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SIMULATION OF MEMORY CHIP LINE USING AN ELECTRONICS MANUFACTURING SIMULATOR

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ABSTRACT

This paper presents an overview of a simulation environment used for rapid modeling of electronics manufacturing lines. This environment, the Electronics Manufacturing Simulator (EMS), consists of a line definer and a static analyzer. Included in this paper are a description of the EMS, an application of the EMS, and a discussion of results of the application.

1 INTRODUCTION

The specification of a production line by components and their defining parameters is a necessary, yet time consuming, part of the simulation process. Line specification requires specialized knowledge in both the determination of the input data and the specification of the model. Therefore, the development of a program that could handle line specification would be an extremely useful and time-saving simulation tool. This visually oriented program would serve the following related functions:

- to make the specification of a processing line as simple as possible
- to store the line description for reuse and as the basis for generating alternative designs
- to approximate the throughput of the proposed system to assist in the early evaluation of design proposals
- to provide access to the stored line description through a simulation model as the source of model parameters (i.e., components), their operating parameters, and descriptive elements (i.e., rate and duration of breakdowns).

The EMS was developed in 1995 by the University of Alabama in Huntsville (UAH) in conjunction with Chrysler's Huntsville Electronics Division to speed the design an analysis of high volume electronics assembly lines. The EMS consist of 1) a catalog of various electronics manufacturing machines and equipment, 2) a line description tool with static analysis capabilities, 3) a collection of reusable WITNESS sub-models to model the behavior of various machines detailed in the equipment catalog, and 4) a set of ARENA templates which model the machines listed in the catalog.

2 SYSTEM OVERVIEW

The current version of the EMS consists of two elements: line definer and static analyzer. The following sections will present these two elements in detail.

2.1 Line Definer

The line definer is used to develop the initial definition of the assembly line though the use of a graphical interface. Individual line elements are defined by selecting the appropriate icon from a master template of elements. The selected element then appears in the center of the line layout window. The element is then moved by using the mouse to drag the displayed icon to the desired location. Line elements are defined for line entry and exit points, assembly stations, buffers, inspection stations, ovens, conveyors, and line convergence and divergence points. Table 1 shows the available manufacturing elements for each component type.

Table 1. Available Manufacturing Elements for Each Component Type

Option	Component Type
General Purpose/Vertical Stacker	Buffer
General Conveyor	Conveyor
Final Test	Inspection
In-Circuit Test	Inspection
Solder Paste Inspection	Inspection
TDK Bar Code Verification	Inspection
X-Ray Inspection	Inspection
Board Inverter	Machine
Fine Pitch Placement Machine	Machine
Glue Placement Machine	Machine
PCB Shear	Machine
Phillips FCM16 Placement Machine	Machine
Phillips MCM8 Placement Machine	Machine
Robot (General Purpose)	Machine
Rotating Device	Machine
Solder Paste Application/Screen Printing	Machine
TDK Bar Code Applicator	Machine
TDK Board Loader	Machine
TDK CX-5 Placement Machine	Machine
TDK RX-4 Placement Machine	Machine
TDK RX-5 Placement Machine	Machine
TDK SS-1 Placement Machine	Machine
TDK VC-5 Radial Placement Machine	Machine
Conformal Coating	Oven
Curing Oven	Oven
Functional Test Oven	Oven
Preheat Oven	Oven
Reflow Oven	Oven

The attributes of individual manufacturing elements and the assembly line process flow are defined by double clicking on the element icon. The user begins by selecting the machine type and the stations preceding and succeeding it in the line (when these are entered, a line connecting the elements is drawn in the line layout window). Cycle times are then entered. The user may enter this information as a fixed production cycle time or as a detailed cycle time specified by a time per component, an index time, and the number of operations/components per board. The user may enter downtimes and repair times in general or specific terms as with the cycle times. The general format allows the user to define downtimes and repair times in terms of their frequency per time period (i.e., daily or weekly). The detailed format allows the user to define downtimes and repair times in terms of a particular distribution with specific parameters. The current version of the software allows the user to define the time distributions for each manufacturing component as exponential, Weibull, or triangular or as specific constants. Finally, for certain machines, such as the Phillips FCM 16 or the TDK CX-5, the user may also enter reel change data in terms of the number of reel changes per unit of time and the time per reel change.

Table 2 lists the input information required for each type of line component. Drop-down menus are used to enter information for fields where multiple selection choices exist. Data type checking and internal unit conversions are integrated into the system to provide an easy mechanism for numerical entries while maintaining data consistency. The user can input information on machine cycle times, downtimes, and repair times as specific constants or as statistical distributions.

Table 2. Input Requirements for Various Component Types

Component Type	Enter Node(s)	Exit Node(s)	Throughpu t Rate	Downtime/Repair Frequency	Speed and Length	Other
Start		x	x			
Assembly	x	x	x	x		
Buffer	x	x	x	x		Capacity, Index, Scheme
Conveyor	x	x		x	x	
Inspection	x	x	x	x		Failure Following
Oven	x	x		x	x	Capacity
Convergence	x	x			x	No. of Convergence's
Divergence	x	x			x	No. or Divergence's
Stop	x					

2.2 Static Analyzer

The static analyzer uses the station processing times to generate an estimate of the maximum throughput for each station in the line. The approximation used in the static analysis is based on a simple queuing consideration. This consideration utilizes a net processing time adjusted for mean downtime and the mean number of reprocessed parts. Net processing can also be reduced to blocking (downstream bottleneck) or starvation (upstream bottleneck). The analysis seeks to identify the line capacity as a function of the following elements: line structure, inspection parameters (pass rate), equipment processing capabilities, and downtime frequency and duration. Variability is not taken into account in the approximation; therefore, the throughput estimates are somewhat optimistic assessments of the mean response. It is not possible to assess the variability (i.e., in daily production) of the throughput with the estimate. However, the estimate does make it possible to rank competing designs quickly and to identify critical factors in the overall design. A full simulation model is required in order to refine the throughput estimate and to evaluate the variability of the throughput due to the random occurrence and duration of downtime, fluctuations in inspection (pass/fail), and the interaction between equipment on the line.

Bottleneck locations for non-branching model segments can be identified by locating the elements within the segment with the smallest throughput values. This analysis is straight forward for most line element types; however, branching elements (i.e., inspections, convergences, and divergences) introduce complications into the analysis. At convergence points, two or more line throughputs are summed to become the input to the downstream elements; therefore, the smallest element throughput value may not represent the bottleneck location. In a similar manner, the upstream elements of a divergence point must handle the summed throughputs of the downstream sublines. Each subline component of the convergent system, shown in Figure 1, must be considered separately. Since some manufactured items may not successfully pass the inspection station and will instead be routed back for rework, inspection stations represent divergence points within the line.

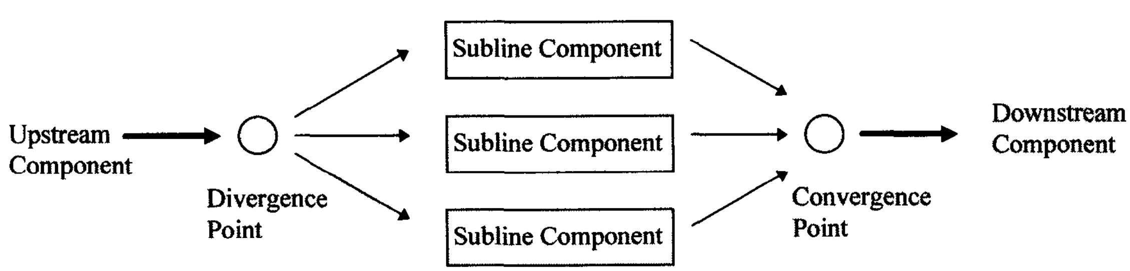

Figure 1. Divergence and Convergence Within the Manufacturing Line

In addition to the static analysis, the EMS provides two input information reports: the Equipment Summary and Detailed Equipment Report. The Equipment Summary lists the various line elements in processing order. This report provides an element description, the production cycle time, the percent of time devoted to reel changes, the estimated downtime, the effective cycle time (i.e., cycle time after accounting for reel changes and the estimated downtime), and the estimated single shift capacity. The Detailed Equipment Report provides a more comprehensive listing of the input information for each type of line element (i.e., starts, machines, buffers, conveyors, inspections, ovens, convergences divergences, and ends). This report presents a summary of the input parameters for each type of equipment by class (i.e., machines, conveyors, ovens, etc.). The Detailed Equipment Report provides the user with access to all the input information in one location for verification and error checking purposes. All reported cycle times and parameter values are in minutes and a shift equivalent to eight hours.

3 APPLICATION OF THE SYSTEM

A simple electronics assembly line is shown in Figure 2. The line receives a continuous supply of boards and processes them through the following stations:

- Solder Paste Application Machine
- TDK RX-5 Placement Machine
- Curing Oven
- X-Ray Inspection

The input template for the Solder Paste Application Machine is shown in Figure 3. This machine has a cycle time of 0.25 minutes, a failure rate of 10 per day, and a typical repair time of 5 minutes.

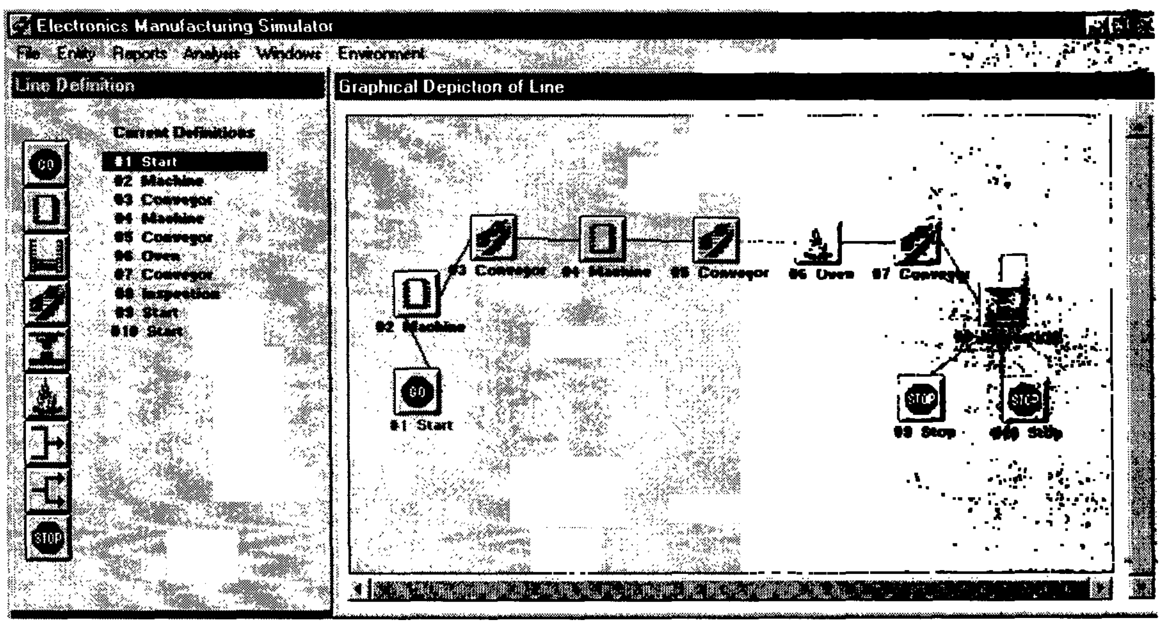

Figure 2. Line Layout Window

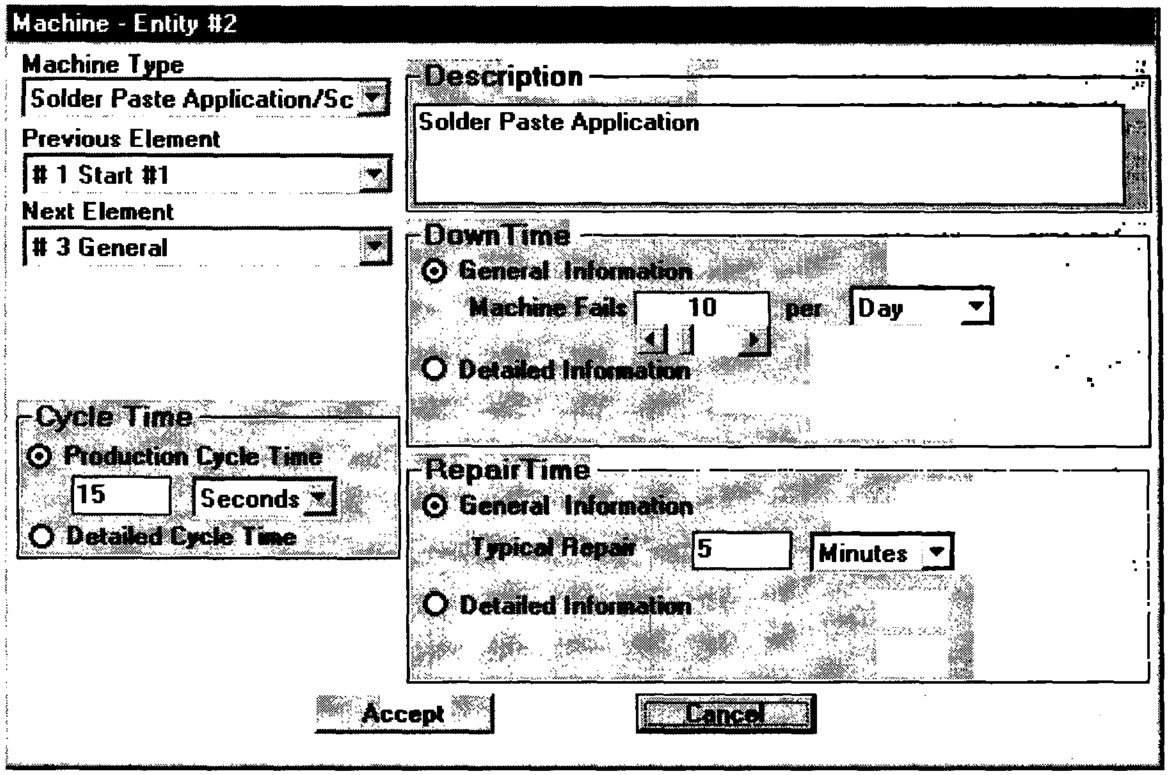

Figure 3. Input Template for Solder Paste Application Machine

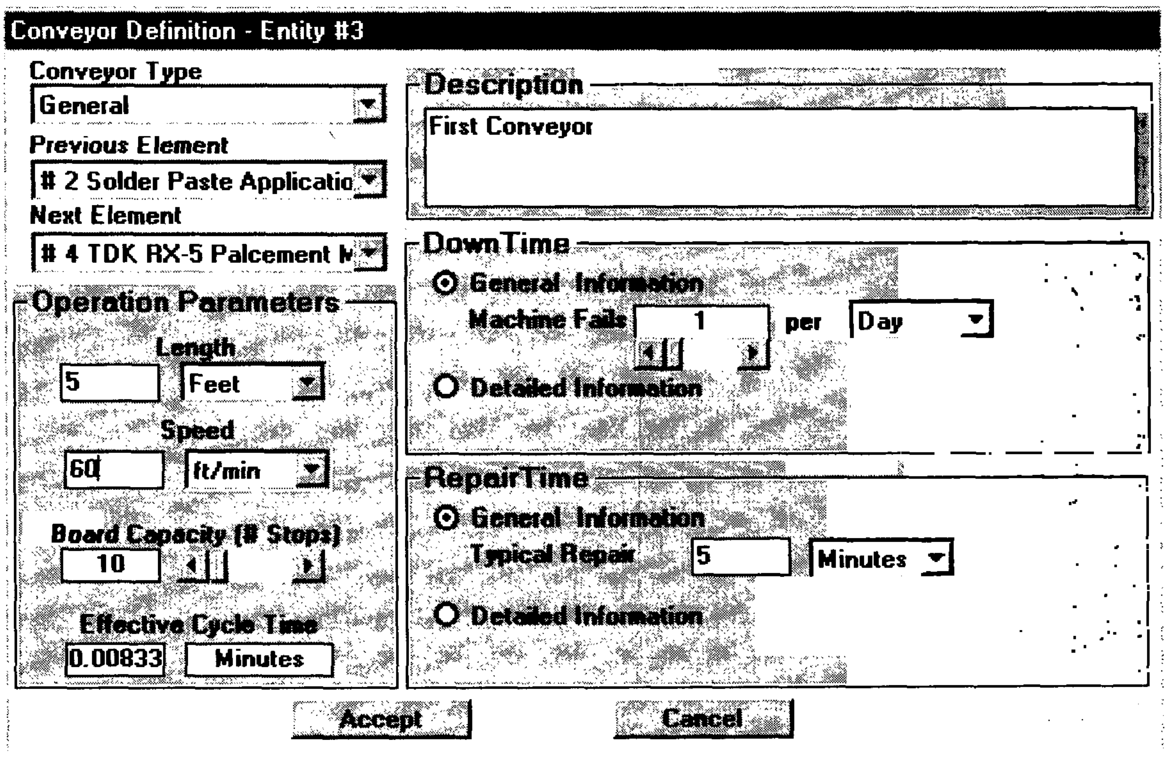

Figure 4. Input Template for Conveyor 1

Figure 4 shows the input template for one of the conveyors. Each conveyor experiences one failure per day with a typical repair time of five minutes per failure. The operation parameters for each conveyor are:

- Conveyor 1: length = 5 feet, speed = 60 ft./min., board capacity = 10
- Conveyor 2: length = 4 feet, speed = 50 ft./min., board capacity = 8
- Conveyor 3: length = 5 feet, speed = 40 ft./min., board capacity = 10.

The input template for the TDK RX-5 Placement Machine is shown in Figure 5. This machine has the following characteristics:

- 50 operations performed per board
- 0.5 seconds required to complete an operation
- an index time of one second
- downtime is exponentially distributed with a mean of 8 hours
- repair time is based on a triangular distribution (4,6,8) minutes
- three reel changes per hour are required with an average change time of one minute each.

The Curing Oven has a length of 10 feet, a speed of 2 feet per minute, and a board capacity of 10. The Curing Oven experiences one downtime per week with a repair time of 10 minutes per downtime.

The X-Ray Inspection station inspects one board every two minutes. Boards which pass inspection (i.e., 95% of the inspected boards) proceed to Line End Pass. Boards which fail inspection are sent to Line End Fail. The downtime of the inspection machine is based on a constant of one per day. The typical repair time is 30 minutes for each downtime.

The EMS output include Equipment Summary, Detailed Equipment, and Static Analysis Results reports. Figure 6 shows the Equipment Summary report. The Static Analysis Results report, in Figure 7, displays the maximum throughput production per hour for each entity.

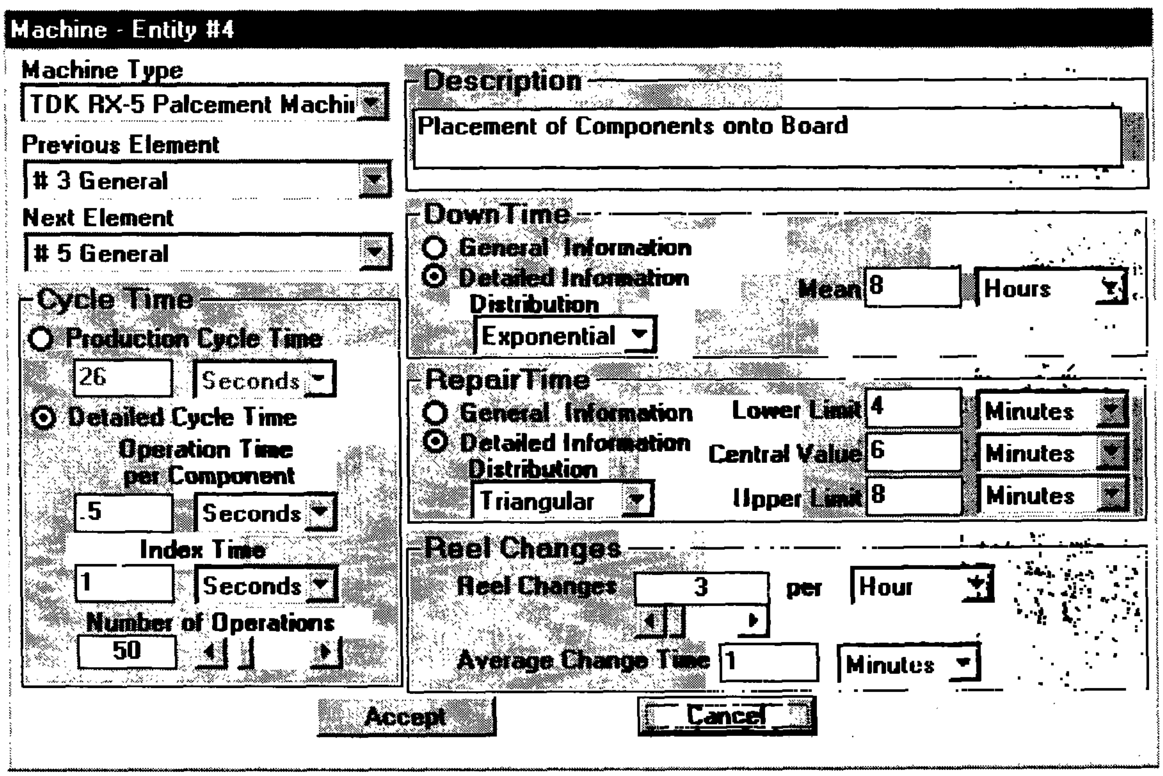

Figure 5. Input Template for TDK RX-5 Placement Machine

Equipment Summary

Operation Number	Description	Production Cycle Time	% Real Change	% Down Time	Effective Cycle Time	Single Shift Capacity
1	Start #1					
2	Solder Paste	2.50E-01	0.00E+00	3.47E+00	2.59E-01	1.92E+03
3	General	8.33E-03		3.47E-01	8.36E-03	5.76E+04
4	TDK RX-5 Palcement	4.33E-01	5.00E+00	1.25E+00	4.62E-01	1.11E+03
5	General	1.00E-02		3.47E-01	1.00E-02	4.80E+04
6	Curing Oven	5.00E-01		9.92E-02	5.00E-01	9.60E+02
7	General	1.25E-02		3.47E-01	1.25E-02	3.84E+04
8	X-Ray Inspection	2.00E+00		2.08E+00	2.04E+00	2.40E+02
9	Stop #2					
10	Stop #3					

Cycle times are in minutes. Shift is eight hours.

Figure 6. Equipment Summary Report

Static Analysis Results

Simulation Entity	Maximum Production	Success Rate	Gross Production	Net Production
Solder Paste	240	1	12	12
General	1440	1	12	12
TDK RX-5 Palcement	138.4615	1	12	12
General	1500	1	12	12
Curing Oven	12	1	12	12
General	960.0001	1	12	12
X-Ray Inspection	30	0.95	12	11.4

Production units are in items per hour

Figure 7. Static Analysis Results

4 CONCLUSIONS

The Static Analysis Results reveal that the bottleneck station of this sample model is the X-Ray Inspection station with a maximum production of 30 units per hour and a net production of 11.4 units per hour. Since there are no convergence and/or divergence points and because the units failing inspection are not routed back for rework, the net production of the entire system is 11.4 units per hour (i.e., the net production of the bottleneck station).

Although the EMS is limited to modeling only electronics manufacturing lines, it provides the modeler with a flexible, simple to use simulation tool. The advantages of the EMS include rapid prototyping of electronics assembly lines, increased modeler productivity, reduced modeler knowledge, increased model flexibility, and improved model documentation.

The EMS has been successfully used for modeling an electronics manufacturing line at MGV Manufacturing, Inc. in Huntsville, Alabama. MGV is an electronics manufacturing facility which supplies expandable memory chips for use in personal computers. The EMS was used to evaluate line expansion proposals. The time required to build the MGV model was less than thirty minutes.

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REFERENCES

Jobes, J., Farrington P., Rogers J., and Swain J. July, 1996. "Electronics Manufacturing Simulator: Users Manual." Huntsville, Alabama.

Jobes, J., Czarnecki, H., Rogers, J. October, 1996. "Rapid Modeling of High Volume Electronics Manufacturing Lines." Proceedings of the 1996 Southeastern Simulation Conference." Huntsville, Alabama.

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