLCE development
- Participant comments

Participant Roles

The roles section of the survey showed that the participants who responded had a good cross section of experience of MLCE development activity (Table 23). The role which was most strongly represented by the participants was Human Scientist, closely followed by User. This was not surprising given that defence organisations retain human scientists who are called upon to support MLCE development and the reliance on user experience in the development of civilian rucksacks. The role that was most weakly represented was Designer (Table 23) although just under one half of participants defined themselves as having a design role. This may illustrate how difficult it was to define what constitutes an experienced MLCE or civilian LCS designer, with most participants either noting it as a secondary role, or one that was equally balanced with another.

Factors in MLCE development

The highest ranked factor from the scoring of all participants was Requirement, although it was closely followed by Evaluations/User Trialling and Feedback and Systematic Approach (Figure 57). The lowest factor in importance to MLCE / civilian LCS development was thought to be Timescales and Cost, which was surprising given their higher ranking in importance in Study 5 (Nominal Group Study). Exploring the factors' ranking though organisational context showed that Requirement was the most important for industry firms and Production Friendly was the most important for government. This was surprising given the lower representation of production orientated roles within government such as Materials Technologist, Development Manager and Designer.

The second most important factor for government participants in Figure 58 was Evaluations/User Trialling and Feedback, which again could be due to the high level of Human Scientist representation in the survey. For industry, however, it was the fifth most important, putting more emphasis on product development and product interfaces (Figure 58). This may more accurately reflect industry's emphasis on design aspects of development rather than the representation of designer roles, than the role scoring suggested (Table 23). Industry also put more emphasis on Knowledge of Past Developments than government participants whose responses varied. There was very close agreement however between government and industry firms with regard to the importance of Championship and Timescales.

Participant comments

Tables 24 and 25 illustrated the diversity of comments related to each factor in MLCE development and the level of agreement (defined as the number of duplicate or related comments for each comment). Tables 24 and 25 shows aggregated patterns from the survey developed from a Table which linked all comments to participant survey returns (shown in Appendix M). The interconnection of factors was clearly evident, particularly the dependence on establishing a robust requirement (the bright-green shaded comments). Comments were made about the necessity of having evidence to underpin the requirement and technical specifications for development, which needed to be timely, and to represent all the issues which influence development. Comments about prioritising requirements were mentioned by a number of participants, as was the need to explore the impact of heavy loads.

Interesting insights were also found looking at the impact on Evaluations of MLCE Development and Champions. This may be due to Evaluations providing much of the evidence that underpins MLCE development. Champions seemed to mean different things to different people but were not rated more highly than Evaluations, despite their strong influence. This may be due to the ambiguity of whom and what Champions do in the process of MLCE development. So while the concept of Champions was useful, championship would be dependent on whom the individual was. Evaluations were linked to a variety of areas reflecting its possible role in MLCE development, particularly Product Development, Systematic Approaches and Experience of Past Developments.

Many participants gave valuable insights as to how MLCE development could be managed, for example in the structure of design teams, and the impact of cost and time on development. These began to provide some heuristic 'rules of thumb' for conducting development:

- Cheap design may get short-term results, but may not be effective in the long term – Cheap development = cheap (inexperienced) designer, and materials and construction.
- Ideally one needs integrated teams – design, scientific (human systems and materials expertise), user (test team) and commercial teams.
- Users should be involved in product development to build support.
- Ideally one should undertake a couple of iterations before production, using appropriate evaluations at each iteration.
- Ease of production (and cost) should not be allowed to limit function or price (these are usually the priority – e.g. without function you won't want it, if it costs too much you won't buy it).
- Evaluations are essential in ironing out problems with designs and can only be done 'in field' since the more users involved, the more the product is de-risked.
- Technology (Materials) and task alter with each MLCE project so each project should be regarded as a new development.

Many of these were 'common sense' aspects to undertaking successful development projects, but were insightful since they were based on a number of participants' experience.

There were a number of other insightful comments which were mentioned that would impact design:

- High-tempo design[27] iterations driven by the development champion enable successful development.
- Affordability should be presented as feature (function) versus cost (also raised in Study 5).
- It may be best to undertake design and prototype manufacture in different organisations, although working concurrently in early development.
- People revert to natural comfort zones so testing early may result in early rejection of innovative solutions.
- The design team should not be involved in evaluations, but should be in the post evaluation review.
- Although MLCE / LCS interfaces were not ideal, and often caused problems, there was a lot of capacity for humans (users) to make MLCE work despite the interfaces being limited.

These were only mentioned by single participants so cannot be regarded as reliably as the other ‘rules of thumb’. They may benefit from further exploration, however.

Looking at the frequency of comments about MLCE development in Table 26, separately from the MLCE Factors, raised the importance of good communication. Communication aspects had not previously been identified as having a definable impact on MLCE design so it was valuable to see how this had positively enabled development. The largest number of statements, as shown in Table 26, were related to Systematic Approaches, where five participants reported that MLCE development was usually conducted as a number of unintegrated components, rather than in a systematic manner. What a systematic approach could be defined as remained ambiguous, although comments regarding use of evidence and data (objective and subjective) and involvement of users and evidence based requirements were all relevant to a thorough development approach.

[27] High-tempo inferred quick prototype development and realisation, followed by quick assessments to enable the next prototype.

8.6 Chapter conclusions

There was enough data to show indicative characteristics of MLCE development from the study. The survey was successful in prioritising the influences on MLCE development from the group of professionals who responded to the survey and so consequently in providing more information to answer Research Question One. The survey also produced more insights into MLCE Development which could used to answer Research Question Two.

Links to previous studies

At this stage in the research it was necessary to put together the findings of all the phenomenological studies to establish if Research Question One and Two had been satisfactorily answered, and if any insights towards answering Research Question Three were visible.

Revisiting the chapter's objectives:

1. The conduct and results of the survey study have been reported
2. The results of the survey have been discussed and a way forward to answer the research questions has been outlined

Key points to be taken forward:

1. At the end of Study 6 it was thought that sufficient information had been gathered to enable a reliable grounded picture of MLCE development to be constructed from the data.
2. Of the prioritised influences it was important to develop these into key characteristics which could be used to improve MLCE development.

Chapter 9: Cross study assessment of MLCE development

The completion of Study 6 gave confidence that it was appropriate, at this stage in the research, to report on the findings from across the studies so far. This chapter reports on the use of the grounded theory approach, initially outlined in Chapter 4, which enabled robust conclusions about the nature and manner of MLCE development.

9.1 Chapter introduction, aims and objectives

This chapter reviews the cross-study analysis of the phenomenological studies conducted to date in the context of a grounded theory approach.

This chapter also aims to outline the assessment of the data from Studies 1 to 6 to determine improvement possibilities using grounded theory principles. Figure 59 shows this chapter in its' place as the evaluation stage of the grounded studies.

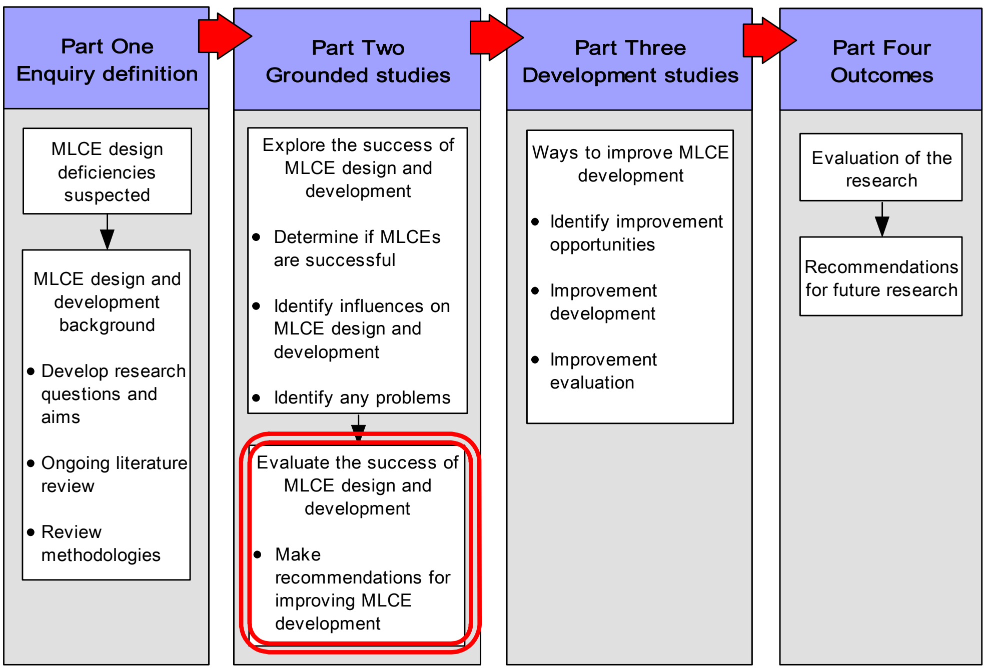

Figure 59. *Chapter 9 research map.*

Chapter 9 reports the findings of the grounded studies, Figure 56 shows this on the research map.

Objectives:

1. To report the modifications to the grounded theory approach, as initially outlined in Chapter 4.
2. To report the conduct of cross-study assessment in the first six studies.
3. To discuss the findings of the assessment and:
    a. Report the construct of MLCE development gathered from Studies 1 - 6.
    b. Report the key characteristics of MCLE development.
    c. Report the extent to which the research questions had been answered to date in the research.
    d. Determine how the research can be taken forward to answer the research questions.

9.2 Approach

The decision to use grounded theory as a way to pull the knowledge gained from undertaking the research studies was based on the number and varying nature of the data-gathering methods used, making triangulation a potentially complex task. The grounded theory assessment approach allowed the findings from the studies to be pulled together to form a coherent construct which could be used to establish what was learned and is now known about MLCE development. Additionally, it enabled the researcher's perspective about MLCE development to be structured and refined so that it was communicable and provided a clear linkage to the next stage of research.

The grounded theory assessment was also intended to determine:

- The extent to which the research questions had been answered by Studies (1 – 6).
- Which areas of MLCE development needed improvement, in order to provide a base for further research to improve MLCE development.

The *grounded theory* approach defined for this research was to follow the four blocks of grounded theory, as defined by Strauss and Corbin (1998): 'discovered, developed and provisionally verified through systematic data collection and analysis of data pertaining to [MLCE design] phenomenon.' The approach was primarily concerned with the study of the social interactions of people engaged in MLCE development.

Presentation of the results from the grounded theory assessment was an evolutionary process which required the researcher to re-visit constructs derived from (grounded in) the data, again as outlined by Strauss and Corbin (1998). During the process of analysis, phenomena were organised into categories that represented facets of MLCE development as it emerged from the data.

The general method used for the grounded theory assessment used in this study is outlined in Chapter 4 and summarised in Figure 60.

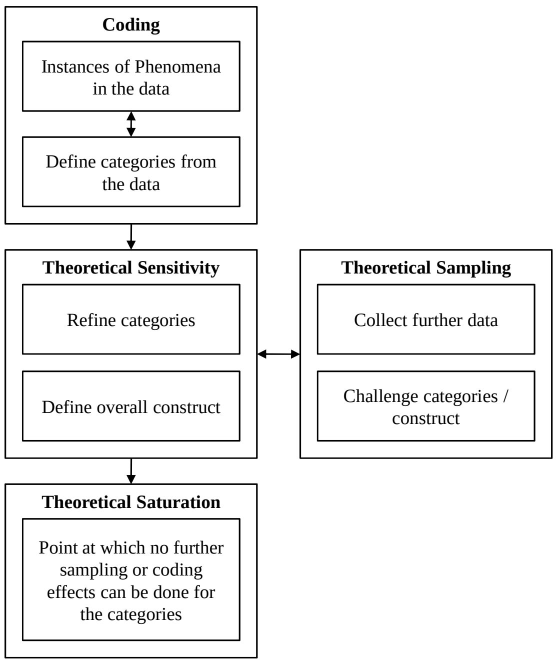

Figure 60. *Grounded Theory 'blocks'.*

The cross-study assessment was conducted throughout the research journey over four years, the categories being identified and defined (in the Coding, Theoretical Sensitivity and Sampling 'blocks') as the studies progressed. This chapter outlines the researcher's findings once theoretical saturation had been reached, and where the collective research findings from studies 1 to 6 could be reported as a whole.

9.2.1 Coding

As described in Figure 60, the first stage in the grounded theory approach used in the cross-study assessment was to examine the data from the early studies (1 to 3) and begin to see if definable concepts or ideas could be seen. By capturing ('labelling' in grounded theory terms) the initial concepts, or categories in grounded theory terminology, the researcher intended to begin to sort the categories into a construct, or grounded theory, of MLCE development. This was done principally using Strauss and Corbin's (1998) *Open Coding* approach where the research attempted to conceptualise the categories presented.

Conditional matrix

The initial categories were defined and given context (from where they had emerged in the data), a property (what they were, e.g. a decision, physical parameter) and dimensional range. This process of coding allowed the researcher to maintain and build an awareness of different issues emerging. These were captured in a Category Table (see Appendix N), essentially a form of *conditional / consequential* matrix, recommended by Strauss and Corbin (1998); a device or database to allow different perspectives to be explored.

Additionally, the table allowed the researcher to track how the categories changed and altered as new data became available, given that the research took place over two years.

9.2.2 Theoretical sensitivity

After the initial table was established, just after the completion of Study 3, the researcher refined the categories and began to develop a construct of MLCE development.

Defining a construct of MLCE development

This initial construct attempted to link the interactions between the categories to help understand what characterises MLCE development from the data in the studies. The first construct, or Category Model, was developed on completion of Study 6 (see Figure 61) and generated by the researcher by working up a diagrammatic representation from a review of the categories.

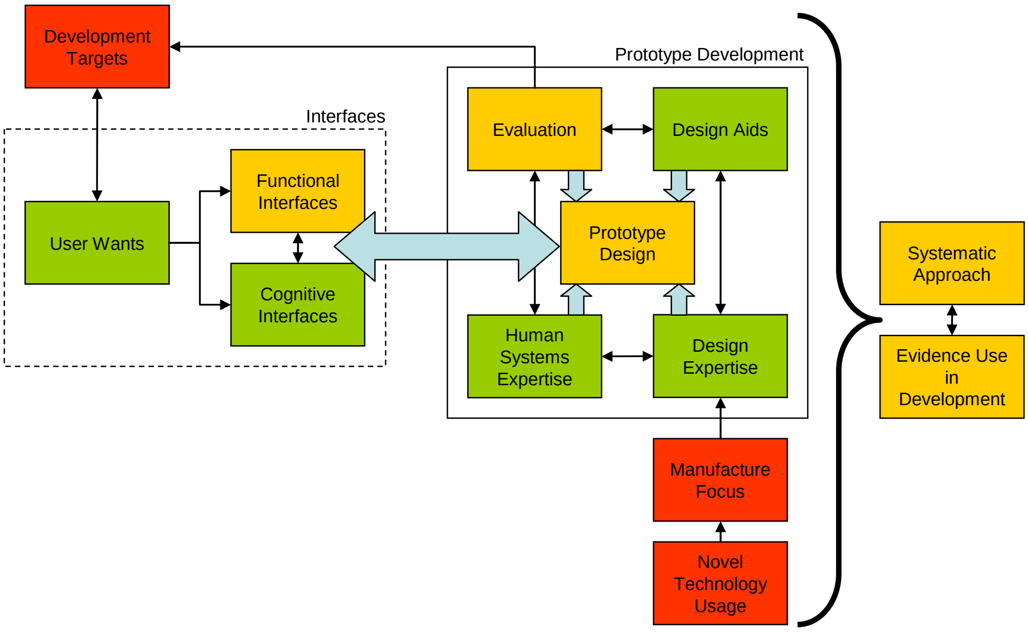

Figure 61. *Category Model.*

The inter connections between categories are shown in Figure 61, which is a model of the categories from the researcher's understanding of the studies conducted up to this point. The Category Model was one of the constructs used by the researcher to analyse and probe the data from the studies, consistent with Strauss and Corbin's (1998) axial coding procedures for relating categories using a diagram. Although it should be pointed out that the researcher used axial coding to bring the categories up to a similar level by looking for 'fractures' or inconsistencies, which then enabled them to be looked at as a whole from which a construct could be developed in a diagram.

Testing the Category Model

Testing the Category Model was important to ensure that the analysis of the data from the studies was thorough, and to examine differences and similarities between the data in the studies. This aided in establishing links which were analogous of triangulation and helped to improve the reliability of the grounded theory approach.

The influence of generic development processes on the Category Model was clear from the use, by the researcher, of the Researcher's Model (Figure 44), developed in Study 3 to test the Category Model (Figure 61) alongside development process representations from the literature reviewed to date.

The possible influence of other generic development processes opened the question of whether the researcher was being influenced by concepts outside the data, from the studies which may limit the representation of MLCE development of the construct. It was possible that the construct would have ended up as a form of development process since the data from the studies was focused on a development process. The Category Model, however, is not a development process simply because it is portrayed without an input or output as it represents how the categories link rather than how a process produces an end [MLCE] product. It should be remembered that with the relative inexperience of the researcher with grounded theory and the nature of grounded theory approaches with single investigators (Strauss and Corbin 1998) the construct should be regarded as a view of the data, rather than a definitive theory.

On first appearance the Category Model may have echoed a product development process (the box Prototype Development) but it also showed useful insights when compared to generic development processes. The main differences between the Category Model and generic development processes were in the dashed 'Interfaces' box, which illustrated the reliance in MLCE development upon good interface design between MLCE and the user. The implication being that if the interface was not good then user satisfaction with the MLCE could be detrimentally affected (the cognitive influences block). While this may be true of other products, how it is achieved in MLCE design appears to be a relative 'black art' from the findings of the studies.

Another, broader, example was Evidence Use in Design, which although must be a factor in all developments, was highlighted as being of concern with MLCE development due to gaps in the evidence which enabled prototype development and evaluations. The initial findings showed, therefore, that MLCE did appear to have some problem product development features. These problem features, therefore, needed to be explored.

Limitations of the Category Model

The main issue with the Category Model is its relative complexity to lay readers, unless it was explained by the researcher, the terms themselves needed defining in relation to each other. This limited the transparency and reliability of the grounded view developed thus far. The category dimensions were also misleading, which limited the effective use of axial coding (Strauss and Corbin 1998), which relied upon linking individual categories using their dimensions and properties to develop the Category Model. The researcher, therefore, decided to challenge the categories further, and try to develop another construct, using an analytical tool (theoretical sampling).

9.2.3 Theoretical sampling

The categories could be further refined by challenging them as new information emerged during the research, and the researcher's knowledge grew. This allowed the researcher to further determine how robust the categories were to new information or different perspectives. There was also a need to see if alternatives constructs to the Category Model were possible.

Illustrative 'macro and micro' model of MLCE product development

As the Category Model did not seem to clearly show the interactions between the categories, or to represent MLCE development as it appeared from the data, the researcher developed an illustrative macro / micro model of product development. The model was a form of analytic tool (Strauss and Corbin 1998) which helped to explore the interactions between individuals and groups through the MLCE development processes used in the cases studied to date, and, give a view point from which to look at the category dimensions.

Macro level

The 'macro' level represented the organisational targets that drove the MLCE product development stages in the cases examined.

Micro level

The studies conducted to date had shown that MLCE development had differences to most representations of product development in how prototypes were being designed and realised as artefacts. This was evident in the effective interaction between designers and materials technologists with little involvement of other specialists, until the prototypes were assessed versus project (macro) level targets. This design activity in MLCE development could therefore be more accurately described as 'micro' level, since many of the differences noted were related to the effectiveness of prototype development in the detail design of MLCE.

It is important to note that the macro / micro model was designed to give a perspective on the categories rather than an attempt to develop a new construct. The macro / micro model could not have stood as a construct since 90 Pattern development (from Study 2 – see Chapter Five) detailed design (Micro Level) was informed at the 'Macro' Level.

The differences between macro and micro levels are described in Table 27, which shows, as well as the broad characteristic differences, the different outputs and emphasis on group and individual interactions.

Levels	**Description**	**Outputs**
Macro	Interactions between teams working on MLCE development	Development Targets (high level User requirements – as per MoD policy guidance for equipment acquisition), Process Assurance (prototypes assessment)
Micro	Interactions between individuals working on prototype development	Prototypes

Table 27. *Macro and Micro level definitions.*

The difference between the two levels in Table 27 is in the focus of activity that is required to produce the outputs. This matched some of the *generic* representations of product development (see Chapter 3), where product designs were referred back to the client to check progress and ratify important design decisions. Within MLCE development this process is less distinct, depending on the organisational setup for the project concerned. In the cases explored it was possible to separate out the different activities of these two levels and refine the categories' descriptions.

The definitions in Table 27 were then used to produce a diagrammatic macro / micro model, shown in Figure 62, which was useful in evaluating the findings from Studies 1 to 6.

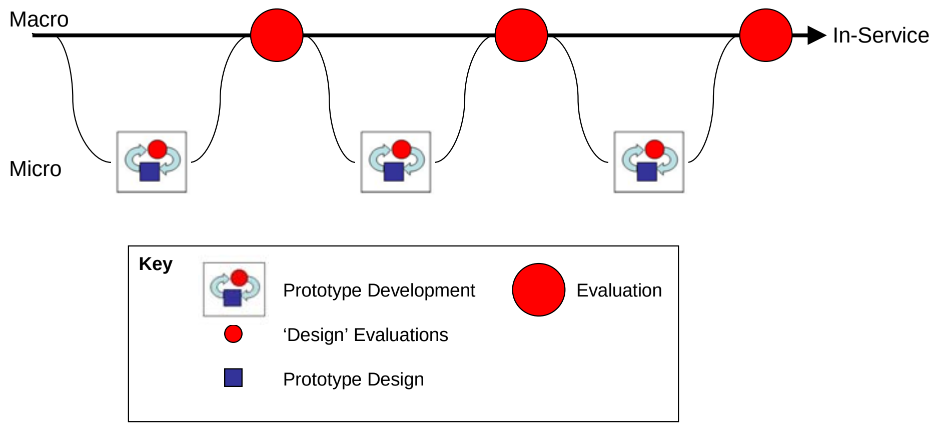

Figure 62. *Macro / micro model.*

Although the macro / micro model was an abstraction of real world development activity it was useful to examine the differences between MLCE and other product development process stages. The macro / micro model was a simplistic representation but does allow one to differentiate between prototype development and the evaluations. Evaluations for the purpose of the macro / micro model were regarded as assessments that were used to confirm the acceptability of a prototype for use by soldiers. This was an important definition since many of the studies indicated that evaluations were at a macro level, which may not be the case in reality since designers often undertake their own detail design assessments, with or without human systems specialists, to refine prototype designs. These 'micro' level assessments are included in the macro / micro model as a localised feedback loop between a design assessment and prototype design. The interaction between design assessments and prototype designs was still an abstraction since interactions vary considerably between MLCE development cases.

Macro / Micro Model comparison of MLCE cases

As noted above, each case of MLCE development looked at in Studies 2 and 4 were different in structure and so varied as to how they linked between macro and micro levels. The three cases; 90 Pattern Rucksack, Airmesh Rucksack (Study 2), and Female Load Carriage project (Study 4) however, could be mapped on to the categories and Macro and Micro levels to see how they differed. According to primary sources (such as the 90 Pattern PLCE trials reports) and people involved in development, 90 Pattern was successful in using macro evaluations to support prototype development activity. In the Airmesh rucksack, macro evaluations were undertaken with the user throughout the project and were linked strongly to prototype development. In the Female Load Carriage project this was managed in a different way, with product development relationships being contractually managed and limited in the use of human systems data in micro-level product development.

Exploration of human-product interface

From looking at the comparison of cases through the macro / micro model one also gets limited insights into how interfaces between MLCE and the user were conducted in development, discussed as being something of a ‘black art’ in MLCE design in Study 4 by one participant. In the cases that were broadly successful (90 Pattern and the Airmesh rucksacks) there was opportunity for design-orientated assessments, whether these were conducted at the macro evaluation or micro evaluation level. In the Female MLCE project, unfortunately, there was not this opportunity, and may have been a contributing factor to the difficulties experienced in the project.

Organisational positions in macro / micro model

Looking at where government and industry sit in the macro / micro model was also an interesting exercise since this also helped to gain an understanding of some of the problems experienced by the Female MLCE project. Government sits broadly at the macro level, since it sets development targets and is responsible for the project meeting those targets. Industry sits (in the case of the Female MLCE project) at the micro level and undertakes prototype development. In the case of the Female MLCE project a problem arose due to confusion over project targets, but there were also some lessons for interface design in the linkage between evaluations. In the case of the Female MLCE project there does not seem to have been many design assessments prior to macro evaluations. There were, therefore, lessons in how macro level evaluations should enable feedback to prototype development, or indeed in how design assessments involving stakeholders should be conducted prior to macro evaluations. These findings were discussed with the Female MLCE project manager who accepted that this needed to be done in the future.

Limitations of the macro / micro model

Ascribing the different aspects of development activity in the cases to the micro or macro level was judgemental and reliant on the available data. This may limit the reliability of the macro / micro model, particularly in that there was no opportunity to gain observational data, two of the cases being historical in nature. It should also be noted that it was very difficult to find evidence of how designers undertook detailed design assessments, particularly in the Female MLCE project where only secondary evidence was available.

Lessons Identified from the macro / micro model

Although the macro and micro model is abstract, it did facilitate the teasing tease out the factors that make MLCE development successful and the extent to which development was detrimentally impacted by different aspects of development activity, whether at the macro or micro level. It also illustrated the problems of using existing representations of product development processes in planning MLCE development activity at the macro or micro level.

9.2.4 Theoretical saturation

The researcher then reviewed the summary Category Table to see if the category properties and dimensions needed to be modified to more accurately reflect the data from which they were derived from and to help in another attempt at axial coding. It was possible to clarify some categories with regard to their context, but not properties or dimension, since these had to be presented in terms that were theoretically possible. For example the dimension for the category ‘Novel Technology Usage’ was defined as being a high-to-low level of technology usage to meet a development target. Novel technology use was a strong factor in two cases of MLCE development from the studies, but was not necessarily a dependency for MLCE development as shown in another case, and therefore had to be defined as a range from the data. This suggested, as far as the categories were concerned, that theoretical saturation had been reached, given the data available.

Inconsistencies in the categories

During this last review of the categories the researcher considered again that the categories might be influenced by his knowledge of better practice from the literature and experience. Reflection enabled the researcher to discount two categories that were not supported by the data from the studies. These were Systematic Approaches and Evidence Use, which were strong aspects of design approaches from the literature, and which the researcher had noted as being a problem with some instances of MLCE development activity. The Category Model was, therefore, modified to reflect these changes through another coding stage. In doing this the researcher did not refer to any information other than the modified Category Table to ensure the new construct was fully grounded in the data, and to minimise any influence from generic development processes.

The new construct, the V2 Category model (Figure 63), was more successful than the initial one, in that it appeared more accessible, and represented the instances of MLCE development from the data that the researcher had used to test it. The V2 Model was also much easier to construct than the first, simply because the researcher was more familiar with the theoretical characteristics of the categories. Strauss and Corbin (1998), in their seminal text on grounded theory, mention that axial diagrammatic techniques often require an element of trial and error and get easier as the investigator becomes more theoretically sensitive.

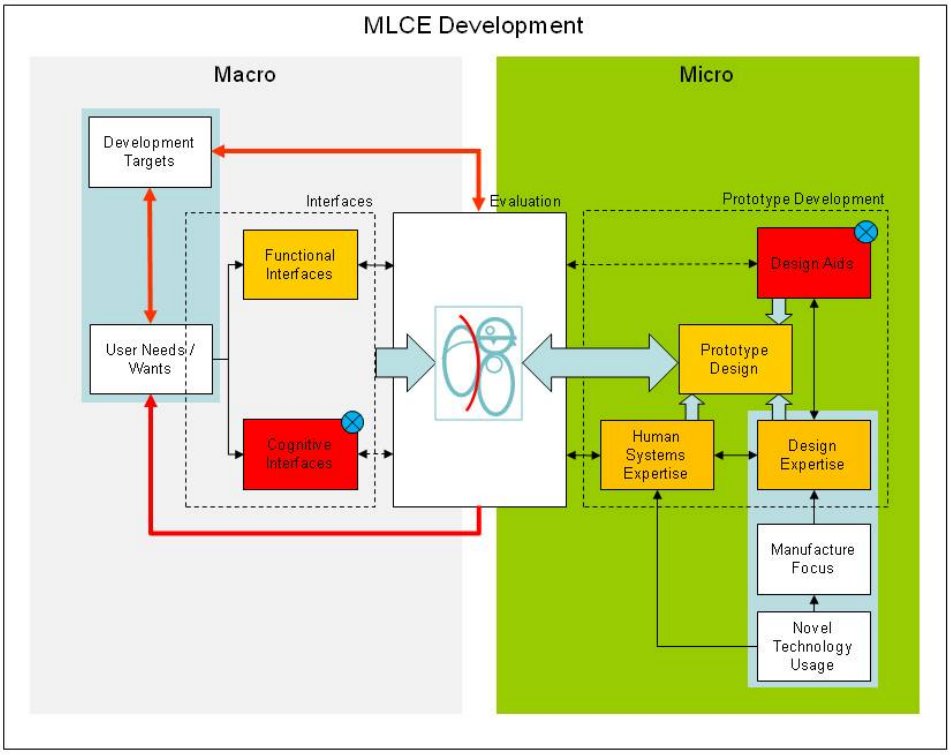

Figure 63. *V2 Category Model.*

At this stage in the research it was appropriate to examine the success of the grounded theory approach and whether the V2 Model (and grounded theory assessment in general) could bring together some of the key aspects of MLCE development and determine the degree to which the research questions had been answered, and what the next stage of research should be.

9.3 Discussion

The illuminative insight which a grounded theory approach offered was useful in enabling the researcher to objectively reflect on the data in the studies and allow a representative view of MLCE development to emerge from the data.

9.3.1 Success of the grounded theory approach

The grounded theory approach to assessing the studies was broadly successful, although it did have a number of issues due to the learning curve needed to apply the principles in a robust manner. The approach did produce a diagrammatic representation of MLCE development from the data generated during the studies, so was successful in producing a definable output which can otherwise be difficult with some grounded theory approaches where the data is disparate.

While the grounded theory assessment did produce an output, it should be stated that additional detail within the categories was difficult to achieve without more data on how prototype development is undertaken and what designers use as design tools. These data would have increased the power of the grounded theory approach since it would have potentially provided greater understanding of the linkages between the categories.

The following table shows how the researcher judged the success of the approach according to the metrics (empirical grounding) suggested by Strauss and Corbin (1998) (see Table 28).

Criterion	Addressed?	Evidence
Concepts generated	Yes	A diagrammatic construct has been presented which shows the interactions between categories derived from data in the studies.
Conceptual linkages / Category development	Yes	The interaction of the categories has been shown through an explanation of how they were developed, with examples cited where appropriate.
Variation built into the theory	Yes	Due to access to three separate cases of MLCE development, variation in the category properties has been incorporated by looking at MLCE development in different conditions.
Conditions under which variation is explained	Yes	Examples of variation have been explained in the analysis of the data and an explanation of the grounded theory construct development.
Process taken into account	Yes	[Research and Development] Process, and its impact, has been discussed in the analysis.
Whether theoretical findings are significant	Yes	The emergence of key characteristic differences from generic development processes appears significant since this does impact considerably on the effectiveness of the MLCE development process.
Ideas exchanged across professional groups	Not done to date	To date the findings of the grounded theory assessment research have not been discussed with other professionals in the field.

Table 28. *Criterion for evaluating grounded theory approaches.*

Lessons learned from grounded theory assessment

Grounded theory offered a flexible approach to making linkages between the studies' findings. The grounded approach was particularly useful in that constructs like the Category Model and macro / micro model could be developed based on the findings from the studies, and then used to test the researcher's understanding of the research conducted to date, as well as to look for new insights. Overall the researcher was confident that the findings discussed above were reliable with regard to the cases examined, with common aspects being present in all three cases, as well as being raised by participants in Studies 5 and 6. Validity was less clear in data gained from individuals, although the researcher tried to mitigate bias as much as possible through the correct application of the research methods and checks on accuracy. The only way to improve the validity of the research conducted to date would be to undertake some observational research to investigate design activity and test the research findings further. The researcher was confident that the research findings were reliable, within the limitations of the available information. The researcher was confident that if the same methods were used by others they would reach similar conclusions, although the models produced to test ideas and research findings may differ. The important aspect, whilst conducting the grounded theory analysis, was to be aware of the contextual nature of the data (particularly the cases) and avoid delivering absolute findings which the studies conducted to date would not support.

Alternative methods

In retrospect there were few methods of analysis which could have provided the level of insight and synthesis provided by a grounded theory approach, especially given the time available and opportunistic nature of data collection. Another approach could have been to rely upon a fewer number of studies with the application of more complex and resource intensive methods such as verbal protocol analysis. Given that the research was focused on exploring and evaluating MLCE development to provide a broad base for further research, these methods were not practicable, nor would they have greatly improved the research findings. The grounded theory approach was sufficiently transparent to allow the data to be re-examined in order to check the categories and construct being developed.

9.3.2 Key MLCE development characteristics

The picture painted of MLCE development through Studies 1-6 was:

1. There is reliance upon craft-based[54] knowledge to develop MLCE (namely informal development processes, with little use of design tools to inform design decision making).

2. Designers are familiar with MLCE systems and sub-components and were able to enable the synthesis with manufacturing and human-machine interfaces – a demonstration of some expertise through knowledge of MLCE 'precedents' (Lawson 2004).

3. There is a high requirement for human-orientated data and expertise to enable design (not just during evaluation checks).

4. There is a lack of objective (and to some extent subjective) data upon which the process of development could be evidence based (particularly human-machine and user needs (physical and psychological data)).

These different features were supported by the grounded theory categories, which show the characteristics that were similar to existing representations of product development such as Pugh (1991), although MLCE development rarely followed a formal 'prescribed' process, as defined by Cross (1995).

Points 3 and 4 also raised the issue of user inclusion within MLCE development, since it was clear that in certain cases a lack of knowledge about user characteristics, tasks and environment had lead to failures in development.

[54] Craft-based knowledge was exhibited in the studies where some designers reported that they often do not need to draw a design before attempting to make it (and indeed do not appear to regard making as distinct from designing), a characteristic of craft-based design (Cross 1995). It should also be noted that this knowledge varies from conventional descriptions of craft as only a technical skill. The Studies showed that MLCE was highly reliant on an appreciation of how to integrate plastic and metal materials with craft-based cut and sewn fabric technical skills (tailoring) for manufacture. This integration places a need for high levels of 'intelligent' craft based knowledge (Yair et al 2000) in the development process.

9.3.3 Answering the Research Questions

By this stage in the research there was enough data available to revisit the research questions and examine the degree to which they had been answered.

Research Question One (What are the influences involved in MLCE development?): Studies 1 – 6 have explored and evaluated the various influences (summarised as categories in the cross-study assessment) impacting on MLCE development and have provided illuminative insights. The studies have reliably highlighted the different possible interplays of factors depending on the context and conduct of MLCE development. From this view the following conclusions can be made:

- MLCE has a number of common aspects to generic product development processes but also has some strong differences (the four key characteristics) which need to be understood to adequately de-risk product development.

- There were some common factors which were functions of the various influences on MLCE development which may be shown to improve the success of development (for example: heuristic rules, iterative design with human factors expertise support).

- Each instance of MLCE was different and required a different balance of influences to enable successful design outcomes:
    - The reliance of MLCE development on a good understanding of the interface between the user and MLCE remained a relative ‘black art’ in terms of design, especially with regard to cognitive user needs (interfaces).

Research Question Two (What needs improvement in MLCE development?): Studies 1 to 6 have shown that there were a number of issues that need to be addressed in MLCE development. All the key characteristics of MLCE development in section 9.3.2 posed potential risks that could be addressed by the provision of some form of support or aid to the process. The four key characteristics were regarded as key dependencies for effective, and perhaps efficient, MLCE development and, therefore, areas which needed some form of support. The four key characteristics, however, needed refining before any specific support could be determined; this was achieved by reviewing the knowledge gaps addressed by the research to date.

Review of knowledge gaps

In order to see how the four key characteristics could be improved the knowledge gaps from the literature review (Chapter 3) and Study 2 were reviewed (Chapter 5) with the additional knowledge gained from studies 4 to 6.

Literature area (following from literature review)	**Gaps in MLCE development knowledge**	**Comments from studies 1 – 6**	**Colour coding**
Design Processes in the context of MLCE	What design process is used in NPD in the context of MLCE? Are design strategies and design processes used? If so, what is the impact?	Few design strategies or processes used, confirmed by studies 4 – 6.	
	Are problems in the context of MLCE poorly defined and consequently not addressed in MLCE development?	The cases indicate that problems in the context of MLCE were poorly defined and not well addressed by the process, confirmed by studies 4 – 6.	
	How and to what extent are users represented in MLCE development?	Users are very evident from officer level, although 'ground level' soldiers, needs were not evident from the cases studied, confirmed by study 4.	
	What affect will corporate taxonomies have in determining requirements which can be used in MLCE development?	This was an ongoing activity within defence at the time of writing (Sparks 2006).	
	Have cost and business performance issues taken a higher priority over human systems and user needs in MLCE development?	Study 6 indicated that cost had detrimentally impacted user needs in overall system performance.	
	Does the process of NPD have an impact on how design teams design, in MLCE development?	The process has an impact at all stages, confirmed by studies 4 – 6, particularly 6.	
	What are the appropriate cues within MLCE design which can be used to prevent error in the process of development?	Although this has not been studied in detail, some insights have been possible in Study 6, which had begun to provide some heuristic rules which could be viewed as cues to avoid development process problems.	
	How are design decisions made during MLCE development?	In historical cases they are made by committees or senior military/civilian development officers. Studies 4 – 6 indicated that design decision-making was focused towards prototype development.	
	What level of design expertise is involved in MLCE development?	Expertise is required not only in design but also in managing the design process / design activity. This was confirmed by studies 4 – 6; Study 6 gave particular insight into the skill sets involved.	
	How are user requirements gathered and how are they used in MLCE development?	User requirement formulation and representation is ambiguous although written requirements are used, confirmed by studies 4 – 6.	

Table 29. *Knowledge Gaps in Design Processes in the context of MLCE by the end of study 6.*

Literature area (following from literature review)	**Gaps in MLCE development knowledge**	**Addressed in comparative study**	**Colour coding**
Design methods in MLCE development	What methods are used in MLCE development?	The methods historically are traditional cut-and-sew technologies – Computer Aided Design (CAD) is not used in industry or MoD; this was confirmed by study 4.	
	What methods are used in military and civilian organisations? Do they differ, and why?	Studies 5 and 6 provided some insights into how military and civilian organisations differ and some of the reasons why.	

Table 30. *Knowledge gaps in design methods in MLCE development by the end of study 6.*

Literature area	Gaps in MLCE development knowledge	Comments from Studies 1 – 6	Colour coding
Influences on the process of development in the context of MLCE?	New knowledge gap: Why is the military load approximately 50% higher than the recommended load, and what impact does this have on the user and MLCE design?	Loads were high because of doctrine and military practice / culture which does impact on user – although may not have the large impact on MLCE design that one may imagine – since it was a constraint a designer works with and was not something he/she can control, as confirmed by Study 4.	
	What effect do particular branches of human science (for example: biomechanics, physiology, ergonomics, physiology) have on the process of development in the context of MLCE? (To date there has been no integrated human factors studies of the affect of load on the human in a military context.)	This area has been addressed by Study 4 and to some extent by study 6 which showed that rather than different branches of human science affecting MLCE design, it is the available data on the man-machine interface which is lacking.	
	What format should human systems information related to MLCE design be presented in to make them useable in the process of NPD?	Although this has not been studied to date, evidence from studies 4 and 5 would suggest that it must be suitable for a craft-based design context and be easily and quickly available.	
	What effect on the soldier does the role of a consumer have upon user requirements in the process of NPD?	Not studied to date.	
	What affect does product failure have upon the process of NPD in the context of MLCE?	Study 4 provided some insight into the consequences of product (prototype) failure on development processes.	
	Are the processes used to develop high quality MLCE?	This was hard to answer without quantifiable metrics; historical evidence would suggest the processes were not as high quality as they could have been, given modern practice (i.e. the same practices would not be acceptable now), confirmed by studies 4 – 6.	
	What lessons can the process of NPD, in the context of MLCE, learn from approaches to NPD of civilian load carriage?	Study 6 would indicate that much could probably be learned from the civilian arena in terms of time saved and innovation. What might take time is the learning about military environment and user needs, as indicated by Study 4.	
	How are human factor issues being represented within the process of NPD in the context of MLCE?	Generally human systems are represented fairly poorly in relation to manufacturing and military requirements, but they could be used more effectively given current human systems practice, this was confirmed by Studies 4 – 6.	
	What are the soldier's needs for MLCE and how can they be successfully represented in NPD?	User needs remain ambiguous and would benefit from being expressed using current guidance / practices, confirmed by Studies 4 – 6.	

Table 31. *Knowledge gaps in influences on the process of development in the context of MLCE by the end of study 6.*

The review captured in Tables 29, 30 and 31 showed that many of the gaps in knowledge had been progressed from Study 2. More was now known about the process of development in the context of MLCE at this stage in the research, which complemented the category notes in Appendix N.

Focus on user needs and environment

From looking through the knowledge gaps, category table and V2 Model, the researcher concluded that the most effective way of improving MLCE was to concentrate on how designers could better understand user needs. The V2 Category Model (and therefore the data) lacked a clear linkage between user needs through the Interfaces and Evaluation boxes to Prototype development. One may have expected a linkage, and so the researcher again revisited the categories and data to see if the Model needed additional modification. However, this was not appropriate since the data would not support a stronger linkage. Much of the user needs information that designers used in MLCE development was provided through some form of specification (developed by the military and civil servants and then given to industry). The success of the development, assuming one had experienced developers, would hinge on how well formulated the specification was, and how well it represented users' needs. Improving developer understanding of user needs may additionally prevent the four key characteristics being blocked. A good example of this was the designers' need in a contemporary case of MLCE development for information; on the user needs with regard to physical interface with load carriage, on how the users would use the equipment (in the pursuit of given goals) and how they would interface with it. This lack of knowledge led to deficiencies in establishing the specification and prevented the design team from challenging the specification which was used to design the MLCE. As it was, the design team lacked any design aids that would have enabled them to identify this as an issue, and were reliant on the MoD to understand how users would interact with their equipment.

The high importance of user needs and requirements had also been raised by participants in Studies 4 and 6. There appeared to be a strong need for support to designers and developers understanding of how users interact with their MLCE, which could be used to design better MLCE. It was interesting to compare this with practice in the civilian arena, where developers usually were expert practitioners as well as being close to the industrial base by which load carriage systems were realised (Parsons et al. 2006). In the military arena the researcher had encountered very few developers with recent experience of being a soldier, which may account for the need for more user needs information for MLCE. If a suitable aid could be developed to allow designers to do this, then all the key characteristics of MLCE development which currently pose a risk to development, bar the reliance on craft expertise, could be de-risked to some degree.

It was appropriate to explore this area further and examine whether soldier data of the sort needed was being generated for design use and what design aids might be suitable to de-risk the key characteristics.

9.4 Chapter conclusions

It was thought that enough research had been conducted to base an improvement in MLCE development. The studies conducted were reliable and the triangulation between studies had shown that the principal characteristics of MLCE development were better understood than at the start of the research.

Exploration and evaluation of MLCE development had been conducted to provide answers to Research Questions One and Two. It was at this stage that more information had to be gathered from professionals in the field to determine the detailed requirements for improvements to MLCE development to answer Research Question Three.

Revisiting the chapter’s objectives:

1. The modifications to the grounded theory approach, as initially outlined in Chapter 4, have been discussed.
2. The conduct of the cross-study assessment of the first six research studies has been reported.
3. The findings of the assessment have been reported with regard to:
    a. The construct of MLCE development gathered from Studies 1 – 6.

b. The key characteristics of MCLE development.
c. The extent to which the Research Questions have been answered to date in the research.
d. How the research can be taken forward to answer the Research Questions.

Key points to be taken forward:

1. Determining how MLCE developers could be helped in understanding soldier needs information required some exploration in the next stage of the research.
2. How the defence environment approaches the gathering and use of soldier needs also required investigation.

Chapter 10: Determining MLCE development improvement options

The cross-study assessment had determined that Research Question Two and Research Question Three were best answered by focusing on helping developers better understand user (soldier) needs. This chapter outlines how this could be achieved and investigates the organisational opportunities for a user needs resource.

10.1 Chapter introduction, aims and objectives

In order to see if the MLCE development characteristics could be mitigated, user needs identification within the UK MoD needed to be explored. This was to see how MLCE development could be de-risked by contemporary processes being used in defence.

This chapter aims to discuss the possibilities for a tool to enable designers and developers involved in MLCE development to get better insight into user (soldier) needs. This chapters place in the research journey is shown in Figure 64.

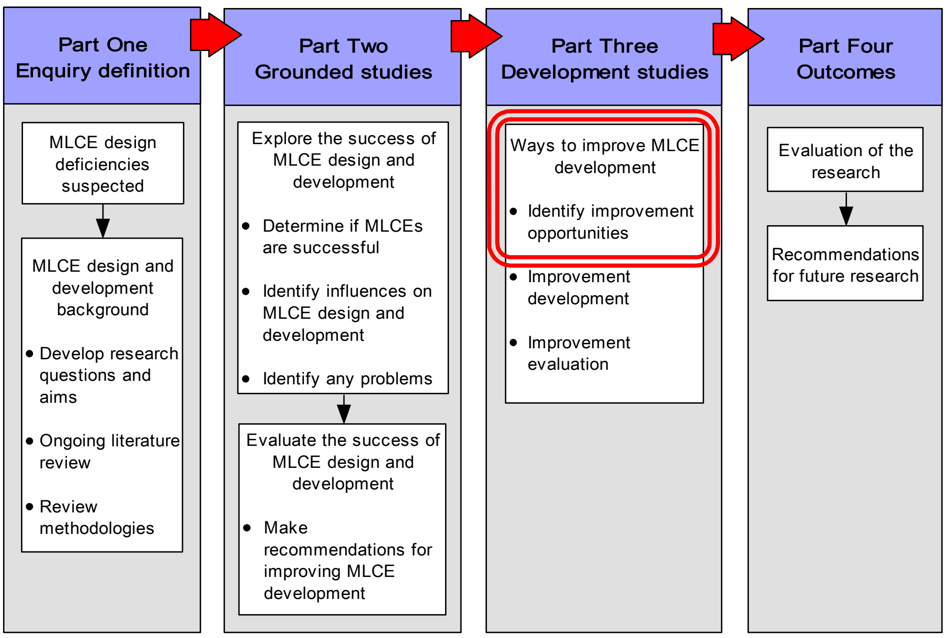

Figure 64. *Chapter 10 research map.*

Objectives:

1. To report on the literature available on contemporary approaches to user needs information in product development, within:
    a. The defence arena.
    b. The civilian arena.
2. To report on the conduct of a study that explores requirements for a resource to allow a better understanding of user needs.
3. To discuss the findings of the study.
4. To determine a way forward for the systematic development of the resource.

10.2 Review of contemporary user needs approaches

In order to meet the objectives it was important to reflect on the outputs from Cycles 1 and 2, and prepare for Cycle 3 by researching the available literature ('Revise Idea' stage in Cycle 3, Figure 65), which would inform the plan for Study 7 ('Amend General Plan' stage in Cycle 3, Figure 65).

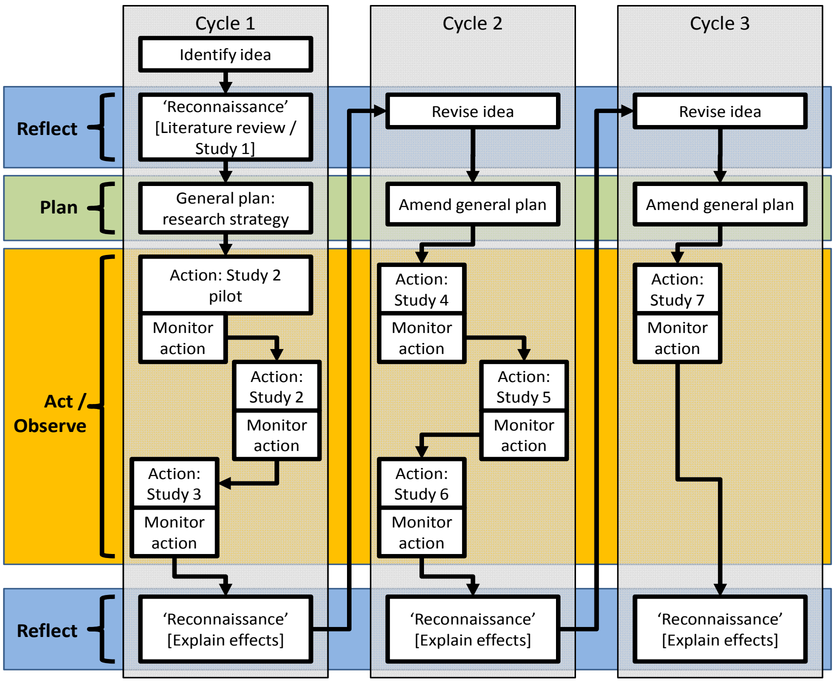

Figure 65. *Research Cycles 1 to 3.*

The previous studies in this research had been focused on eliciting information from those involved in MLCE to understand what happens in the development process. To progress the research it was important to understand what processes were being used in the defence arena to understand user needs.

The UK MoD processes for understanding user needs were identified as falling into two areas:

1. Military requirements management.
2. Human Factors Integration methods.

10.2.1 Military requirements management

In UK defence acquisition, users are represented by military requirement managers (usually serving military officers) within procurement teams who consult with users in operational units to determine the requirement (as an expression of user need) for military equipment. It should be pointed out that from an MoD acquisition policy perspective, user requirements may not necessarily include the detailed needs of the soldiers as operators of an equipment (including MLCE), but usually focus on those who benefit from the use of the system at various levels of command (The User Requirement Document (URD) 'Policy' Paper Version Jan 00, accessed via Dstl Intranet on 9th Feb 06). It was at this stage, at least for MLCE, that the military requirement once agreed with operational units was articulated in the studies looked at to date. Often the requirement would be couched in a manner which began to describe a physical artefact. This type of description could be difficult to deal with since it was a part of the success criteria, and as such regarded as poor practice by limiting novel solutions. Study 4 showed how confusions in requirement can lead to functional and usability problems because of misinterpretations between various stakeholders at different levels in military hierarchy.

Looking at how individual users put their user issues, problems and ideas into development had been difficult to determine in the research. This was in part because of the lack of MLCE projects being conducted during the period of the research. Additionally, requirements were usually gathered, developed and managed by [military requirements] officers, particularly during user needs incorporation in specification development, which was difficult to access. The researcher also experienced strong resistance when approaching some military personnel to discuss this topic. It was clear, however, that senior and junior ranks (non-officers) appeared to be involved at some point in the development process, usually during testing and trialling (if done). The use of experienced users in trials has been noted as a deficiency in existing MLCE research (Vicary and Wood 2005).

User confidence in issued equipment

Current MLCE in the UK has had mixed success; female soldiers in particular have encountered issues with regard to fit, comfort and effective use. Soldiers, however, often do not necessarily get a choice in the equipment they must use. There was evidence to show that soldiers buy commercial MLCE products (Shepherd et al. 2003), but also that there may be a general perception amongst soldiers that issued equipment has been poor in the past and so new equipment will also be poor (Tutton 2008). Little work had been conducted in the UK to establish the need for soldiers to be confident and trust the equipment they are issued. Given that soldiers rely on their equipment in stressful environments, there is a need for soldiers to have confidence in their equipment. Users' dissatisfaction may illustrate how unfit for purpose it was, and how users' feedback was fed into equipment development (Human Systems Group 2007). The lack of user input has been linked to detrimental impacts on user morale generally (Jackson 2007) which is one of the components of fighting power in British Defence Doctrine (Ministry of Defence 2008).

Establishing how MLCE was evaluated in contemporary development was problematic. At first glance MLCE appeared to be evaluated against a requirement (one of Baber's (2005) four evaluation approaches) rather than against a standard, as with most products, although standards for MLCE exist, which could be used. The first standard, STANAG 2411, was limited in that it was broadly a functionally driven standard with few opportunities for objective assessment. There has been considerable effort in developing better ergonomic procedures for MLCE design in Canada, which has been accepted as a NATO standard (Northern Atlantic Treaty Organisation 2005b). The NATO methods have not been used in the UK to date (late 2008) (Tutton 2009). The Canadian procedures have successfully enabled the development of their new MLCE system. The procedure does not appear to influence need definition, although may do in practice. Some of the reasons why evaluations were not used well in the UK for MLCE development, and why it could be hard to use them for improving the user requirements, could be (adapted from Baber 2005):

1. Users do not understand what they want (Norman 1988).
2. User requirements were often incomplete, and not representative of future military systems.
3. Specifications, derived from user requirements, typically represent the *perceived* future system.

One can see all of the above, particularly the last, in previous studies. There were different approaches for capturing user requirements (Hasdogan 1996, Garmer et al. 2004, Paker 2000), though these have not been used within the context of MLCE development to date. One of the main limitations of any method to elicit user requirements is how usable they are by requirements managers, development managers (who in the UK develop design specifications from the user requirements) and operational units, who often lack the time to learn specialised techniques. Users in operational units, or as requirement managers, were from the researcher's experience often good at relating anecdotal instances of user need (especially with functional aspects of MLCE), but often could not provide a record of them. It was also interesting to note that designers may regard methods to understand the user as separate to other methods (Goodman-Deane et al. 2008).

10.2.2 Human Factors Integration (HFI) methods

Human Factors Integration, as outlined in Chapter 3, was the UK MoD's process for managing human-related issues within defence systems (MoD 2008b).

HFI, as practised in the UK, incorporated user needs in a number of different ways, principally by the adoption of user-centred design principles. In requirements definition, HFI insists upon the system requirement having people-related requirements (MoD 2008b). HFI practice also calls for the user group to be clearly identified, ideally within a Target Audience Description (TAD) or user needs study, as used within inclusive design practice. It should be noted that HFI's role in defence projects does vary, as does its influence over system requirements and development, although better practice had been established. No use of systematic contemporary HFI practices could be found on MLCE projects to date.

10.3 Developing a research strategy for the next stage of research

With the development from the cross-study assessment, the research strategy (see Chapter 4) needed to be reviewed.

The purpose of the study was to explore parameters for a resource, in order to support those involved in military equipment development in getting better insight into user (soldier) needs, and de-risk the four characteristics for MLCE development (see section 9.3.2). Additionally, there was a need to explore cognitive[56] interactions soldiers had with their equipment, at an individual level, to see whether this information would be useful in MLCE design. This was an identified knowledge gap (see section 9.3.3).

Exploration of need for a resource

Some form of resource was an appropriate area to investigate, since it may be a way of providing information about individual user needs and preferences in equipment development projects. An added benefit, as well as exploring the functional aspects of military equipment, was that a resource could also begin to look at users' confidence and trust in their equipment, which has been raised as a requirement to the MoD (Human Systems Group 2007). The success of a resource was influenced by a number of factors, but establishing the point, or points, in the MLCE project where the resource could be best used to enable better communication between stakeholders (Porter and Porter 1999) was one of the principal indicators of success. This was determined in discussion with stakeholders.

[56] Cognitive in this design context was defined as processes of perception, attention, interpretation, analysis, memory, understanding and inventiveness (Archer 1992).

Use of a resource, however, could include the following outputs:

1. Design (adapted from Chhibber et al. 2004):
    a. guide and focus design direction
    b. trends across a population – attitudes to equipment
    c. specific people ‘cases’ – to enable analysis of specific user groups or detailed requirements

2. MoD decision making and decision support[57]:
    a. tool / resource for undertaking assessments of current (and future) equipment and novel technologies
    b. trends across a population for analysis of user attitudes to equipment
    c. information resource for design contractors (MoD does not undertake design activity)
    d. human factors integration resource

Support for the design outputs had yet to be determined for MLCE development, but was pursued in interviews with civilian designers. The MoD decision-making and decision-support outputs were required by the human systems community within the MoD, but the needs of other MoD stakeholder groups needed to be ascertained.

Stakeholders included:

- Users (military personnel)
- Designers / materials technologists
- Operational analysts
- Human systems specialists
- Development managers

Sequence of enquiry

[57] Determined in an initial discussion with MoD Human Scientists: Tutton, W.M. (2007) *Notes on a meeting with Human Systems specialists* at Fort Halstead, Kent, 8/1/07.

Before a method for eliciting stakeholder requirements for a tool or resource could be determined, the subsequent use of the tool, by stakeholders, needed to be understood. The use of the tool would need, therefore, to be determined as a part of the overall research strategy and tool-development approach. Both the strategy and development approach needed to be systematic. An initial sequence of enquiry was drawn up to inform the research strategy and tool-development approach (Figure 66).

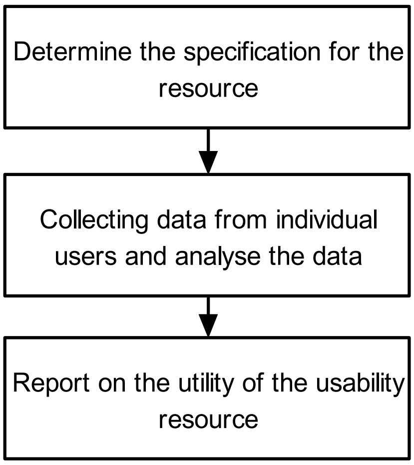

Figure 66. *Sequence of enquiry for a fully populated resource.*

The *research strategy*, and specific methods used within it needed to:

- Be simple for participants to engage in data capture
- Be flexible to allow for opportunistic data capture
- Depend on minimal resources
- Build on existing knowledge of MLCE development in a systematic way
- Deliver outputs that are easily communicable to stakeholders

At this stage it was clear that determining the research strategy would not be possible until the stakeholder requirements had been established. The stakeholder requirements would determine the data that needed to be captured and, therefore, define the methods for the two remaining stages in the sequence of enquiry.

In order to explore the feasibility and utility for the resource, a breakdown of the possible categories were drawn up (see Table 32).

Categories	Sub categories
Gender:	Male / female
Age:	
Length of service:	
Tasks:	
Environment:	e.g. Temperate, arctic, jungle, desert
Role:	e.g. Infantry, Armoured, Engineer, Artillery
Donning and doffing:	
Access and egress from vehicles:	
Use of weapons:	e.g. Platoon weapons and support weapon
Access to equipment:	e.g. Access to ammunition
Bearing different loads:	e.g. 1st line, 2nd line, 3rd line
Different speeds:	e.g. Amble (patrolling), march, sprint

Table 32. *Possible resource categories.*

The categories included many of the usability factors discussed above, such as donning and doffing, and interfaces between MLCE and other equipments. This showed the potential scope for the resource and the scale of data collection which might be needed to be gathered to make the resource fully usable. If it were populated, the number of different analyses would be powerful for exploring functional usability issues, but also user perceived problems. In the first instance, however, it was necessary to limit the initial data collection to provide an initial proof of principle (an 'Alpha' version) of the resource's utility, which will also have to be flexible depending on access to users. The points made above began the discussion of some of the potential features of the resource to frame the interviews with stakeholders.

10.4 Approach adopted

Stakeholder output requirements elicitation approach

In order to get a consistent set of requirements for the resource, the questions asked of stakeholders needed to be simple and to have a structure giving an idea of what was proposed. At the time of conducting this study, eliciting user views was a controversial subject for some in the MoD given recent media attention (Tutton 2007), and so in order to manage stakeholder responses and to fit around the stakeholders diaries, the following approach was adopted:

1. Talking stakeholders through the potential for a tool (via a presentation)
2. Conducting a semi-structured interview

The presentation to the stakeholders was developed to outline a possible approach, based on the RealPeople database (Chhibber et al. 2004). The RealPeople database provided designers the ability to view videoed interviews with consumers talking about certain products that they owned. The database provides information about the consumer (gender, age, home type and income) and information on their product choice, style choice, brand choice and personality. This provided a reference for participants against which to situate their comments. The only problem encountered with this approach was that some participants thought that the output from the database had limitations which may have restricted their responses. The questions asked of participants were broad to stimulate a discussion, which in turn stimulated insights.

The questions asked were:

- Would this sort of resource be useful to you and your colleagues?
- What sort of information would you be interested in?
- How would you prefer to access the information?

These questions allowed for a flexible and informal conversation which put the stakeholders at their ease, and allowed information to be elicited. In some instances stakeholders felt that the topics raised areas which were not their area of responsibility or interest. The researcher, therefore, had to use his knowledge of the MoD to explain the potential value of the study’s output, and where it might sit within the organisational roles and responsibilities within the Department of State.

10.5 Results

Initial discussions with stakeholders took place over two weeks, as they had time available. Notes from the interviews were captured in the researcher's notebook and formed the database for the study. Data were transcribed from the researcher's notes and memory shortly after each interview, to ensure that all the information from stakeholders was captured. The data for the first two interview questions are presented by the themes which emerged from the discussions (shown in Tables 33 and 34). The data to answer the third interview question was presented by stakeholder role, since each had different feedback which could not be grouped (Table 35). Table 36 shows the essential characteristics distilled from the interviews. The characteristics were separated into: 'must have', 'should have', 'must not', 'should not'. This was to polarise the feedback from the stakeholders and make the essential requirements for a resource more apparent.

Key	User requirements	User limitations	Understanding of user / Environment	Unpacking reasons	Key tool characteristic	Timeliness
	Users	**Designers**	**Operational analysts**	**Soldier researcher - systems analyst**	**Soldier researcher - systems engineering**	**Human scientists**
Would this sort of resource be useful to you and your colleagues?	YES	Potentially	YES	Yes	Yes	Yes
	Need to understand soldiers complaints; nature of the user (negative organisation) – there are disciplinary issues.	Have an international market so need (user requirement) information on main markets at least to make it worth while (i.e. products must work in all markets ideally).	Useful for looking at 'soft' issues, military tend toward the 'hard' or 'real' requirement, rather than aspirational > hard to discriminate though.	Users perceptions are complex but need to be understood.	Useful to track user requirement changes.	It needs to provide information about human interaction with equipment.
	Standard of interviewee is low - very hard to probe meaning of responses - difficult to elict open responses.	Influencing 'gate keepers' – (sales, buyers, retailers, consumers) of new ideas.	Amazed that we do not have this information already.	Soldiers can feel they are 2nd class citizens; combat liability in asymmetric battlefield could lead to another one size fits all approach.	Can be a problem with industry going to find out about the problem and requirement.	Input in to HFI and other HF studies supporting the equipment programmes.
	Unsolicited feedback may be best; motivated to complain, no internal method of feedback at present - take with a pinch of salt however.	Less opinion more empirical evidence.	Could be used to support Urgent Operational Requirements (UORs); 'oven-ready' acquisitions (pre-defined acquisitions focused on a particular area / interest area (e.g. desert deployment)) was the best example.	Fair bit of Commercial Off The Shelf (COTS) information available; most people want the best (suspects that this applies to users as well).	Evidence from one person may not be viewed as authoritative; users may have to be involved in filtering.	
	May be a conduit for highlighting problems that need attention.	Paper designing doesn't work well, designers must experience some of the pain a military user experiences - not always possible.		Defining user requirements is a big problem; prioritisation of need, importance and impact.	Access to unspoken meaning is problematic (e.g. Post Operational Reports (PORs)); being able to contact users to clarify issues is very useful.	Tool for technology / equipment assessments, trends analysis, HFI, Information resource (how soldiers perform).
		Development times are usually 12 months; need to speed that process up.		Requirements must be idiot proof; obvious (getting a common understanding is key – communicating it).	Human Sciences people may not understand user – used to general information (used to taxonomies), not specialised areas.	
				Decisions are made on assumption - the imagination of decision makers (visualisation / empathy) – counter imagination often not mooted to prevent gold plating.	Not sure if equipments have worked; all feedback is negative.	

Table 33. *Responses to the question: Would this sort of resource be useful to you and your colleagues?*

Key	User requirements	User limitations	Understanding of user / environment	Unpacking reasons	Key tool characteristic	Timeliness
	Users	**Designers**	**Operational analysts**	**Soldier researcher - systems analyst**	**Soldier researcher - systems engineering**	**Human scientists**
What sort of information would you be interested in?	User perceptions of failure / problems.	Ergonomics 'stats': sizing (heights), shapes, body profiles – what is happening.	Information would have to be orientated towards military parameters – link to strategic drivers (operations / environment (including urban)) / different roles, also socio issues if possible (e.g. views of Parachute Regiment versus Marines).	User perception data has specific uses; must be careful of using wrong data.	Little useful information available (there is a lot of information but it is difficult to access / unpack).	The information should not only be emotionally based; with military equipment it is to do with transitional stressors. Emphasis should be on user needs.
	Scale of 'winge', what: numbers, theatres, positive and negative comments, cross-section of users, cross-section of experience?	Evidence of military use and user comments are essential.	Baseline information would be needed (i.e. views on the performance of current equipment) versus bespoke (comparisons).	Most users are not sophisticated; one would be lucky to get 40% reliable answers for a variety of reasons (e.g. led by commanders, ignorance, illiteracy and apathy).	Complaints don't mean people are unhappy; evidence for the complaint is needed – users perception alters because they hear rumours / folk lore.	Terminology should be carefully defined.
	Un-filtered by the chain of command; organisational issues are a problem here since they can be a political issue.	Wary if the information becomes out of date; things may move on so negating the benefit of the design one has developed.	Information would have to be maintained and kept up to date; information would be time expired, which may be due to changes in operations / personal and tactics, techniques and procedures (TTPs).	Users can verbally describe problems, but one must know about environment and be able to probe quickly; if done in groups soldiers will defer to seniors / people with more experience.	Users can be biased because they haven't used an item, they may have just heard about it, they may also not understand some equipments.	One would need a detailed specification to determine where it lies on the qualitative and quantitative scale.
	Evidence of Urgent Operational Requirements (UORs) success / enables UOR planning as well as influencing longer term acquistions.	UK specific information has no commercial advantage (for this firm, because they don't see an advantage from working with MoD).	One could get information on how troops want to improve equipment - Qu:'What would you like to change?'	Users are generally intellectually limited.	Designers should understand the environment (system including human responses to the environment) and task; equipments are sub-parts of the system.	Sampling would limit its use, i.e. if too few people were in it. There may be cost implications.
		Evidence of where products do not meet user requirement, show that small differences in quality and design matter.		Need to get behind the reasons and meaning of a response; one should make an effort to understand the user's background.	Need to be able to filter the urgent versus generic problems; if one knows the problem getting a solution is easy.	Metrics would have to be carefully defined to determine cause and effect.
		Product (and sub feature) comparison would be essential.				Recording of soldiers would have to be done objectively, as would analysis.

Table 34. *Responses to the question: What sort of information would you be interested in?*

	Users	Designers	Operational analysts	Soldier researcher - systems analyst	Soldier researcher - systems engineering	Human scientists
How would you prefer to access the information?	Depends	Depends	Would depend	Web based is easiest	Depends on who it is for	Depends
	Would want to interrogate database.	Who would access it? – Ideally designers.	Could be accessed in a number of ways.		Access to SMEs could be done anonymously; IT is the constraint.	User (HF specialist) would have to know how to use the tool.
	Simple Information Technology (IT) to process and sift to enable trend analysis and the specific reasons behind the trends.	Would be useful to provide evidence to doubting stakeholders – people are resistant to change.	Could be informed by training / 'winge' websites (e.g. www.arrse.co.uk); filtering biases would be difficult.		Web based is easiest.	If one were looking at user opinion then it should be voice only to protect user identities.
	Could be based on a measure of fighting power tool used for unit assessment.	Useful because there isn't anyone in the industry who has a human factors background – makes the information accessible (corroboratory and less subjective).	Would probably have to be classified if future equipment was being looked at.		Would be useful to have a positives in a database; one does not have these at the moment.	Due to potential misuse of data the uses need to be carefully defined and a custodian's role firmly agreed.
		Must have information from: consumers and retailers.			Would need to baseline equipment to enable comparisons; it would be useful to tease out useful features / user preference.	Would not have to be web based, must be easy to do analysis and then store.
		Web Based best – do not have to learn new software.				Ideally would be available to wide group of stakeholders; the key is to know what it does and does not do.

Table 35. *Responses to the question: How would you prefer to access the information?*

Must have	Should have	Should not	Must not
User opinion / need	Imaged-based for user elicitation	Have a high-intellectual response for participants	Be emotionally based
Baselines	Evidence to influence stakeholders	Be based on large group data capture methods - (or allow leading by commanders)	Be questionnaire-based
Product Comparisons	Information on how soldiers perform		
Empirical evidence	Trend analysis		
Firm paradigm definition (quantitative info or qualitative info)	Positives and negatives		
Allow stakeholders to visualise environment	Level of detail for task analysis		
Theatre specific (link to strategic capability)	No. of people to give statistical significance		
Environmental information (link to strategic capability)	COTS information		
Needs to be quick to access / do analysis	Reasons behind comments	Give contact details of participants to allow clarification / follow up	
	Give links to other evidence		
	Quick to process and get data		

Table 36. *Characteristics distilled from the interviews.*

10.6 Discussion

The study was broadly successful in eliciting useful information to aid research into an MLCE development resource. Most of the stakeholders were prepared to be candid about working with users on research projects, perhaps because they were content talking to someone (the researcher) who was in the MoD and known to them. The study also provided information as to what research methods could be used to capture and analyse soldier-needs data.

User profiles

One of the interesting conclusions to be drawn from talking to stakeholders was the varying ability of users to engage with different research methods. This point was made by most of the stakeholders, particularly those who were practised in research involving soldiers from junior and senior ranks. According to the stakeholders one had to be careful, more so than with most participant groups in civilian society, when selecting research methods; due to the intellectual profiles of some users, as well as 'cultural' attitudes in the military. Stakeholders explained that users could be from backgrounds with limited educational success, and have problems with social interaction. It was also pointed out that the Armed Forces give users a social and cultural structure which may not foster interaction. This was described by one stakeholder as being almost 'tribal' in some units, in that they have a particular want and need to be different from other soldier groups. (It should be remembered that this, to a degree, was encouraged by the British Army, to develop unit morale and identity.) Stakeholders did explain that the best information, in their opinion, came from junior commanders, since they are generally more articulate and had considerable experience of issues that vex individual soldiers.

Methods for eliciting soldier views

Interviewing was a method to elicit user needs which stakeholders thought could be a part of a number of research approaches. This would provide the most in-depth source of usability information, since one can ask from a set of common questions but also react flexibly to issues as they become evident. The main limitation with interviewing as a stand-alone method was whether it is possible to establish a rapport with users that would enable insights about users needs to come to the fore, given the problems highlighted with getting soldiers to ‘open up’. Stakeholders were keen to point out that soldiers may regard civilian interviewers with suspicion, as not being in the military ‘tribe’. However, one researcher conversely reported that he was welcomed because soldiers could tell him things they felt they could not tell senior soldiers. Researchers also raised the importance of being familiar with what soldiers do, so that one had the same language references, and could contextualise the comments made by soldiers. Rapport-building was felt to be at the core of whichever form of interviewing used, and results could be limited in their reliability and robustness since small samples were often used.

The stakeholders who brought up the various methods which could be used to elicit soldier views, almost all were critical of the reliability of questionnaires, due to the potential for errors. One researcher reported that he had seen one non-commissioned officer get his section (group of eight soldiers) to fill forms in as he directed, regardless of the individual views. Other problems reported were that questionnaires had to be designed to be very simplistic in order to allow for low levels of literacy. A lack of proper piloting was also a common issue with soldier questionnaires.

Common requirements

The ‘must have’ requirements for the tool in Figure 36 were broadly echoed by all stakeholders. The study did not look towards prioritisation of requirements, apart from to understand desirable versus undesirable. But it was clear that stakeholders could see a role for a visualisation tool which enabled people to understand the environment and context of military activities. A number of stakeholders brought up the issue of how the tool could be used to solve specific problems. Whether it was possible for the tool to give enough detail to provide objective assessments was unclear, but desirable if the data could be gathered and presented in an accessible manner.

Divergent requirements

Some stakeholders, particularly those involved in civilian pack development, were keen on the ability to examine users’ views, in contrast to MoD stakeholders who were concerned about how one would interpret users’ views. Concerns were expressed about whether one could really determine why a given user did not like a particular feature of MLCE, because of the stressors which may be on the user which informed the opinion. On this point there was some disagreement between MoD human scientists about considering emotion as a symptom of user needs, which differed from the literature (such as Jordan (1998)). Designers were still keen, however, to understand more about users' views, particularly on function preferences with different design features. Designers from the civilian arena felt that the resource would be useful, but would need updating every six months in order to have enough current views to influence their stakeholders, such as buyers.

Resource use

There were four main applications for a resource determined by speaking to the stakeholders:

1. Evaluation setting
2. Design and sub-component information resource
3. Human factors integration evidence resource
4. User-perceived issues resource

The uses are presented in priority order as they link to the results from previous research. Evaluation setting was arguably the most ambiguous, but had the potential to be the most important since it provides the link between the success of the proposed solution and user needs. One could approach the project from this perspective alone, although there would be a risk with resource use being ill-defined and repeating research done elsewhere. At this stage, its utility may be difficult to establish with stakeholders. It was best, therefore, to develop a general resource that could begin to address all the four uses listed above, so that resource use was explored with as wide a set of stakeholders as possible.

Since the organisational situation within defence was subject to change, it was important for the tool to be able to:

- Withstand organisational change – since how MLCE development was managed within the MoD had changed during the research and was likely to again

- Be relevant to civilian design practice – since the MoD was contracting out MLCE development, it would be beneficial if the resource had relevance to load carriage practices beyond the defence context
- Be easily accessible to those without deep expertise in MLCE development

10.6.1 Method review

It had been hoped by the researcher to develop a video / audio resource based on soldier perceptions of equipment, to see if interviews with soldiers about equipment would be useful to understanding user needs. The resources needed to gain this information on soldier perceptions, however, were not available. Eliciting soldier perceptions using Jordan's (2000) ideo-pleasures, as with RealPeople (Chhibber et al. 2004), was thought to have limited utility to the niche design domains (Jordan 2008), such as the MLCE development. It was also thought that there may be a lack of support from stakeholders in the MoD for this approach[58].

The logical step was to look at whether users' physical interactions with load carriage could be examined in a different way to provide developers with insights on how MLCE was used in the military environment. In order to see whether there were any existing ways to do this in a manner accessible by developers, a review of possible methods was undertaken (see Appendix O).

The review provided a number of methods that could be used in a resource, either as a single method or in combination. Of the methods, video was an obvious way in which to provide access to developers which may not be possible through existing methods use such as writing or drawings. Additionally it had also become apparent that little was known about how soldiers were using MLCE on current operations, despite access to written (post operational reports and feedback from military staff) and some image data (from de-briefs of units).

It was known that designers did use video and audio data, but that relatively little was understood about its application (Goodman-Deane 2008 Personal Communication), although Carmichael et al. (2007) had explored the use of 'video plays' to

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[58] Tutton, W.M. (2007) *Notes on a meeting with Human Systems specialists*, at Fort Halstead, Kent, 8/1/07.

communicate user issues to designers. The most comprehensive text found on video design was Ylirisku and Buur (2007), who outline a number of approaches in which video which can be used in product design, including; design ethnography, interaction analysis, participatory design, scenario-based design and usability studies. Of these approaches, the last four were appropriate to improving MLCE development, the exact use of video in design, however, was ambiguous in this text. Ylirisku and Buur (2007) describe two metaphors for video use in design: video as a way to model abstract concerns with a product, and video as a social interaction method which enables participatory design. Which of these may or may not be applicable was not certain given the formal ‘contractual’ nature of the social interactions experienced to date in MLCE development cases, although the former seemed more likely. Ylirisku and Buur (2007) were clear, however, that video use in design was ambiguous because it allowed varied interpretations, just as could happen with observational studies. Additionally they point out that video could be effectively used, particularly with user-centred design approaches, if applied in an adaptive / descriptive manner, with the collaboration of other people. This may have presented a ‘block’ to the exploitation of video within defence projects, since they tend to be formally structured along traditional ‘sequenced’ engineering processes (see Chapter 3).

Audio data was also thought to be useful in the resource to enable one to understand what was happening in the video data. The type of audio data needed to be clarified through the development of the resource.

10.6.2 Rationale for a video / audio tool

At this point in the research it became appropriate to begin to call the resource a tool, since it would, if successfully developed, be one of a number of tools which could be used by MLCE developers, lacking personal experience of MLCE in active service, to better understand user needs. The reasons for the selection of a video / audio tool as an appropriate manner to improve MLCE versus other improvement options were manifold. To make the reasons more transparent, the various options for improving MLCE developers’ understanding of soldier needs are outlined in Table 37.

Serial	**Tool / Resource options**	**Notes on suitability for improving MLCE developers understanding of user needs**	**Existing information**	**Resources needed** – to get to an 'alpha' tool.
1	Prototype and or final product assessments	An assessment framework for objectively assessing personal protective equipment (e.g. body armour), in prototypes and commercial off the shelf (COTS) form, is being developed by Defence Science Technology Laboratories (Dstl) which could be applied in MLCE development. The framework seeks to use serving military personnel, either as subject matter experts or participants in controlled field/lab-based evaluations, the framework is adaptive to different user roles and tasks.	Poulson et al. (1996), Vicary (2001), Neilsen (2005)	High
2	Technology / existing solutions assessments	Assessments of technology and existing solutions are covered in the Dstl assessment framework above.	Poulson et al. (1996), Vicary (2001), Neilsen (2005)	High
3	Sub-component guide	Look at how to collect successful instances of good MLCE design to inform design decision making and development management. HS expertise required to aid in formulation, some guidance available already.	Humm et al. 2006	Low
4	Address current knowledge gap in MLCE design	Address a current MLCE knowledge gap, such as the physical interaction of MLCE with a user's pelvic region. Approach would need to be explicitly human science-based to undertake similar research that was conducted to look at MLCE interface over the shoulders (Jones 2005).		High
5	MLCE management guide	Develop a simple guide for use by MoD and industry to MLCE development. Considerable work would be needed to ensure that it would be accepted by MoD and industry. May experience organisational resistance if it challenged existing commercial practice.		Med
6	Video of soldier's day	Use a video of a soldier's day to give MLCE developers an idea of what soldiers do. In discussion with military advisors and analysts in Dstl the utility of a standard soldiers day has been shown to be limited since soldier tasks vary depending on the equipment and environment in which soldiers are operating. Concern was also expressed that having one soldiers day for all roles, does not represent what people in different ranks and roles do in one 24 hour period.	Ylirisku and Buur (2007), Fulton-Suri and Marsh (1999), Carroll (1995), McCelland and Fulton-Suri (2005)	Med
7	Soldier interviewing	Use of soldier interview data, perhaps collected via video / audio and organised in a RealPeople-like database. Jordan's (1998) ideo-pleasure framework is not viewed as appropriate for niche areas (like MLCE).	Chhibber et al. (2004)	Med
8	Analysis of soldier activities	Application of techniques outlined in Appendix O, such as HTA, CPA, Task decomposition and so forth, to determine where MLCE needs physical improvement.	Kirwan and Ainsworth (1992), McCelland and Fulton-Suri (2005)	Low - High

Table 37. *Review of Tool / Resource options.*

All the options were orientated towards those involved in development, from designers to development managers, as well as human systems specialists and military users, although one or more stakeholder group may benefit more than the others. The 'Resources needed' column in Table 37 was based on a rough estimate of what would be needed to make each option effective, from a cost and people (either numbers of people and level of expertise/knowledge) based on the researcher's professional experience as a technical manager.

The options in Table 37 varied in their suitability for improving MLCE development within this enquiry, in part because some were being addressed via work being conducted in the MoD (options 1 and 2). Option 3 had been addressed by Humm et al. (2006) which provided an up to date list of the information available on various MLCE components for MLCE developers. Option 4 was a generic option in which a specific area of MLCE design could be explored. The example given was the researcher's view on the main gap in knowledge that existed for MLCE design. This option would require considerable expertise of human sciences and is inappropriate to the design studies orientation of this enquiry. Option 5 was interesting, but it was thought that there may be considerable resistance to producing a joint MoD / Industry management guide, as well as limitations in validating any recommendations it would make. Options 6 to 8 provided a number of opportunities for novel improvement to MLCE development. The soldier's day (option 6) has been used in the past to explain what soldiers do, although no previous video examples could be found. Option 7 was not thought appropriate for further research in this enquiry because of the lack of an alternative to Jordan's (1998) ideo-pleasures framework due to the negative participant comments which were elicited by Study 7. Study 7 also raised the importance of improving MLCE developers' understanding of the physical aspects of military equipment use. There were parallels with evolving people's understanding of usability, as they interacted with products (Norman 2004). The use of video / audio data stimulated by option 6 (RealPeople in particular) was of interest, and combined with an analysis of soldier activities was thought to be a new way of accessing soldiers' physical work environment. The decision taken was, therefore, to pursue an 'alpha' tool that could provide visual evidence and analysis of soldier activities that could be evaluated in an MLCE development context.

10.7 Chapter conclusions

This chapter has outlined the possibilities for a tool to enable developers involved in MLCE development get better insight into user (soldier) needs with military equipment. As a result of this study a better understanding of how user needs identification was done within the UK MoD was achieved. The study also identified the need for a tool that could give developers contextual information about how users use MLCE.

Revisiting the chapter's objectives:

1. The literature available on contemporary approaches to user needs information in product development has been reported.
2. The conduct of a study to explore requirements for a tool to allow a better understanding of user needs has been reported.
3. The findings of the study into tool requirements have been discussed.
4. A way forward for the systematic development of the tool has been determined.

Key points to take forward:

1. The researcher now had sufficient information about the context of user (soldiers) needs in defence to enable the development of an 'Alpha' version of a development tool.
2. The tool review had also helped establish the available range of tools that could help in the development of the Alpha tool.
3. The next phase of the research needed to focus on how to develop and evaluate the tool.

Chapter 11: Proposal for improving MLCE development

Study 7 had explored the options for MLCE development improvement, finding that there were four potential avenues for use. This chapter focuses on the development of an 'Alpha' MLCE use tool to improve MLCE development along these avenues.

11.1 Chapter introduction, aims and objectives

Chapters 9 and 10 gave the initial context, opportunities and options for improving MLCE development. This chapter details the approach to attempt to answer Research Question Three[62] and improve MLCE development. Chapter 12 reports on the evaluation of the developed tool, and whether it was found to improve MLCE development.

The aim of this chapter is to outline the development of the 'Alpha' tool that would be used to improve understanding about user needs in MLCE development. This chapter 's place in the enquiry is shown in Figure 67.

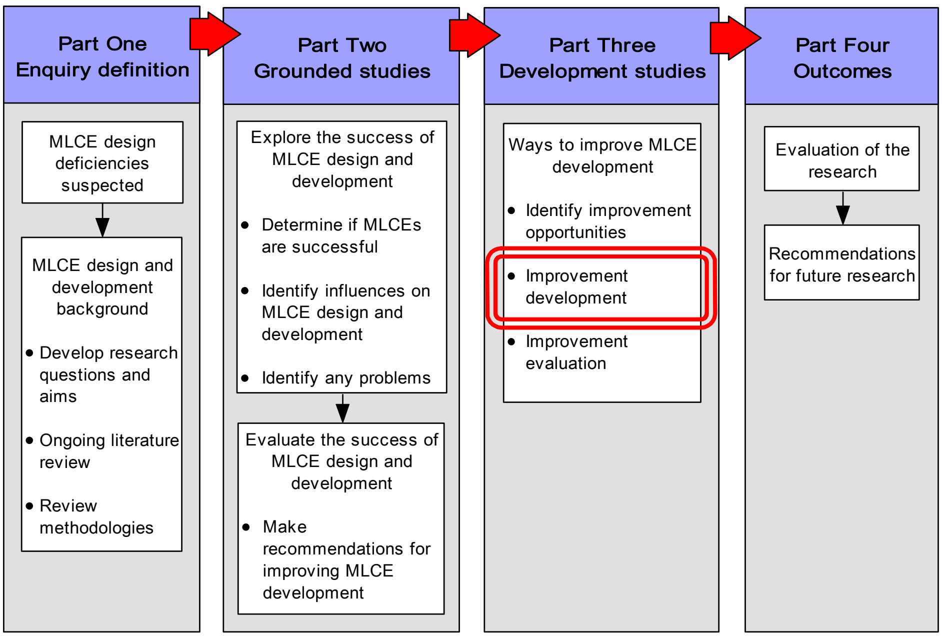

Figure 67. *Chapter 11 research map.*

[62] Research Question Three was: 'How can we improve MLCE development?'

Objectives:

4. To determine an appropriate research strategy for the tool development.
5. To determine the specific methods, within the strategy, for tool development.
6. To report on the development of the tool, including:
    a. Selection of tool elements.
    b. Development of an appropriate tool framework.
7. To discuss how the tool might be used.

The next logical step in the research approach in the chapter objectives after No.4 was to address the evaluation of the tool. The design of the evaluation strategy and methods were developed concurrently with the design of the tool but are reported in Chapter 12, including discussion of the parallels between tool development and evaluation approaches.

11.2 Research strategy development

Before the research strategy could be developed, the initial sequence of enquiry used at the outset of the research needed to be reviewed (see Chapter 4, section 4.2). This ensured the next phase was conducted in a methodological and communicable manner, as all [design] research should be (Cross 2007). The review of the sequence of enquiry was a part of the ‘Amend General Plan’ stage in Cycle 4 in Figure 68.

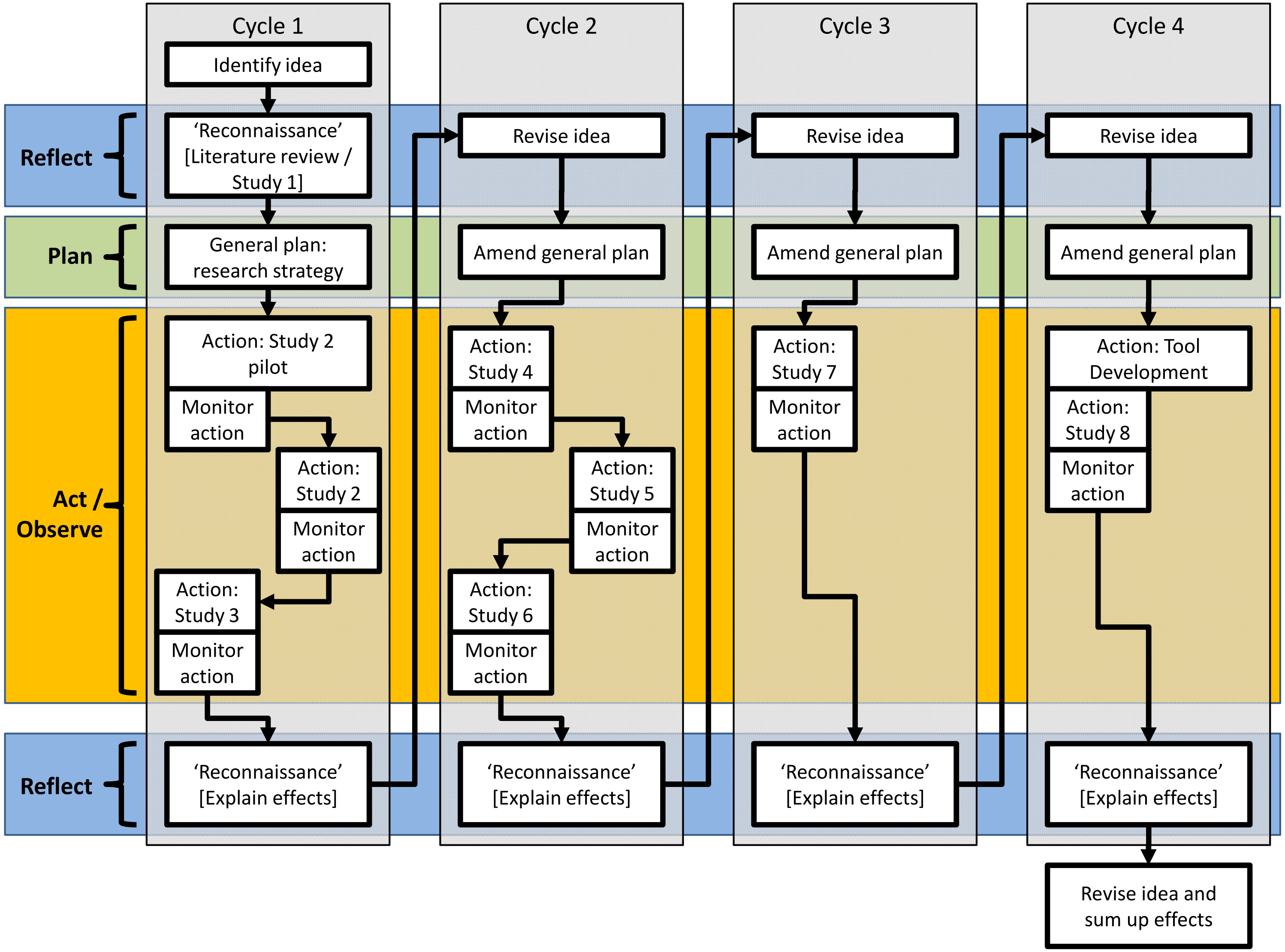

Figure 68. *Research cycles 1 to 4.*

The improvement options study (Study 7, see Chapter 10) had provided some bounding issues with which to provide an initial scope for the tool. How the tool could be assessed was an additional issue; in case it required an evaluation approach that was beyond the resources available to the research. While reflecting on this issue, options for evaluation were considered, as well as the use of the tool (discussed in Chapter 12). One evaluation option, which would have potentially meet the needs of Research Question Three, was to use one of the cases[63] in Studies 2 and 4 to evaluate whether the tool improved MLCE design. Another approach was to review the success of the tool in de-risking the four key characteristics of MLCE development determined in the cross-study analysis (see Chapter 9). Of these two approaches the first appeared more appropriate, since this would allow for comparison of the tool with known deficiencies from a 'real' case of MLCE development.

To support the development of the sequence of enquiry, a number of possible research questions were generated to help focus the research approach, as a focused sub-question of Research Question Three (RQ3). Study 7 had an identified number of options for addressing RQ3, therefore, the question had needed refining within the limits of the research's resources. Of the research questions the following was chosen to be RQ 3.1:

> 'In the opinion of MLCE development specialists, does video / audio information about the use of MLCE, processed using a number of analytical techniques, enable improvement in MLCE development?'

The research question was phrased in this manner to allow the tool to improve MLCE development without presupposing which area of MLCE development process would be improved. Due to the difficulty in accessing all aspects of the MLCE development process in the previous studies the research approach needed to be flexible to changes in where improvement might occur. There was confidence that user needs were an appropriate area for improvement; detailed improvements were not predictable since the research to date had been at development process 'level' rather than at a design activity 'level'. In addition, the chosen research methods needed to be able to

[63] Existing MLCE Cases include: 90 Pattern Personal Load Carriage Equipment (PLCE), Airmesh rucksack, and the Female Load Carriage Project.

demonstrate that an improvement in development process had occurred or was possible. This was also an important aspect to consider in developing the tool, particularly with regard to contributing to human knowledge. One avenue in tool selection could have been to simply select a well-known user-needs technique and apply it to MLCE development, and evaluate the affect it had on the process of development. There was a risk that doing this would neither be novel, nor allow for the specific issues within the context of MLCE development.

11.3 Tool Development Approach

The initial approach to developing the tool in Figure 69 (see Chapter 10) was thought too linear and did not allow for the feedback to earlier stages if needed. The approach taken changed to an inclusive model in order to allow for feedback and gradual learning about issues which may impact the use and successful application of the tool.

Selection of tool development processes

The tool development process was based upon an inclusive design model (i~design 2007) (see Figure 69). The selection of the i~design process was based upon the need to ensure that the tool was designed with feedback from potential tool users, as well as providing structure to the development. It is important to note that it was important to distinguish between applying inclusive design to MLCE development in practice and to the development of the tool. The former was beyond the researcher's control given the constraints of the context within which the research was situated. The researcher was sensitive to potential resistance for a more inclusive approach to MLCE development. Discussions with military officers indicated that there may be resistance to the tool if presented within an inclusive agenda. In part the researcher thought this to be because of:

1. The perception that current organisational processes (and officer ranks) already 'look after' the needs of junior ranks.
2. The perception that inclusive design was effete, 'pink and fluffy' as one military officer put it.

3. A lack of understanding of inclusive design within the context of defence. (At the time of writing User Centred Design (UCD) and inclusive design were applied as a part of the Human Factors Integration (HFI) practice).

Of these were issues only No.3 could be looked at through the evaluation of the tool.

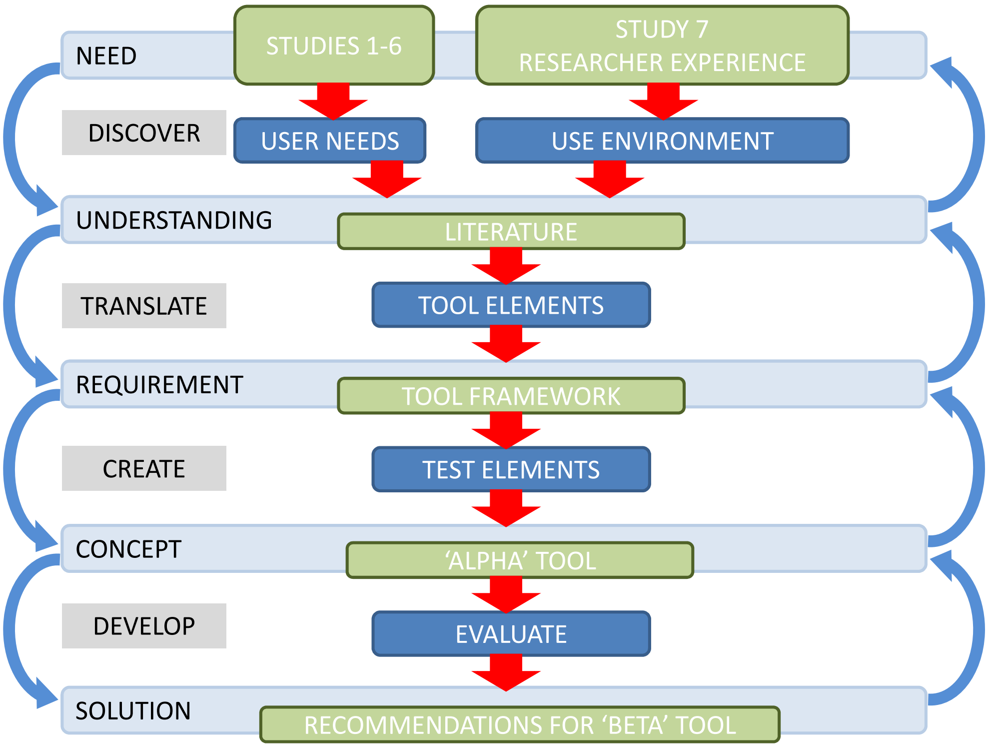

Figure 69. *Chosen tool development 'process'.*

In practice, iterative feedback through stages did occur, particularly in the synthesis of tool elements during the 'Create' phase between Requirement and Concept. This allowed elements of the tool to be checked to ensure that they were being correctly applied, given that the researcher was learning about some of the tool elements during the development. It was also important to note that although the Solution at the end of the process was listed as being recommendations for a 'Beta' tool, this would not be an end to the process in itself. The findings, and hence recommendations for the 'Beta' tool, were the end point for this research so were placed at the final stage of the development process. During the processes, however, it became clear that the feedback through the process to the earlier stages would be needed once the Beta requirements were known, since this would be the start point for the next iteration of the tool.

Tool users

After consideration the primary users of the tool were defined as those people directly involved in MLCE development, either as designers, design managers or associated specialists, such as materials or textile technologists and human scientists. This was in part due to the fact that there were few distinct designers of MLCE, and reflected that MLCE solutions were developed by a group of people. This group were referred to as MLCE developers from this point. The MoD personnel who manage MLCE contractors were a part of this group, since they directly affected MLCE design.

Tool Stakeholders

The stakeholders in the tool were defined as those who studied MLCE or who dealt with defence development processes and policy, but who were not necessarily directly involved in MLCE prototype development. These included:

- Human scientists – who were not involved in MLCE development, but had an interest in either human factors integration and / or soldier performance.
- Operational and systems analysts – involved in researching soldier systems (including MLCE) and current lessons from current theatres of conflict. Analysts often used scenario-based approaches, therefore, the tool may have offered them some useful insights.

Although the latter of these groups were least involved in MLCE development, they included individuals who knew a great deal about soldier activities and defence human factors integration, so would have a perspective on how the tool could be applied and used beyond MLCE development. Additionally, as analysts and human factors specialists, they also had a perspective on the methods [elements] used in the tool. In addition this group included [Military] Requirement Managers and Front line military units. These groups, by being soldiers, were an important group to include since they had perspectives on whether the tool accurately reflects user needs and the military environment in which MLCE was used. In the process of MLCE development they were not directly involved in MLCE design, but were in setting requirements and evaluating prototype solutions. The only exception to this were Requirement Managers in DCIPT, who may have a direct involvement in prototype development and so were included within the MLCE developer definition.

There were a number of tool requirements which needed to be explored in the early stages of Study 8:

- Use of video / audio data as a resource in the development process
- Providing some appropriate structure, or framework, to enable the video / sound information to be used and managed by developers
- Establishing where linkage to the development process was possible
- Opportunity for access to video footage of MLCE being used by soldiers in operational contexts
- Explore resources needed to populate and use the tool, depending on possible application.

Use of video / sound data in the development process

Designers often used video during concept generation, but whether video-use results in more customer-focused designs was not known (Dahl et al. 2001). The researcher was not aware of any video tools being used in MLCE development, either currently or in the past.

Only two papers were found on the use of video in design activities in the literature to date. The first shows a model of logical ways to construct architectural videos (Rhodes and Powell 1994), and to develop strategies that improve the effectiveness of learning and video production. The second paper described the use of video to enable novice designers' reflection on collaborative design projects (McDonnell et al. 2004). While neither of these papers was of direct relevance to the study, both showed instances of research methodology utilising video footage, and allowed for reflection on how video use could be evaluated in the study.

11.3.1 Tool framework

In order to develop the tool framework it became clear that further exploration of how the possible tool elements would be brought together needed to be undertaken.

Soldier tasks

The researcher focused on looking at soldier tasks as a way of providing a framework for the tool which could include video and audio data. The literature review information on task scenarios was explored since they had offered benefit to product design (Stoop 1990, Harker and Eason 1984 and Fulton-Suri and Marsh 1999) and so may benefit MLCE development.

Scenario tools for describing users were found to be varied (Hasgodan 1996) and do so through a fictional portrayal of a specific user (a ‘user model’) doing a task in the context of a realistic future (McClelland and Fulton-Suri 2005). Scenario tools have been ordered into the following categories by McCelland and Fulton-Suri (2005):

a) Journey maps
b) Storyboards
c) Story telling
d) Task-flow schematics
e) Usage scenarios
f) Work mapping

Each of the scenario tools could be applied with different degrees of fidelity, although each varies in its impact on design processes. Of these the most appropriate and useful to MLCE development was thought to be task-flow schematics (d) and usage scenarios (e) based on the findings of Study 7 (Chapter 10). Use of tools a – c above in MLCE design needed to be ascertained. It was thought, however, to be difficult to apply tools a – c without their ‘user models’ of soldiers being unrealistic, and false to military stakeholders, as can happy with civilian contexts (Fulton-Suri and Marsh 2000). This falseness was thought in part to be due to the large variety of soldier roles for MLCE. Video and audio data of real soldiers, as a part of scenario tools, was thought to be one way to counter any issue of realism or falsity. Hasdogan (1996) has presented the largest review on the subject of user model use in design, which illustrated the variety and lack of formalised approaches to frameworks that describe users and their needs.

Since scenario tools appeared to offer a variety of potential advantages, it seemed pragmatic to see if there was a way to combine aspects of them in a framework to optimise the benefit to MLCE development. Of the tools available, the most applicable to MLCE development seemed to be one that structured how MLCE was used. McCelland and Fulton-Suri (2005) describe combination tools as interpretive frameworks which are used to build consensus and make sense of complex user issue information. Combination tools were thought to be forms of 'link analyses' which identify relationships [links] between an individual and some part of the system (Chapanis 1959 in Kirwan and Ainsworth (1992)). It seemed appropriate to begin to explore types of link analyses, as potential tool elements, which could be used to within the tool's framework. Additionally the different aspects of use (scenarios) needed to be analysable using the various tool elements [link analyses].

A framework that used scenarios and had the ability to provide empirically based information for designers was Lim and Sato's (2006) Design Information Framework (DIF). This software-based tool (Jung et al. 2005) provided a number of benefits which were applicable to MLCE design, not least of which was the ability to combine different aspects of use and a formalised approach to developing structured scenarios. DIF has been developed from looking at a variety of use situations. Examples looking at medical equipment show how different views of use have been combined to provide scenarios that were used for requirements elicitation and evaluation of solutions. The methods (essentially link analyses) used in the DIF tool to provide the view included: activity-role analysis, spatial layout analysis, Hierarchical Task Analysis (HTA) (Nemeth 1990) and information flow analysis. DIF appeared to be based on observations, of user interactions with medical equipment. These were then ordered, using the DIF software, to enable analysis using a number of 'aspect models' (link analyses). From the analysis provided by the range of aspect models, scenarios could be produced which provide insights for the design process, primarily requirements for system development. These requirements were identified using simple coding to organise the observed actions, people undertaking them, goals, settings and conditions, with HTA providing the framework for developing the scenarios. The criteria and manner in which information was then identified within the scenarios to feed requirements for systems design was derived from the descriptions within the written scenario. This approach also allowed for capturing notes on, and descriptions of, the problem, as well as describing the activity in pursuit of goals.

Relevance to MLCE development

The limitations of DIF were not clearly apparent from the literature since only one example of use was presented. It was suspected that DIF was complex in structure, in particular the way in which user information was handled by the software, and was reliant on expertise in the various aspect models to produce system requirements for development. DIF appeared, however, to offer a relatively simple way to use established techniques (the link analyses) to explore the requirements and problems that users had with MLCE. The approach used in DIF could also be used with video and sound data, and was flexible and transparent to see where the scenario descriptions came from. This would be particularly important in demonstrating its use to military personnel, since the base data could be soldiers doing realistic soldier tasks, particularly if the data was gathered from operations. It was also attractive since, as a form of link analysis, it did not require direct input from soldiers apart from them carrying out normal soldiering activities.

Alternative approaches

It was also thought possible to approach the MLCE tool development using a similar framework to DIF which did not use video and sound data, but relied upon military experience of given scenarios. This approach was thought to be more limited than one based on video capture since it depended on personal judgement, and so may have lacked reliability. The researcher also suspected that judgement-based approaches, in the context of MLCE, did not tease out little known or understood requirements. The transparency of the data and accessibility of the information was a strong limiting factor. This approach was also reliant on the ability of soldiers to express their experiences in a manner that the designers would find accessible.

Linkage to the design process

Linking the design tool to design processes was important to establish where improvements might be made to MLCE development, and define the tool-evaluation approach (see Chapter 12). If a scenario / link analysis hybrid approach were used, similar to DIF, then the main benefits would be at the initial stages of development, in requirement identification and understanding user needs. Frameworks and use scenarios were likely to impact on the earlier stages of the design process according to McCelland and Fulton-Suri (2005), which are the areas where MLCE development has the most weaknesses. The main benefits adapted from McCelland and Fulton-Suri (2005) being:

- To illustrate the use of MLCE
- To evaluate MLCE functions
- To design MLCE features
- To test an idea (fault find in an existing MLCE concept)

Links to design methods

The low use of design methods in MLCE development, apart from drawing and physical prototyping, had been outlined in the Studies 1 to 6. As a design method to support prototype development it was thought unlikely that a hybrid scenario / link analysis tool would be capable of evaluative 'virtual' use trials (Gyi et al. 2004). A hybrid scenario / link analysis tool would, however, enable developers to familiarise themselves with MLCE use in the military environment, and identify design options and refine design solutions (McCelland and Fulton-Suri 2005). It was possible that the scenario descriptions and tool elements (aspects in DIF), HTA in particular, could provide a supporting framework for formal assessment procedures which already exist for MLCE (Stevenson et al. 2004 and Jones 2005).

Limitations

It was doubtful that a hybrid scenario / link analysis could be used to evaluate load carriage through measurable performance metrics, a common problem with link analysis (Kirwan and Ainsworth 1992). The results may also be limited to a given context or situation. This may mean that, if only information from current theatres were used, that requirements derived may focus on current MLCE technologies and produce requirements only relevant to how soldiers 'fought the last war', a common criticism of defence acquisition. Video data should, therefore, be sought from a wide variety of operations and the potential of using historical images was also thought appropriate as it also applied to the environmental context in which MLCE was used[64]. There was a risk that scenario samples may not represent soldier activities with MLCE. This could have been addressed by undertaking a Mission Analysis, a commonly used technique in MoD Human Factors Integration (HFI), closely related to Operational Analysis. This form of task analysis was usually done in the MoD in concert with soldiers to determine what activities they do, and how often they do them. It was decided that this was outside the scope of this study, since the focus was to establish the utility of the tool rather than develop a fully working scenario set. In addition Mission Analyses tend to be classified due to the nature of the subject matter since some soldier activities, such as tactics, may be classified.

These last two points were regarded as bounding issues for the tool, which should it be used on a real MLCE project, would need to be determined by the MoD. Comments on these issues would need to be collected to explore the impact they might have on the use of the tool's output. It should also be noted that from the researcher's experience and the cases examined in the other studies, it was likely that the MoD would use other tools, as well as the MLCE tool, to determine MLCE requirements, particularly military judgement.

Opportunity for access to video footage

The researcher pursued a number of avenues to get video and sound data footage of soldier activities whilst on operations, in order to begin MLCE tool development. These included:

- The World Wide Web

[64] OA is known as 'mission analysis' in human factors literature (Nemeth 2002) although this was subtly differently to Mission Analysis, as defined within MoD HFI practices, depending on how and at what level a scenario was defined. OA was also discipline used extensively by the UK Ministry of Defence (also known as Operational Research) to determine systems requirements and support decision making, and also uses scenarios which again may be differently defined when compared with human factors disciplines.

- MoD British Defence Film Library (BDFL)
- Other soldier researchers
- Informal contacts in the military
- MoD press office
- Media organisations

In the first instance, this footage proved very difficult to get, despite the number of current and ongoing operations. The main issues associated with this were:

- Access to data of sufficiently high resolution to see and hear the soldier activities
- Access to data in the right data format for editing (much of the information on the web, such as www.utube.com, was protected)
- Access to footage that had not already been edited
- Lack of captured data of soldiers interacting with MLCE sub features (although there was a lot of footage of them wearing MLCE)
- Lack of data of soldiers doing certain military tasks (such as during a fire fight, or donning or doffing MLCE)
- Access to sufficient incidences of each type of activity in order for the tool to be reliable

These were all limiting factors, not only to the development of the tool, but also to its use in practice. Some data was available from BDFL, however, which enabled the development of the tool, and it was hoped that further data would become available throughout the course of the study as links were made through stakeholders. It was also possible for data to be collected from exercises. In order to attend exercises to gain data, the utility of the tool would have to be demonstrated to stakeholders.

It was possible to begin the creation of a hybrid scenario / link analysis tool using the video and sound data from BDFL. The developed tool would be an ‘Alpha’ demonstration tool, to establish the usefulness to MLCE developers and look at its use as an evaluation tool. The ‘Alpha’ tool would also allow stakeholders to review how the tool could be used beyond MLCE on other defence systems.

11.3.2 'Alpha' tool development

During the 'Alpha' tool development it was necessary to revisit the tool framework in order to address a number of tool performance issues, namely:

- Scenario and video / audio data management
- Use aspect models

Scenario and video data management

During the development of the tool framework it became evident that, depending on the specific link analysis (scenario tool) used, it could be difficult to look at the different ways in which MLCE might be used. Lim and Sato (2006) found that using several aspect models together was needed to enable the discovery of hidden problems, which may not have been uncovered through the use of one model. This was a risk to how the tool might be used in MLCE development, since in the future development may be undertaken by relatively inexperienced designers who may not know which models should be considered. This needed to be considered during the evaluation to establish whether designers would do the analysis or not, and how they would use the tool outputs.

There was also an issue in selecting the 'right' scenarios to describe soldier activities when evaluating the tool. This was addressed by explaining to potential users, that:

- The footage was of soldiers doing activities on 'real-life' operations to ensure the 'Alpha' tool scenarios were realistic
- Representative scenarios for use in MLCE development would need to be determined by the MoD in later (post 'Alpha') versions of the tool

In order to develop the tool the researcher used video / audio data of activities from footage available from the British Defence Film Library and Dstl archives. The selection of the clips used was done by editing clips from the footage that showed periods of sustained soldier activity. The footage was selected by whether MLCE was worn within the clip, particularly where soldiers interfaced directly with the MLCE.

In the footage available this provided three clips that could be used to develop the tool, which were clips showing:

- Movement while under fire (a group of soldiers running between cover while being shot at)
- A tunnel clearance (soldiers making sure enemy were not in a tunnel)
- A raid (a group of soldiers breaking into a compound to seize assets or people)

From the researcher's experience as an analyst, these were all representative soldier activities.

Each clip was processed in the following steps:

- View the footage (video and audio)
- Identify an initial idea of the goal, which was written down as a title (listed above, dependent on the researcher's knowledge of soldier activities)
- Revisit the footage to check that the goal, as written, was what the soldiers were trying to do
- Undertaking the relevant link analyses using the selected clip and reselecting the clip if information had been edited out.

Link analysis methods

In order to develop the 'Alpha' version of the MLCE tool the researcher decided to limit the tool to three of the methods used in the DIF framework:

- Activity Role Model (ARM) – a simple outline of the people involved and what they are doing, a simple form of task decomposition (Kirwan and Ainsworth 1992: 95).
- Spatial Layout Model (SLM) – a simple map of the environment in which the activities are conducted, as described by Kirwan and Ainsworth (1992:122).
- Hierarchical Task Analysis (HTA) – a well known human factors analysis approach, the technique was followed as laid out by Shepherd and Stammers (2005).

The possibility of using other methods was to be explored through the evaluation.

Integrating into a scenario story

Once the individual link analyses were completed it was then possible to begin to integrate them, either directly by incorporating the ARM and HTA on to the SLM, or through the writing of a scenario description. The decision as to which approach was used depended on the complexity of the scenarios.

The writing of the scenario description was done directly from the link analyses, giving a summarised account (story) of the footage (video and audio), broken down by HTA stages. The scenario description was also partially coded using the following descriptors:

- Action (derived from the ARM)
- Goal (derived from the HTA)
- Problem descriptions
- Requirements

Since the 'Alpha' tool was looking primarily at footage which contained largely physical use of MLCE, no communication code was used.

The problem description and requirements codes were unpacked to give a layperson an indication as to why they had been highlighted. At this stage in the tool 'development requirements' were coded dually with 'problem description' to highlight they were aspects which needed to be prevented, or that further investigation was needed before they could be authoritatively labelled as a requirement.

Figure 70 shows an example of a summary poster that was used to develop the 'Alpha' tool.

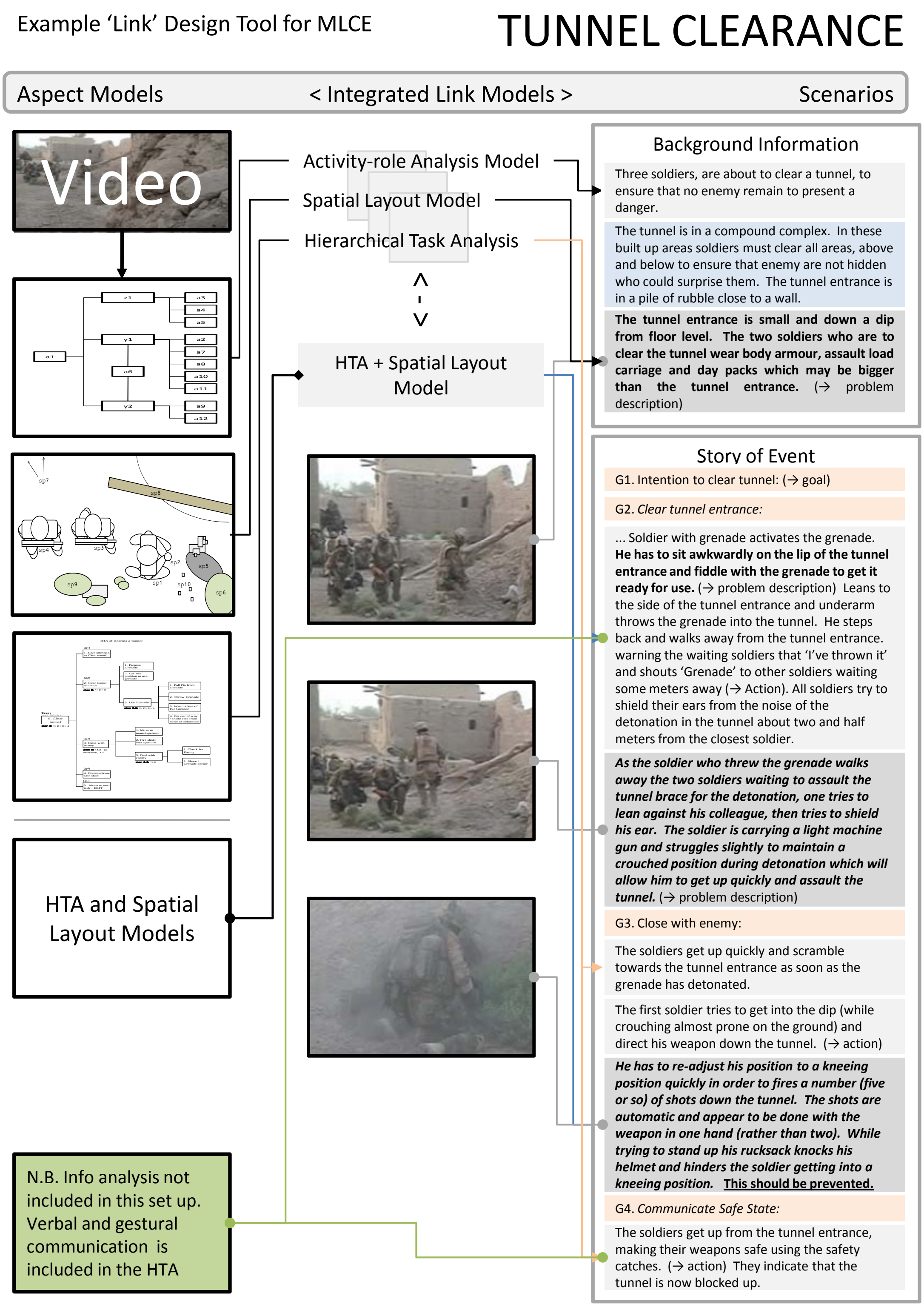

Figure 70. *Example 'link' design tool for tunnel clearance task.*

The three clips were not compared, but a summary of the analysis of each individual was undertaken to see what could be learned about MLCE from the footage. These examples were mostly from the link analyses, but also from the researcher's observations that highlighted aspects such as fatigue and carriage of weapons (moving under fire) and interference with MLCE and other tools (raid). These observations were not overt from the link analyses, so highlighted the importance of noting issues as they were seen rather than relying on the analyses. This approach to video/audio data for design was a form of observational study which was often used to gain insight into ergonomic issues from descriptions of activity (Bisantz and Drury 2005). This last point also made the experience and knowledge of the observer of the footage important, raising the possibility of using expert reviewers to help gain observable insights (explored in the evaluation).

Cognitive aspects of use

One of the deliberate limitations of the 'Alpha' tool was the current lack of any cognitive model to capture people's views on the products they were using, or tasks they were doing. The tool relied on HTA which can be limited as to how it picks up cognitive issues. A solution to this may be Cognitive Task Analysis (CTA), this would have to be done carefully (Shepherd and Stammers 2005). Cognitive performance was implicit (to a degree) in task analysis approaches, so depending on what one needs to know about cognition during tasks, these aspects may require an understanding of experimental psychology to build CTA into the framework. This was thought to be beyond a designer's usual skill set. So CTA was beyond the scope of the study, although it may be an interesting avenue for further research (see Chapter 13).

11.4 Tool use

Potential tool use was important to determine, since the 'Alpha' tool had been developed as a general 'context setting' resource, as discussed in Chapter 10, Section 10.6. It was envisioned that the tool would be used during the early stages of the development process to improve understanding of how soldiers used existing MLCE. The detailed use of the tool was difficult to predict, since development appeared to be conducted according to how experienced developers were.

Another question remained about the degree to which developers would input into the tool. Some of the elements did require specialist knowledge that could be learned by developers, but whether they would have the time was uncertain at this point (also see section 11.5). To explore where in the process the tool might be used, and what it might be used for, the tool capabilities were listed against an inclusive design process (Figure 71).

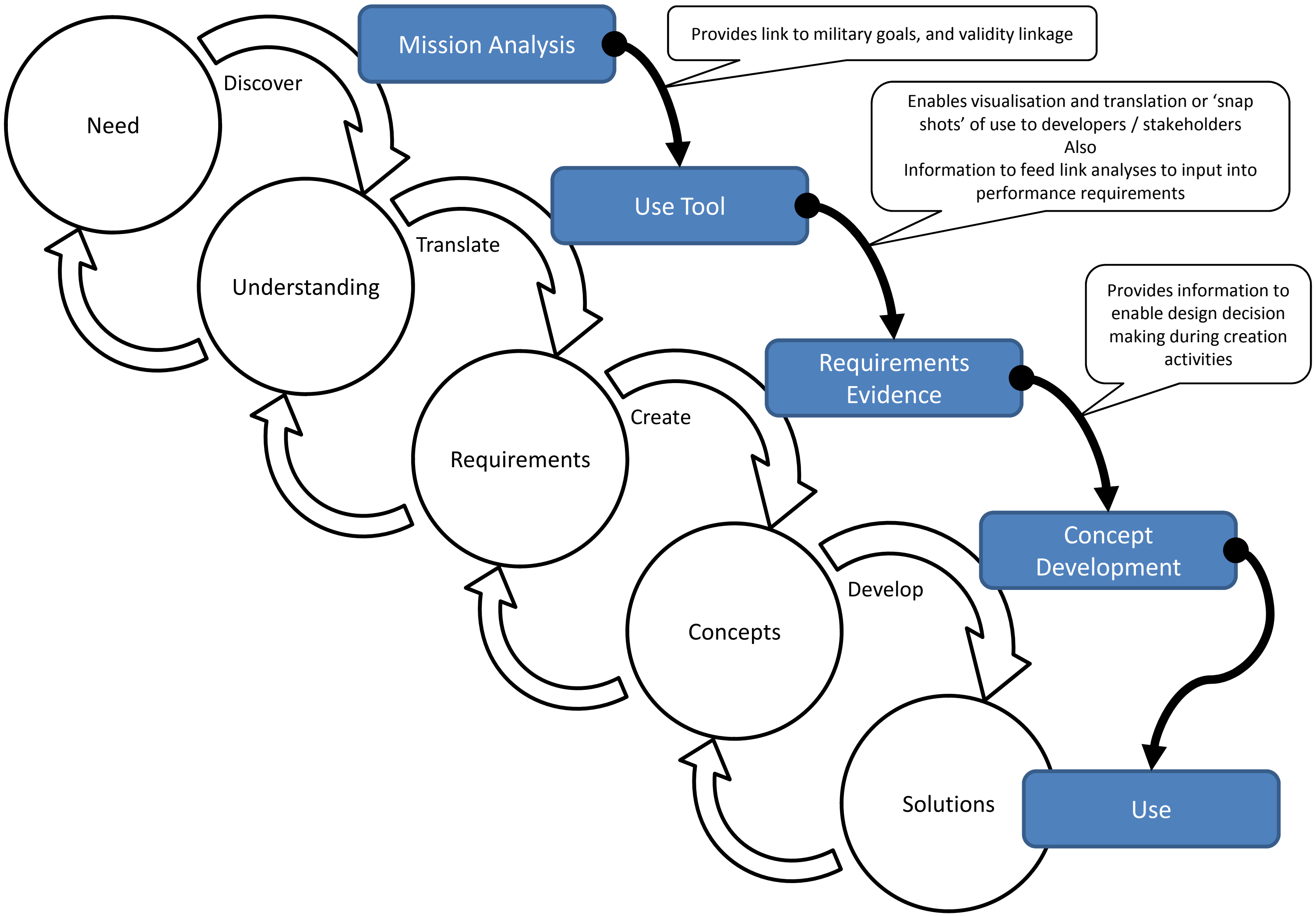

Figure 71. *Potential tool use within an inclusive design process, adapted from i~design (2007).*

The uses noted in Figure 71 were ideas of how the tool could function, and needed to be checked in the tool evaluation. This did raise the importance of checking tool use throughout the development process as a part of the tool evaluation.

11.5 Tool limitations

A number of the tool limitations have been discussed in the sections above, such as representativeness of the scenarios to ‘real-life’ activities, and availability of video and audio data containing MLCE interactions. Through the development of the tool it was also apparent that making causal links was a danger during coding the scenario description and observation data during the analysis. The researcher found several times that because of his knowledge of human systems in relation to MLCE, he was making assumptions as to why problem situations were arising and including them in the analysis. In practice this was not a problem as long as the tool user was sensitive to making casual links and the tool outputs presented as insightful, requiring corroboration by further investigation, or other evidence.

Reliance on specialist expertise

The aspect models were relatively straightforward to develop and use, although specialist reading on HTA was required. It could be argued, therefore, that it may not be appropriate for this to be a quickly applied design technique, since some specialist skills were needed. The tool, however, could be built up by a developer with the requisite skills to provide an enduring resource, given that soldier tasks do not alter much over time. Alternatively it would not be onerous for one designer to learn HTA and build up the tool over time, as footage became available.

11.6 Chapter conclusions

This chapter has provided an outline of the structured development of a tool to improve user needs understanding in MLCE development. The inclusive design process used to develop the MLCE tool was found to be successful, allowing for controlled feedback through the stages. The main benefit in using the inclusive design process was the emphasis on meeting the needs of MLCE developers. Reflection on this issue enabled the researcher to successfully identify appropriate methods for the tool and highlight that users needed to evaluate the tool before it was developed further. Although the initial scenario / link analysis approach did have limitations, it provided a flexible framework in which other methods could be joined, should the tool evaluation highlight the need.

Revisiting the chapter's objectives:

1. A research strategy for the tool development has been reported.
2. The specific methods, within the strategy, for tool development have been reported.
3. The development of the tool has been outlined, including:
    a. Selection of tool elements – a hybrid scenario / link analysis tool has been chosen as the candidate MLCE tool for exploring user needs.
    b. Development of an appropriate tool framework; the development of the tool has been reported, along with the main insights and limitations with the application of the tool found by the researcher prior to user evaluation.
4. How the tool might be used has been reported.

Key points to take forward:

1. With the development of the Alpha tool, the tool now needed to be evaluated to assess whether it would improve MLCE development.
2. Due to parallels between the development of the tool and the evaluation approach these two aspects were worked up concurrently, but reported separately.

Chapter 12: Evaluating the improvements offered by the use tool in MLCE development

The MLCE use tool had been developed as a possible way to improve MLCE development. The tool now needed to be evaluated by the small numbers of practising developers active in the field. This chapter covers the development, selection of the research strategy and methods and reporting the tool evaluation.

12.1 Chapter introduction, aims and objectives

This chapter aims to outline the research strategy taken to evaluate the user needs tool for MCLE, including: the specific methods adopted, conduct, output and discussion of the outputs. Figure 72 shows Chapter 12's place in part three of the thesis, as a part development studies.

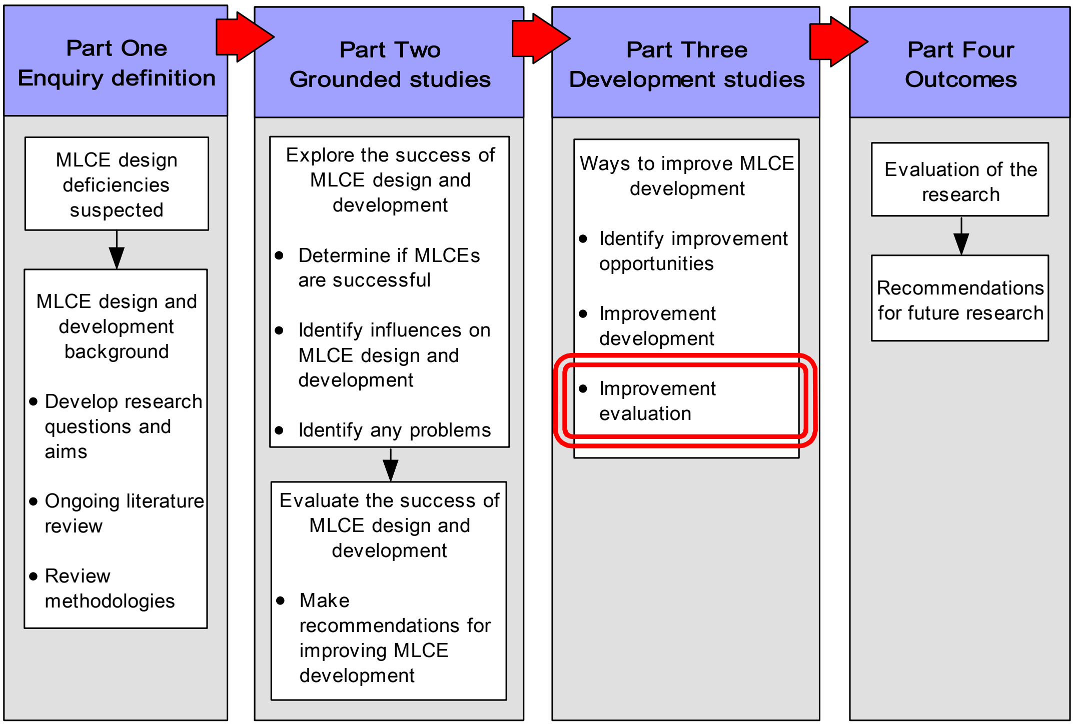

Figure 72. *Chapter 12 research map.*

Objectives:

1. To define the research strategy and specific methods to enable the evaluation of the user needs tool for MLCE.
2. To report on the conduct of the study.

3. To report and discuss the output from the study.
4. To discuss the success of the research in the context of the research question.

12.2 Tool evaluation approach

The approach for the evaluation of the tool was developed concurrently with the 'Alpha' tool. This approach ensured that the tool was developed in such a manner that it could be evaluated by MLCE developers using the resources available to the research. Central to this was ensuring that the tool various elements were transparent to potential tool users. This was shown in the 'Develop' stage of the approach (Figure 69), where tool users evaluate the tool to establish recommendations for the next tool version. This appeared to be a more transparent approach than some development approaches which inferred that once a product was in use that it was unlikely to be developed further. It was realised that the tool would need to undergo a number of iterations and be adaptable to allow new tool functions if needed.

12.2.1 Research question

As outlined in section 11.2, see Chapter 11, Research Question Three could be addressed by a number of development improvements and so modified to:

> 'In the opinion of MLCE development specialists, does video / audio information about the use of MLCE, processed using a number of analytical techniques, enable improvement in the MLCE development?'

In order to begin to determine the research strategy and specific methods to answer this research question (RQ.3.1), a number of objectives and sub-questions related to the utility and efficacy of the tool were proposed. These were stated in order to further define 'improvement' in the research question, so that specific methods could be used to see whether the tool would improve MLCE development. The term 'improvement' used here was a qualitative one, as used in earlier studies. Such 'improvement' was to be measured by establishing if the process of development was made better by the tool, in the opinion of the participants: more desirable, satisfactory, or effective[68].

Objectives and sub-questions:

1) To establish the level of utility to individual developers:
    a. Does it assist them in the development / design activity they undertake?
    b. Is it a desirable improvement?
    c. If so how does it assist?
2) To establish the level of improvement to the process of development:
    a. Does the tool make the process better (more or less efficient / effective, satisfactory)?
    b. And if so how does it make the process better (more effective / efficient / satisfactory)?
3) To establish where in the process of development the tool could provide benefit (and if the tool is not beneficial):
    a. Where does it make the process better (more effective / efficient)?

These objectives and sub-questions were stated to provide a linkage between the research question, chosen research strategy and methods.

The first objective (1) was introduced in order to see if insights could be gathered into design activity, since this had been a difficulty in earlier studies. These studies had also shown that individual team members bring specific skills relevant to MLCE development. It was important, therefore, to see if one could gain insights into whether the tool helped individuals with their area of MLCE development.

The second objective (2) was added to ensure that the tool's improvement to the effectiveness or efficiency of the process was detected. For example in training developers, or familiarising them with the military environment. It was important, therefore, to be sensitive to this possibility and ensure that the selected research methods would detect these benefits.

[68] Definition derived from the Online Oxford English Dictionary, accessed 21/06/08, available from: http://www.askoxford.com/concise_oed/better?view=uk.

The third objective (3) was added in order to define ‘improvement’ within the development process. At the beginning of this study, before the tool was developed, it was uncertain whether the tool would be evaluated against a previous case of MLCE development (discussed in section 12.2.2) or judgementally assessed on its own merits according to individual evaluators’ perceptions of MLCE development. The research methods used in the study would have to be assessed to see which of the two approaches would be sensitive to detect ‘improvements’, and if they could provide a measure as to the level of improvement (assuming that the tool would have a positive impact).

Propositions

The objectives and sub-questions were regarded as initial propositions (Yin 1994) for the expected outcomes from the study. This enabled the researcher to identify what the research methods would have to be sensitive to, to get robust recommendations for the next version of the tool.

12.2.2 Strategy for the evaluation

An influence on the research question and research strategy was the suggestion, by the Director of Research, as to whether the tool could be evaluated in the context of one of the cases from an earlier study. This approach required an MLCE case to provide a benchmark against which the improvement the tool could be judged. To assess the feasibility of this approach the MLCE cases looked at to date were reviewed.

Selection of MLCE development case

Of the MLCE development cases looked at, initially, the Female Load Carriage was most appropriate, because:

- It was a contemporary event for which the problems were well established
- It contains evidence of user problems
- Access to designers could be achieved

The other cases (Airmesh Rucksack and 90 Pattern PLCE) were not appropriate, because:

- The designers were no longer available for either case
- There were too few problems with the Airmesh rucksack
- Access to users was problematic with the Airmesh rucksack (it was for elite users)
- The MoD's organisational processes had changed dramatically from 90 Pattern

There were sensitivities with using the Female Load Carriage case, which made overt referencing to it problematic, in that some interviewees may be familiar with it an so give potentially biased responses. An alternative, therefore, was to use a generic development process having instances of the problems found in the three cases. One possible process was Pugh's (1991) Total Design Activity Model, since it had similar stages and descriptions to MLCE development that would allow interviewees to easily recognise the stages in it. Other representations like Pahl and Beitz (1996) and Ulrich and Eppinger (2004) were thought to be overly complex, and others like Archer (1984) and Lawson (1983) too simplistic and abstracted. Use of an inclusive design process, (http://www.inclusivedesigntoolkit.com/betterdesign/process/, accessed 04/04/08) while desirable, was difficult because it was so different from existing practice. The use of a generic development process was also thought to allow designers and developers from the civilian load carriage arena to comment on the tool.

Benchmarking versus a 'better' practice model

An alternative to using a problem-based generic process was to use a 'better' practice, a model of how MLCE development should be done. This was considered, particularly given the potential benefits from inclusive design approaches. Using this approach, however, was thought to be difficult to apply given the lack of consensus on what was a MLCE 'better' practice model (see Chapter 11). Before the generic MLCE development process with its related issues was adapted, the possible research methods needed to be explored.

Selection of research strategy

The research question, objectives and sub-questions could only be explored using qualitative methods, since the research was trying to elicit the views of participants. It was decided, therefore, to continue the with the phenomenological research strategy outlined in Chapter 4. This helped determine the research methods which could identify people's views of the tool's success. Methods that could enable interpretation of people's views on the tool were:

1. Observation – observe people using the tool
2. Interview – ask developers questions about the tool related to their experience
3. Focus group – ask a group of developers questions about the tool related to their experience
4. Quasi-experimental approaches – determine differences between tool and no tool use by application of the tool in a 'design exercise'
5. Expert review – similar to No.1 and 2, but using a court-like framework to highlight pros and cons of the tool

Research methods, such as a survey using questionnaires, were not considered as a method for evaluating the tool due to the limitations encountered in Study 6 (Chapter 8); presenting the tool by phone or in writing, potentially denying participants the opportunity to ask questions. The summary of the methods review is shown in Table 38, with the review outlined in Appendix P.

Method	Summary notes	Methodological references	Design references
Observation	*Observe people using the tool* – an observation approach needed a developed tool. Observation would also be a part of other analyses, to note people's 'unspoken' view of the tool in gestures and manner.	Kuniavsky 2003, Bisantz and Drury 2005, Ylirisku and Buur 2007	Ylirisku and Buur 2007
Interview	*Ask developers questions about the tool* – interview methods, particularly the use of a 'scenario-based interview' to check participants' views of the tool within the design process, were viewed as the best way to evaluate the 'Alpha' version of the tool. Although the sample of participants was likely to be small compared with other studies, the results were thought to be valid if viewed as an expert review of the tool. It was also decided to use an interpretative approach to analysing the feedback to enable the participants' perspectives and backgrounds to influence the analysis. This method also overcame confidentiality issues present with Focus Groups, and enabled the researcher to build a rapport with participants to get them to volunteer relevant information and feedback on the tool and MLCE development.	Oppenhiem 1999: 67, Smith and Osbourne 2003, Smith 1995, Willig 2001, Bryman 2001: 124, Wilkinson 2003: 196, Silverman 1993, Gray 2004, Althedie's (1996) in Bryman 2001, Silverman 2000, Millward 2000, Spear 2008, Carrol 1995, Crouch and Housden 2003, Stasser and Titus 2003, Cohen at al 2000:113, Watts and Ebbutt (1987) in Cohen et al 2000: 287	Cross and Clayburn Cross 1996, Cross 1998, Petre 2004, Carrol 1995
Focus group	*Ask a group of developers questions about the tool* – focus groups were not used as a method, because of the difficulty of getting participants together at the same time, and the necessity of getting participants to open up to the researcher.	Morgan 1997, Litosseliti 2003, Bryman 2001, Wilkinson 2003, Stasser and Titus 2003, Morgan 1997, Dugglesby 2005, Krueger and Casey 2000, Millward 2000	McDonagh-Philp and Denton (1999), Bruseberg and McDonagh-Philp 2001
Quasi-experimental approaches	*Determine differences between tool and no tool use by application of the tool in a 'design exercise'* – quasi-experimental methods were considered, but not adopted due to the relatively undefined role for the tool within MLCE development. They were simply not appropriate at this stage in the development and research into the tool.	Cohen et al. 2003: 215, Cross et al.1981, Robson 1993	Dahl and Chattopadhyay 2001, Radcliffe and Lee 1989, Hanna and Barber 2001, Fricke 1999
Expert review	See interview.	Schneiderman 1998, Pew and Mavor 2007, Sinclair 2005	

Table 38. *Summary of methods reviewed for Study 8.*

From the review of the methods it was determined that an interview approach was the most appropriate. Interview had the advantage of being an adaptive method, which could be reviewed after each interview to ensure that the right questions were being asked to inform the development of the tool. The other methods had practical limitations as well as requiring an 'operational' (usable by others) version of the tool, and better identification of where it would help in the development process. It was important to explore the 'context of use' with the participants, as recommended by Baber (2005). The purpose of the use tool evaluation was not to undertake a usability inspection or evaluation, however, but to establish the possibilities for the tool's context of use in MLCE development practice. This also had a strong linkage to the possible use of ethnography (see section 12.3.4) as a way to explore the tool's use in MLCE design activity. Since the 'Alpha' tool was not fully developed and the context of use not fully understood, looking at the quality of users' use of the tool was difficult to achieve.

12.2.3 Chosen research method

From the review of the possible methods that could be used to evaluate the tool, an interpretative semi-structured interview approach was developed to enable an expert review. This approach used a scenario-based interview with MLCE developers and stakeholders to frame the tool's utility through the development process. The research approach is outlined in Figure 73.

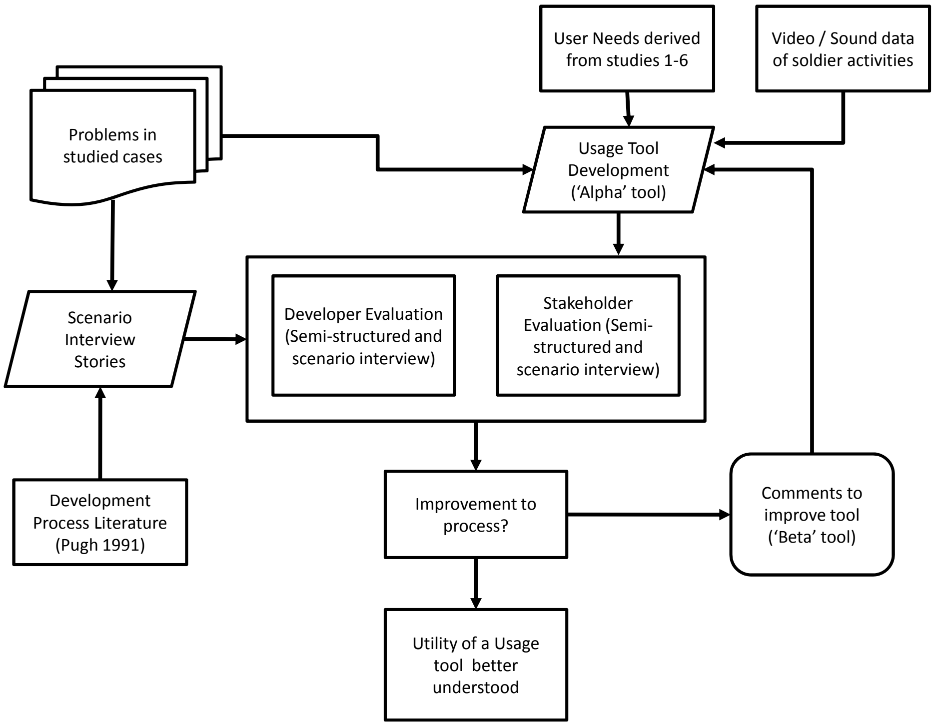

***Figure 73**. Steps in the initial research approach.*

Figure 73 shows how the previous studies fed into the development of the chosen research approach. It was intended to set up the interviews with participants by contacting them through their place of work, and to visit them there; where they would be comfortable. The interviews would be recorded using a digital voice recorder, which would enable easy digital storage and playback to facilitate post-interview analysis. The researcher would also take some notes during the interview, but in order to keep the conversation going would need to rely on the recorder to capture the spoken data.

Participants were exposed to the tool by a short (10 to 20 minutes) brief given by the researcher using the following materials:

- Example clips of soldier activity
- 3 x A3 poster examples of the tool in practice with examples of outputs
- 3 x booklets with the input analyses underpinning the three poster examples

The examples were presented with the clips to allow the interviewees to see the basis for the tool outputs. The example boards and booklets were then introduced to show the sorts of outputs the tool could provide to MLCE development.

Interview question development

The interview questions were based around the research question and its sub-questions, to provide a straight forward link to answering the research question (see Table 39). The interview questions were reviewed after each interview to ensure that they remained relevant to the research question and did not confound the interviewees. Due to the small number of possible participants and to make the most of the interviews, additional questions were developed to build the context to the participants' responses and build rapport. These questions were orientated around placing the participants' experience within the literature of design expertise (see Chapter 3), and placing their comments in context.

Serial	Questions
1	How long have you worked in load carriage development?
2	Could you describe your background in design and development?
Deleted	Did you do any formal training in design and development?
3	How did you get into load carriage development?
4	How would you describe your role within this company / organisation?
5	Could you outline your approach to load carriage development?
6	What experience do you have of using load carriage?
7	Do you have questions about how soldiers use load carriage?
8	*How would you want to use the tool? / How do you think the tool should be used?*
9	Do you think that the tool would be useful to load carriage development from your experience? If not, can you explain why?
Deleted	Who would you think would use the tool, or the information from it?
10	What questions do you think the tool would be good to answer?
11	Would the tool help to improve understanding user/client/customer [delete as appropriate] needs/requirements?
12	Does the tool fit with your *experience /* ideas of the military and how they use load carriage?
13	Would the tool help to improve understanding the human factors of the load carriage being developed?
14	The examples shown in the tool are from a military environment, do you think it has utility in a civilian context?
15	Do you think that the tool would help you produce better load carriage products?
16	Would the tool be useful for increasing the speed or ease of development process? For example make prototyping products quicker and / or easier?

Table 39. *Semi-structured interview questions.*

Scenario-based interview development

The scenarios were based upon an adapted version of Pugh's (1991) Total Design Activity Model and grouped to look at three areas within the model (see Figure 74).

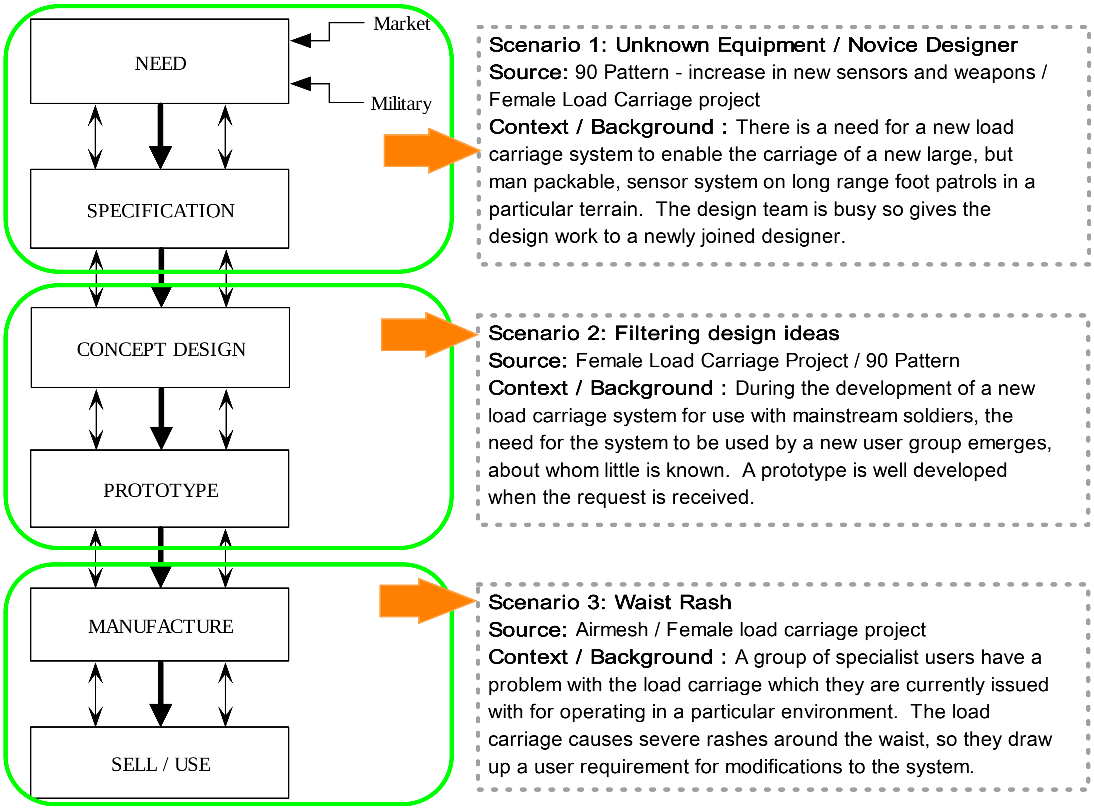

Figure 74. *Interview scenarios based around Pugh's (1991) Total Design Activity Model.*

The scenarios were developed using instances of known issues from the three MLCE cases looked at to date. Since a number of the interviewees may have been involved in the cases, it was important to ensure that the issues were effectively masked. This was achieved by using insights from the older cases (Airmesh and 90 Pattern) as the basis for context of the scenario stories, which fewer participants were involved with. The insights used to provide a context for the scenario stories were:

- Scenario 1 – The increase of specialist sensors and weapons which has lead to some deficiencies in 90 Pattern MLCE
- Scenario 2 – Expanding of user group within an established MLCE project – 90 Pattern
- Scenario 3 – Problems with rashes caused in particular environments or during heavy use of MLCE – Airmesh MLCE

In order to make the stories seem sensible and follow a logical sequence, some events were artificially created. The sources for the events are shown in Table 40.

Scenario 1 Events: Unknown equipment / novice designer
1. An initial manufacturing specification is drawn up. *Would the tool help drawing up the specification?* 2. There is the opportunity in the prototype for different back systems. It is not clear from the specification what type of back system would be best used. *Would the tool help determine what back system would be best?* 3. A stakeholder reviews the system and asks how the users could carry their personal equipment with the back system. Their personal equipment must be accessible at all times in the terrain in question. This was not in the specification and so was not picked up by the new designer. *Would the tool have helped pick up the use of other equipment with the back system?* 4. How and when the soldiers use their personal equipment is reviewed, so that the specification and prototype can be modified. *Would the tool have helped review the specification and the modification of the prototype?*
Scenario 2 Events: Filtering design ideas
1. Information about these users is provided by the customer to enable the developers gain an understanding of the user group (access to the users is difficult since they are often away on operations). *Would the tool help understanding of the user group (assuming video of the new users is available)?* 2. The customer then asks for three quick prototype modification options to be drawn up. The design team produce six option ideas which could work. The options then need to be filtered to give the best three. *Would the tool help in filtering the design options?* 3. On receiving the three options the customer asks whether two of the ideas could be merged to provide another option. *Would the tool help in merging the options?*
Scenario 3 Events: Waist rash
1. The requirement appears, however, to have details missing which could prevent a suitable load carriage solution from being developed. *Would the tool help understand what details were missing?* 2. The requirement is agreed, and initial prototypes are generated. *Would the tool help during prototype generation, in this instance?* 3. One prototype is accepted for a user trial, but the trial is quickly stopped since the load carriage does not prevent rashes from appearing. The possible causes for the rashes are reviewed. *Would the tool be useful in reviewing why the rashes are being caused?*

Table 40. *Story events by interview scenario.*

The way in which respondents were asked to indicate how they thought the usage tool would impact on MLCE development was through scoring against a percentage-based graph at each event in the story. Normal MLCE development was at a midpoint up the y-axis, with the y-axis going up to 100%, either side of the normal MLCE development line. The midpoint y-axis was chosen as the benchmark level to give the respondents an opportunity to indicate whether the tool would be positive or negative in relation to improving MLCE development. Participants would be asked to outline the factors which were important in this event and if they affected the change. The percentage scalar was not critical in providing an accurate measure, since each respondent was thought to have different views on the level of influence the tool might have, but to provide an indication of trend between participants.

Post-interview analysis

It was decided to use a 'bottom up' analysis of the data from the interviews, and see whether there were any emergent themes, linked to the research question and sub-questions. This would be done by looking at the responses to the interview questions which most applied to the sub research question.

This allowed for a number of different responses from the participants, and their reasons for the views to be captured in a meaningful manner.

Analysis was done using the Interpretative Phenomenological Analysis (IPA) methodology outlined by Smith and Osborn (2003) using the following stages:

1. *Looking for emergent themes in the initial interview* – by reading notes from the interview and re-playing the interview recording a number of times to look for similarities, differences, contradictions and amplifications of what the participant was saying
2. *Connecting themes* – by listing the themes in the order they came up in, and searching for interconnections
3. *Continuing the analysis with other themes* – using the subsequent interviews to 'enrich' the initial themes, acknowledging differences as well
4. *Reporting* – themes were listed, by participant; each theme is then described using examples

IPA was used since it was a well-known technique (Smith and Osborn 2003, Willig 2001), consistent with an interpretative research strategy, which could link between the views of the participants in a coherent manner. Coding was also considered, as in other studies, but was not used because of the difficulties of determining an accurate coding scheme which could elicit 'unseen' views on the tool (Silverman 2000: 147).

By 'snowballing'[69] through participants it was hoped that saturation of categories could be reached. The small and disparate nature of the two respondent groups meant that saturation could only partially be reached.

The scenario-based interview helped provide additional information on all the sub-research questions, but was primarily aimed at supporting objective 3.

Interview trial

Due to the small number of possible development participants, it was decided to undertake a methodological review after each interview to update the schedule. It was during these reviews that a decision would be taken on whether to apply any form of structured coding analysis, should a coherent view be expressed by the participants. There were also differences between the developers and stakeholder groups which might necessitate slightly different interview questions for the two groups, these could be examined in the methodological reviews.

12.3 Output and discussion

Ten MLCE developers and five stakeholders were interviewed in thirteen sessions over a two and a half month period. The backgrounds are listed in Table 41. The outputs from the study were analysed and were reported using the interpretative manner recommended by Smith and Osborn (2003). A master themes table can be found in Appendix Q. The following output and discussion was based on feedback from the ten developers, with notes on specific points from the stakeholders. Stakeholders were not asked to undertake the scenario interview because their experience of MLCE development was often limited.

[69] 'Snowballing' was a technique suggested by Oppenhiem (1999) to build information on a topic by iterative interviews to gain an indication of importance via the frequency with which particular pieces of information were presented.

Developer backgrounds	
D1	Experienced government human systems specialist, with experience of MLCE design assessments
D2	Experienced government MLCE developer
D3	Experienced industry human systems specialist, with knowledge of MLCE interface assessment and troop trials
D4	Experienced physiologist, with recent experience of MLCE human science
D5	Highly experienced civilian rucksack designer
D6	Highly experienced civilian rucksack and MLCE developer, with military experience
D7	Experienced industry MLCE developer, with a background in engineering
D8	Highly experienced industry MLCE designer
D9	Experienced industry MLCE designer, with formal textile technology training
D10	Junior government human systems specialist with little experience of MLCE
Stakeholder backgrounds	
S1	Highly experienced government human system specialist, with considerable experience of defence acquisition support
S2	Experienced government psychologist specialist and analyst, with experience of MLCE development and soldier interviewing
S3	Highly experienced government textile technologist, with experience of MLCE development and soldier acquisition projects
S4	Experienced military officer (Major), with recent experience of Operations TELIC (Iraq) and HERRICK (Afghanistan) and support to operations processes
S5	Experienced industry textile developer with experience of soldier interviewing

Table 41. *Developer and stakeholder backgrounds.*

12.3.1 Summary of feedback

The feedback from the participants is reported in Appendix R, and was sorted into eight themes which emerged from the interviews following the semi-structured themes, linked to the research question and objectives. Table 42 reports on five of the themes that described the participants' views of how the tool would help understand MLCE use. Table 43 outlines the themes related to the impact of the tool on the effectiveness and efficiency of MLCE development. Table 44 outlines a theme which examines some specific aspects of the tool which needed development in a 'Beta' tool, and Table 45 details the participants' concerns with the tool. The 'Serial' column references in each table related the themes to the theme analysis reports in Appendix R.

Serial	Theme	Sub Theme	Notes
T1	**Insight into the context of soldier work and activity**	Physical environment	All participants liked the tool because it gave insights into the context of use that they did not know about, or did not know how ‘x’ equipment was used. Also linked to a need to understand environmental effectors like temperature and humidity.
		Video and analysis	The Video was liked because it was easy to understand, but the analysis added an extra dimension which could be used by experienced and novice developers.
		User voice	Comments were made that the analysis also enabled user issues to be identified which would not necessarily have been identified.
T2	**Helping set the right requirements**	Importance of setting the right requirements	All participants thought that the tool needed to have a role in requirements formulation. A sub-text to this was that they felt that requirements were generally not well set.
		Reliance on soldier opinion	Developers without military experience were dependent on soldier opinion to inform design, and the tool was thought to provide a way to inform the judgement or provide additional evidence to support the justification for a particular design option.
T3	**Getting people to a common understanding about soldiers**	Understanding the need	Almost all participants reported that the tool would support them in getting common understanding of the military environment. The tool provided them with information they currently lacked.
		MLCE design experience	An interesting insight, provided by civilian pack developers, was that formal design training was not sufficient to enable successful design and that experience in MLCE design would be needed. They felt that the tool would help designers understand what they did not know about the military environment which they felt was critical to producing successful products.
T4	**Setting or doing evaluation**	Examples of use	An unexpected role for the tool was that it could be used to provide ‘walk-through’ scenarios for prototype assessments, either as studio or field-based studies.
T5	**Identify and clarify issues which can prevent successful MLCE**	Preventing successful MLCE development	A number of participants thought that the tool would help provide them with better information to design against. Rather than specifying ‘how’ MLCE needed to do what it does, they felt they should be told ‘what’ it had to do. This was also linked to the level of innovation industry developers thought that they could bring to MLCE development. A related comment was that often not all the issues related to adequate performance of defence equipments were necessarily identified at the outset of a development during requirements setting.
		Mitigating problems	All the participants felt that the tool provided a way to help mitigate the issues which may prevent successful MLCE being developed. One participant described the ability of the tool to ‘signpost’ (the ‘action, problem description, and requirement’ codes) them to aspects that they needed to consider was an important aspect.

Table 42. *Summary of five themes.*

From Table 42 it was possible to see that the tool was thought to provide a positive benefit to MLCE development. Participants particularly liked the access the tool provided to the activities soldiers did, from which they could either see or infer the sorts of design features needed in the MLCE they designed. In particular participants were keen to understand the reliability of the video and audio data to show the 'right' aspects of MLCE use. From this perspective they usually have to take what soldiers told them about MLCE at face value and had no other sources which they could use to validate what they were told. This meant that they were keen to understand where the video and audio information came from and how the analysis of the video was done. A number of participants mentioned that the analysis would aid the understanding of the video if different data points were linked in each video clip. The immediacy of the tool was also liked, since it could be used either to illustrate a specific point a developer wanted to make. It was also more likely to help build a common understanding with everyone in the development team.

Development deficiencies

The five themes in Table 42 also provided insights on the deficiencies in MLCE development that participants perceived. These came about usually because participants were trying to explain why they liked the tool, so had to explain some of the problems they had at present. Critical in this were difficulties in requirement setting, with design briefs proscribing how, rather than what, MLCE needed to do. These comments tallied with Ryd's (2004) findings that an evolving briefing process was arguably better to aid designers' understanding of customer requirements, and an aspect of previous MLCE cases (Study 4, see Chapter 6).

The tool's impact on MLCE development, as a theme within the participant feedback, is summarised in Table 43.

Impact on development process (T6)	Speed of development	Most participants felt that the tool would not increase the speed of MLCE development since these were usually targets set by the customer. Indeed the tool may extend the process, but would provide more information to go through at the outset of the process.
	Effectiveness of the process	Most participants did think that the tool would help ensure that the process was more effective at delivering a successful MLCE product.

Table 43. *Summary of the tool's impact on MLCE development.*

Tool role in the development process

The potential roles for the tool within MLCE development is summarised in Table 44.

Potential tool uses/ role (T7)	Variety of role	Technology insertion, understanding interfaces, explaining key issues, product modelling (similar to the 'walk-through' above, design specification interpreting, case making, focusing on end use, and remote analysis (N.B. but not in-theatre remote analysis).
	Limitations in role	The tool was not thought to be useful during concept generation, just in understanding how it was to be used.
	Military tasks	It was thought that the clips, in the final tool, should be reviewed by serving military personnel to ensure that they were representative.

Table 44. *Summary of the tool's potential uses in MLCE development.*

Some of the ideas mooted by the participants appeared to match well with the needs highlighted in Chapter 10, although it was not intended for the tool to act as an evaluation tool (see Table 42). The use of the tool as a way to evaluate MLCE concepts and ideas was, however, an interesting one when linked with the tool providing views of users in the environment of use. Redström (2006) has made the point that designers should regard their designs as a route to educating users about the use of products. The use of the tool as an evaluation approach may provide a route, as outlined by Redström. It may also enable a gradually improving briefing process (Ryd 2004) which improves on developers' knowledge of user (soldier) requirements, rather than the check/wish list approach used currently, as reported by the participants. One participant suggested that the tool be used as a part of the tendering process, to enable developers to improve their understanding what they were bidding for.

Tool use limitations

Also some important caveats were captured with respect to how the tool was limited in use, particularly to generate ideas and concepts (also see section 12.3.2). These are summarised in Table 45.

Tool use concerns (T8)	Objective / causal reasons for MLCE problems	The human systems specialists thought there was a risk that the tool might be used to identify the causes for a given problem to be a specific symptom, these dangers should be clearly explained to users of the tool.
	Additional information needed	The amount of information needed to make the tool useful was discussed. It was thought that the tool should as a minimum contain key soldier tasks. Gathering evidence from exercises rather than operations was also discussed.
	Misleading design	Human specialists also raised the possibility of optimising MLCE based on the tool alone.

Table 45. *Summary of tool limitations.*

This feedback provided a good summation of the utility of the tool within MLCE development, which lay primarily in understanding the context of use, and getting a better understanding of user need.

12.3.2 Scenario interview results

The scenarios were broadly successful in checking the comments that the participants had made about the tool during the first part of the interview, and eliciting additional comments. The scoring was used by looking at the trends between participants which may provide additional insights on MLCE development or tool use. The scenario scoring outputs can be found at Appendix S.

According to the scenario interview outputs, the participants scored the use tool as having its strongest impact at the outset of any development activity. Participant scoring was positive throughout the scenario interview, and showed that the participants did not think that the tool would detrimentally impact development in the scenarios presented. This concurred with their comments in the semi-structured interview, and demonstrated that the participants were confident in their assessment of the tool during the two parts of the interview.

Some participants found some of the scenario interview questions slightly confusing, and needed clarification from the researcher. While all participants successfully completed the scenario scoring, two participants felt that the tool needed to be better developed before they could give an authoritative view. These comments were valuable, since they showed how the scenario interview method could be improved; principally by structuring the design problems differently to clarify where the tool would be used. Additionally it provided additional insight in to the potential use of ethnography to explore the tool's use in MLCE design activity (see section 12.3.4).

The scenarios used in the study were designed to establish where in the process the tool could be used, and so were designed to ask a different question to the one that the two participants felt they wanted to answer. Once this was explained, they were content with the purpose of the scenario interview and were happy to provide their view through the scoring approach. During the scenario interviews, many of the industry developers indicated that they had experienced a number of the scenarios in their own practice, particularly the need to train inexperienced designers.

12.3.3 Answering the research question

The approach was effective in answering the research question (RQ.3.1) since participants' views were successfully canvassed on the tool's context of use. Participants reported that all information which was relevant to MLCE development was useful. The form of structured information in the tool was also thought to be useful, if the tool was further populated, since it provided information which participants had not previously had access to.

The participants had a number of comments on the structure of the information presented, mainly on the number of different ways the participants thought it could be used. It was clear from the study that the participants wanted to be able to search the tool to look at instances of use, and have information within the tool which provided insight on those instances. Government stakeholders had broadly similar comments to the developers in what they would look for in the tool. The main difficulty was thought in justifying the tool's benefits within the defence arena. It was thought unlikely that industry would pay for such a resource in the civilian arena, since designers had direct personal experience of use.

12.3.4 Parallels between tool development approach and evaluation

The parallels between the methods used in the tool and the evaluation methods became apparent throughout the development of the tool and evaluation approach. Parallels were principally shown in how the methods which could be used as a part of the tool could also be applied in evaluating the tool. The main difference between the parallel uses of the methods was in how the methods were deployed, particularly with regard to interview techniques and observational methods. An example of this was the questions one could ask soldiers when populating the tool with user views (not done in the 'Alpha' version of the tool) versus the questions asked of the participants evaluating the tool. While the participants and soldiers would probably react better to interview techniques than to written data gathering such as questionnaires, the interviewing approach would need to be different.

The use of observational methods had similar parallels in their use in the tool (which used observational video data) and potential use as an evaluation method. The limitations of observation as an evaluation approach (see Appendix P) also applied to the use of video data in the tool. The limitations such as subjects not liking being videoed, were not a problem for the 'Alpha' tool, since the data was gained from existing archive material. If observational video was needed for a 'Beta' version, these limitations, particularly if video interviews were needed, would require exploration.

One of the principal benefits of the tool was in the way it could use data where researchers were unable to go (i.e. to the frontline of battle[66]), and make the activities that soldiers were undertaking accessible to developers. There were parallels between the act of analysing the raw video data from the frontline, and the organising of the data to make it accessible. These two acts were closely related, and in the 'Alpha' version of the tool the parallels were considered in the selection of the example scenarios. Due to the nature of the archive footage available, the scenarios were not an attempt to provide analysis across all soldier activities, but to show that analysis on frontline video data could be done and portrayed in a usable form.

Ethnography

An area where parallels were found between the development of the tool and the research strategy was the potential use of ethnography (see section 4.3) to gain data on MLCE development and to evaluate the tool in MLCE development. Ethnography

[66] It should be remembered that the cameramen were service personnel who may expose themselves and colleagues to certain risks because they are using cameras. Soldiers would be in the best situation to manage these risks at the frontline because they would be more aware of the risks than an inexperienced civilian.

could use video as a part of fieldwork to augment direct observation in either case. Before video can be used in ethnography the researcher must be familiar with the context of study to determine how and when to set up video data capture (Heath and Hindmarsh 2002), and in this instance access to MLCE development was limited. There was the possibility, however, of using ethnography to gain insight into user needs, as suggested in Study 7, to explore the tribal nature of military user groups, and its impact on user perceptions of equipment. One of the critical issues in using video interview data of soldiers' views was the possible lack of engagement with the camera.

There was anecdotal evidence (from other researchers) that it could be difficult to elicit information from soldiers in the junior ranks due to low verbal skills to articulate their views; this was regarded as a generalisation. In the researcher's experience those in the junior ranks could be articulate; once a rapport had been made and one understood the social or cultural language and meanings which were commonly used by soldiers. Ethnographic approaches, although time-consuming (Chapter 4, section 4.3.1) could be a way to build rapport with soldiers, to place them at ease and allow them to talk openly. In the defence context, from the researcher's experience, one also may need to build a facilitative relationship with senior ranks or officers who may act as gatekeepers (Hammersley and Atkinson 1995) to junior ranks' views (also mentioned by several participants in Study 7). It was thought possible to use an ethnographic approach to gain video data, whether this data could be collected in a military context (given the possible gatekeepers involved) and then used in a development tool was not clear. Ethnographic video making was a specialist area requiring a level of control over the environment and participants one was working with (Hammersley and Atkinson 1995), and so outside the resources of this research. One possible future approach could be similar to that used by Labov (Atherton 2003) to elicit complex ideas from black youths, who, at the time, were perceived as being linguistically and educationally limited. Labov's approach was associated with Bernstein's (1971) ideas on language codes, which are used to 'unpack' the simplistic and inferred meanings from simple sentence structures. This approach was beyond the scope of this research since it required extensive theoretical underpinning, and had sensitivities in how military personnel could be accessed. The benefits and possible direction for an ethnographic approach in this area are outlined in Chapter 13, section 13.4, point 3.

12.4 Chapter conclusions

This chapter has outlined the research approach taken to evaluate the MLCE use tool: the specific methods adopted, conduct, analysis and discussion of the outputs. Study 8 was broadly successful in answering the research question and evaluating the Alpha tool's use to improve MLCE development. The participants were on the whole positive towards the tool and the way in which it presented the user (soldier) environment and distilled user needs. Additionally further information was elicited to provide insights into MLCE development practice; in particular the lack of access to use information which could be useful in MLCE development.

Revisiting the chapter's objectives:

1. The research strategy has been defined, alongside the specific methods to evaluate the MLCE user needs tool.
2. The conduct of the study has been reported.
3. The study's outputs have been reported and discussed.
4. The success of the research in the context of the research question has been outlined.

Key points to take forward:

1. At this stage in the enquiry the researcher was confident that the research questions had been answered, within the limitations of the methodologies applied, to provide a better understanding of MLCE development.
2. The research had established that user (soldier) needs were a problematic area for MLCE development, and that there were tools, primarily video and audio-based, which could be applied to improve this situation.
3. It was thought that to take these tools further would require additional research along a number of avenues; to ensure that the tool would be operationally efficient and effective.

Chapter 13: Conclusions from the enquiry into MLCE development

At the conclusion of the last study, a level of confidence had been built up that the research questions had been addressed producing new understanding about MLCE development within the resources available to the research. This was an appropriate point to conclude and revisit the initial themes which stimulated the research.

13.1 Chapter introduction, aims and objectives

With the conclusion of Study 8, confidence that the research had built reliable and novel insights on the conduct of MLCE development in the UK was reached. Confidence was based on the findings of the Studies throughout the research journey, and the possibility for grounding insights in repeated participant views, which have not been found elsewhere in the literature to date. These views, as analysed through the methodological limits available, have identified a baseline of practice from which further research could be conducted. This baseline is, therefore, an appropriate point to conclude this enquiry, since further research should be specifically focused to continue the research journey, perhaps using alternative methodological approaches.

This chapter aims to summarise the discussion of the research outlined in earlier chapters and, report key findings, explain how the research contributes to knowledge and present recommendations for future research. Figure 75 shows this chapter’s place in the research map.

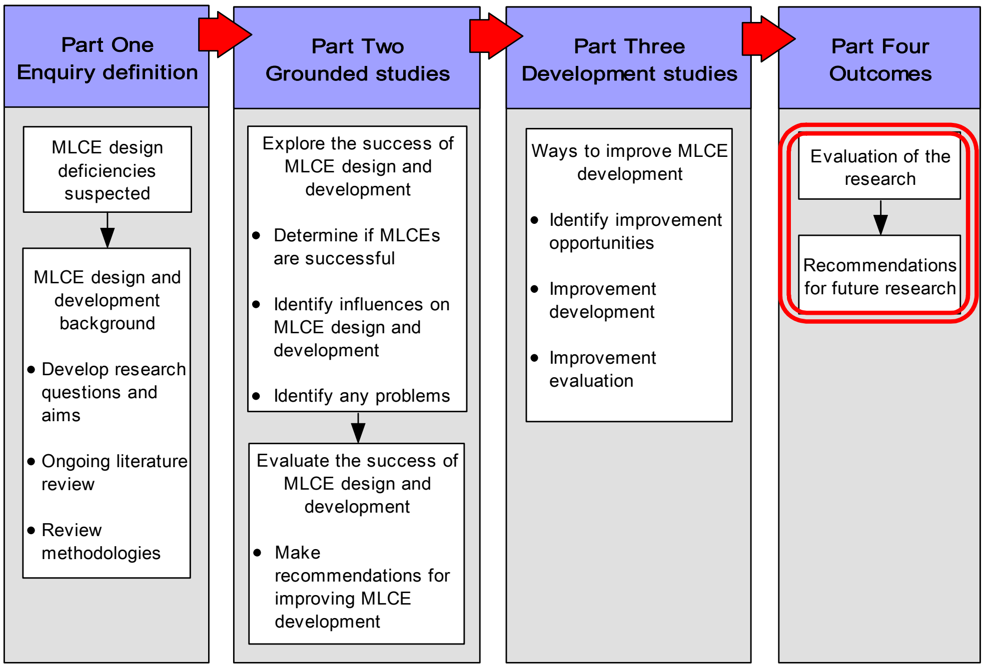

Figure 75. *Chapter 13 research map.*

Objectives:

5. To establish how effective the research had been in the context of the research questions presented in Chapter 2 and Chapter 11.
6. To report key research findings.
7. To establish how the research contributes to knowledge.
8. To identify areas for future work.

13.2 Central points of the enquiry

It was confirmed, through the four research questions, that there were deficiencies with the MLCE development approaches investigated. The questions, while initially broad, had provided a useful and appropriate conduit for exploring the deficiency themes from Chapters 1 and 2. The enquiry had shown that the themes influenced MLCE design and development, albeit to varying degrees. Figure 76 shows how the various studies have linked into the research questions and where in the thesis research findings have been juxtaposed against the literature.

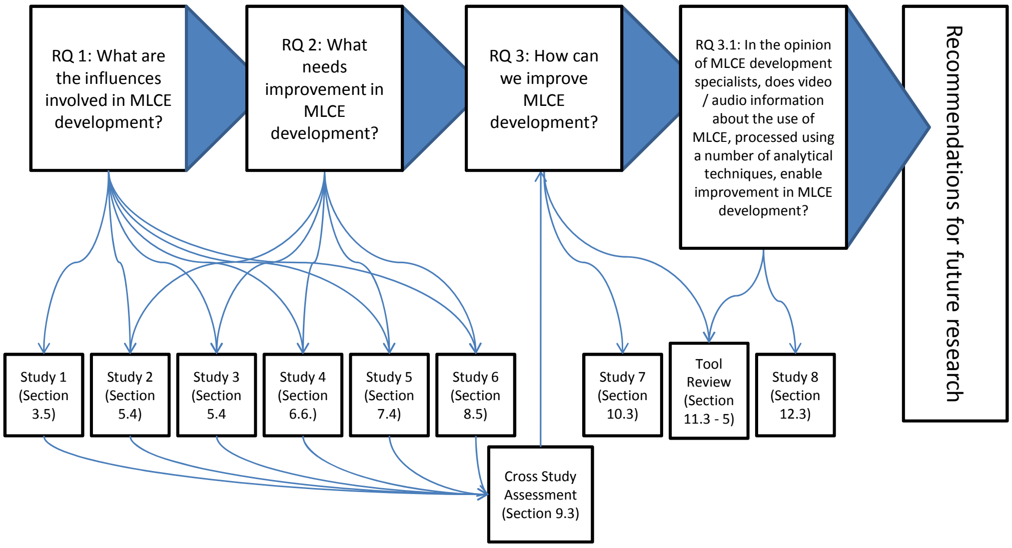

Figure 76. *Research question links to research studies and activities (RQ3.1 is the research question from Study 8 (Chapter 11)).*

The enquiry had established a view of the deficiencies and their resultant influences on MLCE development from a design research perspective, within the limitations of the methodologies employed. It was important to note that there may be other views, for example organisational and military, which may differ from the one presented in this thesis.

The influences on the deficiency themes identified in Chapter 2 were:

- Evolution of MLCE from one in-service design to the next
- The high weight and bulk that soldiers carried, and the different ways to bear military loads
- Tactical influences on load bearing
- Differences between civilian and military arenas (in use and development)
- Role of human systems on MLCE development
- Soldier satisfaction with MLCE

These influences were investigated by exploring how the equipment that the researcher saw in use by soldiers (90 Pattern) had been developed. To do this the researcher needed to determine a baseline of 'better' practice, against which MLCE development could be contrasted. An initial review of the literature (Chapter 3) determined that the information available in the area was varied. The lack of available information on MLCE development made determining a ‘better’ practice model difficult. A review of the theoretical and methodological approaches which could be used (Chapter 4) showed the lack of a coherent and well-understood knowledge base upon which to structure the enquiry. It was decided, therefore, to use a grounded theory approach in the exploratory and evaluation studies in order to provide a structured view of MLCE development through a number of interpretive studies.

Initial exploratory research into the development of in-service equipments was done via a comparative case study (Chapter 5). This study explored the issues which appeared to impact MLCE development and determine whether the problems (the deficiencies observed by the researcher) were present. Through this investigation it became clear that MLCE development was based (and dependent) on tacit knowledge of MLCE manufacturing techniques, and collaboration between professional groups, including: materials / manufacturing, human systems, project management and the military. The cases that had been looked at were initially historical, since at the time of this early research, there was no MLCE development work being undertaken by the UK MoD. Contemporary cases and the views of experts active in the field were needed to validate this initial historical view of how MLCE was currently conducted.

Observational research on MLCE development, in particular design activity, was not possible, so the research, therefore, had to focus on an opportunistic case study (Chapter 6) and assessments by experts in the field (Chapters 7 and 8). This approach enabled the researcher to refine the development process models which were generated during the comparative study (Chapter 5) through the use of Soft Systems Methods (SSM). The comparison of outputs from these studies was then reviewed in a grounded manner to produce themes of influence on MLCE development (Chapter 9). The interaction and importance of the various influences on MLCE development were now better understood, in particular the importance of user needs and requirement specification at the beginning of the development process. The grounded representation of MLCE development is shown in Figure 77.

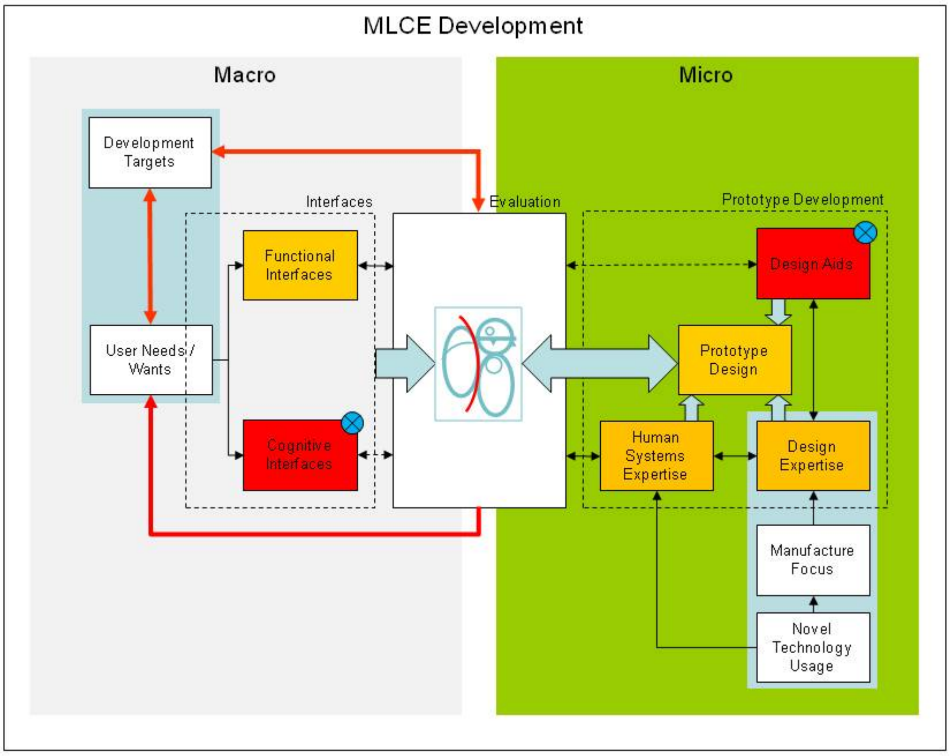

Figure 77. *Grounded view of MLCE Development (from Figure 66).*

Figure 77, was an interpretive view, based on the cases and information available to the research. The main interface between design activity (i.e. within the dashed Prototype Development box on the right) and development targets was shown to be achieved through Evaluation and Interfaces boxes. The degree to which MLCE was evaluated was shown to be highly variable, as has been recently shown in the development of the latest UK MLCE in the Personal Equipment and Common Operational Clothing (PECOC) programme (Tutton 2009). Access to PECOC MLCE development as a case was not possible during the conduct of the research studies. It should also be noted that the view in Figure 65 also does not show how MLCE needs to be developed in concert with other soldier equipment, like body armours, which are beginning to have a strong influence in emerging MLCE systems (Tutton 2008). The grounded analysis enabled an evaluation of MLCE development which helped to better understand the initial influences which had initiated Research Question One and informed answers to Research Question Two.

Evolution of MLCE from one in-service design to the next

The evolution of equipment was linked to requirement setting during the early stages of MLCE development. Requirements reflected the high-risk nature of soldiers' work and the equipment, including MLCE that they needed to fulfil their missions. Problems were seen to arise in this situation as soldiers' loads increased and soldier tasks altered. The normal approach to evolving MLCE, however, did not appear to keep up with this change. An aspect of the evolutionary approach being less successful may, in part, be due to societal change which may have led to changes in soldier expectation and satisfaction with equipment. The development of new human systems techniques, since the historical cases, may also be a factor in identifying these shortfalls. The impact of these aspects was not transparent from the research, but was reflected in the perception that MLCE development was not systematic, and that better MLCE solutions could be found. There was also some evidence to suggest that some soldiers may be resistant to change, perhaps in part due to the risks involved in their work, which had blocked attempts to move beyond an evolutionary approach (Study 4). From the research it was suspected that that an evolutionary approach will become increasingly unsuccessful in the future; as the soldiers' work environment and equipment changes, requiring a more systematic and revolutionary approach to maintain effectiveness.

The high weight carried

Evidence found during the course of the research continues to show that the soldiers' load remains very heavy. There was little evidence to show why this was (Verral et al. 2008 personal correspondence), although they have been anecdotally linked to increases in ammunition loads (partly due to the proliferation of automatic weapons) and personal equipment carried. Additionally little was known or understood about the injury consequences of carrying these heavy loads. It was clear from the human systems literature that the human can only bear so much weight without suffering either temporary or chronic injury. It was also clear that MLCE can only mitigate some of the effects of heavy load, it was demonstrated that current designs do not do this well. The impact that MLCE development can make to this area was, therefore, found to be limited, apart from improving developers' knowledge of the optimal design features that can be used to mitigate heavy loads. During the last study this was found to be a gap even in experienced developers' knowledge because of limited access to government research in this area.

Tactical influences on load bearing

The influence of military tactics on MLCE development, through requirements setting (both explicit and implicit) and acceptance for use was high. It was also identified through the research that developers, particularly those in industry, do not necessarily have a good understanding of the soldier environment, and consequently of tactical influences. Defence organisations attempt to deal with this situation by specifying what they want the MLCE to be like (in physical form) rather than what it should do. In this manner they appear to seek to take the burden off industry in terms of understanding what soldiers might actually want. Questions were raised by participants as to whether this approach produced MLCE which, while low cost, may be deficient in how fit for purpose it was for various user groups.

Differences between civilian and military arenas

The research identified differences between development skills and practice within the civilian outdoor and military arenas for load carriage development. While both were dependent on manufacturing (craft) based development knowledge, they were different with regard to their knowledge of their respective user environment. Civilian developers were almost exclusively expert practitioners (usually with high level mountaineering qualifications or equivalent experience), while MLCE developers rarely had military experience. This was not a criticism of MLCE developers, but simply a reflection of the difficulties of accessing the military work environment. It was also found that practitioners did not think that previous military experience necessarily helped, since the detail of military activities changed with each theatre in which soldiers deployed to. Mitigating the differences between the two arenas in understanding the military environment was found to be helped by the 'Alpha' tool developed during the research. There were parallels in this theme, with the inclusion of junior soldiers in MLCE development. Industry developers were found to be excluded to a degree by the limitations in information which was provided to them during early phases of development projects. While much governmental information was classified for security reasons, provision of more information may enable industry to meet soldiers' MLCE needs more effectively and efficiently.

Role of human systems on MLCE development

Despite the wealth of human factors information available on MLCE, it was found to be largely physiological in nature and have limited use in MLCE development, particularly if scientific evaluations were not possible. Human systems expertise was found to be involved in all the cases of MLCE development examined, although its impact was highly varied. The civilian arena does not rely upon human systems expertise, apart from two well-documented examples. Human systems expertise was not well integrated in MLCE development, in part contributing to some of the problems experienced in some MLCE cases. This was thought to be a missed opportunity, particularly during requirements formulation to help translate military needs into design. There was also a need for Human Factors Integration (HFI) approaches to be tried within an MLCE project, to ascertain whether generic HFI models could help alleviate problems experienced by MLCE users and developers.

Soldier satisfaction with MLCE

Soldier satisfaction was not studied in depth during the research, due to the focus of the research. While soldier satisfaction was thought to be linked to societal changes generally, there was little opportunity to study it as a factor in MLCE development. The degree to which soldiers at a low level were involved in requirements setting was raised at several points in the research, and in the researcher's view, current processes may not be inclusive. The exclusion of lower level soldiers was thought, in part, to be due to the hierarchical nature of the military and the lack of user-centred design practices. This was principally found in the distance that MLCE designers had from users. It appeared that there was either a lack of time or resources within the Army or procurement office to facilitate access for developers. The exact reasons for this were not clear, but it was intimated that there was a block to engaging with soldiers at a lower level. It should be stated that this perceived exclusion appeared to be deliberate, but may have been as a consequence of an informal requirements setting processes or a lack of available development tools within project teams. This also may reflect the extant perceived 'wisdom' that junior ranks may not have the skills to be able to communicate their needs. Such attitudes have been shown to be erroneous since carefully designed research methods can open effective and useful lines of communication with such users (Mayhew 1999, McClelland and Fulton-Suri 2005, Coleman et al. 2007). This could, in part, be addressed by appropriate human systems expertise within the development process.

Improvement to MLCE development

With a better understanding of what needed improvement in MLCE development, there was a need to understand how user needs were identified and used to answer Research Questions Two and Three. A review of MoD user needs information and an interview survey of people involved in user needs analysis was, therefore, conducted (Chapter 10). This survey (Study 7) demonstrated that there were organisational issues which had to be taken into account in the development of a user needs tool and that there were problems with accessing information about how soldiers actually used their equipment on operations. To help filter the options for tool development, a short literature review of user-orientated design methods was conducted (Chapter 11). From this review a hybrid tool was developed which allowed a number of simple techniques to analyse video information to produce meaningful information for MLCE developers (Chapter 11). The tool was then evaluated by a panel of specialists active in the area using semi-structured interviewing methods (Chapter 12).

The results from the panel review were positive in that the tool offered information that MLCE developers, even experienced MLCE developers, currently did not have but potentially needed. Insight was gained from the panel interviews about how MLCE development and design activity were conducted. They confirmed that, in the opinion of the panellists, MLCE development was not only dependent on craft-based knowledge but also an intimate knowledge of MLCE use in order to make the end product usable. The results from the panel review helped in understanding and validating aspects of the MLCE development view in Figure 66, but did not necessitate any modifications to it. Participants appeared to indicate that the tool would be helpful to them in understanding the user interfaces with MLCE better, so, it may be assumed, enabling prototype development to be more effective. The research was successful, within the limitations of the resources available and methods applied, in providing data which could be used in answering the research questions.

13.3 Findings original to understanding

The original significance of the research is discussed within this section in the context of its contribution to our understanding of MLCE development and to design research. This contribution was limited to the context of a solo researcher within in a military environment.

13.3.1 Contribution to understanding MLCE development

The research has moved professional understanding on with respect to MLCE development by a holistic view of the area. The contributions to understanding were found, within the limitations of the methodologies applied, throughout the context of MLCE development:

- The potential benefits of a video 'use context' tool in MLCE development have been demonstrated. In particular, in the gathering of information at the outset of a design project and communicating the use context across a development team. The immediacy of the video information was liked by MLCE developers who said it provided valuable insights on a soldier's working environment. The tool may have relevance to other areas of defence equipment development, although over-generalising from the results of the tool evaluation should be done carefully, due to the limitations of the evaluation method.

- The context of MLCE development was outlined, to provide a 'view' of MLCE development as it appeared to the researcher via the methodologies employed. This view highlighted the specific characteristics of MLCE development, illustrating some of its differences from other representations of product development. As a part of the 'view', an understanding of MLCE development process was produced through a number of descriptive models.

- MLCE development practice was found to be based on path-dependent foundations of skill, such as craft knowledge of the manufacturing techniques of textile products. This was found to be a shared characteristic with civilian pack development (Rose et al. 2007) and other craft dependent industries (Yair et al. 2000). Development practice, during requirement formulation, however, has problems in how it integrates user needs.

- Evidence was found that a proportion of users may be excluded from using MLCE with adequate performance during military tasks. In particular Study 4 highlighted that females and smaller men may have problems during some carriage and agility tasks due to insufficient MLCE. The degree to which soldiers in the lowest ranks were excluded from influencing MLCE design was not determined in the research undertaken, although it emerged as a theme at various stages.

- It was found that development practice in the military arena varies from the civilian arena, with regard to the level of expertise and access developers have to the user environment. The civilian arena was also found to be considerably different with respect to tasks, equipment and consequences of product failure. The level of innovation applied in the civilian arena was also thought to come from a number of aspects, including: durability, alterations to task activity and product market life-cycle (the period a design remains in the market before it is re-designed or replaced) which was twenty years in the military arena, rather than three years in the civilian arena. It may be the case that the frequency and nature of development practice is different between the two areas. It may be that civilian designers' exposure to global markets gives them more exposure to innovative ideas, feedback from users and competitors products. Whether the military arena could adopt these four approaches was not investigated, but thought possible in parts.

- Evidence was found that industry developers (who are now currently the designers of MLCE) do not have the information they necessarily need if required to design from a 'fixed' design brief. Developers expressed this as being asked to design MLCE that worked in a proscribed way, rather than saying what the MLCE had to do. They thought this potentially limited the innovation they could bring to MLCE and that the effectiveness of the product was, therefore, often limited. However, the proscribed manner of defence tasking may reflect either; the cultural resistance of soldiers to alter the way in which they use their MLCE, or the lack of military knowledge in industry to be able to ensure that MLCE solutions offered would do what they needed to. This was an area which emerged relatively late in the research and was a sensitive issue to explore.

The above contributions should be regarded primarily as indicative, given the scale, nature and methodology of the research. A level of reliability has been possible through comparison and interpretation between studies.

13.3.2 Contribution to design research

Contributions to design research were made in a number of areas, primarily in methodological approaches investigating unexplored areas of product development, where access was limited.

- Use of a grounded theory approach in design research has been applied and found to be effective, particularly where access to design activity was problematic. The approach was found to be effective at producing a structured 'view', or representation, of a design domain, albeit with the limitations of the methods applied and context. The context of a solo researcher was thought to be of particular importance as it had a strong influence on how limitations such as reflexivity needed to be managed to improve the reliability of the enquiry. The approach may be appropriate for providing a base upon which to found more reliable, focused research into this area. The approach was found to be time consuming, but possible in a slow-changing research context, allowing immersion in the subject area. As a generic approach it was thought appropriate as a methodological framework for investigating other specialist areas of design, particularly those about which little is known, or craft-knowledge based.

- The use of a combined semi-structured and scenario-based interview approach to conduct virtual, thought experiment-like assessments of development tools was also found to be effective. This approach was useful in exploring a commercial area where sensitivities had to be observed when collecting and analysing data.

13.4 Future directions

From the research a number of future research avenues could be identified:

1. A better approach to MLCE requirements capture is needed that can be effectively translated into design briefs which are understandable and adaptable for industry MLCE developers.

2. A set of adaptable user-orientated design evaluations, based on human systems better practice, needed to be developed to enhance future MLCE acquisitions. This set of evaluations should not be excessively reliant on laboratory facilities and take cognisance of interfaces with other elements of the soldier system, in particular personal protection equipment (helmets, weapons and body armours) (Tutton 2008).

3. Further research into which design methods should be used by MLCE designers, both experienced and novice, is needed, perhaps using an ethnographic approach to first explore design activity within MLCE development. Design methods should be focused on enabling successful solutions which do not require access to specialist human systems equipment (such as a bio-mechanical laboratory) or expertise which are unlikely to be brought in by industry developers. This should also take cognisance of the relative expertise levels within MLCE development (along with point 4 below), which require further exploration as a part of understanding the needs of MLCE professionals.

4. Knowledge gaps which exist with regard to certain MLCE design features, such as hip interfaces, should be explored to provide an understanding of the human / MLCE interface which can be used in design.

5. Soldier overloading should be explored to reliably identify what equipments are carried for particular missions, and why. This should be used to inform defence decision-making as to whether soldiers' loads are too high and how they can be mitigated.

6. Exclusion was an emergent theme within the research. A review of exclusion in MLCE use in military populations is recommended, alongside an exploration of junior soldiers' potential contributions to MLCE development.

7. Linking user needs to particular MLCE design features currently is difficult. There is some evidence that users are 'wedded' to belt order MLCE for some soldier tasks. Belt order MLCE limits the use of rucksacks which can reduce musculoskeletal injury, by occupying the space needed for rucksack hip belts. If innovative designs which enable the use of belt orders with effective rucksacks are to be developed an exploration of soldier tasks will be critical to help overcome user resistance.

13.5 Final comment

Throughout the period of this enquiry, the researcher strove to maintain an open view of the phenomena that started the research. The research strategy and methodology used, achieved a view of the phenomena acting within MLCE development. The methodology used was chosen because of the limited access to design activity and the lack of previous research in the area, upon which other research designs could be based. It was accepted that the methodology, being phenomenological in approach, has not allowed the reliability possible in other research designs. The research has, however, provided a new perspective on MLCE development, and provided a number of avenues upon which subsequent research could focus using alternative research strategies. The research has been able to make original contributions to understanding albeit in a manner limited by the methodology and resources available.

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Exploring, evaluating and improving the development process for Military Load Carrying Equipment

Appendices

by

William Miles Tutton

A Doctoral Thesis

Submitted in partial fulfilment of the requirements
for the award of
Doctor of Philosophy of Loughborough University

30th July 2009

Contents

Appendix A: MLCE Human Sciences Design Information Review

Of the specific literature on Military Load Carriage Equipment, the majority was human-systems related. In order to assess whether the human systems literature could tell us anything about MLCE development, and if it was useful to development, a short literature review was conducted.

Thesis Link: Chapter 3, section 3.4

A.1 Approach

The methods approach was conducted over three stages. First, a review of the available human science information which was relevant to Military Load Carrying Equipment (MLCE) was undertaken. Second, a filtering process was used to determine the human science information that was likely to be useful to MLCE developers. Third, the techniques selected were reviewed using appropriate criteria.

Stage 1 – Initial literature review

Human science literature was searched to find papers relevant to MLCE. The review was conducted in the early stages of the research; hence papers up to 2004 were reviewed. The searches were conducted using keywords on Loughborough University's Library information systems (MetaLib, OPAC and so forth) and through the researcher's personal contacts.

Stage 2 – Literature Filtering

The selected 30 papers were then grouped by HF Area. Grouping the papers also stimulated further searches to augment the understanding of the HF Area. This approach was similar in manner to other literature searching approaches, including Meta-analysis (Cohen et al. 2000, NHS Centre for Reviews and Dissemination 2001). Meta-analysis was not possible because of limited number of published reviews of

MLCE human systems which could be found at the time of undertaking the review. These were:

- Kolnicker and Tolcott (1962)
- Haisman (1988)
- Knapick et al. (1996 and 2004)
- Wheatley (2004)

Stage 3 – Literature review

The selected papers were then reviewed to see how relevant they were to MLCE development. The scoring method applied was simple to tease out the benefits from the paper to MLCE. The scoring was subjective and based on how the information in the paper could be used in MLCE development.

A.2 Review Summary

HF area	Reference	Rucksack structure	Affect on MLCE design	Relevance of use in MLCE design and development	Scoring justification
Lung Function	Bygrave et al. (2004)	Shoulder straps and back system	Designing for the fit of rucksacks and how adjustment can be improved	3	Useful as a guiding principle, and demonstrates the importance of good fit
	Legg and Cruz (2004)	Shoulder straps	Double shoulder straps	3	Useful as a guiding principle, not in a military context
Pressure	Martin (2002)	Shoulder straps, back system	Material selection for MLCE, also level of load expected to achieve mitigation of pressure on user	4	Intended for design application, and began material assessment method for shoulder straps
	Hooper and Jones (2002)	Shoulder straps, back system, hip pads, garment affect on MLCE load distribution	Material selection for MLCE, also level of load expected to achieve mitigation of pressure on user	4	Intended for design application, continued material assessment methods from Martin, and established that clothing has negligible impact on pressure distribution
Load Distribution	Bunting et al. (2004)	Back system, load carrier	Where different items must be put, ease of access	3	Confirmed US research on the principles of load distribution
	Hunter and Turl (1952) in Wheatley (2004)	Assessment of 1950s military MLCE	General information on existing system	2	Dated information
	Abe et al. (2004)	Load carrier	General rules for distributing load	1	Not as detailed as Bunting
	Lloyd and Cooke (2000)	Front and rear loading	Front and rear loading MLCE	3	Similar to Bygrave and Legg

HF area	Reference	Rucksack structure	Affect on MLCE design	Relevance of use in MLCE design and development	Scoring justification
Female Users	Neely (1998)	Shoulder straps, back system, hip pads	Designing MLCE for female users	1	Non-MLCE in focus, physiological study, few ergonomic insights
	Gemmell (2002)	Shoulder straps, back system, hip pads	Designing MLCE for female users	1	Non-MLCE in focus, physiological study, few ergonomic insights
	Llewellyn (2002)	Shoulder straps, back system, hip pads	Designing MLCE for female users	1	Non-MLCE in focus although related, physiological study, few ergonomic insights
	Bhambhani, Y (2000)	Shoulder straps, back system, hip pads	Designing MLCE for female users	1	Non-MLCE in focus, physiological study, few ergonomic insights
User Fitness and Strength, related to Age	Elshaw et al. (2003)	All	Potentially more adaptable and flexible MLCE, either in one system or different MLCE in a range	1	Non-MLCE in focus
Biomechanical	Knapik, Harman and Reynolds (2004)	All	Broad principles	2	Good review of broad principles and human science in the area up to 2004
	Attwells et al. (2003)	All	Heavy loads	2	Comparative study of 90 Pattern vs Airmesh Bergens
	Salford Lit Review (2003)	All	Review of biomechanical influences on MLCE development	1	Early biomechanical review
Medical Influences	Knapik, Harman and Reynolds (2004)	All	Link to injury indicators	2	Link to health hazard consequences for MLCE development

HF area	Reference	Rucksack structure	Affect on MLCE design	Relevance of use in MLCE design and development	Scoring justification
Injury	Birrell (2004)	All	Link to injury indicators	2	Link to health hazard consequences for MLCE development
	Jones et al. (2004)	All	Ergonomic influences on injury	2	Practical aspects within MLCE development
	Tilbury-Davis and Hooper (1999)	Load Levels	Threshold for lower limb injury, design to not allow users to overload	1	Guiding principles of not overloading, not just MLCE
MLCE Evaluation	Stevenson et al. (2004)	All	Objective assessment of MLCE solutions	4	Robust systematic approach to the evaluation of MLCE
	Ried et al. (2004)	Back system, hip pads	Design of stiffening rods in back system design	4	Assessment of stiffening rods within MLCE systems
	Vicary (2003)	All	Beginnings of a framework for looking at pack usability	3	Framework for design-orientated usability assessment
Comfort	Jacobson et al. (2003)	All	Method for gathering comfort information	1	Generic comfort assessment methods
	Martin (2002)	Shoulder straps	Method for gathering comfort information	4	Applied 'in-field' method for assessing shoulder strap comfort

HF area	Reference	Rucksack structure	Affect on MLCE design	Relevance of use in MLCE design and development	Scoring justification
Comfort - continued	Hooper and Jones (2003)	Shoulder straps	Method for gathering comfort information	4	Applied 'in-field' method for assessing shoulder strap comfort
Pack Dynamics / Forces	Ren et al. (2004)	Should straps, hip pads, volume	Quantified 'engineering' aspects of rucksack design	2	Early attempts to quantify MLCE aspects into an 'engineered' approach to development

A.3 Findings and discussion

This review successfully illustrated that the human sciences information on MLCE was limited in its application to MLCE development. The information reviewed was limited by the relative inexperience of the researcher at this point in the research; however, later work with human systems specialists was broadly in agreement with the findings. Average scoring was 2.3, which was largely thought to be because of the concentration on the physiological aspects of MLCE, and the limits of the number of papers reviewed. This was thought to be because many of the studies were focused on the impacts of MLCE on humans, with few studies identifying why the MLCE caused the impacts.

Later in the research the researcher, as a MoD Science Desk Officer, commissioned a short review of MLCE literature by human systems specialists (Vicary and Wood 2005). This later review and another review that the researcher undertook with human systems colleagues (Humm et al. 2007) confirmed the concentration on physiological aspects and a number of gaps in human science literature with respect to MLCE development.

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Appendix B: (Study 1) An initial exploration of the views of MLCE researchers

This appendix outlines an early exploration of the influences on MLCE development with specialist MLCE researchers active in the field. At this stage in the enquiry it was obvious that human systems expertise was critical in the successful development of MLCE. It was decided that it would be useful to undertake a short study to ascertain the researchers' views on MLCE development.

Thesis Link: Chapter 3, section 3.4

B.1 Introduction

The purpose of this study was to begin gaining an understanding of the views of other stakeholders of MLCE development. This was to establish more information about the context of MLCE development, in particular the role of human factors specialists.

Objectives:

1. To establish an initial impression or picture of the issues within the context of MLCE development from the perspective of specialists in the field, in particular; the role of human factors expertise in MLCE development.
2. To enable the researcher to gain familiarity, skills and experience of qualitative research methods.

B.2 Opportunity and Background

The opportunity to gain views from human factors experts in the field came from the researcher's role as the project manager of a number of ongoing research contracts with Salford and Loughborough University. This gave access to MLCE researchers from human sciences, engineering and mathematical modelling with a variety of experiences and expertise. The workshop was open to both groups of researchers whose research, while separate in purpose, was conducted in a collaborative manner. Due to prior work commitments it was only possible to get relatively junior researchers together to do the workshop, although the views of the senior lead researchers were canvassed through unstructured interview and email discussion.

The researcher's experience of the process

At this early stage in the enquiry the researcher was also keen to get views on his own experience from working in MLCE development, Figure B-1.

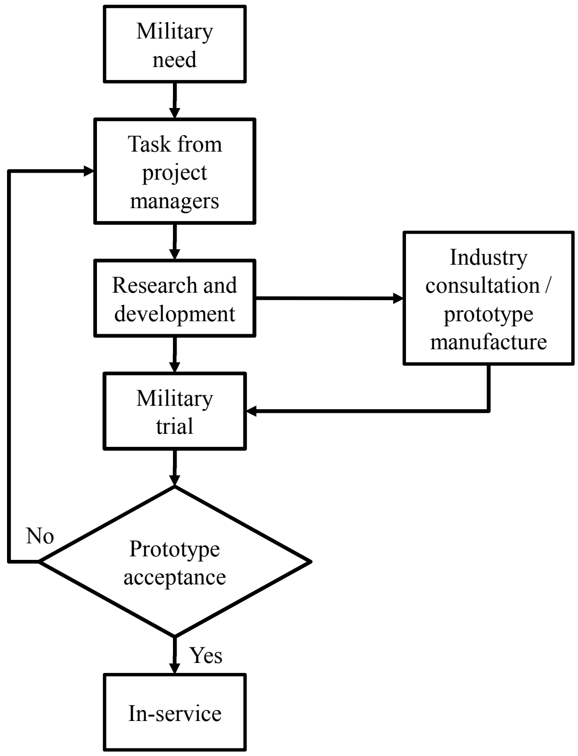

Figure B-1. *MLCE Development process from the researcher's experience.*

The researcher wanted to establish whether this was a view shared by other researchers in the area. Additionally there was a need for a view to be developed that could be used to compare against the process definition which may come from later studies.

Role of human factors expertise in MLCE development

This review was conducted while the literature review was being undertaken. There were a number of questions which the review had raised, which it was hoped that human factors specialists could elaborate on:

1. How and to what extent are users represented in the process of NPD?

2. Have cost and business performance issues taken a higher priority over human systems and user needs in MLCE development?
3. How are user requirements gathered and how are they used in MLCE development?
4. Why are military loads approximately 50% heavier than the recommended load limit and what impact does this have on the user and MLCE development?
5. What effect do particular branches of human science (for example; Biomechanics, Physiology, Ergonomics, Physiology) have on MLCE development?
6. What format should human systems information related to MLCE development be presented in, to make them useable in the process of NPD?
7. How are human factor issues being represented within MLCE development processes?
8. What are the soldier's needs for MLCE and how can they be successfully represented in development?

B.3 Approach

The approach used was an open discussion as part of a short workshop (one hour) conducted in the specialists' gait laboratory where comfortable chairs were available. The discussion was opened by the researcher, who asked the specialists: i) what were the issues in MLCE development, and, ii) what would be the idealised process they would like to use?

A drawing pad was used to capture the process that the specialists thought was best.

In retrospect this approach was limited, because of the possibility for a dominant personality leading discussion, and the difficulty of recording the feedback provided by the participants. The output from the workshop was intended to be insightful, however, to provide the researcher with experience of interacting with others on the subject of MLCE development.

B.4 Output and discussion

Although the participants were relatively inexperienced, they were aware of issues and problems within MLCE development and were keen to help develop an illustrative rather than definitive view of MLCE development. The questions that were highlighted by the literature review in section B.2 could not be answered conclusively by the participants. Some participants had strong views on some of the questions but accepted that there were gaps in their knowledge, since they did not see the whole MLCE process. Insights on the questions were identified, largely by the suggestion of reviewing User Centred Design approaches (see Chapter 3). The view developed by the workshop is at Figure B-2.

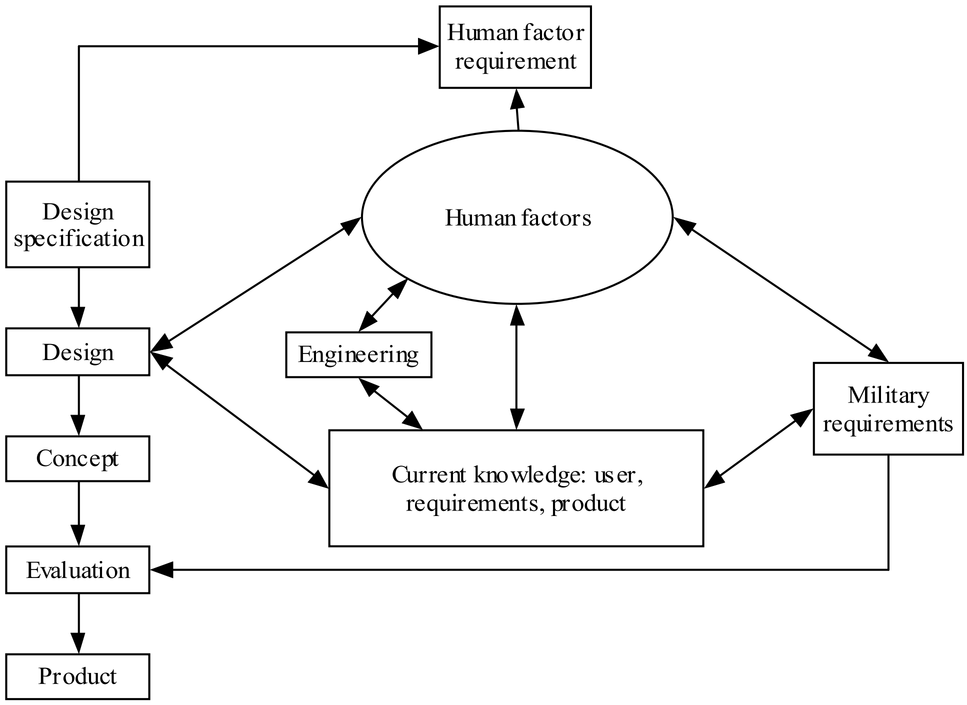

Figure B-2. *MLCE human system researchers' views of MLCE development processes.*

The view had strong biases towards the role of human systems in MLCE development and due to the inexperience of the participants in MLCE development it was not thought to represent how human systems influenced MLCE development at the time of the workshop (2004). Figure B-2 did, however, show how the other aspects may need to feed into design to produce a manufactured artefact, via human systems. In MLCE development, however, all the elements in the diagram have a role in determining the performance characteristics of MLCE, represented by the 'Design specification' stage. Additionally, not all MLCE characteristics can necessarily be represented in human systems terms (Howard 2004 Personal

Communication). Human systems may help define the performance characteristics of an MLCE before any explicit design activity. But it may not have a significant role during the design activity stages.

Due to the limitations in how this view was generated, and the limitations accepted by the participants, it was not used further in the enquiry apart from to improve the researcher's awareness of the potential role of human systems within MLCE development. In addition it was a beneficial learning experience for the researcher, which helped in developing more successful studies later in the research.

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Appendix C: Carriage of Heavy Loads

Throughout the enquiry, the researcher sought to maintain contact with departments within the UK Ministry of Defence to keep a record of the loads that were being borne with personal load carriage. This was difficult to do due to the problems of accessing reliable and auditable data from current theatres. The following is a discussion around the data collected.

Thesis Link: Chapter 3, section 3.4

C.1 The carriage of heavy loads

The carriage of heavy loads was explored to ascertain its influence on MLCE development. Figure C-1 shows the increases in a soldier's load over time.

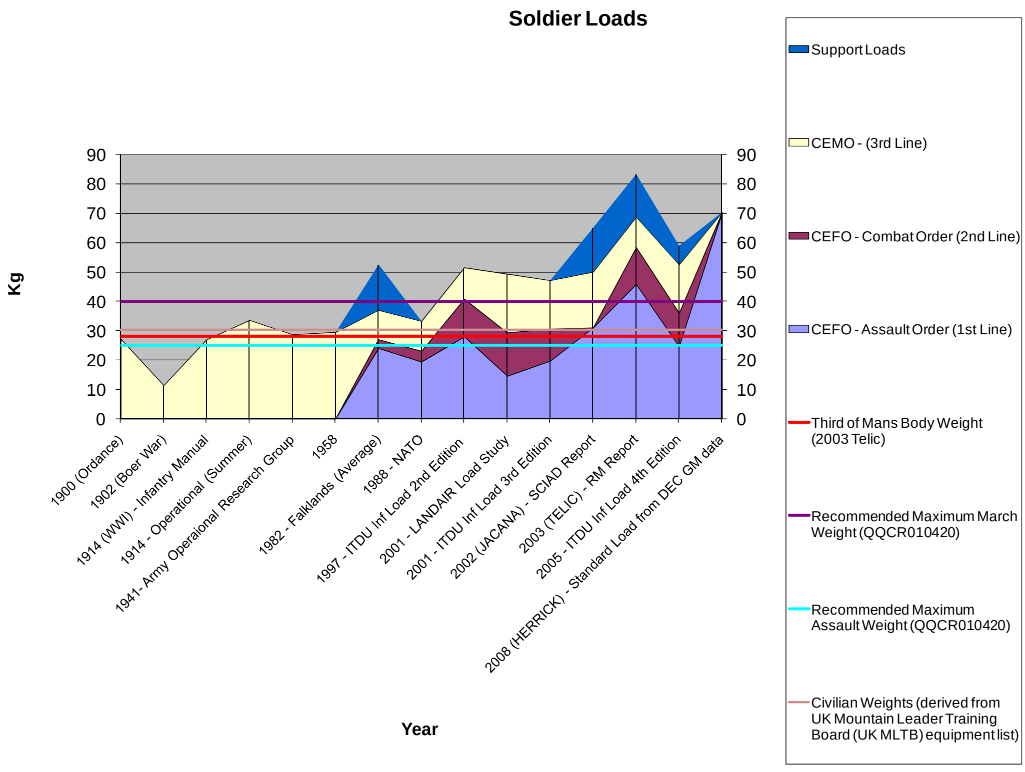

Figure C-1. *Graph showing illustrative MLCE weights.*

A British soldier currently organises load in to three loads (or lines) determined by the military task. The equipment a soldier carries was determined, in the UK

Ministry of Defence, by tactical doctrines which are the fundamental principles which guide soldiers during military missions and tasks (British Defence Doctrine 2001). The loads used in combat, however, vary according to different official pamphlets, depending on the military unit's operating procedures, role, task and enemy threat. This means that some units often carry heavier loads than the loads prescribed, and additionally the load can be affected by the soldier's own decision to carry more. This was often linked to operational experience in that soldiers do not trust logistical re-supply either to bring them essentials such as water and ammunition, or their rucksacks (McCraig and Gooderson 1986, Gardiner 1982).

Wartime versus peacetime loads

McCraig and Gooderson (1986) also note that there is a marked difference between peacetime (training) and wartime loads, which has an impact on the provision of load carriage suitable to wartime loads. It is interesting, looking at Table 9, that the 'one third' body weight rule, which has been proven by experience on the military operations, and in medical reviews during the early part of the 20th century (Wheatley 2004, Wayman 1984, DEF STAN 00-250, MIL-STD 1472F), was apparently not used in the military context in the early 21st century. McCraig and Gooderson (1986) also note the differences in environment between the military and civilian contexts and the affect environment has on MLCE.

Coping with heavy weights

To try and solve the problems associated with heavy loads the British military have taken a pragmatic approach to carrying equipment with MLCE. Military commanders were shown to have the responsibility of deciding what was mission-critical equipment, and so whether to carry the equipment weight or not. A commander was responsible for successfully completing military missions and so must determine what equipment must be taken to complete their goal. This was obviously dependent on a commander's training and experience. This approach was possible while loads did not exceed the point where they cannot be borne by the soldier, or did not reduce the mobility required for the military task. There were many different military goals and therefore different levels of what was acceptable in terms of mobility. What those levels were was uncertain, as was what MLCE was appropriate to enable the carriage of equipment to complete the military goals.

This, however, was highly dependent on the abilities of commanders. Often soldiers may have to bear equipment that cannot be put in MLCE, so must be either carried on the outside of MLCE or by hand (as in Figure 8). This could lead to increasing the affect of the weight of the equipment as it may create additional force by leverage, due to it being away from the centre of gravity. The researcher has also observed soldiers carrying Light Anti-tank Weapons (LAW) horizontally across the top of the rucksack, making the rucksack twist, due to the weight of the warhead at one end of the weapon, causing the soldier considerable discomfort. Therefore weight and its affect on the soldier was clearly a strong influence on the design of MLCE.

The affect of weight on MLCE design

From looking at existing MLCE designs it was not clear that the effect of excessive weight has been taken in to account in the design of MLCE. Additionally a Defence Science Advisory Council report on equipping dismounted soldiers noted that soldiers already carry excessive loads and that in the future the effect of weight must be minimised (Hetherington 2001). MLCE may have to change to limit how much soldiers can carry (as has been done before (Marshall 1950, Harding 2004)), yet still allow them to carry the appropriate equipment to successfully complete their military task.

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Appendix D: Tools used in MLCE development

As a part of the literature review, the tools used in MLCE development were reviewed in order to determine how tools were used within MLCE development.

Thesis Link: Chapter 3, section 3.4

D.1 Approach

The review was based largely on the researcher's experience of MLCE development, interviews undertaken within study 2, and discussions with colleagues who knew the capacities of manufacturing firms.

The review's outputs are reported in the Table below. The tools used in MLCE development were traditional in nature, with some reported differences to garment-design approaches, particularly the reticence by MLCE firms to use Computer Aided Design (CAD). Additionally it was clear that development was strongly reliant on prototyping and drawing.

Design Method	In use	Notes on use in Defence Organisations
User needs analysis	- (not used)	Not formally performed as a user need analysis, although the process of requirements definition is outlined within the UK Ministry of Defence's Smart Acquisition Process.
Drawing / sketching	o (partially used)	Only formally used at the Specification for manufacture stage. Sometimes used at prototyping stage.
Prototyping	• (used)	Used extensively. Often based on hand-made patterns used to make previous designs.
End user interviews / surveys	o	End user surveys are used in reviews of troop trials. Not formally used to clarify requirements. Some concern that interviews do not use an approach that delivers objective data. Informal interviewing may be used in requirement definition.
Usability evaluations	o	Not used at the beginning of the process, only at the end for User Acceptance.
Data searches	-	Used to get relevant information, not used a great deal.
CAD	o	Used to specify for manufacture, after pattern design.
CAM	o	Not used.
Marketing tools	-	Not used.
Brainstorming	-	Used infrequently, if at all.
Creativity tools	-	(e.g. parametric analysis, problem abstraction, SCAMPER (Baxter 1995)) Not used.
Usability tools	-	(e.g. Poulson (ed) et al. 1996) Not used.
Quality tools (e.g. Quality Function Deployment (QFD))	o	No evidence of pre-manufacture use of QFD, although there was some use of specifications in terms of manufacture. Design Specification was not often used as a check or working document to aid the process of NPD in the context of MLCE. Project management techniques and plans were kept. At contractor bid stage the quality of manufacture plan was assessed by quality assurance personnel. Information from product defect reports was used but in an informal and unstructured manner. Systems Engineering Methods are not currently used.
Risk evaluation	-	Done within the project management function, design risks were not formally identified.
Life cycle analysis	-	Whole Life Costs were used under current UK Ministry of Defence processes.
User trials	•	This is the main technique to check if a product was fit for service, and to establish and check user requirements.

Appendix E: Knowledge gaps in MLCE development

Thesis Link: Chapter 3, section 3.6

Literature area	Gaps in knowledge of MLCE development
Design processes in the context of MLCE	What design process is used in MLCE development? Are design strategies and design processes used? If so, what is the impact? Are problems in the context of MLCE poorly defined and so not addressed by development processes? How and to what extent are users represented in MLCE development? Have cost and business performance issues taken a higher priority over human systems and user needs in MLCE development? Does the development process have an impact on how design teams design, in the context of MLCE? What are the appropriate cues within MLCE design which can be used to prevent error in the development process? How are design decisions made during MLCE development? What level of design expertise is there involved in MLCE development? How are user requirements gathered and how are they used in MLCE development?
Design methods in the process of NPD in the context of MLCE	What methods are used in MLCE development? What methods are used in military and civilian organisations, do they differ, and why?
Influences on MLCE development?	Why is the military load approximately 50% higher than the recommended load and what impact does this have on the user and MLCE design? What effect do particular branches of human science (for example; Biomechanics, Physiology, Ergonomics, Physiology) have on MLCE development? (To date there has been no integrated human factor studies of the affect of load on the human in a military context.) What format should human systems information related to MLCE design be presented in to make it useable in the development process? What effect on the soldier does the role as a consumer have upon user requirements in MLCE development? What affect does product failure have on MLCE development? Are the processes used to develop MLCE high quality? What lessons can MLCE development learn from approaches to NPD of civilian load carriage? How are human factor issues being represented within MLCE development? What are the soldier's needs for MLCE and how can they be successfully represented in NPD?

Appendix F: Comparative study protocol

Thesis Link: Chapter 5, section 5.2

This Appendix the protocol, or rules and procedures for the comparative study.

1. Purpose

The purpose of this protocol is to outline the rules and procedures for undertaking a multi-case study exploring Military Load Carriage Equipment development.

2. Key features of the case study method

This study needs to be adaptive, exploratory and comparative as well as to allow an understanding to develop of a complex and integrated number of variables. This makes an experimental approach, where variables can be changed to test an operational hypothesis (Gray 2004) in a controllable environment, of limited value in this context. One approach which meets the purpose of the research is the case study approach, since it tries to: i) find out what is happening, ii) seek new insights, iii) ask questions, iv) assess phenomena in a new light (Robson 1993). Case study is an empirical enquiry which investigates specific instances of phenomena in their context (Yin 1994: 13, Adelman et al. 1980 in Cohen et al. 2000: 181). Yin (1994) also notes that this form of enquiry is especially relevant when the boundaries between the phenomenon and context are blurred, as is the case with the research context of MLCE design. A case-study approach by itself, however, may not be suitable for exploring all the issues the research seeks to look at, therefore the case study approach is a part of a research strategy which uses other research (discussed in section 4). These other methods include action research and the Delphi Technique, which are to be used to explore how improvements to MLCE design could be undertaken after the multi-case study (see Figure 1). The research protocol for these methods are not captured within this case-study protocol since the use of these methods is dependent on the findings of the multi-case study which this protocol describes.

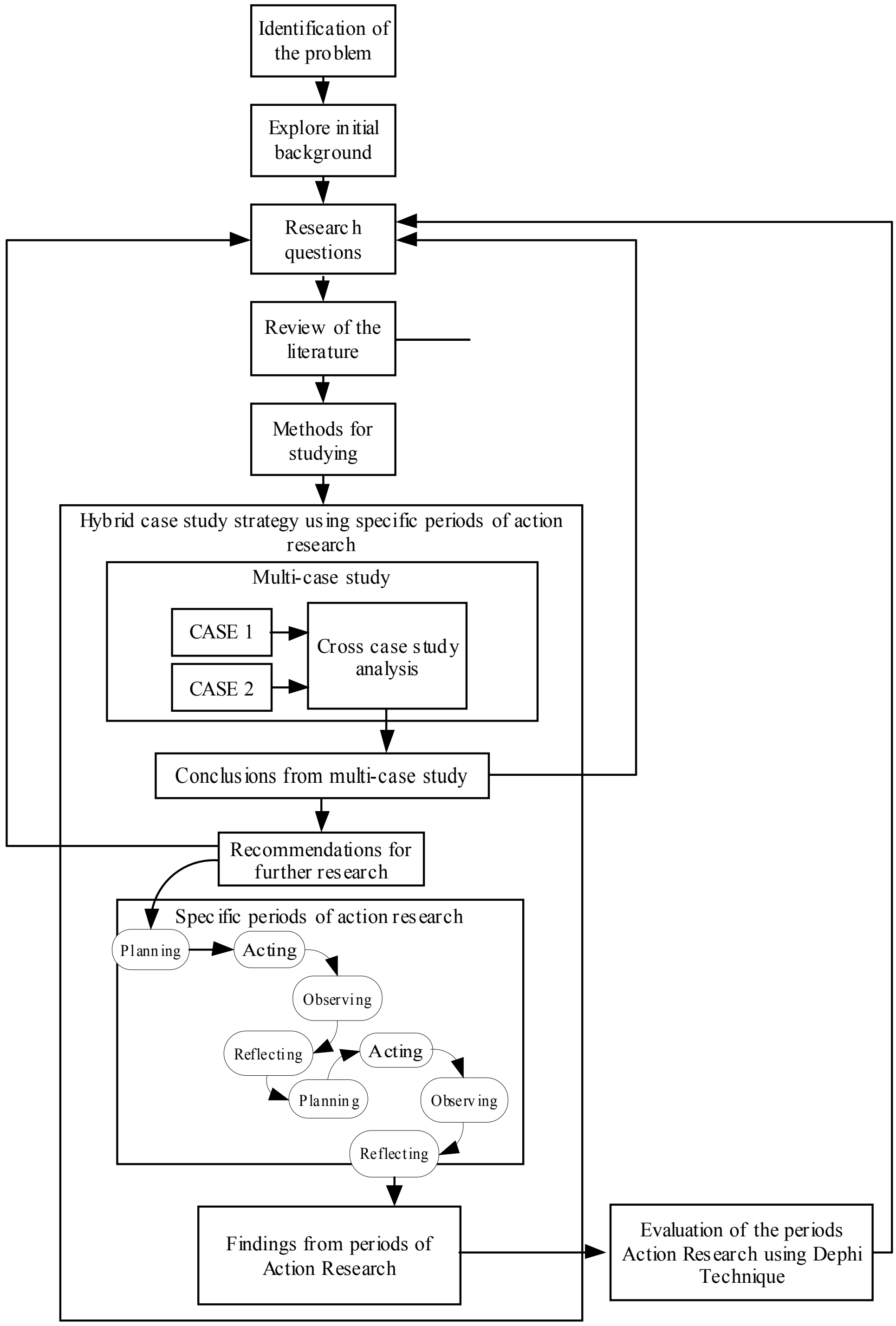

Figure 1. *Diagram of the Research Approach for this study showing the specific methods adopted and the feedback loops to ensure the research is answering the research questions.*

Organisation of this Protocol

For the results of a multi-case study to be reliable, the results must be repeatable which is only possible if the research procedures are documented to allow others to follow the same protocol (Yin 1994: 63). Gray (2004: 138) outlines the following as components of a protocol; their organisation in this protocol is in the brackets:

- Overview of this case study– Objectives and theoretical issues (section 4)
- ‘Field’ procedures – access to ‘sites’ and people, sources of information, back procedures, timescales, contingency plans (section 5)
- Case study questions (section 6)
- Structure and Guide to final report (section 7)

3. Overview of this case study

This case study is a part of a broader research strategy (as discussed in section 2) which aims to: *explore, evaluate and then improve MLCE development.*

The *objectives* for the study are:

1. To investigate military load carriage equipment to:
    a. Identify existing load carriage systems.
    b. Evaluate their success or otherwise.
    c. Understand the process by which they were designed.
    d. Identify the good and bad aspects of the process and methods used which resulted in a successful/unsuccessful design.
    e. Identify what optimum MLCE is.

2. To find out how any new improvements could fit in to current design processes used in the military environment.

3. To identify suitable improvements (e.g. design tools) to the product development of MLCE.

4. To develop suitable improvements by involving researchers and users.

5. To test the improvements in the design process and evaluate their strengths and weaknesses.

From the aim and objectives the following *research questions* have been developed:

- RQ1: What are the influences on MLCE development?
- RQ2: What needs improvement in MLCE development?
- RQ3: How can we improve MLCE development?

Transforming the research questions into questions which can be explained by a case study approach is achieved by developing 'propositions' that articulate the evidence needed to answer the research question (Yin 1994: 21). It is important that the same questions are used for each case otherwise the results may be unbalanced and not allow for commonalities to emerge from the cases. The case-study questions can be found in the table in notes at the end of this annex.

Theory development

Case-study approach does not start with a defined theory from which hypotheses can be drawn and then tested. There could be a benefit in starting from a hypothetical position, since generalising from case study to theory may facilitate the data collection phase of the study and reflect back to inform one's understanding of the theory and its inferences. Yin (1994), however, recommends that some form of theory development takes place at the design stage of case studies, to avoid radical re-design later. At this stage, due to the ambiguous and complex nature of the subject area, it is difficult to identify an existing theory related directly to the research. The earliest time that one may begin to start to generate a theory 'grounded' or developed from the evidence rather than one which may be directed by a preconceived idea (Glaser 1992) is likely to be during the case-study framework analysis. If or when a *grounded theory* emerges from the research it should conform to four criteria (fit, work, relevance and modifiability) which can be used to determine whether the theory is appropriate to the research (Glaser 1992). Yin (1994), however, suggests that it is important at the very least to begin with an idea, which may or may not lead to corroboration by the data later in the research.

In this instance, the approach for this study should be a grounded one owing to the complexity and ambiguity of the area of study.

Initial Hypothesis

Having stated that generating a suitably grounded theory approach is preferred for this study, it is perhaps best not to start with any preconceived idea of what the data from the research may produce. The researcher had some hypothetical ideas, however, on the basis of personal experience that the likely problems in MLCE development will be due to deficiencies in gathering, understanding and using design information. From this perspective there is no clear theory upon which to base a more hypothetical-deductive approach from the literature examined to date. And so working from the basis of grounded theory these ideas have to be put to one side while the initial exploration using case studies is conducted. It is also important that other possibilities, which could also establish grounded theories, should not be biased against, by concentrating on information deficiencies.

Pilot study

A pilot study has been conducted for one of the case studies (90 Pattern rucksack) which aided the development of this protocol.

4. Procedures

The case-study procedures are the instruments for the collection of data as part of the plan to answer the case study questions. Before the procedure is outlined one must state that this multi-case study uses two cases:

1. Development of the UK MoD’s 90 Pattern rucksack
2. Development of the UK MoD’s Airmesh rucksack

These have been selected because they are accessible, still in service and contain rich data sources (e.g. development files – see notes at the end of this annex) for this design context.

Case study one – development of 90 Pattern (Infantry) rucksack

The 90 Pattern (Infantry) rucksack (Figure 2a, 2b) is the standard UK Armed Forces infantry rucksack. It was developed in the 1980s and has undergone some further development since it went in to service in 1990.

Figure 2a. *90 Pattern rucksack from the back, the two large side pouches detach and form a small day pack.*

Figure 2b. *90 Pattern Rucksack from the front, with the two large side pouches detached.*

Case study two – development of the Airmesh rucksack

The Airmesh rucksack (Figure 3) was developed during the late 90s for a specific role (carrying very high loads (80kg plus) during covert operations), but has been trialled by conventionally rolled troops and is widely liked. This rucksack is not on general issue. It has been chosen as a case since access to the designers and sources involved in its development are available.

Figure 3. *The Airmesh rucksack from the back (showing the airmesh fabric) and front showing the six pouches favoured by the users of this rucksack.*

The two available case studies allow for four of the six sources of evidence suitable for case studies articulated by Gray (2004), apart from direct observation and participant observation as there is no opportunity to observe design activity (the MoD is not currently undertaking MLCE development of the case under study). Of the sources available within the two cases, each source has a corresponding research method associated with it, as shown below:

- Documentary* – historical analysis
- Archival Records* – historical analysis
- Interviews – interview techniques

- Artefact – rucksack evaluation matrix

*Documentary and Archival Records have the same research method associated so will be referred to as *documentary* evidence in this protocol.

These techniques are well established and are appropriate to the case studies. Figure 4 shows how the sources of evidence fit in to the multi-case study (see Figure 1).

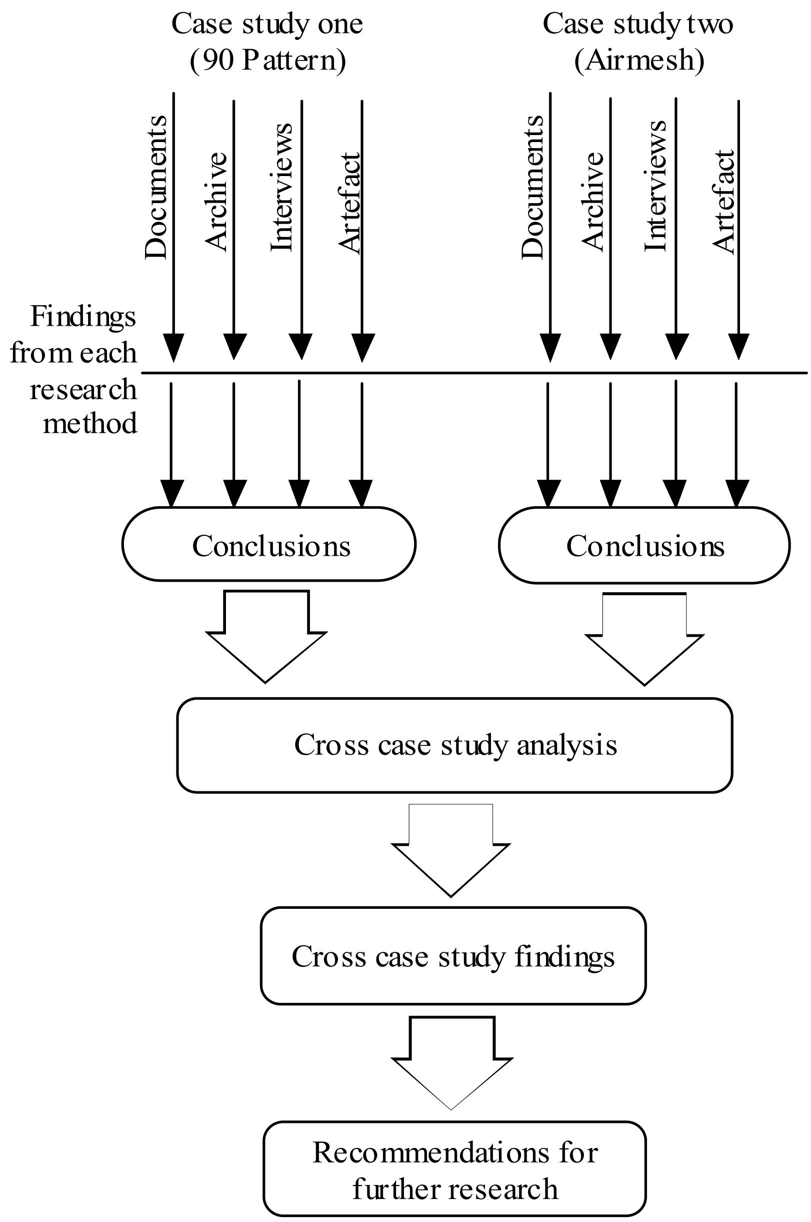

Figure 4. *Diagram showing how the sources of evidence fit in to the multi-case study approach.*

Timing

The case studies should be done close together to ensure that there is consistency of interpretation during the analysis phases of the research methods in each case study.

The notes at the end of this annex show which technique, in terms of the source of evidence, could be used in answering each case study question.

i. Initial scheduling of the documentary evidence

Documentary evidence could be collected from the following UK Ministry of Defence sources (list established by researcher's personal experience and initial reviewing of the evidence):

- Information analysis (Historical Branch (Army))
- Defence Clothing Research and Project Support (DC RPS) Library
- Defence Clothing Integrated Project Team
- Defence Science and Technology Laboratories (Dstl), Land Systems Department, Infantry Strategic Support Team
- Defence Science and Technology Laboratories (Dstl), Information Management Department, Human Systems Team
- Directorate of Equipment Capability (Ground Manoeuvre)
- Directorate of Equipment Capability (Special Projects)
- Equipment Capability Cell – Stirling Lines, Hereford

The evidence could include:

- Primary evidence from development files used by designers
- Trial reports
- Official histories of load carriage development
- Minutes of official meetings
- Details of development and procurement processes used at the time
- Human factors research reports
- In-service performance reports from users and official reports

Any evidence collected should be recorded and handled according to the UK Ministry of Defence (UK MoD) procedures (see section 5,a,ii).

Evidence from other sources may be available, for example the internet and foreign research laboratories (e.g. The US Army Natick Soldier Centre Library).

ii. Review of Preliminary Information

Each piece of documentary evidence should be evaluated (the third stage in Figure 5) as to its i) authenticity and ii) accuracy (Cohen et al. 2000: 162). (Note: Some evidence will have been used during the initial pilot study for the case-study approach which will have enabled the researcher to become familiar with some sources.)

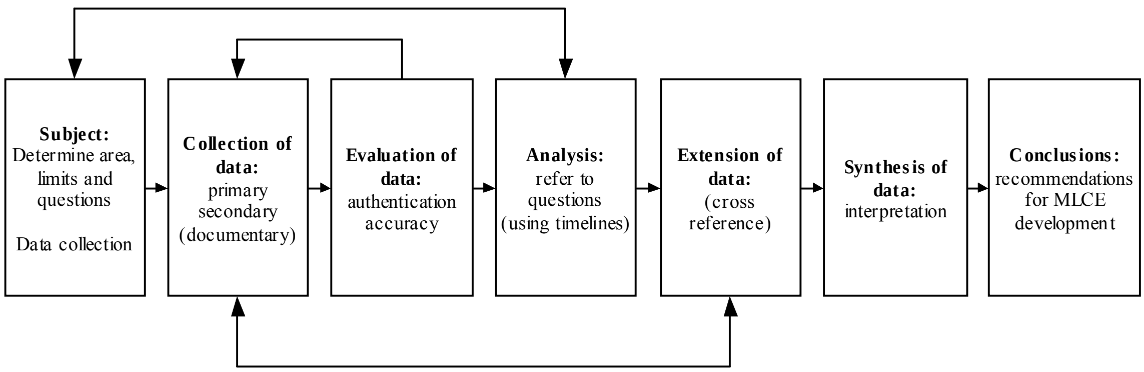

Figure 5. *Diagram showing the stages of historical analysis (Chadwick 1978).*

iii. Special Documents

Some documentary evidence is classified (up to UK Ministry of Defence 'UK Eyes Restricted' level) and should be stored in a secure area and used according to UK MoD procedures for handling and referencing. Direct quotation of classified evidence could lead to needing to classify case study reports, which to enable exploitation of the study results should be avoided.

iv. Persons to be interviewed

Most of those involved in the development of 90 Pattern Personal Load Carrying Equipment are unfortunately now deceased, but some of those involved in the 'in-service' development are still alive, albeit in retirement and so could provide relevant information. They have been traced via the establishments listed in section 5(a). Two of the interviewees were also centrally involved in the development of the Airmesh Bergen.

Mr A – A junior designer during the early development of 90 Pattern PLCE, so knew the main designers and general environment under which 90 Pattern PLCE was developed.

Mr B – Senior designer just after 90 Pattern PLCE went to service, over saw the 'in-service' development of 90 Pattern PLCE. Latterly he was the Head of Section responsible for development of the Airmesh Bergen.

Mr C – Specification Writer during 90 Pattern development, latterly senior designer of Airmesh Bergen.

v. MLCE rucksack design and design processes interviews

Permission will be sought from each participant, including an explanation of how the recordings are going to be used. Interviewee's identities will be kept confidential. The interviews will be held in a quiet comfortable environment to put the interviewee at ease and allow for good recording quality. Details of the interview approach and interview questions can be found in the notes at the end of this annex.

6. Training

Training with the methods in this protocol is needed by those not familiar with: i) MLCE design, ii) development processes, iii) the research methods used within the protocol.

i. Purpose of training

Training should allow researchers to gain knowledge of the research methods outlined in this case study protocol, to undertake an exploration by multi-case study into MLCE development.

ii. Topics for training

Knowledge of MLCE

Unless researchers have a good knowledge of the context of MLCE in terms of the military environment and artefacts (MLCE rucksacks), they may not be able to make best use of the evidence because of confusing acronyms and contextual references. Also some references rely upon the researcher having some specialist knowledge of human factors and the user's environment. This knowledge can be gained by talking with human factor experts and undertaking visits to military units, and by using MLCE, ideally on military training exercises with users.

Development process

Part of the multi-case study is identifying what process of NPD is being used, so that an evaluation of the process of NPD can be undertaken to answer the research questions (as a part of the research strategy which involves other methods see section 2). This can only be achieved by understanding the contextual references in the documentary and interview data. This is aided by using an improvised process definition method outlined in the notes at the end of this annex.

Research methods

From the researcher's experience while undertaking the pilot study, attention should be given to good historical criticism of sources and over-generalisation from the evidence. Using Best (1970) in Cohen et al. (2004: 163) is a good way to be aware of issues surrounding historical analysis techniques. Practice using historical analysis is also recommended before conducting case studies. Interview methods also require practice since familiarity with the context of MLCE is required to be able to ask open questions, depending on the interviewee's answers as the interview progresses. Recordings should be kept for audit purposes or peer review of the data, or if the data is needed for further research.

iii. The case-study database

The evidence used in the case studies must be auditable and provide adequate support to undertake any analysis during the case studies. Usually research strategies include data source collections: i) the data and ii) the researcher's report. In the case of this case-study protocol, a bibliography of the documents being used in each case study will be kept, as well as the researcher's notes, some data, and final case study reports. (Some documentary evidence will have to be returned at the completion of the multi-case study, but will remain accessible through UK MoD archives.)

6. Case Study Questions

The case study questions for this study are complex and require knowledge of the related literature. Part of the difficulty is that many of the definitions identified in the literature are in themselves hard to define. The number of case study questions is difficult to reduce since the context of MLCE design is not defined in the current literature, and so the data collection and analysis must be wide and varied.

a. Topics for research question one (What are the elements involved in MLCE development?)

Research question one (RQ1) needs more case study questions than any other, although the first two are arguably the most critical in answering the RQ1. A strategy to get answers effectively is to try and answer the case study questions in brief, and then use the other case study questions to answer the first two case study questions in detail at the end (see the notes at the end of this annex).

b. Topics for research question two (What needs improvement in MLCE development?)

RQ2 cannot be answered by the multi-case study alone, so interview techniques are also required. Documentary evidence can begin to develop a case as to what may need development, but any interpretation or case building must be caveat as being the opinion of the researcher with the benefit of hindsight and current practices. Interview techniques are also useful in that they give those who were involved in the cases the opportunity to reflect on the process at the time and give additional insights. It must be remembered however that the interviewees may not have current organisational or professional knowledge.

c. Topics for research question three (How can we improve MLCE development?)

RQ3, like RQ2, cannot be answered by the multi-case study alone, and the comments for RQ2 apply to RQ3.

7. Analysis plan and case study reports

a. Individual case studies

The analysis plan for the individual case studies is to conduct each of the research methods (i.e. historical analysis, interviews and so forth) separately, and they can then be drawn together to form an individual case study report (as in Figure 4).

i. Descriptive Information

The individual case study reports should be descriptive only where it is necessary to explain a point or to build an argument about the case. The information in the evidence is not complete in all areas, which occasionally makes describing the case awkward. The use of time lines should be used to illustrate where there is a complete, as well as incomplete, description of the case as well as declaring gaps in information when building the case study report. (The only addition to the research methods which is wholly descriptive is the use of the process definitions, which build a description of the process in each case.)

ii. Explanatory information

As has been stated above much of the information should only be presented if it is explanatory.

iii. Outline of individual case study reports

The individual case study reports should have the findings of the two main research methods (i.e. historical analysis and interviews), with the supporting techniques (Rucksack Evaluation) if used, reported separately. The report should contain a written report which draws the findings from the research methods into a final individual case study report. The report findings should draw evidence from the research methods to support a view of each of the case study questions. From these a summary can be drawn for each report which gives an answer to the research questions for that case, which can be used to aid the cross case analysis.

b. Cross case analysis

The cross-case analysis should be conducted by case study questions, but with reporting done by research question rather than by case study question.

i. Descriptive Information

There should be little descriptive information in the cross-case analysis.

ii. Explanatory information

As with the individual case study reports explanatory information should only be included where necessary. The difference with the cross-case study is that explanations should be between cases, rather than between evidence.

iii. Cross-Case Report

The cross-case report should cover each research question and reference the individual case-study reports and evidence as appropriate. The individual case-study reports should be included as Appendices so the multi-case study is presented as whole.

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Notes on case study questions and sources of evidence

RQ1: What are the influences on MLCE development?

Case-study questions	Info needed	Source (90 Pattern)	Source (Airmesh)
What are the factors which affect the MLCE development process?	List of influences (see Chapter 3 for definition) related to stages of the development process	Historical references / minutes / development files / interviews - all interviewees	Development Files (reports from Loughbrough University / GR Jones / J Martin PhD thesis / interviews (Mr B and C and EC Cell Hereford)
What is the relative impact of each factor?	What factor gives most 'return' i.e. evidence that shows that the factor is important and has large influence	Historical references / minutes / development files / interviews – all interviewees	Development Files (reports from Loughbrough University / GR Jones / J Martin PhD thesis / interviews (Mr B and C and EC Cell Hereford)
What are the relationships and interfaces between these aspects and factors?	Demonstrated understanding of how the elements interface and some prioritisation	Historical references / minutes / development files / interviews – all interviewees	Development Files (reports from Loughbrough University / GR Jones / J Martin PhD thesis / interviews (Mr B and C and EC Cell Hereford)
Who were the designers / product developers?	(Roles in process / organisation)	Interviews with designers? – tech memos / historical docs	Development files (reports from Loughbrough University / GR Jones / J Martin PhD thesis / interviews
How was the product development conducted?	What design / organisational process was used	Downing cycle information (Downey Report 1966)	Development files / interviews (Mr B and C)
How are design tools used within design process?	Evidence of tool use	Tech memos / development files	Development files / interviews (Mr B and C)

Were there legislative issues of Health and Safety or Human Factor constraints?	Evidence of legislative or organisational (e.g. directives) constraints which affected the final design	Development files / interviews	Development files / interviews (Mr B and C)
Who took design decisions?	Where were design decisions taken and by whom	Historical references / minutes / development files / interviews – all interviewees	Development files / interviews (Mr B and C)
How did those involved in the MLCE design process;			
Access and use design data?	Evidence of information used to justify decision making which affected the final design	Interviews / historical references	Development files / interviews (Mr B and C)
Make design decisions?	Evidence of the format of decision making? (i.e. committee, consultative and so forth.)	Historical references (Historical Branch (Army) report) / minutes / development files / interviews – all interviewees	Development files / interviews (Mr B and C)
Collaborate with other professionals?	Professionals involved in decision making and influencing the design	Historical references / minutes / development files / interviews – all interviewees	Development files / interviews (Mr B and C)
Use and access users?	Evidence of user involvement at any level and an indication of their influence on MLCE development.	Interviews / historical references	Development files / interviews (Mr B and C)
Are they experienced MLCE designers?	Evidence of the level of experience of MLCE development those making decisions had.	Interviews / historical references / interviewees	Development files / interviews (Mr B and C)

Was there conflict between organisational decision making and design decision making, and was it a positive or negative influence?	Evidence to support or refute this statement. Ref: Yerkes / Dodson hypothesis	Interviews / historical references (Historical Branch (Army) report)	Development files / interviews (Mr B and C)
Who accepted the item for service?	The criteria for acceptance for service and the influence this had on the process of NPD in the context of MLCE	Historical references / minutes / development files	Development files / interviews (Mr B and C and EC Cell Hereford)
What were the success criteria?	Evidence of the success criteria	Historical references (Director of Operational Requirements archives – minutes of meetings) / development files / interviews – all interviewees	Development files / interviews (Mr B and C and EC Cell Hereford)
How was it tested or evaluated?	Evidence of evaluation and trials	Historical references (Army Personnel Research Establishment troop trial reports) / minutes / development files / interviews – all interviewees	Development files / interviews (Mr B and C and EC Cell Hereford)
Have the MLCEs been successful during service according to the different stakeholders?	Statements of success or deficiency	Minutes / development files / interviews – Mr B and C –Shepherd et al. 2003	Development files / interviews (Mr B and C and EC Cell Hereford)
Have the requirements changed during service?	Evidence of requirement change	Minutes / development files / interviews – Mr B and C – current equipment Branch DEC GM	Interview – EC Cell Hereford

Were user needs identified at the beginning of the project?	Evidence of usability statements	Historical references (Army Personnel Research Establishment troop trial reports) / minutes / development files	Development files / interviews (Mr B and C and EC Cell Hereford)
Were military tasks identified during the project?	Evidence of tasks helping determining define what MLCE had to do	Historical references / minutes / development files / interviews – all interviewees	Development files / interviews (Mr B and C and EC Cell Hereford)
Was this information used?	Evidence of use	Historical references / minutes / development files / interviews – all interviewees	Development files / interviews (Mr B and C and EC Cell Hereford)
What info did designers need?	Evidence of information which designers felt was not available, but would have improved the MLCE development	Interviewees	Development files / interviews (Mr B and C and EC Cell Hereford)
What info did they have?	Evidence of what information the designers had at the time.	Historical references / minutes / development files / interviews – all interviewees	Development files / interviews (Mr B and C and EC Cell Hereford)
What info was not available?	Information which with the benefit of hindsight may have improved MLCE development.	Interviewees	Development files / interviews (Mr B and C and EC Cell Hereford)
How did they use the information?	Evidence of how the information was used.	Historical references / minutes / development files / interviews – all interviewees	Development files / interviews (Mr B and C)
By what criteria can one judge MLCE development to have been successful?	Evidence of how the successful MLCE development was	Historical references / minutes / development files / interviews – all interviewees	Development files / interviews (Mr B and C and EC Cell Hereford)

Can one identify where there were areas of deficiency in MLCE development?	Evidence of deficiency in MLCE development.	Historical references / minutes / development files / interviews – all interviewees	Development files / interviews (Mr B and C and EC Cell Hereford)

RQ2: What needs improvement in MLCE development?

Case-study questions	Info needed	Source (90 Pattern)	Source (Airmesh)
By looking at deficiency areas, can one see where improvement is possible?	Evidence of deficiency and potential for improvement	Historical references / minutes / development files / interviews – all interviewees	Development files (reports from Loughbrough University / GR Jones / J Martin PhD thesis / interviews (Mr B and C and EC Cell Hereford)
How is the product deficient because of limited practice? (Practice has moved on since the design work was done – or practitioners were not using the best techniques of the time.)	Evidence that limited practice detrimentally affected the development process	Historical references / minutes / development files / interviews – all interviewees	Development files (reports from Loughbrough University / GR Jones / J Martin PhD thesis / interviews (Mr B and C and EC Cell Hereford)
Was there something the designers did that led it to be deficient, if so to what extent?	Evidence of where designer may have contributed to deficiency in the product	Historical references / minutes / development files / interviews – all interviewees	Development files (reports from Loughbrough University / GR Jones / J Martin PhD thesis / interviews
Were there time constraints on the project?	Evidence of time constraints on the project	Historical references / minutes / development files / interviews – all interviewees	Development files / interviews (Mr B and C)
Who/What were the;	Evidence to populate the following categories:	Historical references / minutes / development files / interviews – all interviewees	Development files / interviews (Mr B and C)

Customers	Customers	Historical references / minutes / development files / interviews – all interviewees	Development files / interviews (Mr B and C)
Customer Requirements	Customer Requirements	Historical references / minutes / development files / interviews – all interviewees	Development files / interviews (Mr B and C)
Measures	Measures	Historical references / minutes / development files / interviews – all interviewees	Development files / interviews (Mr B and C)
Activities	Activities	Historical references / minutes / development files / interviews – all interviewees	Development files / interviews (Mr B and C)
Supplier Inputs	Supplier Inputs	Historical references / minutes / development files / interviews – all interviewees	Development files / interviews (Mr B and C)
Identify Suppliers	Identify Suppliers	Historical references / minutes / development files / interviews – all interviewees	Development files / interviews (Mr B and C)
Product	Product	Historical references / minutes / development files / interviews – all interviewees	Development files / interviews (Mr B and C)
How efficient is MLCE development?	Evidence to demonstrate the efficiency of MLCE development	Historical references / minutes / development files / interviews – all interviewees	Development files / interviews (Mr B and C)

How effective is MLCE development?	Evidence to demonstrate the effectiveness of MLCE development	Historical references / minutes / development files / interviews – all interviewees	Development files / interviews (Mr B and C)
What opportunities are there for increasing efficiency in MLCE development?	Evidence to indicate opportunities to reduce wastage in MLCE development.	Historical references / minutes / development files / interviews – all interviewees	Development files / interviews (Mr B and C and EC Cell Hereford)
What opportunities are there for increasing effectiveness in MLCE development?	Evidence to indicate opportunities to ways to achieve the wanted result by improving MLCE development.	Historical references / minutes / development files / interviews – all interviewees	Development files / interviews (Mr B and C and EC Cell Hereford)

RQ3: How can we improve MLCE development?

Case Study Questions	Info Needed	Source (90 Pattern)	Source (Airmesh)
What Strategy is appropriate given the resources available to improve MLCE development?	Not appropriately addressed solely by the case studies - (resources are within and without the study – therefore discussion with MoD officials is needed)	Development files / interviews – all interviewees	Development Files (Reports from Loughbrough University / GR Jones / J Martin PhD thesis / interviews (Mr B and C and EC Cell Hereford)
Therefore, MLCE design should be about producing:	Not appropriately addressed solely by the case studies	Development files / interviews – all interviewees	Development Files (Reports from Loughbrough University / GR Jones / J Martin PhD Thesis / Interviews (Mr B and C and EC Cell Hereford)
Effective,	Not appropriately addressed solely by the case studies	Development files / interviews – all interviewees	Development Files (Reports from Loughbrough University / GR Jones / J Martin PhD Thesis / Interviews (Mr B and C and EC Cell Hereford)
Efficient,	Not appropriately addressed solely by the case studies	Development files / interviews – all interviewees	Development Files (Reports from Loughbrough University / GR Jones / J Martin PhD thesis / interviews
Satisfying,	Not appropriately addressed solely by the case studies	Development files / interviews – all interviewees	Development files / interviews (Mr B and C)
Products fit for the intended function (i.e. military task)	Not appropriately addressed solely by the case	Development files / interviews – all interviewees	Development files / interviews (Mr B and C)

	studies		
Are the products effective, efficient and provide satisfaction to the users during military tasks?	Not appropriately addressed solely by the case studies	Development files / interviews – all interviewees	Development files / interviews (Mr B and C)
And does the MLCE design process enable this? (Is MLCE design effective, efficient, and satisfying? – Total Quality Approach?)	Not appropriately addressed solely by the case studies	Development files / interviews – all interviewees	Development files / interviews (Mr B and C)
What information is needed to enable the development of successful MLCE?	Not appropriately addressed solely by the case studies	Development files / interviews – all interviewees	Development files / interviews (Mr B and C)

Interviewing Notes

Sources of information about interviewing can be found in:

Charmaz, K. (2002). *Qualitative Interviewing and Grounded Theory Analysis.* in Gubrium, J. F. and Holstein, J. A. (eds.) *Handbook of Interview Research - Context and Method.* Sage Publications Ltd. London: 675.

Cohen, L., Manion, L. and Morrison, K. (2000). *Research Methods in Education (5th Edition)* RoutledgeFalmer. London: 312.

Glaser, B. G. (1992). *Basics of Grounded Theory.* Sociology Press.

Gray, D. E. (2004). *Doing Research in the Real World.* Sage Publications Ltd, London: 267.

Each should case should contain at least one set of interviews which can be compared and plug in to the other data being used for the cases. Where the interviewees can provide evidence about both cases the interview needs to be split in to two sections to allow the interviewee and interviewer to distinguish between the two cases and avoid confusing references. The large number of case study questions also makes collecting data from interviewees difficult in that one cannot ask them thirty odd questions in one interview session and expect to get valid answers. This is because there is not enough known about the context of MLCE design to undertake highly structured interviews certainly to the extent of providing enough information for quantitative analysis (Cohen et al 2000: 214). The interviews do need some focusing through interview questions which can link to the case study questions. Charmaz (2002) provides a good structure for the interviews which should ideally last no longer than an hour. This structure is as follows:

1. Introducing the interviews - Consent
2. Initial Open Ended Questions
3. Intermediate Questions
4. Ending Questions – Detail

This allows interviewees flexibility as their recollections are stimulated by the initial open ended questions. It also allows the interviewer to not worry about biasing the results of the interview by using leading questions.

Introducing the interviewees to the project should be done before they agree to the interview. The following questions are adapted from Charmaz (2002: 679), they are initially relatively generic and open, it is expected that before each interview more specific questions will be formulated as the researchers knowledge grows from undertaking the historical analysis.

Initial Open Ended Questions:

Tell me what happens when you design/ed MLCE.
When, if at all did you experience / notice ________?
What was _________ like?
Could you describe the stages / events which led to ________?
What contributed to _____?
What was going on in _____ at that time?

At the end of the initial open ended questions if the topic has not come up before, it may be a good opportunity to get some feedback on the Process Definition. The researcher must decide an appropriate time to introduce the process definition for the case so to avoid leading the interviewee's recollections.

Intermediate Questions:

What did you know about _______?
Tell me about you thoughts about _______.
What happened next ______?
Who was involved?
When was that?
Tell me how you handled that?

Ending Questions:

What do think are the most important influences in designing MLCE?
What advice would you give someone who is trying to design MLCE? (Pertinent to RQ 2/3)
(Mr B and C) How has your experience working on 90 Pattern affected how you handled designing the Airmesh Bergen?
Is there anything you would like to ask me?

Transcribing

It is not necessary to transcribe the information verbatim as long as the records are kept and accurate descriptive notes are made from the recordings.

Analysing

The approach one takes to analyse the data in each case depends on the use of the data. Coding the data may produce a better categorisation of the data which could aid analysis. Given the variety of interviewees and the semi-structured and open ended nature of the interviews this may be difficult to do. In a way the individual case study report forces discipline on the data which is then reflected on in the context of other information collected via other research methods.

Validating

Validity is multi-faceted can be addressed in many different ways depending on the context of the research one is conducting (Gray 2004). This research looks at the context of the design of a certain type of product (MLCE Rucksacks) and so needs to be sure that the data collected accurately describes and allows interpretation of what happened in the context of the case. The validity of the interviews must be taken in the context of the wider multi case study approach and subsequent research for example, exposing the results of the multi case study to review via Delphi Technique. Bias is often the most constituent threat to the validity of interviews (Cohen et al. 2000:120) which is usually combated by using a highly structured interview. This study is using an unstructured interview and so cannot rely on this approach to ensure validity. Therefore if bias is suspected in the results of the interview then it must be declared.

Reporting

Discussion of results of the interviews should be done by case study questions to enable comparison with the documentary evidence and illustrative quotes used sparingly. Aspects such as bias on the interviewee or interviewers behalf should be noted.

Notes on the Process Definition Method

Adapted from; Codling, S. (1998). *Benchmarking.* Gower Publishing Limited.

The following process definition method was found to be useful during the pilot study and can be worked up throughout the historical analysis and interview technique activities.

1. Define Boundaries

What is the output of the process? – This changes through the life of the project. Essentially it is the introduction to service of a new MLCE to replace 58 Pattern.

Who is the customer?

The customer is the Army, represented by the Army Operational Requirements Branches from UK MoD HQ.

What does the customer require?

The customer requires a new MLCE in which meets the needs of the Army, in that it enables soldiers to carry heavy loads in the way in which they had become accustomed after the introduction of the GS rucksack.

Is this what the process delivers?

Ultimately the process, as it was, did deliver an MLCE which met the needs of the customer. The process itself did not follow the steps of the current acquisition process, nor did the designers respond using a formalised design process, but rather by responding to the taskings of the managing department (DCT) and the customer.

If not, is the process necessary?

See above.

Where does the process begin?

The process began with the general acceptance within the Army that the current MLCE did not meet the requirements of the Army.

Where does the process end?

With the introduction to service of the Equipment, although developments and improvements to the equipment continued while it was in-service. (It still is)

Who is the process owner?

In a macro context the MoD, and Government, in a micro-scale the managing branch DCT and the Army HQ OR branches who have to work within it to deliver the equipment.

(Process is generalised and so they can create their own process within it to deliver the output, which could have put the designers more in control.)

2. Working Definition

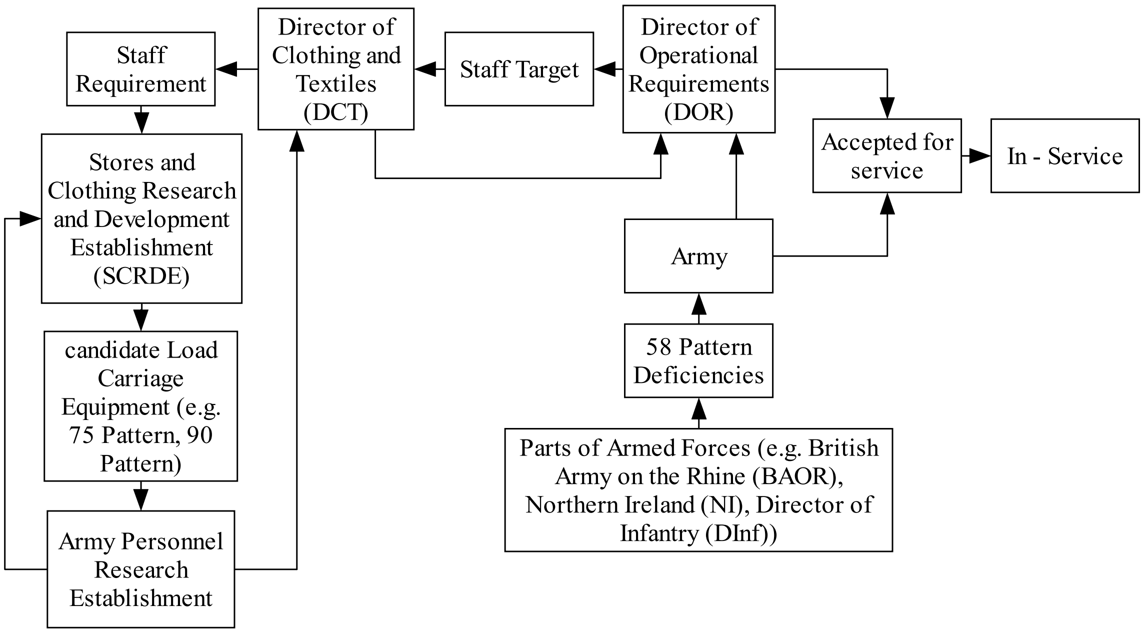
What is the objective of the process?

To deliver an equipment (MLCE in this case) to service

3. Map the process

Combine flow charts into a process map of the organisation.

The figure below is an example of a worked up diagram from the pilot study.



The later stages of the interviews may be a good way to get the Process Definition reviewed.

Appendix G: Comparative study pilot

Thesis Link: Chapter 5, section 5.2

This Appendix contains the pilot conducted to check the initial protocol used in the comparative study, and report the results.

1. Purpose

The purpose of the pilot study was to look at the case study approach in methodological terms to refine how and what data is to be collected. Additionally it allowed the researcher to gain training and experience of the research techniques. The pilot study then led in to the full comparative study.

Objectives:

1. Establish whether a comparative study is appropriate within the proposed research strategy for exploring MLCE development.
2. Establish whether the data collection techniques within the comparative study are suitable for conducting studies in to MLCE development
3. Identify areas of development and refinement to the research methods within the comparative study.

2. Pilot comparative study protocol

Since there were not sufficient cases available within the context of MLCE, the pilot study could only do this by using one of the two cases available for the comparative study. It also allowed the researcher, to practice and learn the skills to use the comparative study techniques defined in the research strategy (discussed in Chapter 4). The pilot study was intended to enable the comparative study approach to be refined, so that the data collection plans could be properly developed, rather than to permit a 'dress-rehearsal'. Therefore as a part of planning the data collection, the pilot study was also used to check the case study questions and their relation to the research questions. This was possible by using one case, as long as the single case's interface with the in the other case are looked at. Figure 1 shows how the data collection was achieved through the research *protocol* (the procedures for the comparative study). The protocol was developed from the research strategy, as discussed in Chapter 4. The blue shaded boxes in Figure 1 show what is included within the pilot study as it progresses from the case study questions up to the case conclusions (blue box marked conclusions).

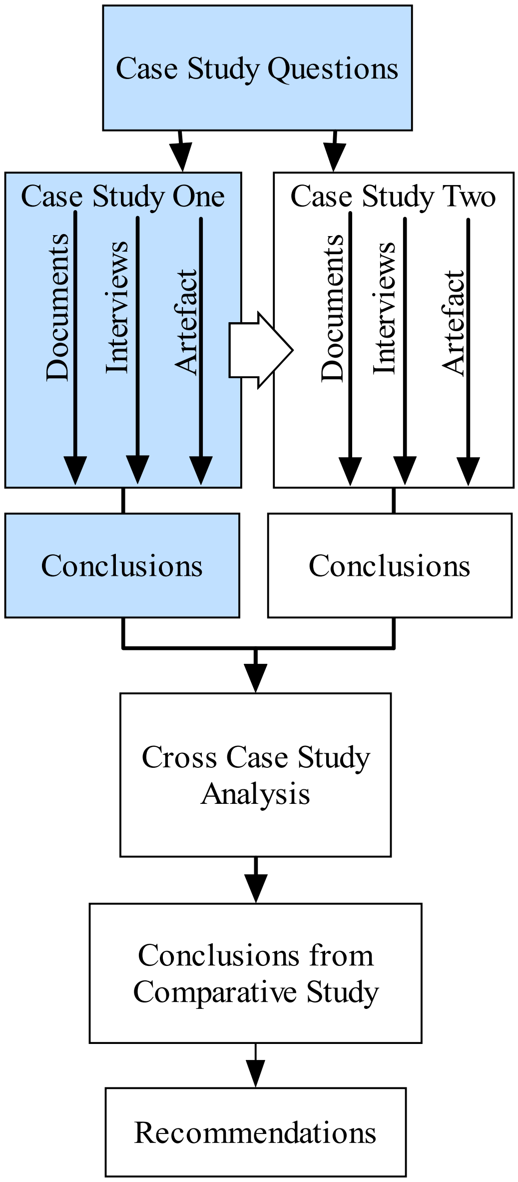


Figure 1. *Diagram of protocol for the pilot of the comparative study, adapted from Figure 31. The boxes in blue show the extent of the Pilot Study using a single case.*

The pilot study used the techniques of data collection for the case studies identified in Table 12, in Chapter 4:

- Historical Analysis
- Interview techniques
- Rucksack evaluation (Artefact)

These techniques were augmented by the following techniques:

1. Process Definition within each Case – to give a common approach to determined the NPD process used in either case
2. Timeline (Optional) – to be used as a reference when undertaking the historical analysis

Documentary analysis in the pilot study

The documentary analysis sought answers to the case study questions using documentary and archive sources. Providing an audit trail from the historical sources was important to ensure the case study questions were answered accurately. It is important to note that the researcher was identifying important points with relevance to MLCE development and so reflexivity was important to control. Reflexivity was managed by the researcher reflecting on his responses to the evidence. Review of the analysis notes to check sources validity and reliability was also important, but often hard to achieve given the limited evidence in some areas. In practice this was not an ideal way to mitigate reflexivity but was the only resource available at the time.

Pilot study database

Notes for the pilot study were written on a laptop in note rather than prose form (to allow for quick recording). Initially a table format was piloted, but this proved to be confusing and hard to use, since there was too much information on the screen. The notes became the case study database and had to be clear to allow analysis of single cases and in comparison with the other case. It was planned to achieve this by noting points from each source under the relevant case study question. Then, by going back over each question, a referenced answer in prose form could capture the critical points which were then used to compare the case against the Research Questions. It was expected that some iteration through the case study questions would be needed as familiarity with the sources was developed. Therefore, there had to be flexibility to revisit case study questions and adapt the answer if evidence from a new source emerged during the pilot. It was also important to maintain the rigours of documentary analysis and as detailed within Figure 32 in Chapter 4 with sources being evaluated and cross referenced before they were used authoritatively. Problems were noted as they arose and solved as required to enable reflection on the ability of the pilot study to collect the data to answer the case study questions and Research Questions.

Interviewing in the Pilot Study

The role of interviewing in the pilot study was to demonstrate how this technique could be used to gain new insights into MLCE development and give the researcher an opportunity practice interviewing skills. The interview protocols used for the pilot were semi-structured, with an aide-memoir of questions which could be used, as outlined in Chapter 4. This approach enabled open questions to initiate a rapport with the interviewee, followed by questions derived from the case study questions, which could be used as the interview developed. At some points in the interviews the researcher also asked un-scripted clarification questions to ensure points were well understood. Also at some points unscripted questions were asked to clarify facts or issues raised in the documentary evidence, although these were referred to using references which had already been discussed. This approach avoided leading the interviewee by citing particular references which the interviewee may not have been familiar with. Interviews would be recorded on cassette for post interview analysis, with hand written notes taken to record additional questions and interviewee responses.

Process Definition within each Case

Defining the MLCE development process for each case was not possible until one had worked through the research methods, and so was not planned to be conducted until the end of the documentary analysis. The approach piloted was adapted from Codling (1998: 22) and seeks to identify answers to a number of questions which can then be used to establish a process diagram for each case:

1. Define Boundaries

   Who is the customer?

   What does the customer require?

   Is this what the process delivers?

   If not, is the process necessary?

   Where does the process begin?

   Where does the process end?

2. Working Definition

   What is the objective of the process?

3. Map the process

The production of a process diagram was to aid understanding the differences between cases.

Evaluation Matrix (of Artefact)

The evaluation matrix could be filled out at any stage in the pilot study and was intended to be a source to enable a comparison of the products should the cases study or cross case study analysis require it.

Timeline (Optional)

A timeline could be drawn up as required during the pilot, and could have been either textual or diagrammatic.

3. Results from the pilot study

The results from the pilot study are best summarised by looking at the development process for this case, shown in Figure 2.

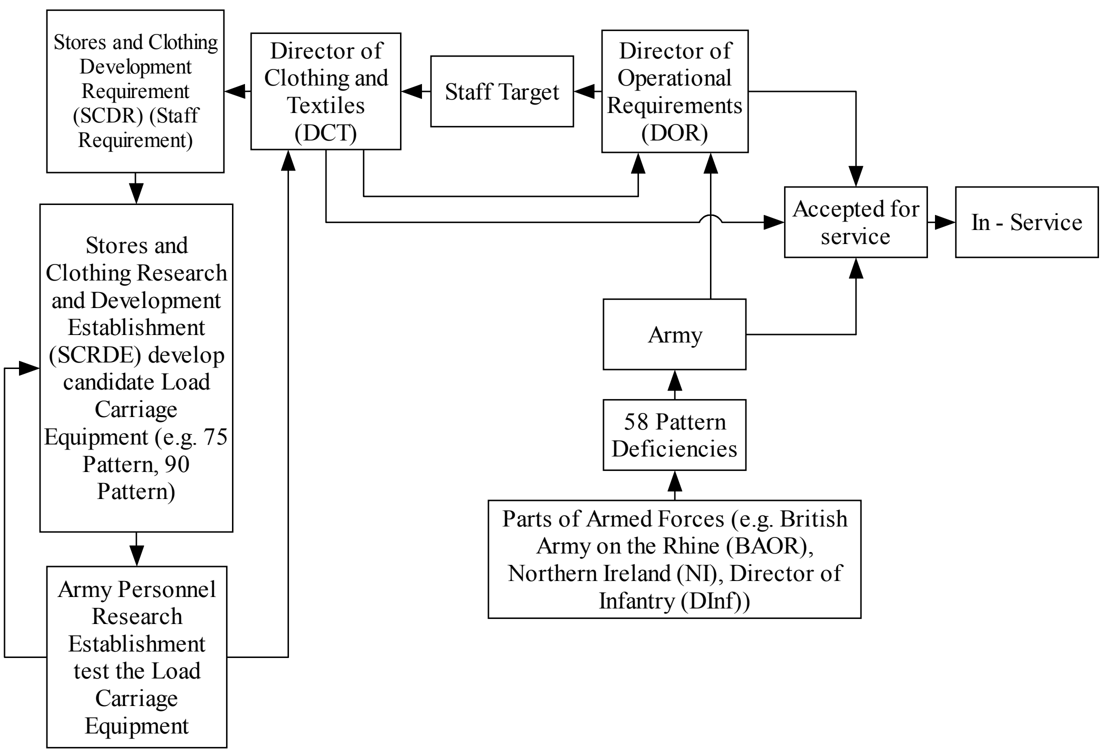


Figure 2. *Development process for the 90 Pattern Rucksack.*

Figure 2 is a representation of what took place during the development of the 90 Pattern Rucksack. It is clear from the documentary sources that there were a number of stakeholders all of whom had varying effects on the MLCE development. There effect on MLCE development is hard to quantify or qualify since the effects are not well documented in certain instances. Figure 2 represents the key interactions that are noted within the documentary sources used for the pilot study. The interactions to the left of Figure 2 represent the main design activity, between those who made the load carriage concepts (SCRDE), those who tested them (APRE) and the supervising agency (DCT). What is not shown is the extent to which the stakeholders such as the School of Infantry (Lane 1982) and Director of Preventative Medicine (Worsley 1981) (and others) had on this cycle. There was obviously interaction between all the stakeholders, but the level of control over design decisions seems to have been very dependent on the level of lobbying between the critical meetings where direction for design was determined. The notes from the pilot study documentary analysis are contained within Appendix A.

Summary of Results from the Pilot Study

RQ1: *What are the elements involved in MLCE development?*

The elements involved in MLCE development in this pilot study were the same as for the influence diagram presented at the end of chapter three (repeated here in Figure 3):

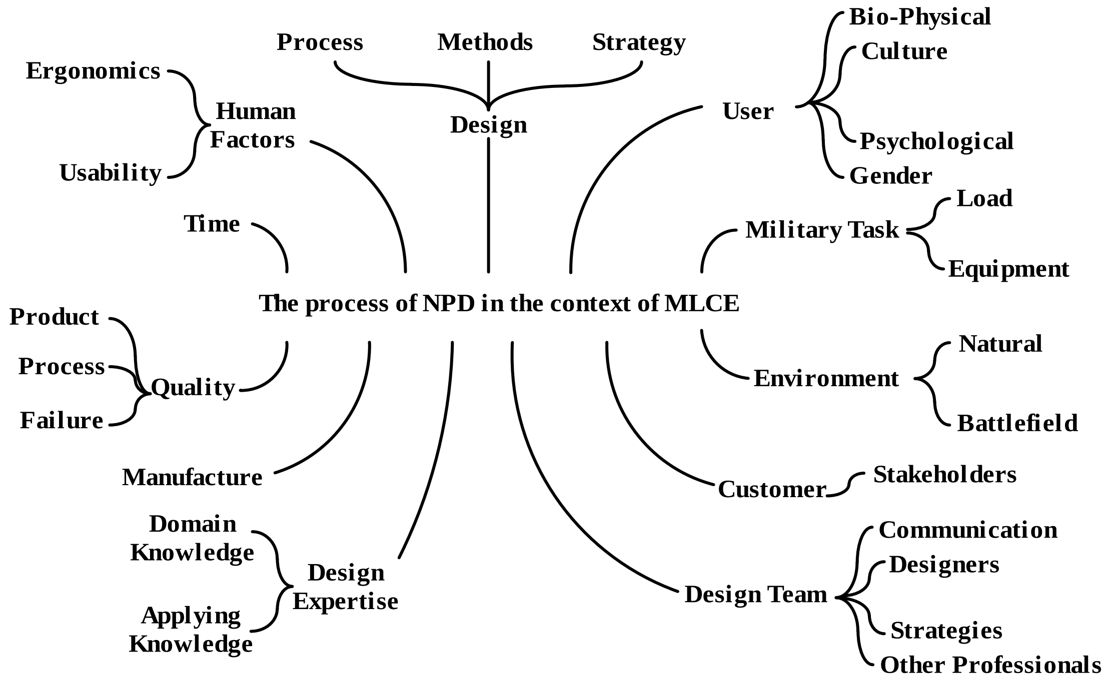


Figure 3*. Figure 22, the influences on MLCE development.*

User and military Requirements

The main influence in achieving effective a successful design was getting the balance of user requirements correct, represented in Figure 3 by User and Military Task. This was critical if the management of influences which affect the functional performance for MLCE were to be properly bounded as a design constraint. This was a particular difficulty in the pilot case. The requirement altered considerably during the time of the project, and so caused many alterations to the design. Additionally the designers did not seem to be in a position to provide much input to the requirement, in terms of explaining to the stakeholders the impact that altering the requirement would have on the ultimate design.

Human systems aspects

The second most important influence in this case seems to have been ensuring that the final design worked from a human systems perspective (Human Factors on Figure 36). The controlling stakeholder in this regard seemed to work very much in a quality control role, in that they were checking the product. This seems to have created at times a confrontational, rather than collaborative, atmosphere which stopped innovation (the case of the use of mesh fabrics, which is used today, is a good example). This seems to have occurred partially because the team was split organisationally, and due to the limited human systems knowledge which was available at the time. (This is only with the benefit of hindsight and the human factors knowledge we have currently that one can make this statement.) It may have been the case that the designers, human systems and military stakeholders did not have a good appreciation of each others areas of expertise with regard to MLCE design (Design Team and Design Knowledge in Figure 36).

RQ2: *What needs improving in MLCE development?*

From the sources examined during the pilot study, with the benefit of current knowledge with regard to MLCE, it is possible to tentatively recommend several areas for development:

1. *Stakeholder Affect on the MLCE development* - The main difficulty experienced by the stakeholders involved in this case was how they affected MLCE development in producing effective MLCE. Each stakeholder in the process varied in the extent to which they impacted MLCE design, some acted positively and others negatively. Each stakeholder had a different agenda as to what the final outcome from the development of new MLCE should be. From the designer's perspective, understanding what they do and do not know in the context of MLCE will be helpful in managing stakeholder aspirations.

2. *Understanding user requirements* – The perception of who the user is and what they require appears to be disparate and changing (Figure 3). Whether this is the emergence of a 'wicked problem' (Coyne 2005) discussed in the literature review (Chapter 3) will need to be explored by the main case study. It is not clear that there was a common understanding of the user requirement, from an Army (organisational or doctrinal) perspective. This aspect comes out clearly in the debates that were had in the degree to which the new MLCE should incorporate the requirements of troops beyond the infantry (e.g. troops in hot / wet climates (Hong Kong)). It is unclear that those involved understood how these two perspectives affected one another or how the influences affected the process through the requirements (Figure 3).

3. *There are still many gaps in our knowledge of MLCE design* – The main shortfall from a design perspective is in our understanding of how human systems knowledge affects design in the context of MLCE. For example an MLCE Rucksack may have to be used without its hip belt; what are the human factors implications of doing so? (And then what is the impact of this on the military requirement to allow the soldier to fire accurately if the

load, now borne on the shoulders has caused 'rucksack palsy' and so the soldier may have difficulty firing. Currently the chance of this happening is unknown, although it is a known, but unproved phenomenon with the 90 Pattern Rucksack). This type of information is simply not available to the designer. Any physical, realised product which goes on to a user will have human systems effects, a designer will be able to manage and mitigate these affects better if they are understood.

4. *Team structure* – The team, as it was formed for the 90 Pattern Rucksack, worked within the organisational constraints that were placed upon it. It appears that the designers and human systems specialists worked well together, but that they had to do what was dictated by the military who managed the development at a senior level. At the time different parts of the organisation were responsible for different aspects of MLCE development, unlike today where there is one department responsible for development. It is clear that each stakeholder needed to understand the benefits brought from working in a manner which allows better communication and design strategies to be used.

RQ3: How can we improve MLCE development?

To address the areas which need to be improved in MLCE development a considerable amount of organisational effort would be required, as well as resources beyond those of this research. The responses to the areas outlined in the responses to RQ2 for this case may not be problems experienced in the current organisational structures. This could be addressed by asking professionals within the current organisation to reflect on the findings of the case study to see if they recognised these issues in current practice. This approach should not prejudice any Delphi technique activity (discussed in Chapter 4), since engaging with professionals would be needed if the periods of action research, as described in Chapter 4, were to be undertaken. Delphi technique could then be used to check the assumptions the action research was based on, namely the recommendations from the comparative study and agreement by professionals to collaborate on action research. To keep these interactions clear of questions of impartiality, those involved in the Delphi and action research could be different.

Discussion of Results

From the results of the pilot case in RQ 1 and 2, further research activity needed to be undertaken to develop our understanding of military requirements for MLCE at the various levels (soldier, non-commissioned officer, officer, senior officer and so forth). This would in part develop designers and stakeholder knowledge of MLCE design, since this was clearly a problem during this case. These results need to be confirmed by the multi-case study before firm decisions can be taken about how to undertake further research or improvement of the MLCE development process.

Tentative findings

From the pilot, however, some comments can be made about how the results would begin to focus further research. From the authors experience, and the resources available to this study, focusing on the stakeholders closest to design activity, such as designers and human factors specialists would seem to be a logical start point. This approach could then lead to providing a more sophisticated understanding of MLCE design. It is difficult after the pilot study to define in more detail what the design and human systems stakeholders would find valuable without engaging them so giving an indication of what could be done after the multi-case study.

Possible aids for stakeholders

Supporting designers and human systems specialists could lead to the development of aids which enable them to understand military requirements better. This could be a bespoke design guide, although guides tend by their nature to be proscriptive, or it could be a series of tools which could be selected depending on circumstance and experience. These could both include better information on how user requirements affect MLCE design, whether through the literature or using design tools and testing. To compliment this, a source of information on MLCE design influences, as far as knowledge exists, for those involved in MLCE design could also be developed. This source would need to be explicit about the gaps as well (the major one being developing an integrated understanding of the human systems of load carriage (Vicary and Wood 2005)).

These suggested improvements to MLCE development are speculative, but would allow those involved in MLCE design understand how well any given idea or solution works in the context of user requirements.

4. Discussion of lessons learned from the pilot study

The pilot study has demonstrated that the structure of the comparative study approach is robust and that the data collection approach worked. A lot was learned by the author with regard to the resources needed and how validity may be affected by researcher bias.

Number of activities - The large number of activities was a constraint on the completion of the analysis. Most of the activities within the case study approach do not need to take very long but it was found that the large number of activities being conducted for one case was time consuming. Since the time needed is likely to increase given more evidence and another case, the only way to adjust this is to ensure a disciplined approach to time keeping is used.

Familiarity with the evidence – The pilot study demonstrated that a familiarity with the sources is essential if they are to be effectively used in all the case study questions.

Consistent approach between the cases – It is unlikely for the other case to confound the case study questions since it is a similar MLCE project, and is easier to analyse due to the shorter development period and availability of information. Determining which influence was more important was difficult, but could be done by using judgement based on the evidence if needed. Maintaining a coherent approach between the cases with regard to determining importance of the influences on MLCE projects can only really be achieved by immersion in the evidence and cross checking results.

Documentary Analysis

The documentary analysis method worked well for the evidence used during the pilot study. The pilot study used a document prepared by the Army Historical Branch (Harding 2003) as a secondary source and the primary evidence which supported it. Some of the evidence needed to cross reference some of the case study questions was missing, but should be available in the comparative study since there is more documentary evidence to be accessed. This presented some issues with validation of some sources in the context of the case study questions. Validity (defined in Chapter 4) of the results of the pilot study is dependent on the reliability of the evidence (possible effect of biases within the sources which may cause misinterpretation) and researcher bias. This is a risk where the evidence from the sources is sparse and where the influences on the MLCE development were based on an argument formed for another case study question. This is difficult to mitigate, apart from by being aware of issues of validity and by practicing historical analysis techniques correctly. The validity of the results of the pilot study was checked against common problems associated with historical analysis techniques (Best (1970) in Cohen et al (2004:163)) and is presented in Table 1.

Problems occurring with historical research (Best (1970) in Cohen et al. (2004:163))	**Cross check of pilot study historical analysis – was the pilot deficient**	**Notes**
Defining the problem too broadly	NOT FOUND	The case study questions are specific or have sub-elements which make the researcher focus on particular aspects relevant to the Research Questions
Overuse of Secondary Sources	NOT FOUND	The sources used in the pilot study used initially a good official history (secondary source) with the primary sources on which this history was based
Inadequate criticism of data	NOT FOUND	Better reference could have been made to issues with each source. Would put more pressure on time to do this. Arguably not needed since most sources do cross-reference and gaps are highlighted
Poor logical analysis / depth of analysis limited	PARTIALLY AN ISSUE	Depth of Analysis was limited - generalisation was identified as being an issue but is inevitable to an extent given the data sources used for the pilot, this would be better if more sources would be used, for example more interviews and documentary data which would be available for the case studies
Expression of personal bias	PARTIALLY AN ISSUE	The researcher is aware that this may be an issue, since he is experienced in this area, this may be inevitable to some degree, but will be mitigated by triangulation using other methods and by being aware of the issue.
Poor reporting style	NOT FOUND	The author is content with the output style of the pilot Study, and would expect the answers for the case studies to be more in depth. These could be reviewed by an Army Historical Branch historian rather than through Delphic review.

Table 1. *Table showing the Cross check of Historical Analysis using criteria from Best (1970) in Cohen et al. (2004:163), which highlights problems occurring in historical research. (A negative response in the middle column indicates that the Pilot Study was not guilty of succumbing to a problem.)*

Reflexivity in the pilot study

Researcher bias was found to be a problem in the pilot study (Table 15) which in part was due to the lack familiarity with the evidence and the lack of experience of the author with historical analysis. These problems could be addressed by the author in the case studies by adhering to the research methodology, by triangulating the results of the analysis with other studies, and improving the robustness of the research framework (see the 'Notes' column in Table 1).

Modification to the case study questions

Another aspect of the pilot study which is linked to common problems with historical analysis was the number of case study questions (See Table 1). The number of questions did become onerous, but it was difficult to reduce the number since they link to the Research Questions. This was mainly a problem with Research Question 1 (RQ1) since it needs more case study questions than the others. Therefore a strategy was developed within the protocol for the pilot study to get answers efficiently (RQ1 took a day and a half to complete out of the three days put aside for the pilot study).

The first two case study questions are arguably the most important in answering RQ1. The strategy was to try and answer the case study questions in brief, and then use the other case study questions to answer the first two case study questions in detail at the end. This strategy was successful and provided enough information to answer RQ1 effectively. This strategy also provided enough notes to form detailed answers to the other case study questions if needed. Although RQ3 could only be answered by conjecture on behalf of the researcher, and so was not reliable.

Interview Techniques

During the pilot the researcher practiced interview technique with a member of the 90 Pattern Rucksack SCRDE team. The interview was invaluable and allowed the researcher to ask many questions related to RQ1 which provided a lot of insight to how the development process worked in this case. The interview was however limited because of the time that had elapsed which affected the reliability of the interviewee's recollections. What was surprising was the long length of time taken to do the interview and the preparation involved. This remains an important method of data collection.

Process Definition within each Case

The process definition provided a common method of working out how each process worked. It was useful to undertake an excursion to map the processes for illustrative purposes and to develop ones understanding of the process.

Evaluation Matrix

The evaluation tool was not used during the pilot study, either as a reference or piece of analysis in its own right. The matrix had been partially filled in before the pilot study, but it was not needed. This could be a valuable tool to record data about the MLCE from each case. The matrix can withstand added characteristics, as long as they are applied across all the cases. It is also difficult to get data on some characteristics. During the analysis phase it was thought that this type of tool may be useful to designers if used in concert with requirements tools. Comparing the evaluation matrix against requirements is a form of product benchmarking or reverse engineering which may be useful for designers trying to understand how requirements and MLCE design interface. This tool does not have to be a part of the comparative study approach.

Timeline – Critical moments

This was not used within the pilot study, although in retrospect it would be useful when writing up the case studies to illustrate the findings from each case show the similarities and differences between the cases.

Case against Research Questions

Some problems were encountered since it was discovered that some of the case study questions could not be answered by the available evidence. During the pilot study the researcher became aware that he was make subjecting judgement to fill in the gaps in evidence, this fortunately was spotted at an early stage. Good examples of this are some of the case study questions for Research Questions 2 and 3. Since the Research Questions are being addressed by a variety of research methods the gaps in evidence should be addressed in follow on studies. As long as responses to these questions are understood as being not consistent with a documentary analysis approach, the answers to these questions should not confound the findings of the comparative study.

5. Redefined comparative study method

As a result of the pilot study the protocol outlined in Chapter 4 needed a number of changes before conducting the comparative study.

Historical Analysis of Case – The historical analysis worked using the pilot study protocol. The adopted strategy for RQ1 does not prevent good data from being collected and therefore should be used. The historical analysis should be done before undertaking interviews, so that one has time to undertake good preparation and be adaptable enough to ask detailed, clarification orientated questions.

Process Definition – The Process Definition should be used in the form used during the pilot study.

Evaluation Matrix (of product) – The Evaluation Matrix remains useful and should be used if needed.

Timeline (Optional) – The use of a timeline is recommended for both cases, ideally during the historical analysis.

6. Summary of the pilot study

Reflecting on the objectives of the pilot comparative study outlined in Section 5.3.1:

- The comparative study within the proposed research strategy is appropriate for exploring MLCE development.
- The majority research techniques within the comparative study have been found to be suitable for gaining data on MLCE development within the resources available.
- Areas of development and refinement to the research techniques within the comparative study to enable the main case studies have been identified.

The pilot study has been successful in developing the researcher's skill and awareness of the limitations with the research techniques for collecting data in MLCE development, and developing. The protocol for the comparative study has been developed and is now ready to be used.

7. References

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Appendix H: Comparative study results

Thesis Link: Chapter 5, section 5.2.1

This Appendix is broken into three Annexes, each of which covers a different element in the comparative study of two cases of MLCE development:

- Annex A – Comparative Study Notes from 90 Pattern (Page H – 1)
- Annex B – Comparative Study Notes from Airmesh rucksack (Page H – 11)
- Annex C – Comparative Study Cross-Case Analysis Notes (Page H – 19)

Annex A: Comparative Study Notes from 90 Pattern

RQ1: What are the influences on MLCE development?

1. What are the factors which affect MLCE development?

Organisational decision making:-
Tends towards managing design alterations – military lead [1, 2]
Policy Level direction for MLCE from three star equipment director - focus on lightweight solution and use current loads as basis[3]
Intervention by Senior Medic[4]
Fighting a War (Falklands)[5] – Also Ergonomics paper by Gooderson and McCraig (1984)

Interface with other equipment programmes in development: –
Development of new rifle (SA80) (ammunition compatibility with pouches – new rifle had smaller rounds (bullets) and magazines)[6],[7]
Effect of Weapons weight noted[8]

[1] Pike, H. J. (1983). *Minutes of a Meeting on Personal Load Carriage Equipment Held in Room 5 Building 39 LE (A) Andover on Tuesday 22 March 1983.* D/DCT/7/1'B' CT1a.
[2] Pike, H. J. (1983). *Minutes of a Meeting on PLCE Sub Committee held at LE (A) Andover on Tuesday 22 May 1984*, D/DCT/7/1 CT1a.
[3] Assistant Chief of the General Staff (Operational Requirements) (1975). *Weapons and Equipment Policy Committee Close Combat Capability Paper*. WEPC/P 975)26. 14 Aug 1975.
[4] Worsley, D. E. (1981). Loose Minute: *Second Draft SCDR 444 Personal Load Carriage Equipment (PLCE '86).* 9 October 1981. D/AMD/11/10/3 (AMD5).
[5] Waygood, M., Gooderson, C., Green, S., McCraig, R., Cooper, C. (1982). *Human Factors Team Report.*
[6] Rowe, N. C. (1972). Loose Minute: *Future Small Arms/Webbing Equipment Interface*, 3rd November 1972. Ref: A GST 3518, DGW(A)/Wpns 3a.
[7] Rook, P. J. (1982). *PLCE 86 Discussion*. 30th September 1982. D/D Inf/74/9B (Inf 2).

NBC Equipment[9]

Functional (inc material / load carriage construction and configuration as a system and interface with clothing and other equipment): –
addressed in above meetings and via trials reports as one would expect[10]
re-iterated in final policy letter with regard to versatility, complication of strapping, and small load carrying capacity[11].

Requirements:-
No requirement statement in 1977[12] - although there is one (SCDR 444 - not found in Archives) in 1981 (Worsley 1981)
PLCE '83 SCDR[13]

'User wants' - cuts across both the above: question of what role should MLCE be for? – Inf or IS [14]
Mechanised concerns[15]

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[8] UK Ministry of Defence (1973) *Introductory Presentation on the Load on the Infantryman* - Report of the Director of Infantry's commanders conference. in The Infantry Liaison Letter.

[9] Sibbald, P. F. A. (1982). Letter to Maj Gen B M Lane from Maj Gen Sibbald (D Inf). 13 August 1982.

[10] Hirsh, P. H. (1973). *Personnel Load Carrying Equipment – A Concept for Modern Times*. in The Infantry Liaison Letter. September 1973. RESTRICTED.

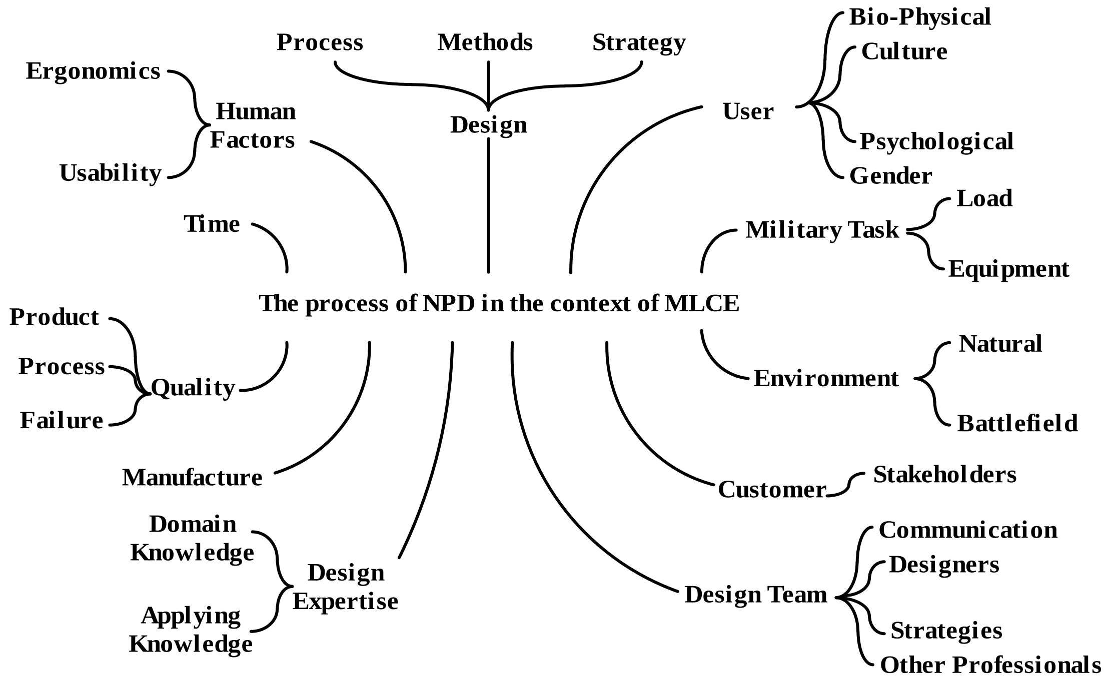
[11] Clothing and Textiles Management Policy Letter (CTMPL) – 90 Pattern (Infantry) Webbing Equipment. 14 November 1989. D/DCT/7/1 CT1.

[12] Director of Defence Clothing and Textiles (1977). Agenda for 238th Mtg of the Clothing and General Stores Committee. D/DCT/5/5, A/70/205 C&T 1.

[13] Parsons, A. F. A. (1983). *Preliminary Draft of 1983 Pattern Personal Load Carriage Equipment (PLCE '83) Stores and Clothing Development Requirement (SCDR).* D/DCT/7/1 C&T 1a. UK RESTRICTED.

[14] PLCE Mgt 25 January 1973. A/70/Misc268691/C&CS 1a.

[15] Hamilton-Baillie, T. R. (1991). *Landset – A Report on Armoured Infantry Equipment in Op Granby*. D/D Sc (Land) 57/2/6. 4 Mar 91. UK RESTRICTED.



Taking all the above points and comparing them with the influences diagram from Chapter Three in the Thesis, one can see that all of the factors for the 90 Pat Rucksack are apparent.

2. What is the relative impact of each factor?

At the basis of all the development is the trials, these focus the sub-committees which control the design of the prototypes. The other factors like the requirements are secondary in that once the requirements are approved to be orientated towards the infantry little other discussion about other users needs until much of the development is done.

From the influences diagram in Chapter Three, some factors are stronger than others in this case, for example:

- Customer / Stakeholders – the organisational structure and boundaries controlled the development, and the design approach to a large extend
- Human Factors / Usability – strong reliance on human factors assessments and field trials
- Manufacture – designers strongly focused on manufacturability and specification
- Quality – strong emphasis on the quality of the equipment and getting their part of the process right, not the whole process however

Weak factors are:

- User – only understood for infantry, although the MLCE is for everyone in the British Army
- Military tasks – Not well understood at all, apart from general battlefield agility
- Design – little or no evidence of use of using design methods / processes to manage or change the process being driven by the organisational structures of the time.

Each factor does have an influence on the process, and the strong and weak ones may be expected from period in which this case is set. There are parallels between this case and how development of MLCE was conducted until relatively recently.

3. What are the relationships and interfaces between these aspects and factors?

Once the requirement is established with an infantry focus there is a clear iterative cycle between the development of prototypes and human factors assessment. Organisationally this is controlled and co-ordinated by a sub-committee which is broadly military dominated.

4. Who were the designers/product developers?

SCRDE were clearly providing the design of prototypes, since the Ministry of Defence is designing the equipment. There are however references in trials feedback from units which provide ideas and suggestions which are used by the designers.

5. How was the product development conducted?

The project is relatively typical of projects of that era in that firm In-Service Date (ISD) is not articulated as the deadline for the project, as is the case today. The delivery of MLCE evolved as the project built up and the decision makers within the Ministry of Defence became more aware of it. From there one starts to see factors like the development of new rifle (SA80) (ammunition compatibility with pouches – new rifle had smaller rounds (bullets) and magazines)[16],[17] affecting the development of the 90 Pattern PLCE, although this had little affect on the Rucksack.

SCRDE however seem to have taken a very much ‘tasking’ approach which probably is because of the level of control they had over the process and decision making. SCRDE had a role as the organisation that could realise and alter prototypes, the role of assessing the prototypes and checking if the prototype was fit for service was the responsibility of other departments. These were strict boundaries at the time of the development of 90 Pattern PLCE for which it was accepted could take a long time.

The technical development for each prototype was very detailed, however[18,19] particularly when the development was relatively established and specification for manufacture was being drawn up.

6. How are design tools used within design process?

They aren’t in the evidence – trialling (surveys, some performance tests, HF assessments – lab based assessments i.e. doning and doffing, sprints, agility courses, jumping tests[20,21]

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[16] Rowe, N. C. (1972). Loose Minute: *Future Small Arms/Webbing Equipment Interface*, 3rd November 1972. Ref: A GST 3518. DGW(A)/Wpns 3a.

[17] Rook, P. J. (1982). PLCE 86 Discussion. 30th September 1982. D/D Inf/74/9B (Inf 2).

[18] D/DCTA/P1626/3/1 (ST) Part A *Specification for Rucksack Long and Short* (P in file reference denotes a development file).

[19] NN/P1626/3/17. Part A *Specification for Rucksack (INF)Short and (INF) Long Back.*

[20] Toft, R. J. (1983). *Human factors Assessment of Three Prototype Versions of PLCE*. 16th March 1983. APRE 105/43 (A). UK RESTRICTED.

(Ramsay,1983)), and from a technical perspective, sketching, technical drawing and the use of relevant textile tests. CAD wasn't widely used for MLCE until the mid-late 90s, and detailed ergonomic assessments are still being established today.

7. Were there legislative issues of Health and Safety or Human Factor constraints?

There were no Health and Safety constraints, only concerns over medical injury / functionality (Worsley 1981), which were addressed largely by the trials.

There are subsequent issues highlighted by the researcher's discussions with Defence Clothing Integrated Project Team surrounding female load carrying with 90 Pattern, there is no evidence of HS trials being conducted in development. (Personal Notes on meeting with DC IPT - Carl Hamilton and Barbara Clark) Sizing is one the main issues.

8. Who took design decisions?

Military committees agreed the designs after trialling and recommendations from APRE, the SCRDE designers would offer up designs to the sub-committee. SCRDE designers would make decisions over what components to use, based on evidence. If their selection or design had failed then they could reflect this in their next iteration.

9. How did those involved in the MLCE design process;

a. Access and use design data?

The design of the 90 Pattern Rucksack was evolutionary, although it was a new to service piece of equipment their had been rucksacks designed by SCRDE before. The design data which seems to have been most widely used were the rucksacks themselves and trials reports (and

b. Make design decisions?

Addressed in other questions

c. Collaborate with other professionals?

Largely this seems to have been done relatively well done, especially the SCRDE / APRE interface although there is little information on the roles, responsibilities and boundaries each organisation operated under.

d. Use and access users?

Very good access compared with today.

e. Are they experienced MLCE designers?

SCRDE were experienced technical designers, but were limited in the level of innovation which they could adopt due to the difficulties with getting military acceptance through the

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[21] Ramsay, D. A. (1983). *User Trial Directive 105/43(A) Personal Load Carriage Equipment*. 26th September 1983.

organisational structure for the project. This was also complicated by the alterations in requirements over the course of the project with a lot of debate in the Army at large which affected the military officers running the project.

Could the designers produced a more innovative design to mitigate the problems in trials? (Toft, 1983) SCRDE designers could have had more chance to innovate before 1983, but as one can see pre-1974 from Harding (2003b) they had been experimenting, but did not develop the more innovative concepts until after 90 Pattern had gone into service. Rucksack innovation could have been difficult due to the nature of rucksacks (i.e. they consist of principally two shoulder straps and a load carrying container). Historically the development in rucksacks in the commercial arena has come from advances in materials and foams. Which is how 90 Pattern was improved after it went to service with the introduction of a convoluted foam back to improve comfort.

10. Was there conflict between organisational decision making and design decision making, and was it a positive or negative influence?

There is no evidence of conflict, however one may not get this from the evidence which is largely official government archive material. Due to the role of SCRDE in the process, it is arguable that conflict was not likely to arise since SCRDE would simply do what it was tasked to do, but this is conjecture to an extent. An assertive approach is adopted by APRE which again is to be expected from trials assessments where one is trying to be constructively critical. Often (form the author's experience) there can be tensions between military and civilian staff, but this certainly does not seem to be case from the documentary evidence.

11. Who accepted the item for service?

There is no formal acceptance document in the evidence, at the time that 90 Pattern went into service the acceptance authority was the Directorate of Operational Requirements and Director of Infantry, with the Directorate of Clothing and Textile acting as the buying agent.[22]

12. What were the success criteria?

These are hard to identify, there are certainly organisational, functional, technical and human factors criteria, how important these four are is uncertain. The final policy letter indicates that functional issues are the most important[23]

Organisationally – a move on in performance to suit 'modern' role of soldiering
Functionally - Better than 58 Pat,
Technical – introduction of a lighterwieght, more durable textile and components
Human Factors – making sure that the equipment was fit for purpose, was comfortable and did not have any medical problems.

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[22] Clothing and Textiles Management Policy Letter (CTMPL) – 90 Pattern (Infantry) Webbing Equipment. 14 November 1989. D/DCT/7/1 CT1.

[23] Clothing and Textiles Management Policy Letter (CTMPL) – 90 Pattern (Infantry) Webbing Equipment. 14 November 1989. D/DCT/7/1 CT1.

Cost is not mentioned a lot in the evidence, although it is interesting to note that the Other Arms Rucksack which was introduced after 90 Pattern was introduced as a way of saving money against 90 Pattern which was regarded as expensive by military staff who the author met in 2000.

13. How was it tested or evaluated?

There are no lessons learned (a requirement for procurement programmes within the Ministry of Defence) from the evidence (this unfortunately was common for many projects at the time). The ultimate test of the process taken though is how well the rucksack performed in service.

14. Have the MLCEs been successful during service according to the different stakeholders?

Largely 90 Pattern has been successful with the OA Rucksack being withdrawn in favour of the Infantry Rucksack. Information from the Dstl Capability Deficiency Database (CDD) shows that the 90 Pat Rucksack is broadly liked, especially amongst Support Arms. Units which are issued the 90 Pat Rucksack however have mixed views, which is shown in the Dstl CDD information, these problems include poor waist belt, difficulty over sizing and lack of external pouches. It suitability for use with vehicles is also open to question.

15. Have the requirements changed during service?

Requirements for the 90 Pat Rucksack altered with the addition of a more comfortable back system and Disruptive Patterned Material (camouflage). The main change however is that there is an increasing use of chest or waistcoat webbing which does not work well with the 90 Pat Rucksack. Organisationally there are issues with the weight that the rucksack allows soldiers to carry which is linked to a concern of potential duty of care issues and litigation (the MoD has been prosecuted twice over claims linked to load carriage).[24]

16. Were user needs identified at the beginning of the project?

User needs were glossed over by prioritising to the infantry the needs of support arms were not addressed or deemed important[25]. See next question. This perspective has changed in the MoD and the needs of support arms are now also important (discussed with Defence Clothing IPT Requirement Managers / DEC GM).

17. Were military tasks identified during the project?

Specific tasks soldiers were expected to undertake with their load carriage were not identified.

18. Was this information used?

N/a, would have been useful see 19.

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[24] Vicary, H.L. and Wood, M.K.S. (2005). *Review of MoD Research Concerned with Military Load Carriage Equipment*. Dstl Human Sciences.

[25] Harding, J. (2004). *The Demise of the 1975 Pattern Design & Route to the '90 Pattern.* Army Historical Branch.

19. What info did designers need?

Probably a better understanding of what the Army wanted in terms of tasks. Understanding the requirements of support arms, despite the focus on the infantry, may have allowed designers to address the needs of the support arms or at least understand where they were not addressing the needs of the support arms. This meant that the development of an Other Arms Rucksack had to be conducted later; this later rucksack is much hated by current service personnel for functional reasons. Additionally the designers perhaps should have had a better understanding of the human factors issues enable them understand the potential for adding a padded back before it went to service.

20. What info did they have?

Initially the designers had access to the SCDR 444 (not available to the researcher) when it was written. And they had an understanding of the prototype work on the 74 and 75 Pattern and the APRE Trials Reports. They also would have had access to industrial material and fabrics advancements.

21. What info was not available?

An understanding of how Load Carriage aids soldiers successfully completing their tasks – assumed that infantry kit was good for all roles. How much they could work with APRE also is hard to determine, they may have attended trials and how much information the human scientists shared is not known from the evidence available.

22. How did they use the information?

It is difficult to get any indication from the evidence of how information was used in design activity. Information, however, provided to the designers was well used and reflected in the design changes made to the various rucksack prototypes, as directed by the sub-committee. (See Process Diagram) Not well in the case of the Other Arms Rucksack which was not a success (Note: comments made that Other Arms couldn't justify a different requirement[26]).

23. By what criteria can one judge the development to have been successful?

Successful product - YES[27] / No[28] - Arguably typical of the Army, many different views, first source may be trying to 'market' the new pattern to service men, the second as trying to get the next rucksack right, i.e. they knew the rucksack needed enhancing when it went to service.
Meeting requirement through service – YES (although not lately) output from Dstl Database is inconclusive – balance is positive towards it but with issues of reliability (clips) and access to equipment.
Developments through service:

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[26] Wilson-Ing, A. H. (1982). *Brief for Col CT on the development of '86 Pattern.* D/DCT/7/1/CT1.
[27] Army Training New (1992). *90 Pattern Equipment - So Far So Good*. No.28 April 1992.
[28] Campbell, A. P. W. (1993). *Personal Load Carriage: Concept Formulation Paper*. 22nd April 1993. D Inf 74/E.

- Convoluted Back[29] - APRE not involved
- Sizing Problems[30]
- Disruptive Pattern Material (DPM) – camouflage added to rucksack (not technically possible until after 90 Pattern went to service) probably to make it inter-operable with the clothing which was made camouflage about ten years before.
- Effectiveness – OK, produced a suitable rucksack, not an innovative design but met the user's needs, such as they were, one would also question how well the human factors issues were dealt with in the design. – however underpinning operational analysis was not conducted – recent work by Dstl shows large loads can affect mission success in dismounted operations[31].
- Efficiency – BAD, poor articulation of user need, even for the infantryman (one can reflect on the success of the US Army ALICE pack designed in fifties, still in-service with some US units), took a long time and large user trials, which may not have been needed if there had been a better understanding of human factors issues.

24. Can one identify where there were areas of deficiency in development?

See Above.
Timeliness
Long term problems with weight not tackled – organisational issue really

RQ2: What needs improvement in MLCE development?

25. By looking at deficiency areas, can one see where improvement is possible?

Main areas for improvement are:
1) Better use of materials technology to improve human factors interface (subsequently addressed in the research programme – Loughborough and Salford University work)
2) Better articulation of user needs and the tasks that soldiers need to perform
3) A better understanding of how evaluation methods and how they link with performance assessment and design

26. How is the product deficient because of limited practice? (Practice has moved on since the design work was done – or practitioners were not using the best techniques of the time.)

The rucksack is not deficient because of limited practices of the time, but probably because of the organisational boundaries which controlled how practices were used and applied.

27. Was there something the designers did that led it to be deficient, if so to what extent?

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29 Long, G. (1992). *Trial Directive SCRDE Rucksack 90 Pattern Equipment (Convoluted Back).* Trials/741 P1626.
30 Passingham, I. (1992). *Trial Report on Rucksack 90 Pattern Equipment (Convoluted Back)*. 25 June 1992. QMT 110 Q.
31 Shepherd, N., (2005) *Mobility OA Report*

The hip belt and poor back system are areas of weakness, but this interface was to an extent governed by the users and the supervising committees. The designers did offer up alternatives, but they may have been too radical for the users to consider them for further development.

28. Were there time constraints on the project?

Time constraints were not really applied the project seemed to have infinite time available.

29. How efficient is MLCE development?

This process is extremely inefficient, and took a long time, with large and expensive trials and little opportunity for innovation from today's perspective.

30. How effective is MLCE development?

It did produce a satisfactory rucksack, but it has been shown to have flaws and little growth potential, as one can see that almost as soon as it was in service there was a plan to replace it[32].

31. What opportunities are there for increasing efficiency in development?

Today there are a number of human factors approaches which are linked to the materials and construction of rucksacks which can be used before the rucksack is trialled with the user. Additionally there is a better understanding of user needs and requirements which link tasks to technology solutions from other equipment programmes. These could be used to give a better approach to making sure any design solution meets the user's needs. These approaches would be quicker, once developed for MLCE, and provide a quicker, cheaper route that the one for the 90 Pat Rucksack.

32. What opportunities are there for increasing effectiveness in development?

The approaches outlined above would also ensure that the process was effective by getting a more effective solution because one knows that it does the job it was designed to perform. The difficulty still comes where one cannot predict what will be required in the future, but arguably that should be addressed by ensuring that one has improvement programmes lined up for when the MLCE stops being effective.

[32] NN/P2376 Part A: *Personal Load Carriage Concept Formulation.* Opened 3-2-93.

Annex B: Comparative Study Notes from Airmesh rucksack

RQ1: What are the influences on MLCE development?

1. What are the factors which affect MLCE development?

Goal for MLCE for organisation – what future equipment programme[33]?
Policy Formulation[34]:

- initiated review of theatres of operation[35]
- doctrinal and medical comments[36]
- task orientated approach to address needs of other users and project planning need to be considered[37] - also reflected in other communications[38]
- issue of increasing weight and integration with other equipment (clothing) raised[39]
- project and procurement issues addressed[40]

Statement of Requirement for Other Arms (OA) Rucksack and Chest Webbing[41] - Interesting to note that the OA Rucksack is being phased out and mechanised troops want the Infantry Rucksack

Research project done to investigate airmesh fabrics and trialled in the jungle[42,43]
Loads from 50-100lbs carried for up to 60 days (note, that is a lot for a jungle environment)
Requirement to cover other users[44] > integrated trial performed – reduced prickly heat (Miliara Rubra) and sweating[45]

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[33] Fisher, A. J. C. (1994). Loose Minute: *Future Load Carriage Systems.* 2 June 1994. D/DCTA/P2414(ST).
[34] Mangnall, N. J. (1994). *Personal Load Carriage: Concept Formulation Paper Branch Level Draft*. 6th January 1994. D INF 74/7. UK RESTRICTED.
[35] Schumacher, A. (1994). *Loose Minute: Personal Load Carriage: Concept Formulation Paper Brach Level Paper*. 26th January 1994. TTB 102/4 G4. UK RESTRICTED.
[36] Downtown, J. G. M. (1994). *Loose Minute: Personal Load Carriage: Concept Formulation Paper Brach Level Paper*. 27th January 1994. HQRM 9/27/5.
[37] Fisher, A. J. C. (1994). Loose Minute: *Future Load Carriage Concept Formulation Paper.* 15th February 1994. NN1P2376T.
[38] Fisher, A. J. C. (1994). Loose Minute: *Future Load Carriage Systems.* 2 June 1994. D/DCTA/P2414(ST).
[39] Hughes, J. T. (1994). *D Inf 74/7 dated 6th Jan 94.* STC/113/15DRAF Regt. UK RESTRICTED.
[40] Kelly, J. L. (1994). *D Inf 74/7 dated 6th Jan 94.* 15 February 1994. D/DCTA/7/1 CT1. UK RESTRICTED.
[41] Walker, R. J. (1995). *Statement of User Requirement (SUR) for Chest Webbing and Other Arms (OA) Bergen For Armoured Infantry Battalions*. 9 August 1995. 074/07/00P2414. UK RESTRICTED.
[42] Watson, M. R. (1997). *Science and Technology Division DCTA Trial Directive Rucksack – Air Mesh*. 28th April 1997. D/DCTA/P3039 Trials 239 (ST).
[43] Gill, S. B. (1997). *Trial of Rucksack Air Mesh.* 28th October 1997. OR 6036.
[44] Egerton, T. C. (1998). *Air Mesh Rucksack – Trials Reports from 22 SAS.* 12 October 1998.
[45] Marlow, K. (1998). *Ops Research Jungle Trials 3-11 Sept 98.* October 1998.

Final testing done – inc Loughborough Physiological and ergonomic testing[46,47]

Small Requirement > limited requirement[48]

Trialled at RM and 'P' Company[49,50]

2. What is the relative impact of each factor?

The development of air mesh fabrics technology and the use by designers is the innovative factor which makes the project successful. Without a product which works this project would not have worked. Since the number of users is small the designers had to demonstrate that the rucksack would increase the effectiveness of the user. This was achieved by the iterative development trialling by the user and their involvement with the designer at S&T Group. The other factor which to an extent is underplayed in the development file[51] is the role of Loughbrough University in providing underpinning human factor assessments to confirm the link to increased user effectiveness by addressing the prickly heat problem.

The early debate about when a replacement to the 90 Pattern Rucksacks is held before the Airmesh Rucksack project is launched, and so this project builds on the research projects that the S&T Group were undertaking at the time the need arose. Where the need for better jungle rucksacks comes from is not clear from the evidence.

3. What are the relationships and interfaces between these aspects and factors?

See Above

4. Who were the designers/product developers?

Together the designers at S&T Group Colchester, with a good working relationship between the Ops Research Cell at 22 SAS and researchers at Loughborough University can be said to have acted as a design team. Albeit a relatively disparate one due to geographical separation, but it is clear that they worked well together. It is however difficult to determine what strategies the team adopted specifically, and it would appear the designers were responsible for project management and lead the development work.

5. How was the product development conducted?

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[46] Egerton, T. W. (1999). *Technical Summary of Airmesh Rucksack for Ops Research 22 SAS.* 4th April 1999. S&TD/P3093.
[47] Egerton, T. W. (1999). Email to Jeroen Vandewater (TNO): *Results of Evaluation of Airmesh Rucksack at Loughborough University.* 10 Aug 1999. 11:06:39.
[48] Marsh, D. W. (1999). *Facsimile: Airmesh Rucksack.* 24th March 1999. D/DCTA/18/7/1 Op Cl.
[49] Cullen, D. (2001). *Field Pack Air Support Back – Trial Directive.* 10 December 2001. ITDU/D&PE/03/02.
[50] Jones, G. (2002). *Airmesh Bergen Trial Royal Marine (CTCRM) and 3 Para Focus Group Results.*
[51] D/DCTA/P3093(ST). *Part A: Supported Air Mesh (For Rucksacks in Hot Climates)*

The development had been conducted with a close relationship between the designers, user and human factors specialists, allowing them the freedom to concentrate on producing an effective product. The product development was relatively quick, with little bureaucratic influence from managers or military officers in the various organisations. There were problems towards the end of the project as funding was sought to get the rucksack in to service, probably because there had been little involvement with the procurement organisation before this phase.

6. How are design tools used within design process?

Design tools appear to have been traditional rucksack development tools of drawing, prototyping, user trials and human factors assessment (although with a special emphasis on heat stress and prickly heat).

7. Were there legislative issues of Health and Safety or Human Factor constraints?

No health and safety issues were mentioned in the files, although human factors factors were central to the function of the rucksack.

8. Who took design decisions?

Design decisions were in the hands of the designers in co-operation with the user and human factors specialists. There no involvement by anyone else questioning the needs of the user or design choices made, probably because of the specialist nature and professional authority of the users (who are arguably the most experienced soldiers in the British Army).

9. How did those involved in the MLCE design process;

a. Access and use design data?

Sources of information for the design team were specifications from suppliers, laboratory reports from SCD2 (a section within S&T Group), reports from users and scientific reports from testing by the Loughborough University. These were accessed by request or more usually seemed to have been forwarded to those who needed the information as a matter of course.

b. Make design decisions?

Design decisions were taken by the designers using the information, feedback, and recommendations from the users and human factors specialists.

c. Collaborate with other professionals?

See Above.

d. Use and access users?

Given the nature of this user group, access to experienced users was not a problem since they were interested and wanted to make sure the rucksack met their needs.

e. Are they experienced MLCE designers?

The designers are specialist designers, with experience of rucksack design for a considerable period. What the exact training and experience was is not clear from the evidence. The design strategies adopted seem to indicate good specialist and procedural skills with evidence of a high level of expertise since the designers are conversant with the area and don't dwell on the design problem but quickly offer up design solutions.

10. Was there conflict between organisational decision making and design decision making, and was it a positive or negative influence?

During the development there was no evidence of conflict. After the development was complete there was some problem between the procurers and the designers, but this seems to have been quickly resolved. See CSQ 23.

11. Who accepted the item for service?

In this case the user accepted the item for service, although there is no evidence of the approval documentation. This is generally not Ministry of Defence procedure, but it not unknown for this user to avoid bureaucratic niceties.

12. What were the success criteria?

From the designers perspective getting a rucksack the user was happy with. From the users perspective getting a rucksack which made them more effective and reduced the prickly heat problem.

13. How was it tested or evaluated?

The rucksack was tested by extensive use on realistic training exercises / low level operations, which the user in this case has access to. Human Factors assessments were the used as confirmatory tests, rather than to prove the rucksack prototypes before they went for trial.

14. Have the MLCEs been successful during service according to the different stakeholders?

The rucksack has been successful, although some users still prefer to use their own purpose made equipment (discussed with a Special Forces Jungle Instructor at a Load Carriage workshop organised by the researcher). There is a perception that the rucksack is good for general jungle and temperate use, but that experienced users require a smaller, rucksack with more refined features, such as a larger lid and metal clips. An example of this is shown in the two pictures below.

15. Have the requirements changed during service?

This is not clear from the evidence, although the rucksack has now been trialled by non Special Forces units to inform future load carriage designs.

16. Were user needs identified at the beginning of the project?

User needs may have been used to derive the early prototype, but there is no formal evidence of this. Given the nature of Special Forces users getting them to write a user requirement given their operational commitments can be difficult. It is interesting to note that a Statement of User Requirements (SUR) was not articulated until towards the end of the project to get the final design procured. Although in this case the lateness of the SUR does not seem to have affected the deliver of a good rucksack. In fact it could be argued that the development process helped in formulating the SUR, although without sight of the SUR this is only a supposition.

17. Were military tasks identified during the project?

There is no mention in the evidence that tasks were identified, other than by making sure that the users needs were addressed by trialling.

18. Was this information used?

N/a

19. What info did designers need?

The information that the designers were looking for from the trials and human factors assessments is concerned principally with functionality issues (pouches in the right place, the length of straps and so forth). They are also looking initially for the affect of the airmesh fabric on the users[52]

20. What info did they have?

See Above

21. What info was not available?

It is not clear from the evidence that more information was required. Some aspects of the initial prototype (i.e. a long vertical zip to allow access to the length of the rucksack compartment) were exploratory and their functionally successfully tested for by user in the jungle. It could be argued that a more detailed understanding of the users needs may have resulted in a different design which may have avoided the criticism suggested by jungle instructors (see CSQ 14).

22. How did they use the information?

To inform design decisions and to influence the direction of the project, since the human factors information was used to influence and justify the procurement decision taken towards the end of the project.

23. By what criteria can one judge the development to have been successful?

The process used by the designers, although there is no evidence of project planning, clearly worked since it produced a rucksack that meets of the users. This was achieved in a timely and practical way there does not seem to be a formulised process for managing the development (from a design perspective). It is clear that there was development planning (although not shown in the documentation) although this seems to have been out of sight of procurement managers to some extent. It is clear from correspondence that there was a formal tasking process from the procurement organisation to the designers, who had a responsibility for managing development activities. But the development seems to have been undertaken by the designers without direct management from the procurement organisation. It is not clear that the involvement of the procurement organisation would have made the process work better since there is no indication of how they would have altered the development approach. The researcher suggests they may have stopped the development if the funding for the procurement of the final prototype at an earlier stage and so prevented the development process from working at all, which it it clearly did in this case. The process also allowed the designers to field test a new and innovative fabric technology and set a precedent for its use, which may not have been possible if their had been more oversight by procurement or military stakeholders.

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[52] Watson, M. R. (1997). *Science and Technology Division DCTA Trial Directive Rucksack – Air Mesh.* 28th April 1997. D/DCTA/P3039 Trials 239 (ST).

24. Can one identify where there were areas of deficiency in development?

This process clearly did not involve the procurement organisation who were responsible for managing the development. The relationship however between the designer's and procurement's respective organisations does not seem to be clear. There is evidence that the designers understood the organisational boundaries and since they had the backing of the users could progress the development. It is also arguable that this process benefited from having a relatively small team working on a well defined problem area, where personal relationships could be built and support the process. Central to this process was the proactive approach and interest of the users, as well as the having only one user group, rather than many (which is the case for other MLCE projects).

RQ2: What needs improvement in MLCE development?

25. By looking at deficiency areas, can one see where improvement is possible?

Better indication of user requirements in detail then linking these to rucksack solutions

26. How is the product deficient because of limited practice? (Practice has moved on since the design work was done – or practitioners were not using the best techniques of the time.)

It isn't, only a more detailed 'engineered' approach may have yielded a better outcome, but that approach has yet to be tried.

27. Was there something the designers did that led it to be deficient, if so to what extent?

No nothing that the designers did lead the final rucksack to be deficient, it met the user needs of the time.

28. Were there time constraints on the project?

Other than getting a result quickly enough so that the user didn't loose interest

29. How efficient is development
This approach is efficient in terms of getting a technical solution which meets the users needs, but did not look at the wider influences on the project

Few iterations – good feedback from user

How did it deal with cost?

30. How effective is development?

This approach is very effective at producing a rucksack design

31. What opportunities are there for increasing efficiency of development?

Minimising the number of field trials needed and doing human trials earlier in the process to make sure it does work before going to trials. – more technology de-risking (making sure the airmesh can be manufactured before using it!)

32. What opportunities are there for increasing effectiveness of development?

Doing better initial work to demonstrate the suitability of the prototype so that those involved (including the procurement and development managers) have a good understanding of what is trying to be achieved.

Annex C: Comparative Study Cross Case Analysis Notes

This annex is broken into two parts the Individual Case Study and Cross Case Reports, and the tables used to show how the study was used to answer the research questions.

Individual Case Study Report: 90 Pattern PLCE Rucksack
1.1.1 RQ1: What are the influences on MLCE development?
All the influences from the literature review (Chapter 3, Figure 21) are present; the strong factors for this case were: • Customer / Stakeholders – the organisational structure and boundaries controlled the development, and the design approach to a large extent. • Human Factors / Usability – strong reliance on human factors assessments and field trials. • Manufacture – designers strongly focused on manufacturability and specification. • Quality – strong emphasis on the quality of the equipment and getting parts of the process right (each stakeholder focused on their part), not the whole process. Weak factors are: • User – only understood for infantry, although the MLCE was for everyone in the British Army. • Military tasks – Not well understood, apart from general battlefield agility. • Design – little or no evidence of use of using design methods / processes to manage or change the process being driven by the organisational structures of the time. • HF low priority The approach to managing the design and iterations through development were military lead, with direction for MLCE priorities coming from a three-star equipment Director; i.e. focus on lightweight solution and use current loads as basis. Although finance was the driver ultimately. The interface with new equipment also added to the complexity of the design challenge (new rifle had smaller rounds and magazines and there was new Nuclear Biological and Chemical (NBC) Equipment). There was confusion over the military requirement for the MLCE which was did not seem to be articulated in enough detail to enable the designers to move away from an evolutionary approach based on a broad MLCE design the Army were familiar with. Information about the use of tools aren't in the documentary evidence, although the HF approach is well documented, and the designers used sketching, technical drawing and the use of relevant textile tests. One could use better technology today – use of computers / pictures and images / video would be useful. Networking was important both informal and formal. 90 Pattern PLCE Rucksack was a broadly successful product which met the user requirement through service, although not lately due to interface and reliability issues

despite some in-service modifications.

The process was relatively effective in that it produced a suitable rucksack, not an innovative design but met the user's needs, such as they were. The process was however very inefficient, it might have been quicker and more effective if the articulation of user need had been better refined so that the human factors trials could have been more focused.

Can one identify where there were areas of deficiency in the process of NPD?

- Timeliness > clear goals > end of development was rushed
- Poor information for designers
- Evaluation could be better today with more systematic approach to ergonomics
- Military got what they asked for – i.e. they almost designed the equipment
- Long term problems with weight not tackled – organisational issue really – need to understand the effect different MLCE solutions have of users

RQ2: What needs improvement in MLCE development?

Main areas for improvement are:
1) Better understanding of how different MLCE features improve human factors interface
2) Better articulation of user needs and the tasks that soldiers need to perform
3) A better understanding of how evaluation methods and how they link with performance assessment and design

The rucksack is not deficient because of limited practices of the time, but probably because of the organisational boundaries which controlled how practices were used and applied.

Today there are a number of human factors approaches which are linked to the materials and construction of rucksacks which can be used before the rucksack is trialled with the user. Additionally there is a better understanding of user needs and requirements which link tasks to technology solutions from other equipment programmes. These could be used to give a better approach to making sure any design solution meets the user's needs. These approaches would be quicker, once developed for MLCE, and provide a quicker, cheaper route that the one for the 90 Pat Rucksack.

The approaches outlined above would also ensure that the process was effective by getting a more effective solution because one knows that it does the job it was designed to perform. The difficulty still comes where one cannot predict what will be required in the future, but arguably that should be addressed by ensuring that one has improvement programmes lined up for when the MLCE stops being effective.

Individual Case Study Report: Airmesh Rucksack
1.1.2 RQ1: What are the influences on MLCE development?
The influences from the literature review are in evidence in this case, the development of airmesh fabrics technology and the use by designers is the innovative factor which makes the project successful. Without a product which works this project would not have worked. Since the number of users is small the designers had to demonstrate that the rucksack would increase the effectiveness of the user. This was achieved by the iterative development trialling by the user and their involvement with the designer at S&T Group. The other factor which to an extent is underplayed in the development file is the role of Loughbrough University in providing underpinning human factor assessments to confirm the link to increased user effectiveness by addressing the prickly heat problem. User requirements were relatively well articulated and were related to a need to carry heavier equipment and integrate with other equipment (clothing). Together the designers at S&T Group Colchester, with a good working relationship between the Ops Research Cell at 22 SAS and researchers at Loughborough University can be said to have acted well together. It is however difficult to determine what strategies the team adopted specifically, and it would appear the designers were responsible for project management and lead the development work. The product development was relatively quick, with little bureaucratic influence from managers or military officers in the various organisations until later in the project. Design tools appear to have been traditional rucksack development tools of drawing, prototyping, user trials and human factors assessment (although with a special emphasis on heat stress and prickly heat). HF tools were developed afresh for this project. The rucksack was tested by extensive use on realistic training exercises / low level operations, which the user in this case has access to. Human Factors assessments were the used as confirmatory tests, rather than to prove the rucksack prototypes before they went for trial. Design decisions were in the hands of the designers in co-operation with the user and human factors specialists. The rucksack has been successful, although some users still prefer to use their own purpose made equipment. There is a perception that the rucksack is good for general jungle and temperate use, but that experienced users require a smaller, rucksack with more refined features, such as a larger lid and metal clips. User needs may have been used to derive the early prototype, but there is no formal evidence of this. It is interesting to note that a Statement of User Requirements (SUR) was not articulated until towards the end of the project to get the final design procured, although an interviewee says there was an SUR given at the start of the project. Although in this case the lateness of the SUR does not seem to have affected the deliver of a good rucksack. In fact it could be argued that the development

process helped in formulating the SUR, although without sight of the earlier SUR this is only a supposition. It is not clear from the evidence that more information was required. Some aspects of the initial prototype were exploratory and their functionally successfully tested for by user in the jungle. It could be argued that a more detailed understanding of the users needs may have resulted in a different design which may have avoided the criticism suggested by jungle instructors. The process used by the designers, although there is no evidence of project planning, clearly worked since it produced a rucksack that meets of the users. This was achieved in a timely and practical way there does not seem to be a formulised process for managing the development. There was development planning according to interviewees (although not shown in the documentation) although this seems to have been out of sight of procurement managers to some extent. Central to this process was the proactive approach and interest of the users, as well as the having only one user group, rather than many (which is the case for other MLCE projects). The proactive approach allowed the users frustration with an overly bureaucratic approach to be mitigated.
RQ2: What needs improvement in MLCE development?
Better indication of user requirements in detail then linking these to rucksack solutions. This is probably akin to a more detailed 'engineered' approach which may have yielded a better outcome, but that approach has yet to be tried in any case. An engineering approach would require more contextual data, which would be expensive to attain. This approach is efficient in terms of getting a technical solution which meets the users needs and got a result quickly enough so that the user didn't loose interest, but did not look at the wider influences on the project This approach is effective at producing a rucksack design, due to the close working relationship of the designers and users. However, minimising the number of field trials needed and doing human trials earlier in the process could make sure it does work before going to trials. – more technology / HF de-risking. Doing better initial work to demonstrate the suitability of the prototype so that those involved (including the procurement and development managers) have a good understanding of what is trying to be achieved.

Cross-case analysis results by research question:

RQ1: What are the influences on MLCE development?
Organisational boundaries and role of the various stakeholders within the organisation does have a profound influence and make both formal processes bureaucratic. There is also no agreed process or understanding of the design and development stages that are needed in either case. Both cases rely upon HF support to a considerable degree, although because the focus is on making kit because of the lead times in getting prototypes made, the role of HF is underplayed. Both developments also leverage changes in textile technology and so need to have an understanding of the impact the changes have on the human user. The approach within both cases in terms of capturing user requirements is very similar, and in both cases does not seem to be handled well. Both rely upon written confirmations alone, with no way for the designers to discuss and refine the requirement. The design approach was different in the two cases in the way in which they worked with human factors one was highly iterative the other used them to aid in de-risking a technological component. The cases however did use user field trials to detail design the solutions and were evolutionary in nature. The two cases are similar in their reliance on user in field trials to develop the final solution they also do not make the most sensible use of human factors support and expertise. This however was probably the best arrangement and used the best knowledge of the day and organisational constraints. It is clear that the professionalism and communication at a working level enabled these developments to produce successful designs.
RQ2: What needs improvement in MLCE development?
Determining what needs development in the process of NPD is difficult since cases of NPD differ quite considerably. However the following are clearly areas of concern and possible development: Formalised HF support approach - flexible dependent on resources / problem situation - aid designers and developers determine what HF support is needed. Better requirement capture and handling approach - it is important to have auditable requirements which designers can challenge with users to look at the effect on technology on the requirement. There must be an articulation of the process of MLCE NPD otherwise the various stakeholders: development managers / procurers, designers, users and HF specialists will not have common reference by which to undertake development. This research question cannot be answered until the results of the first two have been answered by some confirmatory work in a contemporary context.

Influences from literature review reviewed	90 Pattern	Airmesh	Cross-case summary
User	User – only understood for infantry, although the MLCE is for everyone in the British Army	User needs may have been used to derive the early prototype, but there is no formal evidence of this. In fact it could be argued that the development process helped in formulating the SUR, although without sight of the SUR this is only a supposition.	The user was understood in different ways in either case - one focused on a user subset the other evolved the user requirement - it is evident the airmesh approach was more effective and efficient, although more informal
Military task	Military tasks were not well understood, apart from general battlefield agility	It is not clear from the evidence that more information was required. Some aspects of the initial prototype were exploratory and their functionally successfully tested for by user in the jungle.	Dealt with differently in either case. The iterative approach of the airmesh arguably worked well to define the designs in line with military tasks. 90 Pattern made an assumption that the equipment would be sufficient for all tasks, time has shown this approach to have been of limited success.
Environment	Some early discussion about the appropriateness of the MLCE for Arctic and Jungle use - a lot of sources talk about use in vehicles	Started as a jungle requirement – which was the key influence in material selection and the features the pack contained.	The environment of operation was a large influence on both cases - although the influence varied in both cases. 90 Pattern had to work for all environments, so was a general design. The airmesh was designed for the specific requirements of one environment.
Customer	Customer / Stakeholders – the organisational structure and boundaries set by senior stakeholders controlled the development, and the design activity to a large extent	The product development was relatively quick, with little bureaucratic influence from managers or military officers in the various organisations until later in the project.	Eventually in both cases the constraints of the organisation affected both cases, very closely linked to the money the customer had available to buy the equipment
Design team	Good working relationship at working level between SCRDE, APRE and DCT. Also with D Inf. > there were clear boundaries as to what people did and how the interfaces were handled.	A good working relationship existed between various areas. It is however difficult to determine what strategies the team adopted specifically, and it would appear the designers were responsible for project management and lead the development work.	In both cases good working relationships helped make the projects a success
Design expertise	Designers had limited access to requirement information and had little influence on the requirement. The role of designers at that time was to give the customer what they wanted, rather than offer to try more radical solutions.	The designers were experienced. A better indication of user requirements could have helped the designers develop better solutions efficiently and effectively.	The designers in both these cases were experienced and used to working with human factors. They both had manufacturing experience as well as good textiles knowledge.
Manufacture	Designers focused on manufacturability and specification, rather than the innovative aspect of development, although the material used in construction was new and innovative for the time.	The development of air mesh fabrics technology and the use by designers is the innovative factor which makes the project successful. Close relationship with industry.	Both cases were dependent on new technologies which needed to be understood before they could be applied in prototpyes. In both cases the development was aimed at getting the prototype to a manufacturable specification
Quality	Quality – strong emphasis on the quality of the equipment and getting their part of the process right, not the whole process however	The audit trail behind this case is sketchy, although there was a plan according to the interviewees.	
Time	Although the development was spread over several years, there were rarely any clear goals, which ultimately lead to a rush to the final development, which then took over ten years to iron out problems while the equipment was in-service.	Constraint was keeping the SF user interested, they are used to getting their equipment quickly to do a job that needs doing urgently, this development still took three years to get in to service.	Timelines was an issue for both cases although it affected them both in different ways. Its clear that quick development routes were needed.
Human factors	There was strong reliance on human factors assessments and field trials – human factors was a low priority however	HF were used but not in detailed development - designers used feedback from user field trials	Both used HF but in subtly different ways although the support was arguably appropriate at the time.
Design	The prototypes were developed iteratively although there is little or no evidence of use of using design methods / processes to manage or change the process being driven by the organisational structures of the time.	An iterative approach, although there does not seem to have been an articulation of the stages that the development was to undertake.	the designers in both cases did seem to control the mangement approach, although there is no diagramatic or clear written articulation of the approach used. At a working level the designers were very influential.

Table 1. *Table showing comparative factors from the literature review versus the comparative cases.*

Research questions	90 Pattern	Airmesh	Cross-case summary
RQ1: What are the influences on MLCE development?	Customer / stakeholders – the organisational structure and boundaries controlled the development, and the design approach to a large extend.	Since the number of users is small the designers had to demonstrate that the rucksack would increase the effectiveness of the user. This was achieved by the iterative development trialling by the user and their involvement with the designer at S&T Group.	Organisational boundaries and roles of the various stakeholders within the organisation does have a profound influence and make both formal processes bureaucratic. There is also no agreed process or understanding of the design and development stages that are needed in either case.
	Human factors / usability – strong reliance on human factors assessments and field trials - HF low priority however.	Human factor assessments to confirm the link to increased user effectiveness by addressing the prickly heat problem.	Both cases rely upon HF support to a considerable degree, although because the focus is on making kit because of the lead times in getting prototypes made, the role of HF is underplayed. Both developments also leverage changes in textile technology and so need to have an understanding of the impact the changes have on the human user.
	Manufacture – designers strongly focused on manufacturability and specification.	The development of air mesh fabrics technology and the use by designers is the innovative factor which makes the project successful.	
	Military requirements: User – only understood for infantry, although the MLCE was for everyone in the British Army.	User requirements were relatively well articulated and were related to a need to carry heavier equipment and integrate with other equipment (clothing).	The approach within both cases in terms of capturing user requirements is very similar, and in both cases does not seem to be handled well. Both rely upon written confirmations alone, with no way formal (contractual) way for the designers to discuss and refine the requirement.
	Military tasks – Not well understood at all, apart from general battlefield agility.		
	Design – little or no evidence of use of using design methods / processes to manage or change the process being driven by the organisational structures of the time.	Use of ergonomic tests was novel, but the critical aspect of this project was keeping the users interested.	The design approach was different in the two cases in the way in which they worked with human factors, one was highly iterative, the other used them to aid in de-risking a technological component. The cases however did use user field trials to detail design the solutions.
	How these influences interface or which are dominant is harder to establish from the evidence, and essentially comes down to a judgement as to whether the development could have been conducted better **.**	How important the above influences are or how they interface to improve our understanding of MLCE design is difficult. Certainly the proactiveness of the designers / users helped, as did the development of airmesh fabrics (used here before the civilian market).	The two cases are similar in their reliance on user in field trials to develop the final solution, they also do not make the most sensible use of human factors support. This however was probably the best arrangement and used the best knowledge of the day and organisational constraints. It is clear that the professionalism and communication at a working level enabled these developments to produce successful designs.

Table 2. *Cross Case Summary table for Research Question One.*

Research Questions	90 Pattern	Airmesh	Cross-case summary
RQ2: What needs improvement in MLCE development?	From the information in Research Question 1, one could address the deficiency areas above, bar the forth.	This MLCE project went relatively well and so determining what could have been done better within the development process is difficult.	Determining what needs development in the development process is difficult since cases can differ quite considerably. However the following are clearly areas of concern and possible development:
	Main areas for improvement are:	Areas for improvement could be:	
	1) Better understanding of how different MLCEs and loads have to improve human factors interface.	An accepted evaluation procedure which integrated the HF more, since they were really an adjunct to the process	Formalised HF support approach - flexible dependent on resources / problem situation - aid designers and developers determine what HF support is needed.
	2) Better articulation of user needs and the tasks that soldiers need to perform.	Better articulation of the user requirement - more detail than just a written document > this project worked because their was a close relationship between the designers and users.	Better requirement capture and handling approach - it is important to have auditable requirements which designers can challenge with users to look at the effect on technology on the requirement.
	3) A better understanding of how evaluation methods and how they link with performance assessment and design.		
	The first deficiency is perhaps the hardest to solve but could be addressed by having an MLCE design process which developers could use to determine if they are progressing in the right manner. It would also provide a tool which can be used with managers to explain how MLCE should or could be developed to aid in determining clear goals.	Use of an agreed development plan to bring development staff on board and explain what the designers and users were doing.	There must be an articulation of the process of MLCE NPD otherwise the various stakeholders: development managers / procurers, designers, users and HF specialists will not have common reference by which to undertake development.
RQ3: How can we improve MLCE development?	This research question cannot be answered until the results of the first two have been answered by some confirmatory work in a contemporary context.	This research question cannot be answered until the results of the first two have been answered by some confirmatory work in a contemporary context.	This research question cannot be answered until the results of the first two have been answered by some confirmatory work in a contemporary context.

Table 3. *Cross Case Summary table for Research Questions Two and Three.*

Appendix I: Knowledge gaps after the comparative study

Literature area (Following from literature review)	**Gaps in knowledge of MLCE development**	**Addressed in comparative study?**	**Colour coding**
Design Processes in the context of MLCE		*(Green indicates that the knowledge gap has been addressed to some extent and does not need further clarification, amber that some further research was needed, red that some insights were available)*	
	What design process is used in MLCE development? Are design strategies and design processes used? If so what is the impact?	Established historical NPD processes – few design strategies or processes used.	
	Are problems in the context of MLCE poorly defined and so not addressed by development process?	The cases indicate that problems in the context of MLCE are poorly defined and not well addressed by the process.	
	How and to what extent are users represented in the development process?	Users are very evident from officer level.	
	What affect will corporate taxonomies have in determining requirements which can be used in MLCE development process?	Not studied to date.	
	Have cost and business performance issues taken a higher priority over human systems and user needs in MLCE development processes?	Not studied to date.	
	Does the development process have an impact on how MLCE design teams design?	The process has an impact at all stages.	
	What are the appropriate cues within MLCE design which can be used to prevent error in the development process?	Not studied to date.	
	How are design decisions made during MLCE development?	In historical cases they are made by committees or senior military/civilian development officers.	
	What level of design expertise is there involved in MLCE development?	There is expertise required not only in design but also in managing the design process / design activity.	
	How are user requirements gathered and how are they used in MLCE development?	User requirement formulation and representation is ambiguous although written requirements are used.	

Table I-1. *Knowledge gaps in the process of MLCE after the completion of the Comparative Study, developed from Table 10.*

Literature area (Following from literature review)	**Gaps in knowledge of MLCE development**	**Addressed in comparative study?**	**Colour coding**
Design Methods in the process of NPD in the context of MLCE		*(Green indicates that the knowledge gap has been addressed to some extent and does not need further clarification, amber that some further research was needed, red that some insights were available)*	
	What methods are used in MLCE development?	The methods historically are traditional cut and sew technologies - Computer Aided Design (CAD) is not used in industry or MoD.	
	What methods are used in military and civilian organisations, do they differ, and why?	Not studied to date.	

Table I-2. *Knowledge gaps in the process of MLCE after the completion of the Comparative Study, developed from Table 10.*

Literature area (Following from literature review)	**Gaps in knowledge of MLCE development**	**Addressed in comparative study?**	**Colour coding**
Influences on MLCE development?		*(Green indicates that the knowledge gap has been addressed to some extent and does not need further clarification, amber that some further research was needed, red that some insights were available)*	
New knowledge gap	Why is the military load approximately 50% higher than the recommended load and what impact does this have on the user and MLCE design?	Loads were high because of doctrine and military practice / culture which does impact on user - although may not have the large impact on MLCE design as one may imagine - since it was a constraint a designer works with and was not something he/she can control.	
	What effect do particular branches of human science (for example; Biomechanics, Physiology, Ergonomics, Physiology) have on the MLCE development processes? (To date there have been no integrated human factor studies of the affect of load on the human in a military context.)	This remains problematic since most designers do not have human systems training, but all have a role.	
	What format should human systems information related to MLCE design be presented in to make them useable in the development process?	Not studied to date.	
	What effect on the soldier does the role as a consumer have upon user requirements in MLCE development?	Not studied to date.	
	What affect does product failure have upon MLCE development?	Not studied to date.	
	Are the processes used to develop MLCE high quality?	This was hard to answer without quantifiable metrics, historical evidence would suggest the processes were not as high quality as they could have been given modern practice (i.e. the same practices would not be acceptable now).	
	What lessons can the MLCE development process learn from approaches to NPD of civilian load carriage?	Probably quite a lot in terms of innovation - although not studied to date .	
	How are human factor issues being represented within MLCE development processes?	Generally human systems are represented fairly poorly in relation to manufacturing and military requirements but could be used more effectively given current human systems practice.	
	What are the soldiers' needs for MLCE and how can they be successfully represented in development?	User needs remain ambiguous and would benefit from being expressed using current guidance / practices.	

Table I-3. *Knowledge gaps in the process of MLCE after the completion of the Comparative Study, developed from Table 10.*

Appendix J: Account protocol

As a part of the work done to explore a contemporary case of MLCE development, an account protocol was developed to gain insights into MLCE development from people involved in a current project.

Thesis Link: Chapter 6, section 6.4

J.1 Aims

The aim of this protocol was to gain insight about the process of development for military load carriage equipment (MLCE) from the people involved in a current project.

The study builds upon research questions 1 – 3 in that it looks at current influences, looked at gaps in knowledge and what needs improvement. In addition the study triangulates information gained from data gathering for RQ1 and 2 during the Nominal Group Study.

The research method**,** therefore, needed to be:

- Simple for participants to engage in data capture
- Dependent on minimal resources
- Build on existing understanding of knowledge about MLCE development in a systematic way

J.2 Selection of research method

Accounts in Cohen et al. (2000: 293) are largely placed within the ethnographic paradigm and seek to explain phenomena from the perspective of participants in complex situations. Market research however uses diary panels as a data gathering approach and requires participants to record information about their behaviour using diaries and video diaries (Crouch and Housden 1996: 139, Desai 2002: 35). Additionally market research uses techniques such as interviews and story completion to elicit information about behaviour reactions to situations and products (Crouch and Housden 1996). Accounts are framed within a social episode, in this case a military load carriage equipment (MLCE) development project and project team.

Approach:

1. Informants and themes
2. Account gathering situation
3. Transformation of account (analysis)
4. Researchers' account

J.3 Informants and themes

In order to undertake this study the researcher gained the agreement from two colleagues to gather their personal accounts of the female load carriage study project.

Involving colleagues – comparative stories: Colleagues' diaries are used to enable comparison with the practitioner-researcher's account, as follows:

1. The practitioner-researcher (design background) and colleagues (human factors) involved in the same MLCE project
2. The practitioner-researcher (design background) and a well-experienced colleague from human factors
3. A well-experienced colleague from human factors and a novice colleague from human factors *(lower priority and more complex)*

Themes – To enable the analysis and enable data to be grouped into several themes (Ereaut 2002: 71, Desai 2002: 41) have been developed before the account gathering begins:

1. **Influences** – influences on the whole development process, including detail design process identified by Comparative Cases (Links closely to RQ1).
2. **Interfaces** – working between professionals involved in the development process (Links to RQ 1 and 2).
3. **Knowledge** – knowledge needed to develop MLCE, to highlight gaps as well as what is well known (Links to RQ 2 and 3).
4. **Experience** – personal insights into developing professional skills in the development of MLCE (Links to RQ 2 and 3).

These themes do not need to be given to the participants in the first instance since they may lead them to look only at these aspects. As the accounts develop they could be opened to the participants to get their view on the data.

Generic diary prompts – In order to help the participants get into the diary, prompts in the form of questions were included in the instructions to aid the recording of data (Shepherd 2004):

What do I think?
What lessons have I learned?
What action will I take?

These questions also help to understand what the participants learned about the development of MLCE, neither having directly worked on this type of project. This has relevance to RQs 2 and 3 which are trying to understand where there are gaps in knowledge especially for those who are new to MLCE development and what can be done about the gaps.

J.4 Account gathering situation – getting an authentic and reliable account

Data collection: Methods for recording the account should be in-field notes in the form of diaries (Gray 2004: 244, Silverman 2000: 50, Ereaut 2002, Desai 2002: 4, Shaughnessy et al 2006). In addition to the researcher-participant's diary notes should be collected separately on insights in to the development process.

It is the intention to hold periodic meetings individually and as a group to review points raised so far during the keeping of diaries. This fits well with psychological narrative thinking since it is hard for people to express events solely using text (Murray 2003). These review point meetings ideally should be recorded, or at the least minuted in the researcher's field notes (separately to the research practitioner's diary).

At the end of the account period a final review workshop should be held between the three participants to capture the issues that were raised during the project and the lessons learned.

J.5 Transformation of account (analysis)

Analysis: This is done by qualitative comparison of the stories and by examining the issues raised during the review points of the diaries. One is looking for insightful comments on the process of development related to the three main study research questions. This is done by comparing the different accounts and the pre-set themes detailed in section 1. The themes could be altered if insights emerge during the field work. Insights, in terms of interpretations of the data or hypotheses, should be recorded by the researcher since they may lead to an altering of the themes. The insights themselves may not be as a result of analysis but could enable the researcher to improve understanding of the context of MLCE development.

Problems with regard to data capture or the study approach should be addressed as they arise. Notes of the issues discussed during the review points should be circulated to the participants for their agreement after the meeting. This approach is dependent on the researcher having good contextual knowledge of the area.

J.6 Researchers' accounts – research operation / theoretical background

The researcher's account should be kept in the same manner as the participants, to enable comparison during and after the data collection.

Reflective Practice – Ideally an account approach will give insights into how the practitioner knowledge worked in practice (Schön 1987) by looking at how practitioners performed in practice. Robson (1993: 462) gives some guidance for systematic enquiry of practitioner-researcher practice, which emphasises honesty and systemising ordinary knowledge, not replacing it. It should also be remembered that information gained in this manner provides good quality with regard to personal insight but must be used with caution depending on the conclusions being drawn from the results.

Bias – One of the reasons for not focusing on more specific aspects of development is that to do so may lead to errors in identifying influences on the development process. There is also a danger that bias could be introduced by having expectations from the researcher-participant perspective (Shaughnessy et al. 2006). This can be mitigated by being aware that this could happen and by checking for biases during the review point meetings.

Small sample size – While this study has a small sample size it can still provide valuable insights into the MLCE development process as long as the results are used correctly and not overstated. The intention for the study is to use it to triangulate with other studies to answer the Research Questions. So the study will be used within the framework of a wider research strategy, rather than as the main study exploring the MLCE development process. The smaller size of the study also helps the researcher to have a good relationship with the participants, which is important for this type of study (Murray 2003: 102).

J.7 Additional Insights:

Expertise – Establishing what constitutes experience may be difficult, especially with regard to experience of MLCE development, but an be assessed generally by asking questions of the participants versus expertise criteria from the literature review. This is a lower priority than judging the participants accounts from the two different disciplines.

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Account Study - Information for participants

Aim of the study: To gain insight about the process of development for military load carriage equipment (MLCE) from the people involved in a current project.

1. Starting the project

Firstly, thank you for agreeing to take part in this study. This will take place during the female load carriage project from now (March) until the end of the trials (October).

2. Recording the Accounts

Methods for recording the account should be in written or computerised notes in chronological (date) order. They should be kept regularly, ideally soon after the participant has done some work related to the female load carriage project or as ideas or issues emerge.

Some useful questions which can be used to stimulate thoughts each time diary entries are made are:

Describe what has happened, then
What do I think?
What lessons have I learned?
What action will I take?

3. Learning from the Account

This is done by comparison of the diaries and by examining the issues raised during the recording of the diaries. The diaries will be discussed during individual or group meetings to review points raised so far.

At the end of the account period a final review workshop will be held to capture the issues that were raised during the project and lessons learned.

Account Template

Date:

Entry Title:

Notes:

Describe what is happening:

What do I think?

What lessons have I learned?

What action will I take?

Appendix K: Single case results

This appendix contains the summary notes from the single-case study. The case examined was a sensitive one from the project team's perspective, and so individual names have been removed, unless there is a reference in the official record for the project. Additionally there are also notes by the researcher attempting, where evidence was lacking, to interpret what may have been happening to enable the research to reach a reasoned conclusion.

Thesis Link: Chapter 6, section 6.5

Research questions	Propositions	Case study questions	Notes
1. What are the elements involved in MLCE development?	**a. The elements which influence MLCE development can be categorised and their interfaces and relationships understood.**	**1. What are the aspects and factors which affect MLCE development?**	Started because of: 1) A claim brought by Ex-RMAS Cadet – believed to be settled out of court. Basis of the claim was over the cadet's carriage of high loads for long period on an exercise causing nerve injury to the spine. DCIPT contacted the researcher to source documents on the trialling of 90 Pattern PLCE Inf Rucksack in the 1980s. Policy Note on 90 Pattern PLCE Inf Rucksack, has no mention of female users (Defence Clothing and Textiles 1989). 2) A visit by the Assistant Chief of the General Staff to RMAS (Assistant Chief of the General Staff 2005b) raised the above claim to Deputy Adjutant General (Deputy Adjutant General 2005). Deputy Adjutant General then tasked DCIPT to establish a governance structure with Army Training and Recruitment Agency (ATRA) (JLJ Bilzon 2006) to solve this problem. *Direction by ACGS seems very prescriptive (Assistant Chief of the General Staff 2005a), but at the end he does note that this is not his core area of interest, but it should be remembered that he is still a very senior stakeholder and ATRA is a part of his area of responsibility with human science expertise.* A number of issues were identified by the researcher in Oct 05 while reviewing a document produced by DCIPT 2005for the headquarters staff officer tasked to deal with the issue (the researcher was working in the same department at the time). The researcher's view was that the approach outlined was pragmatic, but may not address the underlying causes since better sub-components for the system were not being looked at. It should be noted that the IPT may not have not been cognisant of the possibilities at the time. (*In discussion with the staff officer (Lieutenant Colonel in rank) I also pointed out that the main problem for women was likely to be because of the high loads they were being asked to carry. I was told that reduction in weights for female soldiers in training was not being considered for morale reasons.*) Feb 2006 – RMAS asked if they could provide load data (RMAS-HQ-G7-PAT SO2 2006) by Dstl (not sure by whom). A survey by DCIPT was undertaken in Dec 05 to explore some of the issues prior to Dstl becoming involved (Gillson 2005). While the Dstl reports were being written; DCIPT wrote a Technical Specification with the intention of running a competition for the development of a number of possible

			prototypes. The Dstl reports extent to which the Dstl reports were fed in to the Technical Spec was uncertain, the reports were not given to the successful bidders. The management / design approach was: **to modify the 90 Pattern PLACE Infantry Rucksack back system only, and for the waistcoat to be used with it (DCIPT 2006j).** However, there is a record at the ARWG that states the Bergan has to be compatible with belt order (JLJ Bilzon 2006**)**. A key recommendation from the Dstl Literature Review (*which I co-wrote*) (Humm et al. 2006). Around this time the DCIPT project staff went to Canada to see the work the Ergonomics Research Group had done on the new Canadian MLCE (Joan Stevenson 2007). The trial was stopped after two weeks due to problems with the prototypes and RMAS instructors' objection to waistcoat type belt orders (DCIPT 2006g; RA Gillson 2007). How this was missed from the original User Requirement (note this has not been available from DCIPT) was uncertain, there was, however, a disconnect between the statement made at the ARWG (JLJ Bilzon 2006) and the Technical Specification which was generated from a user requirement between DCIPT and RMAS. From above the main factors were: **Championship direction** – ACGS, as the main champion, set the requirement / outline of the project, SO2 PAT at RMAS could in some ways be regarded as the local (user) champion, although this may be taking the definition too far. **Management / requirements** – Requirements with RMAS seemed to have gone awry at this point (*no evidence as to how this hds occurred*). In retrospect the requirement may have been better worked through with the RMAS Instructors, but they may have changed their opinion once they saw the prototypes, they were negative from the start however (DCIPT 2006f). There is a close link with tactical doctrine (i.e. a lot of instructors are infantry (and male), who tend to prefer belt orders, Other Arms however do not, often being vehicle based. Female Cadets once they graduate will be in the Other Arms not infantry). **H&S / Duty of Care –** This was the requirement for Dstl work. **Time** – Some decisions may have been affected by the tight time constraints (DCIPT 2006e). **Experience of Designers –** designers were confused initially as to how to approach

			the development of prototypes, so neither challenged the decision to use the waistcoat as a part of the waistcoat *(they may have assumed that DCIPT had agreed with RMAS that this was acceptable).*
		2. What is the relative impact of each factor?	Championship and Management were the most critical (important?) factors in preventing this project produce successful MLCE. This is evident due to the constraint ACGS may have (inadvertently?) placed on the project, reducing the possibility of reviewing the female user's loads and options for solving the problem (Humm et al. 2006). Problems were encountered by the manufacturers (designers) at in the early stages.
		3. What are the relationships and interfaces between these aspects and factors?	Championship had a strong impact on how innovative the solutions to the problem could be. The management approach *(perhaps driven by the championship direction (?))* seems to have removed any improvement to the belt order which ultimately stopped the trial and development of the prototypes. *(There does not seem to be any evidence that ACGS has re-visited the problem.)* At first reading of the evidence there seems to be a sequential hierarchy of factors leading into the next: 1. Championship – highest since this started the project and put early constraints on it. 2. Requirement – again impacted by (1), but also at a lower level stopped the trialling of prototypes. 3. H&S – a primary concern for starting the project so arguably part of the requirement. 4. Time – this was deemed to be an urgent project and so needed a management approach that could deliver quickly. 5. Management – the approach adopted by DCIPT in response to the above factors which controlled how the product development was conducted. 6. Experience of the designers – the main factor during the development of the prototypes, where DCIPT had to intervene to provide advice and guidance. Time was perhaps the only factor which may be more important than championship, management and requirement. Many of the decisions and certainly the design management approach seem to have been affected by time, in that a low-risk design needed to be trialled quickly. MoD decided the best way to do this was via industry

			firms using a loose technical spec (i.e. it was not prescriptive of the sizing, and features, apart from the rucksack compartment). Desk officers did visit the manufacturers often to give direction and advice (DCIPT 2006c; DCIPT 2006d).
	b. By looking at the product development of existing MLCE it is possible to understand how the resultant products were designed.	**4. Who were the designers / product developers?**	Industry firms were the designers. MoD desk officers provided the boundaries and constraints within which the designers were working, they also advised on the exit criteria for the MLCE which was not firmly stated in the Technical Spec (*the contractual information was not available at the time of writing*). There was little input from HS areas, either Dstl or ATRA in establishing the exit criteria, although the trials as the final acceptance trial / hurdle were to be run and supervised by ATRA.
		5. How was the product development conducted?	DCIPT ran the development, although they were told to use ATRA to run the trial of the prototypes. The development was meant to be low risk and to produce a design which would reduce injury and discomfort for female soldiers, hence the choice of two companies who currently manufacture for the MoD to undertake the development. They were both used to working to technical specifications and were not thought to have any HS expertise. This may have affected the level of low-risk innovation they could bring to the project (Tutton 2007).
		6. How are design tools used within design process?	There was little in the documentary evidence to show that there were specific tools used by the designers. The Dstl work could be viewed as tools for use by the DCIPT development officers, in that they were use in some of the technical specification development and for personal education. The reports enabled DCIPT development officers to give advice to the contracts, although there was no evidence to quantify this or check this supposition. In conversation with DCIPT one of the 'tools' they developed, however, was a load test the manufacturers could do in house. This constituted of loading the prototypes with the actual equipment that the users would have to get a representative distribution of the load. This was very successful in aiding the design decision making of the designers according to DCIPT (DCIPT 2006b). Whether the manufacturers would have produced a better design if they had the reports was arguable. *(Conjecture: Personally I think they would, since there was some very clear advice in the report on the types of sub-components which were known to work.)*

		7. Were there legislative issues of Health and Safety or Human Factor constraints?	This was the primary reason for involving Dstl and ATRA (see 1). Although no standards were overtly citied by DCIPT, they were reviewed (Humm et al. 2006). Whether the prototypes were assessed against these standards or against MoD HFI guidance was uncertain. *(Conjecture: I suspect due to the tight time scales that they were not.)*
	c. How design decisions were made.	**8. Who took design decisions?**	The designers had local design decision making, but had to consult DC PT since they had the best idea of what RMAS wanted (or had agreed to).
		9. How did those involved in the MLCE design process:	
		a. Access and use design data?	DCIPT controlled all the development activity, Dstl and other stakeholders were not in contact with contractors due to commercial reasons. DCIPT shared information with ATRA and Dstl.
		b. Make design decisions?	Design decision making, i.e. what features and materials to use in the design was done primarily by the industry firms with DCIPT providing advice and guidance. There was no documentation on how this worked, apart from interviews with DCIPT development officers, which gave an example of guidance given (DCIPT 2006a). (*One of the firms I met at another meeting reported that the relationship worked well, but gave no details of how the decision making was made*.)
		c. Collaborate with other professionals?	Since most collaboration was done with DCIPT and Industry firms this was difficult to determine in detail, see comments from no.11. The relationship between Dstl and DCIPT was cordial and had a contractual base, which was how Dstl advice was fed into the project.
		d. Use and access users?	Access to users was handled through DCIPT, with the Requirement Manager providing advice from a user perspective. RMAS as the lead stakeholder were involved as trial coordinators. Despite the early finish of the prototype trial, feedback sessions were held with some positive feedback (DCIPT 2006h).
		10. Are they experienced	One firm understood the problem and the constraints of the project, the other needed more advice and direction. They both needed help, however, with doing studio tests

		MLCE designers?	(hence the development of the load tests – see no.6).
		11. Was there conflict between organisational decision making and design decision making, and was it a positive or negative influence?	There was no evidence that the designers or DCIPT changed the development management approach because of the organisational constraints stakeholders had placed on it.
		12. Who accepted the item for service?	The equipment has not been trailed to date, or been issued.
	d. It is also possible to see how success for MLCE is:		
	i. determined	**13. What were the success criteria?**	The Technical Specification contained a number of technical aspects that were expected within the final product. There was little indication as to how the prototypes were to be assessed although according to the minutes of the ARWG Dstl were tasked to produce assessment criteria (JLJ Bilzon 2006), although this was not in the Dstl contract.
		14. How was it tested or evaluated?	ATRA were to run a large acceptance trail once the initial trial was completed. It was not clear how ATRA approved the initial prototype trial, which was the plan according to the ARWG minutes (JLJ Bilzon 2006).
	ii. in-service	**15. Have the MLCEs been successful during service according to the different**	Not applicable with the failure of the trial.

		stakeholders?	
		16. Have the requirements changed during service?	Probably not given the statement in the ARWG minutes (JLJ Bilzon 2006). Despite comments from DCIPT (DCIPT 2006h), one would need access to the original requirement to determine this.
	iii. during military tasks.	**17. Were user needs identified at the beginning of the project?**	User needs were captured, although since the requirement information was not available how this was done cannot be confirmed. Certainly some user needs must have been determined, as the two surveys explored the problem and would have been a good source of user need data, though that was not their primary purpose (Lewis 2006; Gillson 2005; Gillson 2007). *(It may be that a Statement of User Requirement (SUR) was constructed but probably did not breakout the individual tasks which soldiers may undertake. It appears odd that the belt order requirement was not picked up if the tasks were articulated.)*
		18. Were military tasks identified during the project?	See no.21.
		19. Was military task information used?	The extent to which Dstl reports were used in design activity by the industry firms was probably negligible since the firms didn't get the surveys or literature review, although this was supposition.
	e. The design information needed to design MLCE will be identified.	**20. What info did designers need?**	The designers probably needed more information about how the MLCE was used; to date they were reliant on DCIPT for getting user information and advice on prototype suitability. This was satisfactory as an approach if the IPT could provide the information, which they appear to have (DCIPT 2006i), although there was no documentary evidence to back this up.
		21. What info did they have?	Contracting information, advice from DCIPT from their visits.
		22. What info was not	See no.23.

		available?	
		23. How did they use the information?	How the contractors used the information cannot be confirmed since the firms were not allowed to be contacted by the researcher due to commercial reasons.
	f. It is possible then to evaluate the process of NPD and determine where there are deficiencies.	**24. By what criteria can one judge the process of NPD to have been successful?**	Since there were no formal success criteria, the only measure can be the general satisfaction of the end user. The end user stopped the trial of the prototypes which would indicate they did not regard the solution offered as appropriate.
		25. Can one identify where there were areas of deficiency in the process of NPD?	In this case the omission of the requirement for a 'belt order' seems to have delayed the project and ultimately have caused its failure. Additionally the use of a loose technical specification, specifying a course of action to solve a problem, may have constrained designers overtly. An approach could have been to ask the industry firms to problem solve this area. If the firms could not design a hip-bearing rucksack which worked with belt order then one can go back to the user and begin to challenge the requirement for belt order, i.e. they simply cannot carry everything they want in their Bergens. *(This was a simplistic approach but one that may have worked in stimulating the debate over long-term injury for men and women.)* The reliance of industry on the requirement may in the long term be a worry, since the industries' understanding the military environment may be limited, and so put design risk back on the MoD.
2. What needs improvement in MLCE development?	**a. Areas where attention is needed to enable improvement will be identified.**	**26. By looking at deficiency areas, can one see where improvement is possible?**	Looking at this case, how industry firms were engaged in design management needs to be improved, particularly the translation of requirement into technical specifications. The other obvious area was building designers' understanding of the military requirement and how that affects the design solutions they produce, so that they can probe design briefs which they are given.

	b. There is a need for improvement in the process of NPD in the context of MLCE either because (for example):		
	i. the product is deficient because of limited practice	**27. How is the product deficient because of limited practice?**	From an assessment of the prototypes and debriefing from DCIPT the reasons for product deficiency (shown by the failure of the trials) were because of the manner in which the military requirement was determined and used. The rucksacks were fine as rucksacks, although they did show in some of their features the limitations in an awareness of the military environment (i.e. popper studs on the bottom of rucksacks, where may catch when put down and also collect mud).
		28. Was there something the designers did that lead to deficiency, if so to what extent?	From an assessment of the prototypes there were some features of the rucksack that were problematic, but they were minor and should have been modified through testing. Also the level of expertise of MLCE was also limited, hence the intervention by DCIPT with contractors early in the development. However, DCIPT were happy that the prototypes the firms delivered were fit for purpose.
	ii. The design decisions were made with insufficient evidence due to other pressures beyond the control of the design practitioners, e.g. time.	**29. Were there time constraints on the project?**	There were time limitations in trying get a solution into service in a timely fashion. This may be an area where improvement should be sought to get the requirement right from the outset, and planning what a given intervention will produce (i.e. planning the outcome).
		30. How efficient is the process of NPD in the context of MLCE?	The process was efficient, although it could be argued that a successful solution should have been reached earlier if the tasking on industry was more developed. The project has produced designs which bear load on the hip, which for a procurement project was a first.
		31. How effective is the process of NPD in the context of	Not very from this case, since the trials were stopped. Industry did what was asked of them in this instance although the designs they produced do have some minor problems. Whether they could provide an answer to the problem of belt orders interfacing with hip belts was another matter. *(There was also a suspicion that the*

		MLCE?	*user's needs from belt order have not been identified in this process; could this have been the actual cause of the trial stopping?)*
	d. Determination of what opportunities exist for increasing the efficiency of the process of NPD in the context of MLCE.	**32. What opportunities are there for increasing efficiency in the process of NPD in the context of MLCE?**	With regard to this case the options were limited to a perceived lack of knowledge as to what would work to solve the problem. The perceived lowest risk solution was adopted, although there were others people may not have been aware of the risk. The application of conventional design and HF practices could have helped, but may have increased the perceived risk (although reduced the actual risk), and the time to deliver. Critically the requirements management needed to be tighter and technical risks identified with mitigations.
	e. Determination of what opportunities exist for increasing the effectiveness of the process of NPD in the context of MLCE.	**33. What opportunities are there for increasing effectiveness in the process of NPD in the context of MLCE?**	The main way for increasing effectiveness in this case was to improve the design management of the project in reviewing the various technical solutions, ideally in a systematic and risk based manner. One could also argue that industry and Dstl could have been more involved in helping frame the solutions and identifying the risks, which may have helped to get the issues which meant the trials were stopped to the fore, enabling them to have been addressed.

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Appendix L: Questionnaire for survey of contemporary priorities

Questionnaire on Load Carriage System development

Please fill in your details below:

Name	
Organisation	
Experience in Load Carriage System (LCS) development	

Please indicate your experience of the roles in column A by putting a number in column B:
1 = no experience, 6 = a lot of experience

A	B
Designer	
Development Manager	
Business Manager	
User	
Human Scientist	
Materials Technologist	

1. Please look at the factors in column A on the table below:
   Please score each factor reflecting how strongly you view its importance in LCS development (column B).
   1 = not important, 6 = very important
   Please add comments as to why you have scored as you have in the comment column (column C) and if you want to expand on the description of a factor.

A	B	C
Factors in LCS development	**Importance**	**Comments**
Requirement (= definition of military need)		
Cost constraint (= cost of end LCS and process of development)		
Time scales		
Championship (= customer / owner who can champion the project at a high level)		
Product development (= design of candidate prototypes)		
Systematic approach (= systematic development of LCS from the start of the project to when the LCS finishes service)		
Production friendly (= ensuring the candidate LCS are fit for manufacture)		
Evaluations / trialling / user feedback (= assessments at every stage of LCS development, from designer based tests to final user acceptance and safety trials)		
Experience of past developments (= knowledge and awareness of the design decisions and development of previous LCS (successes and failures))		
Interface / interoperability (= how the interface of LCS with other equipments and platforms (e.g. vehicles) impacts development)		

2.	Are there any other factors or activities which are important to LCS developments which have been missed out of the factors in the tables above?

3.	Please describe the three most important areas of LCS development which need to be improved? (These do not have to be limited by the factors in Question 1.)
1	
2	
3	

4.	Please give the three strongest and three weakest aspects of the LCS development process you currently work with.		
Strongest aspects		Weakest aspects	
1		1	
2		2	
3		3	

5.	Are there any other points which you may feel of help in fulfilling the aim of this research (explained in the introductory email)?

Many thanks for taking the time to fill in this questionnaire

Appendix M: Participants Comments Pattern Matching Data

Thesis Link: Chapter 8, section 8.5

The following table contains the data transcribed from the researcher's notes shortly after each interview.

Key
Blue = aspects raised in another points
Duplicate comments
Data use
Nos. indicate link to participant

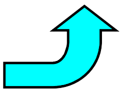
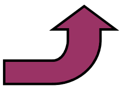
The numbers in the 'Data use' boxes refer to individual participants.

Factors in MLCE Development																
Requirement	1	2	3 AND 6	3	3 AND 6	4	10 AND 5	10	10 AND 7	9	9	7	6	5	11	11
(= Definition of military need)	Must represent user and organisational needs	Start with what you want product to do - then compare against current equipment - don't start with a list of features	Most are written in vague or high level terminology	Must look beyond the product to training, people, how it is maintained and so forth	The essential requirements should be identified versus lower priority requirements	Lack of definition of what equipment is needed for and to do	Needs to include information on weight, environment and life of the system to allow for appropriate materials tests, which should be done as 'ageing' tests (i.e. to represent use)	Components should not be 'over-engineered' to meet a demanding requirement	Effect of carrying heavy loads is not well understood, and indeed is not practiced by some enemies - different approaches need to be explored	To tight a requirement can limit the design process	Informal input from the users 'on the ground' can give excellent insights into how a product may have to perform (may not be a part of the user requirement)	Military needs are different to outdoor sports (location of mass/load, versatility of MLCE)	People tend to 'follow' the pack and like to 'tweak' designs	Performance criteria are more valuable than 'hard' specifications which often lack an evidence base	Military often don't know what they want	By the time requirements are articulated they may be time expired
Cost Constraint	1	2	2	3	3	4	10	9	7	5						
(= Cost of end LCS and process of development)	Cost should not penalise comfort or use	Increased risk of cheap products failing on operations	Cheap development = cheaper (poor) designer (need to correctly establish one is getting best value)	Cost is often used to constrain specification of a product - this has lead to poor construction and integration	Better requirements would protect the product from cost constraints	Development cost should be commensurate with the end product cost	Cost of materials is small compared to labour cost so should not be limited if they enable reliable performance when in use	Affordability should be presented, ideally as feature (function) vs. cost	MLCE is expensive but it is purchased infrequently	Cost should not be important at the beginning of a project						
Time Scales	2 AND 11	3	7	11												
	Best value effects when one sees the benefits from good design (i.e. cheap design may get short-term results, but may not in the long term)	Project timelines are altered by have different requirements and views	People are discouraged if they wait too long for a new MLCE	Speed of development must be quick otherwise MLCE will be outdate by the time it arrives in-service												
Championship	1,9,7, AND 8	2	2	2 AND 7	10	7	7	5,6, AND 7	6							
(= Customer / owner who can champion the project at a high level)	Effective design meetings - communication? - 'Decisions should be made with the right people in the room'	Dialog between industry and government	Must not be designed by committee	Trust (of specialists) is important to enable development?	Champions should understand the risk of failure of the product to perform and the risk of injury to the user even if it does perform	Getting the right champion(s) is essential - ideally; technically aware and good project management skills	High tempo design iterations driven by the champion also enable successful development	Ideally need three integrated teams - design, scientific, user (test team) or commercial team	Champions can also be 'elite' users							
Product Development	1	3 AND 6	4	10	9 AND 5	7	8									
(= Design of candidate prototypes)	Prototypes are essential - development of design / material selection	Not many firms around to provide expertise in product development - (counter argument from one participant however)	May not be a need to generate multiple concepts	Product development is never wasted since it explores the solution space and allows early identification of inappropriate solutions	Users should be involved in product development to build support	It may be best to undertake design and prototype manufacture in different organisations, although working concurrently in early development	Ideally one should undertake a couple of iterations before production									
Systematic Approach	1	1,3,7, AND 5	3 AND 11	3	3	4	4	4	10	10	9	9	9	7		
(= Systematic development of LCS from the start of the project to when the LCS finishes service)	Role of data in development - use of objective and subjective data	Development must be done as a system (rather than systematic in manner) - look at how 'sub-systems are developed / work together (relevant to Interface/Interoperability and Evaluations)	People, training and logistics are infrequently addressed adequately	Lack of applied research to gain base data	evidence base for specifications is needed	Structured or systematic - it may not be necessary to take a new approach	Approach must integrate with the development approach taken for other equipments in 'soldier system'	Human data should be apart of the development approach	A systems approach should not be too prescriptive since products may have to be adaptable to carry unusual loads	User training and expectations need to be addressed in development - especially with regard to fitting MLCE	More to be learned about how to carry loads (from a theoretical perspective)	Poor sharing of information from international community	load carrying is not just an individual activity, group effects also are important	Producing reports and documenting the process can distract from doing the development work		
Production Friendly	1	2	4	9	5											
(= Ensuring the candidate LCS are fit for manufacture)	Production staff should understand function of LCS to enable correct selection of materials	Ease of production should not be allowed to limit function or price (these are usually the priority - i.e. without function you won't want it, if it costs too much you won't buy it)	Productionisation should be looked at in the later stages of development after it has been evaluated	Most designs can be produced, but at what cost?	Higher production costs can be acceptable if user acceptance is a high priority											
Evaluations / Trialling / User Feedback	1	1	2	4	10	10	9	7	8	6	5	5				
(= Assessments at every stage of LCS development, from designer based tests to final user acceptance and safety trials)	Key to the process allowing knowledge from all areas to input to development	Evidence must be provided to enable design alterations	People revert to natural comfort zones so testing early may result in early rejection of innovative solutions	Scenarios may be useful in establishing user feedback if built into development process	Small problems, like a strap being the wrong place, can result in product failure so need to be identified	Human Factors Integration is a high priority	Evaluations are linked to production cost, since they evidence base user requirements and incur costs to development	You do not need to do every level of test at every stage, this should be strategically determined	The design team should not be involved in evaluation, but should be of the review	Essential in ironing out bugs - can only be done in field	The more users involved the more the product is de-risked	Evaluations are not a 'check' at the end of design activity, but should be apart of every stage				
Experience of Past Developments	1	1	2	2	2	3	10, 7, AND 6	9 AND 2	8	6	5					
(= Knowledge and awareness of the design decisions and development of previous LCS (successes and failures))	Must include previous scientific work / assessments	Experienced staff can be very helpful	Get knowledge from civilian experiences	Experienced development teams may not be the best to re-develop or evolve a product, a fresh team may be more appropriate	Users must be eloquent about equipment weaknesses	Awareness of past mistakes makes people wary of conducting development due to perceived need for more development money	Technology (Materials) and task alter with each MLCE project so each project should be regarded as a new development	May help avoid pitfalls	Product knowledge can help evolve products	Product history is important to civilian products since each product is evolved every few years	This is a two way street: can provide useful evidence of uses of features, but can limit innovation					
Interface / Interoperability	1	2	3	4 AND 7	10	6										
(= How the interface of LCS with other equipments and platforms (e.g. vehicles) impacts development)	Interface of assault orders with vehicles is a problem	Interfaces must be identified in the requirement so that the function of the product is clear and can be tackled in development	Often is known about, but often not addressed	Early identification of interface problems is important to de-risk user conflicts, but should be addressed later in process	Although interfaces in theory are not ideal and often cause problems, there is a lot of capacity for humans to make MLCE work	Interfaces are also looked at as a part of civilian pack design										

Appendix N: Grounded Theory Matrixes

This appendix contains the final grounded theory coding matrix used in the cross analysis of studies 1-6. In order to make the matrix transparent as much information and data was left in from previous iterations of the matrix, as the analysis was undertaken after each study, or Cycle of research.

Thesis Link: Chapter 9, section 9.2.1

Key	
	Inidicates where concepts may be merged or split
	Indicates where categories may be integrated in properties and dimensions to enable *Axial Coding*
	Shows where next level of refinement has been done
	Shows where a concept has become a category with *some* alteration
	Shows where a concept has become a category with little alteration
	Null values - concept / category has been merged with another
Orange Text	Shows that a concept is taken from the literature

Appendix N

Appendix O: Tool Review

In order to ensure that appropriate user methods were used and integrated into the tool in the correct manner, as well as identify any duplication with existing methods, a short user tool review was conducted. This was conducted early in 2008 to inform tool development. The review was not intended to be exhaustive, but to provide an overview of methods available to MLCE developers in understanding and integrating user needs in design.

Thesis Link: Chapter 10, section 10.6.1

O.1 Approach

The tool review was conducted over two stages, based on a similar approach by Stanton et al. (2004). First, a review of the available user-orientated tools information which was relevant to Military Load Carrying Equipment (MLCE) was undertaken. Second, a filtering process was used to determine the issues which would affect use by MLCE developers.

Stage 1 – Initial Literature review
The literature was searched to find papers relevant to user interaction, including reviews of methods. The review was conducted to inform tool development, and so papers available up to mid 2008 were included. The searches were conducted using keywords on Loughborough University's Library information systems (MetaLib, OPAC and so forth) and through the researcher's personal contacts.

Stage 2 – Literature Filtering
The selected methods were then structured using characteristics adapted from Stanton et al. (2004), to provide an overview of each approach and some key references applicable to MLCE. Meta-analysis was not possible because of limited number of published reviews of user methods, and the limited number which had been used in MLCE development. Additionally the references in the table were not intended to be exhaustive, but to provide a link to where most of the information about the technique was derived. Stanton et al. (2004) was used where applicable, and not overtly referenced in the table.

Method	Training time	Application time	Related methods	Use in design process	Tools needed	Advantages	Disadvantages	Reference
Hierarchical Task Analysis (HTA)	Med	Med	Task decomposition	Research / Requirements	Pen and paper	1) HTA feeds many other techniques, 2) well known, 3) accurate description of activity	1) Descriptive information only, 2) difficult to access what someone is thinking while doing tasks, 3) time consuming	Kirwan and Ainsworth (1992)
Critical Path Analysis (CPA)	Med	Med	HTA, Task decomposition	Research	Pen and paper	1) Can be used to predict times for doing a task, 2) identifies key activities	1) Time consuming, 2) cannot account for unpredicted errors	Kirwan and Ainsworth (1992)
Task decomposition	Low	Low	HTA, CPA	Research / requirements	Pen and paper	1) Very Flexible, 2) can provide much information, 3) allows for a number of analyses: usability, interaction.	1) Highly time consuming if not familiar, or undisciplined	Kirwan and Ainsworth (1992)
Scenario walkthrough	Med	Low – High	Video Scenarios	Requirements / research / evaluation	Pen and paper	1) Good for checking all aspects have been catered for, 2) flexible approach	1) Dependent on having right people present, 2) dependent on 'right' and representative scenarios being developed	Fulton-Suri and Marsh (1999), Carroll (1995)

Method	**Training time**	**Application time**	**Related methods**	**Use in design process**	**Tools needed**	**Advantages**	**Disadvantages**	**Reference**
Critical incident technique	Med	Med	CPA	Evaluation	Pen and paper	1) Can be used to determine key error incidents	1) Getting reliable outputs can be difficult, 2) requires a number of assumptions to get it to work, 3) familiarity with technique important	Kirwan and Ainsworth (1992)
Video scenarios	Low	Med	Scenario walkthroughs	Requirements / evaluation	Video	1) Flexible approaches available, 2) can be linked to a number of other analyses, 3) easy for others to access	1) Getting representative video information can be difficult, 2) time consuming, 3) reliability of instances shown can be questionable	Ylirisku and Buur (2007)
Expert (User) review (post / during trial)	Low – Med	Low – Med	User trial, fit / form / function	Evaluation	Pen and paper (video)	1) Flexible approach, 2) can be quick, 3) reliable information	1) Assumes that Experts are experts, 2) experts knowledge based on previous experience	Poulson et al. (1996)

Method	Training time	Application time	Related methods	Use in design process	Tools needed	Advantages	Disadvantages	Reference
Activity diary	Low	Low - Med	Expert review, user trials	Evaluation	Pen and paper (video)	1) Gives context of use, 2) audit trail for comments, 3) can use video rather than pen and paper to gain accessibility	1) Needs participant to be disciplined in completing accurately, 2) can be time consuming	Ylirisku and Buur (2007)
Expert (technical) review (post trial)	Low – Med	Low - Med	Product evaluation, fit / form / function	Evaluation	Pen and paper	1) Can provide alot of information quickly, 2) information provided is generally reliable	1) Assumes that Experts are experts, 2) experts knowledge based on previous experience	Schniederman (1998), Poulson et al. (1996)
Fit / Form / Function	Low	Low – Med	Product evaluation	Evaluation	Pen and paper (video)	1) Quick, 2) common sense based, 3) can be done without experts	1) Gives only static or short duration information, 2) need to be clear about what one is looking at	Poulson et al. (1996)
Perceptual methods (Comfort)	Med	Low – Med	Product evaluation	Evaluation				Legg et al .(2003)
User trial	Low – High	Low – High	Expert review, Fit / Form / Function	Evaluation	Pen and paper, video	1) Checks prototypes are fit for general use	1) Feedback can be unreliable, 2) difficult to check the specifics of problems, 3) Unsystematic	Poulson et al .(1996)

Method	**Training time**	**Application time**	**Related methods**	**Use in design process**	**Tools needed**	**Advantages**	**Disadvantages**	**Reference**
User analysis	Low – Med	Low – Med	Task decomposition	Requirements, research	Pen and paper, video, images	1) Gives information about the people who will use the load carriage system, 2) good resource for designers	1) Some information difficult to quantify, 2) can be time consuming	Marsden (2001), i~design (2007), Poulson et al. (1996)
User scenarios	Low – Med	Low	Video scenarios, User analysis	Requirements, Research	Pen and paper, video, images	1) Gives illustrative information about the people who may use the system	1) Mainly aimed at 'marketed' approach, 2) illustrative users may not represent user group reliably	Fulton-Suri and Marsh (2000), Carroll (1995)
Case building	Low – Med	Low – Med	Expert reviews	Requirements, research, evaluation	Pen and paper, video, images	1) Helps to justify why a design is like it is	1) Time consuming, 2) needs an independent and knowledgeable 'judge', and 'advocates'	Schniederman (1998)
Usability evaluation	Low – Med	Low – Med	Fit / Form / Function, user trials, expert review	evaluation	Pen and paper, video, images	1) Ensures that the system is usable, 2) provides information about what needs to be improving	1) Requires some knowledge, 2) access to representative users is also important	Vicary (2001), Neilsen (2005)

Method	**Training Time**	**Application Time**	**Related Methods**	**Use in design Process**	**Tools needed**	**Advantages**	**Disadvantages**	**Reference**
Product evaluation	Low	Low – Med	Expert reviews	Evaluation	Pen and paper, video, images	1) Flexible approach, 2) Can be quick, 3) provides information about what needs improving, 4) does not need access to representative users or experts	1) Needs a structure to give a framework to make it work, 2) results may not be reliable, 3) best to conduct it as a group or compare with another evaluation	Vicary (2001), Baxter (1995), Poulson et al. (1996)
Focus group	Med	Med	Expert review, product evaluation	Requirements, research, evaluation	Pen and paper	1) Provides insights into peoples views, 2) quick	1) Information can be difficult to use in design, 2) facilitation can be difficult	Bruseberg and McDonagh-Philp (2002)
Comfort - Visual Analogue Scales (VAS)	Med – High	Med	Perceptual methods	Evaluation	Pen and paper			Jacobson et al. (2003)

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Appendix P: Study 8 Method Review

As a part of the development of a tool to improve MLCE development, appropriate methods for evaluating the improvement needed to be reviewed. This appendix covers the discussion of the research methods that were considered, details of the chosen research strategy and evaluation approach are detailed in Chapter 12.

Thesis Link: Chapter 12, section 12.2.2

The following methods were reviewed for their suitability for assessing what professionals active in MLCE development thought about the tool:

- Observation – observe people using the tool
- Interview – ask developers questions about the tool
- Focus group – ask a group of developers questions about the tool
- Quasi-experimental approaches – determine differences between tool and no tool use by application of the tool in a 'design exercise'
- Expert review

P.1 Observation

Observational methods cover a range of research approaches which seek to understand people's behaviour, or thoughts about a topic, in an easy and believable format (Desai 2000). Observational methods could be used within a variety of research strategies, and particular methods which require the researcher to interact with people. In the context of the tool evaluation, observation could provide a way to assess how tool users interacted with the tool by assessing their reactions as they use it. Video could be used to record the interactions and review the users' reactions with the tool, similar to usability assessment methods (Kunniavsky 2003). Analysis from observed data collection varies depending on the purpose of the study. In this study the focus was thought to be on the verbal and physical gestures used by the participants. Video observation had limitations in that people can have negative reactions to being videotaped (Kunniavsky 2003). Hidden traps could also be experienced with; lengthy set up and post analysis times, as well as issues of reliability and validity when linking conclusions to what really happened (Bisantz and Drury 2005). Observation in person and using video (the two did not need to be mutually exclusive) could have been used with other research methods to broaden the information available (Bisantz and Drury 2005). Observation was relevant to this study for recording how designers use the tool within a comparative quasi-experimental research design or to record interviews (Ylirisku and Buur 2007).

The limitations of observational methods discussed above have many parallels with the design of the tool itself, since the tool could utilise archival video and specifically obtained video data (see section 12.3.11).

P.2 Interviews

Interviewing techniques were the most appropriate method for getting views on the impact the tool may have on the process of MLCE development due the flexibility of questions, and relative ease of data capture compared with other methods. Indeed the purpose of exploratory interviews was to develop a heuristic understanding of how people (MLCE developers and stakeholders in this instance) think (Oppenhiem 1999: 67). Interview methods offered a number of parallels with the development of the tool since soldier interviews were considered as a data capture method for the population of the tool (see section 11.3.1). It was also thought, given the experience during the previous studies (particularly Study 2, see Chapter 5) that developers would interact better in an interview setting, since there would be no competitors or customers present. The use of interview techniques to get insights on issues within the design processes from experienced practitioners was well documented (Cross and Clayburn Cross 1996, Petre 2004, Cross 1998). The type of interviewing technique most appropriate for getting insights was thought to be semi-structured (Smith 1995), with a core of questions relating back to the research question through the objectives and sub-questions. Interviews also provided the most potential for probing issues as they arose, and offered the flexibility for interviewees to raise points thus far not thought of. Semi-structured interviewing was also familiar to the researcher and so would have a relatively low burden in terms of becoming proficient with the techniques.

Rapport building was also more achievable in semi-structured interviewing (Smith and Osbourne 2003, Smith 1995), and since the number of possible interviewees was low, it was important to have a technique which would encourage participation. Semi-structured interviews can take some time (usually an hour or more) so interviews are best conducted where the respondent feels comfortable (Smith and Osbourne 2003). This was an advantage in that it mitigated some of the logistical problems of getting respondents by minimising the amount of time developers and stakeholders (for definition of the two groups see Chapter 11, section 11.3) were disturbed, since they could be visited at work. Results can be limited in their reliability if small samples were used, as in this study, although they can yield a rich source of insightful data which can be analysed in a number of different ways (Smith 1995, Willig 2001). An issue with exploratory interviews related to the small sample size is the possibility for participants to have a hidden agenda, and so the interviewer must unobtrusively direct the interview (Oppenhiem 1999: 67). Small sample sizes also shift the purpose of interview from formalised data capture to eliciting ideas from the participants, which would suit the nature of the research question and use tool maturity. Other limitations with semi-structured were how questions from the interviewer and respondent answers were interpreted (Willig 2001, Bryman 2001). This was a concern, but could be managed by being sensitive to the respondents' background and work context, and asking clarification questions, such as; 'what did you mean by ...?' Additionally by recording interviews the researcher could also probe for inconsistencies in interpretation and follow up by phone or email if needed.

Since the data produced by the semi-structured interviews may vary depending on the participants' background, experience and work situation, the most appropriate data analysis was some form of 'bottom up' analysis (Wilkinson 2003: 196). This approach can be undertaken using a grounded theory approach (see Chapters 4 and 11) to look at emerging themes arising from the data. This form of analysis can be regarded as a form of content analysis which seeks to quantify content into categories (Silverman 1993, Bryman 2001, Gray 2004). Usually content analysis would use predetermined categories (Bryman 2001), which may be difficult in the context of this study, so would have to use content analysis in a less predetermined manner allowing the categories to emerge from the data, as with Althedie's (1996 In Bryman 2001) ethnographic content analysis (similar to grounded theory approaches). An alternative to these two was to use a coded approach (Silverman 2000), similar in some ways to Althedie, which sorts the data allowing issues related to the evaluation of the tool to emerge unrestrained by any preconceptions as to what participant views were of the use tool. However, Silverman (2000) notes that one should ensure that un-coded activities should be accounted for since they may contain important insights, and have particular meanings to certain groups of peoples. This could be achieved by presenting the analysis in a number of ways, including grouping the participants' ideas by qualitative theme, rather than grouping them by the frequency a given word or theme occurs, while being sensitive to the perspective of the participants and their background.

The alternative to a 'bottom up' approach would be to use a 'top-down' approach which uses a pre-determined theory into which the data is sorted (Wilkinson 2003). This approach would pre-suppose what the likely responses by participants in the evaluation would be. Since this was hard to predict, the researcher considered using a form of structural content analysis to look for instances of positive or negative comments with regard to the tool. This did have a number of issues, not least of which was the reliance on the researcher's judgement; which may bring biases, and sidestepping the broader issues in which the comments may be placed (Millward 2000).

The preferred approach for analysing the interview data was the bottom-up approach since it was not known what the stakeholders' view of the tool or MLCE development would be. A bottom-up approach would allow for some flexibility in analysis, depending on the variance in participant views and allow for alternative themes to be explored as they emerged. An example of an alternative view might be to look at whether there was any difference between participant experience, design background and their view on the tool, or more likely between their experience of military and civilian MLCE development.

One of the limitations of semi-structured interviewing, as mentioned above, was the possibility that there may be misinterpretations between the interviewer and respondent. In order to mitigate this aspect further, and explore the 'improvement' aspects of the research question, the addition of a scenario-based 'interview' was explored. The possibility of using a scenario survey was initially highlighted to the researcher by a colleague who had used the approach to augment interviews with military personnel on morale issues in the British Army (Spear personal communication). Scenario-based interviews were also used in requirements analysis (Carrol 1995) which fitted with the purpose of this study, since it was trying, in part, to inform the requirements for a 'Beta' version of the tool. The use of scenario-based interviews in this study could have been viewed a 'projective' technique (Oppenheim 1999, Crouch and Housden 2003) to probe the frankness of participants' responses and their attitude to the tool. It should be noted that the degree to which scenario-based interviewing was projective to access 'deeper' attitudes was not clear from the literature. Projective techniques, however, did accurately describe the purpose for using the scenario-based interview to access evoking and outlining stereotypes in, and ideas of good practice in MLCE development, as outlined by Oppenhiem (1999). Additionally the use of a scenario-based interview approach could also be regarded as a form of 'thought experiment', since it was trying to test the tool in imaginary scenarios. In this study the thought experiment would be a posterior, rather than a priori (Bird 2002), since the test would be reliant on participant's experience of MLCE development, rather than a proposition that can be reasoned through. Thought experiments had also been used in psychological studies into how unique information may influence group decision making (Stasser and Titus 2003). Stasser and Titus' (2003) research had shown that people were likely to focus on common issues when in group discussion which negated the influence, no matter how important, of unique information. Getting feedback from participants about the tool could be regarded as unique information, which might give a critical insight into what MLCE developers might need. It appeared sensible, therefore, to try and talk to participants individually to allow their unique insights on the tool to come through.

Eliciting information from participants was perceived by the researcher to be a strong element in selecting the research methods for the evaluation approach to answer the research question. The scenario-based interview added the possibility of breaking from the potential monotony of interview questions which might not inspire or stimulate the participants. The scenario-based interview, however, offered the potential to challenge participants to frame their comments on the tool against scenarios that they might not have envisaged when answering interview questions.

The scenario-based interview was similar to cross sectional studies which were usually used to examine selected processes continually over time to provide points of triangulation to demonstrate validity[53] (Cohen et al. 2000, Bryman 2001). A scenario-based interview was thought to offer the possibility of limited triangulation of the data from the main interview by looking at how the tool could be used over the period of an MLCE development, based on the generic development process discussed at the outset of this section. The scenario-based interview was envisaged as a 'snap shot' of the participants' views on seeing the tool, using a number of scenario stories with incorporated events, at which participants would indicate whether the tool would improve MLCE development in that situation.

As a form of cross-sectional study this approach had a number of strengths and weaknesses. The advantages were (Cohen et al. 2000):

- Quick to conduct
- Cheap to administer
- Limited control effects since respondents only participate once
- Stronger likelihood of participation
- Charts patterns provides a way to look at trends at single or multiple points in time.

The disadvantages were:

- Does not permit the analysis of casual relationships
- Comparability of data between groups could be difficult due to different sample group backgrounds
- Comparisons must be planned in advance (Oppenhiem 1999)
- Omission of a single variable can undermine results
- Only permits the analysis of overall 'net' change through aggregated data

On balance the advantages offered by adding a cross-sectional scenario-based interview onto a semi-structured interview were high considering the importance of validating the data gained against the research question. It should be pointed out that the scenario based interview shared some characteristics with survey approaches, particularly its generation of numerical data, and 'one-shot' data gathering. It differs, however, due to the small sample sizes available to the study, which makes statistical manipulation of

[53] See Chapter 4 for a definition of validity.

the data to make detailed relationships between variables (either individual to individual, or between events) difficult. The research question, however, did not require casual links to be identified since the tool could not be tested formally in the MLCE development process. It was more important in the study to ascertain whether the use tool was an acceptable way for participants to access more structured information about how MLCE was used. If the use tool was not an acceptable way for MLCE developers to access MLCE use information, it should determine why not (and indeed if developers really wanted use information) and how the information could be presented in another form (a 'Beta' tool). This was thought possible by asking the reasons behind the respondents' views on the tool's performance in a given situation. The numerical data would be used to provide a charted view of the trend as to where in the development process the tool would provide most benefit. Comparison between the individuals with the two respondent groups (developers and stakeholders) would have to be made cautiously given their likely differences in background. It was thought, however, to be possible to compare the trend between the two respondent groups and mine the interview data for insights on the trend variations and similarities.

Since the researcher had not used this technique before it was thought essential to pilot it, and test the suitability of the usage tool briefing material. If the briefing material could not easily provide the respondents with a good understanding of its use, then the outcome of the data capture would be limited. Piloting and then reviewing the approach (through a methodological review) was also thought to be an important step in the use of interviews to develop links to unknown potential participants suggested by interviewees, effectively a 'snowball' approach. This is an effective technique according to Oppenhiem (1999) when trying to sample a group with unknown or disparate characteristics. One must also be aware that such an approach uses a judgement sample (by the researcher), where usual sampling approaches, errors and estimates do not apply. Oppenhiem (1999) recommends some form of sampling frame, which one uses to judge people's responses. The sampling frame could also be added to by asking about the participants' backgrounds so that they can be placed within the respondent group, perhaps by whether they are design trained, by role, or length and type of experience in MLCE development. Additionally it was important that the tool was not 'oversold' since it may discourage people from giving it a fair and balanced evaluation, and limit the reliability of the research outcomes.

In order to look at the further possibilities offered by interviewing the research also considered group interview approaches such as joint interview (Gray 2004) and focus groups (see the next section). Use of joint (more than one participant present) interview approaches was thought important since from previous experience (Studies 5 and 7) it might be the preferred way for participants from the same organisation to be interviewed. This may be the case particularly where people have worked together for some time, or where it is important for members of the group to be aware of what others are saying (Watts and Ebbutt (1987) in Cohen et al. 2000: 287). Also group interviews can be quicker and create fewer disturbances for the participants. The advantages of being able to undertake joint interviews were: i) they facilitate the collecting of differing or corroborating perspectives, ii) they enable participants to fill in the gaps if information is omitted. The disadvantages are: i) participants can divert each other's attention, ii) one participant can dominate the interview. Watts and Ebbutt (1987) also note that follow up questions can be problematic if aimed at one of the participants, and that applying structural coding can also be difficult. Additionally in professional contexts it can be difficult to get the right group together at the time needed.

P.3 Focus groups

Focus groups are a form of discussion-based group interview which target a specific issue, set by the researcher, between the participants, rather than between interviewer (or moderator) and participants (Morgan 1997, Millwad 2000, Litosseliti 2003). The advantages and disadvantages of focus groups come from their contrived nature, in that they take place in an unnatural setting, with a small pre-selected group for a 'focused' discussion a specific topic (Morgan 1997, Bryman 2001, Wilkinson 2003). This means that focus groups can yield insights into a particular issue which were not previously known about, and they are also relatively economical. This should be tempered, however, with Stasser and Titus' (2003) findings that groups tend to focus on common issues. Focus groups can be used with other methods, and the data gathered analysed in a number of different ways (Morgan 1997). This was an appealing feature given the research question and sub-questions, since other methods would be needed to understand the issues raised by individual practitioners and get an indication of the level of improvement. Focus groups also raise the possibility of observing interactions between participants, a benefit of focus groups (Morgan 1997, Dugglesby 2005). It was thought, however, that looking at interactions between participants would not be easy to set up given the difficulties in getting developers to put commercial issues to one side.

Focus groups have been used within a design context to improve designers' empathic horizon and extend knowledge in specific design tasks (Bruseberg and McDonagh-Philp 2001), both of which were important in getting developers to look at the possibilities for the usage tool. A shortcoming in selecting focus group participants for this research, however, was that they all needed to have a background in MLCE; otherwise the discussion (and therefore the data arising from the focus group) would be unrepresentative. Since focus groups collect information from a group, detecting divergences, or the views of an individual with an interesting background, would only be possible from an examination of transcripts (Morgan 2002, Wilkinson 2003, Litosseliti 2003). This was a risk for using focus groups as an evaluative method, since the developers may not have homogeneity of background, given their different professional roles and experience. Another risk, which for the researcher discounted focus groups, was ensuring that participants would be comfortable to say what they thought, because of competitors being present. Experience from the conduct of the nominal group in study five and survey in study 6 (see Chapters 9 and 10) indicated that there were issues that industry would be reticent to discuss with government personnel present. Focus groups were not ideally set up to test ideas or provide a summary view of a topic given that results are usually stated using illustrative references (Bryman 2001, Wilkinson 2003), so would be unsuitable for managing a structured review of the tool, and to get into the research questions objectives and sub-questions. Litosseliti (2003) and Krueger and Casey (2000) also point out that determining consensus from a focus group can be difficult, which was important in understanding the views of the tool. Krueger and Casey also suggest focus groups should not be used where sensitive information which could be harmful to someone is needed, or where confidentiality may be compromised, as was a potential with the research questions for this study. So, while focus groups were appropriate to the evaluation of the tool from an illuminative perspective, there was low confidence that they could enable post-evaluation activity.

The final reason for discounting focus groups was the difficulty of getting appropriate groups of MLCE practitioners together who would be willing to give their honest views in the presence of competitors or customers. The researcher did consider using focus groups as a way to gather information from government personnel. However, since government personnel included developers and stakeholders, it was thought that backgrounds and perspectives would be too disparate to get data to answer the research question. Additionally there would be a high learning curve for the researcher in learning how to moderate a focus group session, which is often underestimated in focus group use (Millward 2000, and Wilkinson 2003).

P.4 Quasi-experimental approach

Design, put simply, is not like science (Cross et al. 1981) and so traditional 'scientific' hypothetic deductive methods were limited in what they offer to understanding design. Cross (2007) and Dorst (2008) have both recently noted that design is a phenomenon that has escaped positivist definition to date (see Chapter 4, section 4.3). Dorst (2008) places more focus on understanding design practice than improvements to design processes, which is where he argues most design research has been focused. The studies in this research have to date focused largely on two of Dorst's four *thought experiment* descriptive elements of design; design process, and the context of MLCE. In considering Dorst's (2007) viewpoint, the researcher decided if possible to look at the other two descriptive elements (design actors[54] and object[55]), should the opportunity arise, to develop his own perspective on Dorst's view. A quasi-experimental approach may have provided a framework for showing the impact and differences on MLCE development processes and if possible gain insights on the designer (actor), and design problem and solution (object).

Two options possible that quasi-experimental methods were explored for this study (see Annex A to Appendix O) were only appropriate for looking at focused stages of the development process. To answer the research question, however, it was important to look at how the tool could be used across the whole design process, before looking at specific aspects of the design process. Only when the specific aspects of the design process where the tool may have utility had been found, was a quasi-experiment approach thought to be of use. An example of this might be the representation of soldiers in the tool; once developers had confirmed whether soldier representation would be useful and where in the develop process it would be used. Additionally two

[54] Actor = designer

[55] Object = design problem and solution

studies had been found in the literature (Fricke 2001, and Dahl and Chattopadhyay 2001) which could beexemplars for future research.

P.5 Expert review

A method which could answer the research question was to review the utility of the tool with experts in the field of MLCE development, either as developers or stakeholders. Expert reviews were well used in assessments of computer interfaces, and could take a number of forms (Schneiderman 1998, Pew and Mavor 2007), such as usability inspections, at various stages in the development process. Usability inspections were described as a courtroom-style meeting with a judge to go through the merits and weaknesses in the product (Schniederman 1998). This formal approach was problematic due to the immaturity of the use tool. Getting developers and stakeholders to review the tool was, however, a form of expert review embraced by Pew and Mavor (2007) which could be regarded as a form of participatory assessment (Sinclair 2005).

P.6 Summary

Method	Summary Notes	Methodological References	Method
Observation	*Observe people using the tool* – an observation approach needed a developed tool. Observation would also be a part of other analyses, to note people's 'unspoken' view of the tool in gestures and manner.	Kuniavsky 2003, Bisantz and Drury 2005, Ylirisku and Buur 2007	**Observation**
Interview	*Ask developers questions about the tool* – interview methods, particularly the use of a 'scenario-based interview' to check participants' views of the tool within the design process, were viewed as the best way to evaluate the 'Alpha' version of the tool. Although the sample of participants was likely to be small compared with other studies, the results were thought to be valid if viewed as an expert review of the tool. It was also decided to use an interpretative approach to analysing the feedback to enable the participants' perspectives and backgrounds to influence the analysis. This method also overcame confidentiality issues present with Focus Groups, and enabled the researcher to build a rapport with participants to get them to volunteer relevant information and feedback on the tool and MLCE development.	Oppenhiem 1999: 67, Smith and Osbourne 2003, Smith 1995, Willig 2001, Bryman 2001: 124, Wilkinson 2003: 196, Silverman 1993, Gray 2004, Althedie's (1996) in Bryman 2001, Silverman 2000, Millward 2000, Spear 2008, Carrol 1995, Crouch and Housden 2003, Stasser and Titus 2003, Cohen at al 2000:113, Watts and Ebbutt (1987) in Cohen et al 2000: 287	**Interview**
Focus Group	*Ask a group of developers questions about the tool* – focus groups were not used as a method, because of the difficulty of getting participants together at the same time, and the necessity of getting participants to open up to the researcher.	Morgan 1997, Litosseliti 2003, Bryman 2001, Wilkinson 2003, Stasser and Titus 2003, Morgan 1997, Dugglesby 2005, Krueger and Casey 2000, Millward 2000	**Focus Group**
Quasi-Experimental Approaches	*Determine differences between tool and no tool use by application of the tool in a 'design exercise'* – quasi-experimental methods were considered, but not adopted due to the relatively undefined role for the tool within MLCE development. They were simply not appropriate at this stage in the development and research into the tool.	Cohen et al. 2003: 215, Cross et al.1981, Robson 1993	**Quasi-Experimental Approaches**
Expert Review	See interview.	Schneiderman 1998, Pew and Mavor 2007, Sinclair 2005	**Expert Review**

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Annex A to Appendix P: Quasi-experimental approaches

It should be pointed out that the form of experiment for the study was not seeking to control all of the variables impacting on the use of the tool as in the hypothetic deductive paradigm, hence the qualifier of quasi-experimental. The researcher also had concerns given the relative immaturity of the tool that the level of insight provided by quasi-experimental methods would enable the development of the tool at this stage. However, it was felt important to explore a quasi-experimental approach to assess its suitability for answering the research question, and determine its place as a method for developing or validating the tool.

Quasi-experimental approaches have been used in design research studies to explore the impact of design methods on design processes. For example Radcliffe and Lee (1989) used an experimental video protocol to assess design methods used by undergraduate engineering designers. A number of the methods used by Radcliffe and Lee would be appropriate to this study if the tool was thought to be sufficiently mature to be used by a sample group of novice MLCE designers. Since the tool at this stage was still in its 'Alpha' version this would only be possible using the initial dataset available to the tool (three instances of MLCE use). The way in which a quasi-experimental study was thought possible was as in other design studies (Radcliffe and Lee 1989, Dahl and Chattopadhyay 2001) by giving a focused design brief which could allow the mature aspects of the MLCE tool to be used. There were however dangers with this approach in that the design brief was likely to favour the tool's abilities in order to enable the use of the partially developed 'Alpha' version. For example the design brief calls for specific knowledge that can only be found using the tool or by being an experienced MLCE developer.

Reflecting on Cohen et al. (2003) seven steps to quasi-experimental research, further limitations were found:

a) Identify and define the research problem as precisely as possible.

b) Formulate hypotheses to test, making predictions about the relationships between variables. (Including how they can be measurable.)
c) Select appropriate levels at which to test the variables to determine an observable difference.
d) Give thought to the population about which one wishes to generalise to (sampling methods).
e) Choose appropriate instruments for testing and analysis.
f) Pilot the approach.
g) Follow the outlined protocol to the letter.

The principal issue found was that (b) was hard to address within the study, since making accurate predictions about the relationships between the variables was almost impossible given the broadness of developers' backgrounds and processes used. And although novices were thought to a more suitable population to look at (d), there was no guarantee that they would necessarily approach the use of the tool in the same manner. Radcliffe and Lee's (1989) approach manages this problem by capturing design activity using video and sketches generated in the studio, but also by assessing the time designers spend doing certain activities. It should be pointed out that this was suspected to be very time consuming, not only in data capture, but also post analysis. Issue (c), was also thought problematic to address given the limited options for determining metrics for 'improvement' (see section 14.2.1), making it difficult determine the 'levels' at which variable could or should be controlled.

In order to explore fully the question of whether quasi-experimental methods were appropriate to answering the research question, or validating the tool, two possible options for a quasi-experimental approach were developed. Figure shows the two possible approaches and their simplistic sequences of enquiry.

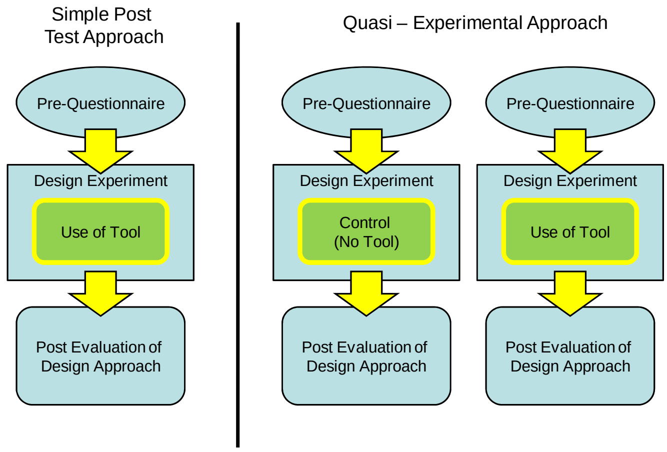

Figure P-1. Options for quasi-experimental evaluation.

Both of the additional approaches were quasi-experimental, although they varied with the degree of control over the variables and potential to meet Cohen et al.'s (2003) seven steps.

Simple Post-Test

Simple Post-Test (on the left of Figure P-1) was thought to be more limited than an idealised quasi-experimental design (on the right) having no comparison (control) group. Initially a Pre-Test was discounted since it was thought to be of limited use apart from determining that the participants had no previous MCLE design experience (the oval Pre-Questionnaire). The Post-Test could be achieved by assessing whether the intervention of the tool would have changed how the participants dealt with the design problem and whether the tool was beneficial. This could be done practically by a simple questionnaire, although short interviews to supplement the questionnaires were also thought useful. The simple post-test approach could also be used to pilot the quasi-experimental approach.

The alternative to the simple post-test, which may have relevance to the study however, was to undertake a pre / post-test approach which measured the perceptions of the novice MLCE developers before and after exposure to the tool. The perceptions could be linked to the research objectives and sub-questions and focus on suitability of the tool, whether it was beneficial, and whether it made design activity better. This approach has been used by Hanna and Barber (2001) to assess the views of novice designers on the use of Computer-Aided Design (CAD) as a design medium. This study was, however, conducted over a week-long period (which was longer than the resources for the MLCE study would allow) which may have allowed the participants to develop their view during a longer design study. This could be looked at within a pilot study to establish whether this might affect the results from using the pre / post test. It was thought by the research, however, that a better approach would be to explore the issues that the novice designers brought out from using the tool.

Quasi-Experimental Options

The quasi-experimental options on the right of FigureO-1 had the addition of a control group (who would have no tool) to look at the difference between the two groups and give a comparative measure of whether the tool improved MLCE design. This option may allow one to see the differences the tool makes to the MLCE design more explicitly than that single pre-post test design. This design was essentially a simple two group design (Robson 1993) and could be done with a small pre-test with most focus going on the post-test. The difference between the two groups would be shown by the difference in time taken to achieve the design brief and in the quality of the outputs, similar in approach to Radcliffe and Lee (1989). This option was attractive in that the benefit of the tool, if present, should be evident; particularly in the time spend on different activities within the design process.

Random sampling

It should also be stated that an ideal (quasi-experimental) approach would have a randomised element to mitigate external biases. This would be difficult to control, again due to the potential influences on the participants, and so the two approaches above must be regarded as non-random. Requesting participants who have no experience of MLCE design may overcome this, if their experience with civilian load carriage equipment was checked during the pre-test.

Limitations with a quasi-experimental approach

The exercise of developing the two options for quasi-experiments was useful in that it demonstrated that a quasi-experimental approach was not appropriate for answering the research question. This was primarily because the method did not offer any benefits over other methods for amount of resources needed to apply it; both options would need to be small and focused to fit the resources of the study, which they were not. The fidelity of the use tool was also such that it was questionable as to whether it was at the stage where it could support the design activity which would be needed during a quasi-experimental design exercise.

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Appendix Q: Master IPA themes table

This appendix contains the transcribed quotes and coded themes from the semi-structured interviews with the panel of specialists who evaluated the tool as a part of Study 8. This table formed the basis of the Interpretative Phenomenological Analysis (IPA) reported in Appendix Q.

Thesis Link: Chapter 12, section 12.3

Participant	Serial	Theme	Reference	Quote
T1: Insight into the context of soldier work and activity				
D1	1	Insight from soldiers		'..to see whats going on here'
D1	2	Part being done by soldiers, tasks part by specialists (HF or otherwise)		
D1	3	Discovery through insight from soldiers		
D2	2	Soldiers have thier own individual preference as to where they carry equipment	05:02	
D2	10	Insight of soldier activities	15:46	'Gives good insight into the conditions, the areas they are working in, and the difficulties'
D2	11	Insight of soldier activities	16:02	'We know about vehicles, but we don't get to see buildings and the restrictions they work in'
D2	13	Insight of soldier activities	18:08	'..[The tool] gives sight of how they configuring, loading and using...'
D2	21	Physical aspects of the product	25:36	
D3	1	Representing soldier activities	20:26	'We often have to present to designers / contractors the soldier tasks, and the transition from one posture to another'
D3	10	Useful for Human Factors people to set the equipment in context	26:08	
D4	3	Valuable in showing users use of MLCE	31:21	'I think what is often missing is how the end user uses the product'
D4	6	Informing about physical environment	34:08	'..good for that kind [looking at physical environment] of education'
D4	17	Understanding MLCE tasks	39:06	'I didn't really appreciate the scenarios it [MLCE] would be used in'

Participant	Serial	Theme	Reference	Quote
T1: Insight into the context of soldier work and activity – continued				
D4	18	Expectations of soldiers by others	39:47	'Helps appreciate what they are expected to do'
D4	20	Soldier voice	41:18	'They [soldiers] don't get to voice this'
D5	1	Determining what soldiers carry and why is not clear	19:02	'There is a mythology [with MLCE load carriage] with what they [soldiers] carry'
D5	3	Military experience to do the analysis	43:04	'You have the ability to scrutinise that'
D5	11	Amazement at what soldiers do	55:45	'When I saw that video clip [exhale of breath - can't believe the soldiers are doing it]
D5	41	Look at whole use context	02:07:52	'Got to consider the whole environment'
D6	20	Increased awareness	35:20	'Increasing the awareness makes a big difference'
D6	21	Increased awareness	35:56	'Video by itself is good, the analysis takes it to a different level'
D6	22	Increased awareness	36:01	'[Analysis] makes it more of a level playing field'
D6	23	Increased awareness	36:30	
D7-9	1	Insight into MLCE use	09:10	'To see how they [MLCE] is being used, is always a good tool'
D7-9	2	Insight into MLCE use	09:50	'We're always talking about what we see [on the news]'
D7-9	13	Insight into MLCE use	13:01	'We never get any information about use, or what they are doing'
D7-9	16	Insight into MLCE use	15:13	'Are they using the equipment as it was designed?... Are they mixing and matching?'

Participant	Serial	Theme	Reference	Quote
T1: Insight into the context of soldier work and activity – continued				
D7-9	17	Insight into MLCE use	15:58	‘We don't know what he needs to carry in that clip'
D7-9	24	Tool helps inform other project information	19:53	
D7-9	25	Soldiers don't appear to be wearing things correctly	21:07	
D7-9	18	Insight in to MLCE use	16:23	‘What we don't get... is a load list'

Participant	Serial	Theme	Reference	Quote
T2: Helping set the right requirements				
D1	6	Use tool to show key requirements	03:58	
D1	7	Can justify the requirements as a part of systematic approach	04:07	
D1	14	Enables tighter requirements	05:10	'Gives tighter requirements in the first place'
D1	38	Helps soldiers set requirements	21:43	
D1	37	Defending requirements	20:33	'Could use to defend requirements to keep them in...'
D1	8	It shows interactions between load carriage and other in-theatre kit	04:13	
D1	44	Potentially produce better MLCE	25:45	'Key is to get requirements right, if users are good it won't be a problem, this helps them identify the right issues'
D2	1	MLCE designed to be adaptable	04:50	'Pouches are design to be reconfigurable to allow them [soldiers] to enable them to move the pouches where they want
D2	3	Soldiers will optimise for most tasks rather than all tasks	12:24	'They may be prepared to put up with some shortfalls to do a 2-minute task'
D2	12	Requirements from user don't give context	17:14	
D2	14	Many different opinions	18:13	'Oh they don't do it like that in-theatre'
D2	15	Opinions on how to do things	19:30	'Often based on one persons opinion'
D2	16	Opinions not representative	20:23	'Often based on one persons opinion... Not, in my opinion the right way to do it'
D2	22	Opinions on how to do things	26:10	'We have to go on their [a soldier's] opinion'

Participant	Serial	Theme	Reference	Quote
T2: Helping set the right requirements – continued				
D2	23	Used as evidence of use	27:35	
D3	3	Need to convince people	20:45	‘Helps to be able to convince them... Give them examples exactly like this [the tool]'
D3	4	Use as evidence	21:15	‘Reference [the tool] as case studies'
D3	8	Summary of user activity to get examples (key words)	23:20	
D3	15	Justification that an activity happens	29:15	‘Worth generating some clips which aren't based on in-theatre clips'
D3	19	Justification that an activity happens	31:15	
D4	8	Identification of wider issues	34:36	‘It [the tool] lends itself to a more open minded approach'
D4	10	Influences on user opinion	35:27	‘There are so many influences on users' opinion'
D4	12	The video is what it is	36:13	‘Videos don't bring their own biases'
D4	19	Decisions on what is carried	40:13	‘Helps to know what conversations went on to decide what they [soldiers] carried'
D5	12	Outdoor expert users did not analyse	55:50	
D5	13	People focus on task not things	58:20	‘People who do activities are not accustomed to thinking, they are accustomed to thinking very hard about what they are doing'
D5	34	Voice tracking opinion of user	01:53:12	
D5	37	Senior stakeholders may not understand	01:59:01	‘Just because someone has rank, doesn't mean they understand'

Participant	Serial	Theme	Reference	Quote
T2: Helping set the right requirements – continued				
D6	2	Experience of use important for meeting requirements (assuming the requirement is known)	03:15	'Design life, as in no one buys it, and those that do buy it decide they shouldn't have bought it, because the design does not relate to the requirements for the product'
D6	24	Primacy of manufacturing and design skills over military experience in MLCE development	37:20	'[The tool] makes the design relevant to now'
D6	28	Military MLCE needs to fulfil a lot of specific tasks	42:03	
D7-9	3	Opinion and agenda	10:01	'Everyone has their own opinion'
D7-9	4	Opinion and agenda	10:03	'They all have their own agenda'
D7-9	12	Design brief can be varied	12:20	'We get a wish list from the user... It could be anything'
D7-9	19	Questioning the requirement	17:20	'We will offer the best solution that will solve the problem'

Participant	Serial	Theme	Reference	Quote
T3: Getting people to a common understanding about soldiers				
D1	9	Used in initial commercial stages to show current kit to potential contractors	04:28	'Show them scenarios to get a more informed debate earlier on'
D1	11	Companies with no previous experience in it	04:50	
D1	12	Companies with experience can get it wrong	04:56	'Experienced companies still go off the mark'
D1	15	Better illustrations	05:16	
D1	18	Basic video of people putting on all their kit	05:58	'Helps people understanding the layering'
D1	20	People may not know what vehicle platforms look like	06:48	'Like what hatches and doors there are
D1	29	People do not understand soldiers	13:11	'It sounds silly, but helps with knowing what a soldier looks like'
D1	50	Tool gives a picture, rather than one creating ones own	39:10	
D1	56	Need to give designers more clarity	51:35	
D1	4	Analysis cannot be done from outside	03:31	
D1	5	Analysis not possible without insight into how equipment is used	03:36	'It's like the comms bit that you've [the researcher] drawn out, joe bloggs couldn't have drawn that out'
D1	27	Could give you a range of issues you would take to a soldier(s) for checking	12:25	
D2	9	Helps understand written info	15:26	'Adds pictures to the words'
D2	4	Insight of soldier activities	13:52	'It [the tool] gives more insight into the activities and roles that soldiers do...'

Participant	Serial	Theme	Reference	Quote
T3: Getting people to a common understanding about soldiers – continued				
D2	5	Insight into soldier activities	14:06	‘We know roughly what they are doing but don't really have a great deal of detail...'
D2	20	Another form of communication	23:58	‘People sometimes can't portray what they mean in the written word'
D2	24	People don't understand that loads change a lot	28:15	‘The necessities of the job require them to carry more than people think'
D2	34	Visual understanding	43:34	‘It [the tool] gives you a visual'
D3	12	Understanding what soldiers do	28:10	‘I’ve been through this before, using a hierarchy, to then walk through scenarios'
D3	13	Improves the ability to check hierarchy understanding	28:45	‘This definitely a lot better than what we had before, which is nothing at all'
D3	27	Understanding what soldiers do	41:27	‘Definitely would help, much more than you currently get at the moment, when you're experienced you can pull a lot more out of it'
D3	36	Visual understanding	48:03	‘Everyone has a different picture in their head as to what’s happening'
D3	30	Visibility of problem	44:42	‘If the problem is visible you can access it'
D3	2	Understanding what soldiers do	20:40	‘Difficult for them [designers and contractors] to get their head around this large generic hierarchy'
D4	1	Little data available	10:04	‘There doesn't seem to be much data out there on the things that should be considered'
D4	2	More information needed on sub-components	10:29	‘Need more individual data that can be used by designers'
D4	13	Helping a novice	37:28	‘This would help an uneducated designer'

Participant	Serial	Theme	Reference	Quote
T3: Getting people to a common understanding about soldiers – continued				
D4	21	Evidence of use	42:05	
D4	23	Visualisation of use	42:25	
D4	31	Helps with designer understanding	50:34	'It helps to see the operator [soldier] in the environment they're expected to operate in'
D4	34	Designer education	54:04	'Would help in educating designers'
D5	2	Firms don't understand user needs	29:17	'They [a and b firms] didn't know how to connect to the end user'
D5	5	Advent of Product Managers and activist designers	51:25	
D5	6	Designers don't have activitist knowledge now	52:10	
D5	7	Gives more information	52:50	'I didn't think I'd be saying yes [to the tool]'
D5	8	Training novice designers	53:20	'Giving one-to-one design tuition
D5	9	Formal design training only helps so far	54:03	'A design degree doesn't give you experience, it gives you a methodology, but not experience'
D5	21	Dangerous to assume you know the consumer and how to use them	01:25:35	
D5	23	Use changes over time	01:29:45	'New concepts in society'
D5	25	Innovation only possible if people understand problems	01:31:55	'A network that recognises that some problems and expertise can shift to a different place'
D5	28	Start point of understanding	01:26:45	'The tool is the start point of understanding'

Participant	Serial	Theme	Reference	Quote
T3: Getting people to a common understanding about soldiers – continued				
D5	38	Scenarios to communicate to different military stakeholders	01:59:57	'People from different services to your tool things there'
D6	1	Limited experience of use leads to limited design	02:45	'That is a major challenge [designers having little experience of use]. We have seen that, just looking at the outdoors [industry] as a whole. We see that in teams and we can tell that teams are technologists and they are designers, but they are not users. And what they end up producing has a very limited design life, if that's a polite way of putting it.
D6	6	Military pack development is done it two ways; either military do it (no experience of design or production), or designer does it (little experience of military)	23:28	'That [the tool] looks like a good link between the tool'
D6	13	Tool helps identify hidden detail		'I think the analysis goes into the detail which would have not been spotted'
D6	16	Design should be job focused	30:57	'You're trying to design something to do a job'
D6	25	How rapid do they need access to equipment	39:10	
D6	26	Adapt MLCE to enable better gait	40:13	
D6	27	In civilian arena one can do the activity	41:04	
D7-9	29	Seeing context would help	29:12	
D7-9	30	Understanding what a soldier does	29:42	'How can anyone not know what a soldier does'

Participant	Serial	Theme	Reference	Quote
T3: Getting people to a common understanding about soldiers – continued				
D7-9	31	More information is always better	30:06	‘Any information is good, but if he’s given nothing'
D7-9	32	Can choose to ignore information	31:11	‘Can't see any information being bad... Because you can choose to ignore it'
D7-9	11	Useful in early development stages	11:30	‘Get it [the requirement] into your head'

Participant	Serial	Theme	Reference	Quote
T4: Setting or doing evaluation and getting feedback				
D1	16	Specific scenarios to test against	05:22	
D1	17	ties development process together	05:30	
D1	25	Evaluating equipment	10:13	'Gives ties through requirements, development and assessment'
D1	46	Would give an indication of how to test	27:20	'Gives criteria against which to assess'
D1	51	Could highlight strengths and weaknesses	40:35	
D3	28	Evaluation of MLCE using scenarios	42:48	'Use scenarios to score and rate your own systems'
D5	17	Some people not right for thinking about MLCE development	01:14:36	'Right sort of person to give the feedback'
D6	14	Analysis tells you what the MLCE needs to do	29:06	
D6	17	Practical quality assurance	32:01	'First thing is function, second the numbers'
D7-9	6	Feedback on MLCE designs	10:13	any feedback is good'
D7-9	14	Question all the MLCE design aspects	13:45	
D7-9	34	Prototype success determined by evaluation	38:19	
D7-9	7	End user gives most valuable feedback	10:23	'If they [soldiers] come and give you feedback, that's the best'
D7-9	8	End user gives most valuable feedback	10:25	'They [soldiers] can physically show you'
D7-9	9	End user gives most valuable feedback	10:52	'We can sit around a table and design something but until that bloke [soldier] is running around a battlefield [you won't know]'
D7-9	10	End user gives most valuable feedback	11:19	'Theory is good but they [soldiers are] actually using it so their information has got to be good'

Participant	Serial	Theme	Reference	Quote
T5: Potential tool uses/ role				
D1	21	Use outside MLCE development	07:24	‘Could be used for a number of things [outside load carriage development] since it has the task analysis element to give analysis and video to give context
D1	22	Good for physical activity	08:02	‘Chows people getting up and down, would be better for dismounted stuff; running and moving, but also getting in and out of vehicles for vehicle design'
D1	23	Good for technology insertion projects	08:16	‘Where you've got existing interfaces, or contexts of use where you're inserting new technology so need to know what’s already there'
D2	7	Looking at interfaces	14:30	‘We have problems with integration... because x garment was not designed to be worn with y MLCE...'
D2	8	Experiencing known MLCE problems	15:08	
D1	32	Sanity check	17:55	
D1	34	Case Building	19:07	‘Depends on the level of case being made'
D1	36	Remote video	19:50	‘If someone had kit for two days, one could use it remotely to identify key issues, with caveats'
D2	6	Presence during soldier activity not needed	14:18	
D2	17	Controlled trial conditions	21:15	‘Controlled conditions not possible in-theatre'
D2	19	Remote access	23:28	‘A good tool for people who don't go to theatre'
D2	33	Remote access	41:20	‘If you can't get to the users, this would help'

Participant	Serial	Theme	Reference	Quote
T5: Potential tool uses/ role – continued				
D1	42	Useful to civilian load carriage	23:55	'Useful for looking at integration issue'
D2	25	Civilian use is very different	30:01	'Military use is completely different'
D2	26	Civilian use is very different	31:01	'MLCE has to integrate with far more pieces of equipment than civilian equipment'
D1	43	More useful in military environment	24:35	'There aren't many other environments or contexts of use which are so varied and complex'
D1	53	Tool isn't essential in generation of MLCE concepts	46:45	
D1	54	Tool needs to be coupled with other techniques if looking for casual links	48:05	
D1	55	Could use photo assessments using scripts/ annotations for quick assessments	48:50	'Could use frames from video... to highlight key issues'
D3	9	Use in understanding front loads	24:34	'Where can I get examples of this?'
D3	11	People will want to pick out the key clips they are interested in	27:45	
D3	17	Relevance to civilian arena	30:48	'Would be easier in a civilian context, certainly easier to get hold of the footage'
D3	20	Frequency that tasks occur	31:48	'As much in the portfolio as possible'
D3	29	Use of tool scenarios to model MLCE product	43:35	'Information you can use to model your product'
D4	5	Use of 'experts' to analyse the video	33:49	
D4	7	Interpretation of issues into the design spec	34:28	'Its difficult to interpret the issues that exist into the design spec really'
D4	9	Brings more creativity to the problem	35:14	

Participant	Serial	Theme	Reference	Quote
T5: Potential tool uses/ role – continued				
D4	24	Helps understand human factors	45:00	‘It’s [the tool] a very human centred approach, you can see what’s happening'
D4	26	Explaining the tool	46:18	‘Useful to have someone to explain how it [the tool] should be used'
D4	27	Less useful to civilian arena	46:43	‘Soldiers have to do a more varied number of tasks than a civilian'
D4	28	Less change in civilian tasks	47:31	‘[Civilian] tasks are less dynamic than for the military'
D4	30	Spatial analysis useful for looking at frequency of interaction with MLCE	50:06	
D5	4	Experience of having to mentor a young designer	49:25	
D5	20	Could be used in civilian arena	01:24:40	
D5	33	Useful to aid understanding, not design	01:45:02	‘Tool helps understand use, but not pack design'
D6	3	In civilian arena one expects designers to have experience	03:35	'You wouldn't expect it to be like that [designers not having much experience of use], you'd expect a very strong input from [users]...'
D6	8	Access of designer to the military environment	26:30	‘Designer cannot go into the field [in-theatre], it’s just not practicable'
D6	18	Focus on to the job MLCE has to do	33:57	‘Makes them [designers] focus on what they've got to do'
D6	29	Design should be job focused	43:57	‘Pure design function can get overdone and we lose sight of the end use'

Participant	Serial	Theme	Reference	Quote
T5: Potential tool uses/ role – continued				
D7-9	27	Good for physical performance equipment in civilian arena	24:01	

Participant	Serial	Theme	Reference	Quote
T6: Tool use concerns				
D1	30	Video is retrospective	13:45	'When you design some things, you have to think beyond current stuff'
D1	31	Cautious of use	16:50	'Be worried about overhead to get it set up'
D1	33	Overhead	18:34	'[I am] concerned about how much video would be needed'
D1	35	Amount of video needed	19:42	'[One] needs to be careful about getting those bits [identifying why something happens] perfect, need to keep to the high level'
D1	26	Needs care in getting into why things happen	11:30	
D2	32	Causal identification of problems	37:45	'Can't see the physical close up fit'
D1	52	Beware of using different context of uses	44:22	'Putting the same people and equipment in a different context, can get different problems and issues'
D3	16	Validation of clips	30:08	
D3	21	Inherent problems video	32:10	'Inherent problem with video is to access the clip you need'
D3	22	Resourcing the tool	32:50	'Initial resource to get the video 'ready' then it would be very useful'
D3	24	Casual linking to comfort	36:47	'Doesn't necessarily give you the feedback on comfort'
D3	25	Knowing what the tool does	37:22	'Got to be aware there are some aspect that you can't pick up'
D3	26	Biasing design	39:55	concerned that you'll design for a different balance of use'

Participant	Serial	Theme	Reference	Quote
T6: Tool use concerns – continued				
D4	4	One example isn't representative	31:45	
D4	14	Use in detail design may be limited	37:43	'Not sure how much you'd get that you could use'
D4	25	Naive viewer could misinterpret	45:30	'I think you can also miss a lot from a users point of view, if it was used by a naive audience'
D4	29	Cognitive aspects limited	48:13	'There is a cognitive side your missing [with the tool]'
D4	35	Access to personal equipment needed in tool	09:45	
D5	24	Loss of information in organisations	01:31:27	
D5	39	Explaining what drives design	02:00:07	'Here's the scenarios we're designing in'
D6	9	Time to consider the tool outputs needs to be refined	26:40	
D7-9	26	Tool not good for human factors of MLCE	23:12	
D7-9	36	More detail needed	41:32	'Would need more detail [from the tool to use throughout development]'

Participant	Serial	Theme	Reference	Quote
T7: Identify and clarify issues which can prevent successful MLCE				
D1	24	Could deal with a range of questions	09:07	'Could answer, what are the key issues, assessing existing kit, getting them [soldiers] to run through their core skills...'
D1	28	May highlight things which may be issues	12:38	
D1	39	Could identify HF MLCE issues although prior knowledge needed	21:00	'Need knowledge to know what to look for'
D1	40	Helps facilitate understanding HF of MLCE	21:43	
D1	41	Helps to prioritise HF MLCE issues	22:10	
D1	45	Users don't think about the wider issues	25:30	'They don't identify the 25% issues which pop up at the end and are the show stoppers'
D2	35	Checking MLCE is being used as it was designed	44:59	
D3	18	Insights into soldier activities and use of MLCE	31:09	'Can be used to support more specific studies'
D4	15	Signposting	37:51	'Good for signposting you in a direction'
D4	16	Prompting further study	38:02	'Good for prompting further investigations'
D4	11	Problems can be from something which doesn't affect the whole user community	35:41	
D5	18	Environmental information needed	01:16:28	
D5	19	Theatres and roles needed	01:23:35	
D5	10	One either has access to users or one needs to have done the activities	54:52	'As soon as you go out of every day touch, you need some experience
D5	14	Health and safety blocking designers experiencing soldier environment	01:03:53	'Your tools are vital [for understanding soldier environment if you can't get on exercises]'
D5	26	Cannot work on short-term approaches	01:34:02	
D5	27	Cross-over products may be way forward	01:35:32	

Participant	**Serial**	**Theme**	**Reference**	**Quote**
T7: Identify and clarify issues which can prevent successful MLCE – continued				
D5	29	Frustration with process	01:37:04	'Future is b****r all to do with us designers'
D5	30	Long product life cycle won't bring innovation	01:38:06	
D6	32	Need to gain video during investigations	01:00:01	
D6	33	Need to look at interfaces with other equipment	01:01:47	
D6	37	Need to have different sizes of people	01:36:40	
D6	38	Get intuitive nature of the product by observing people using it	01:37:01	
D6	15	Defence Organisations specify and buy MLCE knowing they will have to change it	30:02	'Specifier has specified how it is to do things, not what it is to do, so they end up with something that doesn't do it'
D6	34	Over-specification produces the cheapest option	01:08:29	'Don't get commitment from them [defence organisations] so the products aren't as good'
D6	35	Use of cardinal point specification loses the benefits from development	01:11:03	
D6	36	Over-specification produces the cheapest option	01:12:41	
D7-9	5	Evidence use	10:11	'Gives you a better view of how to balance it [what you are hearing]'
D7-9	28	Specifications provide little information	28:46	'Specs we get these days [from a defence organisation] are so basic, it's a list of materials and a wish list'
D7-9	33	Physical movement critical to back system development	32:03	

Participant	Serial	Theme	Reference	Quote
T8: Impact on development process				
D1	10	Able to tie the design down much quicker	04:46	
D1	13	Iterations still needed, but not as many	05:06	
D1	47	Helps to reduce the misfit between requirement and what is delivered	27:32	
D1	48	Might make earlier process longer	28:05	'If you spend at the front end, you are more likely to get it right at the end'
D1	49	Would make the process tighter	24:40	'Would get what you wanted quicker'
D2	27	MLCE would be better designed	32:05	'Gives a greater understanding of the role'
D2	28	Supports MLCE development	32:43	'Would add extra information into the pot'
D2	29	No reduction in time	32:52	'I don't think it would reduce time'
D2	30	Get a better MLCE product	33:12	'The more information one's got the better the end goal would be'
D2	31	Impact on MLCE development	33:29	'The same stages would be needed'
D3	5	Use in design decision making / Use as evidence	22:06	
D3	6	Use as a walkthrough scenarios to check design	22:20	
D3	7	Search through to get answers to design questions	22:48	
D3	14	Justification of human factors	29:03	'Yeah helps to understand the human factors of load carriage and justify it'
D3	23	Integration represented	35:50	'Integration aspects, gives a lot of feedback on postures'
D4	22	Lack of information to inform design	41:42	'People don't have correct information'

Participant	Serial	Theme	Reference	Quote
T8: Impact on development process – continued				
D4	33	Right first time	52:55	‘I think it would help get a product more right first time'
D5	15	Gaining consensus is the longest part of the development process	01:06:16	‘Longest process [in development] was on gaining consensus
D5	16	Innovation comes from the whole system (not just physical artefact)	01:10:02	
D5	22	Cover physical actions and sociological aspects	01:27:49	‘Success of products depends on social context'
D5	31	Useful in early process	01:38:56	‘It [the tool] does speed the initial process, but it’s not the way the product ends up on the soldier’s back'
D5	32	Keep the development moving	01:40:40	‘Keep the development dance moving'
D5	35	Skill of pack developer still is key	01:56:58	
D5	36	Own design processes	01:58:15	‘I don't know how I do it [manage all the design information in design], I exact it and find what really counts'
D5	40	Tool won't stop people going down wrong avenues	02:06:27	‘Unless you have an experienced team you'll go all over the place'
D6	4	Focus from another military organisation on long-term value for money	05:50	

Participant	Serial	Theme	Reference	Quote
T8: Impact on development process – continued				
D6	5	Tool improves their process	21:07	'[The tool analysis] is extremely good, and if could have had that with the stuff I mentioned, then I think we could have done an even better job'
D6	7	Loose benefit of the knowledge of materials and production in design through over specifying	25:30	'The designer gets a better feel [through the tool]'
D6	10	Challenge to get tool into the process	28:05	'Need to make the benefits of the tool real, is one of the major challenges'
D6	11	Has to be done as a part of the induction to the project	28:40	
D6	12	Would not be best sent to designers	29:02	
D6	19	Design should be job focused	35:02	'It would help to make the design to better suit the end useage'
D6	30	Tool wouldn't impact timelines	44:59	
D6	31	Tool enables getting a more appropriate product earlier in process	45:45	
D7-9	35	Tool broadly supportive throughout development	40:56	'It helps in every [design] scenario'
D7-9	15	Design is a compromise	14:02	'Like anything its compromise [design of MLCE'
D7-9	20	Development examples	17:58	'We are a pick and mix to a degree'
D7-9	21	Can reuse designs	18:10	'There isn't much that hasn't been done before'
D7-9	22	People ask for the same things	18:29	'Someone else has asked for it before'
D7-9	23	Some innovation needed	19:16	'With a bit of something new'

Appendix R: Theme output

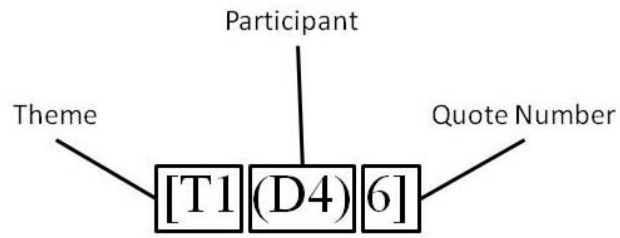
In order to report the comments made by the tool review panel, participant comments were analysed and transcribed into themes (reported in Appendix P). This appendix presents the themes and associated analysis, with supporting comments from the participants.

Thesis Link: Chapter 12, section 12.3

This Appendix reports the findings from the participant interviews conducted to determine the utility of the 'Alpha' use tool in MLCE development. The findings are presented by themes, derived from an interpretive sorting of participants comments, detailed in Appendix P. The themes were:

T1	Insight into the context of soldier work and activity
T2	Helping set the right requirements
T3	Getting people to a common understanding about soldiers
T4	Setting or doing evaluation and getting feedback
T5	Potential tool uses/ role
T6	Tool use concerns
T7	Identifying and clarifying issues which can prevent successful MLCE
T8	Impact on development process

Quotes link to Appendix P are as follows:



R.1 Insight into the context of soldier work and activity

All the participants and stakeholders said they liked the tool because it gave insights into the context of soldier work, and the activities that soldiers had to do. The physical environment in which soldiers operated appeared to be of particular importance:

> '... good for that kind [looking at physical environment] of education' [T1(D4) 6]
>
> 'Gives good insight into the conditions, the areas they are working in, and the difficulties' [T1(D2)10]
>
> '... got to consider the whole environment' [T1 (D5) 41]

The need for physical environment information was also linked to understanding the impact on the human by environmental factors such as temperature and humidity. This was thought to be a gap in the tool, unless it could be linked to metrological data taken at the time the video was taken (difficult to achieve). Participants and stakeholders were also keen on understanding how MLCE was being used by soldiers, since once an MLCE went into service they had no motion of whether it was used as the developers had intended:

> 'Are they using the equipment as it was designed? ... Are they mixing and matching?' [T1 (D7-9) 16]
>
> 'To see how they [MLCE] are being used, is always a good tool' [T1 (D7-9) 1]
>
> 'I think what is often missing is how the end user uses the product' [T1 (D4) 3]
>
> 'I didn't really appreciate the scenarios it [MLCE] would be used in' [T1 (D4) 17]

Interesting and insightful comments which individual participants stressed were:

> 'Video by itself is good, the analysis takes it to a different level' [T1 (D5) 21]
>
> 'They [soldiers] don't get to voice this' [T1 (D4) 20]

The former comment was made by a developer with over ten years experience in the outdoor industry and twenty years in the military, and so had particular weight. He said that the video was insightful, but the analysis, for him, gave particular power to the tool. For him the tool was important for people with and without military experience, since it enabled both to become up-to-date with how MLCE was being used. The second comment, made by an experienced human factors consultant who had worked on a

MLCE development project, raised how, in her experience, soldiers did not get the opportunities to raise the detailed problems they experience with their MLCE.

R.2 Helping set the right requirements

Helping to set appropriate requirements was thought by all participants to be an important role for the tool. The over-riding facet of this theme was the reliance of non-soldier developers on soldier opinion in requirement formulation:

> 'Often based on one person's opinion... Not, in my opinion the right way to do it' [T2(D2)16]
>
> 'We have to go on their [a soldier's] opinion' [T2(D2)22]
>
> 'There are so many influences on users' opinions' [T2(D4)10]
>
> 'Everyone has their own opinion' [T2(D7-9)3]

There was an undercurrent from participants' comments and body language that they were not happy with this approach since they felt that they were not receiving the most reliable basis for MLCE development. All the stakeholders interviewed also sited this as a concern, not just in MLCE development, but in other defence systems development that they had been involved with. As one highly experienced developer explained it:

> 'People who do activities are not accustomed to thinking [critically], they are accustomed to thinking very hard about what they are doing' [T2(D5)13]

A number of participants thought the tool could address this issue by providing reliable evidence upon which to base requirements (alongside military opinion):

> '... gives tighter requirements in the first place' [T2(D1)14]
>
> '... key is to get requirements right, if users are good it won't be a problem, this helps them identify the right issues' [T2(D1)44]
>
> '... reference [the tool] as case studies' [T2(D3)4]
>
> 'It [the tool] lends itself to a more open-minded approach' [T2(D4)8]
>
> '... helps to know what conversations went on to decide what they [soldiers] carried' [T2(D4)19]

One stakeholder, who was responsible for getting feedback from soldiers from operational theatres, also said the tool would be very useful to triangulate the insightful information they received from reports and interviews conducted with units.

Additionally some participants felt that the tool would help frame their MLCE solutions against current requirements:

> '... [the tool] makes the design relevant to now' [T2(D6)24]
>
> '... helps to be able to convince them ... Gives them examples exactly like this [the tool]' [T2(D3)3]

R.3 Getting people to a common understanding about soldiers

The participants were strongly in favour of the tool being able to get people to a common understanding about the context of soldier activity. This was thought to be a separate requirement to getting insights about the context of use and directed at establishing a common view on a project about the soldier environment:

> '... everyone has a different picture in their head as to what's happening' [T3(D3)36]
>
> '... the necessities of the job require them to carry more than people think' [T3(D2)24]
>
> '... [the tool] definitely would help, much more than you currently get at the moment, when you're experienced you can pull a lot more out of it' [T3(D3)27]
>
> 'Would help in educating designers' [T3(D4)34]
>
> 'They [a and b firms] didn't know how to connect to the end user' [T3(D5)2]
>
> '... get it [the requirements] into your head' [T3(D7-9)11]

One of the most interesting comments was the last one, where one of the most experienced developers (with over thirty years of MLCE development experience) felt the tool was important to the design team understanding all the information about what was needed from the MLCE. This developer also added:

> '[I] can't see any information being bad ... Because you can choose to ignore it' [T3(D7-9)32]

The more experienced developers from the civilian arena also made a number of comments about shortfalls they had had with designers with formal design training:

> 'A design degree doesn't give you experience, it gives you a methodology, but not experience' [T3(D5)9]
>
> '... that is a major challenge [designers having little experience of use]. We have seen that, just looking at the outdoors [industry] as a whole. We see that in

> teams and we can tell that teams are technologists and they are designers, but they are not users. And what they end up producing has a very limited design life, if that's a polite way of putting it ... design life as in no one buys it, and those that do buy it decide they shouldn't have bought it, because the design does not relate to the requirements for the product.' [T3(D6)1]

Both developers were not formally trained designers, but regarded experience or extensive knowledge of the military environment as being critical to the ability to develop marketable products. This later comment was also confirmed by a stakeholder interview with developer specialists from an international garment manufacturer. They added thatthe tool would be very useful for communicating to their colleagues about the need for specific research projects to meet a perceived market need. In the military environment both recognised that getting experience or knowledge was difficult, partially because, like in other design areas, the context changes, particularly as new battlefields are experienced. Both thought that the tool, if appropriately developed, could address some of the knowledge gaps some design teams had; indeed one thought it essential to do so.

R.4 Setting or doing evaluation and getting feedback

An unexpected role for the tool which was raised by a number of participants was its possible use to set or support MLCE product evaluation. Although study 7 had identified the possibility of a tool being able to support evaluation, this was not thought a role for the 'Alpha' tool. The participants varied in how they thought the tool should be used, some noting that seeing soldiers using it for real would be a help. They also noted that the scenarios in the tool could be used to 'walk through' candidate solutions, in a similar manner as suggested by Suri and Marsh (2000) and Carroll (1995).

Q.5 Potential tool uses/ role

The number of uses for the tool, outside those discussed in other themes, was varied with the following being suggested:

> *Technology Insertion* – 'Where you've got existing interfaces, or contexts of use, where you're inserting new technology so need to know what's already there' [T5(D1)23]

Interfaces – ‘We have problems with integration ... because x garment was not designed to be worn with y MLCE ...' [T5(D2)7]

Identify Key Issues – 'Could use frames from video ... to highlight key issues' [T5(D1)55]

Frequency – ‘As much in the portfolio as possible' [T5(D3)17]

Product Modelling – 'Information you can use to model your product' [T5(D3)29]

Design Spec Interpretation – 'It’s difficult to interpret the issues that exist into the design spec really' [T5(D4)7]

Case making / Sanity checking – 'Depends on the level of case being made' [T5(D1)34]

Focusing Designers on end use – 'Pure design function can get overdone and we lose sight of the end use' [T5(D6)29]

Remote Analysis – 'If someone had kit for two days, one could use it remotely to identify key issues, with caveats' [T5(D1)36]

This last point was, however, dismissed by a UK Ministry of Defence staff officer, who had experience of getting information remotely from theatres of operation. He reported that there were procedures in place to achieve this and that requesting video information would be very difficult for front line units to do on top of their other tasks.

Reflecting on the four possible uses for a usage resource from stakeholders in study 7 (see Chapter 10):

1. Evaluation setting
2. Design and sub-component information resource
3. Human factors integration evidence resource
4. User perceived issues resource

The first, evaluation setting, is discussed at section Q.4. The others (2 – 4) were less clearly defined from the comments made by practitioners, but were partially covered. Some participants thought that they needed more information about the tool before giving more specific feedback, which may have limited feedback about these specific points.

Two participants did mention HFI evidence, which was due to their role as HFI practitioners, but other participants did mention that they would use the tool outputs for evidence basing.

Limitations of use in concept development

Participants were very clear that the tool would aid understanding of MLCE use, but its benefit was limited during concept generation:

> ‘Tool helps understand use, but not pack design' [T5(D5)33]

The participants thought that the tool would be highly useful, but would not help designers understand rucksack design. This may be explained by the relative backgrounds of the participants. The quotes above were from two experienced civilian pack developers, and raised the possible need for a different tool, but one that developers may be resistant to since it may supplant their expert knowledge and experience.

Use in military and civilian arenas

Most participants had a common view about the differences between the context of civilian and military activity. They believed that the military environment was more complex, and harder to develop MLCE for, because of the high number of specific activities which soldiers had to do. Developers who were familiar with both environments (of whom there were two) commented that this was because if one needed to explore civilian activities one could go and do them. In the military environment this was simply not possible. A number of participants thought that the tool could be used for civilian MLCE development, although experienced civilian developers didn’t think the tool was needed because one could participate in civilian outdoor activities.

The tool was also shown to a military officer who had extensive experience of current operations, both as a commander and UK Ministry of Defence Headquarters military staff officer trying to expedite urgent equipment acquisition projects. He was asked if the clips were representative; he thought that they were as long as the final toolset were reviewed by serving military.

R.6 Tool use concerns

Four participants, three of whom were human factors specialists thought that there was a risk that the tool may be used inappropriately to determine objective reasons for problems experienced with MLCE. The human factors specialists thought however that this could be addressed in the training for the tool by providing a guide which would explain the limitations of the tool.

More information / footage needed

Several participants raised the issue of needing more information in the tool to make it useful, and the validity of the clips used (whether they accurately represented soldier tasks). Participants also raised the possibility of collecting video data from exercises, or staged events, such as donning MLCE, to help populate the tool with key soldier activities. Participants also raised the issue of the effort involved in populating the tool, since this would be needed before it could be used on a 'live' project.

Misleading design

Three participants, all human systems specialists, raised the possibility that the information, could, if interpreted incorrectly, mislead designers in to optimising their solutions to unrepresentative soldier tasks:

> 'Concerned that you'll design for a different balance of use' [T6(D3)26]
>
> 'Putting the same people and equipment in a different context, can get different problems and issues' [T6(D1)52]
>
> 'When designing some things, you have to think beyond current stuff' [T6(D1)20]

This may be a risk with using the tool, but could be addressed by using the tool alongside other information, as well as undertaking some form of Mission Analysis (see section 11.3.1) to give an indication of frequency and wider context.

Q.7 Identifying and clarifying issues which can prevent successful MLCE

This theme was in two parts, the first the identification of issues which could prevent successful MLCE development, the second to determine how the tool could help address these issues. Taking the first part of the theme, the following were identified as being issues which prevented MLCE development.

Limited information at outset of the project

A number of participants, principally industry developers, raised concerns about the lack of information that they were provided with at the outset of a project, and with the manner in which solutions were tightly constrained:

> '[The] specifier has specified how it [MLCE] is to do things, not what it is to do, so they end up with something that doesn't do it' [T7(D6)15]
>
> 'Specs [specifications] we get these days [from a defence organisation] are so basic; it's a list of materials and a wish list' [T7(D7-9)28]

This was an interesting insight into the clear frustration the interviewed developers had with how they could provide innovation in MLCE design to defence organisations. One highly experienced industry pack designer thought a key problem was the expected product life cycle of the products. Since designs were effectively frozen for over a decade, it was difficult for MLCE innovations to be inserted mid-life, and for companies to justify the investment in innovative MLCE products. Another experienced industry pack developer thought that over-specification also lead to cheap, but ineffective, MLCE. Another participant, while not raising this exact point, did raise concerns as to how well requirements were given to industry, since military personnel often did not take a holistic view; 'they don't identify the 25% of issues which pop up at the end and are the show stoppers'. It was known from previous studies that the military were heavily involved in MLCE requirement setting, and so these comments gave further weight to the argument for more holistic and systematic derivation of requirements for MLCE.

Obtaining knowledge of use

The tool was thought to help solve this issue if, as participants had raised (see section Q.3), MLCE developers didn't have experience of military activities. All the industry participants thought that, by the tool providing information beyond an initial specification or wish list, designers could gain a more holistic view of the soldier environment and, therefore, improve their individual knowledge. In order to achieve this holistic view, participants were keen to see the following aspects added:

- Environmental information
- Theatre (context of operations)
- Roles of people in the video

- Descriptions of physical movement

Almost all of the participants were also keen on the tool's ability to provide insights which could lead to further exploration of issues, 'signposting', as one participant described it. This was again dependent, participants thought, on someone knowledgeable providing the signposts, as in the use of the 'action, problem description, and requirement' codes in the scenario stories which were developed as a part of the tool output.

R.8 Impact on development process

All participants thought that the tool would not speed up the development process, due to the necessity to produce a physical artefact and meet deadlines. Most participants thought that the tool would make the process more successful, since it would enable a more effective process. Depending on how the tool was used, participants thought that they would be able to know more accurately what the MLCE needed to do earlier in the process so could make sure that the end solution better met the desired requirements. One experienced civilian arena developer also made a number of comments as to how this could be achieved given the commercial relationship between defence organisations and industry. To get full use of the tool's benefits, the developer thought that this should be a mandatory part of firms' preparation for tendering for contracts, and thus should be used to explain the requirements needed by the customer. The developer suspected that if provided to firms, after contract award, it would not be used because of the time accessing the tool may take. The researcher suspected that this would also be because contracts tend to be against written targets that the firms prioritise too. The developer also inferred that the holistic nature of the tool may be hard to sell to defence clients: '[That there is a] need to make the benefits of the tool real is one of the major challenges' [T8(D6)10].

Other participants commented that the tool would not support idea generation or prevent designers going down an incorrect route (see section Q.6). Participants said that an experienced design team was essential in producing MLCE which met the users' needs. The most experienced MLCE designers interviewed found it difficult to express how they went about designing MLCE, but were sure that they could not do it alone. One of these two designers also said that after a while, he (usually) had a solution for almost every user want; it was a matter of putting the solutions together in one product to provide the innovation. These last comments would seem to fit well with 'Schemata'-based approaches, often associated with 'expert' designers (Ball et al. 2004). The ability of designers to be aware of a number of possible design features which meet certain users' needs could also form the basis of design tool which could match MLCE features to user needs, in a similar manner to Geddes and Haines (2008).

R.9 Summary

Theme	Sub Theme	Notes
Insight on the context of soldier work and activity	Physical Environment	All participants liked the tool because it gave insights on the context of use that they did not know about or did not know how 'x' equipment was used. Also linked to a need to understand environmental effectors like temperature and humidity.
	Video and analysis	The Video was liked because it was easy to understand, but the analysis added an extra dimension which could be used by experienced and novice developers.
	User voice	Comments were made that the analysis also enabled user issues to be identified which would not necessarily have been identified.
Helping set the right requirements	Importance of setting the right requirements	All participants thought that the tool needed to have a role in requirements formulation. A sub-text to this was that they felt that requirements were generally not well set.
	Reliance on soldier opinion	Developers without military experience were dependent on soldier opinion to inform design; the tool was thought to provide a way to inform the judgement or provide additional evidence to support the justification for a particular design option.
Getting people to a common understanding about soldiers	Understanding the need	Almost all participants reported that the tool would support them getting common understanding of the military environment. The tool provided them with information they currently lacked.
	MLCE design experience	An interesting insight, provided by civilian pack developers, was that formal design training was not sufficient to enable successful design and that experience in MLCE design would be needed. They felt that the tool would help designers understand what they did not know about the military environment which they felt was critical to producing successful products.
Setting or doing evaluation	Examples of use	An unexpected role for the tool was that it could be used to provide 'walk-through' scenarios for prototype assessments, either as studio or field-based studies.
Potential tool uses/ role	Variety of role	Technology insertion, understanding interfaces, explaining key issues, product modelling (similar to the 'walk-through' above), design specification interpreting, case making, focusing on end-use, and remote analysis (N.B. but not in-theatre remote analysis).
	Limitations in role	The tool was not thought to be useful during concept generation, just in understanding how it was to be used.
	Military tasks	It was thought that the clips should be reviewed by serving military personnel to ensure that they were representative.

Theme	Sub Theme	Notes
Tool use concerns	Objective / causal reasons for MLCE problems	The human systems specialists thought that there was a risk that the tool might be used to identify the causes for a given problem to be a specific symptom; these dangers should be clearly explained to users of the tool.
	Additional information needed	The amount of information needed to make the tool useful was discussed. It was thought that the tool should as a minimum contain key soldier tasks. Gathering evidence from exercises rather than operations was also discussed.
	Misleading design	Human specialists also raised the possibility of optimising MLCE based on the tool alone.
Identify and clarify issues which can prevent successful MLCE	Preventing successful MLCE development	A number of participants thought that the tool would help provide them with better information to design against. Rather than specifying 'how' MLCE needed to do what it does, they felt they should be told 'what' it had to do. This was also linked to the level of innovation industry developers thought that they could bring to MLCE development. A related comment was that often not all the issues that related to adequate performance of defence equipments were necessarily identified at the outset of a development during requirements setting.
Identify and clarify issues which can prevent successful MLCE (continued)	Mitigating problems	All the participants felt that the tool provided a way to help mitigate the issues which may prevent successful MLCE being developed. One participant described the ability of the tool to 'signpost' (the 'action, problem description, and requirement' codes) them to aspects that they needed to consider as important.
Impact on development process	Speed of development	Most participants felt that the tool would not increase the speed of MLCE development since timeliness were usually targets set by the customer. Indeed the tool may extend the process, but providing more information to go through at the outset of the process.
	Effectiveness of the process	Most participants did think that the tool would help ensure that the process was more effective at delivering a successful MLCE product.

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Appendix S: Scenario scoring output

As outlined in Chapter 12, scenario scoring was used to help provide insights into where in the process of development the use tool might provide benefit (augmenting the analysis made using notes and recordings). The scoring was used by looking at the trends between participants which may provide additional insights into MLCE development or tool use.

Thesis Link: Chapter 12, section 12.3.2

Scenario One

The first of these was difference in scoring between participant D6 and the other participants at Event 3, as shown in Figure S-1. This was explained by D6 requiring, in the scenario event in question[56], for the tool to have information about how soldiers interface between their MLCE pouches and personal equipment, which it currently does not. Participant D6 therefore scored the tool as not impacting on Event 3, but commented it would be higher if the tool did have this sort of information, similarly for Event 4.

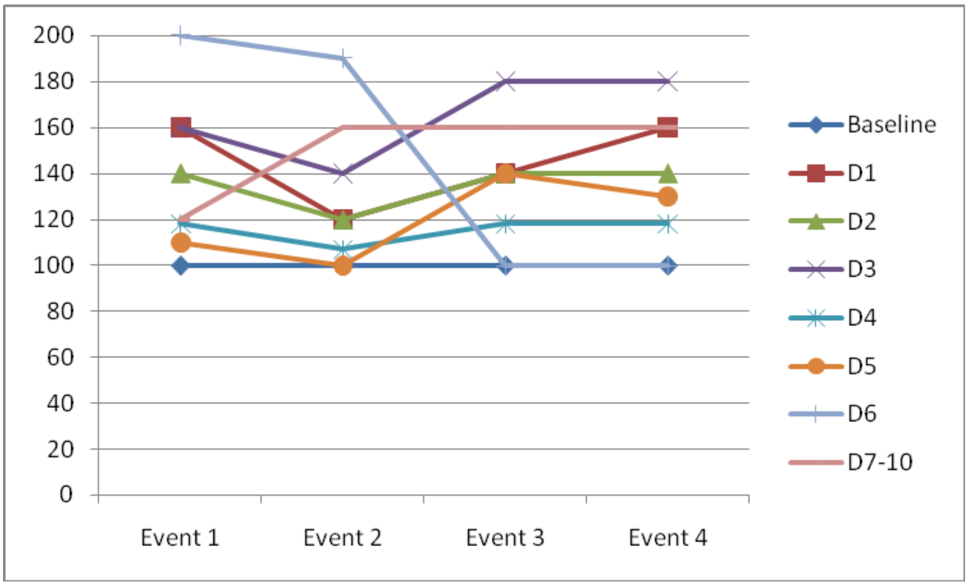

Figure S-1. Participant scoring from Scenario One.

[56] Scenario 1, event 3.A stakeholder reviews the system and asks how the users could carry their personal equipment with the back system. Their personal equipment must be accessible at all times in the terrain in question. This was not in the specification and so was not picked up by the new designer.

Other aspects noted from Scenario One were Participants D7-10 giving the same score for Events 2 to 4. This was due to similar reasons quoted by other participants, but they appeared in the interview to need more information on the tool to differentiate further. This could also be due to the nature of the group interview, where the scoring represented a group consensus.

Scenario Two

Scenario Two was straightforward for most participants the trends were broadly consistent (see Figure S-2), as were the comments made to justify them. In particular the participants felt that the tool would strongly support developers understanding a new, emergent user group (Event 1). Most participants felt that Event 2 and 3 were broadly the same and so scored accordingly, assuming the same information was available at the two events.

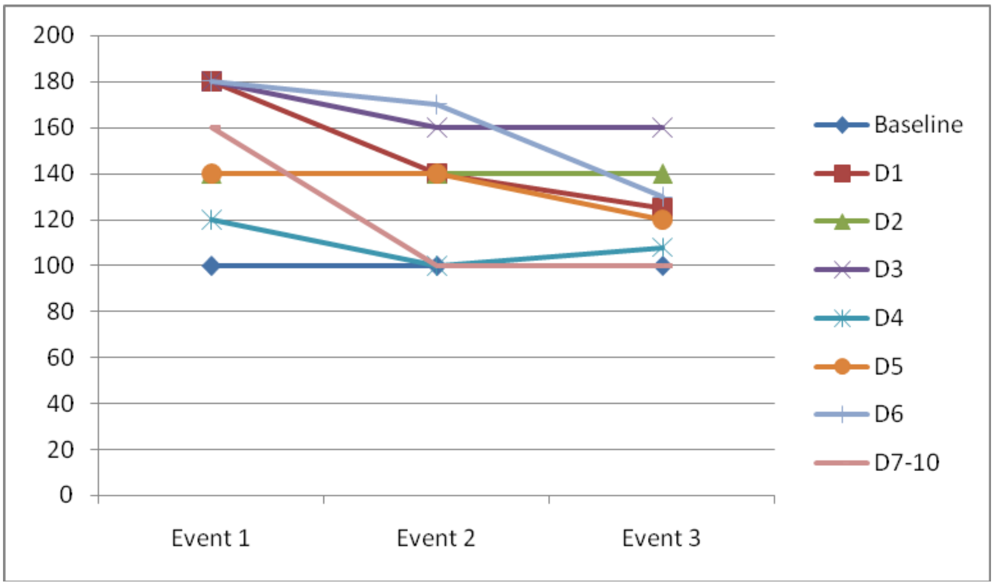

Figure S-2. Participant scoring from Scenario Two.

Scenario Three

Scenario Three split the participants into two divergent groups, with D6 and D7-10 (and D5 to a degree) all scoring the tool as not helping as much at Event 2 as at Event 1 and 3 (see Figure S-3). This was an encouraging trend to see since Event 2 was put into test whether developers would use the tool in idea and prototype generation. D6, D5 and D7-10 were all industry based developers who were often responsible on projects for producing MLCE concept solutions. The other developers were broadly those who were involved in other aspects of MLCE development, whether it was requirements setting, or evaluation, for example. The broad conclusion from developers experienced in concept generation was that the tool, while useful for understanding problems and the use of MLCE, would not help in concept generation, apart from to make sure that prototypes met more accurately what users wanted the MLCE to achieve.

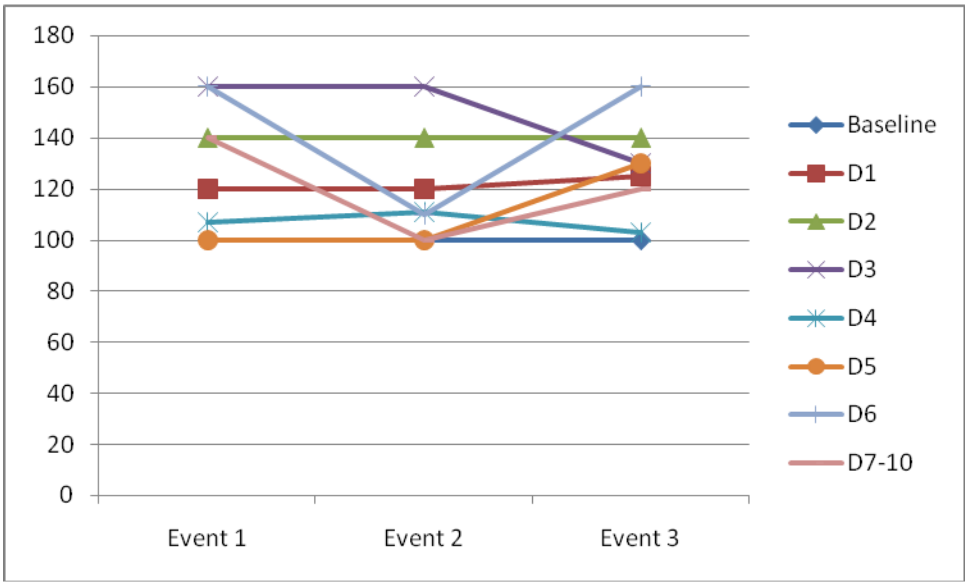

Figure S-3. Participant scoring from Scenario Three.

The other points of note were D3 and D4, both human systems specialists, who scored the tool as not helping as much at Event 3 as at Event 2. This was due to the participants' reservations as to whether further video would be available and whether it would help identify causes for the rashes experienced by users in the scenario.

Summary

According to the scenario interview outputs, the participants scored the use tool as having its strongest impact at the outset of any development activity. Participant scoring was positive throughout the scenario interview, and showed that the participants did not think that the tool would detrimentally impact development in the scenarios presented. This correlated well with their comments in the semi-structured interview, and demonstrated that the participants were confident in their assessment of the tool during the two parts of the interview.