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AUTOMATIC MODEL GENERATION

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Abstract

The Facility Analysis and Simulation Technique (FAST) is a product which has been developed by the Electronics Automation Application Center (EAAC) of the General Electric Company. Currently in version 2.0, FAST has been developed to analyze electronics facilities resource requirements by utilizing years of EAAC expertise in this environment. The part of FAST which is discussed in this paper is the use of the SIMAN model generator. This part of FAST produces complete SIMAN models and allows various configurations. There are two primary benefits of the automatic model generator. First, that the modeling task can concentrate on collecting and verifying the data instead of spending large amounts of time validating simulation code. Second, good models are constructed with no SIMAN programming. The primary aim of this paper is to introduce the reader to FAST and then go into greater detail in explaining the automatic model generator of FAST.

1. The Emphasis of FAST 2.0

After several electronics facility designs, it became apparent to EAAC consultants that the facility design task is a data driven task. The original version of FAST was primarily intended to address the diverse methods of data collection and analysis that had been used in different consulting projects. Because of this initial emphasis of collecting complete data and keeping data integrity, the relationships that exist in the FAST data base are well defined. This data base drives the calculation phase of FAST which determines the resource requirements for a given facility under certain conditions.

FAST defines the factory by defining four different areas and their relationships to each other. FAST models consist of parts, process areas, stockrooms and material handling systems. A "part" in FAST is a group of like parts that have roughly the same bill-of-material, the same routing, and are approximately the same size and weight. For example, LARGE RESISTORS may be a part in FAST. As part of the data collection, an input for LARGE RESISTORS would be how many actual part numbers are included in LARGE RESISTORS. By grouping parts in this fashion, FAST is able to model the facility without the great detail of an MRP system.

"Process areas" in FAST are areas of the factory which do the same type of work with similar equipment. The way the user defines processes greatly depends on the amount of detail that the user wants to see in his output. Two of the most important numbers that come out of FAST calculations are required headcount and required number of machines for each process. If the user is not really concerned with how many radial machines and how many axial machines are required, he can define a process area called AUTO INSERTION. If the user really must know the requirements for radial insertion separate from axial insertion, he should define two separate processes called AXIAL INSERTION and RADIAL INSERTION.

"Stockrooms" in FAST are places in the factory where material is stocked after it is processed, or after it is received. For each stockroom the user can define up to ten carriers. These carriers can be totes, trays, racks, or any other mechanism that is used to hold the material in the stockroom. There are only two critical factors in defining a stockroom correctly in FAST. First, each stockroom has only one stocking device type (i.e. horizontal carousel, shelves, etc.). This may constitute splitting a physical stockroom into several FAST stockrooms. Second, each part is assigned to only one stockroom. The philosophy behind this is that when a part is finished processing, it can be stocked in only one location.

"Material Handling Systems" in FAST are those mechanisms in the factory which move a part from one process in the routing to the next process in the routing. Like stockrooms, the user defines up to ten carriers that are used in the material handling system. The use of material handling systems in FAST are defined in the part routings. In each step of the routing, the user can specify which material handling system and which carrier type in the material handling system was used in transporting the part to that process in the routing.

By correctly defining these four areas of the factory, the FAST user can determine the requirements to run the factory. FAST calculates requirements such as headcount, machines, stockroom size, material handling system size, stockroom transactions, material handling system transactions, and inventory levels. Also, the user can

Figure 1 : FAST Main Menu

determine the areas of his factory which contribute to high labor content, high inventory levels, and large burdens on the stockroom or material handling system. With this information, the user will be able to commit valuable resources to address the causes of problems in the factory, instead of committing those resources to solve the symptoms of the problem.

2. The Program Structure of FAST 2.0

FAST is designed around a menu structure similar to Lotus 1-2-3. All of the input screens are in row-column format. In the following discussion, the menu structure of the program is being used to introduce the functions of the program.

After entering the FAST system, the user sees the options contained in Figure 1. These options are as follows:

Client - The client is the basis for the database organization. Since EAAC is a consulting group, the client distinction is necessary. In the integrated database, performing analysis across clients is possible, but it is not implemented in FAST 2.0.
Scenario - For each client, there can several scenarios defined which address the needs of the client. In the database, scenarios are kept completely separate. This effectively creates a new "file" for each client-scenario combination. A valid client-scenario combination is necessary before FAST will allow the user to enter any other part of the program.
Data collect - As previously stated, data collection is a major part of running FAST. This option guides the user through the data collection part of a project.
Edit - Edit allows the user to enter or edit the data that exists in the FAST database. This data is collected by the data collection sheets generated by the Data_ collect option.
Reports - The reports option allows the user to print any of several reports generated by FAST.
Query - The query option allows the user the opportunity to query the FAST database. This option is particularly helpful when trying to find apparent errors in the database. Through a menu interface, Query builds a SQL-like command to query the database.
Notepad - Because several consultants work on the same project, each scenario has its own notepad for the users to write notes about the progress of the project, or write notes to each other. Each scenario is given up to 32K bytes for the notepad.
Model - The Model option leads the user through a series of question/answer menus in order to build a working SIMAN model of the facility you have defined. This modeling capability will be explained in greater detail later in the paper.
Accounts - The Accounts options simply allows the user to change his password.
eXit - Exit returns the user to the operating system.

The data collection section of FAST is critical to collecting accurate information for any project. The data collection menu is shown in Figure 2. The menu options are as follows:

Structure - The first phase of data collection defines the structure of the model. This generates the sheets that aid in collecting the names of the parts, processes, stockrooms, and material handling systems that will be used in the model. It also generates sheets to help define the scope of the project and the objectives of the client's business.
Detail - The second phase of data collection takes the structure that was defined by the first phase of data collection and generates sheets to collect the detailed information about the structure. This phase includes sheets to collect bill-of-material

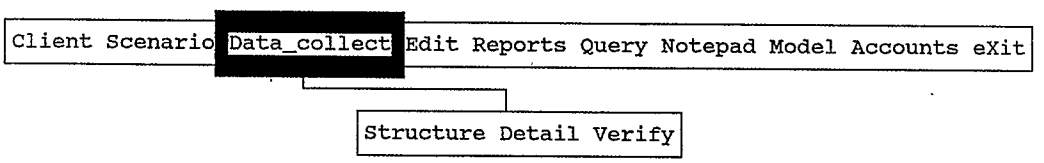

Figure 2: FAST Data Collection Menu

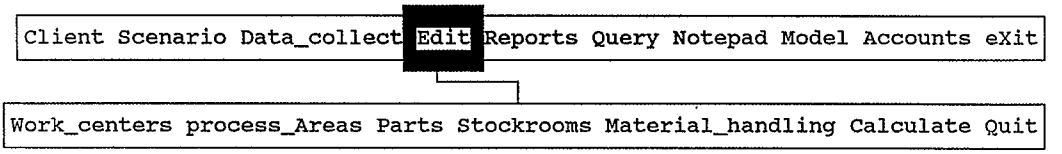

Figure 3: FAST Editing Menu

information, routings, part information, size information, stockroom information, and material handling system information.
Verify - Verifying that the client's data is correct is often a painful task. The Verify option prints out data sheets that will help with the verification part of the project. This option will be fully implemented in version 2.10.

After any of the data collection phases of FAST are completed, the Edit option of the main menu provides the user the means to input or edit information in the database. The edit menu is shown in Figure 3. The edit menu options are as follows:

Work centers - Work centers are a collection of process areas in the factory. This option allows you to list the work centers that are defined in the factory.
process Areas - This option gives the user capability to edit any process area information. The menu with this option allows the user to edit the list of process areas or edit the basic information for each process. Some of the basic information includes the calendar for the process area, the cost per worker and the cost per machine in the process area.
Parts - This options allows the user to edit a range of part information. The menu under this option gives the user the options of editing the list of parts, general information on any part, the bill-of-material for any part, the routing for any part, or size information on any part.
Stockrooms - This option allows the user access to stockroom information including the list of stockrooms, the calendar for each stockroom, and the carriers defined for each stockroom.
Material handling - This option allows the user access to material handling system information including the list of material handling systems, and the carriers defined for each material handling system.

Calculate - The Calculate option calculates all of the formulas for the years that you request. Any apparent data errors or holes in the data will be noted by an error or warning message.
Quit - Returns to the main menu.

After calculating information in the database, the report option will allow the FAST user to see the results of his work. The report menu is shown in Figure 4. It is important to note that any combination of the report menu options can be chosen. The report options are as follows:

All Reports - If you want all of the available reports to be printed, choose this option.
Part Labor/Machine - This report gives all of the labor and machine requirements generated by each part in the system.
Part Cycle Time - This report gives the amount of production time and queue time is needed by each part.
Part Stockroom - This report shows how each part affects stockroom area and number of carriers.
Part Stockroom Trans. - This report shows how each part affects the stockroom transaction rate.
Part MHS - This report shows how each part affects the material handling system requirements for the facility.
Process Labor - This report shows the labor requirements for each process area and work center.
Process Machine - This report shows the machine requirements for each process area and work center.
Process MHS - This report shows how much of the material handling system traffic and area is used in each process area.
Stockroom - This report gives the transactions and size of each stockroom and each stockroom carrier type in facility.
MHS - This report gives the transactions and size of each material handling system and each material handling system carrier type in facility.

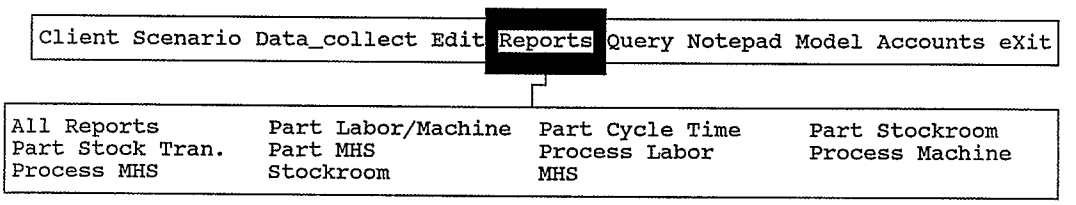

Figure 4: FAST Reports Menu

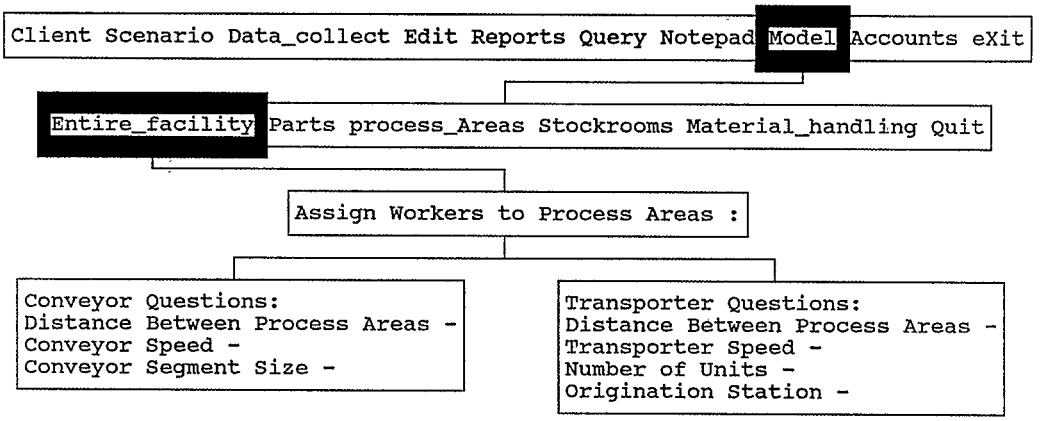

Figure 5: Modeling The Entire Facility

3. Automatic Model Generation by FAST

The model option in the main menu invoke the automatic model generation capabilities of FAST. Through the menu and question/answer session described below, FAST generates a SIMAN model that will run on the IBM PC/AT. Only in extremely large facilities will FAST not be able to generate a working model that runs on the IBM PC/AT.

3.1 Generating a Model for the Entire Facility

To illustrate the structure of generating a model for the entire facility, Figure 5 gives the menu options and questions that are given in the Entire_ facility option.

By choosing the Entire_facility option, the FAST modeling component will ask the fewest questions and build the most complex and complete model. FAST does this by assuming as few things as possible and asking only those questions that the FAST database does not hold the answers to. To illustrate this point, you will notice in Figure 5 that FAST only asks two sets of questions to the user. The logic that is used to model the remainder of the factory is detailed in the following discussion.

FAST models the parts in the factory in as much detail as possible. In the FAST database resides the part bill-of-material structure so that FAST knows what parts are subassemblies of higher assemblies, or which parts are purchased to go into higher assemblies. With this knowledge, FAST creates the SIMAN model with the ability to be certain that higher assemblies are not released to the floor for production until the necessary bill-of-material items are available. FAST generates a SIMAN model that creates "part entities" for purchased parts and "order entities" for higher assemblies. The part entities go through the steps in their routing (which is usually the receiving functions of a factory) and then are put into their stockroom until they are needed by an order entity. When the order entity accumulates all of its needed material, it is released to the factory floor where it goes through its routing steps. The cycle of stocking and accumulating continues until the final assembly exits the system. FAST allows for two exceptions to this cycle. First, FAST allows a part to be "bulk picked", which means that parts are picked from stock in a given time increment instead of being picked to meet an order requirement. Also, FAST allows lower assemblies to bypass their stockroom and by released automatically to the floor. Still, the higher assembly will not start production unless these pieces are in place and available. The difference in the model would be that the stock has been moved from the stockroom to the floor.

Another important part of the FAST is the routing database which holds several pieces of information which are used in each process during the routing. First, FAST has setup, run, and idle time data. Second, FAST knows if the lots size is changed at any given process in the routing. Third, FAST requires that each step in the routing be assigned to the material handling system that is used to move the part to that step in the routing. Fourth, FAST knows if manpower is required for each item in the routing. These pieces of information allow FAST to build a complete model of what actually happens at each step of the routing.

The portion of the FAST database that deals with process areas contains information on the worker schedule of each process area, along with the efficiency of the area and the availability of the machines. These pieces of information allow FAST to construct a model that utilizes the staggered shifts of the facility, along with machine breakdowns. One of the modeling parameters that is put into the generated SIMAN model is a 24 hour clock. The worker and machine schedules are handled in the

SCHEDULES element in the SIMAN experiment file. An important feature of the FAST generation of the SIMAN model is that workers can be assigned to multiple process areas. After you assign a worker type to multiple process areas, FAST will calculate the number of workers needed in that category in order to meet production requirements. This allows the process areas to compete for the workers that are shared.

The pieces of information stored in the FAST database that aid in modeling the stockrooms in the system include the stockroom schedule, and a description of up to ten containers that are used in each stockroom. The SIMAN model will keep track of how much each container is used in the stockroom, how full each stockroom is, and the number of transactions that actually occur in the stockroom. Since FAST already has calculated the number of carriers needed, the SIMAN model can determine the utilization of each type of carrier in each stockroom.

The material handling systems in the factory also are defined by up to ten different carrier types in the system. FAST has calculated the number of carriers and the SIMAN model determines the utilization of those carriers in the material handling system. Also, FAST knows which material handling systems fall into SIMAN's conveyor category and which systems fall into SIMAN's transporter category. Since FAST does not contain actual positions of process areas on the floor or the performance of the material handling equipment, the FAST model generator will ask the material handling questions that are shown in Figure 5.

Now that we have briefly discussed how the components of a FAST model are converted into a SIMAN model, it is time that some basic assumptions of the model were listed. The basic assumptions are as follows:

1. The factory is level loaded and all parts are produced simultaneously. The effect of this assumption is that each created part type has a constant time between creations independent of every other part type in the system.
2. The factory has infinite queues.
3. The factory is initially loaded to the average conditions determined by FAST. It is then unnecessary to monitor the progress of the SIMAN model to determine when it has reached normal operating conditions.
4. Setup times, run times and idle times are gamma distributed with alpha = 4. This distribution was chosen because it creates a bell-like curve that is skewed to the left (around the mean).
5. Time between failure and time to repair are exponentially distributed. Time between failure and time to repair is determined by an assumption that every machine will break down once a week and be repaired once a week on the average.
6. All of the machines in a process area are identical.
7. The priority of items in each queue is first come, first served.

Other that the assumptions listed above, the FAST database contains all of the information needed to create the model. There are, of course, subsets of the entire facility model which FAST can generate. These models contain more assumptions, but can be tailored to focus on one particular aspect of the factory.

3.2 Generating A Model Based On with Parts

The first of these models that are a subset of the entire facility model is the model that concentrates on the parts flowing through the factory. Figure 6 details the flow of questions that are asked if the user chooses the Parts option in the Model menu. This discussion will follow that line of questions and elaborate on the differences that exist between the model that is being created and the model that would have been created with the Entire_facility option.

When the user chooses the Parts option, a menu of all of the parts in the system appears and the user is asked to choose which parts he wants the model to concentrate on. The parts selected in this step are guaranteed to be included in the model. Other parts may be included depending on answers given to subsequent questions.

The next answer solicited by FAST will determine the remainder of the parts that are included in the SIMAN model. The Complete_detail option will force the SIMAN model to include every part that ultimately feeds into the parts the user chose in the previous question. The One_level_detail option will include those parts that are listed specifically in the bill-of-material for each part that was chosen in the previous question. The No_detail option will only use the parts chosen in the previous question.

At this point in the question/answer process, FAST has flagged every part that is included in the model. It then flags every process area, stockroom, and material handling system that is used by those parts. The extent of how these other items are modeled are determined by the remaining questions.

The next menu allows the user to choose which process areas are to modeled in the same detail that the Entire_facility option would model them. If a process area is not chosen in this list, it is modeled as a constant net delay which requires no resources, but may still require the use of material handling systems. If a process area is chosen, all of the resource requirements are determined and modeled. As a part of determining those resource requirement, FAST will ask the user to assign workers to the process areas that are being modeled in detail.

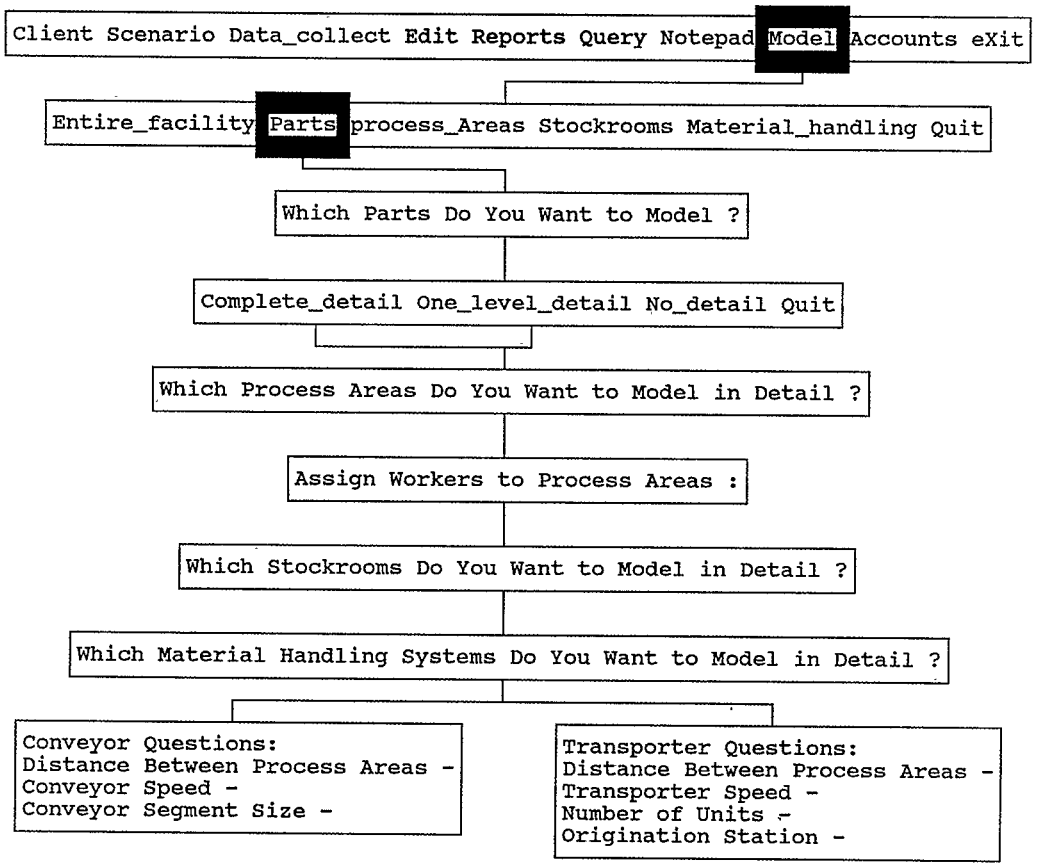

Figure 6: Generating A Model Based On Parts

After the process areas are taken care of, the user must determine which stockrooms are to be modeled in detail. If a stockroom is not chosen in this list, it is modeled as a queue with no limit on its size. A stockroom modeled in detail keeps track of all of the carriers in the stockroom and what they contain.

The next question asks the user to determine which material handling systems will be modeled in detail. If a material handling system is not modeled in detail it will not consider resource requirements, but instead route the entity to the next station and collect statistics on the number of transactions for the material handling system. A system modeled in its full detail is described in the Entire_facility option discussion.

You will notice that the models generated by this option are primarily concerned with parts and will produce simpler models that the Entire_facility option.

3.3 Generating A Model Based on Process Areas

The second model that is a subset of the Entire_facility option is the process_Area option which focuses on the process areas to build the model. The flow of questions needed to build a model focusing on process areas is shown in Figure 7. As was done with the Parts option, the following discussion will focus on the flow of questions and any assumptions that may be included based on answers to the questions.

The first questions asks the user to identify those process areas which you want included in the model. This menu option will list all of the process areas that are defined in the FAST database.

After choosing those process areas you want to model, the next question asks which of those processes should be modeled in detail. To model the process in detail would include modeling resource requirements, setups, run time, and idle time in the process area. In order to model the process area with no detail, the process area would be represented as a net delay, and would only be effected by the calendar of the process area.

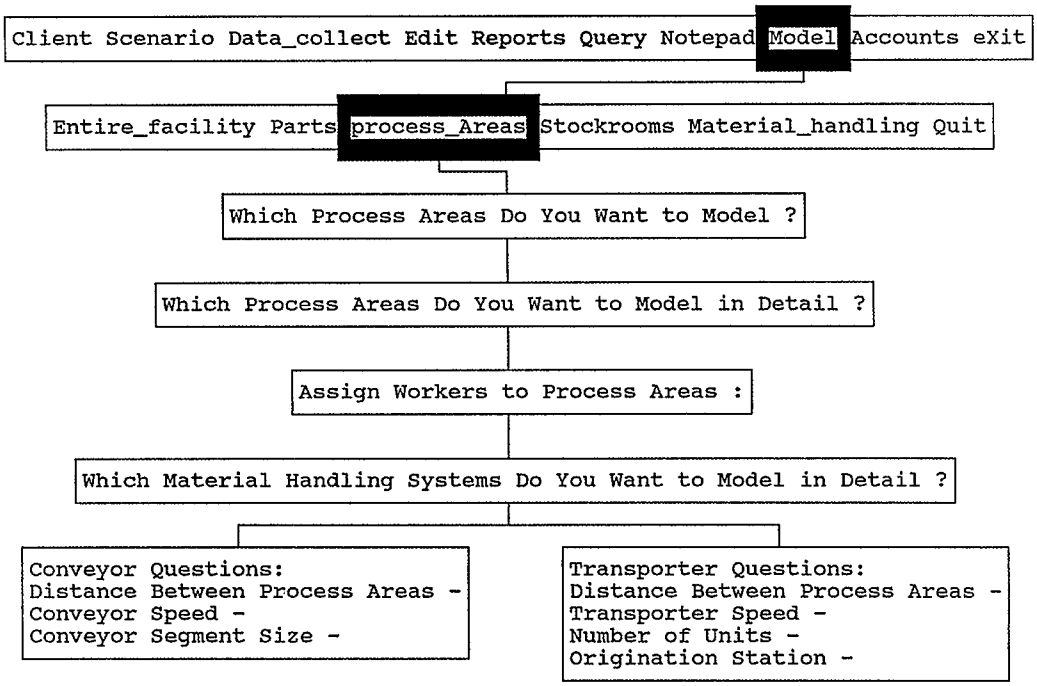

Figure 7: Generating A Model Based On Process Areas

After it is determined which process areas are to modeled in detail, the next question allows the user to assign workers to multiple process area in the model.

At this point, FAST looks into its database to determine the parts that go through the process areas that were chosen. FAST also creates a secondary list of process areas that will be modeled without detail. This secondary list is compromised of those process areas that are in the routings of the parts that will be modeled, but were not chosen as a part of the original list. Also, FAST determines the material handling systems that must be part of the simulation.

The next question asks the user to identify the material handling systems that should be modeled in detail. If a material handling system is chosen in this list, FAST prompts the user for some information on the material handling systems.

Some of the inherit assumptions of the process area oriented model are as follows:

1. All parts that are included in the model are model with no detail. This means that there is an underlying assumption that feeder parts are always available, and that parts are unaware of the bill-of-material structure that exists in the system. All parts are created and managed independently.
2. Stockrooms are not modeled at all because they do not directly effect the work done in a process area.

3.4 Generating a Model Based on Stockrooms

The third subset of the Entire_facility model is the Stockroom model. The question/answer flow for the Stockroom model is contained in Figure 8. The primary purpose of the stockroom model is to test the feasibility of stockroom configurations.

There are only two questions in the Stockroom option. Those two question determine the stockrooms to be modeled and the extent to which they are modeled. Those stockrooms modeled in detail will keep track of every container in the stockroom and its contents. Those stockrooms not modeled in detail will be modeled as queues with no record of containers or their contents.

The important aspect of this model are the inherit assumptions that are included as FAST builds the model. Those assumptions are as follows:

1. All parts are modeled in complete detail.
2. All of the process areas are modeled with no detail. This means that resources are not included in the process areas as they are modeled.
3. All material handling systems are modeled with no detail. All movement in the system is done with SIMAN routes.

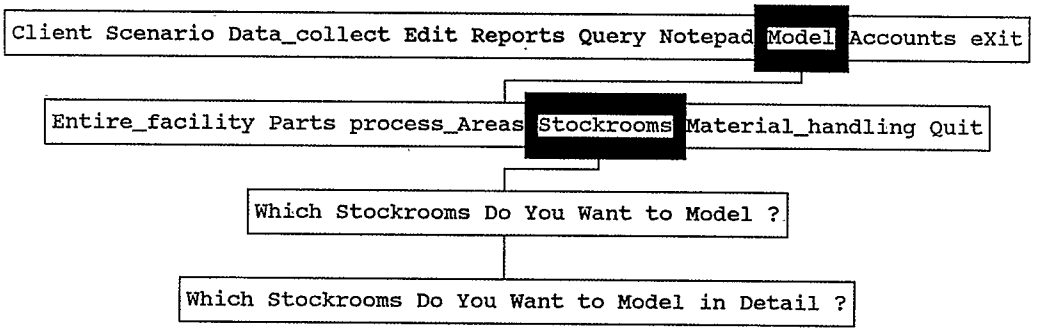

Figure 8: Generating A Model Based On Stockrooms

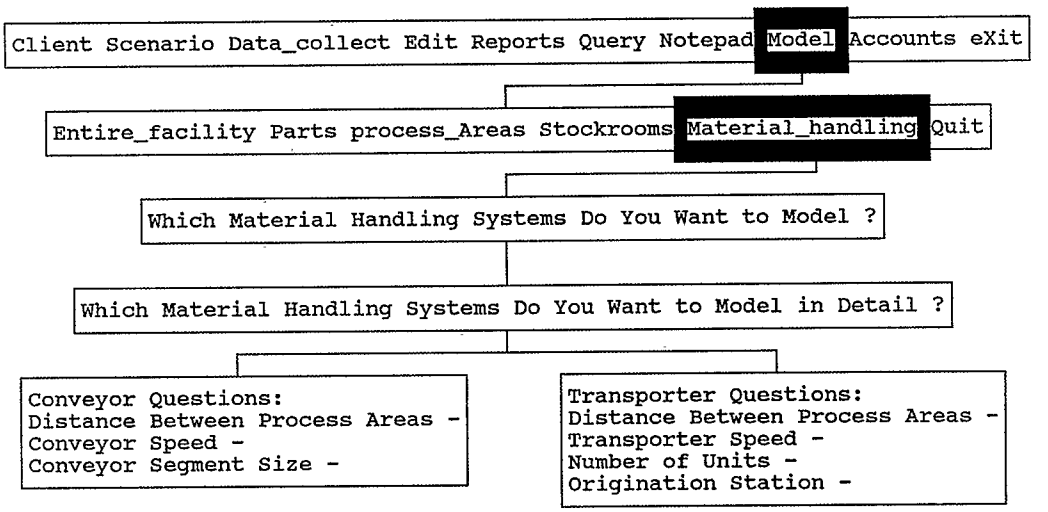

Figure 9: Generating A Model Based On Material Handling Systems

3.5 Generating a Model Based on Material Handling Systems

The last subset of the Entire_facility model is the Material_handling_system model. The question/answer flow for the Material_handling_system model is contained in Figure 9. The primary purpose of the Material_handling_system model is to test the feasibility of material handling system configurations.

There are three questions in the Material_handling_system model. The first two determine those material handling systems to be included in the model, and which of those should be modeled in detail. If the system is chosen to be modeled in detail, the next set of questions determine the operating parameters of the system since those parameters are not included in FAST.

Just as with the Stockroom option, the important aspect of this model are the inherit assumptions that are included as FAST builds the model. Those assumptions are as follows:

1. All parts are modeled with no detail.
2. Just like the Stockroom option, all of the process areas are modeled with no detail.
3. All stockrooms are modeled with no detail. They are modeled only as simple queues in the system.

4. Conclusions

As EAAC continues to refine FAST to meet its needs in the electronics consulting business, FAST model generating capabilities will be refined to better suite the state-of-the-art simulation methods available. The real impact of using the automatic model generating capabilities of FAST has been the ability to concentrate on collecting and verifying the data for the model, and not the time consuming task of verifying the simulation code. Also, the initial models generated by FAST have proven to be easy to edit so that if certain assumptions do not hold, they can be implemented in the model. At this point in time, FAST is only being sold as a part of

electronics facility consulting contracts with EAAC and is not available for public sale.

Acknowledgments

SIMAN is a product of the Systems Modeling Corporation of State College, Pennsylvania. We have chosen SIMAN because of its wide range of material handling capabilities and the commitment of Systems Modeling to continually upgrade the product.

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