

Critical Path Supply Chain Analysis™
A White Paper from Wright Williams & Kelly, Inc.

Daren L. Dance,
Vice President of Technology
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Effective control of the flow of components and materials to the manufacturing or assembly line is a key to cost effective manufacturing. In an optimal supply chain, materials and components are received just-in-time to enable lean manufacturing, i.e., the right product, in the right place, at the right time, at the lowest possible cost.

Michael Simpson, production controller for Nissan Motor Manufacturing U.K. claims, "Once a [delivery] schedule can be met more than 90 percent of the time, Nissan can work with its suppliers to time their shipping schedules in sequence with the build schedule. This reduces inventory on the assembly floor and in the suppliers' warehouses as well."¹

What's the Problem?

Some indications that supply chains have problems include:

- Growing inventories of components and materials
- Growing costs for expediting or accelerated delivery of components or materials shortages
- Growing costs for return or restocking of unneeded components or materials
- Growing costs of scrapping obsolete inventory

In other words, the wrong product, in the wrong place or at the wrong time, at higher than expected cost. How often is one of these problems the case?

Following are quotes from recent press releases that indicate that frequently supply chain management has problems:

"While supply chain management has been the catch phrase since the [semiconductor] industry's last bloodletting..., so many companies were caught off guard by the latest slowdown in

¹ Ephraim Schwartz, "Nissan Drives Down Costs with Optimization Software," *INFOWORLD*, 26 March 2001, p. 62.

demand that it's clear people are not practicing what they preach."²

"There seems to be a divorce between the financial decision . . . and the impact on the operations side."³

"I'm very alarmed at the lack of responsibility and ownership we see regarding . . . what has become a large, massive pool of inventory... We have an [industry] inventory problem."⁴

"Devoid of intelligent supply chain management, . . . companies fall victim to distortion in their customer's supply chain and over react to OEM's forecasts because they are concerned about shortages."⁵

"With tons of excess inventory sitting in warehouses, the electronics industry is once again grappling with an inefficient supply chain management systems and rediscovering that there are no easy answers."⁶

From these quotes, it is clear that supply chain management problems are common. It is not at all clear just what the problems are. Without clearly identifying your supply chain problems, any supply chain solution is likely to fall short of correcting the problems over the long-term.

What is Critical Path Supply Chain Analysis™?

Questions that supply chain management should be able to answer include:

- Where is the weak link or path in my supply chain?
- What is the risk that my supply chain will not deliver as expected?
- What is my risk if demand changes?
- What are the best alternatives if problems occur in my supply chain?

² Christa Souza, "Supply-chain management didn't avoid downturn surprise," Electronic Business News On-line, 3/13/01

³ Carlos Antonio Alvarenga, KPMG Consulting, quoted by Jennifer Baljko Shah, "Outsourcing, supply-chain complexity breed confusion..."Electronic Business News On-Line, 2/27/01

⁴ Harriet Green, Arrow Electronic, quoted by Jennifer Baljko Shah, "Outsourcing, supply-chain complexity breed confusion..."Electronic Business News On-Line, 2/27/01

⁵ Clair Serant, "EMS providers need smarter tools to avoid inventory snags," Electronic Business News On-Line, 4/3/01.

⁶ Bolaji Ojo, Christa Souza, and Jennifer Baljko Shah, "Downturn exposes supply-chain flaws," Electronic Business News On-line, 3/19/01.

Not all supply chain paths are equal! Some are no problem at all. Other paths are replete with interruptions and variances. What's the difference?

Critical Path Supply Chain Analysis™ is a method that uses capacity and simulation models to identify the supply chains with the most potential to interrupt manufacturing and to explore the risks of interruption for critical supply chains. This analysis becomes the foundation for a corrective supply chain solution.

As an example, WWK has modeled a semiconductor supply chain from wafer fabrication through final assembled board test using Factory Explorer® discrete event simulation software using the following stages:

- Wafer Fabrication
- Wafer Test
- Device Assembly and Packaging
- Device Test
- Warehouse and Distribution
- Board-level Assembly
- Board Test

For each stage in the supply chain we consider cost, yield, variability and cycle time. Each stage also includes transportation and handling to the next stage. Some of the management questions that can be answered from this type of model include:

- How much lead-time must be provided to insure sufficient supplies of tested boards?
- How many wafers should be started to provide sufficient supplies of tested boards?
- How much time could alternate sources save?
- At which stages would alternate sources be most beneficial?
- How much time could accelerated transportation methods save?
- What is the average cost per good board shipped (Cost of Ownership)?

We can use this basic model for “what if” analysis to determine impacts such as process time improvements, yield busts, and transportation interruptions. For example, given a distribution of demand for finished memory boards, we could estimate appropriate production requirements at wafer fabrication, die assembly and distribution stages to insure timely delivery.

What does a Critical Path Supply Chain Analysis™ Look Like?

Figure 1 shows the percentage of total available time that each stage requires for processing its portion of the supply chain. In a more complex simulation this chart would show the impacts of rework, downtime (repair), and other interruptions to the manufacturing process.

For a simple supply chain, this example is rather well balanced. The closest to bottlenecks for this supply chain are wafer test (Prober), assembly, final board test. Even though the warehouse has the least free time, it is only operated 12 hours per day so it is not really a potential bottleneck. This is shown in Figure 1 as 50% closed time.

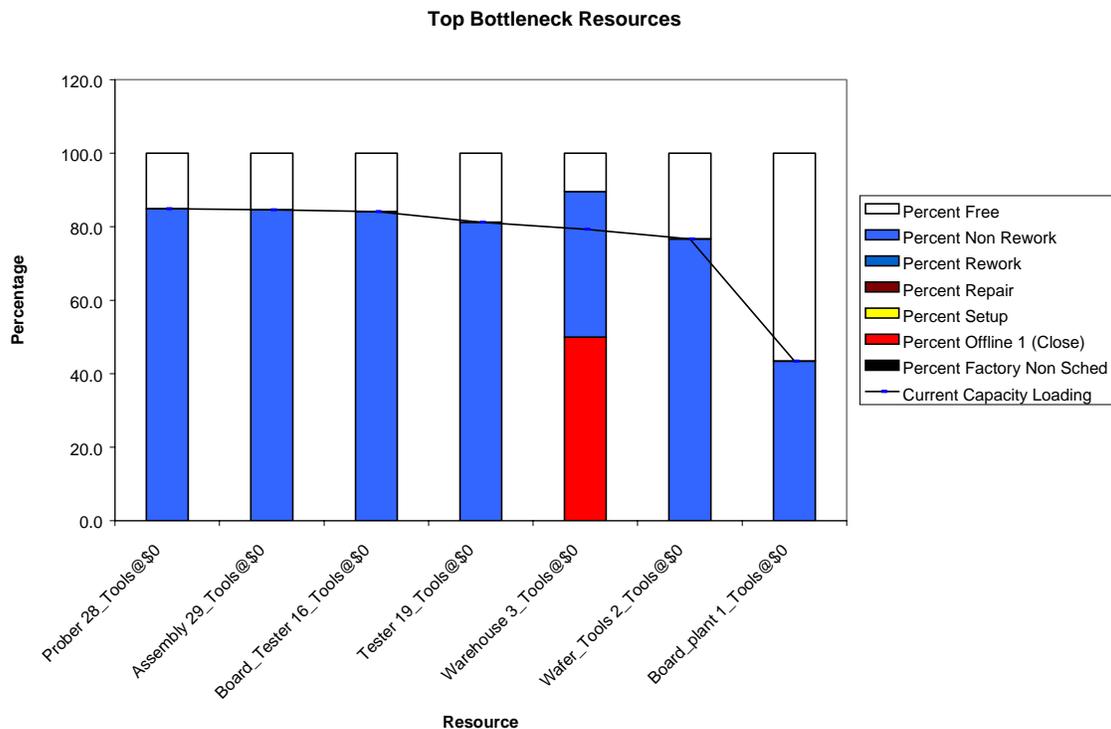


Figure 1: Bottlenecks

Cycle time results for the 15 month duration of the simulation are shown in Figure 2. In this trend chart, the supply chain output has been divided into a number of equal length time periods. The minimum, maximum, and average lot cycle times are plotted for each time period. The first 2400 hours (just over 3 months) have not been included in the statistics as the simulation is filling the supply chain. The minimum and average cycle times per period are quite stable, but the maximum is highly variable, *even with very stable demand*. The lots with large cycle times are the sources of most supply chain and forecasting problems.

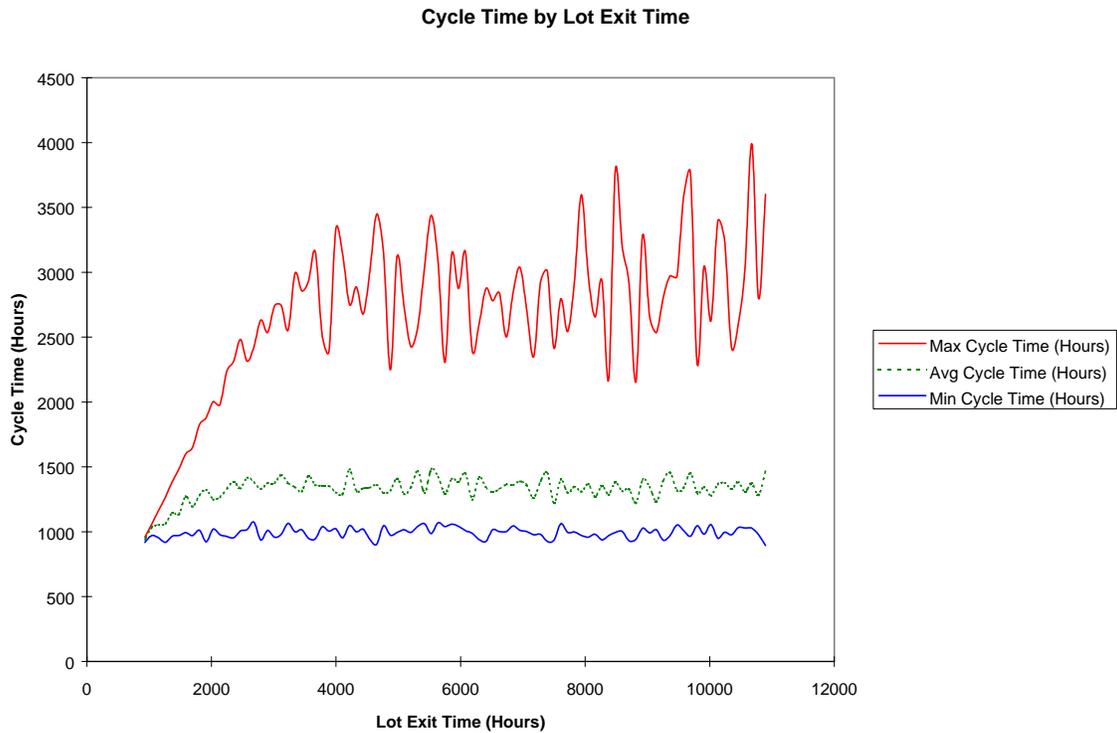


Figure 2: Cycle Time History

Lot cycle times can also be analyzed from other perspectives. See Figures 3 and 4. Figure 3 is a histogram of lot cycle times, which illustrates the cycle time statistics from this simulation.

Table 2: Cycle Time Statistics

Theoretical Minimum Time	886 hrs
Minimum	895 hrs
Mode ⁷	1,120 hrs
Median (50 th %)	1,184 hrs
Average	1,400 hrs
Maximum	4,000 hrs

As can be seen in Table 2, the minimum time from the simulation is very close to the theoretical minimum time. The average delivery time of 1,400 hours is about 1.6 times the theoretical minimum, but the maximum is about 6.6 times theoretical.

⁷ The peak in Figure 3.

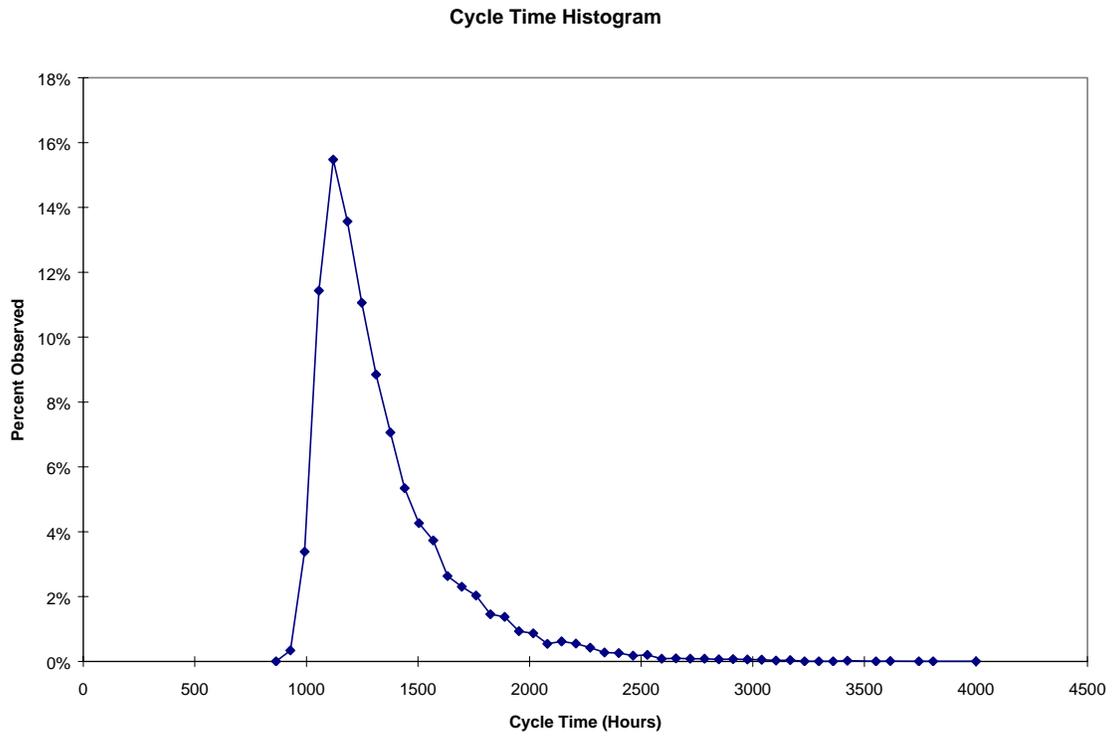


Figure 3: Cycle Time Histogram

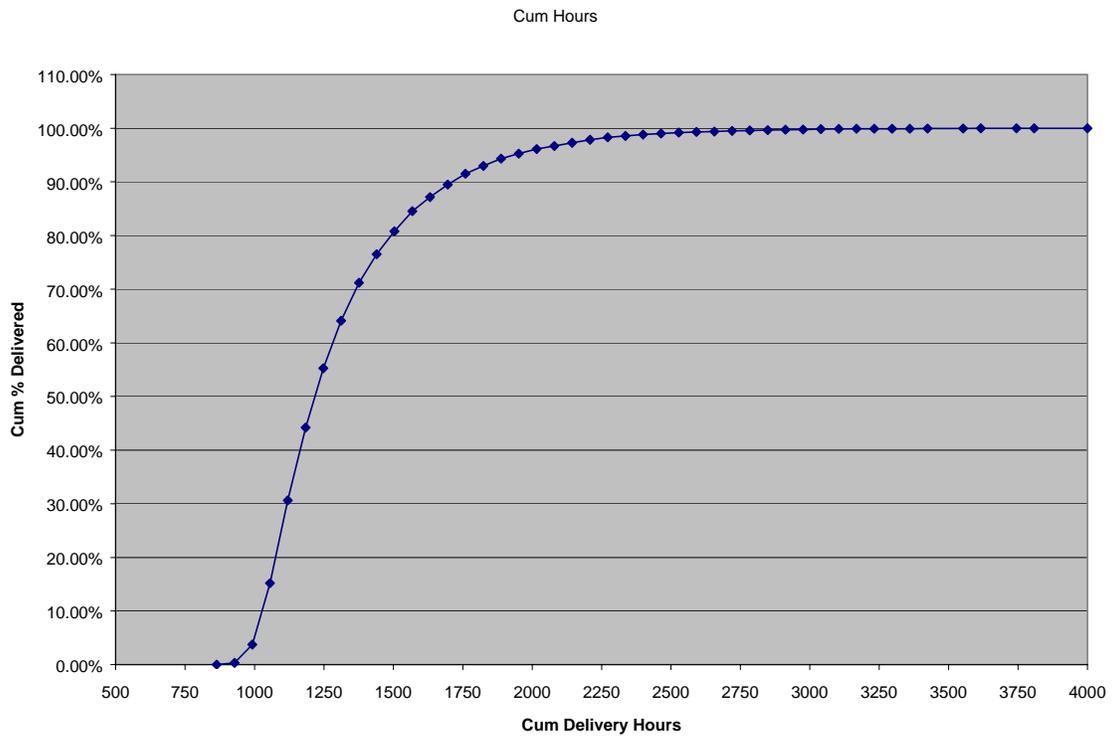


Figure 4: Cum Delivery Percentage

Figure 4 shows the cumulative probability of lot delivery in hours. This chart is created from the integral of the histogram curve in Figure 3. For example, the minimum cycle time from the simulation is less than 1,000 hours, but Figure 4 shows that there is only about a 5% probability of deliveries in 1,000 hours or less.

Cycle time variability has a large cost. Even though the median cycle time is about 1200 hrs, Supply Chain Management would need to plan for a cycle time of about 1700 hours to achieve a high probability (90%) of meeting the needs of the supply chain. That additional 500 hours is a cycle time that is nearly 3 weeks longer. The additional inventory in a 3 week longer cycle time represents nearly \$500,000 in finished goods.

Delivery on the 10% of material with cycle times greater than 1700 hours will account for much of the expediting headache and cost for this supply chain. Even if a planning cycle time of 1700 hours is used, there is still a 1 in 10 chance that a just-in-time board assembly manufacturing operation would be halted for lack of material. Reducing this risk requires a minimum inventory in the warehouse of about 1.2 million units, representing over \$11 million.

Benefits of Critical Path Supply Chain Analysis™

This simple example shows the power of modeling a supply chain. This supply chain is well balanced and on average runs at about 1.6 time the minimum possible. However, even with this near ideal example, Figure 2 shows the high variability of maximum delivery times per week. This variability compounds supply chain forecasting and management problems.

In this simulation, the 3 weeks of added cycle time needed to achieve 90% on-time deliveries represents nearly \$500,000 in finished goods. However this supply chain still has a 1 in 10 risk of halting a just-in-time manufacturing operation. Addressing that risk requires an inventory investment of over \$11 million. This is an additional total investment of \$11.5 million for a single product supply chain with very stable demand.

Further details in the Factory Explorer® model of this supply chain identify sources of variability, impacts of yield loss, and costs of operations. This information can be used to improve the ability to accurately forecast the performance of this supply chain and reduce financial risks for all supply chain stages.

We have used a simulation of a simple supply chain with stable demand to illustrate the innate variability of supply chains and the impact of this variability on forecasting and management of supply chain performance.

Critical Path Supply Chain Analysis™ from Wright Williams & Kelly can help you answer these and other important supply chain questions.

- What will happen when demand changes?
- What do the supply chains of other required components and materials look like?
- How do these multiple supply chains interact?
- How accurate are the forecasts you receive from your customers and suppliers?
- What is the risk of these forecasting issues?

For more information, please contact:

Wright Williams & Kelly
6200 Stoneridge Mall Road, 3rd Floor
Pleasanton CA 94588
+1-925-399-6246
+1-925-396-6174 (fax)
info@wwk.com