# Designing and Managing the Virtual Enterprise

***A Breakthrough Application for System Dynamics Using SimBLOX and scmBLOX***


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***Abstract***

Almost everything we use today is manufactured by a virtual enterprise composed of hundreds of companies. These large distributed systems have led to numerous problems and challenges across multiple industries. The need is great for an analytical technique to examine the performance of a large-scale virtual enterprise. System Dynamics has been successfully used to model these large enterprises and assess the impacts on system behavior of changes in demand and various parameters. These large-scale enterprise models, however, are complex and time consuming to build and are difficult to restructure. For enterprise management, the ability to reconfigure the

network of companies in response to external forces is critical, and models of the enterprise must have similar flexibility and rapid re-configurability. Using System Dynamics agent models of factories, distribution centers and customers, scmBLOX uses drag and drop features that enable fast construction of enterprise models and rapid assessments of alternative enterprise structures. Replacement of a make-to-stock factory for a make-to-order factory or the addition or elimination of distribution centers can be quickly evaluated. On-going research is focusing on the interplay between enterprise structure and performance, the development of additional agent models and new features for current agent models, and the assessment of optimization strategies such as push-pull boundaries within the global virtual enterprise.

## Designing and Managing the Virtual Enterprise
### *A Breakthrough Application for System Dynamics Using scmBLOX*

### Background

Almost everything we use today is manufactured by a virtual enterprise - a large distributed network of companies that provides parts, components, and sub-assemblies to a final manufacturer or integrator. It is not unusual for hundreds, even thousands, of companies to be involved in the production of a product by a large virtual enterprise. Many of these virtual enterprises span the globe. Consider the Boeing 787 Dreamliner. The wings are made in Japan, the wing tips in Korea, the landing gear in the UK, the horizontal tail in Italy, and on and on. The only major part of the plane made in Boeing's "home" state of Washington is the vertical tail. (Avery, 2007) Automobiles are also produced by widely distributed virtual enterprises. The Hyundai Genesis, a "Korean" car, has a transmission built by ZF, a German company, an instrument cluster by Continental, another German company, and fasteners by TRW, an American company. (Automotive News)

The virtual enterprise has arisen largely as a result of outsourcing, the underlying strategy that has led the evolution, if not revolution, away from the highly integrated vertical firm to a widely distributed network of suppliers. The Ford Rouge plant, located near Detroit, is a classic example of a highly integrated vertical enterprise. Developed between 1917 and 1928, the Rouge was an automotive complex that transformed ore into an assembled automobile. (The Henry Ford) Henry Ford's idea was to achieve a continuous, nonstop process from raw material to finished product.

The Rouge plant contained ore docks, steel furnaces, coke ovens, rolling mills, glass furnaces and plate-glass rollers. Each day, workers smelted more than 1,500 tons of iron and made 500 tons of glass. Henry Ford's ultimate goal was to achieve total self-sufficiency by owning, operating and coordinating all the resources needed to produce complete automobiles. Ford Motor Company owned 700,000 acres of forest, iron mines and limestone quarries in northern Michigan, Minnesota and Wisconsin. Ford mines covered thousands of acres of coal-rich land in Kentucky, West Virginia and Pennsylvania. Ford even purchased and operated a rubber plantation in Brazil.

Today, Ford's strategy seems somewhat hard to believe, and, ironically, both grandiose and quaint. The modern MBA and the Wall Street analyst would decry the capital tied-up in low-margin operations, the failure to focus on core competencies and the payment of high manufacturing wages in an urban American setting. The highly vertically integrated firm has now become the virtual enterprise.

The motivation typically cited for the rise of the virtual enterprise is the drive for lower costs, but in reality, the motivations for outsourcing are much broader. These reasons include:

- Reduce and control operating costs
- Improve company focus on core competencies
- Gain access to world-class capabilities
- Free internal resources for other purposes
- Gain control of a function that is time-consuming to manage or is out of control
- Insufficient resources are available internally
- Reduce research and development investment
- Share risks with a partner company
- Grow sales in new and emerging markets through local participation

As pointed out by Chesbrough and Teece, incentive and responsiveness give the virtual enterprise its advantage. (Chesbrough and Teece, 1996) "Virtual companies coordinate much of their business through the marketplace, where free agents come together to buy and sell one another's goods and services; thus virtual companies can harness the power of market forces to develop, manufacture, market distribute, and support their offerings in ways that fully integrated companies can't duplicate." Because of the multiple motivations and advantages, outsourcing became a rapidly growing, if not fashionable, phenomenon. As companies began the process of outsourcing, however, some researchers began to raise warning signs and provide guidance on strategies and identifying and managing risks. In 1993, writing in the MIT Sloan Management Review, Stuckey and White described a number of situations in which outsourcing was very risky to a company. (Stuckey and White, 1993) These risks were related to the design and production of both the components and system being produced. Figure 1 summarizes their strategy guidance. The results stress the danger of outsourcing when the situation involves integral component and system architecture and new or emerging production processes.

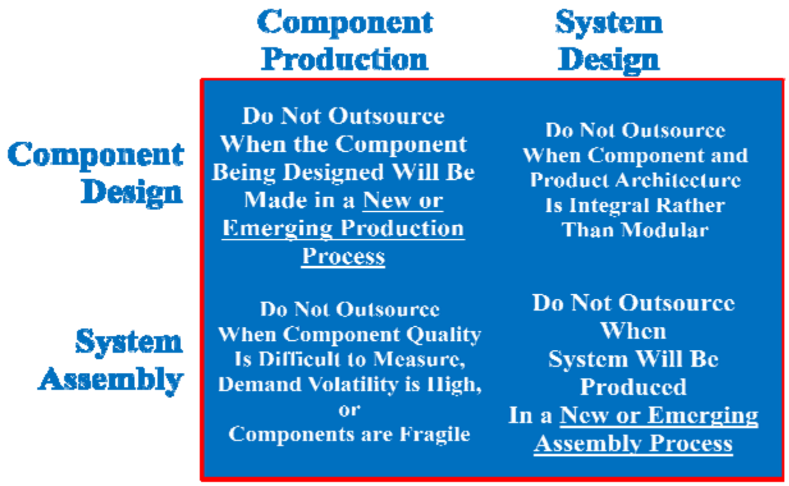



**Figure 1. Outsourcing Related to Product and System Design and Production**

In the Best of HBR in 1996, Chesborough and Teece, analyzed outsourcing from the perspective of the technology and whether capabilities existed outside or needed to be developed. They identified considerable risk involved with outsourcing an integrated technology in which the capability had to be developed. In that case, vertical integration was much preferred. Their guidance is summarized in Figure 2.

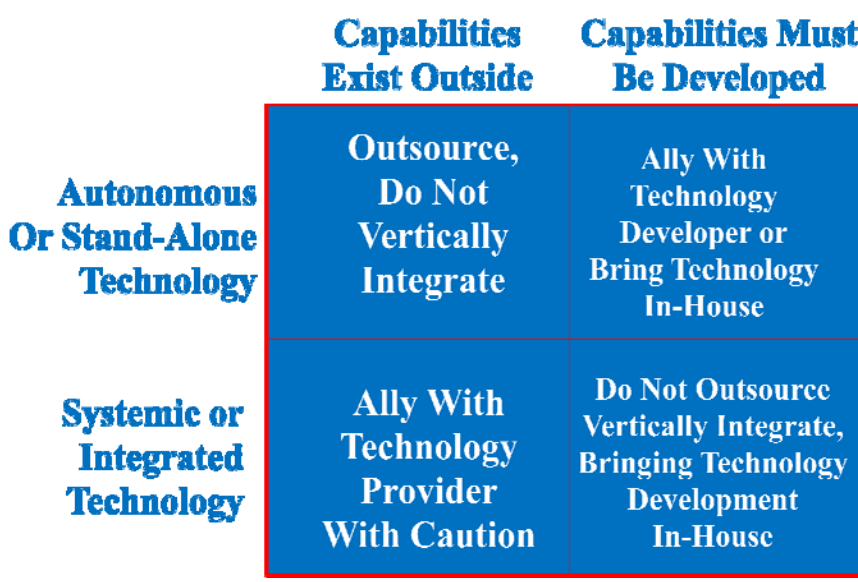



**Figure 2. Outsourcing Related to Autonomous or Integrated Technology and the Presence of Capabilities**

In 1999, Charles Fine addressed outsourcing in the book *Clockspeed*. (Fine, 1999) His strategy guidance identified the best outsourcing opportunity as a stand-alone or modular item with dependency for capacity only, not knowledge. The worst outsourcing situation was a systemic or integral item and being dependent for both knowledge and capacity.

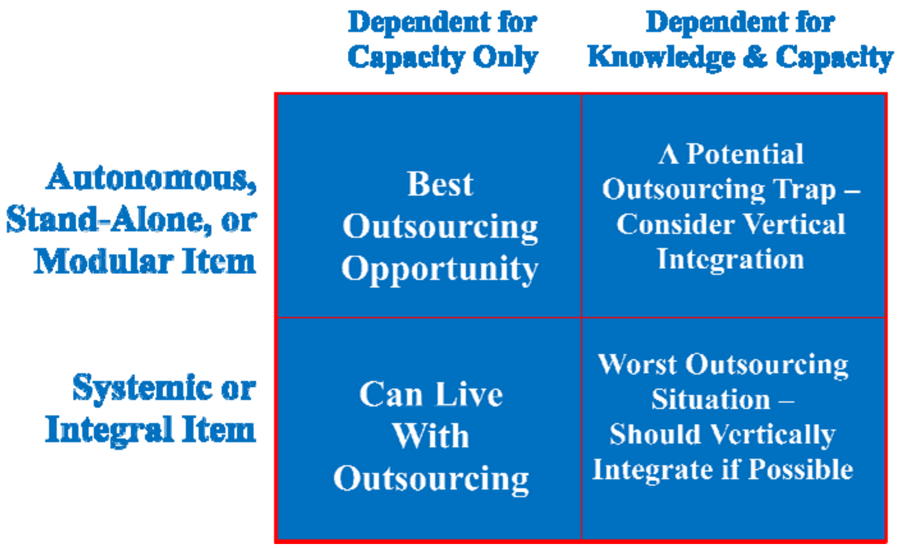



**Figure 3. Outsourcing Related to Autonomous or Integrated Items and the Dependency for Knowledge and Capacity**

In general, these strategy guidelines have been widely ignored. Risky, difficult and innovative components and sub-assemblies are routinely outsourced as are items requiring new production techniques. As one would expect, this has led inevitably to numerous problems and challenges across multiple industries. It would seem that all of the benefits of outsourcing are expected to be realized, and all of the risks are ignored. As Stuckey and White observe, "In all cases, decisions to integrate or disintegrate should be analytical rather than fashionable or instinctual."

**Modeling the Virtual Enterprise Using System Dynamics**

The obvious question, of course, is how does one analytically examine the likely performance of a virtual enterprise that may involve many companies. System Dynamics is certainly an appropriate technique for analyzing the dynamic performance of a virtual enterprise. These large networks of companies function as complex multi-tier, multi-channel supply chains. System Dynamics has been used to analyze supply chains from its very beginning as a modeling and simulation tool for policy analysis. Forrester's (1958) groundbreaking article in the Harvard Business Review demonstrated fundamental supply chain dynamic behavior such as how small changes in retail sales and promotional activity can lead to large swings in factory production, i.e., the so-called bullwhip or Forrester effect. Forrester (1961) also included a supply chain model and demonstrated various modes of behavior. Forrester's models included factory, distribution and retail tiers in the supply chain but no suppliers to the factory. More recently, Sterman (2000) has addressed supply chains with several models and case studies. Again these are forward looking supply chains from factory to customer with perhaps a single supplier. Huang and Wang (2007) addressed the bullwhip effect in a closed loop supply chain using a simple model based on Sterman's (2000) structure. Simchi-Levi (2008) and Lee (1997) address bullwhip from an analytical perspective. Schroeter and Spengler (2005) addressed the strategic management of spare parts in closed-loop supply chains. Angerhofer (2000) presents a thorough discussion of system dynamics modeling in supply chain management. Killingsworth, Chavez, and Martin (2008a and 2008b) addressed an extended supply chain with multiple supply channels and multiple tiers using System Dynamics. This model incorporated twenty-seven manufacturing facilities and five distribution centers.

The overall supply chain system modeled by Killingsworth (2008a) is shown in overview in Figure 4. This supply chain extends from raw material to final customer. Demand arises from four regions of the world. Each region has an inventory, and these regional inventories are replenished from a central distribution inventory thus totaling five distribution centers and inventory control points. Supply of parts comes from three sources: production of new items, commercial repair of returned items, and the potential for repair at a government facility. Each type of production requires that a number of parts be integrated into the major sub-assembly. In general, the repair and overhaul process requires fewer component parts than new part production.

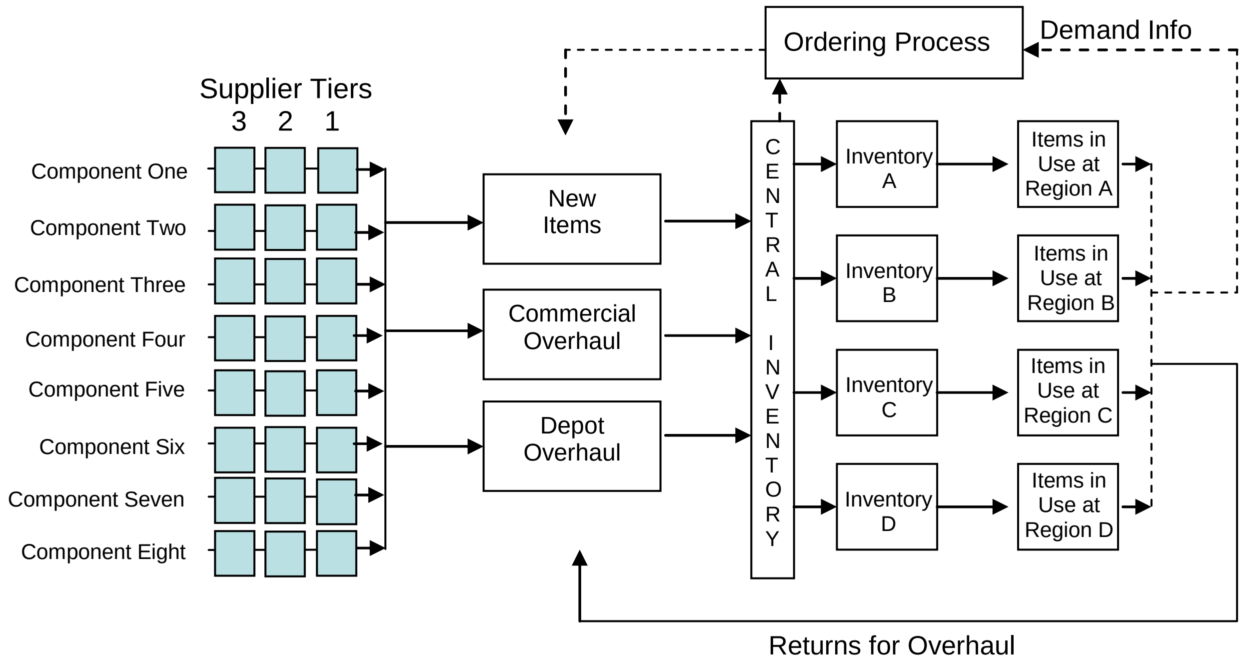



Figure 4. High Level View of Multi-Tier, Multi-Channel Supply Chain

The component parts are each produced through a three-tier supply chain, i.e., three companies in each channel. With eight sub-assemblies, this results in twenty four manufacturing facilities plus the final three integrating facilities. The overall supply process is managed in a feedback fashion by an ordering process often embedded in an ERP system. This process determines the recommended buys for new items and the recommended number of parts to undergo repair and overhaul. The supply chain control system compares current levels of inventory, including due-ins and due-outs, with anticipated needs to calculate recommended buys and repairs. Since the procurement of new items and the repair of returned items lead over time to changes in inventory, the system truly functions in a feedback control fashion to manage the supply chain. (Killingsworth, Chavez, and Martin, 2008b)

Figure 5 provides a more detailed view of the flows present in the model. With twenty seven manufacturing sites and five distribution centers, this represents a difficult and challenging model to construct. Figure 6 illustrates a traditional System Dynamics model structure for just one of the eight component supply chains. Each company in the enterprise requires its own production and inventory models as well as logic for placing orders to its supplier. The model portrayed in Figures 4, 5 and 6 were developed using Vensim as the simulation language. These large-scale enterprise models are very complex and very time consuming to build and test, and once built, they are typically difficult to restructure. For the modern enterprise, however, the ability to reconfigure the network of companies in response to external forces is critical, and models of the enterprise must have similar flexibility and rapid configurability. A key goal in enterprise management is access to *dynamic* system dynamics models that enable and support fast and agile management response.

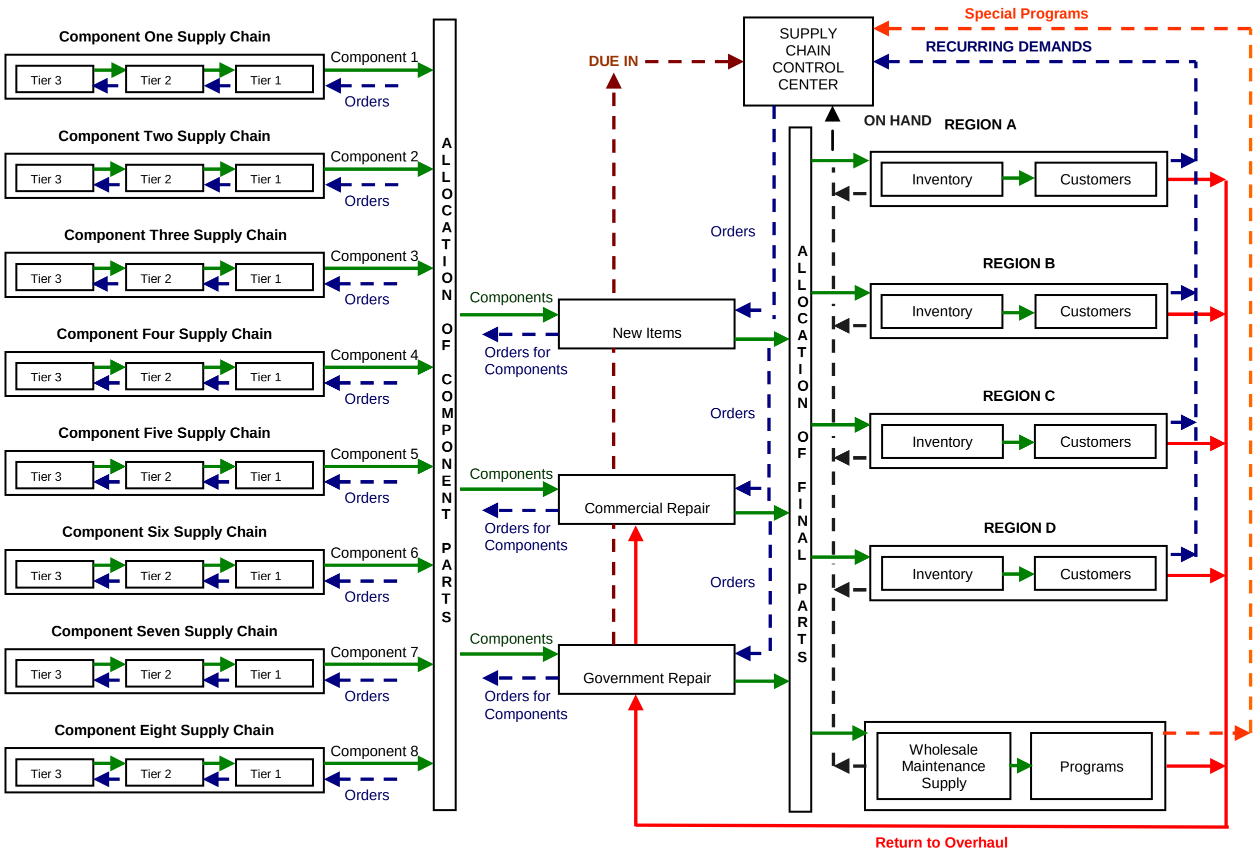



Figure 5. More Detailed View of Multi-Tier, Multi-Channel Supply Chain

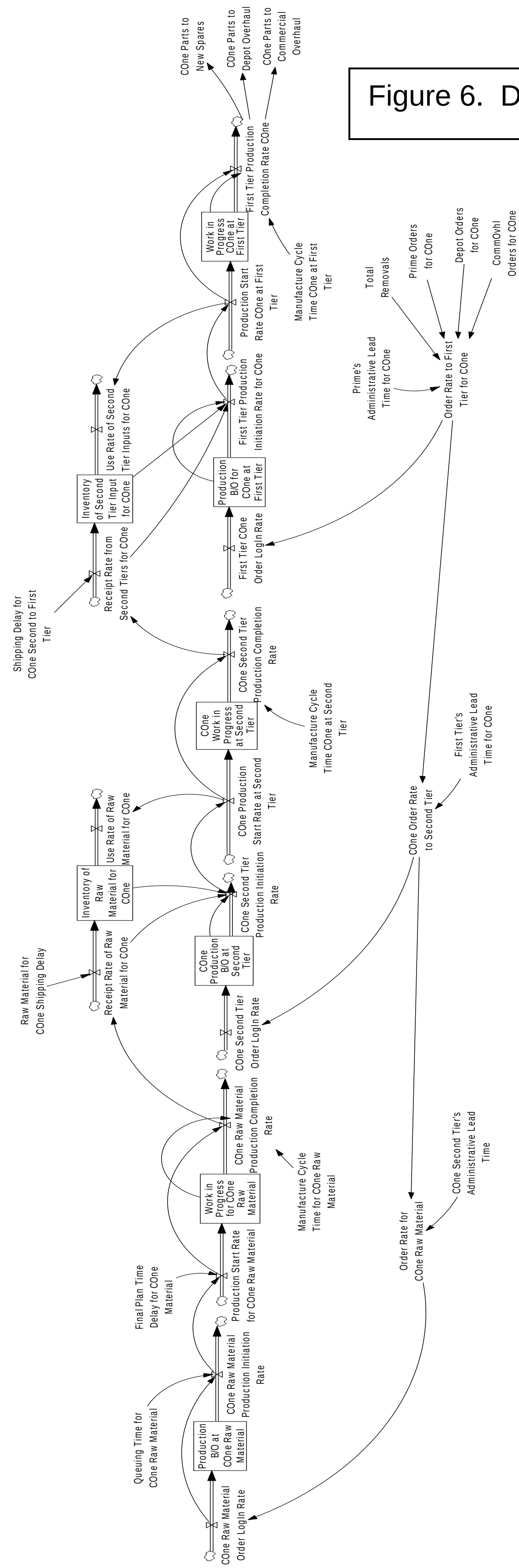



Figure 6. Detailed View of Model Structure

**Modeling the Virtual Enterprise:**
**A New Approach Using System Dynamics and ScmBLOX**

Currently available SD modeling tools (e.g., iThink, Vensim, Powersim) are excellent at developing many types and levels of models. These current tools, however, can be limiting when it comes to building large-scale, dynamic System Dynamics models. For very large enterprise models, today's tools become cumbersome, difficult to manage, and prone to error due to large amounts of manual manipulation. While some features, such as arrays in iThink and subscripts in Vensim, are designed to help "replicate" model structures, these features only allow exact duplication of the same structure in a "parallel" process (e.g., Product A and Product B moving through identical processes, but with different cycle times or inventory levels).

As an example, consider the simple Beer Game model. Even though the model structure for a warehouse is generic, arrays or subscripts cannot be used to connect the Wholesaler to the Distributor to the Retailer. Three copies of this generic warehouse structure must be created and manually connected together on the modeling interface. Each time this replication occurs in building larger supply chains (e.g., 10 warehouses in a row), the copy-paste-connect process must be used. For complex warehouse models, there may be several variables that need to be connected each time. The same is true for multiple manufacturing facilities in a multi-tier manufacturing process. This creates many opportunities for human mistakes, for example, making an inappropriate connection. Moreover, as a model gets larger and larger, this process introduces new issues related to navigation, visibility, and management. If each individual model for a warehouse is 3 pages, then connecting 10 of them together creates a 30-page model, plus any additional model structure needed for aggregate bookkeeping, etc. Moreover, this large model is now largely "static" with regard to structure. If the user desires to change the order of the warehouses, add more warehouses, or remove some warehouses, a good amount of additional technical modeling would be required. Structural changes cannot be done "on the fly" at the macro-level.

SimBLOX is a technology platform that is designed to allow creation and easy management of macro-level models, including dynamic structural changes at a high-level. (SimBLOX) It uses a "building block" format in which simulation models represent the building blocks of a larger, more complex system. In the case of scmBLOX, a warehouse model is a building block (represented by an icon) that can now be dragged-dropped onto the model layout and then easily connected with other building block models (i.e., icons). (ViaSim Solutions) Model visibility and management are greatly improved while still keeping the underlying model structure desired. In SimBLOX terminology, the building block models are called SimBRIX and are represented by icons as shown in Figure 7.

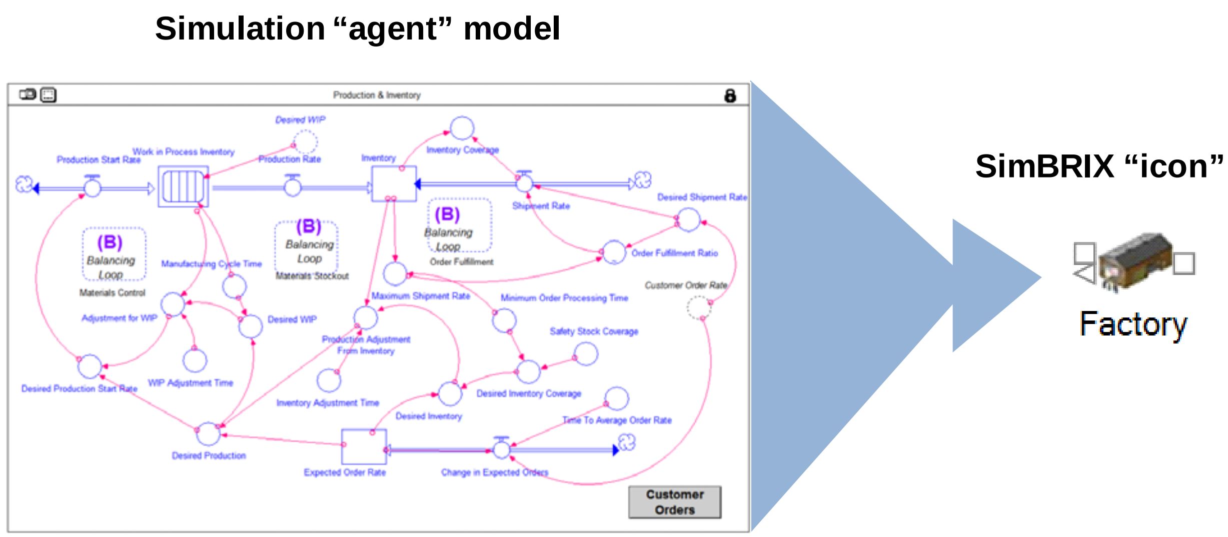
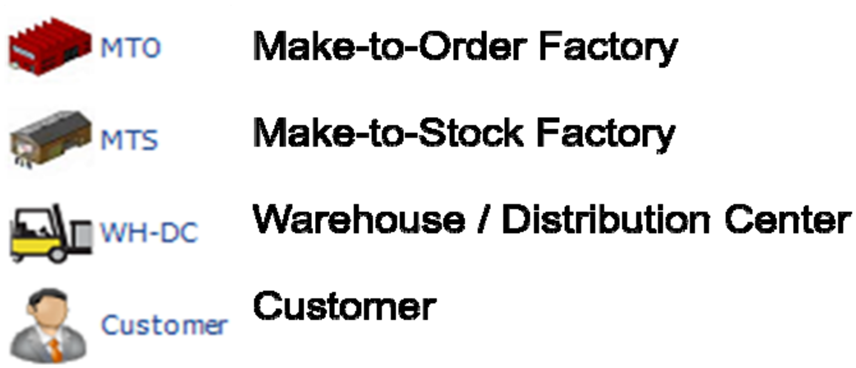



Figure 7. Agent Model for Factory

The technology platform SimBLOX has been used to develop scmBLOX to enable modeling of large-scale supply chains and virtual enterprises. Currently, scmBLOX contains four SimBRIX or agent models:




Using scmBLOX, almost any number of factories and warehouses can be linked together to create multi-tier and multi-channel enterprise models. scmBLOX is still undergoing development and additional agent models are in development as well as additional features being built into the current agents.

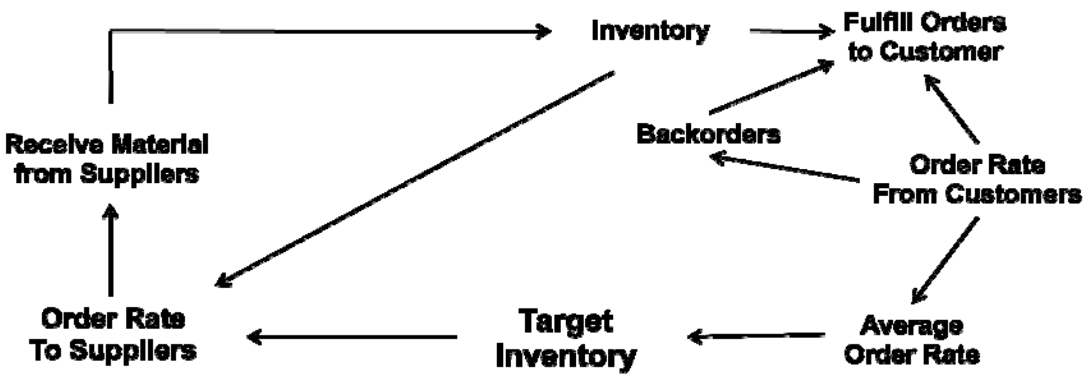
Figure 8 illustrates the primary relationships in the Make-to-Order factory. In this agent System Dynamics model, fulfillment of customer orders is enabled by production. There is no inventory of product. If for some reason, production lags behind orders, a backlog of orders builds-up and influences the level of production. Average orders drive two factors: production capacity and orders to suppliers for material. For example, if average orders are on a growing trend, then production capacity would tend to increase in order to meet demands. Similarly, orders to the supplier would also increase.

Figure 9 illustrates the primary relationships in the Make-to-Stock factory. In this agent System Dynamics model, fulfillment of customer orders is enabled by inventory. If for some reason inventory is unable to meet current orders, a backlog of orders builds-up. Average orders drive three factors in this agent: production capacity, orders to suppliers for material, and a value for the target inventory. In the Make-to-Stock agent, if average orders are on a growing trend, then the target inventory would tend to increase in order to meet demands.

Figure 10 presents a high level view of the model structure for the Warehouse/DC agent model. The Warehouse/DC is managed to maintain a target inventory based upon average orders. If, for example, average orders are increasing, then the target inventory would also increase to enable meeting of demands. If inventory is unable to meet current orders, a backlog develops that is worked-off over time as the inventory is replenished.

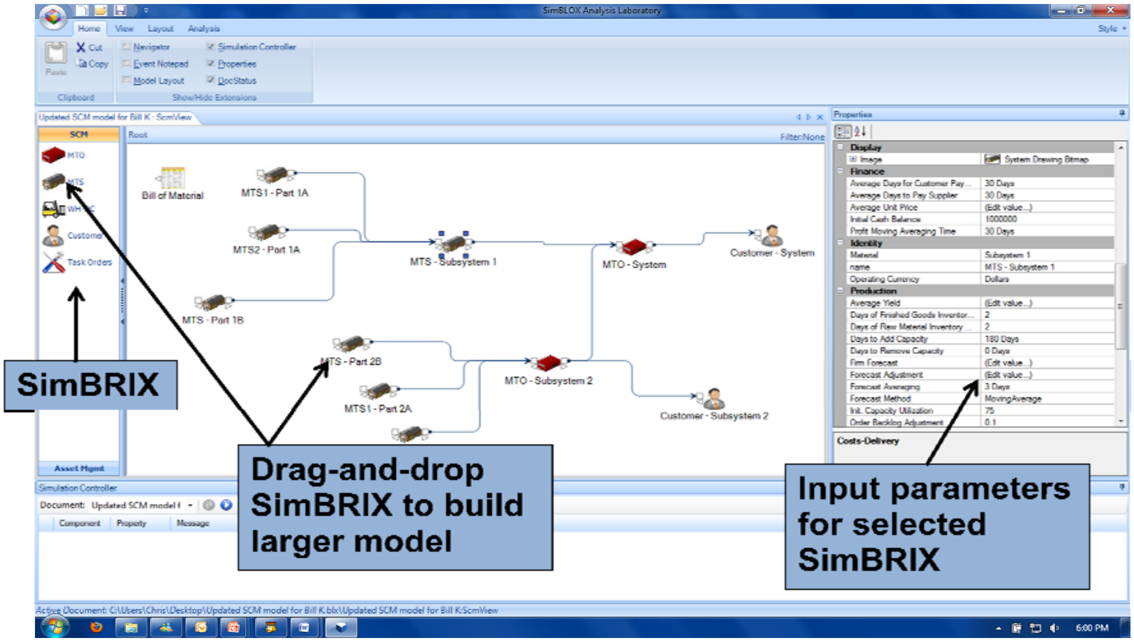
**Figure 10. Overview of Warehouse/DC**

**Note: Diagram Is Intended to Show Primary Relationships and Does Not Include All Variables Such as Time Delays, Averaging Periods, etc.**




ScmBLOX is structured for the user with drag and drop functionality. The icons are simple dragged onto the model layout area and then links are clicked and dragged to connect the icons. Figure 11 presents a screen shot illustrating the drag and drop process.

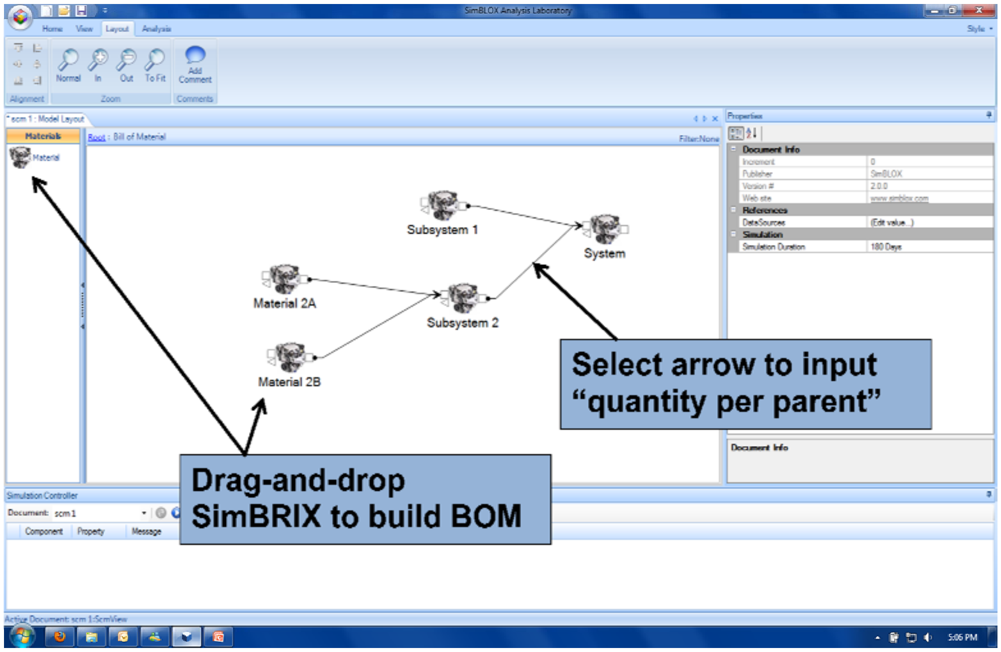
# Figure 11. scmBLOX User Interface




As may be seen in Figure 11, the icons for MTS (Make-to-Stock), MTO (Make-to-Oder), WH/DC (Warehouse/Distribution Center) and Customer can be dragged into the model field and given specific names. It is important to note that for each agent dragged into the model structure, there are many input parameters that must be specified. These input assumptions such as time lags, desired inventory coverage, etc. are on the right side of the screen for user input.

A very important feature of scmBLOX is that for the manufacturing portion of the virtual enterprise (as opposed to the distribution part of the enterprise), the structure is driven and determined, just as in the real world, by the Bill of Material (BOM) of the product. That is, the components that are manufactured and integrated into sub-assemblies which are then integrated into the final product not only map into the BOM but the structure of the virtual enterprise as well. Figure 12 illustrates the user interface for specifying the BOM. As with the other agents, there are input assumptions that are specified for each component and sub-assembly.

# Figure 12. Bill of Material (BOM)




Using these tools, a model of a very complex virtual enterprise and associated supply chain can be easily developed. Figure 13 illustrates such a model. Note that customers are not only present for the final product but also exist for the components and sub-assemblies. This is important because in many situations, components and sub-assemblies are used in multiple products, and developments in one product line can spell-over and adversely affect other product lines.

**Simulation and Analysis Using scmBLOX**

**Base Case Analysis**

Figure 14 presents the Bill Of Material (BOM) for an example product. The product system is composed of two subsystems. Subsystem 1 is made from two parts: Part 1A and Part 1B, and Subsystem 2 is also fabricated from two parts: Part 2A and Part 2B. Figure 15 presents the Base Case structure for the supply chain of the system. As may be seen in Figure 15, there are two customers: one customer for the complete system and one customer for subsystem 2. The demands of these customers are independent. The system is assembled in a Make to Order facility. The system factory receives subsystem 1 from a Warehouse/Distribution Center and receives subsystem 2 directly from a Make to Order factory. The MTO factory for subsystem 2 also ships directly to the Customer for subsystem 2. Subsystem 1 is assembled at a Make to Stock factory. Two MTS factories supply Part 1A. A single MTS factory supplies Part 1B. The MTO factory for subsystem 2 receives Part 2A from two MTS supply factories and receives Part 2B from a single MTS factory.

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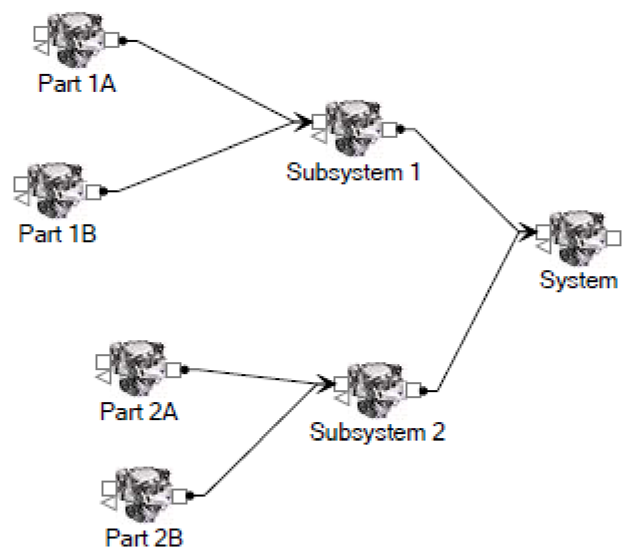


Figure 14. Bill of Material for System

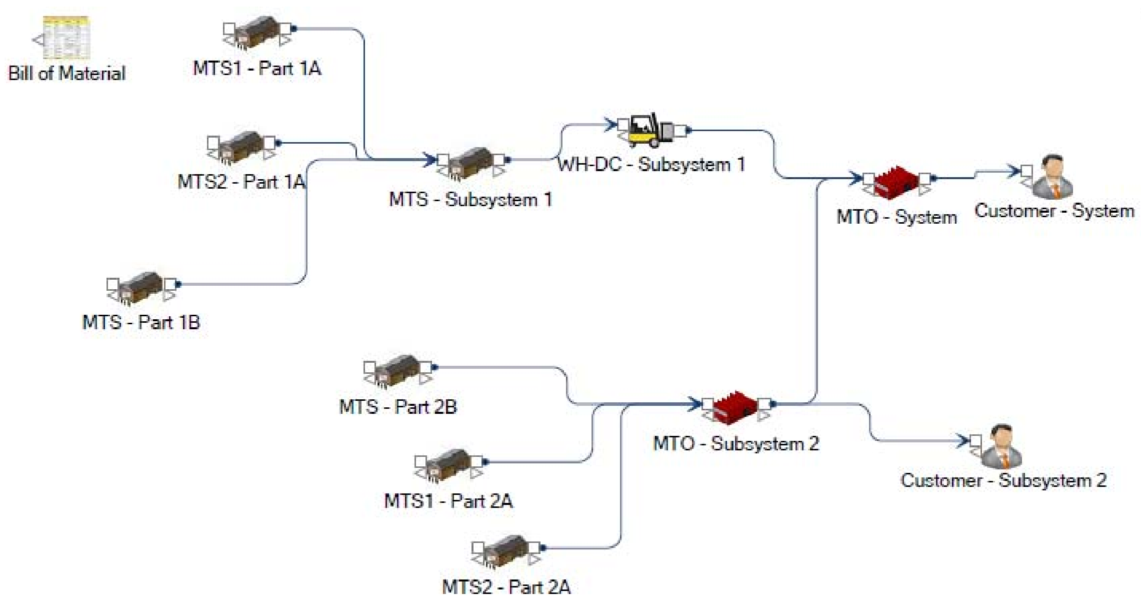


Figure 15. Base Case Supply Chain

Each factory has a broad array of input parameters that specify its costs and operations. There are five primary categories of input assumptions for each factory:

Costs – Delivery
Costs -- Production
Costs – Sourcing
Finance
Production

The assumptions are different for the MTS and MTO factories since the MTS factory must have assumptions regarding inventory and its management. Figure 16 presents as an example the production assumptions for the MTS factories.

| **Production** | |
|---|---|
| Average Yield | (Edit value...) |
| Days of Finished Goods Inventory Desired | 2 |
| Days of Raw Material Inventory Desired | 2 |
| Days to Add Capacity | 180 Days |
| Days to Remove Capacity | 180 Days |
| Firm Forecast | (Edit value...) |
| Forecast Adjustment | (Edit value...) |
| Forecast Averaging | 20 Days |
| Forecast Method | MovingAverage |
| Order Backlog Adjustment | 0.05 |
| Order Distribution | (Edit value...) |
| Planned Production Capacity Changes | (Edit value...) |
| Production Capacity Calculation Method | Calculated |
| Push vs. Pull | Pull |
| Raw Material Order Adjustment Time | 0.05 |
| Shipping Details | (Edit value...) |
| Specified Production Capacity | (Edit value...) |
| Specified Target Finished Goods Inventory | (Edit value...) |
| Specified Target Raw Material Inventory | (Edit value...) |
| Target Finished Goods Inventory Calculati... | Calculated |
| Target Raw Material Inventory Calculation... | Calculated |
| ⊟ Definition | |

Figure 16. Production Input Parameters for MTS

| Production | |
|---|---|
| Average Yield | (Edit value...) |
| Days to Add Capacity | 180 Days |
| Days to Remove Capacity | 180 Days |
| Order Distribution | (Edit value...) |
| Planned Production Capacity Changes | (Edit value...) |
| Production Capacity Calculation Method | Calculated |
| Shipping Details | (Edit value...) |
| Specified Production Capacity | (Edit value...) |

Figure 17. Production Input Parameters for MTO

Once the parameters for all of the factories, warehouses and customers have been entered, scmBLOX enables a wide range of events to be simulated and examined:

Increase or decrease in demand by any customer;
Loss of capacity by any factory;
Increase in delivery or shipping times;
Raw material shortages; and
Change is distribution strategy.

For the Base Case, it is assumed that Customer 1 increases the order rate from 100 systems per day to 125 at day 10 and that this increased demand lasts until day 70 and then decreases to 80 systems a day for sixty days and then returns to 100 systems per day.  Customer 2 orders a constant 50 subsystems 2 per day throughout the simulation period.  Figure 18 presents the customer orders for the simulations.

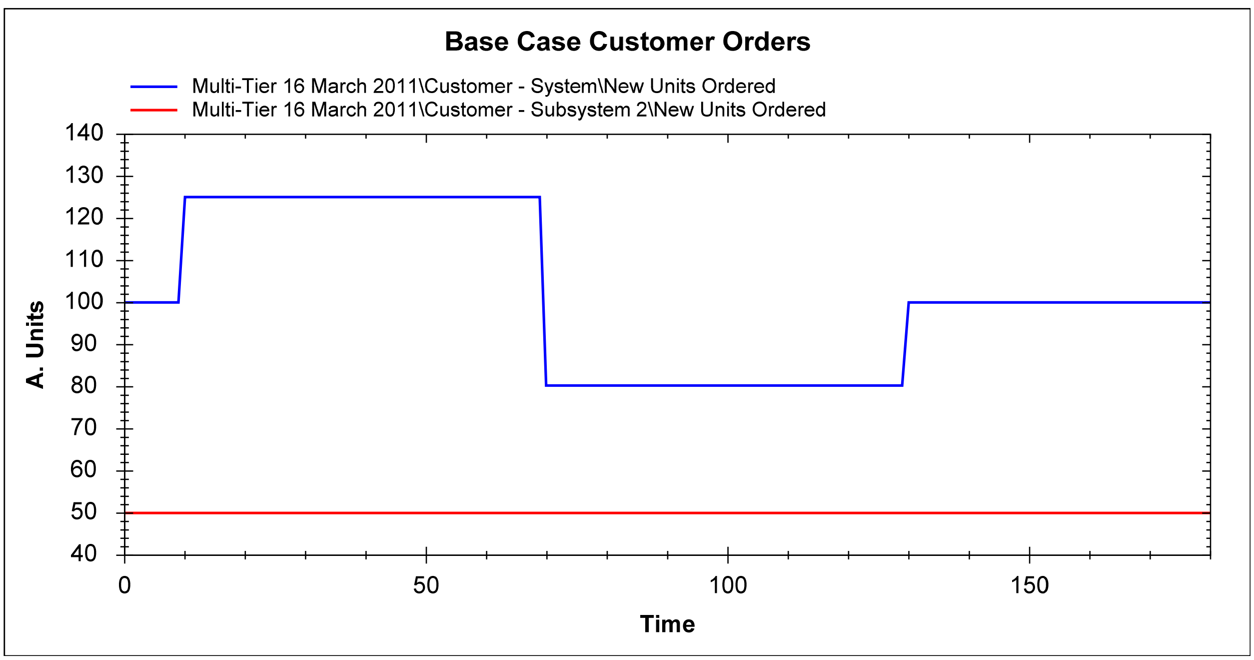


Figure 18. Base Case Customer Orders

Figure 19 presents both the customer orders as well as the customer receipts. As may be seen, system receipts lag the increase in orders and then exceed the order in order to reduce backorders. After the system orders decrease, the receipts continue at a higher level until the backorders are cleared. When the demand increases again, there is a slight lag in receipts. It is interesting to note the increase in demands for the system adversely affects the customer for subsystem 2 given that shortages in subsystem 2 reduce deliveries. These types of cross-channel impacts are often unexpectedly encountered in the real world.

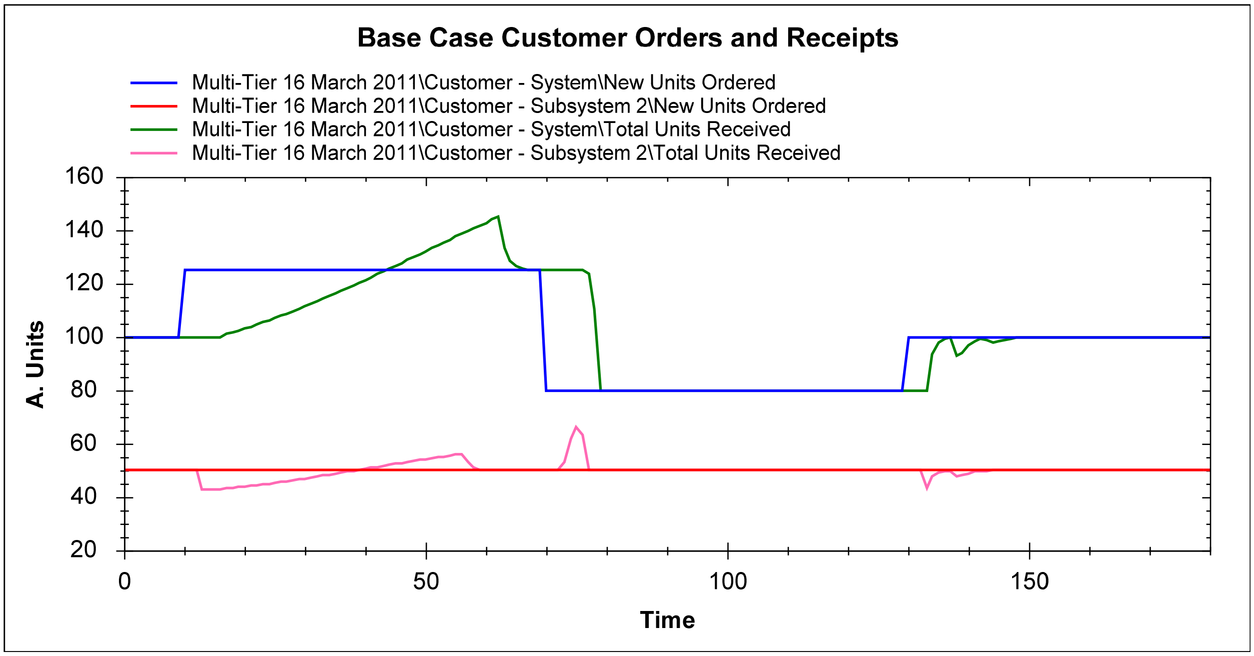

Figure 19. Base Case Customer Orders and Receipts

Figure 20 presents the Units Shipped for the Base Case. Key points are that the Warehouse/DC enables the shipment of subsystem 1 to meet the growth in demand. However, since subsystem 2 is supplied by a Make to Order factory, shipments lag the increase in demand. As a result, shipments of the complete system are limited by the availability of subsystem 2. The shipments of subsystem 1 from the Make to Stock factory exhibit greater variations because of the corrective ordering process of the warehouse – this is an indication of bullwhip in the lower tier.

Figure 21 presents the Base Case Inventories. As may be seen, all inventories decline with the increase in demand, however, inventories of subsystems 2A and 2B are more or less depleted in an attempt to satisfy demand. This lack of subsystems then restricts production of the complete system. When demand drops on day 70, inventories begin a rapid climb due to production in the pipeline but are then brought under control and begin to be reduced. Finally, when demand increases on day 130, inventories for subsystem 2A and 2B are once again under pressure.

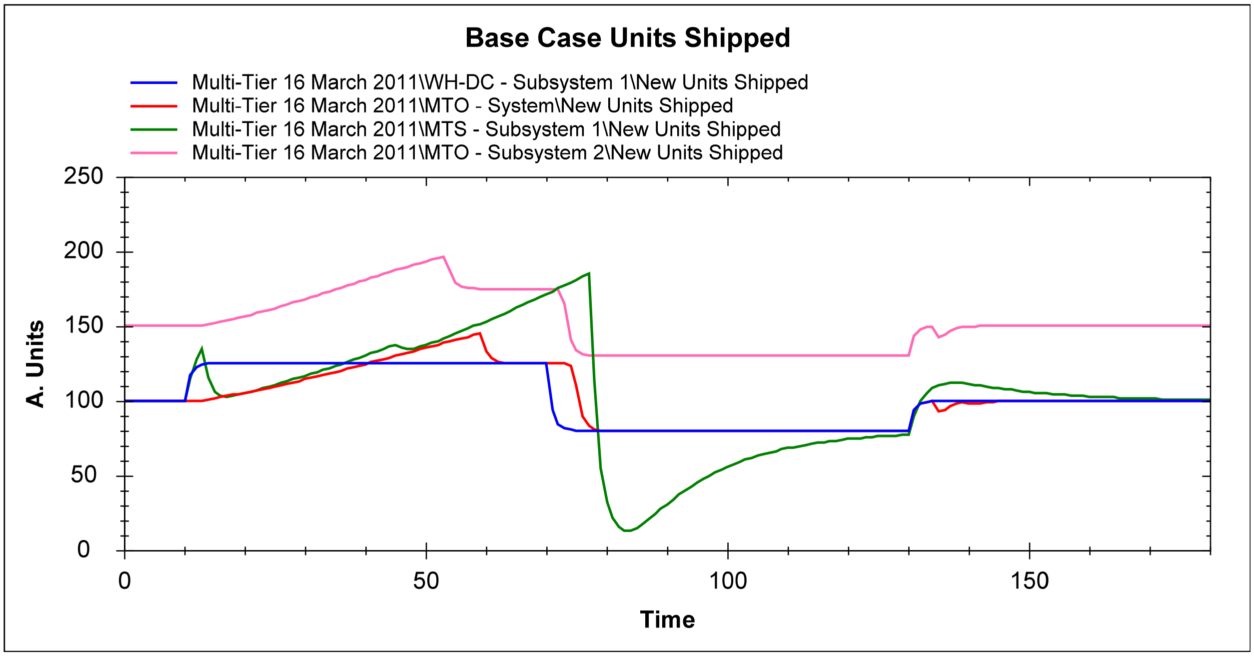


Figure 20. Base Case Unit Shipped

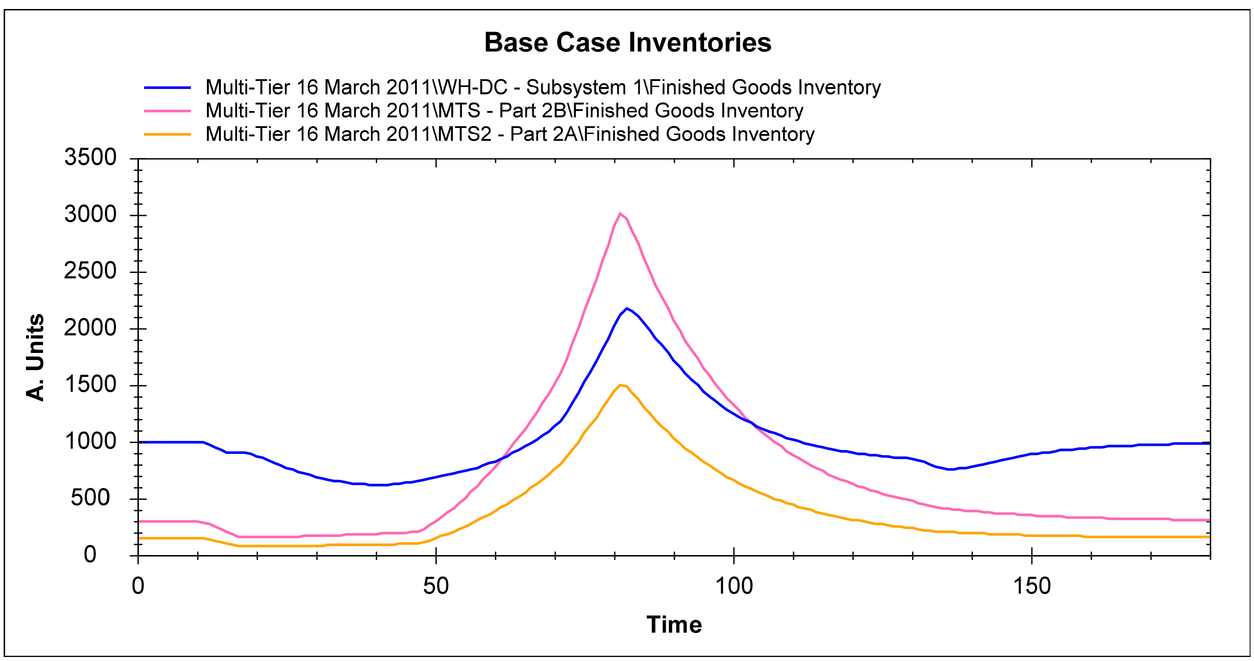


Figure 21. Base Case Inventories

Figure 21 presents base case backorders for the system and subsystem.  The greatest increase in backorders occurs at the Make-to-Stock factory for Subsystem 1.  This backlog largely arises due to the incoming orders arriving from the Warehouse/DC in an attempt to meet its own orders as well as correcting for its drop in inventory.  These high levels of orders tend to create instability at the MTS factory and initiate a bullwhip effect.

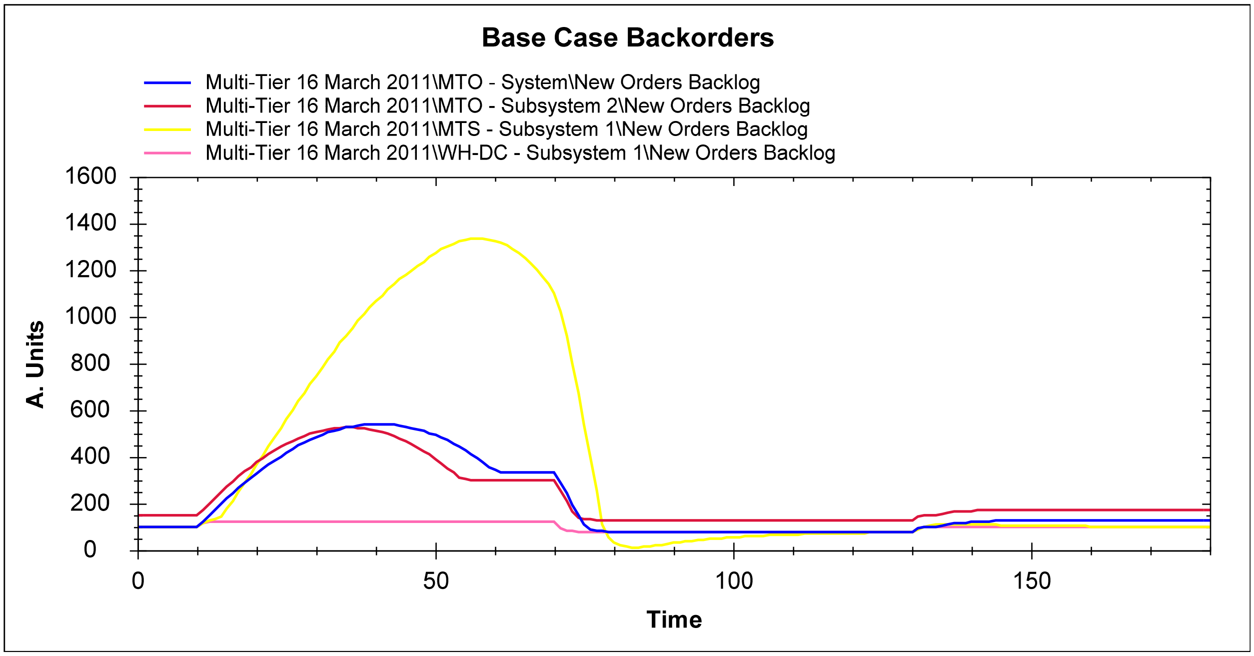


Figure 21. Base Case Backorders

## Alternative Cases of Enterprise Structure

### Elimination of the Distribution Center

In an effort to cut costs, many distribution centers have been closed within the virtual enterprise.  This action reduces inventory holding expense, building operational costs and labor. The downside risks, however, arising from closing a distribution center are lower levels of customer service and product availability. To examine the impacts of such a structural change, the Warehouse/DC was eliminated from the enterprise model shown in Figure 15. The warehouse stored five days of subsystem 1 inventory. Deleting this agent and establishing the direct shipping link from the MTS subsystem 1 factory to the MTO system factory required less than a minute of modeling time.  The new enterprise model is shown in Figure 22.  Figure 23 presents customer orders and receipts for the new enterprise assuming the same demand pattern as the base case. As may be seen, closing the warehouse has no impact on customer service.  Thus costs have been reduced and customer service has not been adversely impacted.  The reason for this outcome is relatively straightforward.  The Make-to-Stock factory for subsystem 1 plus the warehouse for subsystem 1 meant two levels of inventory for subsystem 1.  As a result, subsystem 1 was available for system assembly in both the base case and the alternative. Assembly of the final system, however, was limited by the availability of subsystem 2. This simulation makes that constraint very clear.

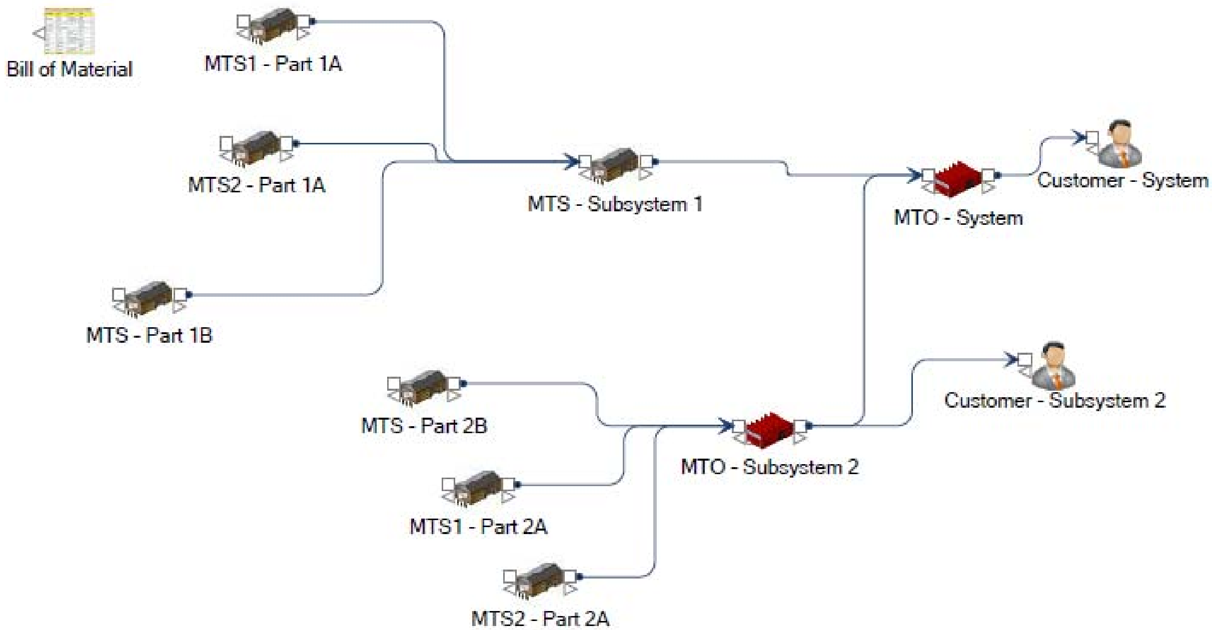


Figure 22. Enterprise with No Distribution Center

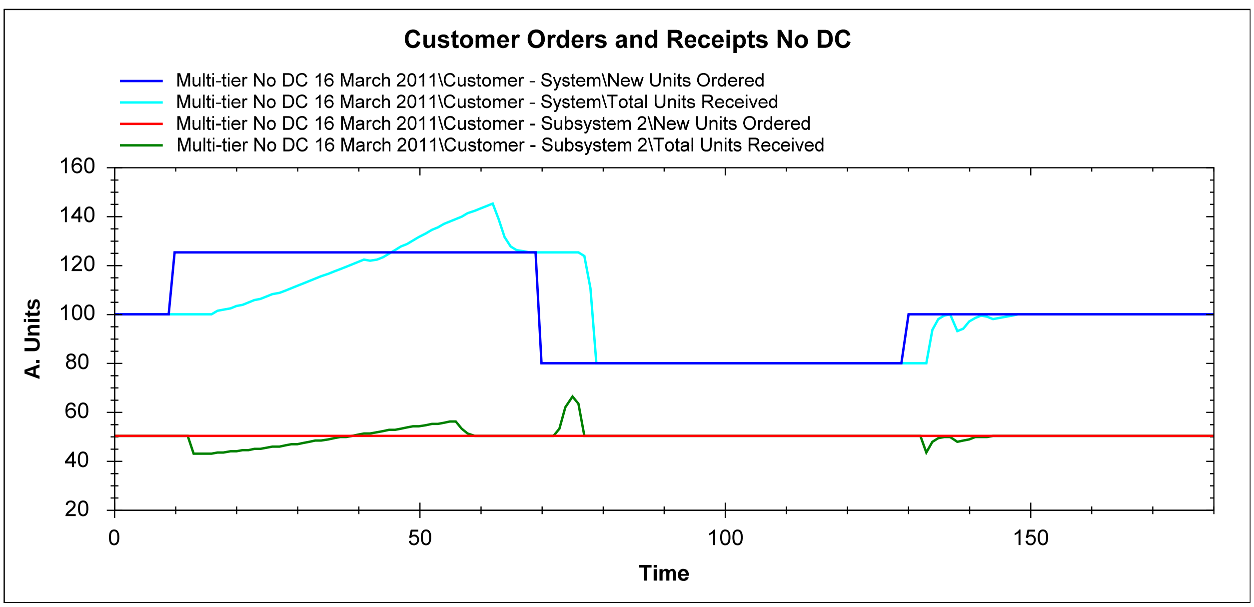


Figure 23. Customer Orders and Receipts for Enterprise with No Distribution Center

**Elimination of Distribution Center and Addition of Make-to-Stock**

One strategy for improving customer service is to produce subsystem 2 in a make-to-stock facility rather than a make-to-order facility. This would provide an inventory buffer for subsystem 2 and support final system assembly. This model change is accomplished by deleting the MTO factory, dragging a MTS icon to that location, and creating the new flow links. Again, this took less than a minute of modeling time. This structural change is shown is Figure 24. In the previous two cases, the make-to-stock factory for subsystem 1 attempted to maintain two days of final inventory. For this case, that target is increased to five days. A similar target inventory is established for the new make-to-stock factory for subsystem 2. Figure 25 presents customer orders and receipts for this case, again assuming the same demand pattern. As may be seen, the cross impact on the customer for subsystem 2 has been greatly reduced and service improved. It is this ability to rapidly assess impacts on performance of structural sensitivity that makes this approach so valuable to management of the global virtual enterprise.

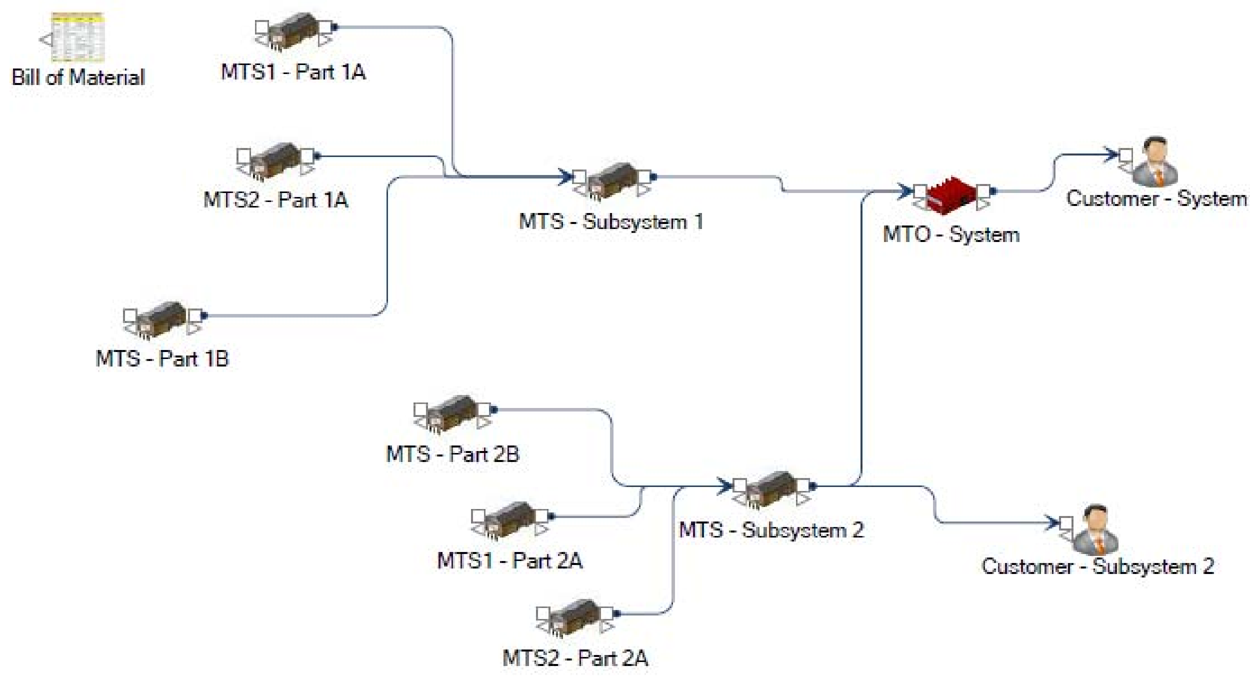


Figure 24. Enterprise with No Distribution Center But with Improved Make-to-Stock

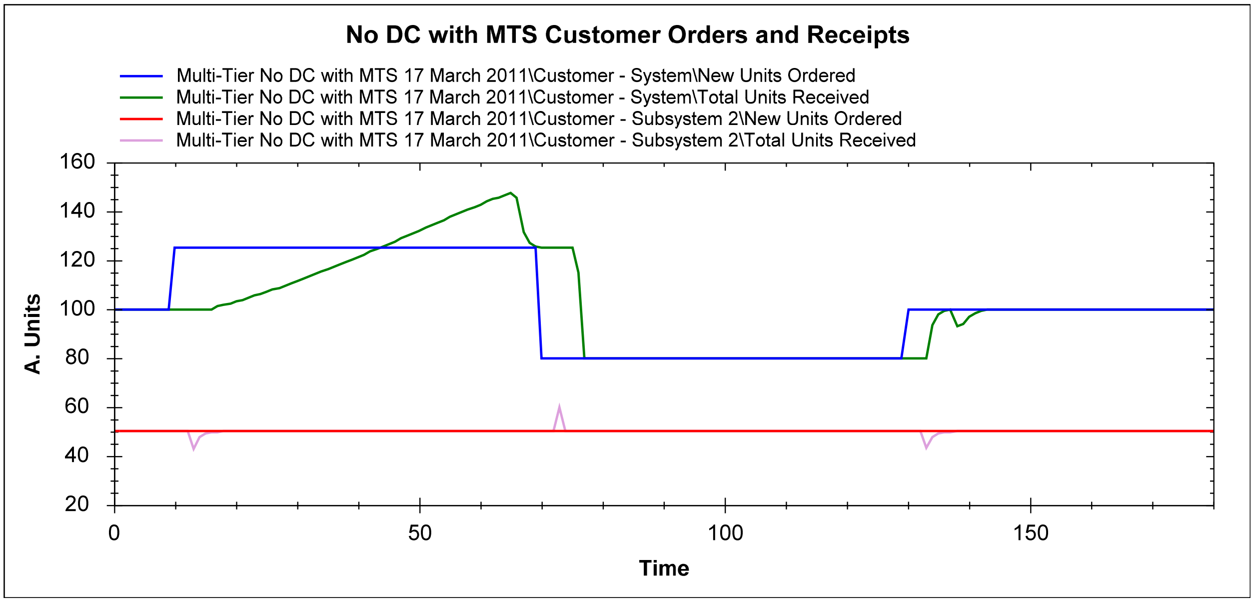


Figure 25. Customer Orders and Receipts for Enterprise with No Distribution Center and With Improved Make-to-Stock Management

## Conclusions

Almost everything we use today is manufactured by a virtual enterprise - a large distributed network of companies that provides parts, components, and sub-assemblies to a final manufacturer or integrator. It is not unusual for hundreds, even thousands, of companies to be involved in the production of a product by a large virtual enterprise. The virtual enterprise has arisen largely as a result of outsourcing, the underlying strategy that has led the evolution, if not revolution, away from the highly integrated vertical firm to a widely distributed network of suppliers. Risky, difficult and innovative components and sub-assemblies are routinely outsourced as are items requiring new production techniques. As one would expect, this has led inevitably to numerous problems and challenges across multiple industries. It would seem that all of the benefits of outsourcing are expected to be realized, and all of the risks are ignored. A great need exists for an analytical technology that enables improved design and management of the virtual enterprise.

System Dynamics is an appropriate technique for analyzing the dynamic performance of a virtual enterprise. These large networks of companies function as complex multi-tier, multi-channel supply chains. System Dynamics has been used to analyze supply chains from its very beginning as a modeling and simulation tool for policy analysis. These large-scale enterprise models, however, are very complex and very time consuming to build and test, and once built, they are typically difficult to restructure. For the modern enterprise, however, the ability to reconfigure the network of companies in response to external forces is critical, and models of the enterprise must have similar flexibility and rapid configurability. A key goal in enterprise management is access to *dynamic* system dynamics models that enable and support fast and agile management response.

SimBLOX is a technology platform that is designed to allow creation and easy management of macro-level models, including dynamic structural changes at a high-level. It uses a “building block” format in which simulation models represent the building blocks of a larger, more complex system. In the case of scmBLOX, a warehouse model is a building block (represented by an icon) that can now be dragged-dropped onto the model layout and then easily connected with other building block models (i.e., icons). Model visibility and management are greatly improved while still keeping the underlying model structure desired. The technology platform SimBLOX has been used to develop scmBLOX to enable modeling of large-scale supply chains and virtual enterprises. Currently, scmBLOX contains four SimBRIX or agent models: Make-to-Order Factory, Make-to-Stock Factory, Warehouse/DC, and Customer.

Using scmBLOX, almost any number of factories and warehouses can be linked together to create multi-tier and multi-channel enterprise models. scmBLOX is still undergoing development and additional agent models are in development as well as additional features being built into the current agents.

A very important feature of scmBLOX is that for the manufacturing portion of the virtual enterprise (as opposed to the distribution part of the enterprise), the structure is driven by the Bill of Material (BOM) of the product. That is, the components that are manufactured and integrated into sub-assemblies which are then integrated into the final product not only map into the BOM but the structure of the virtual enterprise as well.

An example product BOM was developed and a related virtual enterprise model was created using system dynamics agents. Simulations were performed to examine the performance of the virtual enterprise. Rather than conducting parameter sensitivity analysis as is typically done, scmBLOX allows structural sensitivity assessments to be rapidly conducted. Addition or elimination of distribution centers can be easily modeled and performance measured. Revising the manufacturing and outsourcing strategy by adding factories can also be easily addressed. On-going research is focusing on the interplay between enterprise structure and performance, the development of additional agent models and new features for current agent models, and the assessment of optimization strategies such as push-pull boundaries within the global virtual enterprise.

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