Proceedings of the 1994 Winter Simulation Conference
ed. J. D. Tew, S. Manivannan, D. A. Sadowski, and A. F. Seila

THE AMP-AKZO COMPANY'S SIMULATION-BASED FINITE CAPACITY SCHEDULING SYSTEM

Mark A. Flower

AMP+AKZO Company
PO Box 700
West Lane
Aqueboque, NY 11931

Michael C. Cheselka

AT&T ISTEL
Visual Interactive Systems Inc.
25800 Science Park Drive
Beachwood, OH 44122

ABSTRACT

The AMP-AKZO Riverhead Circuits Division is responsible for manufacturing printed circuit boards. Scheduling problems have resulted from both physical and operating constraints.

The AMP-AKZO PROVISA Scheduling System (APSS) was developed to better manage order due-date and plant throughput performance. The fully integrated system is made up of the Production Control Inventory System (PCIS), and the PROVISA scheduling system. The APSS automates the majority of routine scheduling decisions, and provides capabilities to recover from unplanned events, such as machine breakdowns. Furthermore, the system provides "what-if" analysis capabilities to test scheduling alternatives and opportunities.

The APSS is capable of forecasting very accurate schedules and can be used as a continuous improvement tool. Since released to production in February 1994, the scheduling system has improved the company's overall scheduling effectiveness. Consequently, AMP-AKZO has reported an increase in both order due-date and plant throughput performance.

1 DEFINED SCHEDULING PROBLEM

Scheduling problems resulted from several compounding factors. 80% of the customer delivery requirements change in a one week time period. Due to this high rate of change in customer demand, an enormous amount of work in process (WIP) was placed on the floor to help buffer the churn in the order requirements. This high level in WIP has lead to long manufacturing cycle times. Compounding the problem is the fact that there are more than 125 different process flows that lead to a wide variety of end product features. Because of the different process routings it was impossible to accurately project work center schedules for all of the 15 process areas for greater than a 16 hour period.

These issues resulted in inaccurate projections as to when product would be completed and available for shipment. As a result AMP-AKZO Riverhead Circuits decided that a finite scheduler would allow us to address all of the issues and improve our delivery performance to our customers.

2 PLANT BACKGROUND

The load on the AMP+AKZO Riverhead Division is defined by the number of panels released daily from material issue. This load varies from day to day, which can be attributed to the actual order mix of incoming lots, and other economic factors. Typically, AMP+AKZO receives several new orders per week. The plant maintains 61 thousand of panels in WIP, and processes 45 hundred of panels per day.

2.1 Scheduled Operations

There are approximately 125 different part routings scheduled at the AMP+AKZO Riverhead Division. As customers change part specifications, the actual number of routings will vary over time.

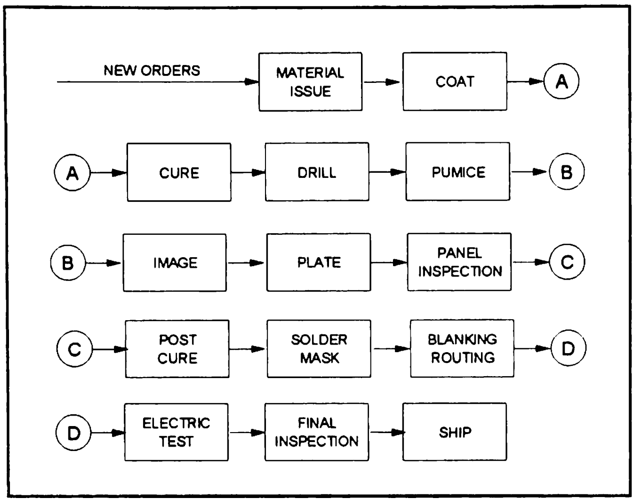

Figure 1: Process Flow

A routing is made up of about fifteen major process steps. These steps are shown graphically in Figure 1. Based on the customer specification, the actual number of steps and processes may vary. All part routings are maintained by the PCIS by the process coding system. Listed below is a description for each step required to manufacture a circuit board.

(1) Material Issue - Firm customer orders (units of lots) are queued in material issue until released to the shop floor for manufacturing.

(2) Coat - A two pass process that coats both sides of a panel with an adhesive material.

(3) Cure - A conveyor styled oven, capble of curing the adhesive to multiple panel simultaneously.

(4) Drill - CNC machines drill holes in the circuit boards.

(5) Pumice - A cleaning process that removes panel drilling burrs.

(6) Image - A process that applies the circuit image onto the panel.

(7) Plate - A process that adds the copper circuitry to the panel according to the applied image.

(8) Panel Inspection - Visual inspection process.

(9) Post Cure - A process used to dry panels.

(10) Solder Mask - A process that adds a protective mask over the circuitry.

(11) Solder - A process used to apply solder to any exposed copper surface.

(12) Blanking/Routing - A process that separates a panel into individual circuit boards.

(13) Electrical Testing - A process used to check individual circuit board continuity.

(14) Final Inspection - Visual inspection process.

(15) Shipping - Ships to regional customer warehouses.

3 PROJECT GOALS

The mission of the project was to increase on-time delivery performance to a world class manufacturing level, such that the AMP-AKZO Company can diversify its business to increase total revenue and profitability.

3.1 Project Objectives

The AMP+AKZO PROVISA Scheduling System was designed to achieve the following objectives:

* To accurately set promise due dates in the Production Control Inventory System.

* To automate the majority of routine shop floor scheduling decisions consistent with all operating constraints, rules and objectives.

* To provide decision support capabilities relative to exceptions. For example, machine breakdowns, rush orders, etc.

* To extend the scheduling horizon to several weeks so that a comprehensive strategy for all orders is generated.

* To provide additional information to anticipate scheduling problems and opportunities. Concurrently, to provide simulation-based "what-if" analysis and continuous improvement capabilities to evaluate scheduling alternatives.

4 SYSTEM DESCRIPTION

The AMP+AKZO PROVISA Scheduling System is comprised of two main modules:

* PCIS Data Collection Program
* PROVISA Scheduling System

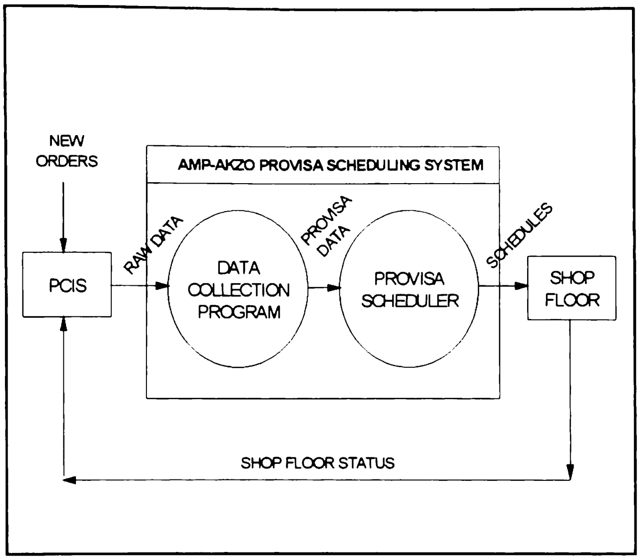

Figure 2: System Overview

The PCIS is responsible for managing all AMP+AKZO Riverhead orders. This includes adding new, maintaining existing, and removing old orders from the PCIS database. In addition, the PCIS is responsible for tracking all work-in-process and shop floor status.

On a daily basis, raw PCIS data is acquired and formatted by the data collection program. The PROVISA data is then transferred to the PROVISA scheduler. Once updated, PROVISA uses simulation-based finite capacity technology to generate the shop floor schedules. The schedules are fine tuned and distributed to the shop floor for execution. Figure 1 shows an overview of the APSS and the cyclic nature of the system.

4.1 System Data Flow

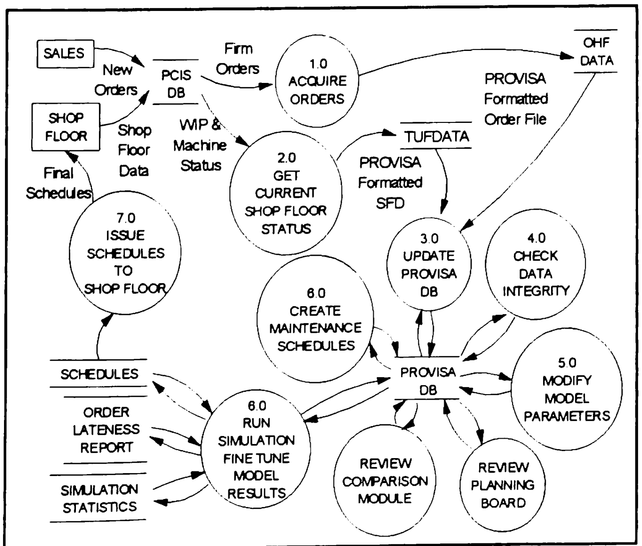

Figure 3: APSS High Level Data Flow

The data flow diagram, shown above in Figure 2, illustrates the basic APSS functionality and data relationships. Structured Data Analysis notation is used where the bubbles represent system functions or actions, and the horizontal bars represent data stores. The arrows indicate the data flow between functions and data stores.

The PCIS database (DB) is a combination between AMP+AKZO's current orders, and shop floor status information. Firm orders, WIP, and shop floor status information is pulled from the PCIS DB daily or as needed by the scheduler. The order information is formatted to the required PROVISA OHFDATA file specification, and the shop floor status and WIP data is formatted using the TUFDATA file specification. Next, the files are imported into the PROVISA DB. This is accomplished by first deleting all the old PROVISA orders and shop floor status data, and then loading then new information.

Using the PROVISA model validation facility, the user checks for potential data problems to ensure total scheduling accuracy. If a data integrity problem is identified, the conflict is resolved before invoking the PROVISA scheduler. Potential data integrity problems are:

* A referenced shop floor work order not found in the OHFDATA file.
* An order in the OHFDATA file with missing key information.
* A new part routing not found in the part routing definition file.

Once the PROVISA database is validated, a first pass schedule is generated. Model output reports include:

* Department schedules
* Order lateness report
* Simulation statistics

All the output reports, along with the PROVISA planning board, are used to review the quality of the current schedule. The planning board is a graphical display of the generated schedule in a Gantt chart-like layout. For evaluating multiple scheduling scenarios, the PROVISA comparison module is used to graphically compare key scheduling parameters such as:

* On-time delivery performance
* Utilization of key equipment
* Cost of the schedule, etc.

Scheduling with the APSS can be an iterative process. A schedule is generated, reviewed, and then if needed, fine tuned. Schedule fine tuning is done by adjusting principle model parameters, such as:

* Rules and rule parameters
* Planning horizon
* Work patterns
* Resources
* Machine efficiencies

This process is repeated until the best possible schedule is generated, and the schedules are issued to the shop floor for execution.

5 MODELING APPROACH

The approach taken in implementing the APSS was to create a model of the Riverhead Circuits operation that mimicked the manufacturing process as closely as possible. In doing so there are several key elements that needed to be defined. They are:

* Customer Orders
* Work Units
* Resources
* Part Routings
* Shop Floor Data
* Resource time availability

The objective of the model is to establish schedules for each of the work centers that can be used to achieve the best on time delivery performance possible. The models can be run as many times as desired by the scheduler in order to try different scenarios that will result in optimal results. These what-if scenarios can analyze changes in resource availability, the impact in expediting specific jobs on the entire schedule, and testing different priority rules that sort the order in which jobs are to be processed.

Accurate representation of the factory elements is key to the generation of realistic schedules. PROVISA is a flexible modeling software package that will allow most processes to be defined quickly and easily. In the case of the APSS these elements were populated with information that best described the process as it is today.

In developing the model for the APSS we decided that instead of developing part routings for each individual part we would instead create generic parts that specify a specific routing and then have an order defined as this generic part and provide additional information as to the specific customer part number by use of the order user field. This approach as resulted in 125 generic routings and part numbers. This reduced the number of part numbers for the APSS by more than 200, and it also help to prevent 5 - 10 new customer parts numbers that are created each week.

Each customer part number is described in a 12 digit operation process code that is used to describe the unique characteristics of each part. In examining this process code we realized the only 7 digits described unique operations, with the other 5 only being minor variations on common process. This resulted in identifying a part from PCIS and converting it into the following format:

Table 1: PCIS Part Identification

CHY	910	I	160
Customer Name	Part #	Rev	Lot #

Table 2: APSS Part Identification

2	0	1	1	1	1	1
Material Type	Final Fab\V Score	Image Type	Screen Mask Type	Legeng\Carbon	Blank\Rout	Solder

An order user field as attached to each APSS order that carried the information from PCIS so it was very easy to cross reference between the two systems.

The APSS part identification system is the critical means of verifying the identity of both the part type and the routing. The process routes were developed from the part numbers in that each position in the part number represented a unique operation in a specific work group, center or station. The part routings were then developed to follow the exact manufacturing process that is prescribed in the PCIS operation sheet program.

The key to the success of using this format is that the Process Code establishes,not only the part number, but the part routings is correct. If the process code does not match the actual part routings and the operation sheet on the factory floor, the APSS will not run. In the start-up process of the APSS we found that the creating the logic of the simulation was only 20% of the total project time, the other 80% was spent correcting bad information currently resident on the PCIS.

6 SCHEDULING LOGIC

Developing good sort rules is the means to implementing a successful simulation project. Historically at AMP+AKZO, Production Control has established the master schedule, and the work group supervisors have generated the detailed schedules for their individual departments. For most cases this has been effective, however some delivery dates have been missed because of a emphasis on throughput, and not due date performance. This philosophy of meeting the production throughput requirements had merit, however, at the same time the scheduler can use the APSS as a tool to show why some days throughput requirements may not be as great as other days depending upon the actual cycle time of a particular order. The APSS also gives the supervisor a detailed schedule for the work group that he/she can fulfill and be measured against.

The APSS uses several different sorting procedures. Jobs that are considered hot, either because of their due date requirement or because of new part or special process receive a priority code of 1. In the *BASICSORT* rule logic, all jobs with a priority code of less than 20 would be processed first in order of their due date. After all the "hot " jobs had been completed, jobs would the be sorted by the operation float time, (the value of the operation due time minus the average set up time plus the cycle time).

The drilling department sort rules were fairly complicated. Although all orders were routed to the same group, stations within the group were only capable of handling specific product. Rules were developed to look at the type of material that was to be drilled, the time for each drill cycle, and the size of the panels to be drilled. Rejection logic was the applied to insure that the correct orders could only be drilled on appropriate machines.

MARKV

```
    VARIABLE {
    HOTLIST            NUMBER    ; Hot List Priority Code
    }
    ;**************************
    ;*** Rejection Logic ***
    ;**************************
    ; *** Check if lot is Mass Lam ***
    if ( work_unit() != "1309" and substring(PRSCODE[batch],1,1)
= "2" ) then
        reject
    else
    ;*******************
    ;*** Sort Logic ***
    ;*******************
    ;*** Get the lot priority ***
    HOTLIST = batch_priority()

    if (string_to_number(substring(PANEL_SIZE[batch],1,2))) =
18 then
    return order_due_time() + 800000
    else
        if (HOTLIST <= 20) then
        return order_due_time()
        else
        if jobs_in_queue_at("291") > 15 and
(substring(PRSCODE[batch],4,1) = "1" and this_op_number != 700)
        return (400000 + order_due_time())
        else
        if jobs_in_queue_at("290") > 15 and
(string_to_number(substring(PRSCODE[batch],4,1)) >= 3 and
this_op_number != 700)
        return (400000 + order_due_time())
        else return order_due_time() + 100000
        endif
        endif
    endif
endif
endif
}
```

In the imaging areas it was important that setups be minimized. As a result, sort logic was developed to group similar part numbers together to minimize set ups. This was done only within a certain operation due date window in order not to impact overall due date performance of other jobs.

The plating process was also unique, in that certain jobs could not be put into work if the current day was between Thursday and Sunday. This product could only be produced during the week day when the process was guaranteed to run continuously.

PLATESORT

```
    VARIABLES
    {
    HOTLIST            NUMBER    ; Hot List Priority Code
    IMAGETYPE            NUMBER    ; Image Type Number
1,2=PP, 3,4=SP
    }

    ;*******************
    ;*** Sort Logic ***
    ;*******************

    ;*** Get the lot priority ***
    HOTLIST = batch_priority()
   IMAGETYPE =
string_to_number(substring(PRSCODE[batch],4,1))

    ;*** Determine if PP Job can be Activated ***
    if     ((sim_day_of_week = DAY_OF_WEEK) and
```

```
(IMAGETYPE <= 2))
            reject
    endif
    if      (HOTLIST <= 20) then
            return order_due_time()
    else
            return (100000 + order_due_time())
    endif
```

After all the sort rules had been developed, the simulation was run and schedules were developed. These schedules were scrutinized by the work group supervisors, and with their feed back the scheduling methodology was improved.

7 MAJOR BENEFITS

The benefits of the APSS are numerous. The most important benefit is the ability to generate realistic schedules that accurately predict department workload, and order completion dates. This has resulted in better on time delivery performance. With the constant changes in the release requirement from our customers we can now quickly see the impact of the changes and accurately respond to the customer as to how we can meet these new requirements.

This system has also allowed AMP+AKZO Riverhead Circuits to reduce the amount of work in process (WIP). The APSS schedules work to be released according to the operation float time of a particular order. This has allowed us to release the job on a specific day with a predicted cycle time, instead of releasing the job several days early and hoping it will be completed on time. In the first month of operation we have achieved the following results.

Table 3: Project Results

Measurable	Before APSS	After APSS
Lead Time	6 wks	4 wks
WIP	78000	61000
Thruoghput/day	3800	4500
Ontime delivery	90%	98%

The impact on the shop floor has been dramatic. Schedules were constantly being changed as new orders were coming into a work center. Now with the APSS, the work group sees exactly what will be arriving into the area over the next several days, and at what times. This allows ample time to order any tools that may be necessary to run the job. This has resulted in a reduction of confusion and lost time.

The impact on the Production Control department has been dramatic as well. In the past it would take at least 24 - 48 hours to understand the impact of customer order changes. It was then just a guess as to how well the shop could respond to these changes, and what effect these changes had on other orders that were already in work. Now with the APSS it takes less than 2 hours to fully understand the impact of the changes and be able to respond to the customer with anticipated delivery dates. This 2 hour process includes 1 hour for transferring the data from the PCIS to PROVISA, and the to run the simulation. The second hour is spent analyzing the data, and making any minor changes to the schedule that may be needed, and the finally releasing schedules to the individual work centers.

From the sales side of the business, more accurate decisions can be made as to whether a rush order should be taken, and what impact it will have on other work that is already promised. The salesperson can now decide whether a premium should be charged for a rush order. Additionally we can see if the request date can be met, if other jobs will become late as a result, and the financial impact to the company. These intelligent decisions were never able to be made in the past, and they were done strictly on an instinctive level.

The final benefit is that the APSS has forced that data in PCIS to become more accurate. In the past the impact of inaccurate data was difficult to measure. Because data integrity is the key to successful simulations, it has forced AMP+AKZO Riverhead Circuits to become more disciplined in its information and operating systems.

8 CONCLUSION

AMP+AKZO Riverhead Circuits is a contract manufacturer of printed circuit boards. In the past Riverhead Circuits has suffered from poor delivery performance, and long cycle time. The inability to generate a reliable schedule was the major cause of these problems. As a result AMP+AKZO Riverhead Circuits decided that a finite capacity scheduling simulation package would improve the manufacturing performance. The system chosen was PROVISA from AT&T ISTEL.

The AMP+AKZO PROVISA Scheduling System was developed to create schedules to better manage order due-date and plant performance. The system imports information from the existing shop floor control system, and then simulates the manufacturing process to determine projected order delivery dates. The APSS also provides "what-if" capabilities to test the impact of order changes, machine breakdowns, and any other unexpected event.

The project goals set for the APSS have been realized. On time delivery performance has improved, WIP has been reduced, and cycle times have been shortened. Schedules are now generated on a routine basis for each work center that provide the supervisor with what is reasonably expected to be produced in a given time frame.

REFERENCES

Flower, M.A. 1993. *An Evaluation of How to Reduce Manufacturing Cycle Times Using Simulation Models.* Hawthorne, New York: Polytechnic University .

Cheselka, M.C., Flower, M.A. 1993. *AMP+AKZO Technical Qualification Report.* Cleveland, Ohio: AT&T ISTEL.

AUTHOR'S BIOGRAPHY

MARK A. FLOWER is the Production Control Manager at AMP+AKZO Riverhead Circuits. He holds a Bachelor of Arts in Chemistry from Drew University, and a Master of Science from Polytechnic University. His interests are in the area of cycle time reduction and factory simulation.

MICHAEL C. CHESELKA is a PROVISA Technical Consultant at AT&T Istel Visual Interactive Systems, Inc. He holds a Bachelor of Science Degree in Mathematics from the Defiance College, and Master of Science in Computer Science from the Kent State University. He has managed several projects applying simulation and finite capacity scheduling technology to a wide range of manufacturing environments.