

## Rapid Modeling: How It Assists Manufacturing Competitiveness

Rajan Suri

Industrial Engineering Department  
University of Wisconsin  
1513 University Avenue  
Madison, WI 53706

### ABSTRACT

The Rapid Modeling Technique (RMT) allows manufacturing analysts to quickly build new models for various manufacturing scenarios, as well as to rapidly explore a large number of "what-ifs" for each scenario. A set of integrated tools further extends RMT to allow the efficient investigation of decisions in virtually all stages of the design and operation of manufacturing systems. The use of these tools leads to cost-effective and timely analysis of manufacturing decisions, and hence to greater productivity and competitive position of the manufacturing enterprise. We present a set of five compatible tools for rapid modeling and analysis of manufacturing systems. Spreadsheets form the basic tool for simple calculations. RMT tools allow the user to study the dynamics of manufacturing systems using efficient mathematics: whole models can be built in hours and each "what-if" is analyzed in minutes. Translators allow almost instantaneous conversion of the analytical model into simulation code. Simulation Languages provide very detailed modeling abilities. Finally, Animation gives analysts the ability to present their results to co-workers and management in a convincing manner. We describe instances of these tools as well as the way in which they are integrated to form a compatible toolkit.

### 1. INTRODUCTION

#### 1.1 The Reality of Manufacturing

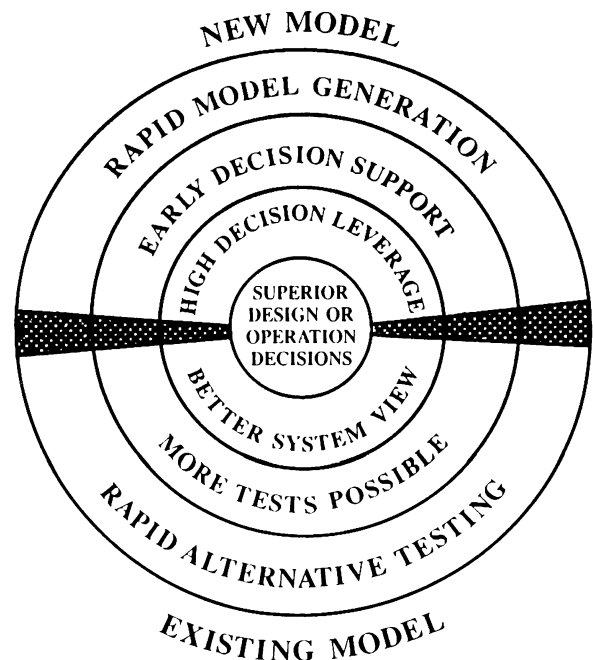
The reality of manufacturing is that decisions are made under time constraints. However, there aren't many analysis tools that support the rapid exploration of manufacturing alternatives. For example, available information systems such as MRP (materials requirements planning) systems are not easily adapted to new configurations, nor quick in their response, and many are not easy to use except by information systems personnel. Discrete-event Simulation, while being a powerful tool, requires considerable experience and training to use correctly, and model-building or what-if exploration can be quite time-consuming. These factors generate

a reluctance to use such systems to perform quick "what ifs". Faced with unresponsive tools with which to study alternatives, the analysis is deferred. Eventually, this leads to the following situation.

#### 1.2 The Enigma of Last-Minute Analysis

Those of us who work or consult in the manufacturing arena are well aware that when it comes to analysis, it is often put off until it is "needed yesterday". At this stage, under the time pressure for decision-making, one can no longer afford to wait weeks or months for a detailed study. Usually, all hopes of analysis are dropped and managers rely on their experience or intuition (with fingers crossed!) to come up with the right decision. Isn't there a better way?

There is. It means understanding some of the key ideas of the Rapid Modeling Technique (RMT), and using the approach effectively.



### 1.3 Getting 80% of the Answer Now

The first key point is this: *In competitive manufacturing, getting 80% of the answer now is worth more than knowing the complete answer in six months.* As an example, consider a firm that is trying to reduce its lead time from 15 weeks to 10 days (not uncommon in today's JIT world). Suppose a rough model, that might be off by 20%, predicts that a set of decisions will achieve a 10 day lead time. At worst, this means that the actual lead time achieved may be 12 days, not 10 days. Sitting at 15 weeks, 12 days still looks terrific!

This rough model may be enough to justify an initial decision. Instead of waiting for detailed analyses, management can proceed before the competition does. The details and fine tuning down to exactly 10 days will come in later.

### 1.4 The Forest Before The Trees

RMT encourages, indeed stipulates, building rough models first, understanding the forest now, and refining the trees later. So the second cornerstone of RMT is one that is oft drilled into us by key thinkers: *study the forest first before examining the trees.*

## 2. TOOLS FOR RAPID MODELING

Elsewhere, (Suri and Tomsicek, 1988), we have described in detail a set of tools for Rapid Modeling of manufacturing systems. Therefore we will keep this section brief and refer the reader to that paper for details.

### 2.1 Spreadsheets

In order to perform quick analyses, the most responsive and flexible analysis tool available today is the electronic spreadsheet, an example of which is **Lotus 1-2-3**, from Lotus Development Corp., Cambridge, MA. Such a tool allows calculations to be set up quickly and easily, on a personal computer. Today's spreadsheets also serve as databases for the wealth of information needed in analyzing a decision, such as product demands, routings, and lot sizes. As an example, in manufacturing system design a rough estimate of the number of machines required can be quickly obtained using such data along with elementary calculations set up in the spreadsheet. Thus, the first step to be considered when conducting analysis under time pressure, is the use of a spreadsheet model.

However, despite the power of spreadsheets, manufacturing systems possess complex dynamics that are not easily captured in a simple formula. Multiple products move through multiple work centers, demanding resources, setups, and cycle times. Machines fail. Material may not be available as expected. Parts may be scrapped or require rework. All this affects lead times, work in

process, and overall production capacity. It is precisely this complexity that has led to the use of computer simulation tools that capture all these dynamics in detail. While simulation is an important modeling tool, it may be more power than is required for many situations.

### 2.2 The Rapid Modeling Technique (RMT)

The centerpiece of the whole approach described here is the Rapid Modeling Technique itself (Suri, 1988). This method, on the one hand, addresses the complexity of the manufacturing system, but on the other hand, avoids the complexity of the other analysis tools such as simulation or MRP. How is this possible?

The basic idea is to capture the dynamics of the manufacturing facility in terms of mathematical equations, using techniques known as queueing network theory. Ten years ago most theoreticians would have claimed that these equations could not be solved. But there has been a lot of progress in this field (Suri and Diehl, 1987). By aggregating some of the dynamics of the system (albeit with some loss of detail) approximate solutions can be obtained for the system performance with amazingly little computer time. The complexity of the equations means that specialized software must be written to solve them. However, such software fits on personal computers, and can be written so that the manufacturing user does not have to deal with the complex mathematics, but only with simple inputs and outputs, bringing the techniques within reach of every engineer.

An example of such a RMT tool is **ManuPlan**, from Network Dynamics Inc., Burlington, MA. Industrial case studies from leading firms report the ability to build a ManuPlan model in a few hours and run each "what if" in a few seconds, with corresponding impact on major projects. Examples of published studies include use at Alcoa (Nymon, 1987), Digital Equipment Corp. (Harper and O'Loughlin, 1987), IBM (Haider et al., 1986; Brown, 1988), McDonnell Douglas (Mills, 1986), and Siemens (Anderson, 1987).

### 2.3 From RMT to Simulation

While RMT is a very powerful analysis technology, it does have some limitations. Since analytical models deliver results based on steady state estimates, they cannot be used to research issues related to very detailed scheduling or very short-term conditions (such as start-up procedures). They also do not accurately model buffer size constraints. Likewise, it is not possible to animate the analytical model directly. Although a RMT tool such as ManuPlan cannot perform these tasks by itself, the following tools effectively compensate for these deficiencies.

SimStarter is a unique program that allows ManuPlan model files to be directly converted into simulation code for certain simulation languages. The key benefit of the SimStarter package is the drastic reduction in time

required to develop and debug an initial simulation model. As noted above, ManuPlan is far more effective than simulation for rapid modeling and for initial decisions or decisions under time pressure, but it is unable to perform some more detailed analysis tasks. For such analyses, using SimStarter the analytical model can be directly converted to simulation code. Now one can easily incorporate the detailed features of the manufacturing system into the simulation code.

In addition to the reduction in model development time, SimStarter minimizes debugging time by constructing an error-free initial system configuration, and error-free placement of a large amount of initial data and parameters in the simulation code. Experienced simulation users will appreciate the importance of such a starting point from which they can enhance the model with other details. Examples in Anderson (1987), Brown (1988) and Shimizu and Van Zoest (1988) illustrate effective use of ManuPlan and SimStarter in electronic assembly and metal fabrication applications.

#### 2.4 Simulation and Animation

Simulation is a sophisticated modeling technique and several powerful simulation and animation packages exist. Introductory tutorials on these can be found in this conference proceedings, so we will not cover these topics here. We simply mention that, in the context of our rapid modeling approach, after a simulation model has been generated by the SimStarter program, then additional details and intricacies of a manufacturing system may be included in the model, enabling very accurate results to be compiled. The code produced by SimStarter is at the "ManuPlan level" of modeling. Usually, the analyst will enhance this model by adding code on such features as: specific scheduling and priority policies; labor allocation policies; buffer size constraints; material handling paths and routing policies.

The traditional disadvantages of using simulation analysis, namely, extensive model development and run time requirements [Thesen and Travis (1988)], are diminished by the rapid modeling approach just described. When used in conjunction with the other tools discussed, simulation is applied "down the line" in the analysis process. Early decision-making and guidance will already have been assisted by ManuPlan, affording more time for models to be built and data gathered to support final analysis and eventual decisions. Time to develop and debug the simulation model is also considerably reduced.

Animation is not actually an analysis tool, but it has become a very popular approach for presenting the results of modeling studies. It provides a way of visually communicating complex system models to managers, other design engineers, and shop floor personnel.

In some cases, after SimStarter is used, it may not be necessary to add more details in the simulation code -- Suri and Tomsicek (1988) describe how ManuPlan and SimStarter enable analysts to rapidly generate working Animations with no programming, and describe a case study where this proved beneficial in generating management support for a project.

#### 3. THE IMPORTANCE OF INTEGRATION

A key feature of the tools discussed here is that they are compatible, allowing the user to build, in effect, only one model. That model can be successively refined at each stage of analysis without duplicate data entry or coding. A version of ManuPlan, namely **Manuplan II**, uses **Lotus 1-2-3** as its interface. ManuPlan or ManuPlan II models can be directly converted to Simulation code using **SimStarter**. Good Animation packages allow for models to be laid out using a CAD-like interface, and then driven directly from the simulation code. The benefits of using an integrated set of tools for manufacturing analysis are discussed by Anderson et al. (1988), Shimizu (1988), and Shimizu and Van Zoest (1988).

#### 4. CONCLUDING REMARKS

Speed of response can be crucial in today's manufacturing world. The use of Rapid Modeling Tools for fast decision making can significantly enhance the performance of a manufacturing enterprise. Elsewhere (Suri, 1989) we describe several case studies showing how RMT enabled Lead Time Reduction. Cheng (1989) discusses the conceptual and business reasons why RMT enhances manufacturing competitiveness. Making RMT part of an integrated toolkit -- spanning from simple spreadsheets, through the rapid dynamic analysis of RMT, to simulation and animation -- can provide the analyst with a powerful approach to addressing a broad spectrum of manufacturing decisions.

#### ACKNOWLEDGEMENT

Some of the concepts mentioned here have been developed and explored jointly with Ken Anderson of Siemens RTL, Gregory Diehl and Mike Tomsicek of Network Dynamics, and Masami Shimizu of the University of Wisconsin. Mr. Bor-Ruey Fu of the University of Wisconsin assisted us in the preparation of this manuscript. This work was supported in part by NSF Grant No. ISI-8700394.

#### REFERENCES

- Anderson, K. R. (1987). "A Method for Planning Analysis and Design Simulation of CIM Systems", **Proc. 1987 Winter Simulation Conference**, pp. 715-720.
- Anderson, K. R., G.W. Diehl, M. Shimizu and R. Suri (1988). "Integrating Spreadsheets, System Modeling, and Animation for Rapid Computer-Aided Design of Manufacturing Systems", **Proc. 1988 University Programs in Computer-Aided Engineering, Design and Manufacturing (UPCAEDM) Conference**.

Brown, E. (1988). "IBM Combines Rapid Modeling Technique and Simulation to Design PCB Factory-of-the-Future", **Industrial Engineering**, June, pp. 23-26 and 90.

Cheng, J.C. (1989). "Competitive Advantage through Rapid Modeling Techniques", **Managing Automation**, July, pp. 72-73.

Haider, S. W., D. G. Noller and T. B. Robey (1986). "Experiences with Analytic and Simulation Modelling for a Factory of the Future Project at IBM", **Proc. 1986 Winter Simulation Conference**, pp. 641-648.

Harper, R. and M. J. O'Loughlin (1987). "Manufacturing Process Analysis -- Tools and Applications", **Proc. 1987 Winter Simulation Conference**, pp. 731-737.

Mills, M.C. (1986). "Using Group Technology, Simulation and Analytic Modeling in the Design of a Cellular Manufacturing Facility", **Proc. 1986 Winter Simulation Conference**, pp. 657-660.

Nymon, J. (1987). "Using Analytical and Simulation Modeling for Early Factory Prototyping", **Proc. 1987 Winter Simulation Conference**, pp. 721-724.

Shimizu, M. (1988). A Case Study in Application of an Integrated Approach for Rapid Design and Analysis of Manufacturing Systems. Technical Report, Manufacturing Systems Engineering, University of Wisconsin-Madison.

Shimizu, M. and D. Van Zoest (1988). "Analysis of a Factory of the Future Using an Integrated Set of Software for Manufacturing Systems Modeling", **Proc. 1988 Winter Simulation Conference**.

Suri, P. (1988). "RMT Puts Manufacturing at the Helm", **Manufacturing Engineering**, February, pp. 41-44.

Suri, P. (1989). "Lead Time Reduction through Rapid Modeling", **Manufacturing Systems**, July, pp. 66-68.

Suri, R. and G. W. Diehl (1987). "Rough Cut Modelling: An Alternative to Simulation", **CIM Review**, Volume 3, No. 3, January, pp. 25-32.

Suri, R. and M. Tomsicek (1988). "Rapid Modeling Tools for Manufacturing Simulation and Analysis", **Proc. 1988 Winter Simulation Conference**.

Thesen, A. and L. Travis (1988). "Introduction to Simulation", **Proc. 1988 Winter Simulation Conference**.

#### BIOGRAPHIES

Rajan Suri is Professor of Industrial Engineering at the University of Wisconsin-Madison. He received his Bachelors Degree from Cambridge University (England) and his M.S. and Ph.D. from Harvard University. In 1981 he received the Eckman Award for outstanding contributions in his field. He is a member of the University of Wisconsin Team that received the 1988 LEAD Award (for Leadership and Excellence in Application and Development) from the Society of Manufacturing Engineers. In 1988 he also received a Research Award from Ford Motor Company "in recognition of outstanding contributions made to the field of Perturbation Analysis of Discrete Event Systems". His current interests are in modeling and decision-support for manufacturing systems. He is the author of many journal publications and several books, and has chaired international conferences on this subject. He serves as Associate Editor for the *SME Journal of Manufacturing Systems*, and the *International Journal of Flexible Manufacturing Systems*. Dr. Suri is a consultant to major industrial corporations, and conducts seminars in his field for the Institute of Industrial Engineers and the Society of Manufacturing Engineers.

Rajan Suri  
IE Department  
University of Wisconsin  
1513 University Avenue  
Madison, WI 53706.  
Tel: (608) 262-5536