ENTERPRISE INFRASTRUCTURE PLANNING
Modelling and Simulation Using the Problem Articulation Method

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Abstract: Current systems development costs rise almost exponentially as development time increases, underlining the importance of effective project management and enterprise planning. Enterprise infrastructure planning offers an avenue to efficiently improve and shorten design time; and to develop a system of high quality and with considerably lower operating and development costs. The Problem Articulation Method (PAM) is a method for articulating business and technical requirements in an organisation. It is capable of assimilating the internal systems changes in response to the dynamics and uncertainties of the business environment. The requirements and specifications from this analysis constitute as a baseline for managing changes, and provide the mechanism by which the reality of the enterprise and its systems can be aligned with planned enterprise objectives. An illustration of planning and development of a procurement system will be used to demonstrate the enterprise infrastructure requirements using a discrete-event enterprise simulation package "Enterprise Dynamic". This paper will examine the capability of PAM in the articulation and simulation of complex enterprise requirements.

1 INTRODUCTION

The evolving business environment has caused a paradigm shift in the way business operates. The traditional business paradigm has changed significantly with the integration of IT, business and organisational systems. This transformation has accelerated in response to the evolution and globalisation of information and communication. Unlike the business view of the old, which focused on a one dimensional business domain, today's enterprise paradigm is dynamic and multi-dimensional. It is more crucial then ever for enterprise to remain agile and to integrate seamlessly across the technical, business and organisational functions. Enterprise infrastructure planning can be used to adequately address the evolution of requirements and the convoluted behaviours of the enterprise.

Enterprise engineering as defined by Liles and Presley (1996) is referred to as the body of knowledge, principles, and practices having to do with the analysis, design, implementation and operation of an enterprise. It uses a multi-disciplinary engineering approach for analysis, design, and implementation of enterprises. For enterprise engineering to be effective it has to address three fundamental issues. Firstly, the ability to capture complex enterprise requirements and its evolving needs. Secondly, the capability to embed organisational behaviours in the enterprise 'conceptual' model. And thirdly, the ability to incorporate and translate the enterprise model into simulation software for the purpose of analysis and validation.

An enterprise model is a dynamic representation of a business organisation, in which activities, processes, relationships, constraints, information, resources, people, behaviour and goals are modelled. It must therefore be able to represent organisational behaviours and reflect the diverse enterprise requirements. Tan and Liu (2004) have identified the weakness of information requirements, attributing it to the inability of requirements engineering to elicit complex organisational behaviours. The dynamics of process, however, cannot be sufficiently expressed using either linear computation or graphical representation alone, which is unfortunately still in practice by many modellers. The existing problems with most modelling method can be attributed to the following reasons:

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- Lack of a comprehensive method to describe and valuate the stakeholders' feedback.
- Emphasis placed on hierarchical decomposition of a system without placing analysis of other related systems that form an integral part of the organisational infrastructure.
- Scalability is difficult, and often incompetent in addressing the different levels of enterprise modelling.
- Difficulty in estimating project resources such as time, cost, and expertise in a dynamic manner.
- Problem in integrating the diverse functions of business and IT infrastructure within the organisation.

This paper proposes an enterprise infrastructure model, and examines the capability of Problem Articulation Method (PAM) in the articulation of problem situation, using simulation for analysis and validation. Section 2 describes the integration of enterprise model with simulation model. Section 3 highlights the problems associated with enterprise modelling methods and explains how PAM may be used to address these issues. Section 4 provides an illustration of the collateral structuring technique and explains how simulation model can be used for enterprise requirements analysis and validation. Finally, Section 5 concludes the paper with findings and further work.

2 INTEGRATING ENTERPRISE MODEL TO SIMULATION

In traditional simulation model building, the simulation software application acts as a model development environment. The simulation development environment is a non-specific modelling environment that supports an infinite variety of modelling problem situations. It is precisely this characteristic of modelling, with its infinite scenario that makes enterprise simulation extremely difficult. The simulation-based application is likely to adopt different functions to model the different aspects of an enterprise.

Enterprise infrastructure planning (EIP) model (Figure. 1) provides a high-level model using PAM for the capture of enterprise requirements using a generic discrete-event simulation environments, and the associated requirements of the model functional layers as the basis for organisational simulation standard. The requirements places upon this software program allows the attributes to be embedded within the simulation applications and are therefore a better representation of the 'real' organisation, as oppose to one where the requirements and attributes of the system are pre-determine by the users. EIP uses PAM as an enterprise model for assimilating the internal systems changes in response to the dynamics of enterprise requirements. The requirements elicited from the enterprise must be able to interpret the attributes directly from the modelling method.

The simulation model thus needs to provide the attributes and parameters of human and software agents to correctly model the enterprise. This requires an interface, which could seamlessly translate between the conceptual model and the simulation software. Aalst (1990) realises the crucial need to model the specification of concurrent and dynamic systems, and has developed a framework with a modelling language called ExSpect, which serves to describe and simulate business processes using *discrete event systems.* ExSpect is executable in application and thus design for prototyping and simulation modelling.

Enterprise Dynamic (Enterprise Dynamics 2003) is an object-oriented software program for discrete-event simulation to model, simulate, visualise and control dynamic processes. This software is designed for enterprise modelling where the user can use the 4D-script programming language to create and customise the conceptual model. It allows a predefined set of simulation objects referred to as 'atoms' and statistical distributions to create the model. Current simulation software provides the tools to model the 'real world', but do not provide methods for modelling specific entities of the systems.

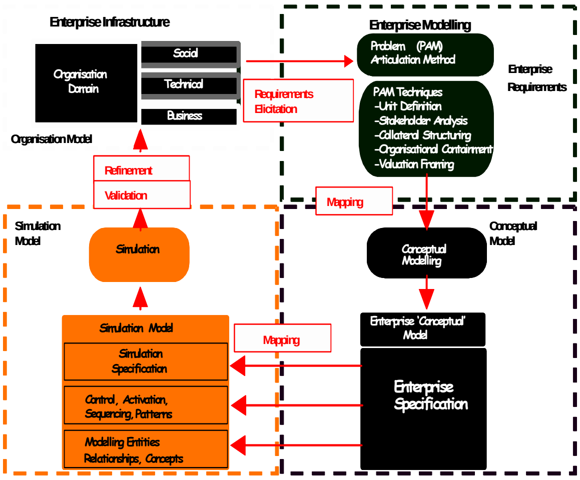

Figure 1: Enterprise Infrastructure Planning Using PAM and Simulation.

3 THE PROBLEM ARTICULATION METHOD

Probably the most difficult tasks in designing and building a discrete-event simulation models is in addressing the ambiguity and defining the scope of the system. The modeller must explicitly translate the 'real' system into an abstract system-of-entities, interactions-between-entities, and entities interactions-with-system environment. A modeller who desire to create an abstract representation of processes has three possible options: (1) build a detailed model to capture actual problem situation, (2) comprehensive modelling to capture the specific aspects of processes, or (3) operation through a process model "black box". A modeller will make the "level of detail" decision based his discretion on whether he deems that additional detail will significantly affect the output statistics he is attempting to model.

The Problem Articulation Method was designed for the analysis and planning of enterprise infrastructure developed by Stamper and his colleagues (Stamper et al. 1988, Kolkman 1993), based on organisational semiotics (Stamper 1993, Liu 2004) offers an effective means for enterprise modelling. PAM addresses the complex organisational issues and provides for the cost-benefit analysis, project management and project planning. It facilitates the co-design of business and IT systems by identifying relevant agents, eliciting the domain language and valuate stakeholders' feedback to uncover the gross architecture of the enterprise. Liu and Sun (2002) highlighted the importance of the co-design of business and IT systems, which facilitate the evolution of information systems.

Collateral structuring, one of the PAM techniques is concerned with the definition of unit systems that forms the constellation or supporting structure of the focal system. A focal system can be broadly defined as a kernel that revolves around the problem situation (Checkland 1981). The collateral systems (Figure 2) are systems that surround the focal system. Collateral analysis helps to place the focal system in its context and uncovers the infrastructure in which the focal system fulfils its functions. The method provides structure and will reveal the incompleteness of the infrastructure. It is possible to configure these structures as cycles. The method provides a guide to safeguard against inconsistencies, incompliant and incompleteness of the infrastructure. Collateral structuring forces the analyst to focus on the structure in relation to the overall system intervention and to consider scenarios, which include external environments e.g. suppliers process, economy, demand and supply.

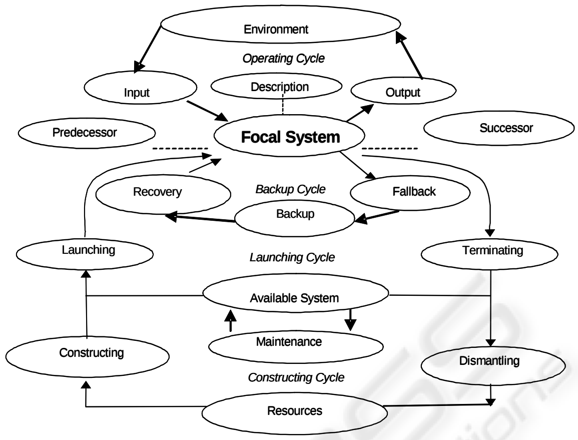

Figure 2: Collateral Structuring Model

In technological innovation, the focal system starts as a new technical 'system-in-operation'. But before the system can be installed to serve the organisation, it must first be available and launch from the launching System; which periodically needs to be taken down for maintenance or repair. The focal system will eventually have to be taken down via the Terminating System, when the system-in-operation is no longer required. However, before this takes place, the system must be switched off-line for it to be used/re-used as an available system. The new system will then be constructed from the Resources; and at the end of the lifecycle of the focal system, it will be dismantled (refer to the Construction Cycle in figure 2). In the operation of the Focal System, a Backup System is usually required in the event of system breakdown, where the system can be switch to Backup System with the help of the Fallback system. Once the focal system is repaired and launched, the Recovery system can switch the operation back from the Backup system to the Focal system.

4 MODELLING A PROCUREMENT SYSTEM USING COLLATERAL ANALYSIS

Purchasing and procurement represent different processes, although people tend to use the words interchangeably. Purchasing refers to the actual buying of materials and activities associated with the buying process, which focused on generating, and processing orders. In this paper we define procurement to include both human procedures and

IT systems functions. It is especially testing in the acquisition of hardware and software Information Technology (IT) sector, where there are many suppliers and a wide variety of products and services. The purchaser has to select the best options by collating product availability and price information from different sources, and then acquires the lowest price product, which meets the requestor needs through a series of selection procedures.

Focal System

The focal system “procurement” represents the core operation that provides services for the entire organisation. At the inception of the system only the central functions to be performed have to be given attention. The focal system will have a start and finish lifespan. The size of the focal system at this stage is not significant, but a larger size will entail a complex internal structure.

PAM addresses the planning of focal and collateral systems (Figure 3), the attributes in the template captures the resources and time required for building each unit system. These attributes describe the behaviours of the systems.

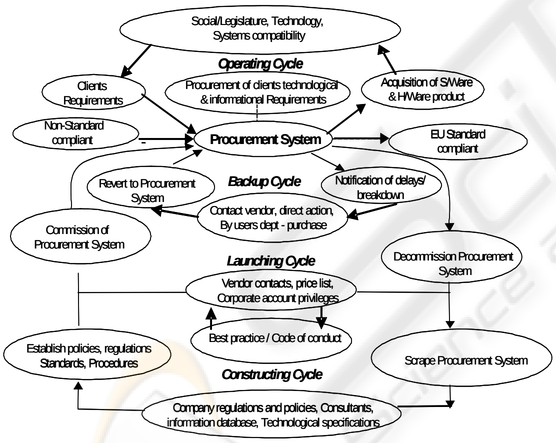

Figure 3: Procurement system and its collateral Systems

The unit system template (Table. 1) defines the objectives, stakeholders (skill-set, staff number, responsibilities and estimated operating costs) of the focal unit. The unit system templates also define the unit system, objectives and comments on each collateral unit.

Model Mapping

The process of developing a conceptual model and attempting to represent this in the simulation software has made a significant contribution towards understanding the procurement process. The conceptual model for simulation must address the simulation’s context and how the entities and relationship will be represented. It have to address the issue of (1) assessing a simulation’s validity for situation not explicitly tested and (2) determining the appropriateness of a simulation (or its parts) for reuse or use with other simulations. There are currently no de-facto standards or approaches for abstracting representation or translating the conceptual model into the simulation model. It is crucial to map the entities and relationship with the aim of describing and documenting the conceptual model, which must be incorporated in the simulation model.

Specifying Simulation Requirements Using Collateral Structure

Collateral structure provides a supporting framework within the enterprise model. It forces practitioner to consider systematically the overall enterprise ‘conceptual’ model, specifying the architecture requirements. The unit system is not analysed in isolation but within the collateral life cycle, which explicitly define the behaviours of entities and its relationship in relation to the overall system intervention. The enterprise requirements elicited from PAM are directly applicable for use in the implementation of simulation model, ‘atoms’ in the enterprise dynamics software.

Table 1: Unit system template

Focal System (Procurement IT System)

GOAL:	**TIME:**
UNIT SYSTEM	Start Date: 01-05-04
Procurement System in Operation	End Date: 05-07-04
OBJECTIVE	Duration : 65days
1) Procurement of Software/Hardware/Services	MTBF : 150days
2) Satisfy client requirements	MTTR : 5 hours
3) Obtain product/services at best value	FIFO/LIFO/Batch: Batch
4) Meet Procurement criteria	Trigger(s) : Input (On Entry)
	Import format: Requisition form

ROLES/RESPONSIBILITIES:

Stakeholders	**Skill-Sets**	**#Staffs**	**Responsibilities**
Procurement Manager	PAM method	2	Authorise and allocate projects
Procurement Supervisor	ERP	3	Manage project
Consultant	IT & Procurement	2	Consultancy services (integration)
Programmer	C++	4	Programming

COSTS:
Estimated Expenses:

(1)	Programmer = £12 per/hr X4 person = £ 48per/hr	[7x48x74=£24,864]
(2)	Consultant = £100 per/hr X2= £200 per/hr	[7x200x74=£103,600]
(3)	Procurement Manager = £40per/hr X2 = £80 per/hr	[7x80x74=£41,440]
(4)	Procurement Supervisor = £30 per/hr X3= £90 per/hr	[7x90x74=£46,620]

Total (Focal) Operating Costs	£216,524
Actual Expenses	£198,000
Balance (Surplus/Deficit)	£ 18,524

INFORMATION:

Questions:
1) What is the required input for the system?
2) How should the input be presented?
3) What is the quality or quantity of input?
4) What are the alternative source of input?

Checklists:
1) Organisational policies?
2) Departmental budget?
3) Governmental laws?

Deliverables:
1) Lists of documents?
2) Work flow diagrams
3) Contracts (warranty)

Triggers

The collateral analysis template uses three types of triggers, that is congruent to the Enterprise Dynamic input parameters: `1) trigger on creation, 2) trigger on entry and 3) trigger on exit.` The collateral structure triggers regulate and facilitate control over the activation, sequencing and timing of the different events. The model operates as an integrated sub-system, using a dependency-linked mechanism within the business processes.

Simulation Model

The procurement simulation model incorporates the enterprise requirements from PAM. The building of the simulation models will take a significant step forward in supporting project plan and control activities. This is made possible with better scoping and reduction of ambiguity in the requirements of enterprise infrastructure planning. It also provides for a finer level of granularity and utilising lower-level of requirements elicited from the enterprise. The information from PAM will adequately guide and provide the users with the information needed to model a system that considers time, resources, schedules, expertise and possible eventualities. The properties of a unit system described in the unit system template Table 1 will form as inputs to the simulation model.

The repository of information templates, life cycle structure and control, enable the modeller to translate the requirements and specifications attained from PAM to be used in the simulation model, which can be easily interpreted by Enterprise Dynamics. The attributes includes: MTBF, MTTR, MTTF, FIFO, LIFO, Batch or Real-time system. The mean-time-between-failure (MTBF) is equal to the sum of the mean-time-to-failure (MTTF) and the mean-time-to-repair (MTTR). FIFO (first-in, first-out) and LIFO (last-in, first-out) is an approach to handle program work requests from queues or stacks. The attributes of agent's behaviours within the enterprise model are elicited from the PAM specification, which includes the cycle-time, products number and unit-capacity. The organisational behaviours will be embedded into the simulation model to reflect the behaviours and characteristics of all the agents.

All systems are subjected to periodical breakdown and down-time for maintenance, either online or offline. The conditions or properties to calculate approximate repair time or system downtime enables the system to factor in eventualities in the simulation of a 'real' environment. Collateral analysis as such can provide a comprehensive set of properties and structure needed for this purpose, which could be entered directly into the simulation software. Based on the PAM model requirements, a simulation model can be created using the simulation package provided by Enterprise Dynamics. The determination of the business process of the procurement cases is a result of selection, timing and description of agent's behaviour. In the simulation model (Figure 4) the 'source atom' is the first element created in the procurement model. The 'source atom' then sequences the products for entry into the model at a pre-determined rate into the Specifications process. 'Specifications' is the second object created, which is a 'server atom'. The server atom is use to model the operations of parameters

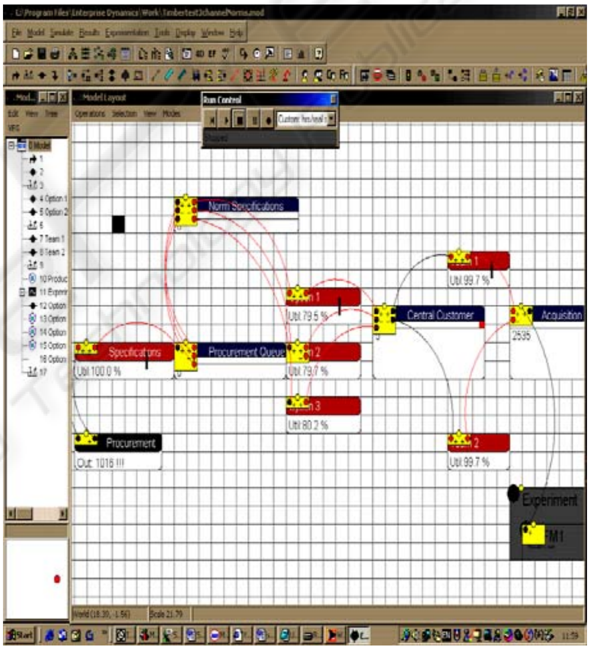

Figure 4: Simulation procurement.

such as triggers e.g. trigger-on-creation, trigger-on-entry or trigger-on-exit, MTTF, MTTR and Cycle-time. It generates the output (processing time) which is illustrated in Figure 4 at 100% utilisation rate.

Next, the 'queue atom' places the procurement request, in the Procurement queue and assigned priorities to it. In the IT procurement system, there are three procurement channels: 1) In-house development (79.5%); 2) Outsourcing (79.7%); and 3) Software acquisition (80.2%). Prior to the channel selection, the product will go through the norm-specification or business rules, where a series of rules will be checked to determine the option it should take next, either queue 1, 2 or 3. Next the central customer department handles the process of procurements, operating at an utilisation rate of 99.7% and 99.7% respectively. Both teams upon completion will hand the request ‘product’ to the acquisition process for accrue of total output (2535) produced by the procurement process.

5 CONCLUSION

This paper presents the concept, method and techniques of PAM which allows simulation software to be constructed within a well-defined interface that can be easily embedded in the Enterprise Dynamics simulation software. PAM is an enterprise modelling method, which uses the semiotic approach for enterprise requirements engineering. Empirical studies in organisational modelling have shown conclusively the importance of social-technical, business and organisational systems in modelling an organisation. This paper makes a case for further research and development in the next-generation of enterprise modelling for simulation model. PAM is well equipped to meet most of the enterprise requirements, which other prominent methods do not adequately address in the capturing of enterprise infrastructure and agents behaviour modelling. The central problem addressed by PAM, is to provide the modellers with information about the organisation, but how it could be use collaboratively with the simulation software for analysis and validation. More importantly it allows users to explicitly define the social-technical context of the system, and how they can be expressed unequivocally. By providing the intellectual tools for these tasks, which should empower analysts to correctly capture the organisations requirements and therefore be able to model the complex and evolving enterprise requirements.

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