01 Apr 1991

Simulation Modeling in Manufacturing Cell Design

Debra A. Hunke

Simulation Modeling in Manufacturing Cell Design

Debra A. Hunke

ABSTRACT

The interwoven phases of the manufacturing process in Computer Integrated Manufacturing (CIM) require a carefully designed facility. Simulation modeling can be combined with other techniques to provide a rigorous methodology for CIM system design. This paper describes CIM, simulation and their relationship. A case study demonstrates the described methodology in the design of a flexible manufacturing cell.

Introduction

Computer Integrated Manufacturing (CIM) combines all phases of the manufacturing process - design, manufacturing planning, manufacturing control, and business functions. The technology applied in CIM makes extensive use of computer networks and data processing techniques to control and integrate automation at all levels of the manufacturing process.

Simulation modeling is a technique used to evaluate a manufacturing system's design before implementation. Simulation can uncover problems in the layout and material handling system as well as provide a means to perform sensitivity analysis on the components of the system.

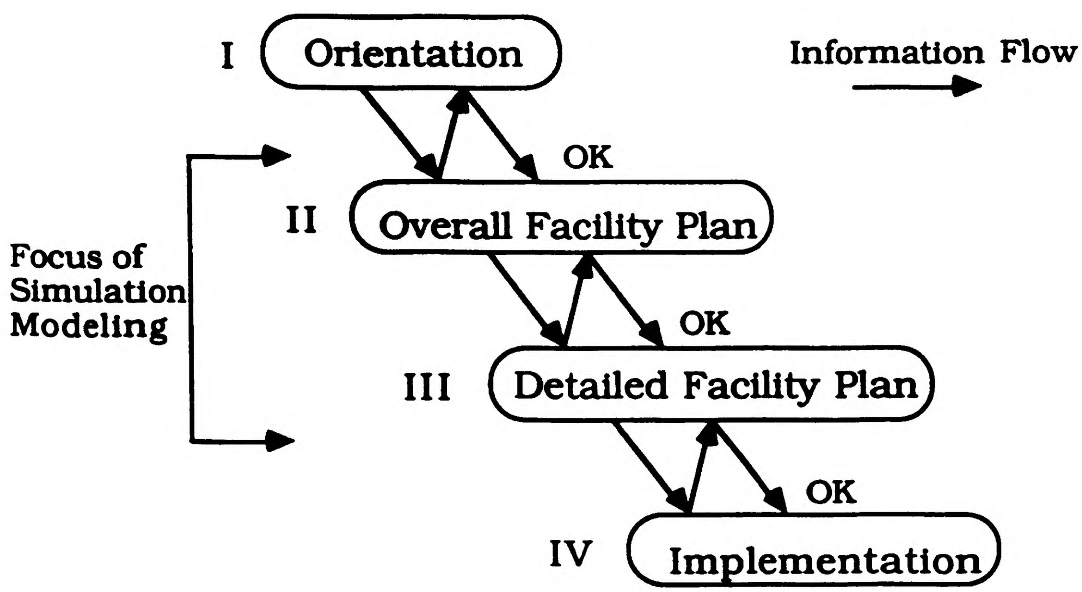
Simulation modeling can be successfully integrated into CIM system design. This paper describes simulation modeling and its application in CIM system design. These techniques are then demonstrated in a case study involving the design of a flexible manufacturing cell.

Computer Integrated Manufacturing

Computer integrated manufacturing (CIM) denotes the use of computers to design the products, plan the production, control the operations, and perform the various business related functions needed in a manufacturing firm. CIM brings all of these processes in an automated factory together by performing the information-processing functions necessary to support the production operations (1).

The process of planning and implementing a CIM facility can be divided into four phases as shown in Figure 1.

Figure 1 Phases of Integrated Facilities Planning



The orientation phase, Phase I, begins with the definition of the project and its objectives. It involves an evaluation of all constraints and influencing factors, such as: machinery to be used, projected capacity, and costs. A preliminary economic analysis should be done in this phase also.

Phase II, the overall facility plan, involves the development of an initial plant layout. This layout may be revised upon evaluation.

Phase III, the detailed facility plan, includes a second, more detailed economic analysis and the development of detailed layouts. This phase also includes development of the computer software for integrating and controlling the system elements.

Implementation is Phase IV. In this phase, the plant is built, debugged and put into operation.

An effective methodology for designing a CIM system layout is Systematic Layout Planning (SLP) developed by Richard Muther (2). The steps involved in this manual method are shown in Figure 2.

Simulation Modeling

Simulation modeling is one of several modeling techniques available to Facilities Planners and Designers. These techniques range in decreasing level of abstraction from mathematical models through computer simulation to pilot plants (3).

The results of a 1980 survey by Shannon et al (4) indicated that Operations Research practitioners in U.S. industry felt that simulation modeling was the second most widely used OR technique and the one most respondents were eager to learn more about. This is supported by the recent study conducted for the Society of Manufacturing Engineers (SME) (5).

Simulation modeling utilizes a computer to emulate the manufacturing system. After the important components have been modeled, the system can be analyzed. Simulation can be used to perform sensitivity analysis to optimize goals such as production volumes as well as to pinpoint problems in the layout or materials handling system.

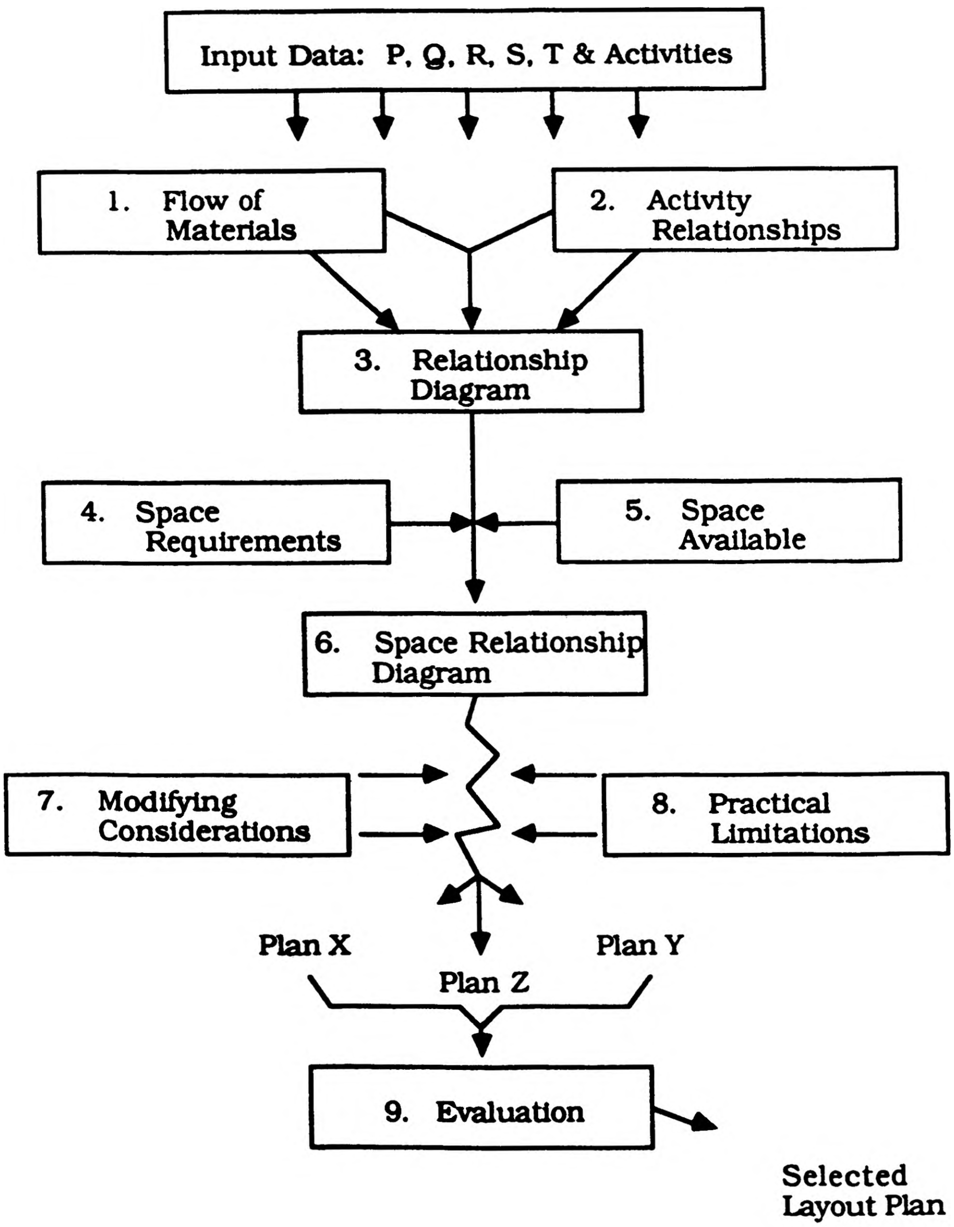
Simulation is also useful in generating funds for the project as it increases the confidence of planners and investors. Animation is a very useful enhancement in this situation. Animation makes it easier for the observer to understand the process being modeled.

There are a few limitations with simulation. First, any simulation requires a lot of programming time. This problem is currently being addressed with programs which allow the user to develop a model without actually programming. Secondly, simulation cannot optimize the system. It can only describe the results of a "what-if" question. Finally, the simulation model is only as accurate as the input data and it can only describe system characteristics that have been explicitly modeled.

A simulation study should follow the same four phase process discussed earlier.

Phase I, orientation, begins with the formulation of the problem. The external considerations should be examined and the study planned.

Figure 2 SLP Pattern of Procedures



Phase II is system modeling. In this phase, data is collected and the model is defined. Then the model is validated. This phase includes the construction and verification of a computer-based version of the model. Pilot runs of the model are made and the validity is again checked.

System analysis, Phase III, includes designing simulation experiments and making production runs. The output data is analyzed, results interpreted, and decisions made.

The final phase, Phase IV, is implementation. Here the model and work are documented. Funding for the project is acquired now and the results are applied.

There are several software packages available for developing a simulation model. These packages range in price from $500 to $100,000 and must be evaluated on several factors: animation features, underlying simulation language, brand and type of required hardware, and the special class of problems which can be modeled (6), (7).

Applying Simulation in CIM System Design

Simulation modeling is most effective in Phases II and III of facilities planning. During Phase II, simulation modeling can be used to evaluate different layout alternatives. A simple model will provide a quantitative measure to the evaluation procedure.

In Phase III simulation modeling can be used to further evaluate the system. Here a more detailed model is appropriate. The model can be used to fine-tune the layout and to evaluate the material handling system. The simulation can also lay the foundation for the controlling computer software.

Simulation can also be used after the plant has begun operations. In an operating plant, simulation assists management in scheduling and staffing. It can also determine equipment availability and estimate production capacity.

The Flexible Manufacturing Cell - A Case Study

The Flexible Manufacturing Cell (FMC) is a 900 square feet educational facility equipped with industry grade equipment. This includes a CNC mill and CNC lathe, a loop conveyor, a GE robot, an IBM robot, a Mercury robot, a bagging machine, three controllers and one CAD/CAM workstation.

The FMC is capable of producing six small toys and souvenir items: a key chain, a 3-D maze, the Tower of Hanoi, the Cam Critter, a single-hole pencil holder, and a multi-hole pencil holder.

The key chain displays the company's logo as well as other alpha-numeric characters. The maze is a tri-level plexiglass maze. The Tower of Hanoi consists of a horizontal base with three vertical pegs. On the middle peg are seven disks arranged largest to smallest. The Cam Critter is a pull-toy that has a cam attached to the front axle to cause the critter to bob up and down. The pencil holders consist of a dumbbell shaped body with holes in the top surface to accommodate pencils.

Since the FMC is to be used for educational purposes, it must be designed with several factors in mind. It must demonstrate the principles involved in CIM. It must be safe and easily accessible for demonstrations. Richard Muther's SLP methodology was used in designing the layout for the FMC.

Following the design of the layouts, the alternatives must be evaluated. The alternatives were evaluated on the following factors: ease of servicing, ease of expanding, safety, ease of material flow, ease of machine control and supervision, and accessibility for demonstrademonstrations. A simulation model was attempted at this point to help in the evaluation process. However, due to the restricting relationships between the machines, the layouts did not differ enough to affect a model. For layout alternatives which vary a great deal, simulation modeling can help in determining the most effective layout.

For each of the factors, Alternative 3 rated as well as or better than Alternatives 1 and 2. Therefore, Alternative 3 is the "best" layout. The dimensioned "best" layout for the Flexible Manufacturing Cell is shown in Figure 3. Having chosen the "best" layout, simulation modeling can be used for further evaluation.

The educational version of XCell+ was used first to model the FMC. XCell+ is a computer program which allows the user to build a simulation model without actually programming. It is an interactive program with animation which also utilizes graphics during the construction phase (8).

The educational version of XCell+ was not capable of handling all of the processes in the FMC. Since the production version was not available, two simplified models were designed. The two models, designated Group 1 and Group 2, differed only in the mix of products. Group 1 modeled the production of the Tower of Hanoi, the single-hole pencil holder, the 3-D maze, and the Cam Critter. Group 2 consisted of the key chain, the multi-hole pencil holder, and the 3-D maze.

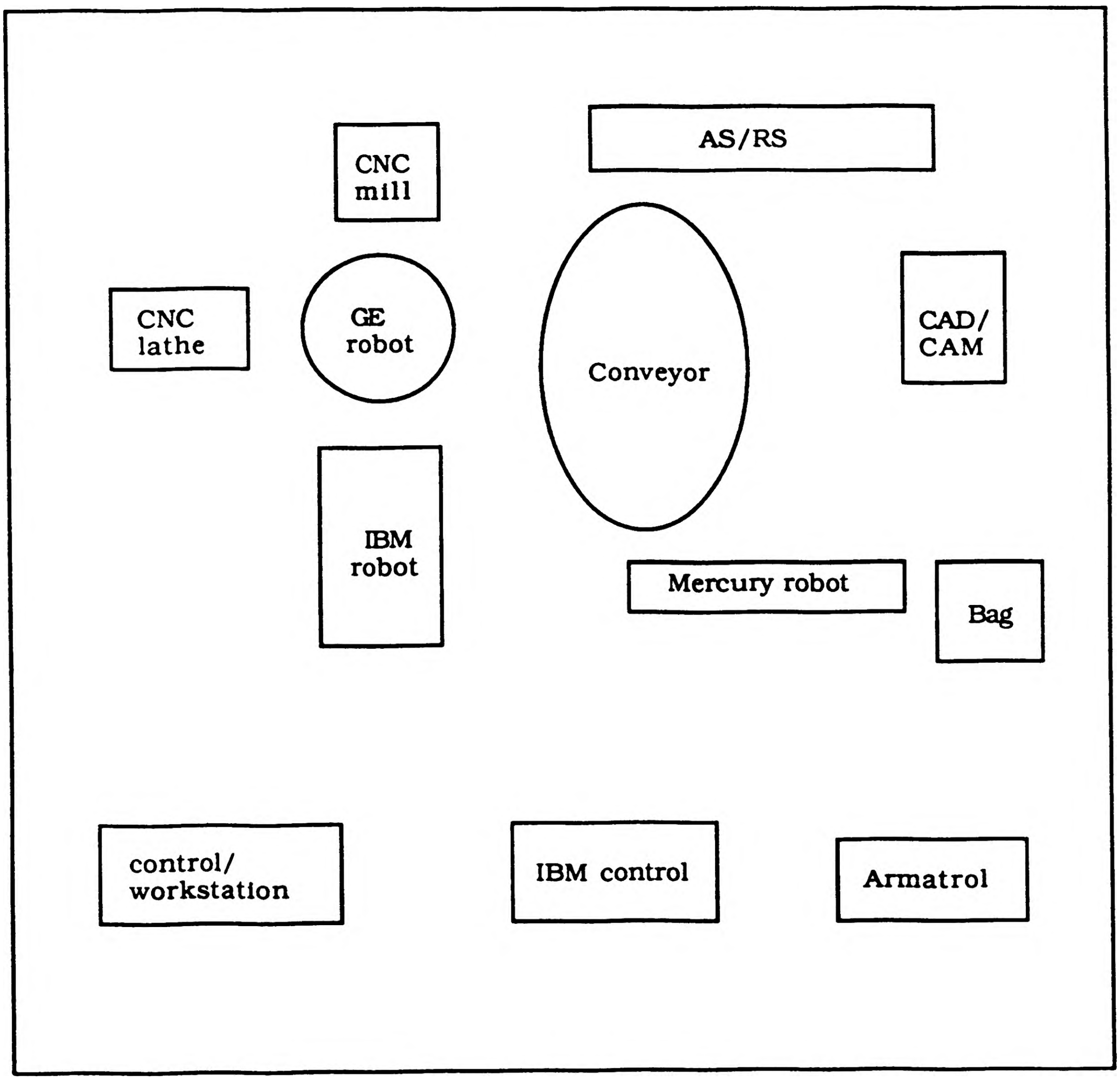
Because of the required processes, the GE robot was modeled with three and four workstations. Thus, when analyzing the data, these workstations must be combined. Although this is not a perfect model of the FMC, it is a good approximation.

The models were each run for a period of 740 minutes. The factory throughput of Group 1 was 264 units while Group 2's throughput was 241 units. An analysis of Group 1's workcenter utilization indicates that the GE robot (W1 + W2 + W3) was busy 20.15% of the time, the CNC lathe (W4) was used 31.28% of the time, and the assembly cell (W5) was used 27.29% of the time. This model indicates that although the machines aren't utilized to their fullest potential, the FMC is fairly well balanced.

A similar analysis of Group 2 reveals that the GE robot (W1 + W2 + W3 + W8) was used 39.12 % of the time, the CNC lathe was busy 38.52% of the time, the assembly cell was used 20.10% of the time, and the CNC mill was busy 55.03% of the time. Again there is low machine utilization, but this time the FMC is not balanced. The mill is in use more than the rest of the cell and it will be the limiting factor in cell throughput. A second mill might be needed.

Since the FMC was simulated with two separate models, a more detailed simulation incorporating everything into one model was done. A knowledge-based program called EXSEMA was used to select the appropriate simulation software (9). EXSEMA is an expert system using the Level Five knowledge engineering shell. A typical consultation

Figure 3 FMC "Best" Layout



session prompts the user for information describing the proposed application and existing constraints. EXSEMA then identifies the simulation system which provides the best fit with the user's needs. The system is based on the 1989 survey by Law and Haider (6). The following guidelines were used in selecting the software for this model:

- time is restricted
- programming expertise is not available
- application orientation is manufacturing
- input modes are interactive
- cost range is medium
- available computer class is pc
- animation is necessary
- animation development concurrent with model construction is required

SimFactory, a menu-driven program written in the SimScript II.5 simulation language, met all of these criteria (10).

SimFactory was capable of handling all of the required processes, so one model was designed to simulate the system. Each machine was represented by one station, thus providing a more accurate model.

This model was also run for a period of 740 minutes with a warm-up period of 30 minutes. The total throughput of the cell was 348 units. An analysis of the output indicates that the GE robot is in use 79.45% of the time, the lathe 37.12% of the time, the assembly cell 29.05% of the time, and the mill 44.57% of the time. This again suggests that the FMC is not balanced. However, in this model the GE robot is used the most. The mill is still utilized more than the lathe and assembly cell, but the GE robot is the limiting factor.

The utilization of the GE robot was not accurately represented in the XCell + models since three and four workstations were used to emulate it. The workstations could operate at the same time, essentially performing two or three jobs at once. The SimFactory model used one transporter to emulate the GE robot, thus successfully representing its utilization.

"What-if" analysis can now be done on the SimFactory model. Areas of investigation should include the GE robot and the mill. "Could a faster robot be helpful?" "Should a larger, faster mill be acquired?" "Could another robot be added to the system to transfer material?" All of these are questions which should be addressed in further study.

Finally, the SimFactory model can be used to optimize the throughput and minimize the raw material queue by adjusting the raw material arrival times and quantities.

Conclusion

Simulation modeling is an effective OR technique to use during the design of a CIM system. It enables the planner to evaluate and improve the system without costly physical models or pilot plants. Used with animation, simulation becomes an effective communication tool, allowing the observer to easily understand the process being modeled. Simulation also is a powerful evaluation tool during the manufacturing cell design process.

These benefits show that simulation modeling can indeed serve the manufacturing company and is a worthwhile investment.

REFERENCES

1. Mikell P. Groover, Automation, Production Systems, and Computer Integrated Manufacturing, Prentice-Hall, Englewood Cliffs, NJ, pp. 4, 1987.

2. Richard Muther, Systematic Layout Planning, Missouri: Management & Industrial Research Publications, 1973.

3. R. Borchelt and S. Alptekin, "Physical Modeling - A Tool for CIM Educators", International Journal of Applied Engineering Education, January, 1990.

4. R.E. Shannon, S.S. Long, and B.P. Buckles, "Operations Research Methodologies in Industrial Engineering: A Survey", AIIE Transactions, Vol. 12, No. 4, pp. 364-367, 1980.

5. D.F. Koska and J.D. Romano, Countdown to the Future: The Manufacturing Engineer in the 21st Century, A.T. Kearney Research Study, Profile 21, Executive Summary, SME, Fall 1988.

6. A.M. Law and S.W. Haider, "Selecting Simulation Software for Manufacturing Applica tions: Practical Guidelines and Software Survey", Industrial Engineering, May 1989.

7. J.W. Grant and S.A. Weiner, "Factors to Consider In Choosing A Graphically Animated Simulation System", Industrial Engineering, August 1986.

8. R. Conway, W.L. Maxwell, J.O. McClain, and S.L. Worona, User's Guide to XCELL + Factory Modeling System, 2nd Edition, The Scientific Press, Redwood City, CA, 1987.

9. C.O. Benjamin and O. Hosny, "EXSEMA - An EXpert System for sElecting simulation software for Manufacturing Applications", Department of Engineering Management Working Paper No. 90-12-37, University of Missouri -Rolla, Rolla, Missouri, May 1990.

10. SIMFACTORY with Animation, Version 1.6, User's and Reference Manual, CACI Products Company, La Jolla, CA, 1988.

BIBLIOGRAPHY

- Bachers, R., Augustin, M., and Dangelmaier, W. "Using simulation in the planning of final assembly: a case study from a German car manufacturer", Simulation in Manufac turing, Proceedings of the 2nd International Conference, June 24-26, 1986, Chicago, Illinois, U.S.A.

- Ben-Arieh, D. "A Knowledge based system for simulation and control of a CIM", Simula tion in Manufacturing, Proceedings of the 2nd InternaInternational Conference, June 24-26, 1986, Chicago, Illinois, U.S.A.

- Branstrator, J. and McCormick, M. "Computer Simulation Justifies Construction of CIBA-GEIGY Dyestuff Production Facility", Industrial Engineering, May 1989, pp. 22-26.

- Benjamin, C.O. and Smith, M.L. "Simulation Modeling in Cim System Design", Depart- ment of Engineering Management Working Paper No. 90-13-38, University of Missouri-Rolla, Rolla, Missouri, May 1990.

- Benjamin, C.O. and Smith, M.L. "The CIM Laboratory Facility", Case Study, Case Clearing House of Great Britian and Ireland, Cranfield Institute of Technology, England, May 1990.

- Carlier, J., "Simulation as a planning tool for an FMS", Simulation in Manufacturing, Proceedings of the 2nd International Conference, June 24-26, 1986, Chicago, Illinois, U.S.A.

- Chaharbaghi, K., Davies, B.L., and Rahnejat, H. "Application of simulation in planning the design of flexible assembly systems", UK Research In Advanced Manufacture, Proceedings of the Institution of Mechanical Engineers, 1986.

- Godziela, R. "Simulation of a Flexible Manufacturing Cell", 1986 Winter Simulation Conference, December 8-10, 1986, Washington, D.C.

- IIE, Simulation: Modeling Manufacturing and Service Systems, Industrial Engineering and Management Press, Norcross, Georgia, 1987.

- Law, A.M. and McComas, M.G. "Pitfalls in the Simulation of Manufacturing Systems", 1986 Winter Simulation Conference, December 8-10, 1986, Washington, D.C.

- Makin, A.J. "The use of simulation-from specification of an FMS through to its opera- tion-a case study", Simulation in Manufacturing, Proceedings of the 2nd International Conference, June 24-26, 1986, Chicago, Illinois, U.S.A.

- Martin, D. "Simulation Analysis of an FMS during Implementation", 1986 Winter Simulation Conference, December 8-10, 1986, Washington, D.C.

- Mishra, P.K., Pandey, P.C., and Singh, C.K. "Simulation studies of flexible manufactur- ing systems", Simulation in Manufacturing, Proceedings of the 2nd International Confer ence, June 24-26, 1986, Chicago, Illinois, U.S.A.

- Roy, R. and Grinsted, S.E. "The role of simulation in manufacturing and how to use it effectively", Simulation in Manufacturing, Proceedings of the 2nd International Conference, June 24-26, 1986, Chicago, Illinois, U.S.A.

- Smith, Charles A. "The Role of Simulation Analysis in Improving the Manageability of Integrated Systems", Autofact '85, Conference Proceedings, November 4-7, 1985, Detroit, Michigan.

- Warnecke, H.-J., Steinhilper, R., and Zeh, K.-P. "Simulation as an integral part of an effective planning of flexible manufacturing systems (FMS)", Simulation in Manufacturing, Proceedings of the 2nd International Conference, June 24-26, 1986, Chicago, Illinois, U.S.A.

- Wortmen, David and Miner, Robin "The Role of Simulation in Designing Manufacturing Systems", Autofact '85, Conference Proceedings, November 4-7, 1985, Detroit, Michigan.