Proceedings of the 1986 Winter Simulation Conference
J. Wilson, J. Henriksen, S. Roberts (eds.)

THE MANUFACTURING MODELING PROCESS: FROM CONCEPTION TO SHOP FLOOR APPLICATION

Peter M. Waller
Intel Corporation
Chandler, Arizona

ABSTRACT

Many shop floor manufacturing decisions are made through simple queueing theory or back-of-the-envelope calculations. These techniques tend to overlook the effect of a change on the entire manufacturing system. This paper presents a methodology for using simulation as an analytical tool to make strategic shop floor decisions at the department manager level. Concepts are discussed on how to tie factory expertise with the corporate simulation group to be successful. A methodology is presented for use by the factory team to use the model in project selection. An actual application of a wafer fabrication model is discussed to demonstrate the various techniques.

INTRODUCTION

Manufacturing optimization using simulation is relatively new at Intel. Traditionally, decisions were made by department managers which tend to optimize their area, but may actually reduce output of the total factory (i.e.: batching lots in an area which feeds a single wafer processing step). A methodology was developed to use simulation as a strategic, analytical tool to understand the total manufacturing system. Our target receiver is primarily a manufacturing department manager, but includes both the maintenance and process engineering managers. A department is defined as one of the four areas within wafer fabrication: lithography, etch, diffusion or thin film.

Our approach as a corporate simulation group has been to develop models with the factory, demonstrating initial results. The factory industrial engineering group will then assume responsibility of the model to work with the department management teams in area optimization. The key components to being successful through the complete process are:

- Conception of the model through factory commitment and ownership;
- Construction of the model, culminating with valid output; and,
- Transferring the tool to the factory for use in project prioritization.

CONCEPTION

Team Commitment

To achieve initial factory commitment, we have found it is best to start with a small application; in this case, the lithography department. In this way, we worked on a current factory problem directly with the department management team.

The team is a combination of the corporate simulation group which supplies technical expertise in modeling, and the factory area team which guides the model direction and eventually assumes model responsibility. The corporate group manages the project. A core team is established to focus on the construction of the model, and includes the factory I.E. The I.E. is directly involved with the project fomulation and modeling. Model ownership becomes his/her responsibility upon project completion, so their time commitment is significant at 40%.

An expert team is established to steer model reality. This consists of department managers from Production, Maintenance and Process Engineering. The time commitment which consists mainly of weekly team meetings varies, but is approximately 5%. This team is also responsible for presenting model results to factory management.

Establish Objectives

The corporate simulation group organizes a brainstorming session with the expert team to establish model priorities. After all issues are stated, each member rates each line item based on ease of modeling. The product of the item ratings is compared to prioritize the brainstorming list. Any disagreement on the priorities are then discussed. The first-cut project objectives are now established, though revisions will occur throughout the project.

The objectives of the lithography project included:

- Build a multi-process/multi-product model to understand:
  - Elimination of test wafers,
  - Manpower effects of operators, maintenance and engineering technicians, and,
  - Different scheduling algorithms within the department.

- Forecast future bottlenecks.
- Model must be flexible with features to test other concepts.

The model outputs are mainly utilization and through-put-time of both equipment and labor.

MODEL CONSTRUCTION

Process Flow Chart

To define reality, a process flow chart is developed. This is compiled by the corporate I.E. and can be very valuable in giving the corporate group credibility with the factory team. Data is collected through observation on the factory floor and through discussions with front-line personnel; including: operators, production supervisors, maintenance and engineering technicians. It is also essential to view procedures on several shifts. The process flow chart includes all details and works as a methods analysis for process simplification. Factory operational changes may be made as this data is initially reviewed with the expert team. An example is the elimination of a test which was installed to monitor a problem which no longer exists.

Compilation of the Database

Data is a critical factor in defining model complexity. We build our models to the current database and do not force new data requirements on the factory. This eliminates "insufficient data" as a reason for the model to fall out of our use. Our lithography model database included: I.E. set equipment and labor standards; product flows, scheduling algorithms and yields from Production Control; test wafer pass rates from Engineering and equipment downtime data from Maintenance.

Team Buy-In of the Model Coding

Constuction of a model typically spans a period of four to six weeks. The sales approach is generally to build, test and review individual sections of the model as they are being constructed. The factory I.E. is heavily involved with the modeling, but minimally involved with the coding. Users' documentation by the factory I.E. at this time also helps to insure that the I.E. understands the model versus factory reality. To ease model use, we construct a "LOTUS" output processor to translate the computer output to factory language (example: Intel utilization is equivalent to the time equipment runs product only, not just equipment busy time).

Validation

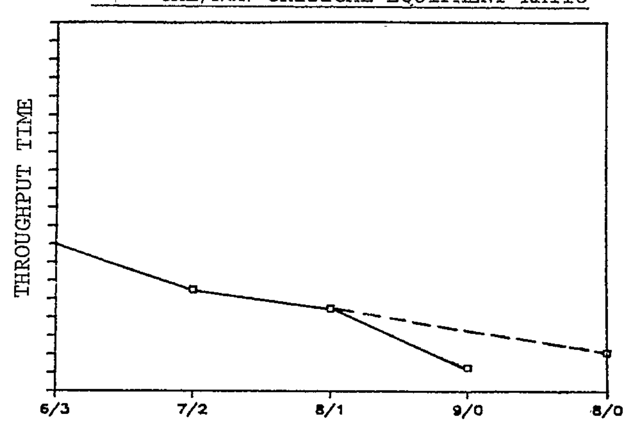
Validation of the model is an ongoing process throughout the project. This includes from the intial formulation of the problem with the expert team through the process flow chart, compilation of the database and the team buy-in of the coding during construction. Weekly expert team meetings plus periodic reviews with the factory management are a good means of verification. The final model validation pulls everything together. Since the lithography model was used as a strategic planning tool, several months of data was compared to the model output. Our lithography results were within 5% of the actual factory indicators. Key validation components were throughput time of test wafers and production wafers through the system, and equipment and labor utilization.

Sensitivity Analysis

Sensitivity analysis is run on each of the parameters set forth in the objectives. Basically, separate simulation runs are made, evaluating different conditions (i.e.: number of operators available). The expert team develops action plans where applicable, and presents the data and plan to the factory management. An example is shown in Figure I, below:

FIGURE I

CRITICAL/NON-CRITICAL EQUIPMENT RATIO



This graph shows the effects of converting equipment from being able to run non-critical layers to critical and non-critical layers versus throughput time. Based on conversion costs and labor availability, an action plan is developed. This analysis would be presented by the Lithography Maintenance Manager.

SHOP FLOOR APPLICATION

The above discussions on model conception and construction solve the initial objectives. The following discussion takes this a step further, developing a methodology for factory application.

Training

Factory understanding is critical for the model's longevity. The corporate group's charter is only for development and future technical support to handle factory operational changes which affect model validation. Our approach to factory training is through documentation, I.E. User training, and management training. The factory I.E. is trained in the applicable simulation language. This entails a one-week, Intel class on both modeling and the simulation language. Training should occur before the coding begins, to enable the I.E. to understand the model concepts as they are developed. The I.E. also has the responsibility to develop the Users' Manual. The Systems Manual is developed by the cörpororate group.

Management training is also critical. The meetings held during model conception and construction with both the expert team of department managers and the factory management should insure model credibility. The Users' Manual developed by I.E. keeps the model together through future organizational changes.

Factory Application

Since our models are strategic, a specific methodology was developed with the factory area team for their use. Quarterly operation reviews of the department's performance already existed, so the model use was worked into this cycle:

1) The factory I.E. runs the model using current equipment parameters and forecasted product loadings. The database of equipment parameters and the output is distributed to the department management team.

2) Potential projects addressing the equipment parameters are listed by each department manager.

3) Each project is run separately by the factory I.E. The projects are prioritized based on TPT and utilization.

4) Using this data, the department managers determine the actual projects to be supported given their constraints of cost and manpower.

5) All committed projects are reloaded into the model. The output from this run determines the team commitments.

6) The project determination phase of Steps 1 - 5 occurs within two weeks. Throughout the quarter, project status is reviewed in department meetings. At the quarter's end, projected success versus actual indicator trends are reviewed with factory management in the regular department operation review.

SUMMARY

This methodology of the manufacturing modeling process can optimize an existing manufacturing environment. The lithography model discussed, resulted in increased productivity and utilization achieving lower costs and higher factory output. Working within the existing factory framework is key. We did this through all phases of the project by involving an existing factory team, keeping the model within database constraints and driving implementation/model transfer through the existing operational review cycle. Conversely, factory commitment is also essential. Final model ownership is with the factory, therefore the expert team participation and industrial engineering training and eventual model assumption must occur.

REFERENCES

1. Law, Averill M. (1986), Introduction to Simulation: A Powerful Tool for Analyzing Complex Manufacturing Systems. In: Industrial Engineering, May 1986.

2. Peña, William (1977). Problem Seeking: An Architectural Programming Primer. Wall Company, Inc., Houston, Texas.

3. Pegden, Dennis C. (1977). Introduction to SIMAN, Version 3.0. Systems Modeling Corporation, State College, Pennsylvania.

BIOGRAPHICAL SKETCH

Peter M. Waller is currently Manager of the Simulation Group for Advanced Manufacturing Engineering at Intel Corporation. He has been with Intel for seven years in Die Production Manufacturing. Positions held include: Industrial Engineer, Industrial Engineering Manager, Production Department Manager and Manufacturing Manager. He received an MSIE from Purdue University in 1979 and a BSIEOR from Virginia Tech in 1976. He is a senior member of the Institute of Industrial Engineers.