Proceedings of the 1988 Winter Simulation Conference
M. Abrams, P. Haigh, and J. Comfort (eds.)

Analysis of different AGV control systems in an integrated IC manufacturing facility, using computer simulation

BY

Kowdle Prasad and Madhav Rangaswami

Intel Corporation
MS CH2-31
5000 W Chandler Boulevard
Chandler AZ 85226

ABSTRACT

In an integrated Manufacturing Facility, consisting of various individual manufacturing cells, an automated material handling system (AMHS) - such as an Automated Guided Vehicle System (AGVS) - servicing each of cells plays a major role. In order to understand, and choose, the correct type of AGV system, simulation techniques can be used very effectively. In this paper, two different AGV Control Systems have been analyzed with computer simulation models. These animated graphic models also include details of all the individual process steps from the Wafer Sort operation through the Test processes of an IC Manufacturing Facility at Intel. The simulation model is used to analyze the behavior of the AGVS, as measured by the average AGV utilizations, AGV congestion levels, average AGV response times, as well as process characteristics such as Throughput Time through the line, Work in Process levels and overall product throughput through the line. The model has been used to recommend the proper AGV control logic, as well as the number of vehicles required.

1. INTRODUCTION

Implementation of automated material handling systems in an integrated manufacturing facility requires detailed knowledge of the manufacturing process as well as the control algorithms used by the handling system. Traditional static analysis techniques become too complex when the system being studied includes AGVS, robots and conveyors which interface with process equipment. Complexity increases even more when material handling control logic, and material scheduling algorithms are also to be considered in the analysis.

Dynamic simulation models could be effectively used to analyze the details of the material handling system integrated with process equipment. Today, there are a number of simulation modelling tools commercially available, such as SIMAN, SLAM, AutoMod, SEE-WHY,etc. In this paper, AutoMod has been used as the primary tool to develop the graphic simulation model of an integrated Semiconductor Sort, Assembly and Test Facility.

2. MANUFACTURING PROCESS AND AGV LAYOUT

The simulation model includes details on all Post Wafer Fabrication processes from Wafer Sort through Packaging and Product Test. Process details in the model include product type, individual process times by product, lot sizing and batching mechanisms, and equipment capacity and physical layouts. The manufacturing layout consists of individual automated cells connected with an inter-cell material transport system.

Each manufacturing cell consists of an input dock for material delivery, process equipment(s), and an output dock for material pickup. Some of the cells have internal material handling systems, such as a robotic system serving multiple machines.

Material arrives from the Wafer Fabrication facility in a wafer cassette, which is termed as a Fab lot. As this lot moves through the Assembly area, it's size changes based on the product/package configuration, which in turn gets re-aggregated as a Test lot within the Product Test section of the integrated line. Part of the simulation study is to understand the impact of different lot sizes within the Assembly and Test section of the line. However, for this paper, we will concentrate on the study of the material handling system.

The material movement within the cell is as follows:

a) material from the previous cell is delivered to the input dock of the next cell.
b) material moves to the process machine.
c) material moves from the process machine to the output dock, to be picked up by the inter-cell transport system.

The complete system works like a "pull" system, whereby material leaves the present cell only when a process machine at the next cell makes a request for the material, and there is space available at it's input dock. Until that time, the lot waits on the output dock of the present cell.

Figure 1 shows the details of the process flow, while Figure 2 provides details on the AGV layout.

3. MATERIAL HANDLING SYSTEM

The inter-cell material transport system is an Automated Guided Vehicle System (AGVS). For this analysis, the vehicle is assumed to carry one load, where a load could be a Fab, Assembly, or Test lot.

The simulation model also includes details on the AGV system being used. These include:

a) AGV velocity,
b) AGV acceleration/deceleration
c) load pickup/setdown times,
d) spur speed,
e) crab speed,
f) curve speed,
g) rotate time and
h) AGV size (length, width, height).

The simulation tool automatically resolves AGV deadlocks and collisions, when more than one vehicle is involved.

The AGV guidepath consists of segments connecting different control points. Control points define pickup and delivery locations, AGV parking spots, and temporary wait points. In addition, certain sections of the layout allow only one AGV in that section, at any given time, due to space constraints.

4. AGV CONTROL LOGIC

In this analysis, two different types of AGV control systems have been modelled. These can be classified as global and local control systems. Consider an example of each system, where an AGV has just delivered a load at delivery location d_1, and a load has appeared at pickup location p_4 (refer to Figure 3).

Global control system: Here, the control system knows the status of all loads appearing in the system (in this example, the load which appeared at p4). The AGV is directed to the first pickup location on its pickup list. Contentions are resolved based on distance (here, the AGV is instructed to move along spur s1 to get to pickup location p4). Once the load is picked up, the controller directs the AGV to its delivery destination, using the shortest path. If no loads appear at any pickup location, the controller instructs the AGV to move to a designated parking location (called park1 in the example), until a load needs to be picked up at a pickup point.

Local control system: Here, the control system does not know whether loads are waiting to be picked up at any location (p1, p2, p3 or p4). Hence, in this example, the AGV would be directed to location p2. Once the AGV is at p2, the controller communicates to the AGV to move to the next pickup location p3, as there was no load to be picked up at p2. At p3, the controller tells the AGV to move to location p4, as there is no load waiting to be picked up at p3. Once at p4, the AGV is instructed to pick up the load and move it to its destination, using the shortest path. Unlike a global control system, there is no parking of AGV's in a local control system. All the AGV's operate in a "taxicab" mode, where they move along the AGV guidepath looking for work.

5. SIMULATION ANALYSIS

The simulation study, for this paper, is to compare the two AGV control algorithms, using the number of vehicles in the system as the independent variable.

The simulation model provides a host of outputs, describing the material handling system and the process performance. These include (but are not limited to):

1) AGV utilization,
2) AGV congestion,
3) Average wait time,
4) Throughput time through the entire line,
5) Work in Process in the line.

In this paper, we shall concentrate on the AGV performance, as measured by it's utilization, traffic levels and the average wait times.

5.1 AGV Utilization.

In this model, the AGV utilization is defined as the percentage of time that an AGV was used to transport a load from one location to another. The AGV move time associated in moving to claim a load, is included in the utilization calculation. Figure 4 compares the AGV utilization for the two control systems.

As seen in Figure 4, the average AGV utilization for a local control system is lower than the AGV utilization for a global control system. In a local control system, the AGV move time to claim a load is, essentially, the time taken to move from the control point previous to the point at which the load appears, to the load pickup location. However, in a global control system, the move time to claim the load is the time taken for the AGV to move from the control point where it claimed the load to the load pickup point. In general, this time is always greater than the equivalent time for a local control system.

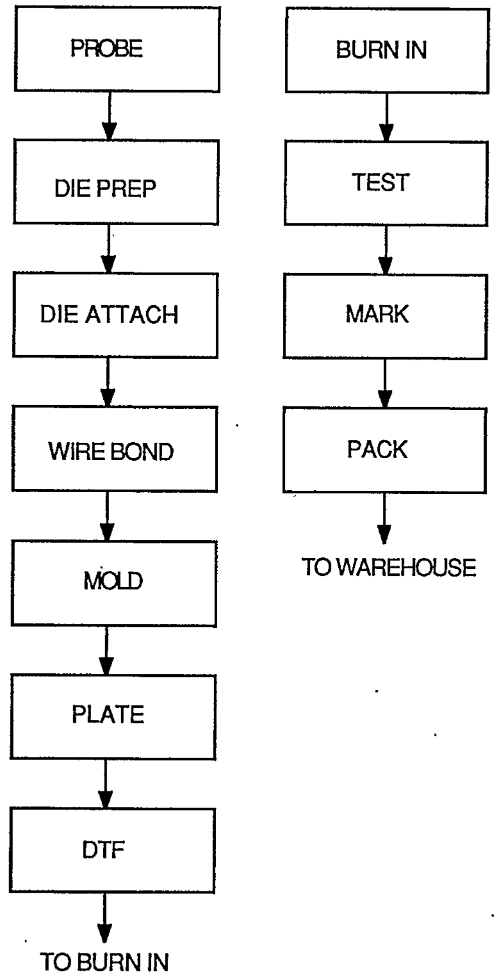

Figure1: Process Flow For Complete Line

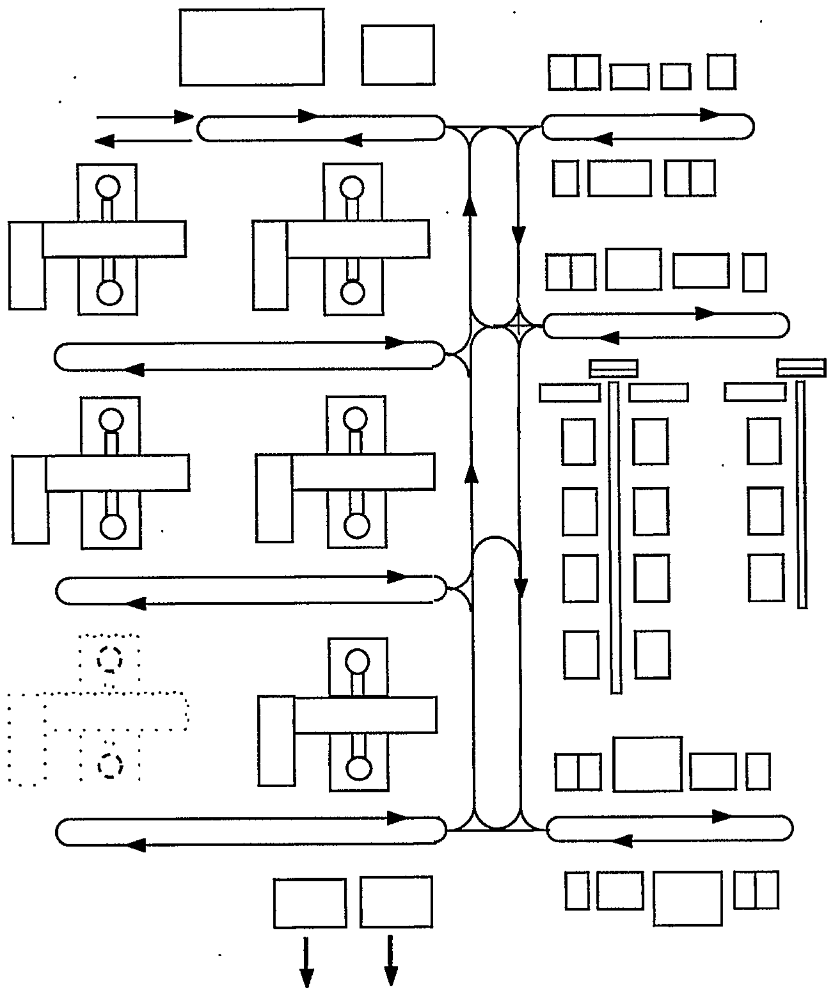

Figure 2: Layout For Agv System

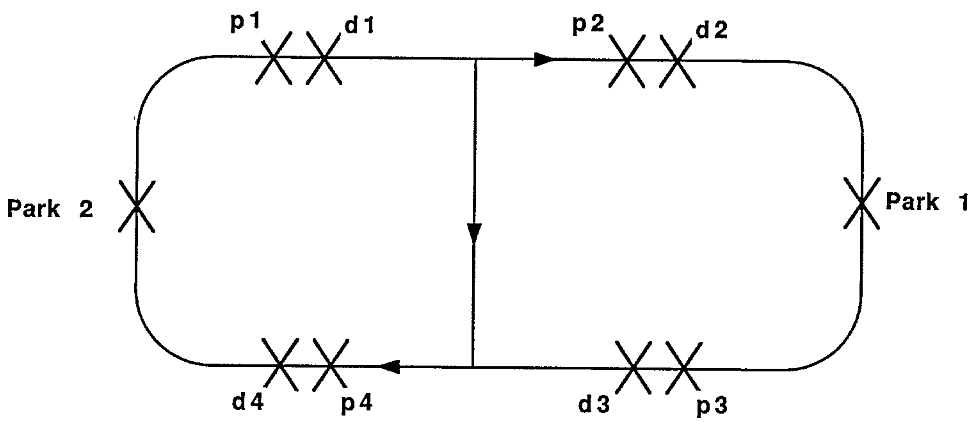

Figure 3: Agv Control Logic

With the increase in the number of AGV's from 1 to 6, the AGV utilization decreases since the total work needed to be done by the AGV system is now distributed over a larger AGV base.

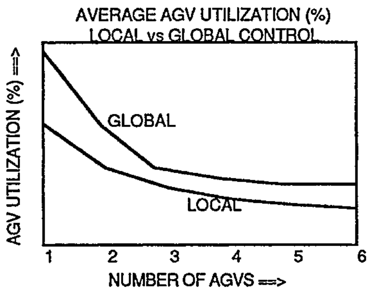

FIGURE 4

5.2 AGV Congestion/traffic level

In this model, AGV congestion is defined as the percentage of time that the AGV waits at a control point, due to traffic jams downstream.

As seen from Figure 5, the congestion levels for a global control system is more than the congestion levels for a local control system. The layout plays a major role in contributing to higher congestion levels (see Figure 2). Due to the manner in which the layout is spread out, there is a "randomness" associated with AGV movement in the case of a global control system. In a local control system, however, AGV's tend to follow each other looking for work. The only time that AGV's wait due to traffic is when the "lead" AGV has stopped to pick up a load. This contributes to lower congestion levels for the local control AGV system.

When the number of AGV's in the system increase from 1 to 6, the congestion level increases. This increase is more rapid in a global control system due to higher probabilities of traffic jams associated with the randomness in AGV movements.

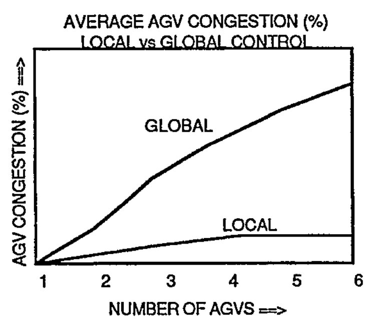

FIGURE 5

5.3 Total wait time

The total lot wait time is defined as the total time taken for a lot to reach it's destination point, from the time it was requested by the destination process step. This time includes the wait time at the output dock for an AGV to pick up the lot, and the actual AGV transport time.

As seen from Figure 6, the average wait time for a local control system is much higher than the wait time for a global control system. In a local control system, the AGV does not know the presence of a load for pickup until it has reached the pickup location. If an AGV is busy elsewhere in the layout, it is conceivable that it might never "see" the load to be picked up for a large period of time, as seen in the graph. However, as the number of AGV's in the system increase, there is a reduction in wait time, until the increased effect of congestion/traffic begins to counteract the wait time decrease.

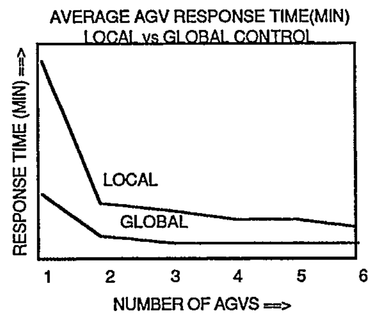

FIGURE 6

5.4 Simulation language/animation capability

The simulation model was developed using AutoSimulation's modelling package called AutoMod. AutoMod is a "macro" language which is based on GPSS. This tool is ideally suited for modelling material handling systems, such as AGVS, ASRS, conveyors and robots. The animation feature, which is part of this package, played a very important role in this analysis. AGV bottlenecks, congestion and deadlocks could be easily identified, which would have been difficult through the use of other conventional simulation packages.

6. CONCLUSION

In this paper we successfully applied animated computer simulation to analyze two different AGV control systems in the IC manufacturing facility. The simulation analysis identified AGV utilization, AGV congestion/traffic levels and wait times for local and global control AGV systems. The analysis results were used to make decision in choosing the correct type of AGV control system. Animation feature helped us resolve AGV deadlocks and bottlenecks. The results of the simulation and graphic animation was successfully presented to the management.

7. REFERENCES

AutoMod Users Manual, Version 3.1.1. AutoSimulations, Inc. Bountiful, Utah.

Hammond,G (1986). *AGVS at work - Automated Guided Vehicle Systems.* IFS (Publications) Ltd, Bedford, UK.

Pegden C.D (1986). *Introduction to SIMAN with Version 3.0 Enhancements.* Systems Modelling Corporation, Pittsburgh, Pennsylvania.

Pritsker A.A.B (1986). *Introduction to Simulation and SLAM II.* Second Edition, Halstead Press, New York.

Schriber, T (1974). *Simulation using GPSS.* John Wiley and Sons, Inc., New York.

AUTHOR'S BIOGRAPHIES

KOWDLE PRASAD is a Senior Industrial Engineer in the Factory Automation Group within Intel's Components Technology and Manufacturing organization. He has a Master of Science in Industrial Engineering from the Arizona State University, and a Master of Technology degree in Maintenance Engineering and Management from the Indian Institute of Technology in Madras, India. As part of the Material Control and Simulation Engineering Group within Factory Automation, Prasad is responsible for analyzing Intel's manufacturing processes, using simulation and other analytical techniques. He has over 4 years experience.

Kowdle Prasad
Intel Corporation
M/S CH2-31
5000 W. Chandler Blvd
Chandler, AZ 85226
(602) 961-8698

MADHAV RANGASWAMI is a Senior Industrial Engineer in the Factory Automation Group within Intel's Components Technology and Manufacturing organization. He has a Master of Science degree in Industrial Engineering from the University of Florida, and a Master of Engineering degree in Mechanical Engineering from the Indian Institute of Science in Bangalore, India. As part of the Simulation Engineering Group within Factory Automation, Madhav is responsible for analyzing Intel's manufacturing processes, using computer simulation and other analytical techniques. He has over 4 years of experience in the semiconductor field.

Madhav Rangaswami
Intel Corporation
M/S CH2-31
5000 W. Chandler Blvd
Chandler, AZ 85226
(602) 961-5364