Proceedings of the 2000 Winter Simulation Conference
J. A. Joines, R. R. Barton, K. Kang, and P. A. Fishwick, eds.

SIMULATION BASED DECISION SUPPORT FOR FUTURE 300MM AUTOMATED MATERIAL HANDLING

Mathias Schulz
Timothy D. Stanley

SEMICONDUCTOR300
P.O. Box 10 09 46
D – 01079 Dresden, GERMANY

Bernhard Renelt

Infineon Technologies Dresden
Königsbrücker Strasse 180
D - 01099 Dresden, GERMANY

Roland Sturm
Oliver Schwertschlager

Fraunhofer Institute Manufacturing Engineering and Automation (FhG - IPA)
Nobelstrasse 12
D – 70569 Stuttgart, GERMANY

ABSTRACT

Integrated factory models of semiconductor fabrication facilities allow conclusions to be drawn on the impact of a given Automated Material Handling System (AMHS) and interactions between material flow and factory performance. A generic model of a 300mm wafer fabrication facility has been built to support decisions to be made in terms of dimensioning of the potential AMHS solutions.

1 INTRODUCTION

Factory productivity is the most important focus item that the 300mm transition must address. The technological solution to increasing productivity while addressing the economic issues is to provide an increase in factory automation both in wafer and carrier handling (Ghatalia 1999). It has been widely discussed in recent years that fab wide automated lot transportation including direct tool loading bears a high potential for improved factory productivity. But there are still no final answers on what transportation concept might be best to meet chip manufacturers needs. The so called “zero footprint automation” has attracted the interst of fab planners as clean room size represents a major part of investment and running costs for a semiconductor fabrication facility. Both monorail/hoist systems and overhead conveyors belong to the currently considered and most advanced solutions.

2 SIMULATION FOR WAFER FAB PLANNING

When planning a factory one typically uses discrete event simulation with two different levels of detail. In a first step, a dynamic model needs to be built in order to analyze the required capacities of the processing tools. This capacity analysis provides the input required to design a factory layout. But we have to note that these calculated capacities and tool counts neglect the impact that lot transportation and storage may have on the overall factory performance. This means that the model assumption either has no time delay at all for lot transfer between different locations, or if time delay is used, no limited resource needs to be dedicated for transportation and hence will never become a bottleneck.

To avoid this shortfall, as a second step more detailed models will be built. Because of model complexity and high computation times (e.g. 24 hours computing time for 1 year simulated time) the common approach was to split up the model into its subsystems and analyze them seperately. However, the drawback of this will be the loss of an overall picture on interactions that occure between different components outside the boundaries of these submodels. Therefore, despite the system complexity caused by several hundred processing tools in the layout and a re-entrant process flow it is considered a worthwhile approach to model and simulate the whole system with an increased level of detail.

3 INTEGRATED MODELING APPROACH

As we felt that a single integrated model offers a better opportunity to understand interactions between the different areas and components of the system, we decided to develop a model consisting both of the equipment model and the material handling system. A similar approach had been used and described by Sturm et al. (1999) or Wright (1999).

3.1 Model Structure

A base model was developed using AutoSched™/ AutoMod™ (6.0/9.0) by AutoSimulations™ Inc. that includes the material handling components for lot transportation between bays and tools. The system was designed to run a weekly production of 5000 WSPW (wafer starts per week). For automated material handling in this generic model a combination of conveyor (interbay) and monorail/ hoist systems (intrabay) was chosen. On the shop floor of the generic fab are several hundred tools distributed over a number of functional areas with FOUP stockers in each intrabay system. The intrabay automation assumes direct tool loading using monorail hoist vehicles. The link between interbay and intrabay transportation was done in the traditional way via the bay stocker as shown in Figure 1.

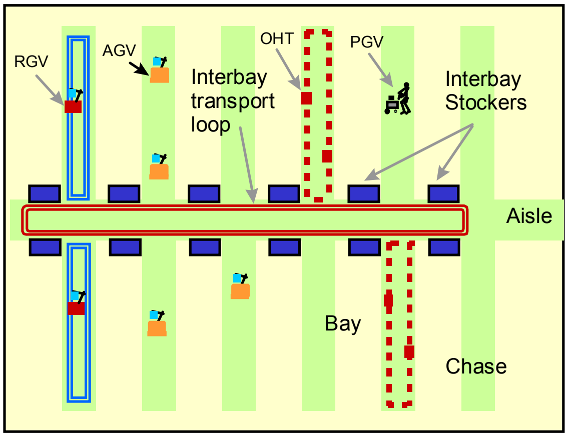

Figure 1: Schematic Layout of a Semiconductor Fabricator with different Options for Material Handling (AGV – Automated Guided Vehicle, PGV – Person Guided Vehicle, RGV – Rail Guided Vehicle, OHT – Overhead Hoist Transport)

3.2 Pros and Cons of the Integrated Approach

The aim of building an integrated simulation model was to analyze the interaction effects of process equipment and the automation solution. In this context, the dimensioning of the stockers, the number and capacity of the load ports and their impact to the performance of the processing equipment and vice versa was of interest. This in turn requires the modeling of the exact behavior of the system components along with their typical operating procedures.

During the modeling work it became clear that the communication of AutoSched features used for process equipment modeling and AutoMod features used for modeling material handling systems, is a major concern. For instance, it is not possible to model alternative transport routes (called itineraries) between two process steps in the current version of the simulation software without going to extensive customizing work. Therefore, the modeling of parallel stockers connected to the same bay was avoided for this study. Moreover, the routing of lots to different bays which belong to the same process area (e.g. furnace area) is an unsolved problem using the integrated AutoSched/AutoMod approach. Hence, the assignment of parallel processing equipment (stations belonging to the same family) to different bays was also avoided due to the difficulty of modeling alternative transport routes.

For the modeling of the bay stockers, the rack master is modeled as a movement system in AutoMod. The stocker ports were modeled as queues with limited capacity defined in the process system of AutoSched as connection to the interbay and intrabay movement systems. The stocker storage itself was modeled as storage queue with unlimited capacity. However, the operating policies of movement systems in AutoMod are not able to consider the state of the queues (load port status) in AutoSched. This may cause congestion or even deadlocks caused by occupied load ports as depicted in Figure 2.

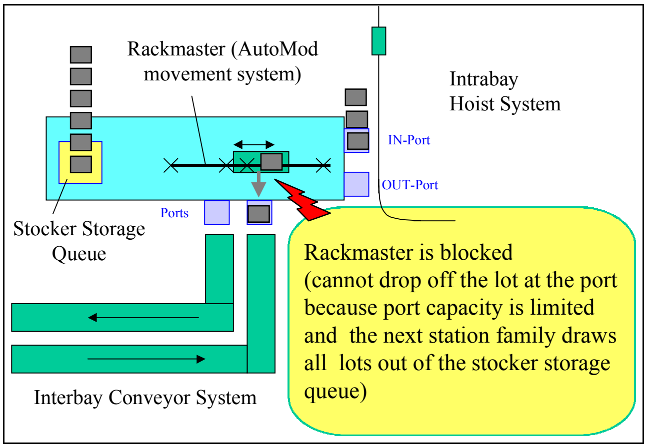

Figure 2: Modeling of Stockers and Risk of Congestion due to Limited Port Capacities

Furthermore, the configuration of the intrabay hoist systems is problematic. Standard work and park lists provided in the path mover system of AutoMod are insufficient to control the hoist system, especially when two or more hoist vehicles are foreseen. Thus, vehicle bumping and correct transport job selection, even in the current version of AutoMod (v. 9.0) is not easy to handle and requires a lot of customizing effort.

The advantage of the integrated modeling approach is that once a modular set of transport routes (itineraries) is defined, the respective itinerary information can be attached easily to the process flow data sheet defined in AutoSched. Consequently, when process flows are changed later on, which happens frequently during a fab planning project, the simulation model can be updated easily with a new routing using the previously defined itineraries. The attachment of the itineraries to the process steps in the routing file can even be accelerated using database queries.

The experimentation work with the integrated AMHS model has shown that stockers are key elements for the lot transportation. The configuration of the stocker parameters such as handling speed, load port capacity and operating policies have a tremendous effect to the overall performance and stability of the simulation run. Therefore, the sensitivity of the stocker configuration parameters to the model stability are supposed to have a much higher effect than configuration parameters of the interbay and intrabay transportation systems.

4 UTILIZATION ANALYSIS OF INTERBAY CONVEYOR TRANSPORTATION SYSTEM

There are many pros and cons for using continuous transportation means such as conveyors or discrete vehicle solutions. The most important reason in favor to deploying conveyor type systems is their capability to act both as a means of storage and transportation at the same time. Therefore, one could potentially reduce the number of stockers needed in a fab when using conveyors. Conveyors are also well known for their characteristic to cope with peak loads and to decouple the subsystems they are connecting. The question is whether these features are really a general benefit for semiconductor manufacturing compared to vehicle based solutions. To understand these implications, several experiments were made. The quantitative pictures observed for the two scenarios were confirmed during multiple replications.

The information collected from these experiments showed the utilization of the storage capacity of the inter-bay conveyor system. Surprisingly in the case of a stable system with sufficient tool capacities the average WIP traveling on the conveyor was much lower than expected.

4.1 Scenario A: Stockers Causing Bottlenecks

In a first scenario, several high throughput bays were equipped with only one stocker. Here the stocker handling cycle time appeared to be critical and made these stockers become the bottleneck. Lots were delayed by the stocker when trying to leave the conveyor and enter the intrabay stocker.

But the conveyor was not able to compensate the bottleneck caused by the bay stockers. The total WIP kept growing without reaching a steady state, regardless of the dynamic buffering capability of the transportation system. Figure 3 shows the WIP curve for this scenario.

These data were collected during a period of 25 days with 1 observation every 12 hours, after an initial run time of 20 days. As it can be seen in Figure 3, total WIP kept growing during that time with the system finally collapsing.

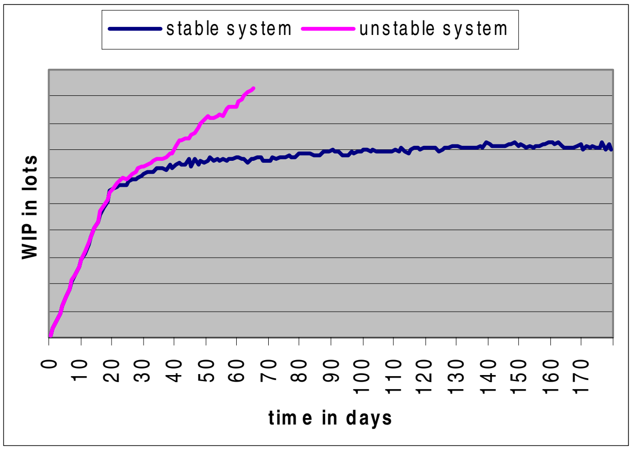

Figure 3: WIP Graphs of the Stable Factory Model with Little Conveyor Utilization Compared to Unstable System with Bottlenecks

The histogram in Figure 4 shows the number of lots observed on the conveyor while running the not-fully stable system. Because of some stockers causing bottlenecks, the storage capacity of the conveyor utilized by moving lots is obviously higher than would be the case if running a stable system with a more continuous material flow. The histogram shows 8 classes, beginning with 30 lots as upper boundary, followed by 30 to 40 lots, and so on. Most of the 50 observations were made in the class from 70 to 80 lots.

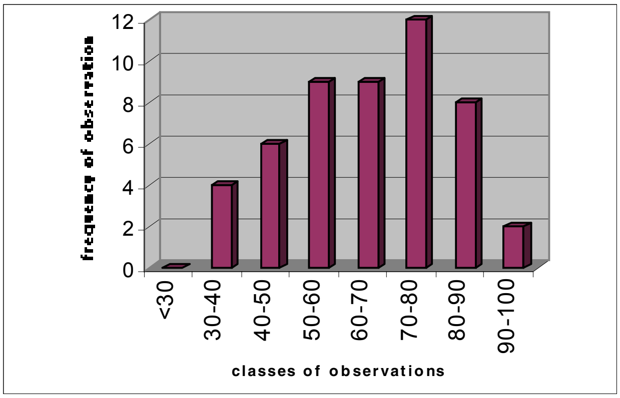

Figure 4: Histogram Showing the Number of Lots Present on the Conveyor in an Instant when Running a System not Perfectly Balanced.

It would have been an obvious conclusion that while the total WIP increases the number of lots buffered on the conveyor would go up as well. But the simulation showed an unexpected result. While the WIP rose by approx. 200 lots, an increased utilization of the storage capacity offered by the conveyor could not be observed. The storage capability was only utilized temporarily, as it can be seen from the cyclic graph in Figure 5.

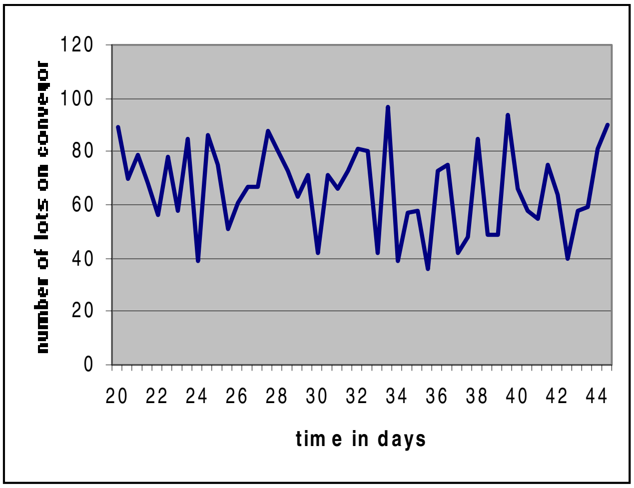

Figure 5: Observation of Number of Lots on Conveyor Over a 25 Day Period

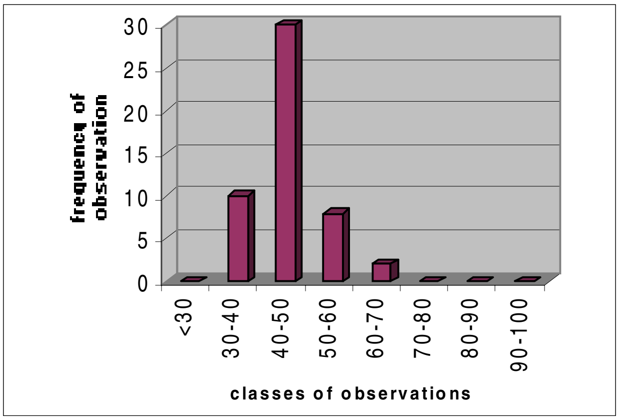

Figure 6: Histogram Showing the Number of Lots Present on the Conveyor in an Instant when Simulating a Stable System

4.2 Scenario B: Observations from a Stable System

In order to get a picture of the conveyor utilization in a stable and balanced system, the handling speed of the critical stockers was increased. Having removed the bottleneck this way, after a transient phase the system reached steady state in terms of WIP and cycle time. The data were collected after a warm up period of 40 days. At this point the WIP curve indicated the end of the transient phase. For the subsequent 50 days a snapshot of the conveyor utilization was taken every 24 hours.

In the case of this stable system, the average number of lots on the conveyor went down. Having removed the bottlenecks caused by the stockers, the system became stable without claiming a considerable part of the storage capacity offered by the interbay conveyor system. Not more than 70 lots were observed on the conveyor. By far the most observations were made for the range between 40 and 50 lots traveling on the conveyor.

5 CONCLUSIONS

The main conclusion of these experiments is the fact that although a conveyor system offers a much better capability to cope with peak load situations, the number of lots located on the conveyor interbay system is only slightly higher than it would be for the case when using an AMHS with discrete vehicle characteristics. Therefore it is not considered a realistic expectation that the usage of conveyors would allow a dramatic reduction in the number of stockers in a semiconductor fab. The feature of a conveyor system to better cope with high peak load factors is unlikely to add a serious benefit, as stockers building the bridge between interbay and intrabay offer a decoupling effect, also. Certainly there is potential benefit from introducing conveyor systems in semiconductor manufacturing, but this might require new concepts for fab layout design and operation. A traditional layout and transportation concept with seperation between interbay and intrabay AMHS does not seem to be the best approach to utilize the potential benefits of conveyor systems.

ACKNOWLEDGMENTS

The technical material discussed in this paper was accomplished with the support of the German Federal Research and Technology Department from Grant number 01M2992. The responsiblity for the technical content and layout of this publication is solely the authors.

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AUTHOR BIOGRAPHIES

MATHIAS SCHULZ is a System Specialist working in the Automation/CIM Group at SEMICONDUCTOR**300,** a joint venture between Infineon Technologies and Motorola. He has 3 years of experience in the semiconductor industry including 6 months at International SEMATECH in Austin/Texas, an international consortion of leading semiconductor manufacturers. His working areas include Automated Material Handling Systems, and Factory Modeling, Simulation and Analysis. Mathias Schulz holds a Ph.D. and a graduate degree in engineering from Technical University Dresden. He is a member of ASIM. His email address is `<mathias.schulz@sc300.de>`.

TIMOTHY D. STANLEY is a Project Manager responsible for Factory Cost Analysis, Dynamic Simulation and Logistical Analysis for SEMICONDUCTOR**300**, a Motorola/Infineon joint venture with the World's First 300mm Pilot Line which is located in Dresden, Germany. He has been a Motorola employee since Feb 1995 in 300mm Technology Development and part of the SEMATECH start up and Project manager in their Future Factory Team. Before that he served as an Officer in the US Military for 20 years with responsibilities in Microelectronic technology development retiring as a Lieutenant Colonel in July 1991. Tim Stanley holds a Ph.D. in Electrical Engineering from the University of New Mexico as well as MS. degrees in Nuclear Engineering from the Air Force Institute of Technology and Economics at South Dakota State University and a BS in Physics from Brigham Young University. His email address is `<Tim.Stanley@sc300.de>`.

BERNHARD RENELT studied Business Administration at Technical University Dresden and received his graduate degree in 1984. From 1984 to 1991 he worked in R&D planning at Zentrum Mikroelectronic Dresden (ZMD). Since 1991 he has been with Siemens and since 1995 with Infineon Technologies in Dresden, formerly Siemens Semiconductor. Bernhard Renelt is currently responsible for simulation activities related to factory planning for 300 mm wafer fabrication. His email address is `<Bernhard.Renelt@infineon.com>`.

ROLAND STURM obtained his diploma degree in Production Engineering at the University of Erlangen in 1996. Since 1997 he has been a scientist at the Fraunhofer Institute of Manufacturing Engineering and Automation (IPA) in the Department of Cleanroom Manufacturing. He works in several industrial and research projects in the field of information technology, enterprise logistic concepts as well as factory modeling and simulation for semiconductor and microelectronics industry. Before joining Fraunhofer Institute IPA he worked as a scientist at the Institute of Manufacturing Automation and Production Systems, University of Erlangen in the area of electronics assembly. For further information please contact `<rgs@ipa.fhg.de>`.

OLIVER SCHWERTSCHLAGER obtained his diploma degree in Mechatronic Engineering at the University of Applied Sciences, Esslingen, in 1999. Since 1998 he is a scientist at the Fraunhofer Society, Institute of Manufacturing Engineering and Automation (IPA) in the Department of Cleanroom Manufacturing. His working fields are the development of automation, logistic concepts and simulation models. For further information please contact `<schwertschlager@ipa.fhg.de>`.