ENRICHED MULTI-PROCESS MODELLING

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Abstract: An (enriched) multi-process modelling approach is described that provides a capability to document and analyse various dependent aspects of multiple threads of activities carried out in ME processes. The approach deploys commercially available computer modelling tools to operationalise the method so as to facilitate (1) the design of dependent activity flows, (2) the resourcing of activity flows by suitable human and technical systems (3) the control and management of workflows and (4) exception handling. Key features of the modelling method are described, as are the stages of modelling and the associated use of proprietary modelling tools.

Keywords: Business Process Engineering, Enterprise Modelling, Simulation, and Organisation Design, Socio-Technical System.

1. INTRODUCTION

Different enterprise modelling (EM) architectures and methods, such as CIMOSA, IEM, PERA and GRAI-GIM have been conceived. Also methods like value stream mapping (VSM) are being widely used in industry to support enterprise engineering, and associated decision-making. Most EM architectures and VSM approaches recommend the capture of models of AS-IS situation in an enterprise under study. Typically this provides a relatively enduring representation of standard ways of working in that enterprise and by so doing implicitly documents important structural aspects of the enterprise. Generally though EMs are non computer executable in the sense that they do not encode sufficient time dependent information to enable the behaviours of actual processes to be replicated, or future possible behaviours to be predicted. Hence the use of these non-computer executable models alone can limit analysis about possible alternative ways of working. (Table 1 shows some pros and cons of enterprise modelling and value stream mapping). Therefore Chatha et al (2003) suggest that simulation models can be used in conjunction with enterprise models to analyse effects of temporal dependencies that link the entities of an enterprise; and that this can facilitate the identification and specification of needed change. In addition another class of computer executable models (namely workflow models) can be used to co-ordinate interoperation between modelled processes and actual processes of an enterprise; and this can facilitate the implementation of process and resource system change, and help manage and control the operation of resources in a model driven way. As simulation models and workflow models naturally capture time-dependent characteristics of Manufacturing Enterprises (MEs), they can be termed ‘dynamic models’. Table 1 also contrasts pros & cons of general simulation modelling approaches.

Table 1: Pros and Cons of static and simulation modelling approaches

Enterprise Modelling (EM) e.g. CIMOSA, GRAI/GIM & IEM	
Pro’s	Con’s
(1) EM formally captures relatively enduring threads of ME activity to realise products and supports developing ME long & mid term. (2) Can attach many other modelled entities to activity models. (3) Has formal decomposition technique to (a)	(1) Generally don’t encode time dependencies, e.g. related to control & exception flows. Hence cannot replicate existing ME behaviours or predict ME futures. (2) Detailed EM can involve significant modelling & data

fractionalise process segments & resource systems & (b) facilitate systems integration. (4) Can capture holistic view of ME covering concerns of various personnel.	capture effort. (3) EM tools may not provide version control as ME models are developed & changed.
Vale Stream Mapping (VSM)	
Pro's	Con's
(1) Graphically represents product flows, normally through threads of 'as is' activity used to realise products. (2) Can attach values to products at different stages of processing. (3) Normally optimise conversion processes of an ME by identifying waste & core activities. (4) VSMs can be produced relatively quickly & without significant training.	(1) Limited ME semantics are captured & value streams are not positioned explicitly in a specific context. Hence the optimisation of value streams may not optimise the ME as a whole. (2) Generally there are many forms of VSM. Little effort has been focused on developing reusable & standard VSMs.
Continuous Simulation Modelling (CSM)	
Pro's	Con's
(1) Generally model real systems (& processes) in terms of partial differential equations, with causal dependencies linking system variables & their changes over time. Behaviours often generated by solving these differential equations at regular instants in time. (2) Simulates the overall functioning of systems.	(1) The modelling concepts & constructs provided by CSMs are flexible and can encode many types of system behaviours. (2) Model complexity grows rapidly as the system scope is widened or as the level of detail is increased. (3) CS are difficult to place readily in an explicitly defined context.
Discrete Event Simulation (DES)	
Pro's	Con's
(1) Model real systems & processes in terms of states, queues, routes, stochastic events, resource utilisations, etc. (2) Simulates the flow of objects through activity (or work) centres. This enables system behaviour to be replicated & predicted.	(1) Modelling concepts & constructs may encode both system behaviours & relatively enduring structures. (2) Their complexity grows rapidly as the system scope is widened or as the level of detail is increased. (3) DES are difficult to place readily in a defined context.

One key potential benefit of coherently developing static and dynamic models of MEs is that together these models can inform the optimisation of processes. Business process (BP) optimisation is typically centred on an analysis of dependencies between enterprise activities (and their involved resources) so as to identify process and resource systems that best fit activity needs (Cheung & Bal, 1998), (Chan & Jiang, 1999), (Irani et al, 2000), and thereby realise objectives whilst satisfying given conditions. If the number of variables in a BP model are few, analysis may be carried out manually. However, where BP models are populated with causally dependent entities manual analysis may become impossibly complex or time consuming. Some simulation packages facilitate the modelling of BPs and their underpinning resources by capturing their interrelationships. This can help visualise and communicate key characteristic behaviours of a modelled process. Once such process representation has been formally captured, what if analysis and optimisation of process designs can proceed. Here data can be fed to the model and simulations can be run. These simulations can help suggest conditions under which a process can be executed in an effective manner. The optimised process models generated via simulation modelling can also be transformed into coherent descriptions of workflow models that can be enacted by a suitable workflow management tool. It follows that dynamic models can play an important role in organisation (re)design leading to improved process operation. Figure 1 reviews benefits that can be realised when using simulation models in conjunction with static models.

2. ENRICHED MULTI-PROCESS MODELLING METHOD

The experience gained from creating and using the Multi Process Modelling (MPM) method (Chatha et al, 2003) led to the design and realisation of an Enriched version of MPM. This comprises:

(i) an enriched set of multi process modelling constructs that are operationalised within the context of an Enriched Multi Process Modelling (E-MPM) Framework, such that they naturally support process simulation and enactment.

(ii) an Enriched Multi Process Modelling (E-MPM) Method that structures multi process modelling along similar but improved lines to its predecessor MPM; except that it is designed to structure the use of E-MPM modelling constructs, and

(iii) an Enriched Multi Process Modelling (E-MPM) Environment, which comprises a specific instance of the E-MPM Framework, the E-MPM Method and a selection of proprietary tools that facilitate process modelling, simulation and workflow enactment.

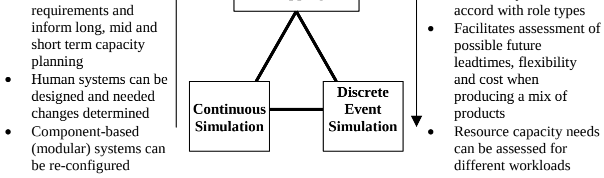

Fig. 1. Benefits of using simulation modelling in conjunction with static modelling

Besides inheriting a number of modelling concepts from CIMOSA, E-MPM introduces new complementary concepts. The outcome has been the E-MPM Framework (illustrated by Figure 2) (Chatha, 2004) and the E-MPM Method (see Table 2) which structures and enables the creation of enriched process and simulation and enactment models. When developing first generation static and dynamic models using MPM, it was realised that the CIMOSA modelling framework lacks certain needed modelling concepts to capture and represent time dependent (or dynamic) attributes of an enterprise. It was also observed that existing CIMOSA modelling constructs lack explicit means of representing and supporting key enterprise engineering concepts, such as 'change capability', 'modularisation' and 'collaboration'. This observation provided the prime motivation for devising and adding new E-MPM concepts that have an ability to explicitly encode selected: collaboration concerns; exception types and their handling; aspects of process modularisation; and developmental aspects of dynamic models. A significant number of CIMOSA concepts were retained, but in some cases amendments were needed to enable them to be used coherently with the new concepts. All new and amended concepts were organised in relation to the pre-existing CIMOSA modelling specification. Hence the E-MPM Framework has three dimensions, namely 'generation', 'instantiation' and 'derivation' dimensions. E-MPM's instantiation dimension closely mirrors that of the CIMOSA instantiation dimension. However the 'generation' dimension is split into three strata namely 'physical'; 'intellect and knowledge'; and 'social' strata that represent reality, where the strata chosen are akin to key aspects of human beings; namely 'physical body'; 'soul' and 'self' (Al-Hujweri, Translated by Nicholson, 1976). Authors like Schael (1998) have conceived (manufacturing) organisations to be socio-technical systems. However, the present authors consider (manufacturing) organisations to be knowledge carrying socio-technical systems. Hence the three corresponding strata along 'generation' dimension (Figure 2). The physical stratum captures aspects related to physically building an organisation. The knowledge stratum captures aspects related to the knowledge used and produced by or for an organisation. This includes tacit knowledge as well as explicit knowledge. This may also encompass procedures for handling change. The social stratum captures aspects related to social behaviour and the social environment of the organisation. In the current version of the E-MPM Framework, the social stratum is centred on coordination, collaboration and communication concepts and principles. Each of these three strata of an organisation is considered to be 'open' in the sense that the E-MPM Framework is eclectic, having been designed to accommodate the introduction of additional concepts. Together the concepts incorporated into the three strata of reality can be used to structure and represent different perspectives when seeking to study, design, develop and change an organisation.

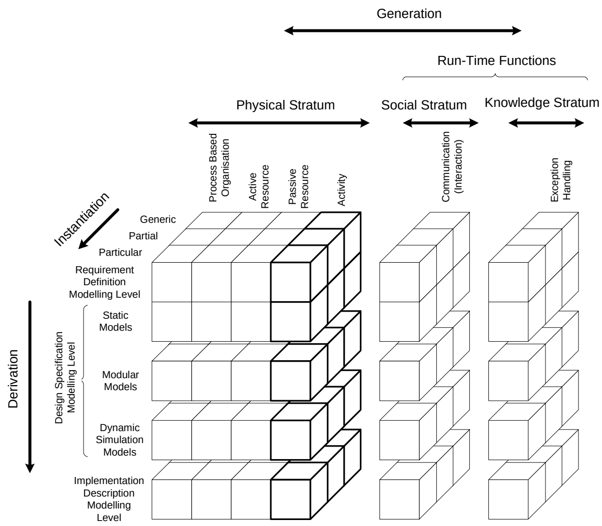

Fig. 2. Enriched Multi-Process Modelling Framework

Returning to the physical stratum of the E-MPM Framework, a number of concept enhancements were made to CIMOSA. First and foremost it is assumed that (most) MEs can be usefully viewed as being process-orientated organisations but that various other organisational perspectives can be interpreted relative to that primary view. Following an associated logical line of reasoning, the 'function' view of the CIMOSA framework was explicitly replaced by an 'activity' view. Here focus of attention is on activity execution and the requirement for active resources, that have capabilities to do functional operations, and thereby carry out defined activities. In general activities will also require passive resources on which either functional operations are carried out to produce outputs or which are used or consulted when carrying out activities. To address this need in a way which naturally provides activity models that can be readily transformed to coherent simulation and enactment models, additional modelling concepts were added. The derivation dimension encodes and represents requirements of systems during their lifetime. Notable differences in this dimension (compared to the CIMOSA framework) are concepts provided to create semantically rich: static process models; modularise processes; and dynamic models of process and resource systems. Based on the concepts developed and incorporated into E-MPM, the E-MPM method was developed to facilitate and systemise enterprise modelling. Key elements of that method are presented in Table 2.

3. ILLUSTRATION OF THE USE OF E-MPM

The E-MPM method has been used while re-engineering sets of BPs deployed by some UK MEs. One such set of BPs is used by a consortium of car producers to design and build Engine Assembly Lines. One such BP belonging to that set is a so called "Schedule and Monitor Engineering Performance" business process. Subsequent sections of this paper illustrate how E-MPM models of this "Schedule and Monitor Engineering Performance" process have been used to facilitate process improvement.

In conformance with the E-MPM method re-engineering of the example 'Schedule and Monitor Engineering Performance' process was initiated by collecting and structuring appropriate process related information followed by developing a semantically rich graphical (static) process model of the enterprise process under study (see Figure 3) using E-MPM's Generic Process Modelling Language. This modelling language enables coherent modelling of: process flows, exception flows and resource flows. It also supports the capture of information about resource dependencies that may occur within or between multiple processes. Once this rich picture is developed it enables the development of suitable simulation models which can support the analysis of time-dependent aspects of process working. Based on results of this analysis, candidate TO-BE processes can be conceptualised and selection can be made between alternative ways of resourcing the process based on time and cost criteria, by using E-MPM's feasible resource selection simulation modelling capability (Figure 4). Hence TO-BE processes and resource systems can be re-configured in a virtual world. During this (re)configuration enterprise activities are re-grouped to form meaningful modules comprising enterprise activities and associated resource systems.

Table 2. Enriched Multi-Process Modelling Method

	Outline Description of Modelling Activities Needed at each Main Step of the Modelling Method	**Method & Concepts used to 'Structure' Modelling Activities & Multiple Process Representations**	**Modelling Techniques & Tools Deployed to Represent & Analyse Modelled Entities & their Interrelationships**
Stage 1: Elicit 'As Is' Process Data from Engineering Partners	Elicit and record multiple understandings about current business processes deployed by engineering partners, with the aim of developing a unified set of process representations that collectively form a static pool of enterprise knowledge that can be reused for various purposes.	A developed approach to document alternative views of multiple business processes; held either within the heads of people responsible for different process segments or previously recorded in company documents. Structured interviews (which constitute an integral part of the approach) are organised with reference to the need to develop E-MPM conformant static and dynamic models.	Various paper based sketches of E-MPM conformant 'domain processes', 'business processes' and 'enterprise activities' are developed to facilitate knowledge elicitation and multi-process documentation, leading to the development of static and dynamic models.
Stage 2: Create and Validate 'Static Views' (or representations) of 'AS-IS' Processes	Reuse of elicited data to populate and validate multiple 'static views' of 'AS-IS' business processes that collectively and coherently provide a 'semantically rich picture' of relatively enduring enterprise entities and their interrelationships that can be reused by different enterprise personnel in support of their various roles.	Static views captured and populated in conformance with enhanced-CIMOSA E-MPM diagramming templates & models needed to encode 'enterprise requirements'. Thus fragmented process views, at multiple levels of abstraction are organised into 'context', 'interaction', 'structure' and 'process' modelling templates pertaining to both partnership enterprises and individual partner businesses. Individual and collective validity of the views is rechecked with appropriate personnel.	A structured approach to the use of a combined POWERPOINT and VISIO was developed to facilitate the generation of graphical (non-computer executable) representations of 'AS-IS' static model views, based on the use E-MPM modelling constructs. Use for this purpose of various specialist commercial tools (such as FIRST STEP, MO^{2}GO and METIS) was considered but not adopted.
Stage 3: Develop & Validate Dynamic Models Pertaining to Focussed Aspects of 'AS-IS' Processes	Selected aspects of the static representations of 'AS-IS' processes are recoded into computer executable models with capability to simulate process operation and behaviours from some perspective and thereby provide new insights into 'AS-IS' *process design, process resourcing* and *process operation*. Initial	Various general CIMOSA-based modelling concepts (pertaining to *'derivation', 'generation'* and *'instantiation'*) were adopted in E-MPM and used to focus and structure dynamic model generation. However use of these concepts and associated E-MPM decomposition principles needed to be translated into an alternative set of modelling concepts which can be practically implemented	Various modelling studies have, for different purposes, generated alternative dynamic models using the *ithink* and *Simul8* modelling tools, by recoding selected entities and entity relationships previously coded by the static base data. This yields computer executable models that via the application of numerical

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	dynamic model analysis and development is focused on model validation with subsequent analysis on identifying possible constraints arising from 'AS-IS' practice.	using a selected dynamic systems modelling tool.	integration techniques, or discrete even techniques simulates and displays metricated dynamic behaviours in various programmable and interactive forms.
Stage 4: Create Static Views of Possible TO BE Processes	Reuse of the elicited data to develop static views of 'TO BE' business processes that collectively, coherently and agreed with enterprise personnel provide a 'semantically rich picture' of relatively enduring enterprise processes that can be reused by different enterprise personnel for various purposes.	Static models of TO-BE processes are developed in conformance with E-MPM diagramming templates namely: 'context', 'interaction', 'structure' and 'process' modelling templates pertaining to both partnership enterprises and individual partner businesses. Models are agreed on with appropriate personnel in the enterprise.	A structured approach to the use of a combined POWERPOINT (general purpose presentation software) and VISIO was developed to facilitate the generation of graphical (non-computer executable) representations of 'AS-IS' static model views, based on the use E-MPM modelling constructs.
Stage-5: Modularis-ing To-Be Processes	Creates modules of enterprise activities based on dependencies they have among themselves within a process class and between two process classes thus realising intra-process and inter-process modules of enterprise working.	Information contained in Static views of TO-BE processes was reused to identify process modules using E-MPM module identification method.	E-MPM module identification method was deployed to identify process modules using Excel Spreadsheet as a tool to support concepts.
Stage 6: Develop & Validate Dynamic Models of Focussed Aspects of Possible 'TO-BE' Processes	Based on knowledge of 'TO-BE' process properties (static) new business process scenarios are developed and are run under simulation. This provides metricated analysis of alternative: *process designs; attributions of resources to process elements;* and *process operations*.	Use of E-MPM concepts help structure 'TO-BE' scenario generation. Use of *enterprise activity* and *active & passive resource* concepts help structure process resourcing activity. These and new concepts needed to be mapped onto modelling concepts and constructs made available by the selected dynamic systems modelling tool.	Causal loop diagramming techniques and simulation tools such as *ithink and/or Simul8* are used to 'visualise' and 'simulate' causal effects and the operation of various candidate 'TO-BE' scenarios. This enables conceptual thinking and focused simulation of possible 'TO-BE' behaviours and metricated performance measurement made relative to 'AS-IS' benchmarks.
Stage 7: Focussed Deployme-nt and Use of Static & Dynamic Process Models to Control Actual Workflows	One potential use of 'AS-IS' and 'TO-BE' static and dynamic process models is to manage and control workflows. At this stage of the modelling method selected model fragments (previously captured and validated) are recoded so that they can be executed (in a suitable workflow tool). This allows computer executable models to be linked to the actual process and its resource entities.	E-MPM decomposition principles, particularly its *active* and *passive resource* modelling concepts and adopted modelling concepts (from CIMOSA) *instantiation, enterprise activity, functional entity, information object* and *enterprise event* are used to partially structure the reuse of previously coded process knowledge into recoded forms (namely *control flows* and *data flows*) that need to be enacted by the set of modelling constructs provided by the selected workflow tool.	The *i-Flow* workflow management tool was selected to operationalise focused workflow aspects of the 'AS-IS' and 'TO-BE' process models previously captured, validated and analysed.

Resource systems are re-configured in terms of role sets that they have competencies and capacities to carry out. Once a process has been redesigned and suitable resource systems have been selected and re-configured their activities can be coordinated using E-MPM's workflow models (in the form illustrated by Figure 5). The workflow models facilitate co-ordinated management of actual process instances needed for different work types. They facilitate storage, release and co-ordinated interoperation of instances of processes, by achieving realtime linking of enterprise activities to resource systems (based on roles they play). They also coordinate resource interactions and manage the timely completion of processes.

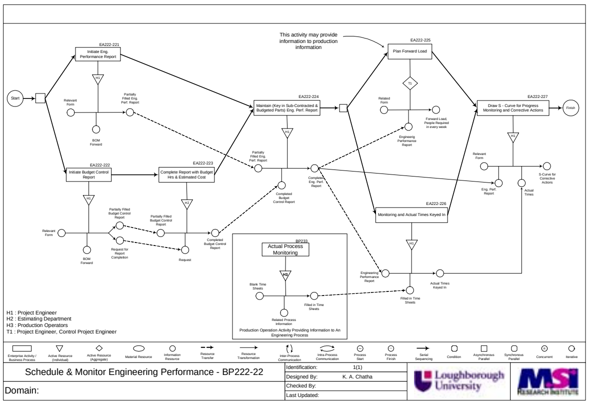

Fig. 3. Semantically Rich Static Process Model

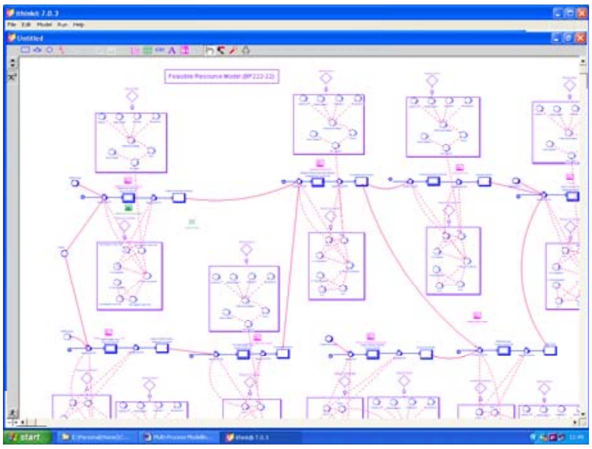

Fig. 4. Resource Selection Simulation Model

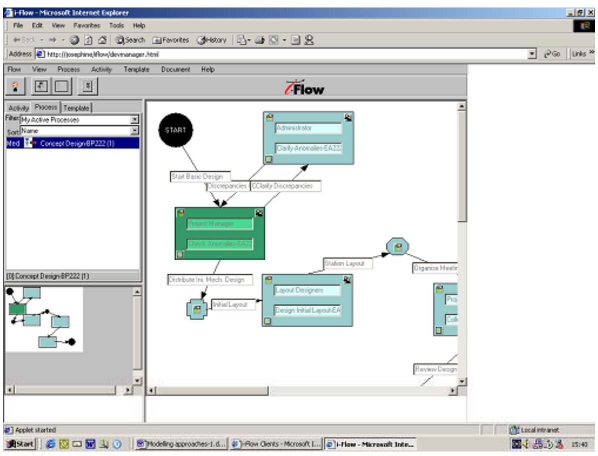

Fig. 5. Workflow Model in support of E-MPM

4. CONCLUSION

The E-MPM method has potential to facilitate key aspects of business process re-engineering and can be applied with respect to strategic, tactical and operational processes of an organisation. E-MPM's modelling formalism and model types provide a capability to support various aspects of process design, resourcing and enactment. E-MPM has been deployed to successfully change a number of case study ME processes currently used industrially. Here it has been observed that significant modelling effort is required but that effort can yield very significant business benefits and can provide process and system models that can be reused on an ongoing basis to facilitate much improved organisational dynamics. Additional concepts and model types are being developed that will further enhance E-MPM's capability to support the life-cycle engineering of MEs.

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