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ANALYTICS FOR SUPPLY CHAIN AND OPERATIONS

Background

In the last few years, there has been increased interest in using analytics in many areas of business. Part of the interest is driven by increased availability of data from Enterprise Resource Planning (ERP) systems as well as "big data" from sources such as social media or in the supply chain context from sensors and RFID tags. There are also more advanced technological capabilities to use analytics packages running on hardware that has larger memory and processing capacity or on the "cloud."

Analytics have always played an important role in supply chain and operations in the form of demand forecasting and planning, transportation routing, inventory optimization and network design. Analytics are also widely applied in related areas such as manufacturing, procurement and pricing. More recently analytics have been applied to supply chain segmentation, risk management, complexity reduction and manufacturing flexibility.

Many companies struggle with where to start investing resources in analytics. They may also be concerned with the possible disconnect between the business requirements and the analytics process. They would also prefer to have this capability in house so as to be able to continuously support operations with analytics.

OPS Rules has developed expertise that enables this process through its analyze/innovate/transform approach to Supply Chain and Operations Analytics.

- Analyze
    - ❖ Understand the challenges
    - ❖ Define the goals and related tradeoffs
    - ❖ Select the correct analytics modeling technology
    - ❖ Apply proven methodology to make sure the model corresponds to the customer's operations
- Innovate
    - ❖ Work with the customer to come up with the questions that will drive the scenario and trade-off analysis
    - ❖ Work closely with the customer to make sure the work corresponds to the needs and produces applicable results.
- Transform
    - ❖ Actionable results that can help achieve results fast
    - ❖ Transfer of knowledge to the customer team for long term productivity

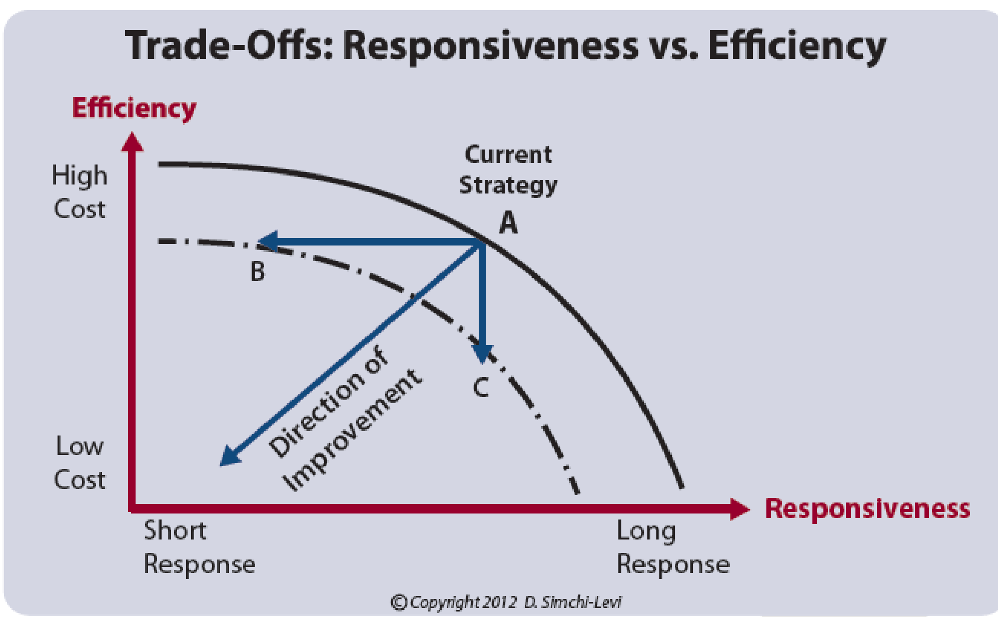
This methodology provides not only a proven way to achieve significant results, but also a way to transfer the knowledge and skills to the team in order to continue to benefit from this approach.

Supply Chain Tradeoffs

When starting a supply chain analytics project, there are several important questions to consider foremost of which are the goals and specific plans that are related to achieving those goals. Creating a supply chain strategy is fraught with tradeoffs – between responsiveness and efficiency, flexibility and cost, inventory and service levels, risk and cost, quality and price and many more. In addition, different products and channels can have different characteristics requiring different solutions that all need to be integrated.

Analytics can help companies understand these trade-offs and how they are performing relative to the opportunity. For example, a typical tradeoff is between responsiveness and efficiency as companies try to do both at the same time as best they can. Often the focus is on reducing costs without understanding how that impacts service to customers. But what if you could improve both at the same time? What if you could quantify the savings or expense of providing a certain level of service? What if you have new opportunities and you need to understand the cost of the decisions made in order to take them on?

The trade-off chart below from *Operations Rules* shows the relationship between efficiency and responsiveness. The current strategy moves on the high curve so increase in responsiveness increase cost along the curve. However, through use of supply chain optimization the whole curve can move down to provide overall better performance.



Modeling Methodology

Our goal is to apply proven analytic and data-driven approaches to examine the opportunities we believe exist for many organizations. After understanding the area of concern and how it can best be approached, we create a validated model of the current system. We compare the model results to the details of the business. Once the results are acceptable, we analyze a complete set of improvement scenarios using simulation and optimization tools.

The results of these models provide a way to analyze the tradeoffs in the system as well as provide new ideas for improvement. Using detailed mathematical models and universal manufacturing and supply chain laws that are always true to reflect the relationships between:

- ❖ Demand variability and supply chain performance
- ❖ Inventory, capacity and response time
- ❖ Redundancy and Supply Chain cost
- ❖ Information, lead time and variability

One interesting aspect of modeling is that if results for a specific scenario are inconsistent with the intuition about the business, you need to understand where the discrepancy is coming from. Sometimes, the model suggests a new and surprising insight that would have been hard or impossible to obtain without the model. But, sometimes, it is an indication of a problem with the data, the assumptions or the model. Any such discrepancy needs to be understood before continuing with the model.

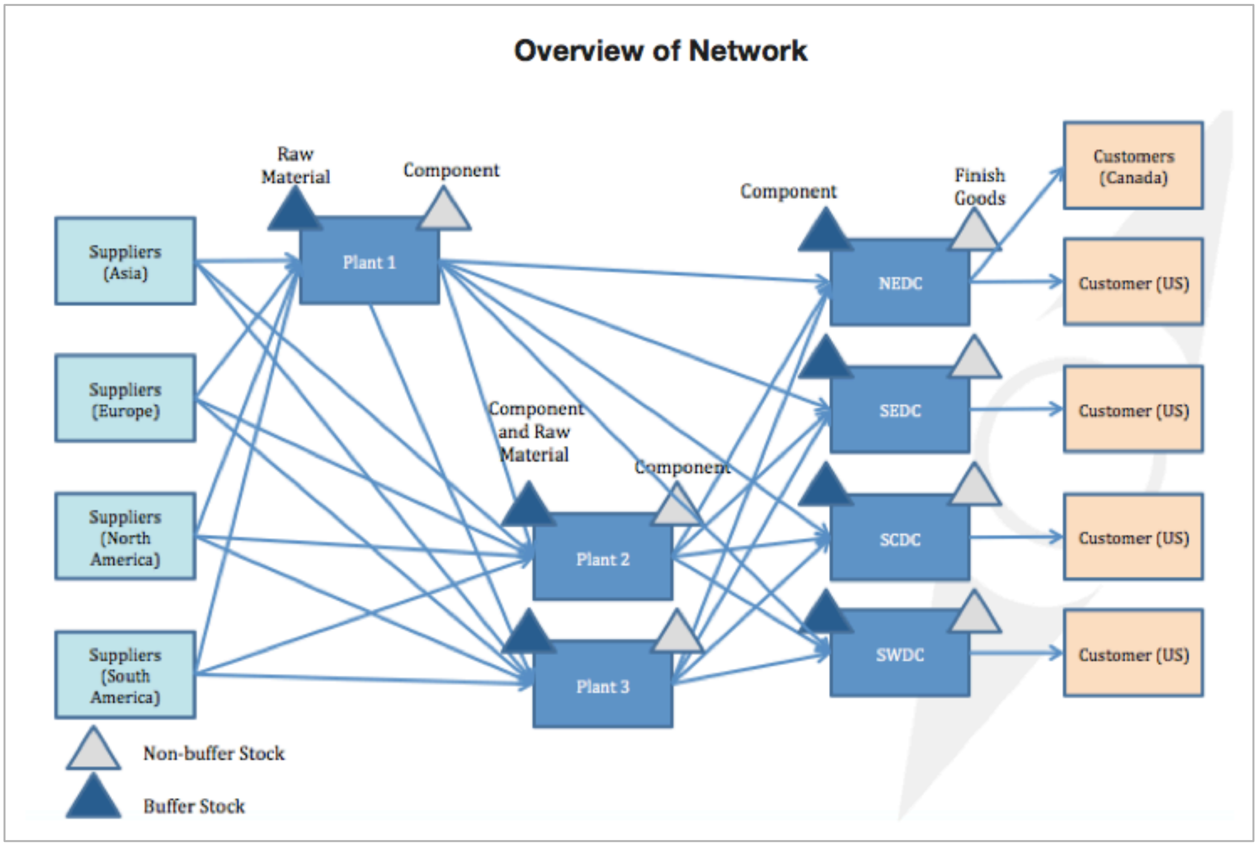
We also leverage empirical rules, based on prior research at companies that explain relationships between operations strategies and channel characteristics, product attributes, customer value and Information Technology capability.

Typically, we follow a 9-step process with the customer involved in all steps:

1. Define the problem and plan
2. Create the baseline model
3. Validate the baseline model
4. Quantify key drivers and find quick wins
5. Identify and create scenarios
6. Optimize scenarios
7. Consolidate and iterate
8. Drive change
9. Create a repeatable process

The experience and complexity required to perform this type of analysis is threefold. First, it requires deep understanding of the company's operations. Second, it requires knowledge of the analytics tools and modelling technology finally, it requires knowledge of supply chain principles in areas such as inventory, production and transportation. Capabilities in these three areas will combine to come up with ideas for scenarios and drivers of costs or inefficiencies in the system.

A good example for what this type of analysis involves is the work we did with PepsiCo Worldwide Flavours (PWF) on end-to-end inventory optimization, which they call Attila the Hun inventory optimization. PWF recently went through a reorganization that led to reassessment of inventory in the manufacturing plants. With a multi-tier network of three plants, four Distribution Centers (DCs) in the domestic and international markets, ~500 finished goods and ~2000 components and raw materials, this was not something that could be done easily. Management realized that this complex multi-level supply chain network could not be fully optimized using single-echelon optimization methods.



Therefore the company chose to work with OPS Rules and deploy an end-to-end inventory optimization process. The initial part of the process was to create a validated baseline model of PWF's network. You will recognize these as step 1, 2 and 3. We also created optimized models of the baseline, which is step 4.

The next steps, covering 5,6 and 7 in our methodology and the most creative parts, were to plan the various scenarios that will uncover the most information about the drivers of inventory in the PWF supply chain.

Our first discovery was that most of the excess inventory was in raw materials at the plants. This led to devising several scenarios to see what was driving the raw material inventory. These included:

- Improving demand forecast
- Eliminating some packaging options to reduce complexity
- Changing the frequency and size of production batches
- Analyzing the impact of lead times.

We examined what would happen if we changed supplier lead times for the raw material by either reducing or increasing it. It turned out that this had a relatively minor impact on the amount of inventory held in the plant.

Then we looked at another factor that is often neglected by inventory planners and that is lead-time variability. We discovered that reducing lead-time variability even a little had a significant impact on supply chain costs.

This implies that one of the best ways for PWF to reduce inventory at the plants is to work with suppliers to improve their performance by focusing on improving “on time delivery.” This was an unexpected insight, as management typically expects other factors to be more important. Steps 8 and 9 would ensue from this conclusion.

Machine Learning and Optimization

Analytics is of course a very wide area, we would like to focus in this section on a technology that has not been implemented widely in supply chain until recently called Machine Learning and in particular how it can be combined with optimization to produce breakthrough results.

A good definition of machine learning is here: "Machine learning is about learning to do better in the future based on what was experienced in the past. The emphasis of machine learning is on automatic methods. The goal is to devise learning algorithms that do the learning automatically without human intervention or assistance. The machine learning paradigm can be viewed as *programming by example*. Often we have a specific task in mind, such as spam filtering. But rather than program the computer to solve the task directly, in machine learning, we seek methods by which the computer will come up with its own program based on examples that we provide."

Some examples of machine learning include demand and price forecasting, character or face recognition, medical diagnosis, fraud detection, topic spotting (such as trending news). There are several types of machine learning results – the main ones are:

Regression – this is where the values are real. For instance if you need to price a product or when putting your house on the market – the machine learning algorithm will learn from previous sales and predict what is the product price based on this information.

Classification – this is where the values are discrete – for instance whether you will be accepted into a certain program or whether you have a certain disease or not. The machine learning algorithm will again look at previous cases and predict whether your characteristics place you in or out of certain groups.

Another aspect of machine learning is what type of process is used – these can be:

Supervised – this is where the information includes the result such as providing a list of characteristics and the resulting price or conclusion and using these to predict a new case. This is typically used in price forecasting but also used in recommendation engines as well as in character and face recognition.

Unsupervised – this is where information is provided with no clear conclusion in mind and the algorithms come up with correlations based solely on the data. This is used for data mining and has become more sophisticated in recent years with the use of visualization to help data matter experts determine the meaning of the results. This type of process has applications in fraud detection, genetics analysis and finance.

A natural application of supervised machine learning in supply chain analytics is forecasting. This is true in particular for fashion products where there is low volume, no similar products and high volatility. Another application is in customer segmentation where grouping of different customer characteristics can be enhanced with machine learning techniques. Unsupervised machine learning has been used to scour customer records for unexpected correlations in buying habits and can also be used in the same way to look at supplier information for new clues for determining quality and risk.

While a machine learning approach enhances the quality of grouping and forecasting, the results are often independent of each other. In order for a system to work in a meaningful way, it needs to make sure all the parts are optimized relative to each other.

Examples

The following are examples of implementing analytics in different operations areas and at different levels from manufacturing operations to end-to-end supply chain optimization.

1) Complexity Reduction
2) End to end inventory optimization at Schneider Electric
3) Supply chain risk management at Ford
4) Simulation of complex manufacturing process
5) Machine Learning and optimization at Rue La La

Example 1: Complexity Reduction

Challenge: Many companies are aware of the need to simplify their supply chains and processes in order to become more efficient and profitable. One way to achieve this is to gain a deeper understanding of customer needs and product performance in order to reduce complexity. Once a firm focuses on complexity reduction, many opportunities for profit improvement may become evident, but where do you start?

Approach: Using David Simchi-Levi's framework for supply chain segmentation that takes advantage of synergies to reduce complexity and benefit from economies of scale. One important concept in this method is "trimming the tail" to reduce product complexity and cost, which results in increased margins.

A critical component is to constantly evaluate your portfolio of products and offerings. Most companies typically measure each SKU by units sold, revenue and profit contribution. Then, depending primarily upon which products are the most profitable, they decide which should be eliminated.

Process: To ensure complete assessment of the company's portfolio, three things need to be considered:

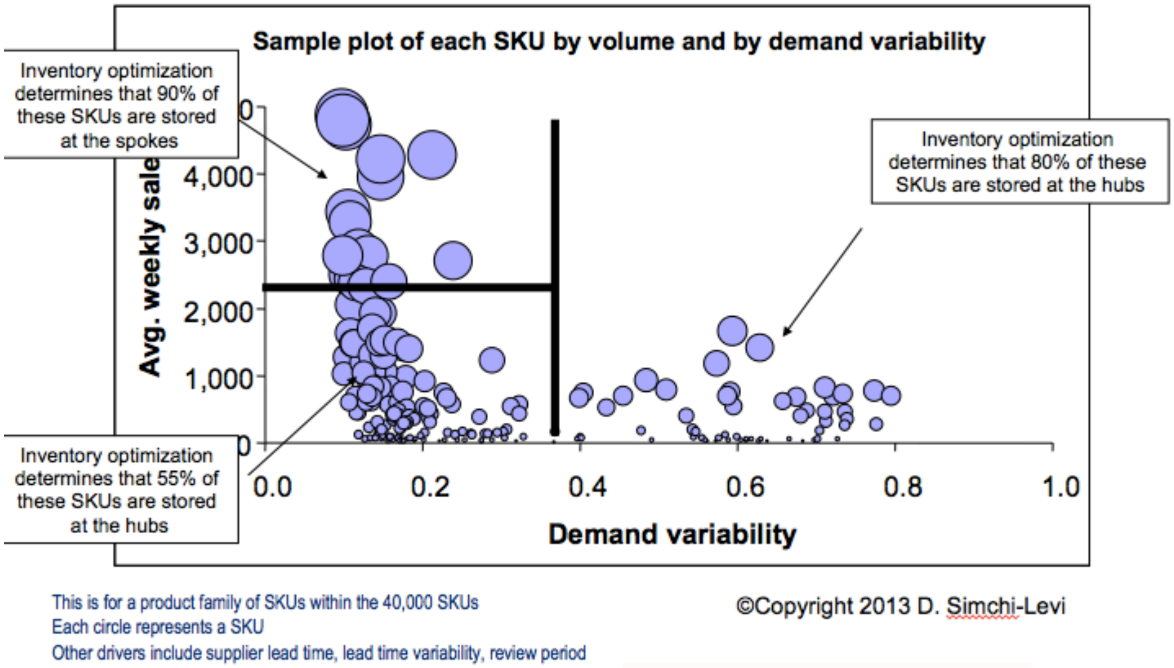
1. All costs have to be figured into the equation: Inventory costs, logistics costs, manufacturing set-up costs, costs to configure or assemble, and cost of direct materials.

2. Variability: how much will the demand for the SKU fluctuate?

3. Relationship Analysis: assess the relationship between SKU's (some SKU's help drive demand for others).

Once costs are calculated and variability is determined, and product relationships are taken into account plus a few other factors, then a map of the portfolio can be created. With these illuminating facts and metrics, better analysis can be performed and decisions can be made about the portfolio. Below is an example of one of the maps/charts we use to plot the portfolio and make decisions about where to best hold inventory for which SKU's. Similar graphs are used to show the total landed cost, variation and profit contribution characteristics of each SKU in the portfolio.

The graph below shows an example of the power of understanding demand and its variability so that inventory can be positioned effectively across a distribution network. In this case the analysis was used to determine the retailer's Hub and Spoke policy. Items with high variability and low sales are mostly stored in the hubs as that way there is the benefit of risk pooling demand from many stores. Items with high demand and low variability are mostly stored in the spokes as they are replenished often. Items that are low volume and low variability are split between the hubs and spokes depending on other characteristics.



Benefits: The evaluation of your portfolio can be a painstaking process. Many companies hold hundred thousands of SKU's, but this analysis is vital and must be performed and periodically re-assessed to ensure you are maximizing the profitability of your business. You should also remember that increasing the number of products in your portfolio increases the variability of ALL existing products in your portfolio.

Example 2: End-to-End Supply Chain Optimization

Challenge: Many companies are now looking at their supply chain structures as different events in the market are making it necessary to reevaluate how they serve their customers. In order to do this, they need to consider the entire supply chain with the goal of analyzing the supply chain on an end-to-end basis.

Approach: In order to do this, first the company needs to identify ways to optimize this supply chain to improve its performance in order to increase productivity, reduce cost and improve asset and working capital efficiency. Through this analysis the company can identify operations strategies for further cost reduction.

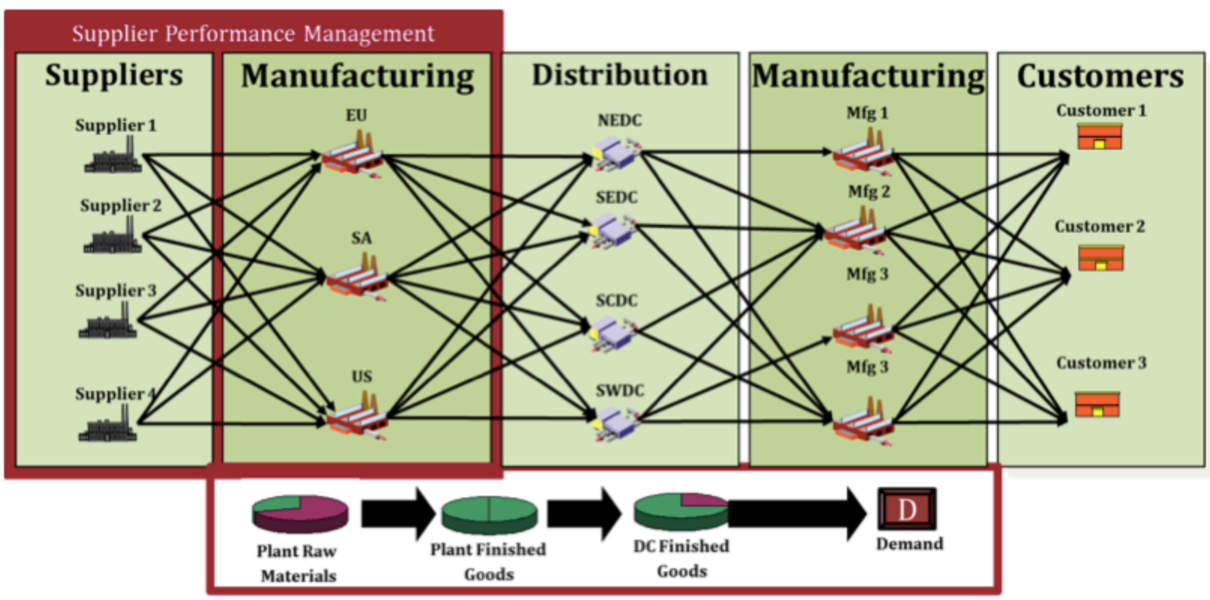
- Model current process steps and network using actual client data and commercially available analysis tools
- Perform optimization analysis with simulations to understand financial impact related to sensitivities in

- ❖ Inventory levels
- ❖ Customer service levels
- ❖ Forecast accuracy
- ❖ Supplier uncertainty

❖ Develop alternatives for client evaluation

- ❖ Support and complement current planning practices
- ❖ Identify key drivers of inventory
- ❖ Understand global vs. site implications of inventory policies

End-to-End Supply Chain Model



Benefits: Performing end-to-end supply chain optimization enables the following:

- ❖ Truly breaking down silos in the supply by analyzing total costs.
- ❖ Better understanding of why optimizing on local activities such as production plants or transportation lanes may not benefit the entire supply chain.
- ❖ Tradeoff service and cost in a data driven way
- ❖ Determine the time to recovery and cost of risks
- ❖ Optimize decisions across the supply chain on an ongoing basis in order to improve performance and reduce costs.

Example 3: Supply Chain Risk Management

Challenge: Management teams have a hard time mitigating the numerous sources of supply chain risk. The risks range from the controllable execution problems or “known-unknown” to the uncontrollable natural disasters also called “unknown-unknown” or “black swans” as described in figure 5.1 from David Simchi-Levi’s book, *Operations Rules*.

For the controllable risks, there are standard strategies and approaches related to day-to-day operations such as maintaining inventory and backup plans. With their past experience, companies can anticipate some of these controllable risks. But for the “black swans” the perception is that they are so rare and unexpected that there is not much that can be done. We believe that both these assumptions are wrong.

Approach: While a specific unexpected event is very hard to forecast, there are still quite a few of these in a given period. In the last few months of 2012, we experienced Hurricane Sandy, an extended strike at the Long Beach port, renewed unrest in Egypt and a small Japanese earthquake.

There are several actions that can be taken to prepare for these events:

- Quantifying the impact of the risk and prioritizing where to invest
- Adding system capabilities such as flexibility, locating inventory or adding key suppliers

❖ Responding fast to an event when it happens

In order to understand the impact of supply chain disruptions, it is necessary to model the supply chain and assess the cost and recovery time from various closures and other scenarios. We also do a qualitative benchmarking and assessment of existing risk management processes and systems. We avoid trying to create an “incident-based risk prioritization” for a few reasons. First, it is better to analyze the network and see where the potential incidents or events will have the greatest impact.

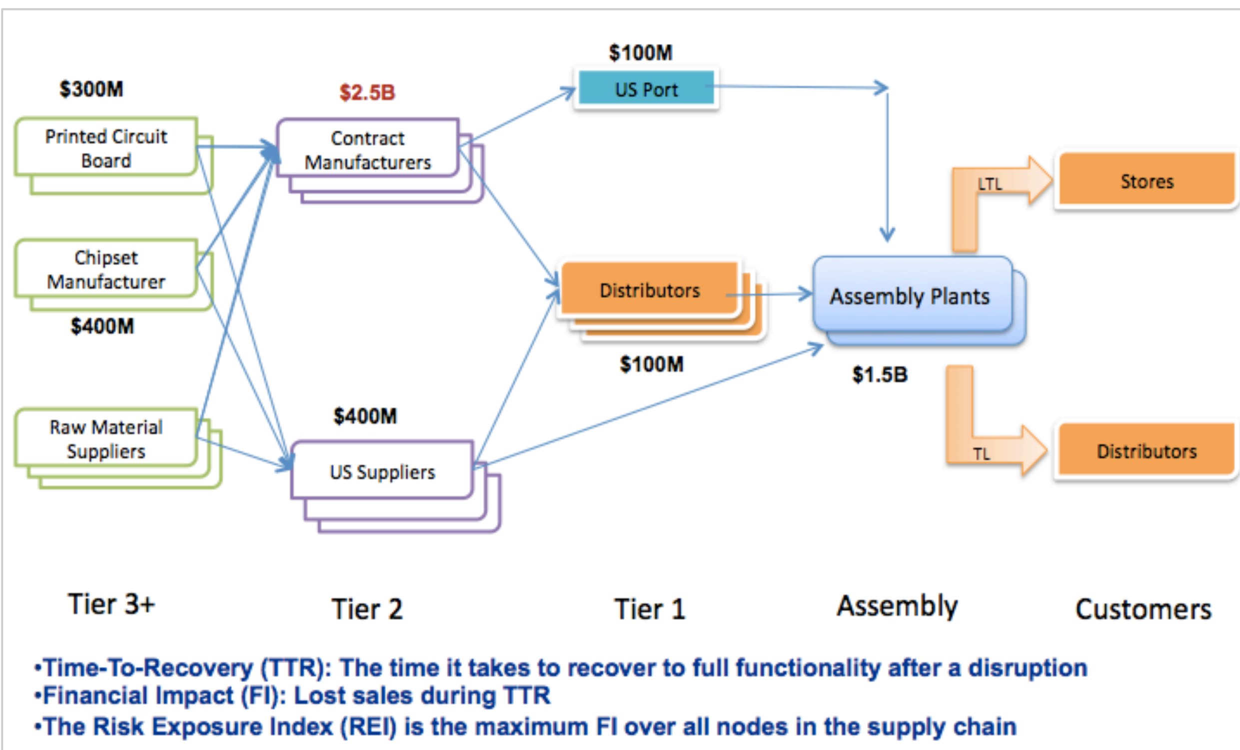
Process: To arrive at a quantitative measurement of risk, we follow a methodology that was developed by Dr. David Simchi-Levi through his work with various clients.

❖ Step 1: Identify each critical node in the system for a given business unit, product line, geographical region or just for the most critical products in the portfolio.

❖ Step 2: Calculate the Time-To-Recovery (TTR) for each of these nodes in the network.

  ❖ TTR is the time it takes to recover to full functionality after a disruption.

❖ Step 3: Using the TTR information in the model developed in Step 2, we then help companies calculate the cost of lost Sales during TTR – this provides you with what we call the Financial Impact (FI).



❖ Step 4: Finally, we calculate the *Risk Exposure Index* ™ by aggregating the Financial Impact (FI) across all nodes. The figure below is a simplified illustration of a network and the measurements at each node. The aggregation of the individual measurements allow us to create a *Risk Exposure Index* ™ for a given value chain.

Benefits: Using *the Risk Exposure Index* ™ provides the following:

- A quantified measure of risk--it determines the cost of risk, based on the entire network
- There is no requirement to try to forecast or scenario plan against the myriad of events that could possibly occur and affect your operations. Measuring the risk allows you prioritize and locate the areas of focus that will be bottlenecks during a crisis.
- It forces a discussion to understand why TTR for similar facilities or suppliers is different
- It forces a process to reduce TTR in various stages of the supply chain and allows you to do so in a prioritized fashion
- It increases the understanding of supply chain dependencies

The *Harvard Business Review*, From Superstorms to Factory Fires, describes how this method was successfully applied at Ford Motor Company.

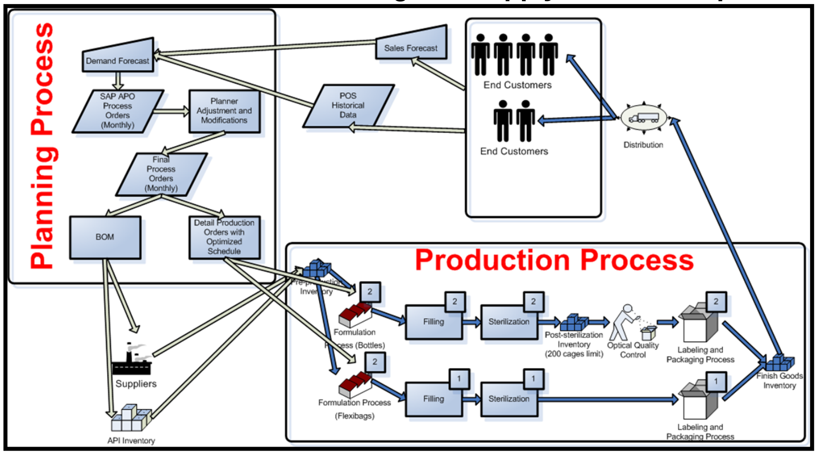
Example 4: Complex Manufacturing Process

Challenge: Companies need to keep their manufacturing fast and responsive as the market changes. This requires understanding of the production process; setup costs and how decision made in a plant impact the rest of the supply chain.

Approach: Using a simulation model you can review the current process and discover the bottlenecks. New ideas can then be analyzed for time and cost. You can experiment for instance with a fixed schedule for production to reduce setup costs as well as other changes to the process. The next step would be to expand the analysis to improve the production process by looking at how the outcome is coordinated with the overall supply chain planning process through an optimization model.

Process: Using the company's data, we can build an initial model to simulate the real system. Typically, this requires several iterations, to validate the simulation model so as to ensure it correctly represents the system we are optimizing. This process achieves multiple outcomes. First, we learn about the uniqueness of the specific facility and production.

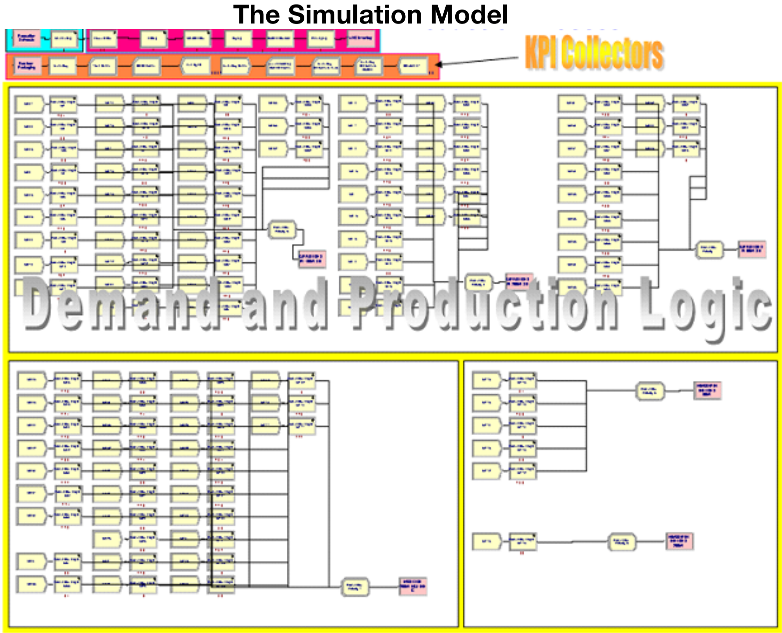
Overview of the Manufacturing and Supply Chain Example



Second, we create a baseline that we can then change the constraints to illustrate what happens under a different set of conditions/constraints.

The simulation model – current state has four modules: Demand and production logic, production sequence, production process and KPI collectors.

The Simulation Model



The simulation model includes information on both demand and production logic so as to capture trade-offs between cycle times, set ups, fill rates, etc. This logic includes four components:

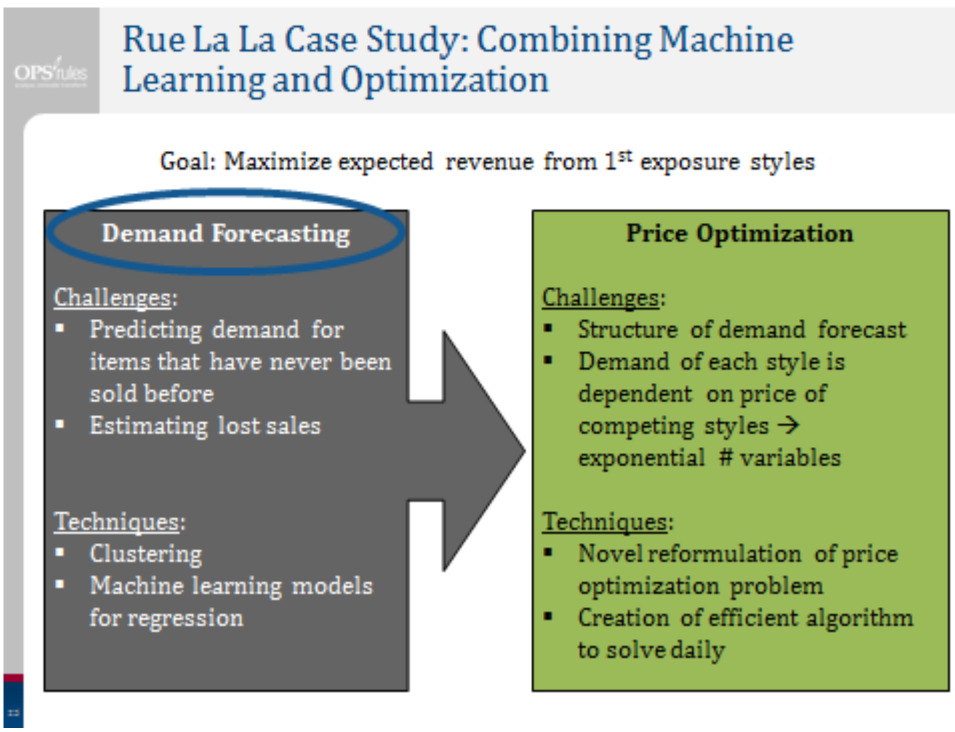
- ❖ Demand is generated using probabilistic distributions based on historical data
- ❖ Production decisions are made
- ❖ Production lot size are determined
- ❖ Inventory checkout

Benefits: The simulation model allows us to optimize production decisions so as to minimize changeover costs, allocate resources efficiently and understand the true cost of different customer orders.

Example 5: Pricing Optimization

Challenge: Rue La La is an online fashion sales company offering extremely limited-time discounts ("flash sales") on designer apparel and accessories see an overview of the project. One of Rue La La's main challenges is pricing and predicting demand for these first exposure styles, which was reflected in either quick sale-outs or too much leftover inventory. Therefore, Rue La La first approached David Simchi-Levi's team at MIT to reduce inventory in their supply chain.

Approach: The team started looking at historical data and discovered that by setting prices using historical data it could solve both problems. This approach involved using a combination of machine learning in order to predict demand for new items and estimate lost sales followed by optimization in order to take into account competing styles when setting prices.



This approach produced increased revenues of 10% and won the team the 2014 INFORMS Revenue Management and Pricing Section Practice Award.

Process: Integration of the MIT Demand Forecasting and Price Optimization Tool with Rue La La's Business Processes. Every day the price optimizer suggests recommended prices for the first exposure style events that are starting the next day. It prices all styles for an event together for the next day in a single run. It takes about an hour and at the end of that run an email goes out to all of the merchants with recommendations for prices for the exposure styles for next day's events.

Part of this process is to ensure that a couple of things are accounted for:

1. The model does not utilize competitive prices as its input and therefore, need somebody to make sure that the prices are not outside normal ranges. This ensures competitive pricing because that is the fundamental value proposition to Rue La La's customers.
2. Educate the merchants in terms of how the prices are actually set. Typically, merchants have price control and there is some art to this process. To ensure that they are not completely cut out of the loop, prices are shared with them and they make sure that the recommendations are sensible.

Benefits: Implementing this approach produced increased revenues of 10% and won the team the 2014 INFORMS Revenue Management and Pricing Section Practice Award.

Conclusion

Deploying analytics to make business decisions is generating tremendous interest and results for companies. The ability to make decisions based on data is particularly important in supply chain and operations where the tradeoffs are complex.

Supply chain analytics is therefore not just about crunching data and finding correlations; it requires deep understanding of the way supply chains work and the factors that influence costs and risks. If the tradeoffs are balanced well, these types of analytics projects can result in large savings, 10% to 30% are typical, while maintaining service levels and other important performance measures.

OPS Rules' proven approach and methodology can be the key to successful projects that can lead to developing internal capabilities for continued use of analytics to make the right decisions for your business.

About OPS Rules

OPS Rules is a leading operations strategy consulting company with capable partners and associates who provide expertise, distinctive viewpoints and reputation for developing and implementing new ideas with leading companies. We take an analytical approach that is fact-based and data-driven that leads to recommendations and innovations that are followed through to successful implementations. We employ a flexible transformation approach that ensures successful adoption of essential new skills.

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