A Centralized Approach to Factory Simulation

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Abstract

This paper describes the goals, practices, and methodologies of the Siemens Semiconductor Division's Factory Modeling and Simulation team. The team's charter is to implement performance modeling capability (simulation, capacity analysis, and cost analysis) at factories throughout the division, both wafer fabrication and back-end operations. Findings of recent modeling activities are discussed, along with applications of simulation and a hierarchical modeling approach. The authors wish to use articles such as this to initiate discussions with other organizations using modeling techniques to analyze factory performance.

Introduction

In early 1996, the semiconductor division of Siemens AG created a small, centralized group of technical engineers to assist its burgeoning efforts in static modeling and simulation. The primary goal of this team is to implement performance modeling and simulation throughout the division with factory-specific roadmaps and goals. All current work is done at the factory level (as opposed to strategic business unit level or enterprise modeling, for example). The primary objectives are:

1. Definition of a standardized data format to be used across all factories.
2. Recommendation and implementation of a standard software tool for static modeling of the production planning tasks.
3. Implementation of modeling and analysis at each factory, using discrete-event simulation.

The team's approach is to augment its capabilities by importing the assistance of software and methodology experts, from both academic and commercial sources.

This paper focuses on the third goal, implementing simulation techniques at the factory level, and discusses the modeling philosophy and approach of this project. Each factory will be able to perform their own simulation and modeling. The centralized team helps construct and validate the models and also performs specific case studies to identify potential performance improvement. This paper discusses motivation behind the use of simulation, the software approach, a hierarchical method for building initial factory models, and other supporting strategies. Findings of a recent fab performance analysis are also included.

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Why Simulate?

The primary reason to employ discrete-event simulation methodologies and analysis is to increase the understanding of the production operation. We strongly feel that simulation is not the panacea for all manufacturing ills. It is one modeling tool, to be employed with other existing tools, to assist the manager's decision-making process. If used properly, computer simulation can effectively evaluate the impact of business decisions on the factory's performance capabilities.

One of the greatest benefits of modeling is the ability to conduct sensitivity ("what-if") analysis, allowing the manager to experiment without disrupting the actual manufacturing operation. Major changes in fab product mix or production lot size, for example, could have disastrous results on factory throughput if not evaluated in advance. Modeling these scenarios in advance can help the factory predict possible outcomes and avoid unpleasant surprises. In addition, computer modeling allows detailed analysis of current operating practices and cost-improvement prospects. Used as part of an integrated framework with capacity and cost analysis, simulation provides an effective way to seek total solutions that bring the factory closer to optimal performance. Within this framework, we can investigate trade-offs between capacity, cycle time, wafer cost, and capital investment.

Today we recognize that effective capacity management is one of the keys to increasing semiconductor productivity. In the very complex world of wafer fabrication, modeling tools and techniques (including simulation) have greatly enhanced the industrial engineer's ability to find opportunities for productivity enhancement that go beyond simply adding production equipment.

The Software Connection

The simulation team's goal is to have a standard data format for modeling and external storage of the data. One structure being investigated is the Testbed Data Format that was developed under the JESSI/SEMATECH joint program MIMAC (Measurement and Improvement of Manufacturing Capacity). Therefore, at Siemens it is not necessary that all factories use the same software package for performance analysis. The team assists the factory personnel to construct a model in their software-of-choice. This is especially important for the increasing number of joint-venture fabs, where the partner company may have established a software preference or standard.

The team does, however, use a standard software package for our initial work to implement modeling and analysis at each factory. Incorporating data-driven software that easily imports available data allows the team to quickly build a useable model while assisting the factory personnel to construct a model in their chosen software. The Factory Modeling and Simulation team chose Factory Explorer™, from Wright Williams and Kelly, as their standard tool.

A key reason for this choice is that Factory Explorer™ enables quick model construction by importing data from Excel™ files (common in most, if not all, factories today) directly into an Excel™ model. The template predefines input required to provide output commonly desired for wafer fab analysis. The calculation time and computer run time is quick and the software is oriented to the semiconductor industry. Input data can be translated automatically between Excel™, ASCII, and Testbed formats. An added advantage is that output is expressed in Excel™

format, which is comfortable for analysts and managers alike. Figure 1 graphically depicts this data.

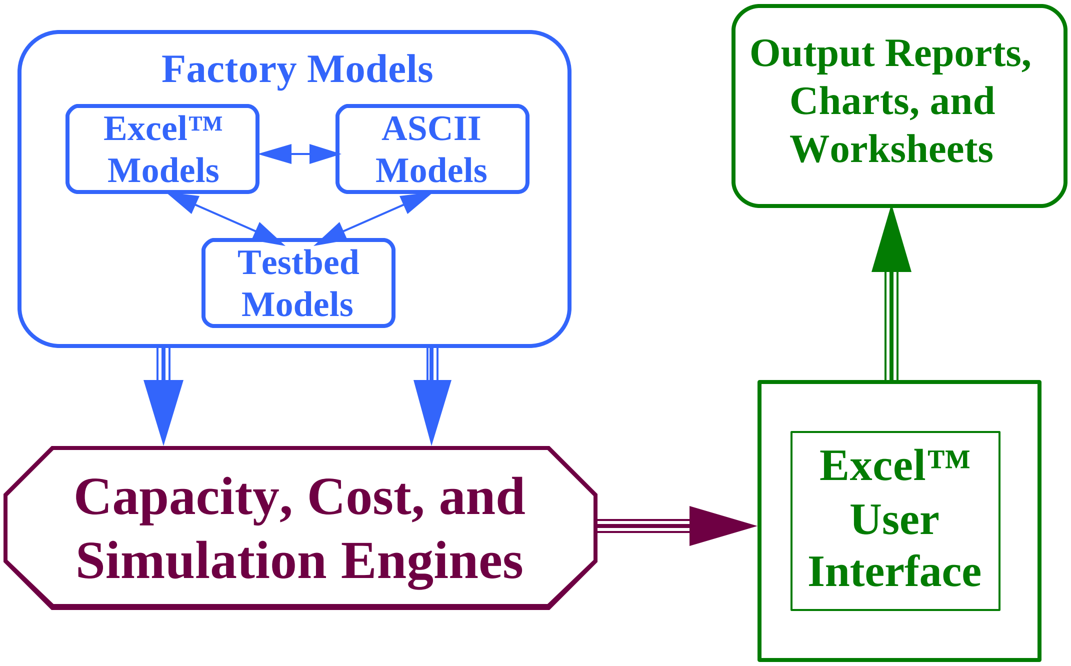


Figure 1. Data Flow Overview for Factory Explorer™

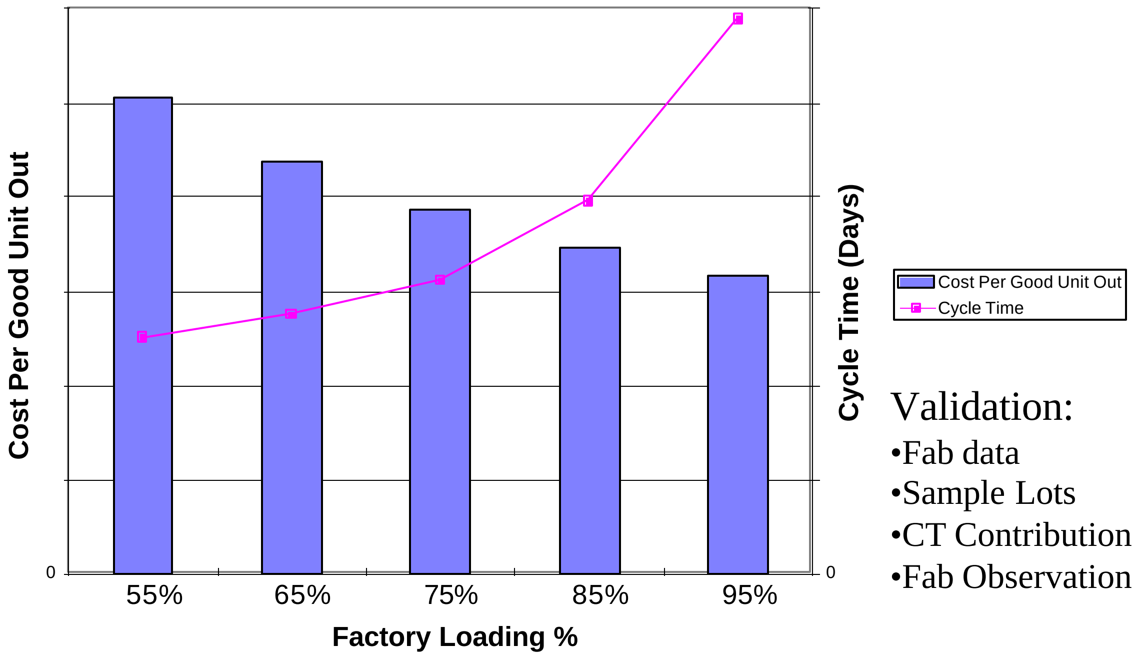
So far, Factory Explorer™ has been used successfully in one Siemens factory, and is currently being implemented in another. In the first fab, Factory Explorer™ allowed the team to build and validate the initial model in eight weeks, to create a useable model with first-pass analytical results in an additional five weeks, and to deliver a detailed case study of fab operating practices six weeks later. Some findings and specific results are shared in this paper. Additional analyses and results will be presented in future papers.

Hierarchical Model Building and Some Specific Results

Simulation has been criticized because of the heavy requirements for detailed input data and the length of time required to construct the initial model of the factory. In most simulation projects, it is a major effort to collect the input data in a software-compatible format. In some projects, people try to construct a perfect model. Such an absolute model requires painfully detailed input data and considerable time to build. In addition to its high cost, a major disadvantage to this approach is that "what-if" questions go unanswered during the model-construction time - usually many, many months. Additionally, very detailed models require very long computer run times, even if the question being asked could be answered with a much less detailed model. For example, a five-year capacity forecast does not require the same level of detail as a one-year production plan. An important consideration is that a "perfect answer" delivered after the meeting is of little help to the decision-maker.

We take a hierarchical approach to the simulation projects, building a factory model from the "top down":

1. As the team begins at each production site, we quickly build a model of the factory using available input data. The idea is to determine what data is immediately available, what additional data should be collected, and what is needed to properly format the data.
2. From this point the analyst works to create a characteristic curve showing the relationship between factory loading (start rate), cycle time, and cost per unit produced. For this analysis, the equipment set is held constant and the start rate is varied. An example of a characteristic curve for a wafer fab is shown in Figure 2. We then use the characteristic curve to validate model performance against actual fab information. This comparison highlights areas in which more detail is needed.



Validation:
- Fab data
- Sample Lots
- CT Contribution
- Fab Observation

Figure 2. Factory Characteristic Curve

3. Once a useable model is developed, we then use the modeling activity itself to drive the need for more detailed input data. The goal is to build a "good model" of the factory. "Good" is defined as the simplest model possible that provides information that is acceptable to management and is used as input to the decision-making process.

The idea of this process is to get a reasonable model in place as quickly as possible, and only add detail where it is really needed. In many cases, we are able to apply reasonable assumptions to capture the effect of a situation or practice, instead of collecting detailed data. For example, at this level it is not necessary to input the process qualifications of each operator in the furnace area. It is only important to realize that not all operators are trained at every operation and that often a furnace is idle because a qualified operator is not immediately available. This effect can easily be depicted in the model by assigning dedicated operator groups, resulting in a degree of "no operator" idle time that imitates the fab reality.

Only where a specific question being asked requires a more detailed answer do we make the model more detailed. This enables effective answers with a quick response time and eliminates the burden of supporting unnecessary data updates. For example, when we wanted to evaluate how changing personnel staffing levels would impact cycle time in a specific Siemens' factory, we required more detailed data. Figure 3 depicts the results of this analysis, showing the significance of operator staffing as factory loading is increased. The study quantifies the effect of operator constraints on cycle time for three different scenarios. Certainly, this particular analysis is sensitive to cross-training assumptions.

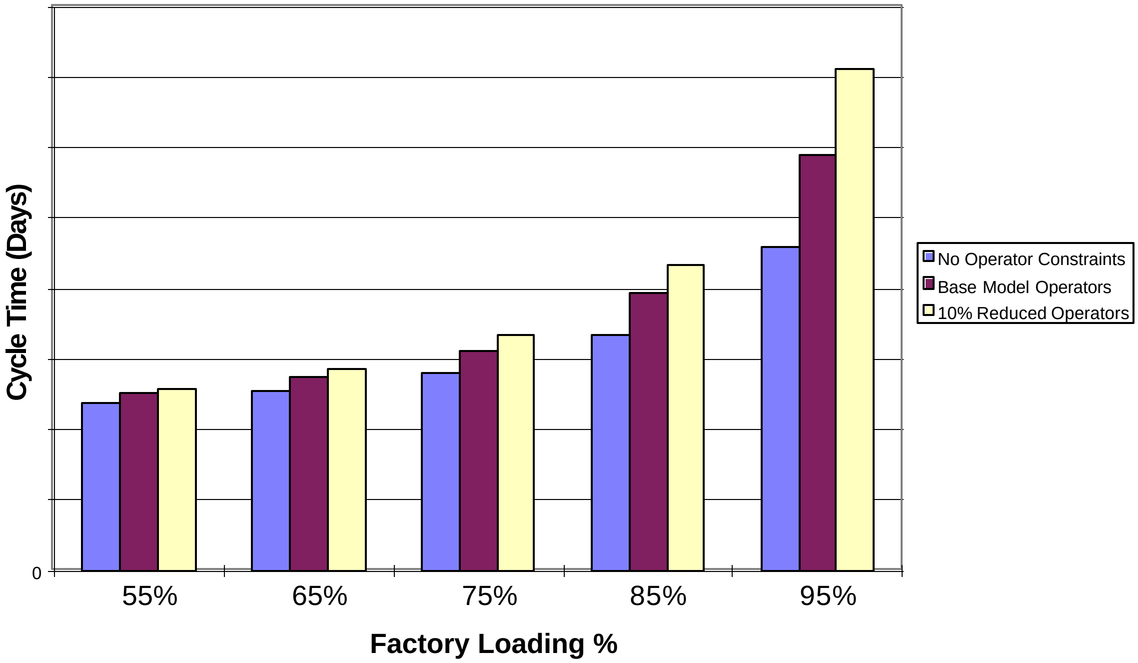


Figure 3. Sensitivity Analysis of Operator Constraints on Cycle Time

A more detailed analysis of this fab revealed several opportunities for possible productivity improvement:

1. implementing a strict setup avoidance policy at ion implantation.
2. relaxing the existing scenario for photolithography equipment dedication.
3. incorporating modifications to the Workstream dispatching rule when operating at high factory loading levels.

This gave an indication to management of areas where a change in the operating practices would have the greatest benefit in overall factory performance.

Figure 4 depicts the results of this case study. The first line (blue) is the current factory characteristic curve, assuming that all lots are processed according to the Workstream priority list. The second line (red) shows the advantage of implementing a strict setup avoidance rule in the implant area: capacity may be increased by almost 7% while maintaining current cycle time performance. A strict setup avoidance rule allows that a setup is done only if there are no lots waiting that match the current equipment setup. The third line (green) shows an additional benefit of more than 5% capacity potential by reducing the level of stepper dedication and by adjusting the WorkStream dispatch rules. This study also analyzed the 95th percentile of the cycle time and the variance of the cycle times and found that these changes lead to lower values in both measurements. So making the recommended changes should not only lead to better throughput, but also to a tighter distribution of cycle time and therefore better on-time delivery performance. Although the model may provide a "best case" improvement, such analysis certainly alerts management of areas in which to concentrate their efforts for manufacturing enhancements.

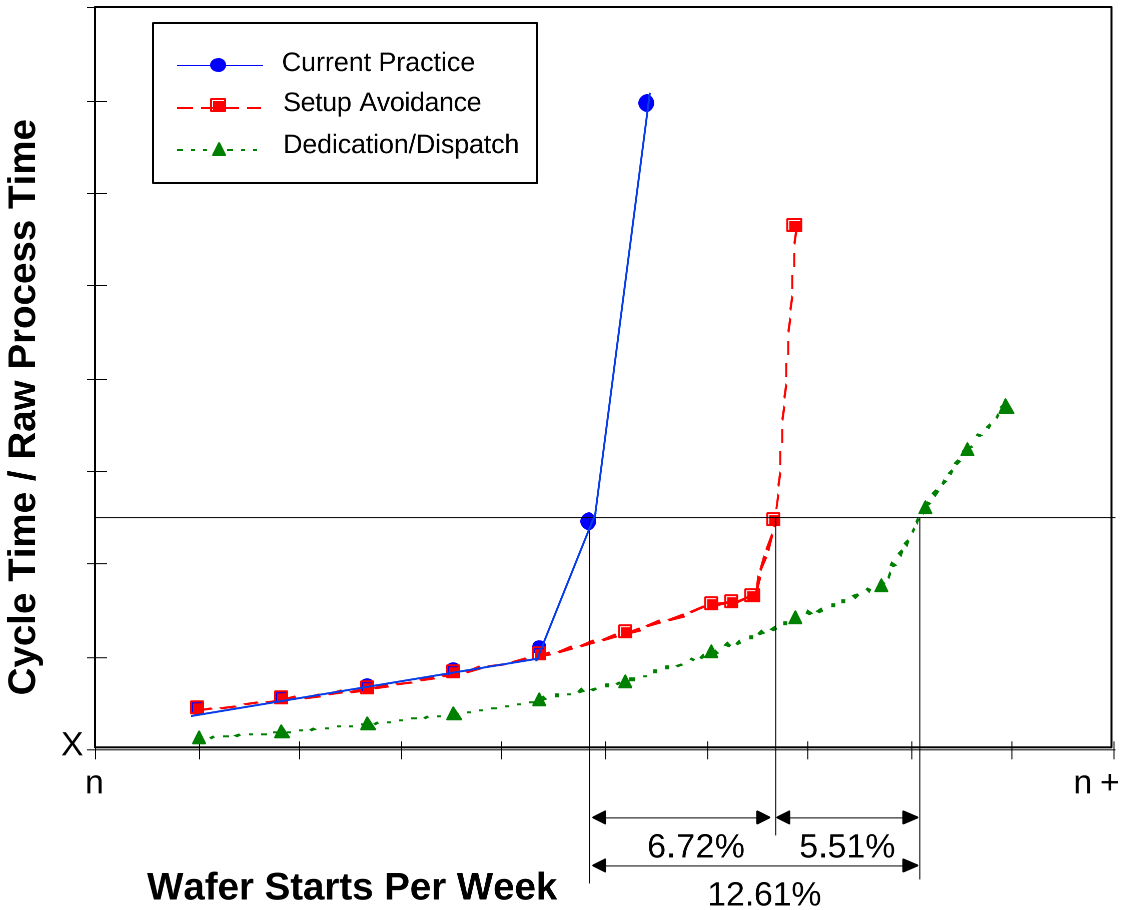


Figure 4. Potential Capacity Increases under Alternative Operating Practices

Additional Techniques for Quick Modeling

A common approach to simulation is to hire a technical analyst for the factory, evaluate available software capabilities, purchase the software, and begin to build the model. A major problem is the time and effort required to learn the software package and the initial difficulty of building an effective model. Many projects experience such severe problems that they are abandoned before they ever really get started. As a result, simulation software packages are sometimes criticized as ineffective before they are truly understood. Collecting and formatting the data is usually a very time-consuming part of the project, much more so than people expect it to be. Consequently, not enough time remains for the analysis portion.

An important part of the team's approach is to partner with outside consultants. Along with the software purchase order Siemens hires the developer, to assist with software training, data definition, data formatting, and validation of the initial model. "Ease of use" issues quickly disappear when the software developer is on the team. We also use technical experts from universities, consulting companies, and software firms as needed to assist detailed, timely analysis and case studies for specific factory questions. These individuals are able to bring lessons learned from past projects, helping Siemens to keep from experiencing the same problems, and significantly shortening the development process.

The authors have found that successful simulation projects are very dependent upon effective project specifications that begin with a clear understanding of goals, expectations, milestones, and output. We cannot overemphasize the importance of an effective kick-off meeting that defines a clear and consistent written specification. The project manager must keep this specification updated and must distribute it frequently to the project team to assist effective coordination of assignments.

Concluding Remarks

This simulation project will conduct detailed analyses and case studies as the implementation program spreads across Siemens' semiconductor factories. In addition, we will coordinate with projects involving data management, static modeling, production planning, and supply chain management. Results from additional studies and updates on interesting tasks will be regularly communicated through conference presentations and discussion papers such as this. We hope that others will share similar experiences. The authors welcome discussion with others interested in factory management topics. Readers are encouraged to contact any of us.

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Biographies

Steven Brown is the project manager of Factory Modeling and Simulation for Infineon Technologies (formerly Siemens Semiconductor Division). He has thirty years of management experience in various industries, including more than twenty years in semiconductor manufacturing. He has worked in fab production management for Mostek, National Semiconductor, Honeywell, General Instrument, Cypress Semiconductor, and Motorola. Since 1993, Steven has been actively involved in semiconductor manufacturing simulation projects, first at SEMATECH and now at Infineon. Prior to his work in the semiconductor industry, he served six years as an Army medical evacuation helicopter pilot and flight team leader. His formal education includes Bachelor of Science and Master of Science degrees in Business Management. His primary area of interest is in the performance analysis of existing semiconductor factories.

Frank Chance is a specialist in the operational analysis of complex manufacturing facilities. He is the author of Factory Explorer®, an integrated capacity, cost, and simulation analysis tool. He is president and co-founder of FabTime Inc, a provider of wafer fab cycle time reduction software and services. His clients in the semiconductor industry have included Seagate, Siemens, Headway, and IBM. Frank holds MS and Ph.D. degrees in Operations Research from Cornell University. He has taught at Cornell University and was a visiting assistant professor at the University of California, Berkeley, prior to founding FabTime.

John W. Fowler is an Assistant Professor in the Industrial Engineering Department at Arizona State University. Prior to his current position, he was a Senior Member of Technical Staff in the Modeling, CAD, and Statistical Methods Division of SEMATECH. He received his Ph.D. in Industrial Engineering from Texas A&M University and spent the last 1.5 years of his doctoral studies as an intern at Advanced Micro Devices. His research interests include modeling, analysis, and control of manufacturing (especially semiconductor) systems. John is the co-director of the Modeling and Analysis of Semiconductor Manufacturing Laboratory at ASU. The lab currently has research contracts with NSF, SRC, SEMATECH, Intel, Motorola, Siemens, SGS Thomson, and Tefen, Ltd. He is also an Associate Editor of IEEE Transactions on Components, Packaging, and Manufacturing Technology Part C: Manufacturing and on the Editorial Board for IIE Transactions on Scheduling and Logistics. He is a member of ASEE, IIE, IEEE, INFORMS, POMS, and SCS.

Jennifer Robinson is co-founder and chief operating officer of FabTime Inc., a provider of wafer fab cycle time reduction software and services. Previously, she worked as an independent consultant in semiconductor manufacturing. Her clients in that industry have included SEMATECH, Digital Equipment Corporation, Seagate Technology, and Siemens AG. Jennifer holds a B.S. (1989) degree in civil engineering from Duke University and an M.S. (1992) degree in Operations Research from the University of Texas at Austin, and a Ph.D. degree in Industrial Engineering from the University of Massachusetts at Amherst (1998). Her research interests center on factory productivity measurement and improvement.

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