Order Planning Decision Support System for Customer Driven Manufacturing

Henrique Proença
Escola Superior de Tecnologia de Castelo Branco
Av. do Empresário
6000 Castelo Branco Portugal
e-mail: henrique@est.icb.pt

Américo Azevedo
Faculdade de Engenharia da Universidade do Porto and INESC Porto
Rua Roberto Frias S/N
P-4200-465 Porto, Portugal
e-mail: ala@fe.up.pt

Abstract

An important goal in schedule production orders through a manufacturing facility is to assure that the work is completed as close as possible to its due date. Work that is late creates downstream delays, while early completion can be detrimental if storage space is limited. Production planning and control manufacturing is becoming more difficult as family products increase and quantity decreases.

This paper presents an ongoing information system development that aims the production planning of special test tables equipment for automobile components manufacturers. The simulated based information system will be used to support planning and schedule activities; to compare and analyze the impact of planning rescheduling; to forecast the production completion date; to detect bottlenecks and to evaluate machines performance.

Key words: Production Planning, Scheduling, Decision Support System

1 Introduction

To survive in the current highly competitive economy, it is necessary to set up products in the market. The success depends on many factors like rapid reactions to market changes and a permanent strive for minimizing costs. Better manufacturing schedules provide competitive advantage through reduced production cost and increased productivity (Chase et al. 2001). In order to accomplish the competitive edge, goals such as optimization of capacities, minimization of lead times, compliance with deadlines and production flexibility should be supported by information systems oriented to operations management, namely production planning and control systems (PPC).

In general, PPC systems are responsible for scheduling and controlling the whole production process, through the definition of the order quantities, definition of start and finish dates and planning of routings for each order. One of the main goals of these systems is to co-ordinate the resources involved in fulfilling production orders. The planning process is based on descriptions of the products and of the required operations and resources, along with dynamic information concerning demand and capacities.

The major weaknesses of this traditional approach include:

- lead times are assumed to be known and constant over time
- very high degree of labour division
- fixed product routings
- inflexible planning procedures (the sequencing logic prioritizes orders only by date)
- infinite capacity is assumed
- low frequency of planning runs (the plan regeneration takes a considerable amount of time).

In addition to the above shortcomings traditional PPC-systems have difficulties in coping with new organizational forms of manufacturing, like production and assembly "islands", product oriented or customer-driven manufacturing (Azevedo and Sousa, 2000 b).

Customer-driven manufacturing is the key concept for the factory of future. The markets are nowadays marked by an increase in variety, while at the same time showing steadily decreasing product life-cycles. Customer-driven manufacturing requires greater customer satisfaction at lower cost. In addition, tailoring the product to the customer's needs is becoming increasingly important in quality improvement. In this environment, the availability of the right kind and quantity of resources able to engineer, manufacture and assemble a product in line with the customer's needs is very important. Therefore, the engineering and production processes constitute the manufacturing system that has to be managed (Wortmann *et al*., 1997).

The work presented in this paper was guided by the design and implementation of a order planning decision support system, addressing the requirements of a make-to-order environment, in order to overcome some of the drawbacks identified in current PPC-systems, and hopefully able to produce realistic satisfactory delivery dates. This work has being developed under a research project in collaboration with a manufacturer of special test equipments for the automobile industry, and the ultimate objective of the work, as expressed by management, is to optimise the performance of the plant.

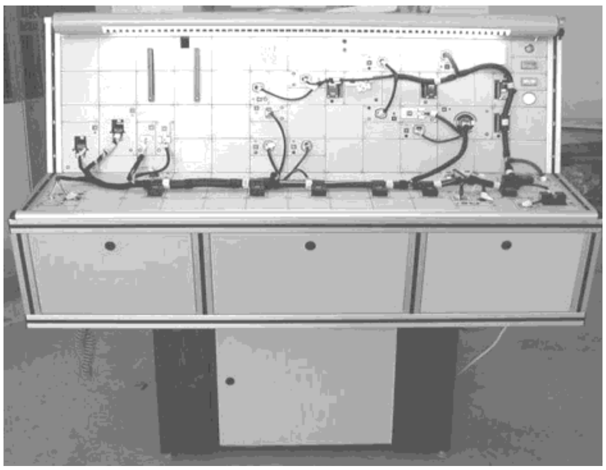
The frequent needs for anticipate deliveries or to satisfy customer's orders, that are crucial in company strategy, give rise to constant changes in current production orders, as well as this situation results in loss manufacturing capacity. In order to overcome these limitations, the system under development aims to simulate the company's engineering and manufacturing process. This will allow evaluating the effectiveness of the engineering and manufacturing process in terms of resources performance and in terms of quality of planning schedule generated. Also, the company will be able to analyze the impact of rescheduling the manufacturing planning and to predict the production orders finish date and even detects possible bottlenecks.

This paper is structured as follows. The following section describes the company, presents their main products and its main manufacturing process, and concludes with some issues concerning production planning and control. An overview of the main requirements for the decision support system under development is presented in section 3. Finally, we will summarise our results and make a brief reference to some topics for future work.

2 The manufacturing process

2.1 Company description

The company to which reference is made throughout this paper produces special test equipment tables for automobile test components manufacturers, namely cable testing tables, as show in figure 1 (left side). For each variant of automobile cable, the company, at most, produces three testing tables and they are always product specific. This means that the same testing table cannot be used for different automobile cable models.



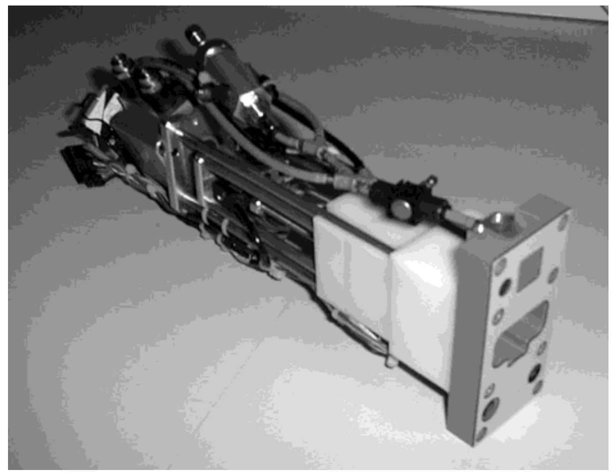


Figure 1. Table for automobile testing equipment and Push Test Module

The most important organisational aspect of the company is their manufacturing production model to be *Make-to-Order* oriented. The company plans the production taking into account firm customer's orders and available capacity. Even though they have a product portfolio, every potential customer order, due the particular technical specification, is nearly always a new product, and their manufacturing cycle time is usually very tight, normally between two or three weeks.

2.2 Range of products

The company holds three different product families in its portfolio: Mechanical Modules, Electromechanical Modules and Test Tables. The different possible configurations of each product are based upon a wide variety of options at the subsystem level.

The manufacturing of test tables product family, who's set up by electric control modules and control tables, is responsible for more than 80% of total company production. The difference between these two products can be found at final product level. While in the first there are only constructed separated modules (e.g. to replace parts in maintenance activities), in the second is built a complete table, which is composed by a set of modules. This family is constituted by a set of fifteen different modules similar to the one that's present in figure 1 (right side).

The number of modules in a testing table changes with the cable test. The existing modules only provide a small set of technical characteristics that the module must guarantee in order to execute his task. Each type of cable tests and mainly its terminals specifications imposes the module technical specifications resulting different testing table, i.e. different final products.

2.3 Manufacturing Process

It is possible to describe the company as a make-to-order manufacturing plant with a discrete production model. The resources are organised as a functional layout, exploring at cell level, group technology. This layout organisation was prepared for 'one-of-a-kind' production (small series) and can be conceptualized and managed as job-shop manufacturing environment. In these areas are manufactured all components and assembled the final product, according order specification. Figure 3 is an activity diagram of one module manufacturing process.

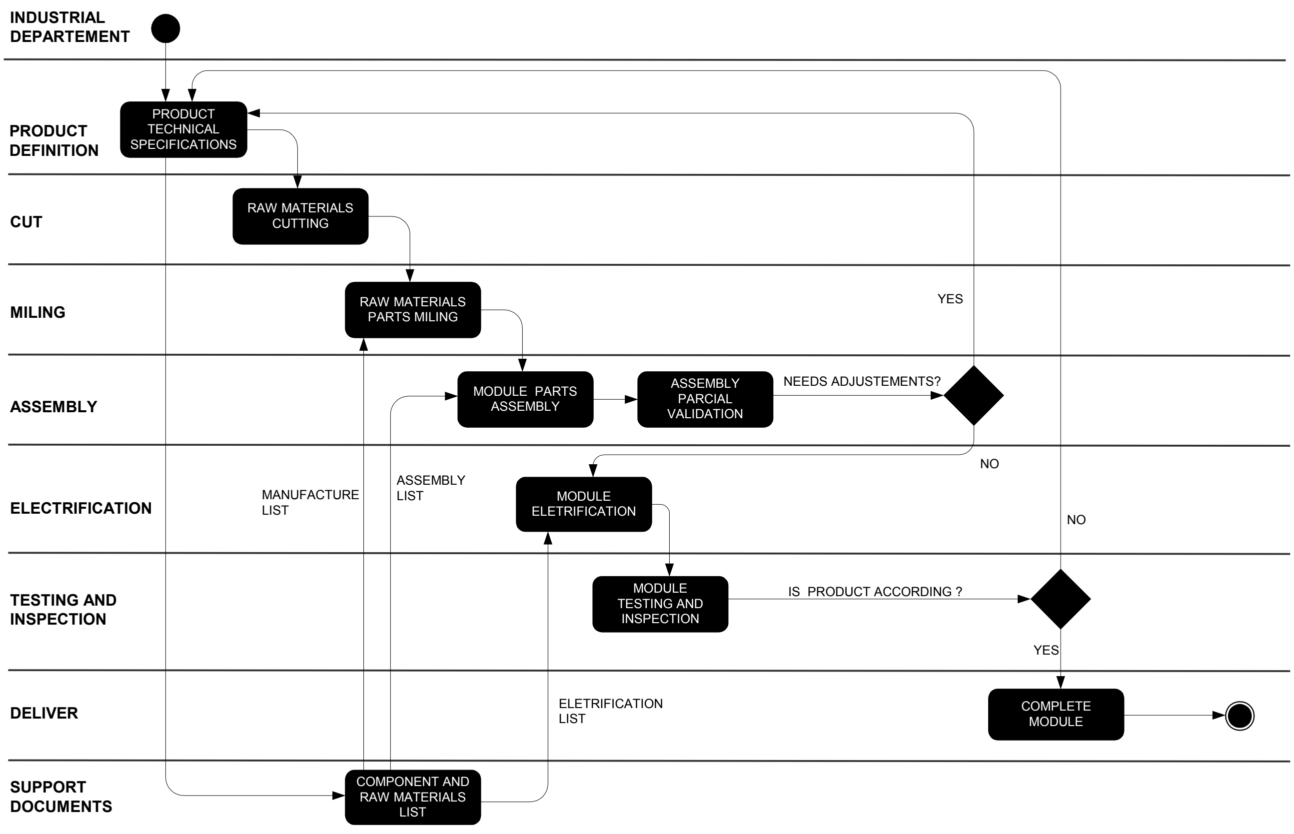


Figure 3. Activity diagram of one module manufacturing process.

The first step in the development of a testing table is done in the product definition cell, here is evaluated the specific cable testing needs, which allow to find how many modules will be needed to build the table, what kind of modules, and their specific test characteristics. With this is created a component and raw materials list, which contains all the needs for building an entire testing table. Three sub lists compose the component and raw materials list, they are:

- The manufacture list, which indicates the parts that will compose a module;
- The assembly list, which indicates the parts that is necessary buy in order to assembly the parts manufactured in the previous sub list;
- The electrification list, which indicates the parts that is necessary to buy in order electrify the modules, and what kind of electrification each module needs.

The next cell is responsible for cutting all the raw material that will be used to manufacture the parts. After this all parts enter on the milling cell, which will give the correct shape to each one.

In the assembly cell is performed the assembly of all module parts, and also a partial test to evaluate the module behaviour. If is necessary any adjustment in the module, it will go back to product definition cell in order to evaluate the problem. If the module does not show any problem he follows the manufacturing process. At this point the module is almost finished and is designated by *incomplete module*.

With the electric systems assembled the *incomplete module* is considered a *full module*. This is done in the electrification cell. For last but not least is the testing and inspection cell, which is responsible for evaluate the module and approve him. If the module is according then it is ready to be used, if not is necessary proceeds to corrections. The manufacturing process flow is continuous among all cells and even inside them, except on the milling cell, where exists a parallel flow.

After all the modules are available, starts an assembly activity. Figure 4 describes the testing table assembly activity diagram.

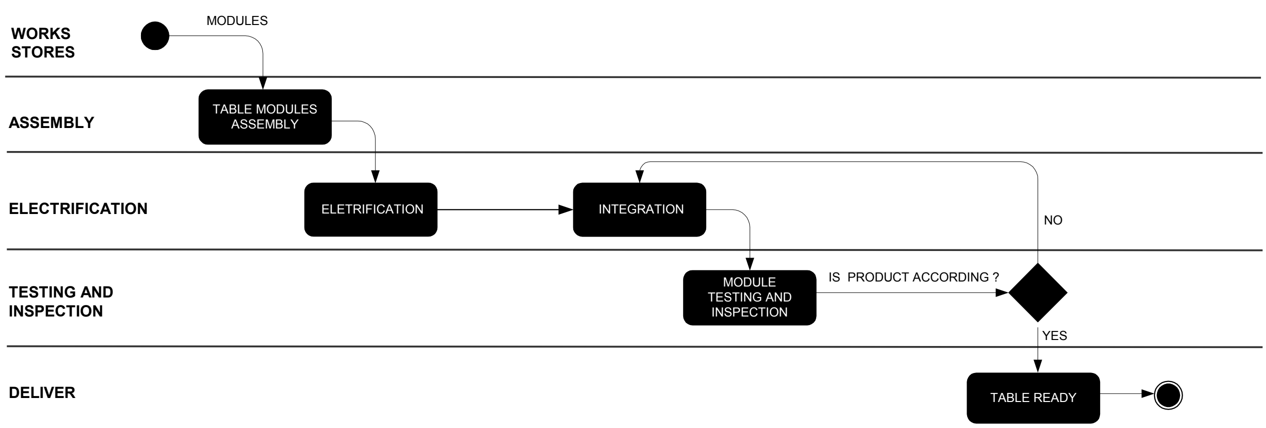


Figure 4. Activity diagram of a testing table production.

The assembly cell is responsible for the assembly of all modules in the table. After this the electrification cell is charged with the electrification and the integration of all the table components (e.g. modules, test equipment, PC). The table is considering finish after one final test to evaluate the table behaviour, which is done in the testing and inspection cell.

2.4 Production planning and control issues

Presently the factory performs the manufacturing scheduling based on the delivery date of each order. When arrive a customer order, it goes to an orders queue. The orders with short delivery time (most urgent) are the first to be manufactured, what means that the orders are orderly by priorities.

Top priorities are given to express deliveries. Second priority is given to modules orders. Normal priorities are given to orders with large delivery margin and their priority is raised as due date became closer. In the beginning of every week the production department analyzes the delivery date for each order and with that, the current production status, the modules lifetime and the better management practice the week planning schedule is done.

The basic control problem of the company is that the capacity need in different phases of production changes abruptly as the needs for anticipate deliveries or to satisfy orders that are crucial in company strategy. The effect is that modules progress through production quite randomly and the lead times became longer what results in a high level of WIP (*Work-in-Progress*). Ideally, the planning and control method should level the need for capacity in a way that allows for prediction completion for each order and simultaneously results in adequate capacity utilization.

.

3 Overview of system requirements

3.1 Context

Planning and scheduling of flexible machine cells is a very demanding task involving significant decision making based on a number of manufacturing parameters and variables. A large number of conflicts constraints and manufacture goals such as meeting due dates, maximizing the capacity utilization and balanced the work load across the shop floor make the planning task a very complex decision problem (Rahimifard and Newman, 1995).

Simulation models have been used widely as decision support tools to provide answers for "what if" queries. These models allow users to realize the effect of decisions on the system under evaluation. In the last ten years there has been a considerable increase in commercial simulation software that is easier to use, which largely means reducing the amount of programming required do build a model. This has given rise to something designated by *manufacturing-oriented-simulator*, which consists in a simulation package designed to model a manufacturing system in a specific class of system (Law A., McComas M.,1997). The major advantage of a simulator is that if it is applicable to the problem under study, then the amount of time required to develop the model may be reduced considerably.

The company here considered, had already try to implement commercial software at the manufacturing process level. Even thought the results were not dissatisfied, it takes to much time to setup the information related to each new order. In fact, the company tried two different kinds of software solutions. The first one was lot production oriented (MRP planning approach), but it reveals to much weaknesses, namely concerning some assumptions such as: lead times are assumed to be known and constant and fixed product routings. The second information system considered, was oriented to engineer to order production and the major weaknesses of this solution was the higher needs concerning project details (several types of data), it was specific or oriented for large and complex engineer projects.

In order to overcome these drawbacks, and taking into account the specificities of company's production system, the decision support system to be implemented aim to follow an approach based on simulation. The main goal is to develop a hybrid application that simulates the plant production system, loaded with the production plans under evaluation, in order to determine machine and cells performance, detect bottlenecks, forecast production completion date, compare and analyze the impact of planning rescheduling.

3.2 Related research

In recent years, there has been an enormous research interest in topics such as manufacturing modelling and simulation, techniques of due date prediction, capacity planning methods and decision support systems for order planning. Such interest comes naturally from the need to respond to extremely competitive and dynamic environments shaped by an increasing globalisation, fast technological advances and customer-driven manufacturing.

Related to our problem there are several interesting research references. New *et al*. (1991) present a visual interactive implementation of simulation for capacity planning for an FMS cell. Due to computational time and complexity, however, discrete event simulation tends not to be suitable for capacity analysis at the factory level. The detail involved makes the output 'nervous' to small changes. However, Srivatson and Kempf (1995) present an abstract simulator which uses WIP allocation rules to simulate the movement of lots through the system with large time buckets. Roman and del Valle (1996) present a method of assigning due dates by means of simulation once the job arrives at the shop, however the success of their method is reliant on the use of a certain dispatching rule.

3.3 Main system requirements

As referred before, in customer-driven manufacturing environment, it is crucial to provide fast, reliable and on-time responses when dealing with new customer inquiries (potential orders) and order commitments. These are the most important high-level and general requirements to be fulfilled by the system to be implemented.

System requirements are usually divided in into two classes – functional requirements and non-functional requirements. The first describe what the system should do and are perceptible to the user, while the second describes constraints on how the functional requirements are implemented, and are not necessarily perceptible by the user (Sommerville and Sawyer, 1997).

3.4 Functional requirements

Capacity modelling. To allow capacity planning to be performed, the capacity of the different production cells in the shop floor needs to be appropriately translated into capacity models. This requires some form of interface to translate the 'real world' into a computer model. Each capacity model should provide a measure of the corresponding production unit capacity, support the creation of capacity plans and evaluate the implications of a given customer order (Azevedo and Sousa, 2000 a).

Parts lifetime. This feature is considered a very important method for measuring the performance of manufacturing systems, as it is used to measure the time spent by a part in the system from the arrival time to the time that all its corresponding process are finished. Through former work (Verissimo et al, 2002) its possible to know the parts mean time on each manufacturing operation.

Monitoring the production status. One efficient strategy to reduce production costs is by better control of the manufacturing process (Choi et al, 2002). By monitoring the production status is possible analyze on real-time the machines performance, detect bottlenecks, analyze the impact of this on the manufacturing process if disruptive events occur in one or more machines, and know all the orders status.

Support for order promising. The efficiency of the company is on its ability to make immediate order acceptance with absolute commitment to due date, quantity and quality (Azevedo and Moreira, 2003). Thus, when an order arrives to the enterprise, is necessary check its feasibility taking into account the existing capacities and the current manufacturing planning. The system must be able to answer the following questions:

- What the impact on the current manufacturing planning?
- On what date will be the customer request complete?
- What additional resources would be needed in order to satisfy the customer request?

Global and cell optimization. In order to optimize the manufacture flow across the shop floor, and thus reducing the high level of *WIP*, the OPSCOP must perform capacity optimization at cell and shop floor level.

3.5 Non-Functional requirements

Performance. The system response time depends on how detailed or sophisticated the capacity models and algorithms are. If the capacity models details are rough and the algorithms are simple, the system will be faster but no so accurate when using sophisticated algorithms and high detailed capacity models. In order to provide a faster response the system shall require a reasonably small amount of memory so that enough for being permanently resident.

Legacy Integration. In order to reach feasibly responses on capacity planning the system must know the current production status. This is done by integration with current company information system.

3.6 Conceptual framework

The framework considered to develop the application is based on Anderson M. and Olsson G. (1998) proposal for a simulation based decision support system, and it has the same working principle.

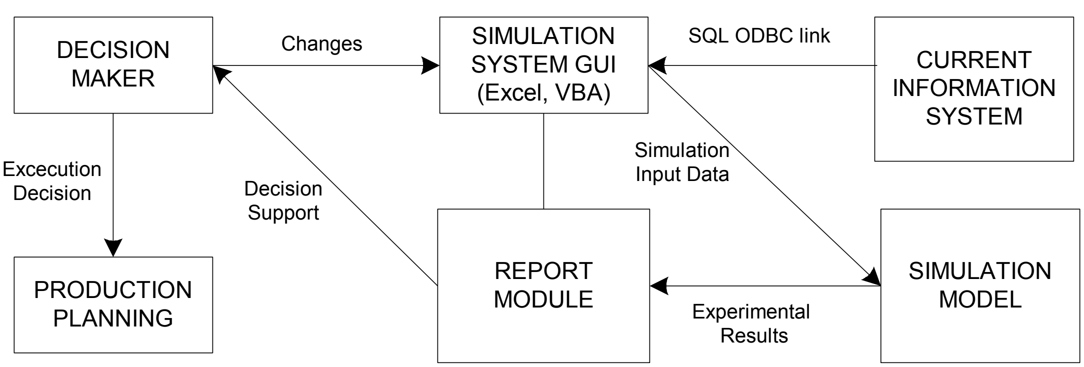


Figure 6 – Conceptual Framework of a Simulation Based Decision Support System

The framework presented in figure 6 could be described as follows: The decision-maker has a set of alternatives scenarios. He communicates these to the simulation model through a graphical user interface. The current status of the studied system is further reported to the simulation model via the same interface and them the simulation model starts to run. After the experiment the results are reported back to the interface and are communicated to the decision-maker, who takes a decision and executes it.

3.7 Use Case diagram

In order to model the information system under development, an object-oriented approach was followed. To do this, we are using the UML - Unified Modelling Language (Booch et al., 1999). One of the first steps considered in the modelling was to describe the system as a number of *use cases* that are performed by a set of actors.

A Use Case diagram presents a set of use cases, actors and their relations. Their common applications are usually divided into two - system context modelling and system requirements modelling. The former gives emphasize to the identification of the boundary system, their actors and the meaning of their functions, while the second consist on the identification of what the system should do, no matter how. In figure 5 is presented one of the Use Case diagrams considered for the system.

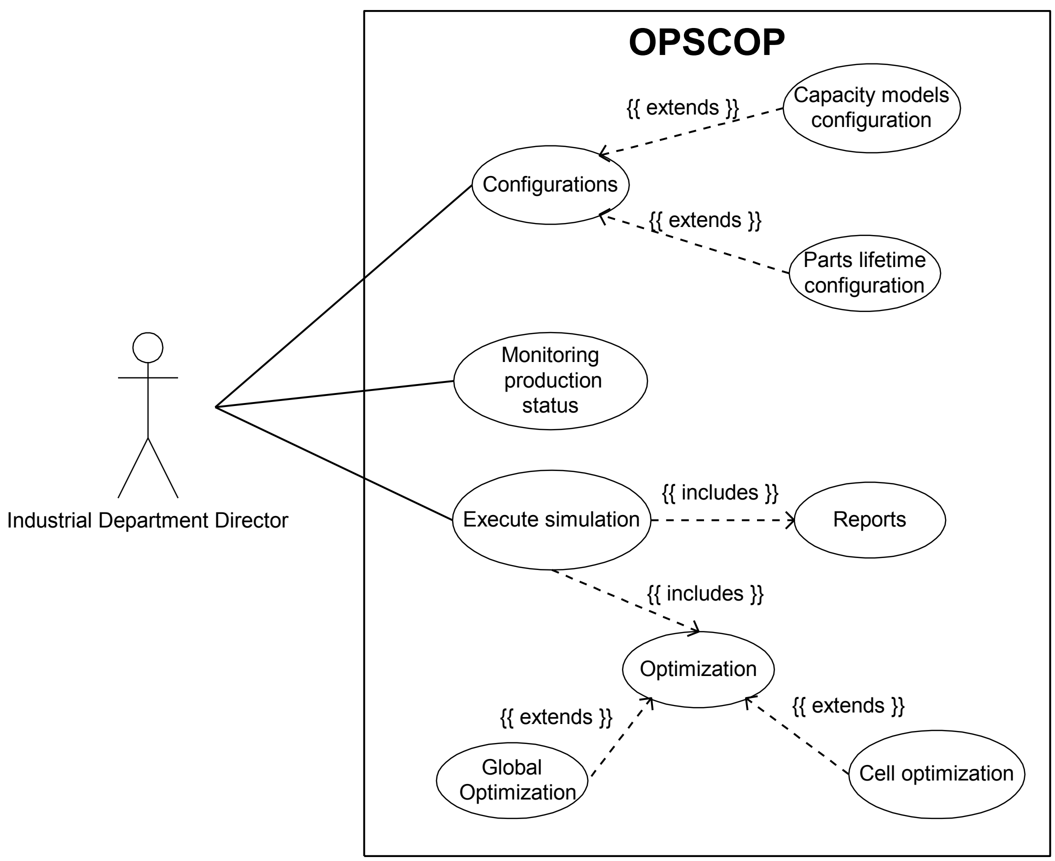


Figure 5 – Use Case diagram for the proposal system

3.8 Data requirements

The structure of the data to be considered is organized according to its nature and the context of its use. We identify the following data requirements in order to model the problem.

Manufacturing process and time information

- Manufacturing process data (resources used, process time, queue time, setup time, alternate routes)
- Calendar data (shift information, holiday information, preventive maintenance information)
- Machine data (name, type, mean time to failure, mean time to repair, alternate resources data, preventive maintenance time)
- Bill of material structure
- Monitoring data (state of operations available)
- Forecast data (scrap rate, stock levels, supplier lead-time and capacity, etc)

Demand information

- Firm orders and sales forecast
- Order control policies and dispatch policies
- Demand pattern

4 Conclusions and further work

The work presented in this paper has been guided by the design and implementation of a decision support order planning system, addressing the requirements of a make-to-order environment. In fact, the goal is, for the company considered, overcoming some of the drawbacks identified in current PPC-systems, and at the end to implement an information system, based in a real-time simulation model, able to produce realistic satisfactory delivery dates taking into account the available manufacturing capacity and the specificities of the company's manufacturing system.

Some general functional requirements to help planners make effective and efficient capacity planning decisions are identified. Among the goals considered, we expected that the application would help to levelling the workload at each production cell and avoiding at the same time the high level of WIP at shop floor.

Further work will involve the refinement of the requirements and the choice of specific modelling approaches, techniques and algorithms to use in the system development.

Acknowledgments

We would like to thank DINEFER company for given the opportunity to do this work, especially to Eng. João Pedro Conceição for his availability and patience in company discussions.

References

Azevedo, A.L. and Sousa J.P. (2000 a). Order Planning For Networked Make-To-Order Enterprises- A Case Study. Journal of the Operational Research Society, Volume 51, Issue 10, October 2000

Azevedo, A.L. and Sousa J.P. (2000 b). A Component-Based Approach to Support Order Planning in a Distributed Manufacturing Enterprise. Journal of Materials Processing Technology, Volume 107, Issue(1-3) pp431-438,2000

Azevedo, A. and Moreira, A. (2003). Requirements of a Decision Support System for Capacity Analysis and Planning in Enterprise Networks. To be published in ICEIS'03 proceedings – International Conference on Enterprise Information Systems. France.

Anderson, M. and Olsson, G. (1998). A simulation based decision support approach for operational capacity planning in a customer order driven assembly line, *Proceedings of the 1998 Winter Simulation Conference*, D.J. Medeiros, E.F. Watson, J.S. Carson and M.S. Manivannan, eds, Washington, DC, December, 935-940. IEEE, Pistcataway, New Jersey.

Booch, G., Rumbaugh, J. and Jacobson, I. (1999). The Unified Modeling Language User Guide, Addison Wesley.

Chase, R.B., Aquilano, N.J. and Jacobs, F.R. (2001). Operations management for competitive advantage (9thEd.). McGraw-Hill/Irwin, New York, NY.

Choi, S. D., Kumar, A. R. and Houshyar A. (2002). A simulation study of an automotive foundry plant manufacturing engine blocks, *Proceedings of the 2002 Winter Simulation Conference*, E. Yücesan, C.H. Chen, J.L. Snowdon, amnd J.M. Charnes, eds, San Diego, CA, December, 1035-1040. IEEE, Pistcataway, New Jersey.

Law, A. and McComas, M. (1997). Simulation of manufacturing systems, *Proceedings of the 1997 Winter Simulation Conference*, Ed. S. Andratóttir, K. J. Healy, D. H. Withers, and B. L. Nelson, Atlanta, GA, December, 86-89. IEEE, Pistcataway, New Jersey.

New, S.J., Lockett, A.G. and Boaden, R.J. (1991). Using Simulation in Capacity Planning, Journal of the Operational Research Society, Vol. 42, No. 4, pp 271-279, 1991

Rahimifard, S. , Newman, S. (1995). The role of simulation in operational planning control of flexible machine cells. *Proceedings of the 1995 Winter Simulation Conference,* ed. C. Alexopoulos, K. Kang, W.R. Lilegdon, and D. Goldsman, Hyatt Regency Crystal City, Arlington, VA, December, 793-798. IEEE, Pistcataway, New Jersey.

Roman, D.B. and del Valle, A.G. (1996). Dynamic assignation of due dates in an assembly shop based in simulation, International Journal of Production Research, Vol. 34, No. 6, 1539-1554

Sommerville, I. and Sawyer, P. (1997). Requirements Engineering: A Good Practice Guide, John Wiley & Sons. Chichester.

Srivatson, N. and Kempf, K. (1995). Effective modelling of factory throughput times, Proceedings of the 1995 IEEE/CPMT International Electronics Manufacturing Technology Symposium, IEEE 1995

Wortmann, J.C, Muntslag, D.R. and Timmermans, P.J.M. (1997). Customer-Driven Manufacturing. Chapman & Hall

Veríssimo, J., Apolinário, J., Metrôlho, J., Martins, C. and Conceição, J. (2002). Modelação de Processos Industriais, *Projecto final de Bacharelato do Curso de Engenharia Informática*, Escola Superior de Tecnologia de Castelo Branco.