Introduction

What if you could predict how your supply chain would perform under any circumstance? The value is obvious, but how is it possible? The answer is supply chain simulation.

Simulation technology has been around for decades, used by engineers and scientists to help predict behavior under the challenge of real-world variability. However, simulating the end-to-end supply chain has proven challenging for numerous reasons:

- Complexity of the corporate supply chain
- Scale of decisions and volume of transactions
- Accessibility of simulation software to supply chain business professionals

However, the recent convergence of two unrelated factors has brought supply chain simulation to the forefront. The first factor is the new business climate driving unprecedented demand for simulation; the second factor is the IT evolution enabling the supply of reliable technology to support this new demand.

This white paper will explore why the time for supply chain simulation has come, and demonstrate how simulation has become a vital component of the supply chain design function within leading global companies.

Why Simulate the Supply Chain?

The answer to this question seems simple. If you could accurately predict the behavior of your supply chain, you should be much better equipped to make key decisions on strategy and execution.

But what type of behavior can you actually predict using supply chain simulation? And just how accurate will these predictions be?

Discrete event simulation is a unique form of analysis that truly factors time and variability into each individual transaction, decision and movement throughout the supply chain. By creating a detailed model of the end-to-end supply chain that incorporates variability into elements such as demand, sourcing lead times, transport times, handling and production, a simulation will report key point-in-time metrics such as:

- On-time deliveries
- Inventory levels
- Expedited shipments
- Costs (e.g. variability in commodity pricing)
- Risks (e.g. probability of stock outs, production disruptions)
- Product perishability (e.g. shelf life)
- Sustainability (e.g. GHG impacts)
- Sourcing delays
- Lost orders

If you run multiple iterations, you can also track how drastically the accumulation of these different variables will affect supply chain performance and how wide the swing can be in both a positive and negative direction.
## How Simulation Can Be Applied to Business Challenges

Here are a few examples of where supply chain simulation can be used to help predict performance and guide key decisions.

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<th>Simulation Can Be Used To:</th>
<th>Examples</th>
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| **PREDICT SERVICE**      | **Lost Sales**: To track potential lost sales due to store or shelf-level stock outs, analysts can simulate the flow of goods through the supply chain and onto the store shelves, adding the appropriate supply chain variability (sourcing, transportation, etc.) along with historical or projected demand variability.  
**On-Time Deliveries**: To predict the percentage of on-time deliveries based on different transportation policies or product flow-paths, analysts can create a simulation model that emulates multi-stop transportation routes or specific replenishment policies, including the inherent variability of these routes. |
| **TEST INVENTORY POLICIES** | **On-Hand Inventory**: To predict the actual amount of inventory that will be on-hand for each product at any point in time, a simulation of the supply chain can be run testing different inventory policies with varying trigger levels such as reorder points, reorder quantities, or time between reviews.  
**Stock-Outs & Back Orders**: Simulating historical demand using different inventory policies can quickly provide an analyst with predicted dates, times and quantities of stock-outs and back orders, helping evaluate if changes will improve or degrade performance. |
| **ANALYZE PRODUCTION CAPACITY** | **Production Levels**: Creating a simulation model that emulates the production process, including the times and capacities associated with work centers and work resources, can enable analysts to predict how different schedules, lot sizes or sequences can affect overall production throughput or capacity utilization.  
**Product Flow Bottlenecks**: Simulating the end-to-end supply chain including the time, capacity and variability associated with key processes like customs, loading/unloading, stocking or shipping can help point towards the biggest potential bottlenecks and the impact these bottlenecks can have under different levels of demand or seasonal capacity loads. |
| **DETERMINE ASSET UTILIZATION** | **Railcar Fleet Size**: Creating a simulation model of the railcar transportation network can help analysts compare the trade-offs between service and cost by running hundreds of iterations with varying fleet sizes, car positions and schedules. The result can help determine the service/cost sweet spot and required level of railcar investment.  
**Omni-Channel Validation**: By simulating the order fulfillment logic using both traditional DCs and specific stores, retailers can help test their omni-channel strategy to validate how capable they are of delivering same-day or next-day orders to their e-commerce customers. |
| **VALIDATE OPTIMIZATION ANSWERS** | **New DC Structure**: Network optimization algorithms drastically simplify time and variability in order to propose the “optimal” supply chain footprint. By adding actual SKU-level orders along a true timeline, a supply chain simulation can predict the actual flow of products through the network to identify if seasonal demand or stacked variables such as transportation and sourcing lead-times could adversely affect the new network.  
**Near-Shore Sourcing**: Offshore sourcing often provides the cost optimal supply chain structure. However, the actual effects of the inherent variability and long-tails associated with cargo shipping can only be tested through an end to end supply chain simulation. Results showing high risk of extended stock-outs or late orders may lead analysts to near-shore recommendations. |
Opportunities to use supply chain simulation for more robust decision-making or to flat-out save a company from making a drastically bad decision are plentiful. So why doesn’t every company simulate their supply chain operations before making critical decisions?

The reality is that until very recently, it simply hasn’t been possible to simulate the complex dependencies of a global supply chain, nor was it possible to simulate the sheer magnitude of products, nodes and transactions that make up these supply chains. Unprecedented supply chain volatility coupled with technology breakthroughs are now unlocking the potential for supply chain simulation.

Why the Time is Right for Simulation

Enterprise simulation is moving into mainstream use throughout corporate supply chain organizations due to the convergence of supply and demand. Supply, in this case, refers to the availability of relevant, scalable and user-friendly simulation technology. Demand refers to new business conditions that are creating an increased need for simulation technology. The following section explains the most critical factors affecting the supply of and demand for simulation technology.

Supply: The Evolution of Technology

Historically, the ability to simulate an end-to-end corporate supply chain with hundreds of global sites (suppliers, manufacturing, distribution, customers, etc.); thousands of products and millions of orders was simply not possible. However, numerous technology advances have enabled a new type of enterprise simulation which can truly analyze a supply chain at the operational level of detail.

The most important of these recent technology advances that are unlocking the power of enterprise simulation include:

- Computing power—Simulating each individual event and decision at the SKU and order level of detail throughout the entire supply chain requires some serious computing horsepower. Huge improvements in RAM and processing speed, which had been the biggest bottlenecks, have removed many of the obstacles to running simulations on standard corporate servers.

- Availability of “big data”—The exponential growth and availability of data from sources such as ERP and APS software makes valuable data for simulation readily available not only to IT but to business users—and more data can mean more accurate analysis.

- New supply chain simulation software—The use of simulation software has traditionally been limited to engineers and scientists, in part due to its extreme complexity. Today, simulation applications such as LLamasoft have widened the reach and usability of the technology to business analysts who are applying simulation as a key component of their corporate supply chain design practice.
Demand: The New Business Climate

The pace of change, volatility and rapidly evolving consumer behaviors mean that companies must continuously analyze their supply chain strategy and operations to adapt. Companies often need to act quickly and don’t have the luxury of testing their new strategies in the real world before rolling them out across the organization. Instead, companies must simulate the behavior of their supply chain to help predict behavior and the expected effects of changes on performance metrics including cost, service, sustainability and risk.

What’s Driving the Need for Simulation Technology in Business?

- The pace of change—Product models that used to last multiple years or even decades are now turning over multiple times each year or even every few months, meaning a continuous management of new product introductions and old product phase-outs. Meanwhile, the traditional old-world markets are being trumped by new-world markets and altogether new consumer groups, meaning a major shift in demand and the end point of the supply chains.

- Volatility—Distribution and unpredictability is the new norm. Fuel and other commodity costs now seem to rise and fall in extremes, with major impact on the landed cost of goods. Suppliers that have been stretched into thin margins or single sourced due to cost measures suddenly fail, leaving supply chain executives in precarious positions. Port congestion and customs delays lead to significant lead-time issues.

- New consumer behaviors—Today’s customer acts very different than customers of even a few years ago, and the rise of e-commerce has drastically altered the consumer’s shopping patterns and expectations. Real-time price comparisons challenge brick-and-mortar companies to offer competitive pricing and strategies to keep the customer in the store. Same-day service expectations are forcing everyone to consider new strategies for fulfilling demand and stocking product.

Making the wrong decision, such as investing tens of millions for capacity in the wrong place or running out of inventory during peak buying periods can get people fired or put companies out of business. Predicting the effects of these decisions through enterprise simulation helps reduce the risk and validate the decision before it is implemented in the real world. Each of the factors listed above push the demand for relevant, scalable and easy-to-use simulation to an all-time high.
LLamasoft Enterprise Simulation Technology

Proprietary SimServer™ Engine

LLamasoft was built on deep simulation domain expertise applied to the corporate supply chain. Over the years, LLamasoft has continuously updated its proprietary simulation technology, SimServer. SimServer is the only discrete-event simulation engine specifically designed for the enterprise supply chain, and architected from the ground up to scale with hardware to tackle SKU and transaction level detail.

LLamasoft® Supply Chain Guru® is a market-leading supply chain design application that integrates numerous optimization and simulation technologies into a single user interface and data model, including the SimServer engine. By integrating these different analytical techniques into a unified application, Supply Chain Guru enables rapid iterations between optimization recommendations and simulation testing.

The Supply Chain Guru scenario manager further improves the analysis process by enabling users to quickly adjust multiple variables and create dozens of what-if scenarios and sensitivity analyses. These scenarios can be run locally or in the LLamasoft cloud for faster and parallel solving.

Having the power to generate and solve what-if scenarios quickly and easily has changed the way businesses look at supply chain design. Rather than evaluating individual solutions, businesses are now using LLamasoft technology to evaluate ranges of options and test them under real-world variability for better decision making.

Simulation Case Studies

LLamasoft has supported more than 1,000 supply chain design projects for leading global businesses world-wide. Here are some real examples of how businesses have leveraged LLamasoft simulation technology as part of their supply chain design function.

Case Example: Representing Complicated Business Logic

Challenge: A large consumer goods manufacturer performed a strategic network design project to identified considerable savings in transportation costs, warehouse costs and inventory costs by consolidating warehouses. However, the inventory savings assumed full consolidation of inventory at the new warehouses; this was not consistent with the management incentives that were used in the business. An alternative suggestion of separate stocks for each market wiped out a large chunk of savings.

Solution: Using simulation, the team was able to evaluate some potential compromises under real-world conditions to find the best solution.

Results: The first suggestion was to share safety stock, but to allocate cycle stock to particular market organizations. This still didn’t provide satisfactory savings, but a second attempt showed that by sharing 25 percent of their cycle stock as well, the market organizations could still get 70 percent of the desired savings.
**Case Example: Using Simulation to Validate Inventory Optimization**

**Challenge:** A global healthcare and consumer goods company needed to better understand their customer demand patterns, improve customer service and identify more effective postponement and risk-pooling strategies to enable overall reductions in working capital.

**Solution:** Using LLamasoft Supply Chain Guru, the company realized that their current safety stock methods had been incorrectly classifying the demand for their healthcare products, resulting in significant excess inventory or missed service metrics for most products. Simulation was used to validate recommended inventory levels (blue line) compared to the company’s existing safety stock method (purple dashed). Green line represents the actual simulated safety stock results (using Supply Chain Guru simulation).

**Results:** Simulation showed that the existing method significantly overstocks, while the recommended levels more closely match actual test results (green), identifying a $2 million annual inventory savings opportunity.

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**Case Example: Smoothing Production Planning and Order Variance**

**Challenge:** A consumer goods company wanted to get better performance out of their manufacturing plant. Instability in ordering patterns combined with ad-hoc scheduling led to inefficient use of machines in the plant.

**Solution:** Managers thought efficiency could be improved by segmenting fast and slow moving inventory and initiating regular schedules for their manufacture. They used simulation to test out the improvements from this strategy before implementing them.

**Results:** The simulation suggested that these strategies could result in a 40 percent improvement in stock levels together with dramatic improvements in workcenter change-overs and adherence to production plan.

Result: 40 percent lower stocks, less warehouse space required, regular stable pattern of orders
Case Example: Using Simulation for Railcar Fleet Sizing

Challenge: A company needed to determine how many railcars were needed to transport product from their manufacturing plant.

Solution: A simulation model was built with key inputs including forecasted demand, railcar assets with capacity, variable travel, unload/load and delay times and maintenance implications. First, a baseline model was built, then a series of scenarios were run changing the number of railcars available and evaluating key output metrics.

Results: The simulation showed the trade-off between railcar availability (green bars) and utilization (red bars)—more railcars in the fleet would lead to higher service but lower utilization.