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REAL TIME DISCRETE EVENT SIMULATION OF A PCB PRODUCTION SYSTEM FOR OPERATIONAL SUPPORT

Mats Jackson
ABB Management Consultants AB
S-721 83 Västerås, SWEDEN

Christer Johansson
Department of Mechanical Engineering
Linköping University
S-581 83 Linköping, SWEDEN

ABSTRACT

The purpose of this paper is to investigate how discrete event simulation can support the growing need of information in the production system. Agility, one key to future competition, is the ability to quickly manage and compensate for disturbances and uncertainty. It is achieved by combining flexible production technologies with a flexible and motivated workforce. To quickly respond to the demands from customers and compensate for internal disturbances, it is necessary to have information which supports decentralized decision making in target oriented teams. Discrete event simulation is a tool that can be used to generate customized information for decision support. The results from a case study at ABB Industrial Systems in Västerås, Sweden, show the possibility of using simulation and real time forecasting for operational support in target oriented teams.

1 INTRODUCTION

The ability to quickly manage a production system to compensate for external demands and internal disturbances is becoming an important competitive factor. This is a consequence of the accelerated rate of change in the world around us. The competition is globalizing at the same time as the market is moving to economically growing areas. The development of technology in products and processes demands frequent changes in the production system. Customers expect to get the best product at the best price with immediate availability. There are also always internal disturbances that must be compensated for and managed. Consequently, a company must be agile to quickly implement changes.

The Iacocca Institute Report (1991) describes agile manufacturing as one key to future competition. Agility means the ability to thrive in rapidly changing, fragmented markets.

Agility is a comprehensive response to the challenges posed by a business environment dominated by change and uncertainty [Goldman et al., 1995].

External demands and internal disturbances force production system changes. These changes can be divided into:

* Long term changes due to technology development in products or processes, and
* Short term changes due to internal disturbances or customer demands.

In Sweden, it is common to have an organization with target oriented teams. Use of teams is one way toward agility in the organization by decentralizing the decision making. The team is used as the core actor of the company, not only for efficient production but also for resource allocation and adjustment to external market and customer needs [Berger et al., 1994]. To support and motivate target oriented teams, it is necessary to have an information system, which provides necessary decision support and gives feedback of the results.

To achieve agile manufacturing four types of flexibility must be present: flexibility in materials, information, tooling, and equipment [Ross, 1994]. Information is a critical resource for manufacturing to produce the right product at the right time in the right quantity with the necessary capacity.

The act of collecting, evaluating, organizing, and distributing information becomes a decisive enabler and infrastructure requirement of agile product development and delivery [Goldman et al., 1995].

This paper examines the possibility of using discrete event simulation as one tool to generate customized information, which support agility in production systems.

A case study dealing with real time forecasting as operational support will be presented as one possible application to generate information which supports resource allocation in target oriented teams.

2 METHODOLOGY

It is difficult to gather quantitative data about how simulation can support the growing need of information in the production system and about the results when using real time forecasting. Very few companies use simulation and almost none uses real time fore-casting for decision support. Instead, practical insight about the possibilities and problems in this area is needed in qualitative terms. An extensive case study dealing with the implementation of such a tool is presented and discussed.

The risk in using only a few case studies is the loss of external validity. Still, the insight and relatively deep understanding facilitate analytical generalization so that findings can be generalized to theory [Yin, 1984]. Having this in mind, the aim of this case study was to develop a prototype planning tool and use it to investigate the utility of simulation and real time forecasting for production support of a PCB manufacturing line at ABB Industrial Systems in Västerås, Sweden.

The project, which was based on theoretical studies, aimed to verify theory in practice. ABB's interest in this case study was to increase knowledge about the use of simulation and real time forecasting, and to minimize the risk of implementing a commercial planning tool.

3 DISCRETE EVENT SIMULATION

Discrete event simulation is a tool by which it is possible to model a system as it evolves over time. The system changes as events occur, which can be calculated in regard to the time scale. This calculation can be done by hand but the amount of data which must be calculated due to real world complexity suggests the use of computers.

By using simulation several benefits are given such as:

* Lower analysis cost and less disruption by testing
* Form alternatives in a computer instead of on the production floor,
* Test more solutions than would be possible in real world,
* Help speed successful implementation of production system changes by visualizing the change, and
* Estimate effects of different planning scenarios.

A discrete simulation model is a model in which variables change instantaneously at separate points in time. The time can be advanced and a calculation of a particular action can be done which diminishes the risk before implementing a change. A deterministic model uses constant variables and a stochastic model uses stochastic variables. By using stochastic variables in the model it is possible to include the dynamics in the production system. Typical examples of stochastic variables are variable batch sizes, repair times, and operational times.

The production system's life cycle can be divided into four phases [Thompson, 1993]:

Phase 1. Planning
Phase 2. Design
Phase 3. Implementation, and
Phase 4. Operation

Today, simulation is a tool mainly used for different types of production system analysis. It has been used in phases 1 and 2, strategic simulation, by building a model, experimenting on it and analyzing the results.

Typical examples of strategic simulation are:

* Development of a new production system by for example, optimizing production flows, dimensioning buffers and space, and
* Improvement of a production system by analyzing capacity, throughput times, utilization, flexibility, or the need for new equipment.

This paper is focusing on applications of discrete event simulation in phases 3 and 4; operational simulation. Recent advantages in technology have allowed simulation to expand its usefulness beyond a purely design function and into operational use [Thompson, 1993]. Operational simulation means a continuous use of one or more models to optimize the utilization of the production system, now and in the future. [Saven, 1996].

Typical examples of operational simulation are:

* Estimates of capacity needed for a particular product mix,
* Consequences of work in progress for a particular product mix, and
* Consequences in delivery dates due to a particular plan.

Operational use of simulation requires models to be integrated with plant information. This can either be done automatically by communicating with the plant information system or manually by entering data before running the simulation.

One type of information, which will support decentralized decision making in target oriented teams, is a forecast of the coming work load. This forecast will enable the group to compensate for lack of capacity before it occurs. A forecast would help teams handle the short time changes caused by internal disturbances and customer demands. This type of information can be generated with discrete event simulation by a real time forecasting model.

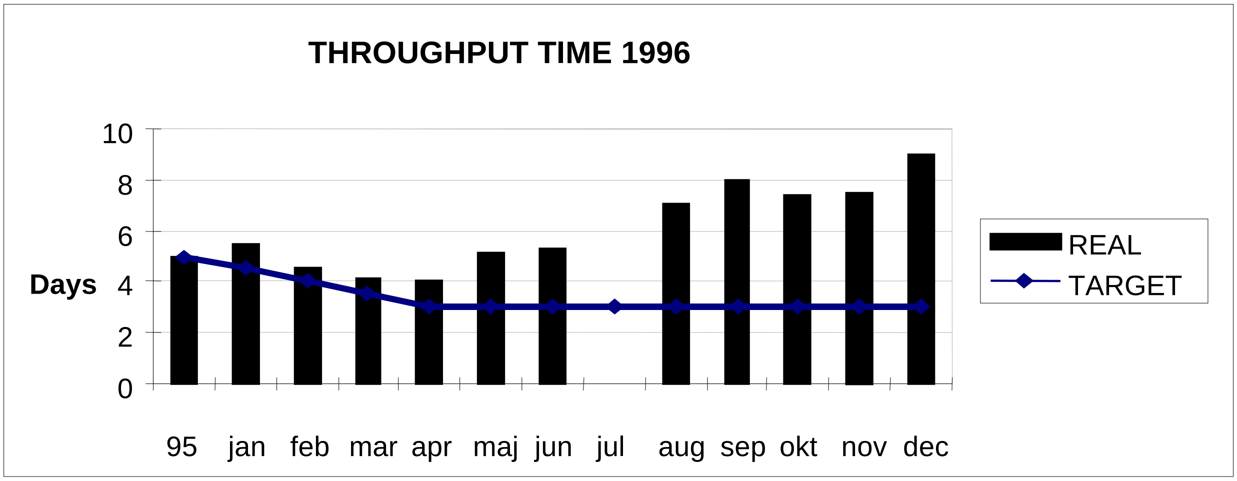

Figure 1: Throughput Time PCBs

A real time forecasting model takes an accurate factory status update and simulates forward in accelerated time, much like traditional analytical models with one important exception: the model's starting condition is the current factory status [Thompson, 1993].

Another possibility when using discrete event simulation for operational support is the ability to perform system analysis on the same model. It also gives long term advantages by using the same model for testing and exploring new ways of improving the production system. In this way time is saved when developing the current production system.

To investigate the practical use of real time forecasting a case study has been done. The following questions have been of particular interest:

* How to integrate a simulation model with plant information system?
* How often should a forecast be updated and how should it be run?
* How should a forecast be presented and to whom?

4 CASE STUDY: REAL TIME FORECASTING

A case study to investigate if and how discrete event simulation can be used for real time forecasting has been done at ABB Industrial Systems AB in Västerås, Sweden. The purpose of this project was to investigate the possibility of real time forecasting before deciding what information support that is needed and investing in more sophisticated and expensive software.

4.1 Background

The study was made in a production facility for printed circuit boards (PCBs). Two hundred persons work in this line and about eighty different types of PCBs are manufactured per day. The production volume is about one thousand per day and the work in process is about four thousand. The organization in the production facility is based on target oriented teams.

The production equipment is highly automated with a CIM concept for automatically generating machine programs. The line consists of both automatic and manual assembly. The production line is sequential, starting with automatic assembly then manual assembly of those components that are too big or too complicated and finally soldering and test.

Each PCB has its own routing which specifies the sequence through the different machines and work stations in the automatic and manual assembly.

Much focus is given to the throughput times of the PCBs. This is a critical factor for competition and future survival. As shown in Figure 1 the target of 2.5 days throughput time was not reached during 1996. The production work load varies greatly at different machines over the day. If necessary resources are not available when needed, queues form before the machines, which affects the throughput times.

The resource allocation today is done manually by the operators who estimate the present situation and then decide who should work where. Due to the large number of PCBs in work in progress and the individual routing of each PCB, it is difficult to estimate the future work load at each machine.

The problem of working at the right place at the right time with the right order increases tremendously if there are limited resources. Previously the only way to handle this problem was to make sure you have over capacity which in the long run increases product costs.

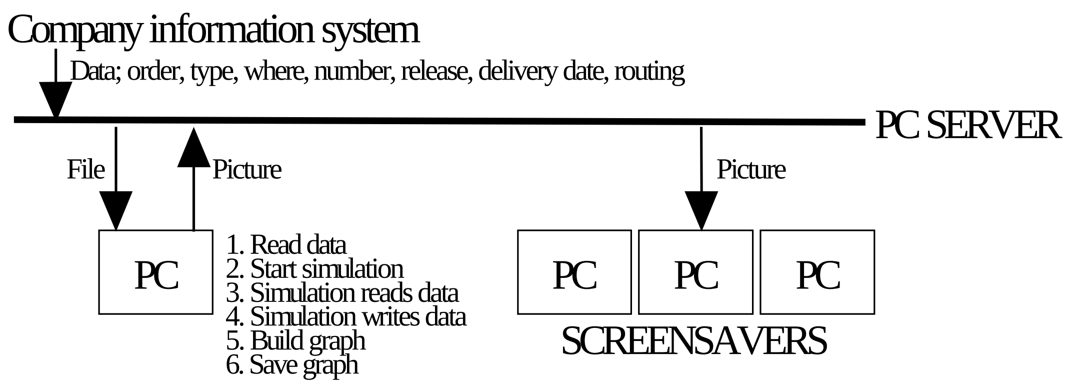

Figure 2: Planning Tool

The question is then how to manage the resource allocation with limited resources?

4.2 Project Description

A forecast of the upcoming production load would support the target oriented teams in their resource allocation. The goal of the case study was to generate this forecast for a six hour window and update it every ten minutes. Data would be downloaded from the computer system and the results presented on computer screens in the area. This planning tool was built as a prototype.

The development of the prototype was made in a project involving both engineers and operators employed at the company. The operators specified how the planning tool should work in practice and how the output should be presented. There was a very big interest from the work shop to get a tool for resource allocation.

Specifications on the planning tool include:

* Forecast of coming 6 hours,
* Update every 10 minutes with real plant information,
* Information of coming queues should be presented in a diagram,
* The present state and a forecast should be displayed,
* The number of late PCBs should be included, and
* Information should be presented on screen savers.

The project started in December 1996 and a prototype was built in February 1997. This prototype was then tested in the production for ten weeks. The company already had the Taylor II simulation software product, and it was used for this project.

Data was downloaded from the computer system to an ASCII file every 10 minutes by a SQL-program, as shown in Figure 2. The data includes all information about the present situation; orders, types, order location, order numbers, releases, delivery dates and routings. A Visual Basic tool using Excel was built to read this file and start the simulation (Taylor II). When the simulation was ready it returned the forecast to Excel and a diagram was built. This diagram was then saved as a bitmap-file and used in screen-savers on PCs in the work shop, as shown in Figure 3.

The model was built with 32 elements with operation time as a stochastic variable with a mean equal to an estimate depending on the type of product. If a queue existed before a machine at time equal to zero this machine was assumed to have an operator. If no queue was present then no products would be processed at that operation during the simulation. A product with a late delivery time in the queue had priority. The download of data, the simulation, and the building of the graph took about 10 minutes on a Pentium 166 (16 Mb RAM).

In Figure 3 is an example of the diagram showed on the screen savers which contains queue's before every machine in the production facility.

Eight different queues are displayed in the graph;

* The amount of late PCBs,
* The current queue before each operation, and
* Forecast of queue's for the coming six hours.

The graph will show trends which will enable the production facility to compensate for lack of capacity. This information will be used by all operators to decide where to work.

During the testing period the planning tool was run from a computer in the office. The results were presented on one computer in the work shop. The members in the project team were responsible for checking both the validity of the information and how the tool worked.

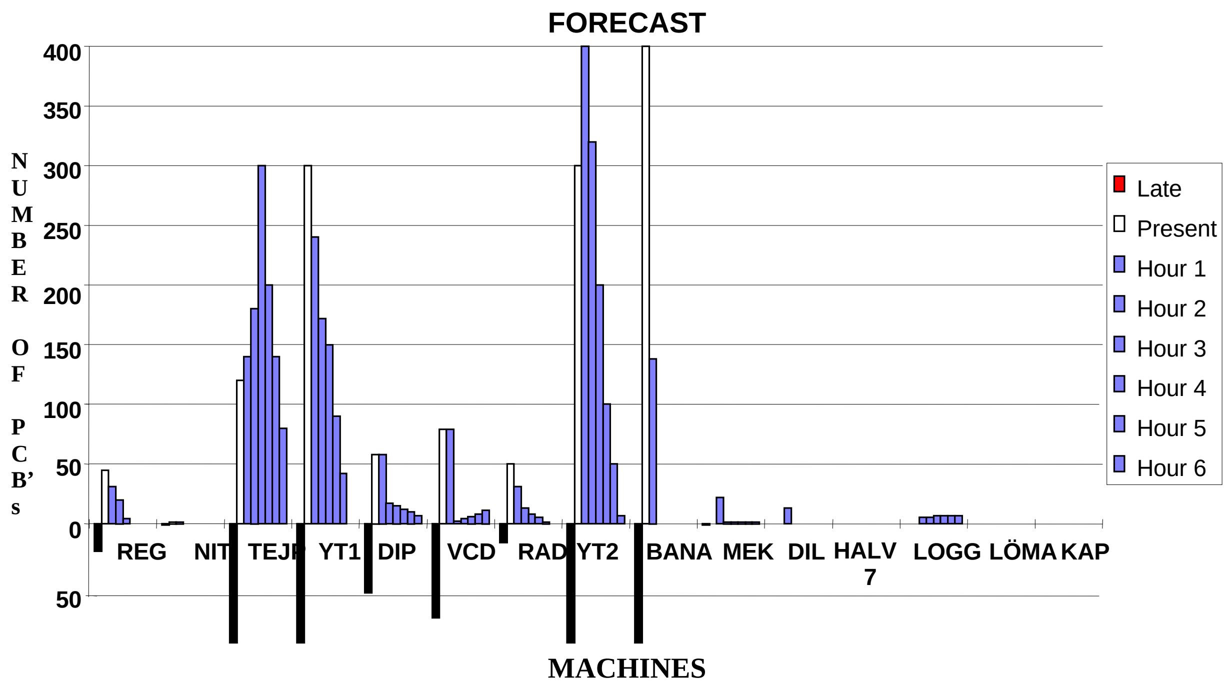

Figure 3: Forecast

The case study shows the importance of involving users from the beginning to be successful and to get acceptance when implementing information support. The interest from the users in this project made the modeling and the evaluation of the model very easy. It also gave focus to the project not to only produce an interesting application study but a real planning tool.

4.3 Results

After the test period the model was accepted as accurate enough. The evaluation of the results showed, in some cases, a deviance between the forecast and reality. After analyzing the causes of this it was concluded that the data sometimes was inaccurate or incomplete. No quantitative effect on the throughput times could be measured before this was fixed.

The routing of each product was sometimes changed manually which the present datafile did not include. Also the estimates of the operation times was not good enough in some cases. It is necessary for the estimates to correspond with reality to get a good forecast.

Another problem that occurred was when the SQL-program stopped or the server went down. It showed that the maintenance and administration of such a program is very important for reliability in the long run.

It is therefore necessary to develop further in the following areas before a real implementation:

* Datafile with current status, this data can be improved in regard of the routing,
* Operation times, which should be stored in a database and constantly improved, and
* Importance when building a permanent planning tool to think of the maintenance.

These changes and development can be done but it will demand some investment in development. Before doing this a decision must also be taken in regards of which simulation software that should be used.

Still, in qualitative terms, the prototype developed has shown possibilities for simulation to support target oriented teams in their resource allocation. It has shown that such a tool can be developed without major investments in the current information system. By improving the information support the throughput times will be shortened.

Given these results the company decided to go on further investigating how such a tool can be used in the production. The question is how the target oriented teams shall work in the future and what type of information support that is necessary? A forecast of queues may not be the only information that should be generated and communicated.

When this strategy/vision has been worked through in 1997 there will be a final decision on investing the money in hardware, software, and development.

5 CONCLUSIONS

The ability to quickly manage and compensate the production system, due to external demands and internal disturbances, is becoming an important factor for competition. To cope with an environment dominated by change and uncertainty it is necessary to quickly get information for decision support.

Information is a critical resource for manufacturing to produce the right product at the right time in the right quantity with the necessary capacity. Advances in hardware and software allow discrete event simulation to expand its usefulness into operational use. Customized information can be generated which supports decentralized decision making in target oriented teams.

The case study shows the possibility of using simulation to generate customized information and real time forecasting for operational support. This will enable us to handle short term changes in the production system more effectively by facilitate resource allocation in target oriented teams. Lack of information is compensated with overcapacity but with planing support the resource allocation can be optimized which shortens throughput times and diminishes work in progress.

It is important to realize that software and hardware costs are significant when building tools for operational support and that the developing takes time. It is also easy to forget the data and maintenance problems when implementing such tools.

Still the development of information technology has made it more or less up to our creativity what we can do with it. How we shall and can work in future production systems depends on what information we can generate and communicate and discrete event simulation can be of great support in this area.

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AUTHOR BIOGRAPHIES

MATS JACKSON is a manufacturing engineer at ASEA Brown Boveri, Management Consultants AB, where he provides consulting in discrete event simulation. He is also a Ph. D. candidate at the department of Mechanical Engineering, Assembly Technology at Linköping University, Sweden. He received MS degree in mechanical engineering at the same university in 1991 and joined ABB the same year. His current interest includes the use of simulation in the planning, design, and scheduling of production systems.

CHRISTER JOHANSSON is a professor at the department of Mechanical Engineering, Assembly Technology at Linköping University, Sweden. The Division of Assembly Technology currently has a staff of 23. A total of 14 graduate students are currently employed in the division. The research program within Assembly Technology covers four main areas; assembly system design and evaluation, design for manufacturing, disassembly and robotics. The scope of the research provides wide coverage of the production technology associated with assembly.