THE MANUFACTURING MODELING PROCESS:
FROM CONCEPTION TO SHOP FLOOR APPLICATION

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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.

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 formulation 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:

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

- 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.

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.

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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...
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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 corporate 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


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.