Integrated modelling approach in support of change-capable PPC strategy realisation

T. Masood[a,b], R.H. Weston[a,b]

[a] Manufacturing System Integration (MSI) Research Institute, Loughborough University, Leics, LE11 3TU, UK
[b] Centre of Excellence in Customised Assembly (CECA), Loughborough University, Leics, LE11 3TU, UK

Abstract

The increasing demand for customization, reduced time to market and globalization are the real challenges for today's manufacturing enterprises (MEs). Therefore MEs can reduce these competitive pressures by becoming more and more change-capable. The agile and lean manufacturing philosophies must complement the application of reconfiguration techniques. However, choosing and applying the best philosophies and techniques are far from being well understood and well structured processes because most MEs deploy complex and unique configurations of processes and resource systems, and seek economies of scope and scale in respect of a number of distinctive product flows. It follows that systematic methods of achieving model driven reconfiguration and interoperation of component based manufacturing systems are required to design, engineer and change next generation MEs. This paper discusses research aimed at developing and prototyping a model-driven environment for the design, optimization and control of enterprises with an embedded capability to handle various types of change in an example of a production planning and control (PPC) scenario. The developed environment supports the engineering of common types of strategic, tactical and operational process found in many MEs. Also reported are initial findings of manufacturing case study work in which coherent multi-perspective models of a specific ME have facilitated process reengineering and associated resource system configuration and interoperation. In order to understand the system prior to realisation of any PPC strategy, multiple process segments of organisations need to be modelled. The paper considers key PPC strategies and describes a novel systematic approach to create coherent sets of unified models that facilitate the engineering of PPC strategies. Case study models are presented with capability to enable PPC decision making processes in support of complex organisation design and change (OD&C). The paper outlines key areas for future research including the need for research into unified modelling approaches and interoperation of partial models in support of complex OD&C.

Keywords: Organisation design and change (OD&C), reconfigurability, change-capable, production planning and control (PPC), enterprise modelling (EM), simulation modelling (SM).

1. Introduction

The increasing demand for customization, reduced time to market and globalization are the real challenges for today's MEs. This has induced a need for faster, better and cheaper production. Therefore MEs can reduce these competitive pressures by becoming more and more change-capable. One key common response is for MEs to have a broadened product portfolio. But to compete they must deploy an effective and change capable set of human and technical resource systems. Also because of falling product lifetimes and growing customisation requirements the deployment of these resource systems will increasingly need to give rise to economies of scope and mass customization [1]. For many companies around the world, staying in business necessitates:

- meeting specific customer requirements innovatively and effectively
- reducing the time-to-market of products
- manufacturing quality products at competitive cost.

The present day customer typically imposes constraints on MEs via their specific and changing quantity, quality, cost and delivery product and service demands. The implications of this customer focus are that; time to market is shortening, products are tailored to meet a breadth of customer needs, and demand is variable [2,3,4]. However, MEs cannot simply respond by deploying new processes and resources. Generally they need also to redeploy (i.e. re-configure and re-integrate) their use of existing processes and resources such that they can respond competitively to the ongoing business dynamic created by the specific and changing demands of their customer base.

The identification of methods by which manufacturing improvements can be achieved is ongoing and has led to a range of approaches in recent years including Lean and Agile Manufacturing. In addition, progressive improvements to information system capabilities continues to offer the belief that significantly improved support for effective decision making can be achieved [5,6].

Hence it has been observed that modern manufacturing systems must be; flexible/agile, reactive, integrated, and cost efficient [3]. It also follows that ME personnel must have (individual and collective) in-depth understandings about specific processes and resource systems and that these processes must be flexible enough to change whenever the need rises. The complexity of manufacturing systems is reaching that of many natural (e.g. economic and political) systems, thus ongoing re-design and re-engineering of such systems require the use of systematic approaches which deploy various types of system model to understand current and possible future behaviours and to inform systems engineering decision making.

This paper presents an application of the integrated modeling approach presented in [7] in an example of a change-capable PPC scenario in a manufacturing SME. The developed environment supports the engineering of common types of strategic, tactical and operational process found in many MEs in support of reconfigurable manufacturing.

2. Need for change-capable model driven PPC strategy realisation

An efficient production planning and control (PPC) system is crucial in making a manufacturing system 'live', responsive and change capable. It is also of vital importance to satisfy dynamic customer demands and expectations in highly competitive manufacturing environments [8]. In general, any given choice of PPC strategy will impact on the way in which a ME realises management of customer demand; planning and meeting material requirements; and capacity planning, scheduling and sequencing of jobs. Appropriate choice of PPC strategy should help a business to: minimize Throughput Time (TT) and Lead Time (LT); reduce Work in Progress (WIP); keep inventory costs at a minimum; improve responsiveness to change in demand (resulting in changes in product and process some times); and improve Delivery Date (DD) adherence. These are important objectives, and choosing the right PPC approach and system is hence a crucial strategic decision which should be consciously made by managers of MEs [8].

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There have been recent advancements to extend the coverage of public domain open systems architectures and to bridge the gap between static modelling and dynamic or simulation modelling. Computer Integrated Manufacturing Open Systems Architecture (CIMOSA) has been central to most of such developments as also mentioned in [7]. A natural focus of these modelling efforts has been to make the models 'live' and responsive to the upcoming rapid changes. Here the idea is to have modelled real elements of complex and changing sets of processes (and their underlying resource systems) interoperate in a readily integrated and change capable manner which satisfies specific dynamic requirements of the business environment in which the processes are used. The PPC system plays a vital role to depict the 'liveness', responsiveness and reconfigurability of a manufacturing system.

3. Change-capable model-driven approach in support of PPC strategy realisation

This paper describes a systematic approach to creating coherent sets of unified models that can interoperate to replicate and predict changing organisational behaviours in support of PPC. The modelling approach used to support PPC strategy realisation is based upon the methodology presented in [7] and is illustrated in Fig. 1.

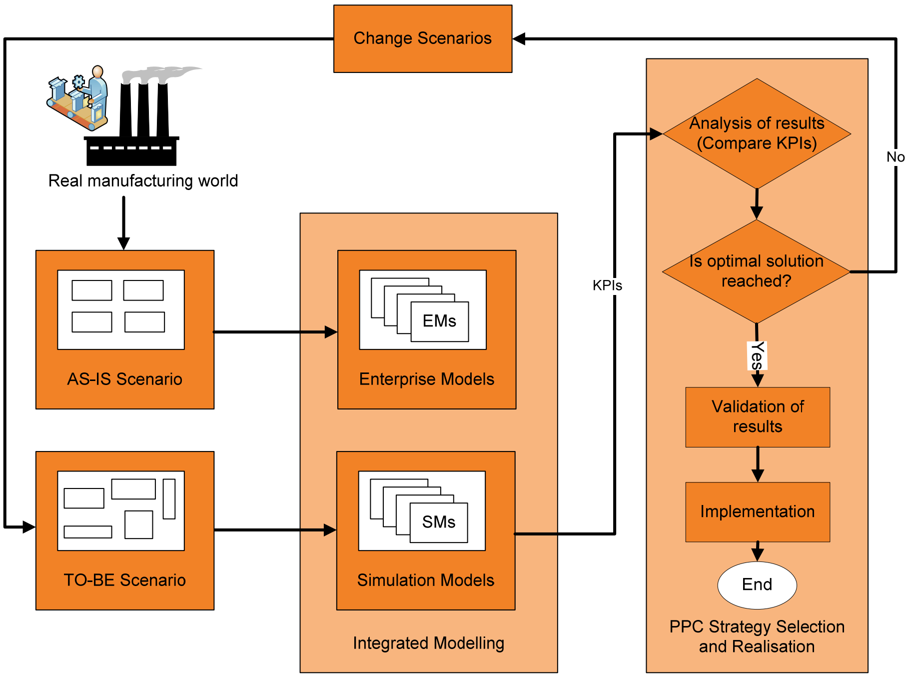

Fig. 1. Change-capable modelling approach in support of PPC strategy realization.

4. Case Study

The case study company (referred to as ABC onwards) is a furniture manufacturing SME with 50 employees. It operates primarily within the UK but has European suppliers of raw material. It manufactures over 300 different furniture products from pine wood; including a range of tables, cabinets, beds, wardrobes and other furniture items that are designed for house hold and business users. The application of a number of different PPC concepts is being investigated at ABC. A coherent set of enterprise and simulation models were created to explicitly represent and computer execute behaviours of ABC's business processes, (human and technical) resource systems and dynamic patterns of multi-product workflows.

Machining, assembly, spraying and finishing are the main production processes involved in ABC's furniture production. ABC's current production system implements a make-to-order (MTO) strategy in which production operations are triggered by groupings of customer orders based upon logistical criteria related to customers categorized by UK location. A fleet of lorries are used by ABC to deliver customer orders to specified regions of the UK. Production 'runs' are constrained by the capacity of these lorries or by a pre-set maximum order collating time of four weeks (whichever constraint is exceeded first).

According to ABC's current PPC strategy, the company compiles orders received from customers on a weekly basis. The production starts with the issuance of a production order (known as 'sales order picking list' in ABC) to the assembly shop. The production order is then reviewed by the assembly shop coordinator who generates a 'Machine Shop Production Order', that requests needed parts from ABC's machine shop. The job list of the machine shop is regularly updated and priorities are set in order to maintain smooth running of the assembly shop. The production order is then moved through the assembly shop after receiving parts to be assembled from the machine shop where assembly processes are carried out. Fig. 2 shows interactions of plan and control business process in sub interaction diagram of the business management domain of ABC.

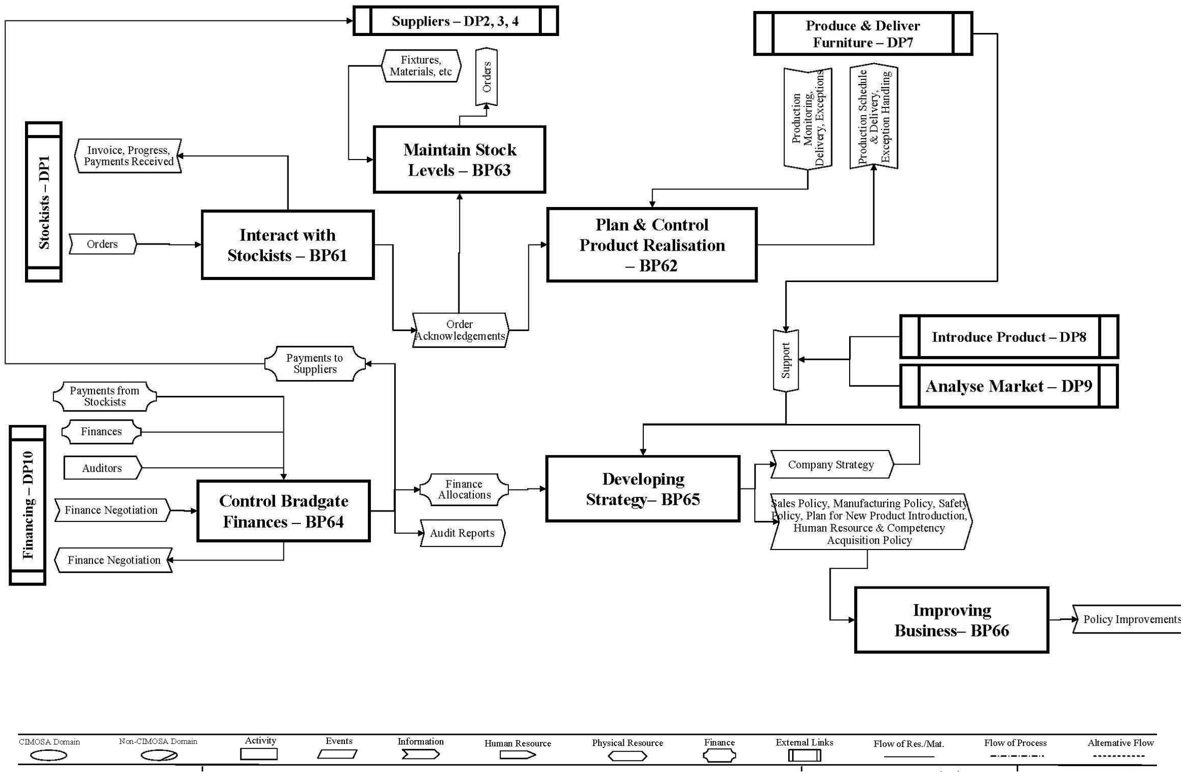

Fig. 2. An exemplary enterprise model of ABC's Plan and Control Business Process

A high variety of more than 300 products in ABC contain both less frequent and highly demanded products during certain periods which were unknown. There were no forecasting methods being adopted primarily because product demands are unpredictable. After a number of visits to the company and number of discussions with company management and operators, initial data was collected.

The assembly area works on '*real-time scheduling'* approach in which production schedules are prone to change at any time. The next job to do is decided after finishing the predecessor based on the current status of frequently changing job list, level of resources and due dates. The (human) resources are considered very flexible across different sections, sometimes even across departments.

The assembly area has three production supervisors, one being the overall assembly coordinator, the other two being the respective section sub-supervisors for table and cabinet sections. The picking list is received from customer order processing department twice a week by the assembly coordinator.

Then he prepares '*partial picking'* lists by highlighting the relevant furniture items for each assembly area and pass it to the work benches. Every time a workbench finishes a job the next job is picked from the highlighted list according to earliest due date (EDD) and minimum setup time (MST) sequencing rules. The similar items are grouped together and some items are made in batches to save the setup time if they are in the same delivery run.

In addition to the picking list, a number of times a week a machine shop request list is prepared and passed to the machine shop by the assembly coordinator. When the relevant partial picking list is received, the corresponding assembly section checks the component stock levels against the requirements due to new order and then if there is a need an order for that component is added to the machine shop request list.

It should be noted that there is a time lag between the receipt of the partial picking list and the actual start of the assembly production. Therefore this time lag, that is usually around one week, is used to manufacture the required components by the machine shop. It is also used to make the auxiliary cabinet parts such as drawers, doors, and plinths before the assembly operations starts. Each cabinet subsection calculates the required amount of these items as soon as a partial picking list is arrived and the necessary orders are passed to the auxiliary items maker. This synchronisation is achieved by the careful planning efforts by the assembly production supervisors.

In this case study conceptual AS-IS and TO-BE models were developed after number of visits to the case study company, conducting a number of useful discussions with company management and operators and collecting useful data. The products were grouped on basis of commonality of their operations and process times; for example cabinet assembly products were divided into 11 groups. An exemplary simulation model of cabinet assembly of the case study system developed in Plant Simulation ® is shown in Fig. 3.

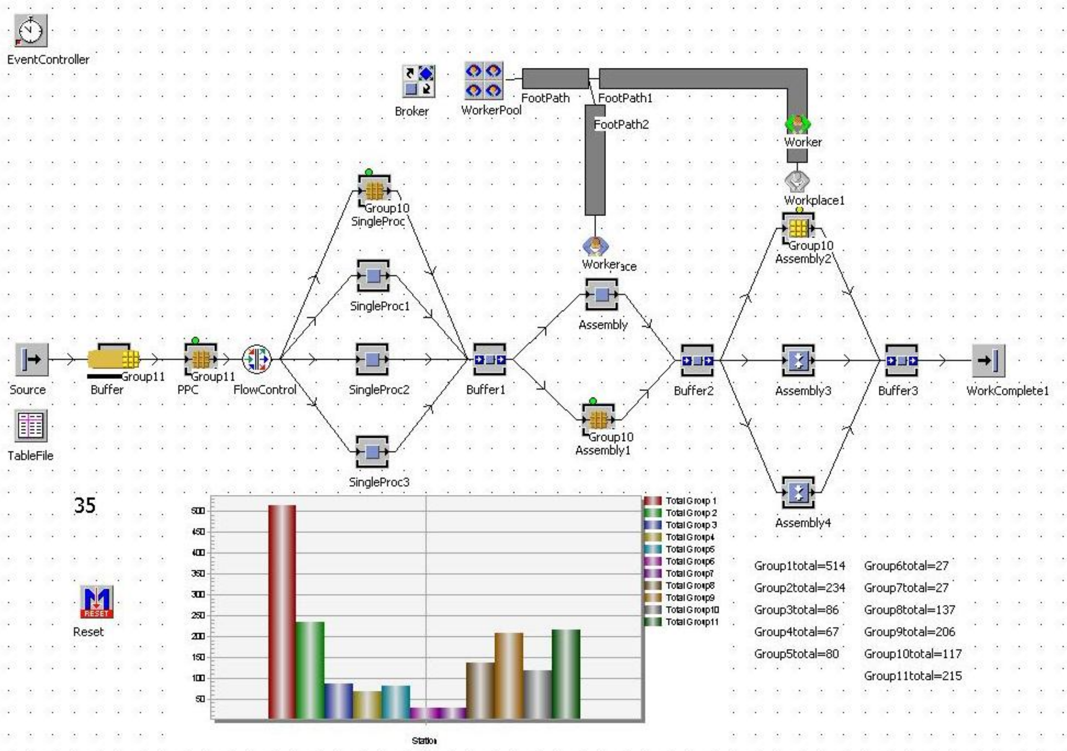

Fig. 3. An exemplary simulation model of cabinet assembly during the model run in Plant Simulation ®

Enterprise and simulation models were developed in order to enable decision making about ME possible realisation of an improved PPC strategy which could make this assembly process segment (and its underlying resource systems) become more reconfigurable and interoperable. One of the key performance indicators is lead time as also mentioned in [7]. Fig. 4 summarizes lead time KPIs of the proposed cabinet group assemblies.

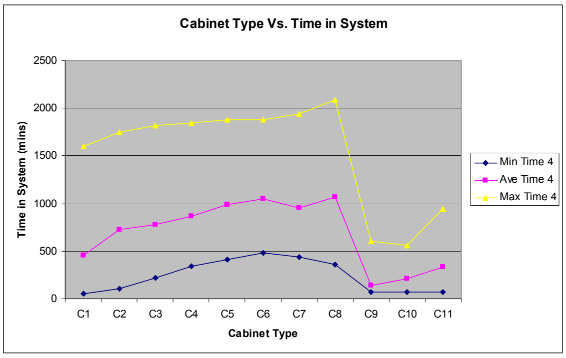

Fig. 4: Lead time results for different cabinet types

It was noted that the combined use of EM and SM techniques helped to gain in depth understanding about the ABC's PPC methods, their shortcomings and possible ways of improvements as tabulated in [7]. Such PPC decision making supports OD&C process. There is a need to develop methods and technologies for unified modelling and interoperation of partial models in support of complex OD&C. The future research also relate to the use and updating of enterprise and simulation models.

5. Conclusions

This paper presents an application of the integrated modeling approach presented in [7] in an example of a change-capable PPC scenario of cabinet assembly in a manufacturing SME. The developed environment supports the engineering of common types of strategic, tactical and operational process found in many MEs in support of reconfigurable manufacturing. The coherent multi-perspective models of a specific ME have facilitated process reengineering and associated resource system reconfiguration and interoperation. It follows that systematic methods of achieving model driven reconfiguration and interoperation of component based manufacturing systems are required to design, engineer and change next generation MEs. The basis of a systematic approach to creating coherent sets of unified models that facilitate the engineering of PPC system is described. Example enterprise and simulation models have been presented in the paper which supported model-driven reconfiguration of manufacturing systems. The paper has identified key areas for future research which relate to the use and updating of enterprise and simulation models.

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