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Use of Simulation in Different Phases of Manufacturing System Life Cycle

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Abstract:- *This paper covers different phases of the manufacturing system life cycle. Starting from conceptual system design to planning of operations. Material handling and logistic are the key factors in modern networking manufacturing. The author proposes use of discrete event simulation as a system design and operation-planning tool. Traditionally simulation tools have been used in the system planning and design; today the simulation models are used in all the different phases of manufacturing system life cycle. This paper presents two case studies. First case shows a modular semiautomatic assembly system planning using simulation. Second case presents a simulation tool developed for operations planning, management of production capacity and decision helping for planning of operations.*

1. INTRODUCTION

Product life cycles are getting shorter and customers want variations. Production system flexibility is the key factor and systems are getting more complex (Figure 1).

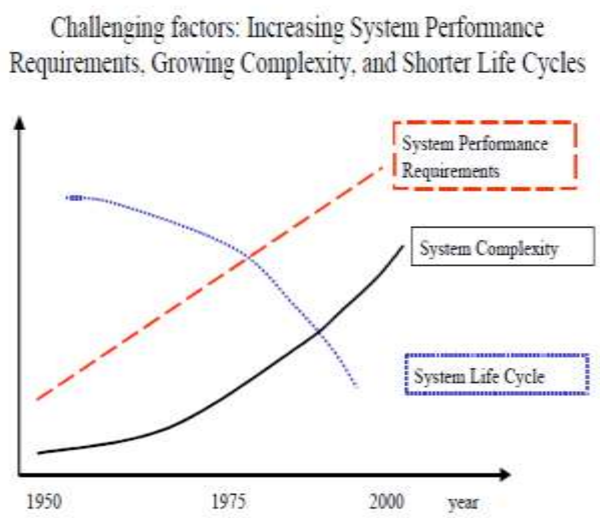

Figure 1. Challenging factors

Time-to-market is critical; this means faster manufacturing system designs and faster ramp-up processes. Production simulation and virtual manufacturing tools are valuable in shortening the design steps, Figure 2.

Figure 2. Digital manufacturing tools

Manufacturing system design involves a number of interrelated subjects, e.g., tooling strategy, material-handling system, system size, process flow configuration, flexibility needed for future engineering changes or capacity adjustment and space strategy.

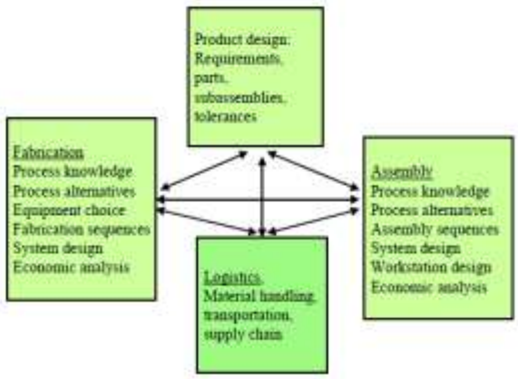

Figure 3. Connections between product design, fabrication, assembly and logistic system

Manufacturing process design is critical area. Material handling is another area that deserves intensive study.

Time-to-customer, punctuality and throughput time, are important competition factors in make-to-order manufacturing. The products are usually complex systems consisting of components, which are manufactured in different factories, sometimes in different countries. Manufacturing is performed on the basis of customer orders and each order can be unique. Naturally, the throughput times of the components may differ from one another. The production systems have to be flexible and able to react to changing production capacity requirements. All this makes planning and management of production networks a complex task.

2. DEFINITION OF SIMULATION

"Simulation is the imitation of the operation of the real-world process or system over time. Simulation involves the generation of an artificial history of the system and the observation of that artificial history is draw inferences concerning the operating characteristics of the real system that is represented". [Banks J et al 1996]

Discrete event simulation involves the modeling of a system as it progresses through time and is particularly useful for modeling queuing systems. There are many examples of queuing systems: manufacturing systems, banks, fast food restaurants, airports and the list goes on.

A major facet of discrete event simulation is its ability to model random events based on standard and non-standard distributions and to predict the complex interactions between these events. For instance, the 'knock-on' effects of a machine breakdown on a production line can be modeled.

The focus of this paper is in dynamic discrete event simulation. Discrete event simulation is used for wide range of application, which are summarized in eight categories [Robinson, 1994]:

- Facilities planning – when designing a new facility, simulation is used to check that it performs correctly.
- Obtaining the best use of current facilities – potential solutions could be tested and identified.
- Developing methods of control – more than just physical equipment, for example experimenting with different control-logic as MRPII or kanban.
- Material handling – experiments can be performed to control the flow of materials to find for example bottlenecks.
- Examining the logistics of change – to minimize interruptions simulation can be used to examine the logistics of change.
- Company modeling – high-level model showing for example the flows of resources and information between sites.
- Operational planning – simulation can be used in day-to-day planning and scheduling.
- Training operations staff – supervisors and operators are trained in the operation of the facility.

3. MODELING OF MANUFACTURING AND LOGISTIC SYSTEMS

Modeling of manufacturing system requires an understanding of the types of manufacturing systems that exits and the objectives and issues associated with each type of system.

Manufacturing and material handling systems can be arbitrarily complex and difficult to understand. Some of the characteristics needed for modeling are listed in Table 1 and 2. The number of possible combinations of input variables can be overwhelming when trying to perform experimentation. Other methods of analysis, such as spreadsheet models or linear programs, may not capture all the intricacies of process interaction, downtime, queuing, and other phenomena observed in the actual system.

Table 1. Characteristics of a manufacturing system model

Manufacturing System parameters	
Physical layout	Product • Product flow, routing and resources needed • Bill of materials

Labor
• Shift schedules
• Job duties and certifications
	Production schedules
	• Make-to-stock
	• Make-to-order
	  • Customer order
	  • Line items and quantities

Equipment
• Rates and capacities
• Breakdowns
  • Time to failure, MTTF
  • Time to repair, MTTR
  • Resources needed for repair
	Production control
	• Assignment of jobs to work areas
	• Task selection of workcenters
	• Routing decisions

Maintenance • PM schedule • Time and resource required • Tooling and fixtures	Suppliers • Ordering • Receipt and storage • Delivery to workcenters
Workcenters • Processing • Assembly • Disassembly	Storage • Suppliers • Spare parts • Work-in-process (WIP)
	Final goods • Packing and shipping • Order consolidation • Paperwork • Loading trailers

Table 2. Characteristics of a material handling model

Material Handling parameters	
Conveyors • Accumulating • Non-accumulating • Indexing and other special purpose • Fixed window or random spacing • Power and free	Storage systems • Pallet storage • Case storage • Small part storage • Oversize items • Rack storage or block stacked • Automated storage and retrieval systems (AS/RS) with storage -retrieval machines
Transporters • Unconstrained vehicles, Fork Lifts • Guided vehicles, AGV • Bridge cranes and other overhead lifts	

3.1 Analysis of Manufacturing System

There are several ways to study the system as shown in Figure 4. In some cases even experiments with real system could be feasible [Law and Kelton 1991].

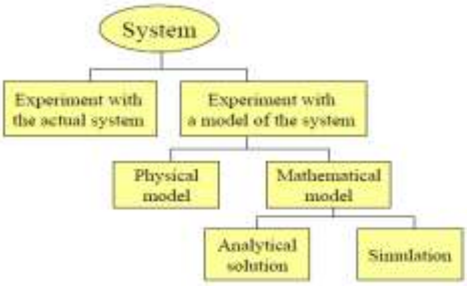

Figure 4. Ways to study a system

4. SIMULATION TOOLS

Simulation models can be build with general programming language such as FORTRAN or C/C++. Some routines can be found from the literature [Law and Kelton, 1991]

Currently there are several commercial simulation tools available. These tools can be divided into three basic classes: general-purpose simulation language, simulation front-ends and simulators. The general-purpose simulation language requires the user to be a proficient programmer as well as competent simulationist. The simulation front-ends are essentially interface programs between the user and the simulation language being used.

4.1 Rapid Modeling

The need for rapid model development is challenging because production systems are in a constant state of flux due to fluctuations in demands, annual design changes, and the introduction of new processing technologies. The ever-changing design process requires frequent, rapid (i.e., a few days or weeks) evaluation of system changes ranging from simple parameter modifications (i.e., new cycle times) to total line configuration. A model developer must be able to create accurate, realistic models in a short space of time. The second challenge faced by the simulationist is that there are a number of groups in the enterprise that could benefit from the information available from simulation models.

Thus there is a need to speed up simulation projects. One of the challenges is the shortening of the modeling time as described above. There are different ways to speed up simulation modeling:

1. *Reference Models*: A complete set of model structures together with a description, how these structures apply and how they can be adapted to a given problem.

2. *Simulation module library*. Hierarchical modeling allows the user to save whole models as clusters, groups that can be deleted, moved, or scaled as a single object as shown in Figure 5.

3. *Application Solution Templates (AST).* Industry-specific templates allow customization of the software so the user can automatically start up with specific icon libraries, functions, element terminology, element types, and other industry-specific settings.

4. *The integration with other software tools*, like CAD, spreadsheets and databases. It is important to be able to use existing information stored in computers.

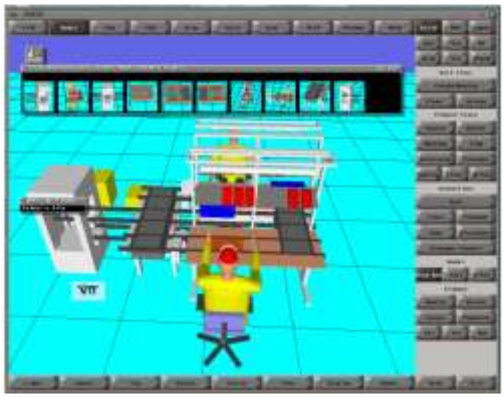

Figure 5. Example of simulation library [Heilala, Montonen 1998].

4.2 Scale and Scope of Simulation

Simulation is useful in different levels of enterprise, Figure 6. The machine or human level is continuos simulation with high level of detail and the focus is in process and equipment design.

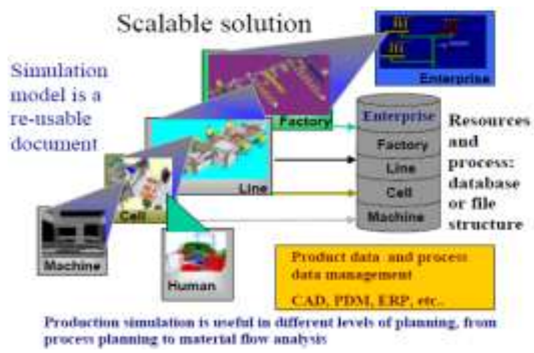

Figure 6. Simulation in all levels of manufacturing.

4.3 Simulation Project

A simulation project is described in Figure 7, [Banks et. al. 1996]. Set of steps guide a model builder in a thorough and sound simulation study. Following steps should be present in any simulation study [Shannon, 1998]:

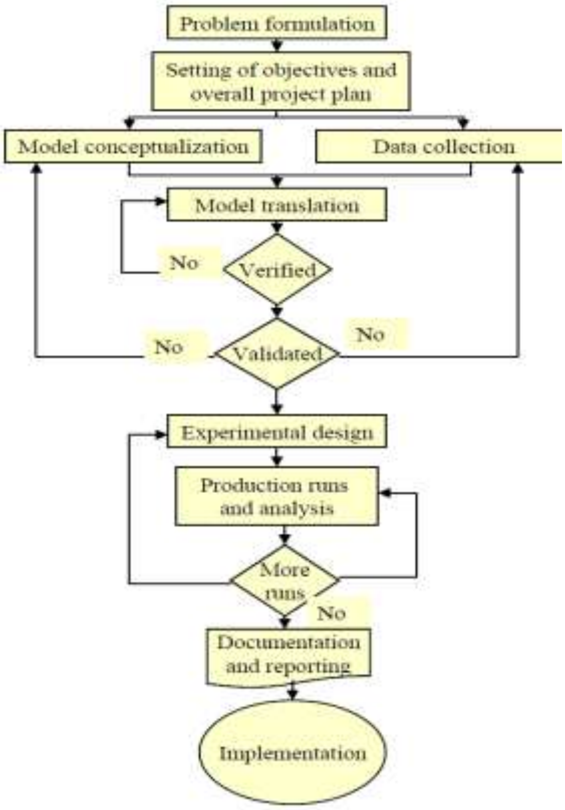

Figure 7. Simulation project

Tabular reports are very general. Table could be anything from just one figure to a large array of numbers. The table can present the information, results in different ways. Graphical reports are very useful in presenting information. (Table 3.)

Visualization and animation during simulation runs are also ways to point out the problem areas. The modern manufacturing simulators can produce VRML and avi or mpeg files as a report.

Table 3. Reporting the results.

Tabular reports	Graphical reports
• Cumulative total and percentage	• Time series
• Mean and standard deviation	• Histograms
• Median and quartiles	• Gantt charts
• Mode	• Pie charts
• Minimum and maximum	• Scatter diagrams
• Statistical tests	

Before starting simulation model building the designs must been "frozen" for analysis. The Figure 8 shows what kind of information is needed for model building.

In manufacturing systems, all starts from the product, product structure and process information. The input is also the production mix and forecasts of volumes.

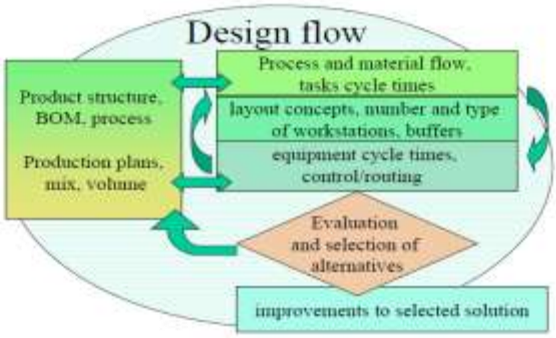

Figure 8. System design flow, simulation is the analysis tools for Evaluating

4.4 Many Uses of Simulation

In the manufacturing system life cycle following steps can be found: concept creation, layout planning, production simulation, software development, operator training and potentially operational use of the simulation model in decision support for managers. The use of simulation model can shorten the sales cycle of production system.

- ➢ Layout and concept creation (3D, animation)
- visualization, communication
- cell, lines, factories
- ➢ Production simulation (data, analysis, reports)
- control principles, routing, buffer sizes, capacity, utilization, throughput-time, bottlenecks, etc
- ➢ Software development (emulation, system integration)
- ➢ Training of operators (emulation, VR)
- ➢ Operational use of simulation (Data, speed, integration)

4.5 Goals and Metrics for Simulation Project

The simulation projects must have clear goals and metrics. The aim is to identify problem areas and quantify system performance:

- ➢ Throughput under average and peak loads
- ➢ Utilization of resources, labor and machine
- ➢ Bottlenecks and choke points
- ➢ Queuing at work locations
- ➢ Queuing and delays caused by material handling devices and systems

- WIP storage needs
- Staffing requirements
- Effectiveness of scheduling system
- Effectiveness of control system

4.6 Advantages and Disadvantages of Simulation

Advantages:	Disadvantages
• Choose correctly • Compress and expand time • Understand why • Explore possibilities • Diagnose problems • Identify constrains • Develop understanding • Visualize the plan • Build consensus • Prepare for change • Invest wisely • Train the team • Specify requirements	• Model building requires special training • Simulation results may be difficult to interpret • Simulation modeling and analysis can be time consuming and expensive • Simulation may use inappropriately

Advantages and disadvantages of simulation

5. Assembly System Design Using Simulation

5.1 Design and Analysis of Assembly Line

In the modern manufacturing systems the engineers are combining automated and manual tasks and often operation process cycle times are not balanced. There are different variants and even different product families in the same assembly line. The lot size varies from order to order. Bottleneck location is changing dynamically, from one resource to another.

5.2 Analysis Method

Material flow analysis in a conveyor system could be done using different approaches. One analysis views a workpiece on a conveyor as a vehicle on a highway and traffic-engineering principles are applied directly. The second approach treats material flow on a conveyor as flow in a network. By solving a maximal flow problem, the capacity of the conveyor can be analyzed. The third approach is to assess a conveyor system using a stochastic model; for example a queuing model may be employed. The author prefers using the material flow simulation, DES (Discrete Event Simulation).

5.3 Modular Semiautomatic Assembly System

The core of the assembly system consists of manual and automatic workstations. The workstations are the basic modules of the system, which can be configured, in different layouts according to the production needs. In addition to the workstations, the assembly hardware consists of a transfer system based on conveyor modules.

5.4 Simulation of the Assembly System

One of most sophisticated computer factories in Europe is shown in Figure 10. The customers can get the PC computer they specify in 24 hour. The production logistics and information delivery to the assembly operators are the key factors for paperless production and thus the production technology is enabling lot size one. The automated material handling frees the operators to do value added tasks.

6. CONCLUSION

The design of semiautomatic assembly system is very complex. Simulation is indispensable here. Both the technical and economic properties of the conceptual system design can be analyzed by means of a discrete simulation model. The authors have justified the use of simulation techniques in the design of semiautomatic assembly system. The result shows that the use of the virtual system does speed up the design process and increases the quality of design. Use of simulation can speed up sales cycle of system vendor, while the engineers create better design faster and solutions tested. Secondly the simulation model is a document of the system, improving communication between end-users and development engineers. Thirdly simulation model can be used for training of personnel and operators.

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