Simulation Model Interoperability in Support of Complex Organisation Design and Change

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Abstract

Simulation Modelling has a key role to play in enabling decision making in dynamic manufacturing organisations. However in general the complexity levels involved necessitate multiple simulation models to be systematically developed and deployed. This paper describes a new systematic approach to creating coherent sets of simulation models that can interoperate to replicate and predict changing organisational behaviours.

1.0 Introduction

Manufacturing organisations are very complex yet need to function as dynamic systems, such that they remain competitive during their lifetime. One aspect of their complexity arises as understandings, knowledge and data (UKDs) about the organisation (and its business, managerial, technical and social structures and behaviours) is normally distributed amongst many knowledge holders. Hence to realise organisational change on any significant scale, **consultative decision making** is needed to

- conceive and agree upon improved ways of working
- resource and implement agreed changes.

It follows that constraints on consultative decision making will limit the quality and frequency of change decisions and impact negatively on the organisation's competitiveness.

Common change decision making in industry is centred on ad hoc meetings (involving persons with necessary influence, responsibilities and expertise) interspersed with periods during which responsible individuals consult with colleagues. Therefore current change decision making is often based upon accessing and processing distributed UKDs, but the processes used are typically very time consuming and ill structured. In some cases the time delays involved lead to 'solutions' to 'outdated problems', while in other cases pragmatic (non consultative) decisions are deemed necessary to facilitate responsiveness. The quality (fitness for purpose) of individual and group decisions made will first and foremost depend upon the quality of the personnel involved. However decision making qualities will also critically depend upon people availabilities and the time they can expend, the quality of UKDs they can access and the ease of that access.

With the foregoing observations in mind the present authors have (a) conceived and instrumented a new approach to structuring and enabling consultative decision making and (b) applied this approach within a number of small and large manufacturing organisations. Underlying research assumptions made (and being tested) are that suitable combinations of state of the art modelling frameworks, concepts and tools (including Enterprise Modelling, Dynamic Systems Modelling and Simulation Modelling) can be used to improve the quality and timeliness of organisation design and change decision making.

This paper considers in overview the role of Simulation Modelling (SM) in support of consultative decision making and reflects upon case study results.

2.0 Use of modelling in support of strategy realisation

Weston et al (2006) explain that an overview of consultative decision making in manufacturing organisations can be gained through referencing Strategy Realisation (SR) activities. According to Mintzberg et al (1998), SR encompasses strategic thinking, strategy programming and strategy deployment. Weston et al (2006) also catalogue some popular business concepts with respect to different life phases of SR and explain how different classes of modelling technique can support decision making and action taking. Table 1 classifies types of organisation decision making that state of the art modelling techniques can naturally support. However, used on their own specific modelling technologies (including SM) can only provide limited support.

significantly outweigh the cost of their continued deployment.

Table 1 Candidate Modelling Technologies – that support key aspects of strategy realisation

Purpose of Modelling	Nature of Modelling	Focus of Modelling	Example Threads of Modelling	Useful 'Business School' Concepts	Candidate Modelling Technologies
Opportunity Modelling	abstract structural & behavioural modelling, of wide scope with a medium to long-term focus	modelling causality between the ME & its environments to identify strategic opportunities	*** Analyse market structure, requirements & opportunities** *** Analyse product portfolio opportunities** *** Analyse competitor strengths & weaknesses** *** Conduct internal capability analysis** *** Identify candidate strategic intents**	* Scenario Planning * Game Theory * Porters Forces * Organisational Structure (Mitzberg & Walters) * Supply Chain Analysis * Process Classifications * Competitor Analysis	* Dynamic systems modelling * Causal loop modelling * Dependency & constraints modelling * Simulation based on numerical integration
Requirements Modelling	primarily mid-level abstractions of structural aspects, of medium to wide scope with a medium to long-term focus	modelling of needed process oriented organisational forms that the ME can use to compete for identified opportunities	*** Analyse business process networks relative to candidate strategic intents** *** Analyse supply chain alternatives** *** Analyse work organisation alternatives under financial &resource constraints** *** Analyse & short list viable production strategies** *** Identify candidate business models**	* Porters Forces * Organisational Structure * Process Classifications * Benchmarking * Process configurations (MTS-MTO-ETO etc) * Product Structure * VAT Plants * Postponement * Lean/JIT/Agile	* Enterprise & process modelling * Various types of simulation modelling * Value stream analysis * Cost modelling * Decision network modelling
System Solutions Modelling	primarily mid to low level abstractions of structural & behavioural aspects, of narrow to medium scope with a short to medium-term focus	modelling to inform the resourcing of process-oriented roles with candidate human & technical systems & analysing & predicting their behaviours when subject to work pattern dynamics	*** Identify process oriented roles amongst viable Business Process networks** *** Match viable candidate human & technical resource systems to identified roles** *** Analyse competitor strengths & weaknesses** *** Exercise resourced roles with historical and predicted work patterns** *** Select suitable work structures via dynamic analysis of short listed business & production strategies**	* Process classifications * Postponement * Lean * JIT- Kanban * CONWIP * Agile * Competency models * Team working theory * Scheduling techniques * Flexibility theory	* Enterprise & process modelling * Discrete event simulation * Value stream analysis * Cost modelling * Role modelling * Resource capability modelling * Work pattern modelling * Exception modelling

3.0 A 'component-based', 'mixed reality' approach to modelling organisations

The present authors have conceived and case tested the use of the Unified Organisation Modelling approach illustrated by Figure 1.

Underlying assumptions being tested are that: (1) 'reusable components' (both modelled and real) of organisations can be 'configured' into 'interoperating systems of mixed reality components', such that these systems can realise changing organisational requirements (including ongoing change in customer demand for new and existing products and services); (2) models of real systems components can be deployed (with sufficient quality and utility) by combining the use of state of the art modelling techniques to capture and exercise UKDs in support of timely and effective consultative decision making; (3) potential organisational benefits arising from using mixed reality component based modelling environments can

4.0 Integrating concepts

The authors and their colleagues have adopted the use of existing modelling concepts and technologies and as required have conceived and deployed new integrating modelling concepts.

Public domain Enterprise Modelling (EM) techniques were observed to usefully provide means of handling organisational complexity, by offering modelling concepts to decompose (general and specific) process networks into their component process segments. Also existing EM techniques were observed to provide means of documenting and visualising associated flows of activities, material, information, controls and so forth. Thereby UKDs distributed amongst personnel concerned with 'operational', 'tactical', 'strategic' and 'infrastructural' processes of any organisation can be modelled in a visual, reusable fashion; so as to formally specify what needs to be done by the organisation over given timeframes and how various decisions and actions carried out can causally impact on other process segments of the organisation. Also observed were various complementary process, product and resource modelling techniques which can be used to attach specific structural and parametric data to Enterprise Models (EMs) so as to provide a 'big picture' of the current organisations 'configuration'. Such a 'big picture' provides a framework for positioning various kinds of UKD and proved useful to decision makers in the case organisations modelled. However such a developed EM naturally only encodes relatively enduring properties of organisational entities and relationships between those entities.

To enhance the utility of EMs and their connectivity with dynamic (time dependent) models of selected enterprise components the present authors conceived and developed the use of 'role' and 'dynamic producer unit' (DPU) modelling concepts.

need the present authors deploy decomposition principles of EM techniques, so as to identify 'organised sets of process segments' (i.e. 'component building blocks' of process networks) which can be treated as being equivalent to 'organised sets of roles'. Of course in real organisations various feasible decompositions may be determined and this leads to the identification of alternative role sets, for which alternate resource systems may be assigned a responsibility. A key advantage of using an enterprise model to determine viable role sets is that naturally previous activity, material, information and control flows related to each process segment will already have been explicitly specified. This phenomenon is used by the authors to explicitly model 'role requirements' for specific process network cases. Further, by understanding the nature of the activities, and activity relationships associated with each role, it is natural to explicitly attach to each 'role requirement'

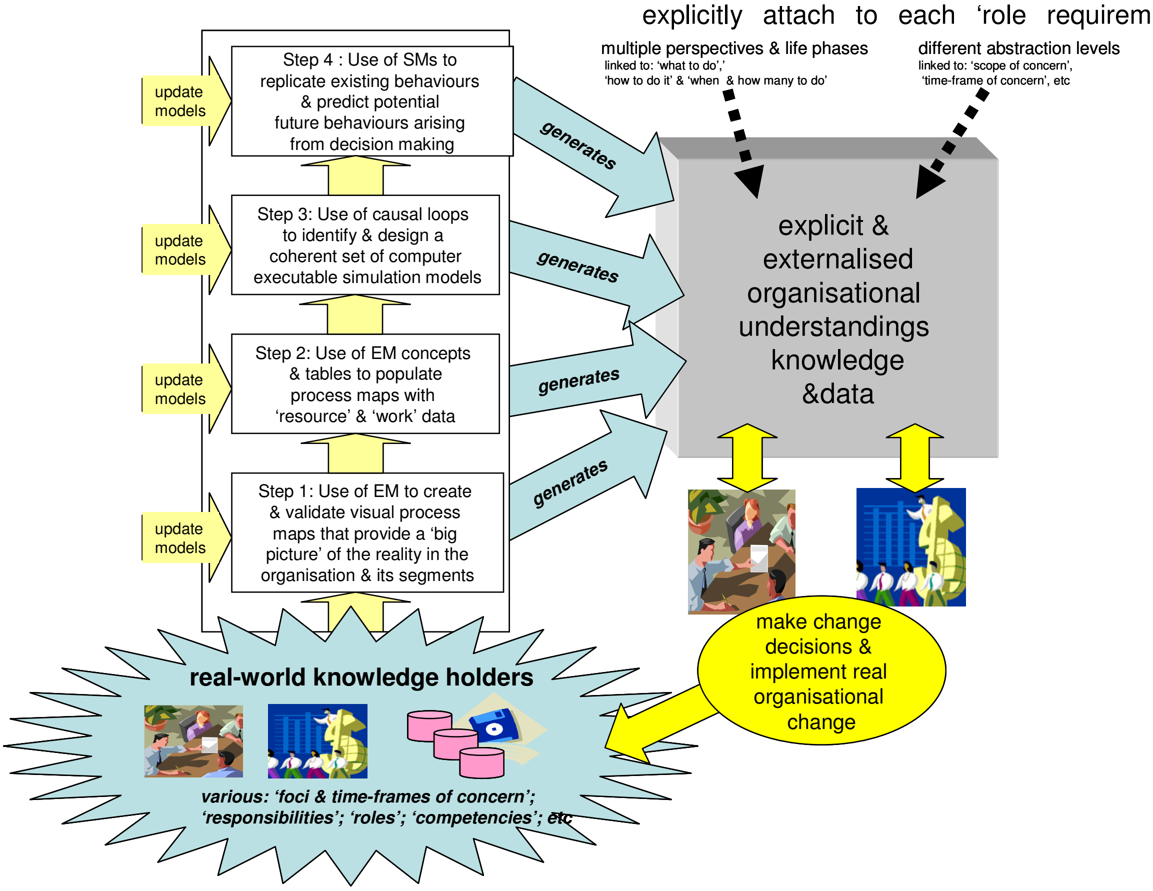

Figure 1 Overview of systematic modelling approach - **leading to the development & deployment of coherent simulation models**

In general 'process and organisation designers' need some means of determining sets of 'roles' that must be resourced (by suitable systems comprising human and/or technical resource elements) to realise the various ordered sets of activities that comprise a specific process network. To satisfy this

model, explicit descriptions of 'competency requirements' needed to realise each role. To operationalise the use of explicit 'role requirements' definitions during consultative decision making, the present authors have also developed the use of complementary models of 'potential roles' that candidate resource systems could play within a specific process network. By using common modelling concepts to explicitly describe 'required' and 'potential' roles, suitable candidate human and technical resource systems can be systematically identified and short-listed as viable role holders.

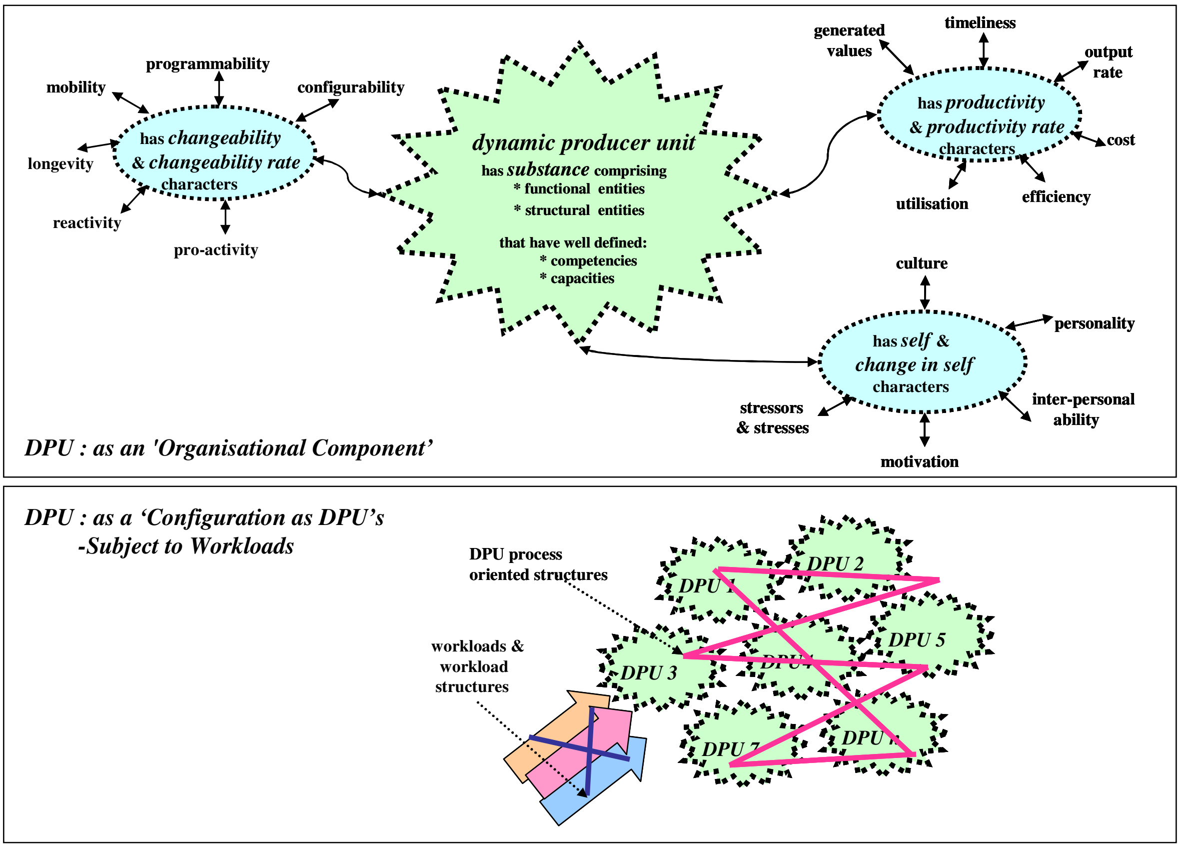

Figure 2 The Dynamic Producer Unit (DPU) Concept

The DPU concept was conceived as a means of achieving coherent abstract descriptions of common reusable components (or building blocks) of manufacturing organisations. Here it was assumed that (1) DPUs will function individually, as a holder of one or more assigned roles and (2) configurations of multiple DPUs will interoperate so as to function collectively as holders of one or more higher level (more abstract) roles (i.e. roles composed of lower level roles). In real manufacturing organisations, actual building blocks comprise various systems of people, production machines and computers. These common building blocks (or systems of resources) are typically configured into various systematically operating groups (via the imposition of organising structures and parametric data) so that they function and behave as required in a specific workplace and under specified sets of workload conditions. It follows that configured resource systems need to possess specified competencies, behaviours and levels of performance to realise all needed instances of process segments to which they are assigned. Example stereotypical resource systems (or DPUs) include workgroups, teams of people, production cells, production lines, workshops, departments, business units, companies and partnership enterprises. Hence a research assumption being tested is that all such types of organisational unit can be usefully modelled using role and DPU modelling ideas as a means of treating them as configurable, reusable and interoperable components of complex organisations. As illustrated by Figure 2 therefore it has been assumed that physical and logical configurations of DPUs (whether they actually comprise people, machines and/or computers) can all be usefully characterised in terms of their:

- *Relatively enduring DPU functionality* – expressed in terms of 'functional competencies', including for example competencies[1] to assemble product X,

[1] Here the term 'competencies' is considered to encompass human systems oriented competencies and technical (machine and computer) system capabilities, bearing in mind that many enterprise

process orders of type Y and design products of type Z

- *Relatively enduring DPU structures* – expressed in terms of activity, information, control and material flows that are linked to role assignments and descriptions of needed interactions between roles
- *DPU dynamic characters* – expressed in terms of performance levels (e.g. lead-times, rate of value addition and costs consumed), behaviours (e.g. availability, reliability, change capability and operational flexibility) and relevant cultural concerns (e.g. level of workforce motivation and influential cultural values).

In case organisations considered thus far, by modelling stereotypical DPUs as potential holders of roles, significant benefit has been observed; this has enabled the design and explicit specification of systematic methods for modelling organisations, their change requirements and impacts of change types on organisations, and has provided a formal basis for instrumenting new ways of externalising and reusing UKDs.

5.0 Coherent modelling of human and technical resource systems

Role modelling, work pattern modelling and DPU concept development has centred on enabling a two stage process of (I) short-listing viable candidate resource systems and (II) selecting from amongst viable candidates by predicting and comparing their performance and behaviours under varying workload conditions.

During stage (I), DPU characterisations of candidate configurations of resource elements are compared in terms of the relatively enduring functionality (i.e. competencies) they can bring to bear on specific workplace roles; thereby providing a first stage systematic basis for selecting between candidates and drawing up a short list of viable resource systems. To explicitly systemise resource system selection during stage (I), a previously captured Enterprise Model describing the case organisation (and its current process network) is analysed, assuming that it comprises 'process segments' (i.e. organised groupings of enterprise activities) that collectively specify a natural decomposition of a specific case of 'required roles' and 'dependencies between required roles'. The approach of considering 'process segments' as being 'possible roles' which can be played by 'alternative candidate resources' has provided significant flexibility with respect to organisation design and change, yet can formally specify key aspects of roles and role assignments. The approach has also provided useful explicit descriptions of dependencies between roles which can later be referenced during resource system implementation as explicit structural descriptions of control information, material and data flows associated with different configurations of DPUs and their varying assignment to roles and specific instances of roles.

During stage (II), dynamic systems analysis (based on the combined use of causal loop modelling and simulation modelling) is carried out to select between short-listed candidate resource systems on grounds of their ability to (1) perform given work patterns and (2) behave appropriately, so as to befit their specific work environment short, medium and long term.

Causal loop modelling is used to understand in qualitative terms how causal and temporal impacts propagate through complex organisations as dynamic patterns of work (e.g. works orders, projects, etc) are assigned to 'process segments', 'roles' and 'role holders'. This has proven effective as a basis for specifying the purpose, scope and focus of multiple simulation models that individually can support resource system design and change decision making and collectively can replicate and predict performances and behaviours in the wider case organisation. This naturally leads on to (a) the design of simulation models and simulation modelling experiments and (b) the ability to realise interoperation between simulation models.

6.0 Illustrative case

Because of space constraints, this paper will only illustrate in outline how the concepts reported in this paper have been beneficially applied; so as to deploy simulation modelling in support of complex decision-making in a case study manufacturing organisation. In this case study the method of externalising distributed UKDs illustrated by Figure 2 was deployed to provide a coherent set of enterprise, causal loop and simulation models. Following model validation involving extensive

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activities can be realised by either people, machines, computers or organised combinations of these active resource types.

discussion with knowledge holders, the developed set of models explicitly documented key characteristics of the current configuration and current reachable states of the case organisation. Figure 3 illustrates examples of some of the current state models created; where these models took various forms including: graphical models of relatively enduring entities and entity relationships; tabulated models related to (process, resource and product) structures, parameters and data; graphical models of causal and temporal impacts linking organisational variables; and various computer executable models that are exercised by simulation and workflow management tools.

the product dynamics and constraints arising from a need to maintain a sufficiently competent and change capable set of human and technical resources. The company had also experimented by implementing various organisational changes, alternative business and manufacturing policies and rules, new business systems and had sought to minimise waste and cost, whilst coping with human resource change and maintaining flexibility where and when required. However inevitably it faced significant complexity issues and previously had no analytical basis for change decision making.

In collaboration with case company personnel, the university team (mainly comprising the

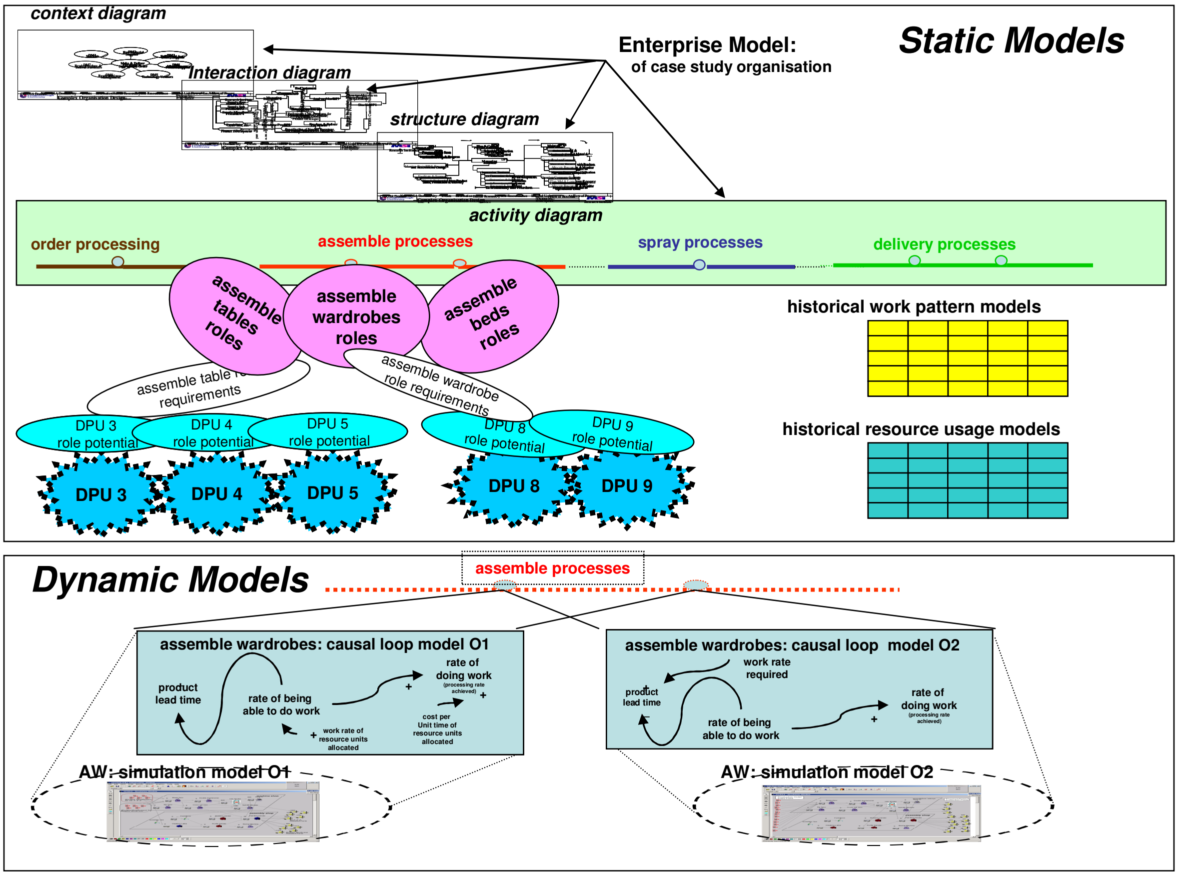

Figure 3 Case Study Illustration of the Modelling Methodology: to create various simulation models of individual process segments

The case company employs circa 50 people to make high quality pine furniture in response to orders received mainly from furniture stockists. Circa 350 product variants are made, each of which can have a number of colour finishes. Many of the case company problems revolved around their product dynamics; because the mix and volume of products ordered during any given planning window has (and likely will continue to) varied very significantly. Therefore key issues were to maintain competitive product quality, lead-times and cost despite

present authors) has successfully used the current configuration and state models (illustrated by Figure 3) along with various future configuration and state models to provide analytical decision making support. On an ongoing basis this is improving the competitiveness of the case organisation by minimising time loss and the loss of significant investments in change (that previously had resulted in poor performance because of making ill advised change decisions). In a number of related modelling studies the authors have recommended (1) localised improvements to specific process segments of prime concern to the case organisation and (2) recommended improved business and manufacturing policies that span multiple process segments.

7.0 Reflection and conclusions

This study has observed key roles for simulation modelling in support of complex organisation design and change. However it has also observed practical constraints on the use of single simulation models, in that they can only either model (1) the whole organisation in a simplistic manner or (2) segments of the organisation in detail, based on the assumption that segmented models can usefully be modelled in isolation.

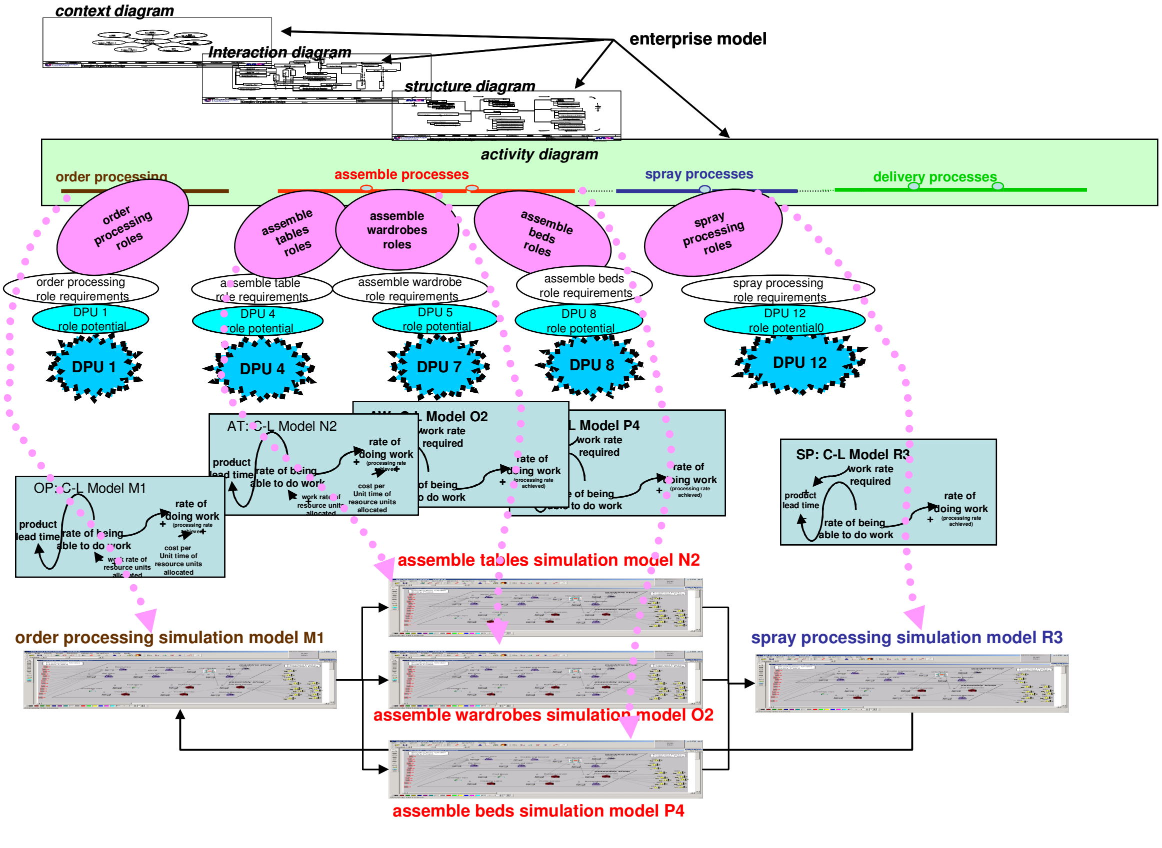

Figure 4 Use of Methodology to Create Coherent Simulation Models: with embedded capability to interoperate

The purposes of the modelling concepts and approaches reported in this paper are to:

(a) capture and operationalise UKDs distributed mainly amongst human knowledge holders in complex organisations.
(b) enable unified use of enterprise models, causal loops and simulation and workflow modelling to understand and analyse specific organisational dynamics.
(c) provide an explicitly defined foundation for model unification and simulation model interoperation.

Early findings when modelling a number of small and large manufacturing organisations have been very encouraging. Although more extensive testing is required in respect of (c), the use of process network, role, DPU and resource systems (competency and performance level) modelling concepts (informed by causal loop modelling) has provided an enhanced basis for creating coherent simulation models. As illustrated by Figure 4, the developed modelling methodology results in experimental simulation models that share common semantics about a specific and complex organisation. Further key separations related to structural aspects of these simulation models facilitate both decoupling and flexible integration of 'process', 'resource' and 'work pattern' aspects. Therefore in theory the modelling structures, concepts and techniques researched can usefully input to ontological developments related to complex organisation design and change.

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