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EFFECTIVE SIMULATION MODEL REUSE: A CASE STUDY FOR AMHS MODELING

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ABSTRACT

The application of simulation as a performance estimation tool in automated material handling system design is well documented, as is the amount of time required to build, debug, and analyze a typical AMHS simulation model. In the rapid growth, high technology industry it is infeasible to continually employ sufficient staff to create unique models of all of the possible scenarios that require examination. Typically the model is not complete before the project requirements have been modified. An alternative to unique model creation is to reuse an existing generic model. Generic models are similar to a group of software tools called simulators; software packages that contain a pre-programmed model. Investigation has indicated that a special purpose reusable generic model, designed to address the set of issues faced by a specific commercial entity, is efficient and necessary for fast model turnaround. If correctly developed, the generic model could be reused, thereby reducing model building time as well as increasing simulation accuracy. This paper discusses the use of such a model and illustrates the improvement to model build cycle time.

1 INTRODUCTION

Two of the important criteria considered by customers of automated material handling systems (AMHS) in the selection of an equipment supplier are the overall quality of the AMHS designs proposed by the competing vendors, as measured by how well the designs meet customer-specified performance requirements, and the costs of the vendors' equipment sets. To remain viable business entities, AMHS vendors must successfully bid on and capture a sufficiently large enough number of projects to maintain profit margins acceptable to stockholders. This means that AMHS vendors must develop the capability for quick turnaround of high volumes of design projects, the objective of which is to develop low cost, high performance solutions to customers' requirements. The iterative nature of the AMHS design process – initial design, customer review, modified design, customer review, etc. – demands that the modeling tools used must be highly flexible, so that customers' changes can be quickly and easily incorporated in model revisions.

Quick turnaround of high volumes of design projects is incompatible with creating individual models for all the possible design scenarios which have to be examined, and the staffing levels which would have to be employed to support such large numbers of models. An attractive alternative to unique model creation is to reuse a small family of models which can be easily configured for individual projects through flexible interfaces. Simulators are such tools: software packages that contain pre-programmed models which can be populated with data pertinent to individual applications. For simulators to be competitive as modeling tools in fast turnaround, high volume environments, the core model must be accurate, flexible, and reusable. One concept is to employ a special purpose reusable model which is designed to be quickly configured within specific applications' domains. Reuse of a core simulation model also increases the accuracy of the modeling, since the construction of the core model is consistently repeated. This forces capturing of the differences among projects through the configuration of the model to represent each individual project as an extension of the core construction. The speed and reliability of special purpose reusable models make them the ultimate form of simulation model reuse.

2 BACKGROUND

Simulation is an established performance estimation tool in AMHS design (Colvin et al. 1997, Mackulak, Colvin and Sokhan-Sanj 1997), and the amount of time required to build, debug, and analyze a typical AMHS simulation model has been reported (Cochran, Manathkar and Mackulak 1993, Cochran, Mackulak and Savory 1995, Mackulak, Savory and Cochran 1994). The competitive pressures for quick turnarounds of high volumes of AMHS design projects mandate the use of special purpose reusable simulation models to reduce model building time and increase model accuracy. These pressures are severe in the semiconductor manufacturing AMHS sector, because of the rapid growth, high technology nature of the semiconductor manufacturing industry.

Any simulation model written contains some level of abstraction (Law and Kelton 1991, Pegden, Shannon and Sadowski 1995, Pritsker 1986). Model builders learn through experience that the cost of modeling is minimized when only the appropriate level of detail is included. Textbooks state the somewhat obvious fact that a good model contains only the "necessary" detail. The problem facing the inexperienced modeler is the determination of this "necessary" level of detail. If too little detail is included the accuracy of the model suffers, yet if too much detail is included the cost of the model increases.

Research has been conducted that attempts to address this issue for novice model builders (Mackulak and Cochran 1990, Ozdemirel and Mackulak 1993, Savory and Mackulak 1996, Savory, Mackulak and Cochran 1994). The generic/specific concept investigates the ability to define models that would be applicable to a wide range of situations, yet are only detailed enough to accurately represent the system being studied. The generic/specific concept is of particular value to situations where the same basic model type is used to evaluate many diverse yet fundamentally identical systems (Ozdemirel, Mackulak and Cochran 1993).

A model is identified as generic when it is applicable over some large set of systems, yet sufficiently accurate to distinguish between critical performance criteria. The model becomes specific when the data for a particular system is loaded (i.e. part types, equipment, process times, yields). This is similar to the approach used in some of the early software packages called "simulators" such as Pro Model, Witness and SimFactory. These early packages contained what could be termed a generic manufacturing model that became specific when the model builder populated the model through the user interface.

The general problem with the implementation of such an approach is the design and creation of a usable generic model (Lung et al. 1994). Figure 1 illustrates the increase of model complexity against the projected desired response time. As illustrated, model complexity is growing rapidly, while the expected response time is required to continually decrease. Response time reductions are necessitated by cost and responsiveness requirements.

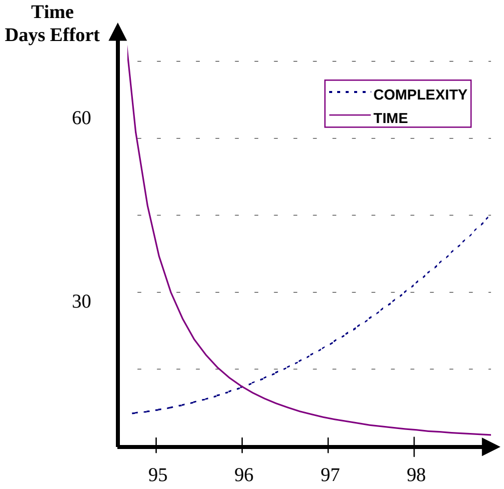

Figure 1. Model Complexity and Time to Build.

The concepts behind creation of a generic/specific model were tested on the IntelliSim project (Mackulak 1993). Researchers gathered information on the application of generic/specific modeling from over 135 respondents. Results from this study indicated that model building, model formulation and model translation absorbed approximately 45% of a project's effort, yet the available computer assistance for these tasks was under 20%. Prior research has thus indicated that there is a need for generic/reusable models if they are properly structured to provide sufficient accuracy and computer assistance. Their primary advantages are that they eliminate major portions of the up-front model design process, they are bug free, they have been code optimized for fast run times, and they can be consistently applied throughout the corporation.

3 MODEL DEVELOPMENT

PRI Automation, Inc. is a supplier of AMHS equipment for clean room operations in the semiconductor manufacturing industry. The Automation Planning and Design group within PRI Automation develops better than one AMHS design solution on average every week. Few solutions consist of only a single layout equipment set. In many instances similar designs prove to have very different performance profiles. The only way to predict the performance differences of these systems is to perform a discrete event simulation study.

Building a new simulation model every week would not only be expensive, but almost impossible due to the response time required by customers. If the marketing team had to wait for the normal 12-14 week model analysis cycle time, it is unlikely that the customer's requirements would be the same as when the project started. What is needed is a way to reuse a small number of existing simulation models by reconfiguring them with data specific to each customer's alternative designs.

3.1 The Components

The process of creating a design solution for AMHS begins with a layout diagram (Figure 2). The layout is developed by an AMHS design engineer, who attempts to provide an equipment set and a vehicle transporter movement path that meets desired performance objectives while minimizing cost. This design is translated from CAD into IGES format so that it can be directly input to the simulation model. Accurate model representation is dependent on both the physical system and logical system components. The generic model component is the vehicle routing logic, while the specific components are the paths over which the material must be moved in this scenario.

The elements that typically comprise an AMHS can be rendered in a relatively homogenous fashion from one simulation project to the next. However, the configuration and quantity of these elements with respect to different layouts can be highly diverse. AMH systems range in size and complexity from simple, low volume loop or "racetrack" configurations to elaborate, multi-level systems that can span several fab facilities. Table 1 illustrates the broad spectrum of equipment and operational requirements that are frequently encountered when preparing these simulations.

Model accuracy requirements dictate that these detailed operating characteristics be included in the generic formulation, while model building time restrictions necessitate that the method for inclusion be simple and efficient. Implementation of reusable models therefore, involves the use of spreadsheets for data input and macros for post processing report generation.

	Min	Max	Mean	Std Dev
Number of cars	2	120	42	26
Track length	110	3195	1567	789
Number of turntables	0	27	10	6
Number of 180 degree turns	0	27	4	4
Number of 90 degree turns	2	130	21	19
Number of 45 degree turns	0	90	24	19
Number of stockers	2	55	22	12
Length of layout	55	650	344	122
Width of layout	19	400	136	108
Interbay moves / hour	5	851	293	193

	Pct.
Multi-level layouts	0.32
Dual stocker transfers	0.20
Center aisle configuration	0.43
Distributed track configuration	0.33
Spur configuration	0.24

Table 1. Range of Simulation Components.

3.2 Validation

The concept of model validation is of extreme importance in any environment, especially an environment that proposes to use the same model numerous times. If a model has been incorrectly validated the error will be amplified through reuse. The approach used for validation is a direct result of the type of model constructed. Since the model being reused is a model of an AMHS, validation is tantamount to assuring that model logic performs identically to the control logic of an actual material handling system.

If a model were designed to represent a production process it would need to consider the logic associated with process tools, scheduling, down time, batching, and a host of other variables. This model is only designed for prediction of the AMHS performance parameters subject to a predetermined movement load. The AMHS system can therefore be divorced from the production model if an appropriate load interface can be assumed. The data interface used to drive this model is the area to area average hourly from/to movement requirements.

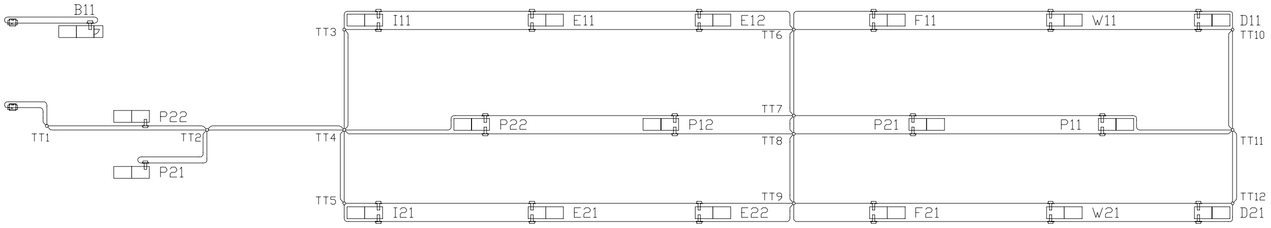

Figure 2. A Generic Facility Layout.

The model would easily be proven valid if the movement logic in the model identically mimicked the logic in an actual system. In fact, this is the approach used in this project. Close cooperation with the software controls group allowed the base model to be constructed with the <u>same</u> code used to control the actual system. Physical system parameters unique to each layout design are installed on top of this control code. Since the code in the model is the <u>same</u> as what would be installed in the actual system, the model executes identically to the real system. This has been verified through comparison of model output to actual implementations. In fact, the software control group uses this same model for the development and testing of new AMHS control strategies.

The only remaining validation issue pertains to whether the movement levels and timings driving the model are consistent with those experienced in an actual system. Unfortunately, the highly competitive nature of semiconductor manufacturing makes such a validation impossible. Manufacturers are reluctant to divulge any information on scheduling or sequencing for fear of losing a competitive advantage. Validation in this sense can only assure that the model represents a facility operating in steady state, independent of surge processing techniques.

4 RESULTS OF IMPLEMENTATION

Simulation model reusability has resulted in an order of magnitude improvement in AMHS design project turnaround time. Model building and analysis time has been reduced from over six weeks to under one week. A sustained rate of 4.5 projects per month has been achieved and maintained. Based on an average of 22 working days per month, this has resulted in an average of 4.9 day turnaround per AMHS design project.

Although customers and management increasingly demand quantitative characterization of the performance of AMHS designs, simulation animation remains an attractive tool for both marketing of final designs as well as visual identification of operational behaviors of preliminary designs (Figure 3). Congested track segments and bunching (queuing) of transporter vehicles due to the "gate effect" of equipment which is operating too slowly to keep up with vehicle traffic are easily seen in AMHS design simulations. When the transporter vehicles are color coded to indicate status (moving empty to an assigned pick up, moving loaded to an assigned delivery, moving empty to a charging station, charging, etc.), undesirable vehicle movement patterns, which would otherwise not be visible in summary statistics (cyclic behavior) can also be recognized. AMHS simulation animations in preset run formats can be automatically generated through the use of script and camera location files with the underlying simulation engine.

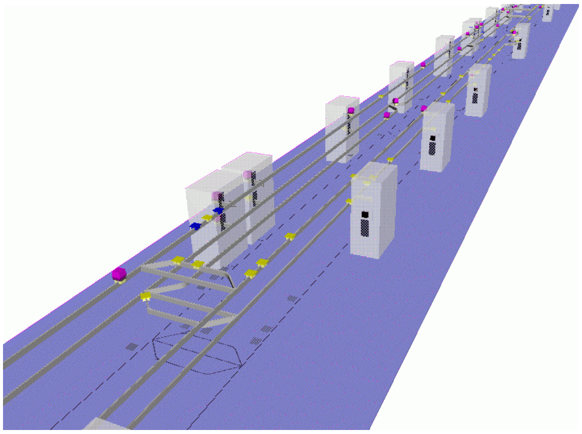

Figure 3. AMHS Simulation Animation.

To automate post processing report generation, macros have been written to extract output data from the simulation summary reports and reformat the data into custom summary graphs and tables (Sokhan-Sanj et al. 1998). Delivery and transport time distributions for transporter vehicles and the utilizations of AMHS components (stocker robots, turntable [node] crossings, transporter vehicle loading and unloading/moving to charge/charging, et al.) are examples of customized output, which are included in technical reports and presentations to AMHS customers (Figures 4 and 5). To insure statistical correctness of simulation results, autocorrelation analyses are performed, although these are typically not discussed with customers.

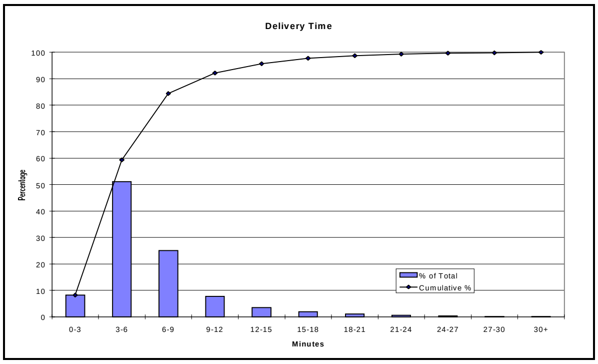

Figure 4. Delivery Time Distribution.

5 CONCLUSIONS

The rapid model build-and-analysis cycle time required in the semiconductor AMHS supply environment necessitates that each new simulation study be conducted with reuse of an existing simulation model. It would not be possible to evaluate all the AMHS design alternatives which must be

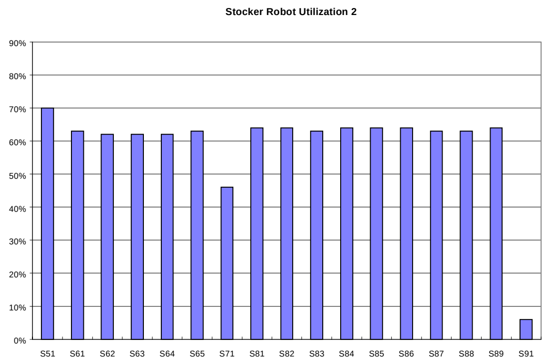

Figure 5. Stocker Utilization.

considered for each project, if every simulation model had to be created from scratch. It has been shown that a generic model can be constructed to meet the needs of reuse for a situation with a reasonably small set of unique components. When properly constructed this special purpose reusable model can be more accurate and efficient than new models individually constructed for each application's scenario. Additionally, it has been shown that software utilities for controlling data input for model reconfiguration and post processing report generation can be reused.

Applying this approach to AMHS model building and analysis has reduced the design project turnaround by an order of magnitude. The initial model construction and debug effort, although expensive, is easily justified in an environment like semiconductor AMHS design, where similar models must regularly be constructed in short periods of time.

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