Proceedings of the 1998 Winter Simulation Conference
D.J. Medeiros, E.F. Watson, J.S. Carson and M.S. Manivannan, eds.

THE VALUE OF SIMULATION IN MODELING SUPPLY CHAINS

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ABSTRACT

In business today, re-engineering has taken a great deal of the cost out of internal corporate processes. Our factories and internal support organizations have become much more efficient, but there is still a great deal of unnecessary cost in the overall delivery system, or the supply chain. Although your corporation does not own all of the supply chain, the entire chain is responsible for product delivery and customer satisfaction. As one of several methodologies available for supply chain analysis, simulation has distinct advantages and disadvantages when compared to other analysis methodologies. This paper discusses the reasons why one would want to use simulation as the analysis methodology to evaluate supply chains, its advantages and disadvantages against other analysis methodologies such as optimization, and business scenarios where simulation can find cost reductions that other methodologies would miss.

1 INTRODUCTION

Business Process Re-engineering (BPR) continues to be a driving force in the improvement of the operations of many large companies. BPR has its basis on a very simple concept, simplify. The idea is that the more simple an organization, the better material and information will flow through the system. This concept has been a driver for companies using some traditional operations research optimization methodologies as they never have before. Especially in the planning and scheduling area, optimization is enjoying a growth that was unimaginable just a decade ago. One simply has to look at the success of i2 Technologies, Manugistics, Aspen Technologies, Chesapeake Decision Sciences (which was recently bought by Aspen), and others who are showing extraordinary growth. i2, perhaps the leader of this group, has seen revenues roughly double every year for the last 5 years.

Yet for all its success, Manugistics acquired Tyecin Systems, a simulation company that has specialized in the simulation and scheduling of semiconductor fabs. Yet in Manugistics press release annoucing the merger, the word simulation was not mentioned. Rather, Manugistics decided to describe Tyecin as ”the leading supplier of advanced planning and scheduling applications for the semiconductor industry.”

In a similar move, Symix purchased Pritsker Corporation for $9 million. Although Pritsker Corporation has a long history in the area of simulation, Symix said that “the acquisition will make Symix the first enterprise resource planning (ERP) company to bring advanced planning and scheduling (APS) to midsize manufacturers.” The meaning is clear. Pritsker Corporation was bought for its simulation-based scheduling software and not it the general purpose simulation software.

What can we make of these acquisitions? For all their success, there are some supply chain and scheduling problems that the large supply chain software companies do not have a good solution for today. This is where simulation comes into play.

Throughout the remainder of this paper, we will discuss the use of optimization and simulation as tools for supply chain analysis. We will also discuss business drivers and scenarios where supply chain analysis is better accomplished using simulation instead of optimization.

2 WHY SIMULATION TO EVALUATE SUPPLY CHAINS?

2.1 Traditional Supply Chain Analysis

When taking the Production Planning, Scheduling and Inventory Control class at Texas A&M, we went through several fairly complicated multi-stage, multi-plant, multi-product problems that could accurately be described as a supply chain. In class, the traditional approach was a linear program whose objective was to minimize cost or maximize profit. In some problems, we may have used dynamic programming because the problem had stochastic demand. These problems had to be quite simple, usually single product, single-stage, just to make the problem tractable. Although these were classroom problems, the basic techniques are not much different from the implementation of supply chain algorithms in today's leading software. There may be a mixed-integer formulation of the problem or a "clean-up" algorithm after the optimization is finished to handle difficult rules that the user may put it, but underneath it all, it is still optimization.

While at SEMATECH, we developed the Manufacturing Enterprise Model (MEM). MEM is a global strategic planning tool for the semiconductor industry. Since its development in 1994, MEM has been customized by Motorola and is used throughout their semiconductor business. IBM has also customized MEM for their own use. Except for the time horizon (2 to 5 years instead of minutes or days or weeks), MEM is not unlike the major supply chain analysis products as far as the underlying methodology. To understand the scope of such a system, let me take a section from the MEM User's Manual.

MEM helps Sematech member companies make two- to five-year corporate planning decisions for all critical facets of manufacturing:

1. *Product allocation: Which products to make at which facilities in order to speed manufacturing and operate most cost-effectively.*
2. *Factory expansions: When to expand existing facilities and build new ones.*
3. *Factory closings: Which facilities to close and when to close them.*
4. *Major resource planning: How to plan for the acquisition of expensive major resources and how to eliminate bottlenecks.*
5. *Foundry (sub-contractor) management: Which work and which products to sub-contract to and from other manufacturers. The model will consider sub-contracting at all four stages of manufacturing: wafer manufacturing, wafer probe (testing), assembly, and chip testing.*

The way MEM helps make decisions is by finding the best answers to Eight Questions.

Q1 Meet Demand - Minimum Cost

Which products should we manufacture in which facilities to meet demand at minimum cost, without violating capacity?

Q2 Relax Demand - Minimum Cost

If we cannot meet demand with current capacity, which products should we manufacture in which facilities to make the most money, without violating capacity?

Q3 Meet Demand - Add Resources

If we cannot meet demand with current resources, what resources can we add (and when) at the least cost to meet demand, without building new facilities.

Q4 Meet Demand - Add/Expand Facilities

If we cannot meet demand with current four-walls capacity, what new facilities can we add at least cost to meet demand?

Q5 Relax Demand - Add/Expand Facilities

Allowing for expansion and addition of facilities, how can we maximize profit if demand does not have to be met?

Q6 Meet Demand - Minimize Cycle Time

How can we meet demand by minimizing cycle time when facilities and resources are fixed?

Q7 Add Resource - Minimize Cycle Time

With a limited amount of money to spend on resources, how can we add resources to meet demand and minimize cycle time?

Q8 Add/Expand facilities - Minimize Cycle Time

With a limited amount of money to spend on resources and facilities, where and when should we add resources and facilities to meet demand and minimize cycle time? (Ingalls, 1994)

How did we solve these problems? It was a mixed-integer program with different objective functions for each question. The formulas were non-trival, especially considering the multi-period, multi-product, multi-facility, multi-resource nature of the problem. However, it was achievable and its use in industry today shows the benefit it has for the semiconductor industry.

2.2 Optimization Misses Key Business Issues

I hope that you are thinking to yourself, "What more could someone want?" When we completed the MEM project, the team members thought the same thing. However, there are a couple of key business issues that this type of supply chain analysis does not handle.

First and foremost is "demand variance" or "forecast error". Due to my experience at Compaq, I have become convinced that no one variable effects the movement of material through a supply chain like demand forecast. Unless you are blessed enough to know your demand for several months or years in advance (like a government contract), the demand forecast is always changing, and sometimes drastically. What does the supply chain do in response? It starts moving material. If the demand forecast is up, the chain tries to produce more product in order to fill inventories up to their proper levels. This can mean overtime expenses, expediting charges, and other charges. If the demand forecast is down, then manufacturing sites go idle, materials already in inventory go obsolete, and costs already in the chain have to be absorbed. Optimization has no way of handling this problem. There have been some attempts, including robust optimization. However, robust optimization has not proven itself to be commercially viable.

The second key business issue is related to making Wall Street happy. The process has several steps, including:

1. The company announces earnings and makes “forward looking statements”.

2. Based on the “forward looking statements” and other information, the Wall Street analysts estimate the company’s earnings in the future, starting with the next quarter.

3. The stock price goes up (or down) based on the future earnings estimates.

4. The company announces the next quarter’s earnings.

    4.1. If the company does not meet the earnings estimates, the stock price plummets, the senior management are on the verge of loosing their jobs, and everyone’s stock options are worthless.

    4.2. If the company meets (or even exceeds) the earnings estimates, the stock stays stable.

5. Go to Step 2.

If this is your world, and your job is to be sure that you hit the earnings target, what are you worried about? You are worried about hitting the target. Exceeding it does not buy you much and missing it is catastrophic. If that is your environment, you manage the downside risks of the business. How does optimization help you with this? Frankly, it does not. The reason is that the plan that an optimization gives you may be a good one, but it is wrong. The assumptions that go into the model will not play themselves out over time. The demand will be different, the cost of materials will be different, the supply of key material will be different, everything will be different. In essence, you have optimized a problem that will never exist in reality. And because of the nature of optimization, <u>the optimal answer can change dramatically if there is a slight change in the inputs.</u> A manager must know that a plan is robust, meaning that the variance in the business will not drastically effect the overall answer.

2.3 How Best To Use Simulation for Supply Chain Analysis

There are three areas where optimization and simulation compete – scheduling, tactical planning, and strategic planning. These three areas have different advantages and disadvantages when it comes to using simulation.

Scheduling is typically a short time horizon with a limited scope, possibly one plant, at part number level. Resources are typically known and fixed. The demand either fixed, or known to an extent that it could be considered “firm”. Variance, though critical, can usually be dealt with on an exception basis. For scheduling applications that can be modeled with optimization techniques, optimization is clearly the better choice. In this case, simulation should be used when optimization cannot be used.

In tactical planning, time horizons are longer, perhaps up to several months in length. The scope is at least regional, and perhaps corporate-wide. The tactical plan is either developed at the part number level or an aggregate level, such as a family of products. Some resources, such as the location of manufacturing facilities, are fixed. Others, including what products are produced in which facilities, could be changed, but that would happen toward the end of the tactical planning horizon. Some capital could be bought and deployed toward the end of the tactical planning horizon. Most other resources are open to adjustment. Certainly, most materials have short enough lead times so that they are ordered during the tactical planning horizon. Labor can be hired, transportation can be procured, etc. But depending on your industry, the demand forecast could be simply a best guess. If the demand forecast is a guess, and you want to be sure that the supply chain will meet the demand without risking high amounts of obsolesence, then simulation is the best choice. If the demand forecast is firm in this time horizon, perhaps an optimization would be the best.

In strategic planning, time horizons are even longer, up to several years in length. The scope corporate-wide. The strategic plan is developed at an aggregate level, perhaps at the level of product divisions or product families. Basically, there are no fixed resources. Manufacturing sites can be opened or closed, any capital can be procured, product deployments are completely open, etc. The demand forecast is certainly a guess at this point. However, decisions with some of the largest costs to a manufacturing operation must be addressed in this time horizon. Primary among these decisions is manufacturing and inventory site locations, which includes the size of the facility, and the basic logistics infrastructure (if it is not already in place). Based on site location, future costs such as labor, taxes and tariffs are set. This is a point where optimization and simulation can both play a role. Because of the level of abstraction at the strategic level, an optimization can be used to help decide the location of new facilities and the closing of others. Based on the output of the optimization, a supply chain simulation can then be used to be sure the supply chain deliver product as expected. The simulation would help set inventory policies based on demand variability and demand risk. The simulation can also give a more realistic capital purchase plan, labor requirement, and a better overall cost estimate.

3 BUSINESS SCENARIOS WHERE SIMULATION IS THE BETTER TOOL

3.1 Too Complicated to Optimize

Despite the protests from the optimization crowd, there are some problems that can be too complicated to optimize. Even if we assume that variance does not exist, there are some problems that are very difficult for an optimization.

One type of systems that comes to mind rule based systems. To give an example of a rule-based system, let us consider a product allocation scheme that a company has for allocating constrained product among its customers. It is common to give certain customers (or a certain group of customers) a high priority for product. In this case, they may receive all of the product that they need, or simply a higher percentage of the product that they need as compared to those customers with a lower priority. This type of problem is difficult in an optimization unless it is highly correlated with the objective function. If it is not correlated with the objective function, then the optimization must be run iteratively, or a "clean-up" activity must occur in order to enforce the allocation rule. Either one of these is time consuming, and certainly non-optimal. Simulation is an excellent tool to evaluate the effectiveness of a given rule. Certainly, almost any rule can be modeled and the modeler can determine the system performance based on any changes in the rules.

3.2 Variance, Variance, Variance

This is the primary reason for using simulation over optimization. If variance is a key driver in your supply chain, an optimization will not capture the supply chain dynamics. Whether it is the number 1 reason on my list, demand forecast variance, or supplier reliability, or quality of incoming material, or any of a number of other variance problems, then optimization simply cannot handle it. Simulation is the tool.

To help drive this point home, let me use the demand forecast variance example. Let's say that today is December, 1998 and we are forecasting for April, 1999. That demand that we are forecasting is still 4 months away, but we must order long-lead time materials and perhaps start some production of our own for that demand. If we are in the window for ordering new capital to help produce the demand, we order more capital. The actual demand will not be known until April, 1999. How close is our estimate? It could be off by 10%, 25% or more. Regardless of how bad it may be, it is our best estimate and we have to run the business on it. Let's say that the forecast for April is 1000 units.

Now it's January, 1999. We're three months away from the real demand for April, and we revise our forecast. We've noticed some weakening in the market and we move the forecast downward to 800 units. Now we start canceling previous material orders, or we realize that we

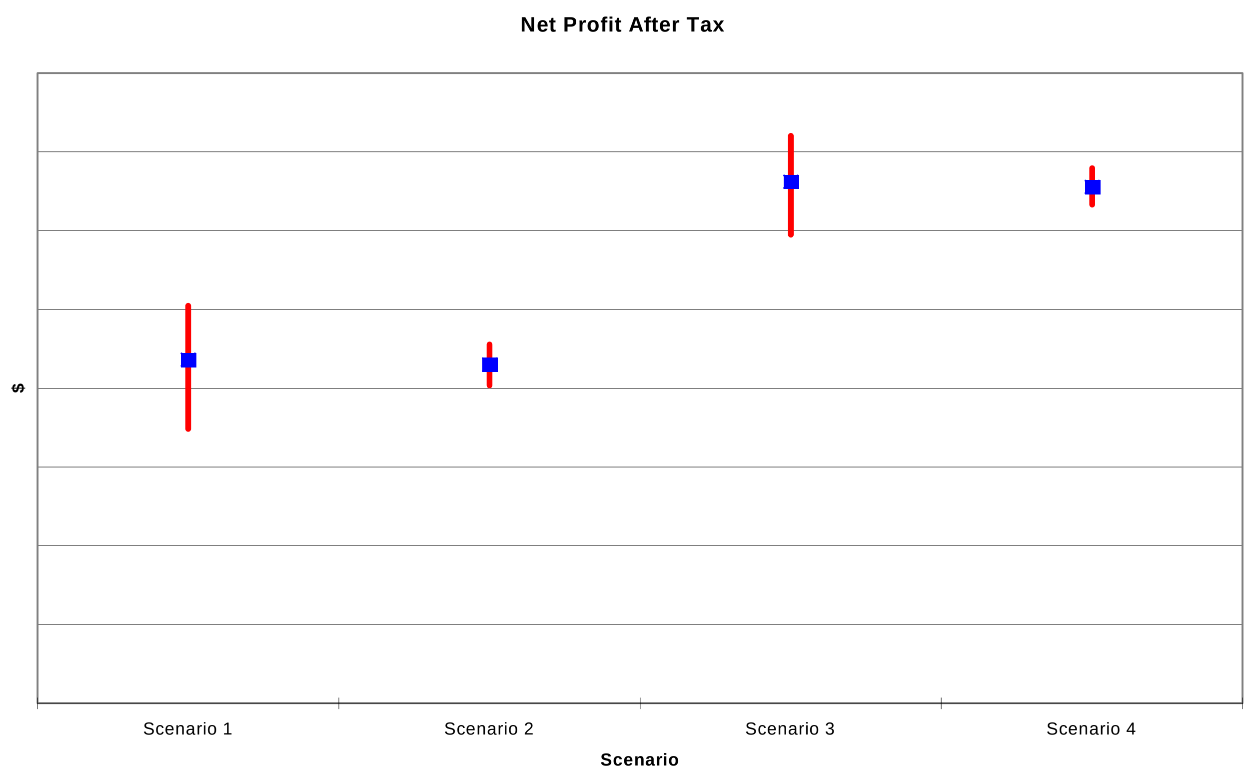

Figure 1: Example of Supply Chain Simulation Output

have excess raw material inventory. We halt production, or build "unneeded" inventory. The capital that we ordered in December will now be idle in April. The cost of the demand forecast variance continues to add up.

Obviously, this a very simple example of something that happens on a large scale in most major corporations. It is something that re-engineering will never solve, because forecasting is inherently wrong. The best of forecasting techniques will never pinpoint consumer demand. Re-optimizing the plan every forecast cycle will not keep the supply chain from reacting the way described above. This type of variance is the very reason that simulation is a key technology in evaluating supply chains.

3.3 Senior Management Could Care Less About Optimization

If you have heard your senior management use the word "optimize" in the last year, odds are that they are not using it in a technical sense. In a business sense, to optimize is to make something as good as you can, in spite of the variance. In business, an optimal supply chain delivers product even if the demand forecast is dead wrong. An optimal supply chain operates at an acceptable cost regardless of machine breakdowns, labor shortages, and material shortages. To senior management, an optimal supply chain is not optimal at all. An optimal supply chain is robust.

Earlier, we discussed the management need to manage downside risk. Given the outputs from four scenarios in Figure 1, which option would the senior management pick? Even though Scenario 3 is optimal from an average profit standpoint, its downside risks are much greater than Scenario 4. With Scenario 4's ability to control the variance of the supply chain, Scenario 4 would be chosen by management. Again, it is not the optimal decision, it is the most robust decision. Only through simulation would you be able to identify the most robust decision.

4 CONCLUSION

Although optimization has been the analytical tool of choice for supply chain analysis, there are business scenarios where variance plays such a large part that an optimization will not paint a realistic of the business. In these cases, simulation should be used. Using simulation will allow the user to understand the total cost of variance on the business, including labor variance, material obsolescence, material shortages, capital shortages, and most importantly, the demand forecast variance. These problems are common for any business that serves a dynamic market.

REFERENCES

Ingalls, Ricki G., 1994. Manufacturing Enterprise Model User's Manual. *SEMATECH.*

AUTHOR BIOGRAPHY

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