White Paper:
The Impact of Structure on Supply Chain Performance and Resilience

J. Chris White

The primary purpose of this white paper is to show the impact of supply chain structure (i.e., shape) on the performance of the supply chain using a simple example reminiscent of The Beer Game. The secondary purpose is to demonstrate an approach that allows “scientific experimentation” on supply chains such that individual parameters can be tested independently and in isolation to determine their impact on supply chain performance.

The Problem:

Today’s extended enterprises and supply chains are becoming increasingly complex, especially in the automobile industry where supply chains can easily span multiple continents. As a result, executives have to allocate a growing portion of their time and energy to supply chain issues in addition to normal organizational management functions. However, today’s supply chains have grown beyond our intuitive capabilities and it is no longer obvious how any member within a supply chain might react to a given set of circumstances (e.g., large increase in customer demand, new political environment).

Today’s approaches to enterprise resource planning (ERP), supply chain management (SCM), and material forecasting are simply not capable of predicting how supply chains behave. The approach currently used by ERP/SCM systems for forecasting supply chain performance uses statistics as its foundation. The systems analyze past historical data and fit a curve to this data, then use the equation for that curve to project into the future. This is often called trend analysis, regression analysis, curve-fitting, or parametric estimating. Unfortunately, the statistical approach suffers from several major flaws.

First, the ERP/SCM statistical approach treats the process or system as a “black box.” There is no knowledge of the process/system or its causality (i.e., cause-and-effect relationships among activities). Thus, only correlations or trends can be calculated. But, correlation is not causality. Second, the ERP/SCM statistical approach assumes future conditions are the same as past conditions. Buried in the statistical approach is an insidious assumption that the future conditions must be the same as the past conditions for the forecast to be valid. If all the data used to make the forecast come from a set of historical data that occurred while a particular set of conditions were present, the only way for that forecast to be useful is if the same set of conditions continues to exist. If there is a different set of conditions in the future, obviously the data are no longer valid because they came from a different set of conditions, which means the forecast is no longer valid. For companies in a relatively stable market, this underlying assumption may be okay. But, for many companies, the whole purpose of forecasting for a supply chain is to understand what happens when conditions do change. Third, the ERP/SCM statistical approach does not capture management processes, decisions, actions, and reactions that managers make. As a result, current ERP/SCM tools allow for one-time static views of the supply chain, but not dynamic reaction and re-planning that occurs as conditions change. The statistical approach does not help managers understand the consequences of their decision-making patterns or policies that they put in place because there is no way to represent them with statistics.

The inherent flaws with the commonly used statistical approach indicate the approach is simply not capable of incorporating many of the real-world dynamics necessary for realistic forecasting. Hence, we need a better approach than statistics, an approach that addresses these major flaws.

The Solution

With the increasing complexity of today's enterprise supply chains, statistical forecasts can be highly erroneous because they are not operational models that capture actual activities, processes, policies, and relationships. Statistical techniques are powerful for capturing data in correlations, but they are insufficient for making projections into the future because correlation is not causality. When conditions change, the method of prediction must incorporate how the changes will be manifested. In other words, an operational model is needed, a model that includes the structure of the system being modeled. The structural modeling approach does not focus on data but instead focuses on the activities themselves. Consequently, an operational or activity-based model is developed that captures all relevant causal relationships among the various parts or elements of the process. Data are still used, but they are now used to calibrate the model and make it unique to a particular process. By incorporating the actual activities into the model, structural forecasting more accurately represents a process and how it will perform. Furthermore, the impacts of management decisions and policies can be incorporated. This allows a structural model to capture changes in the underlying conditions surrounding the process, which is impossible with the statistical approach. As such, the structural approach creates much more realistic and accurate forecasts, especially when future conditions are expected to be different from past conditions, because the activities themselves are simulated. Understanding the short-term and long-term strengths and weaknesses of different supply chain structures is imperative today, especially when global operations are involved. Simply passing order information up the chain more quickly is not the answer. The real answers are deeper than that and need a new approach that can capture and demonstrate the impact of supply chain structures on overall performance.

Today, there are no decision support tools that are capable of analyzing significant long-term, strategic structural issues for supply chains. What happens when a key supplier goes out of business? How long will it take for the supply chain to adjust to a new level of customer demand? Current ERP and SCM software manage daily transactions and automate ordering among suppliers, but their ability to forecast long-term strategic issues is severely limited. Instead, structural simulations can be created and run within minutes so that numerous alternatives can be considered. The more entities in the supply chain, the more powerful the structural simulation approach.

- Gain end-to-end visibility of the entire supply chain.
- Conduct LEAN studies on the chain to balance inventory.
- Ensure capital projects are timed perfectly.
- Optimize policies to limit the bullwhip effect.
- Use Monte Carlo to minimize the impacts of uncertainty.
- Determine the impact of adding or removing suppliers.
- Test the impact of multiple disruptions in the chain.
- Analyze outsourcing options.

An Example

The following figures walk through a simple example of a structural simulation of a supply chain. In this example, every entity has the exact same variables and values, such that they would all react to the same information in the same way. Thus, any differences in performance for a supply chain in this example are solely due to the structure of the supply chain and not the effectiveness (or ineffectiveness) of any entity in the chain. Figure 1 shows the two supply chain structures used in this example. Type A represents an OEM with only a single tier of three (3) suppliers. For Type A, the OEM assembles all three components into a final product. Type B represents an OEM that relies on a single first-tier supplier who relies on a single second-tier supplier who relies on a single third-tier supplier. For Type B, all the same components are used as in Type A, but now each tier adds their part on to the lower-tier part to build up the final assembly, with the assumption that the OEM does some final minor work on the assembly.

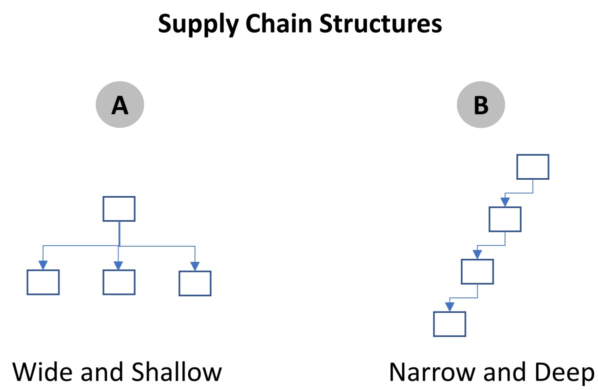

Figure 1: Two simple supply chain structures.

Figures 2 and 3 show the results for the OEM in Type A and Type B supply chains, respectively, to a bump in customer demand to the OEM. The purpose is to show how the same bump in demand propagates through two supply chains that have identical entities, with the only difference being the connection of the entities to each other. In this example, OEM customer demand is constant prior to the bump in demand (hence, the straight lines for the first 10 weeks on the graphs) and remains constant after the bump. Thus, any fluctuations seen in the graphs are the results of how the various entities react to orders changing throughout the supply chain as each entity attempts to regain its balance of inventories and production rates.

Figure 2 shows the results for the OEM with Type A structure (wide and shallow). Starting after week 10, the chart shows the fluctuations in receipt of raw materials from the OEM's suppliers, raw material, production rates, finished goods inventory, and deliveries to the OEM customer. It is not important to know the exact values for this example. What matters are the relative differences seen in the fluctuations, which can be considered measures of disruption and resiliency for a supply chain. We could look at all the variables, but let us just focus on raw material inventory levels (blue line at the top of the graph marked with the number 2) to keep it simple. In Figure 2 for Type A, notice that the raw material inventory hits a peak of about 35% higher than normal and takes about 26 weeks (from week 10 to week 36) to settle down to a smooth flow to meet the new demand.

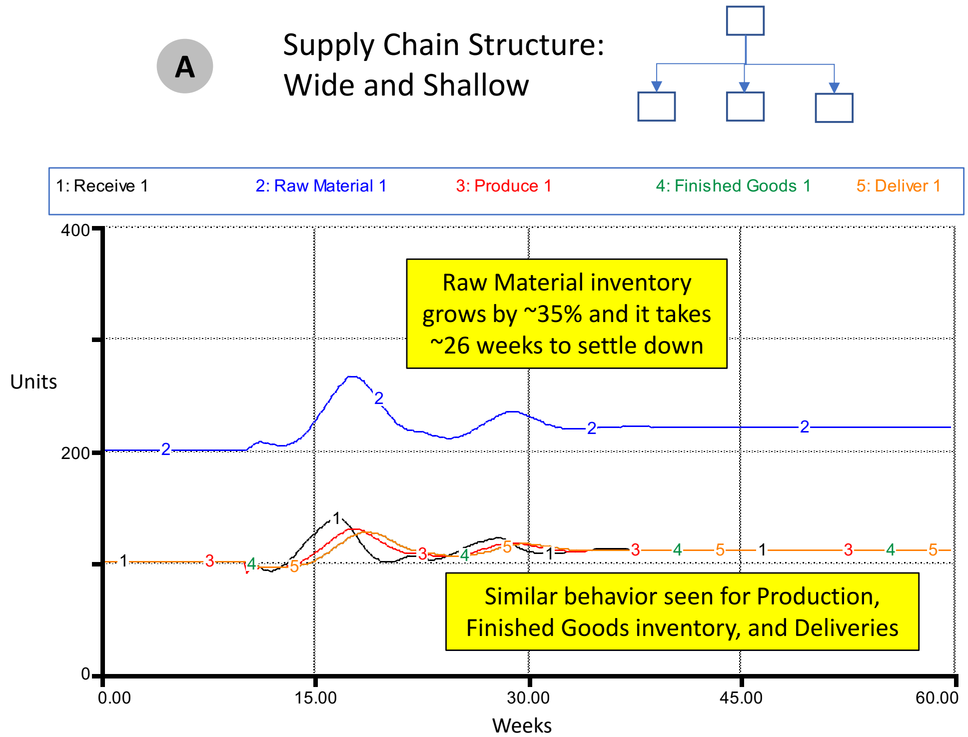

Figure 2: Simulation results for bump in demand at OEM level for Type A supply chain structure.

Figure 3 shows the results for the OEM with Type B structure (narrow and deep). Similar to Figure 2, starting after week 10, the chart in Figure 3 shows the fluctuations in receipt of raw materials from the OEM's suppliers, raw material, production rates, finished goods inventory, and deliveries to the OEM customer. Again, just focusing on the raw material inventory levels (blue line at the top of the graph marked with the number 2) to keep it simple, notice that the raw material inventory in Figure 3 hits a peak of about 70% higher than normal and takes about 13 weeks (from week 10 to week 23) to settle down to a smooth flow to meet the new demand. Compared with the Type A structure in Figure 2, the disruptions seen for Type B cause a much higher peak in inventory: 70% above normal for Type B compared to 35% above normal for Type A. Conversely, compared with the Type A structure, the disruptions for Type B do not last as long: 13 weeks for Type B compared with 26 weeks for Type A.

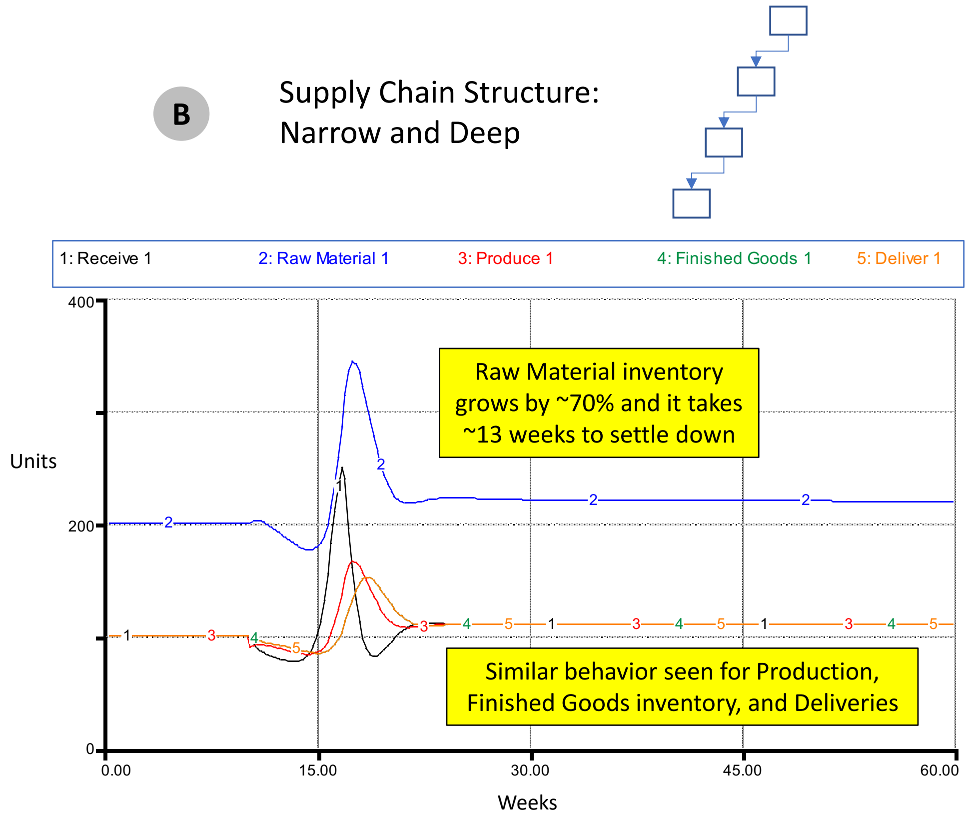

Figure 2: Simulation results for bump in demand at OEM level for Type A supply chain structure.

This begs the question: Which is the better supply chain structure, Type A or Type B? Well, that depends. If the OEM is sensitive to lengthy disruptions, perhaps Type B is better with its high excessive inventory but shorter adjustment time. Or, if the OEM does not have much storage space, perhaps Type A is better with its smaller impact on inventory and longer adjustment time. There is no optimal answer that works for all situations. It is a trade-off between fast recovery versus massive fluctuations in internal operations. The structural simulation provides companies an opportunity to see and evaluate these trade-offs that are impossible to see and evaluate through current ERP/SCM approaches. As such, companies have a higher degree of control and higher probability of success when structural simulation is used as part of the supply chain planning and management process.