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PANEL SESSION: OPPORTUNITIES FOR SIMULATION IN SUPPLY CHAIN MANAGEMENT

Jerry Banks

1096 Tennyson Place
Atlanta, GA 30319, U.S.A.

Steve Buckley

IBM Thomas J. Watson Research Center
Yorktown Heights, NY 10598, U.S.A.

Sanjay Jain

Alexandria Research Institute
Virginia Tech
Alexandria, VA 22314, U.S.A.

Peter Lendermann

Singapore Institute of Manufacturing Technology
Singapore, 638075, SINGAPORE

Mani Manivannan

Vector SCM
27275 Haggerty Road, Suite 550
Novi, MI 49377, U.S.A.

ABSTRACT

It has become a matter of survival that many companies improve their supply chain efficiency. This presents an opportunity for simulation. However, there are many challenges that must be overcome for simulation to be a contributor to play an effective role. Four contributors discuss the opportunities that they see for simulation to play a meaningful role in the area of supply chain management.

1 INTRODUCTION

Simulation has been used in supply chain management (SCM). But, there are many additional opportunities for application of the methodology. However, many of these opportunities require that challenges be overcome.

This article includes the responses of four knowledgeable people on the opportunities and challenges. Steve Buckley discusses the use of simulation in process control, decision support, and proactive planning. Sanjay Jain discusses how simulation can be used through the supply chain life cycle. Peter Lenderman discusses characteristics of firms for which simulation appears to be particularly feasible for SCM. Mani Manivannan provides some ten opportunities for simulation in SCM.

2 STEVE BUCKLEY, IBM THOMAS J. WATSON RESEARCH CENTER

IBM Research has been very active in supply chain simulation for over ten years. The bulk of our work in this area has been strategic in nature – standalone, one-time simulations used to make structural or policy decisions in IBM's internal supply chain or a supply chain of an IBM customer.

For example, IBM reengineered its global supply chain during this period to achieve quick responsiveness to its customers with minimal inventory. To support this effort, we developed a supply chain analysis tool called the Asset Management Tool (AMT). AMT integrated graphical process modeling, analytical performance optimization, simulation, and activity-based costing into a system that supports quantitative analysis of extended supply chains. IBM used AMT to study such issues as inventory budgets, turnover objectives, customer-service targets and new product introductions. It was used at a number of IBM business units and their channel partners. AMT benefits included over $750 million in material costs and price-protection expenses saved in 1998. IBM was awarded the prestigious Franz Edelman award from INFORMS in 1999 for this work (Lin et al. 2000).

AMT was later made into an IBM product called the Supply Chain Analyzer (SCA) which was used in consulting engagements by IBM Global Services (Bagchi et al.

1998). SCA was used to perform strategic studies for IBM customers addressing issues which include:

- Number and location of manufacturers and DC's
- Stocking level of each product at each site
- Manufacturing and replenishment policies, e.g. Build To Plan (BTP), Build To Order (BTO), Assemble To Order, Continuous Replenishment
- Transportation policies
- Supply planning policies
- Lead times
- Supplier performance
- Demand variability

SCA was a standalone tool running on Windows with a user-friendly graphical interface. In order to provide model data to SCA one had to prepare a number of flat files in a specified format. In most cases this was a one-time manual process using query tools and spreadsheets.

During the past two years we have been more focused on operational supply chain simulation. We are developing operational supply chain simulators that have the following characteristics:

- Simulation model data is integrated with the enterprise IT system.
- The simulation tool is integrated into the enterprise business processes.
- The user interface of the simulation tool is customized to the needs of each user.
- The simulation tool is web-enabled since business process management is shifting to the web and data is readily available on the Internet. Modern web portal technology supports customizable user interfaces.
- The simulation is very fast due to improvements in computer technology coupled with careful design of simulation granularity.

We have recently identified three valuable scenarios for operational supply chain simulation:

1. Process control. Simulate a process, then track the process against the simulated results. For example, we are engaged with one of our divisions to predict their product inventory levels for future periods. Actual inventory will be tracked against predicted inventory for early detection of unexpected situations.
2. Decision support. Value assessment of potential responses in an event driven enterprise (Lin et al. 2002). For example, the potential responses to a late supplier delivery may include a re-optimization of inventory levels. Simulation can be used within the current business environment to predict the cost, serviceability and revenue impact of the new inventory levels. From multiple runs these predictions can be stated in stochastic terms and used for risk management.
3. Proactive planning. Prediction of potentially harmful business trends using intelligent sensing of the business environment (Lin et al. 2002).

ACKNOWLEDGMENTS

The list of people who contributed to supply chain simulation research at IBM during the past ten years is far too long to include in this space. However I would like to highlight the pioneering contributions of Chae An, Dan Connors, Markus Ettl and Grace Lin.

3 SANJAY JAIN, VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Simulation has wide ranging opportunities to support SCM. The role of simulation in SCM has to be established in reference to a defined scope of such models of supply chains. The scope of such models is discussed first, followed by examination of the role of simulation in SCM through supply chain life cycle stages. Approaches to meet the challenges to the increased role of simulation in SCM are suggested in the last section.

3.1 Scope of Supply Chain Simulation Models

The scope for modeling supply chains is different from traditional modeling of manufacturing systems. Traditionally, simulations of manufacturing systems modeled the material flow through different machines and material handling systems. Parts release was usually modeled using an inter-arrival distribution or some basic rules. These models provided value through determination of machine utilizations, cycle times, bottleneck analysis, etc.

One may model a supply chain by integrating a number of manufacturing and logistics models and studying the flow of material. While flow of material is the purpose of the supply chain, a simulation that only models the material flow may not be very valuable. The model has to include other major processes and flows in the supply chain, in particular the flow of information through major business processes that trigger and control the flow of material.

A supply chain simulation model should be built by integrating models of manufacturing and logistics systems only if these component models include sub-models of the business processes and information flows in addition to the material flow. Such holistic models of manufacturing and logistics systems have been referred to as Virtual Factory and Virtual Logistics (Jain et al. 2002). These models can be integrated together to form a Virtual Supply Chain, a simulation model that includes integrated models of material and information flows. Ideally, it should also include the third major flow, that of money transactions through the supply chain.

3.2 Simulation through Supply Chain Life Cycle

The role of a Virtual Factory to support a manufacturing system through its life cycle has been described (Jain et al. 2001). A Virtual Supply Chain can be similarly used to support a supply chain throughout its life-cycle phases of design, operation and termination.

During the supply chain design phase, simulation can be used to evaluate different configurations of a supply chain. These can include those formed with different manufacturing and logistics companies as supply chain members and those with different locations of manufacturing and distribution facilities. The models can also support evaluation of different product configuration postponement decisions. More often than any of the preceding decisions, the supply chain partners may use simulation for establishing desired inventory levels at different stages of the supply chain such that the performance can be maintained within an established range in face of inherent uncertainties. The partners can set service level goals and determine the inventory levels at successive stages that will allow them to achieve the goals based on the uncertainties at each of the stages.

Virtual Supply Chain models can provide valuable support during the operational phase of the supply chain. The use of simulation during this phase can support supply chain planning and scheduling and supply chain execution. Simulation can be used in a generation and an evaluation role for establishing the production and logistics plans and schedules to meet long and short term demands. For supply chain execution, simulation can be used for event management by evaluating alternative courses of action available on the occurrence of an interruption. Distributed simulation is well suited for this role as it allows speedy execution and allows supply chain partners to maintain their proprietary data (Gan et al. 2000).

During the supply chain termination phase, simulation models can be used for evaluating product phase out and phase in plans. Alternative plans for "emptying the pipeline" can be evaluated. The plan for phased shut down of manufacturing and distribution facilities can be evaluated for its volume and cost impact. The ability of the supply chain to provide service parts for maintenance and repair operations can be verified and the cost impact quantified.

3.3 Meeting the Challenges

The simulation community has to rise to meet a number of challenges before these opportunities can be fully exploited. Modeling approaches that allow execution at different levels of detail will help counter the need for multiple models. Advancements in integration of existing models and their execution in a distributed framework are required to address the issues of model building effort, execution time and the reluctance for sharing proprietary data among supply chain members. Advances in integration with operating systems such as ERP systems, manufacturing execution systems, databases, event monitoring systems, and the Internet should make it easier to establish simulation in the SCM arena. Interfaces with expert systems and rule bases that rapidly create desirable alternatives on the occurrence of unplanned events can reduce the user expertise requirement and provide the needed support to the supply chain managers.

Simulation has a promising future in supporting the design and operation of supply chains if the scope of models includes the material and information flows and if the simulation community exerts itself to meet the various challenges to such applications.

4 PETER LENDERMANN, SINGAPORE INSTITUTE OF MANUFACTURING TECHNOLOGY

Excellence in operational execution in manufacturing and logistics along the supply chain depends on the timely and effective translation of customer demand into material control decisions across the supply chain. This challenge is complicated by the range of products, complex processes at each stage of the supply chain, suppliers and customers who also may be competitors, third party logistics, and a variety of technical, business, and economic constraints.

Supply chain operational planning is essential in order to know "how execution should be" such that products can be made at the lowest possible cost and delivered to customers on time. Many of today's state-of-the-art supply chain planning (SCP) systems take information about customer demand and historical information about supply chain performance, and generate material planning and control decisions in an analytical manner.

The limitations of such deterministic planning approaches are realized at the moment when it comes to the actual execution of such plans:

- The operational performance can be assessed only on the real history of the system. But parameters in the past cannot be changed.
- Experimentation with the real system is often disruptive, seldom cost-effective and sometimes just impossible.
- Random effects do occur and are difficult to portray.
- Precise prediction of the dynamic evolution of the system over time is not possible.

Discrete event simulation (DES) technology is able to address these shortcomings. Simulation has in fact been used to address issues regarding how to manage supply chains within the four factory walls for a long time by verifying what effect different system configurations have on "how execution would be." But the concern that "averages kill" (Grabau 2001) is of course an issue beyond the factory walls as well. Unlike on the shop floor, along the logistics nodes of supply chains a lot of potential for lead-time reduction and throughput optimization is yet to be exploited in many industries. And on a supply chain scale with larger quantities involved, even small relative changes may have a high impact in absolute terms.

Simulation tools specifically for supply chain simulation are already available in the market. An example is described in Archibald, Karabakal and Karlsson (1999). Using a centralized approach, these tools integrate supply chains into one single simulation model.

However, a high degree of flexibility and scalability is required to be able to address a wide range of strategic, tactical and operational challenges in a fast changing business environment. In fact it must be possible to address the entire cycle from simulation modeling, model validation, configuration of simulation runs, data input, execution of simulation, analysis of output data, optimization, and implementation of optimized business execution models all the way to model maintenance sufficiently fast.

Development of robust, high-performance distributed simulation has enabled tackling the issues of geographical distribution of supply chains, data shielding, local maintenance and scalability. Application of distributed simulation technology for supply chain management has been pioneered for example by the Manufacturing Planning and Scheduling Group at Singapore Institute of Manufacturing Technology (SIMTech) in collaboration with Nanyang Technological University (Gan et al. 2000) and the Georgia Institute of Technology (Julka et al. 2002), and also by the Manufacturing Engineering Laboratory of the National Institute of Standard and Technology (McLean and Riddick, 2000).

Depending on the challenges to be tackled, two alternative implementation approaches for distributed supply chain simulation can be applied: Simulation models can be developed from scratch, adding additional layers of granularity over time (top-down-approach). Alternatively, very complex simulation models can be integrated with each other and refined to create high-fidelity simulations (bottom-up approach).

While simulation models are quite useful in understanding the interactions between supply chain components, they generally incorporate a relatively crude abstraction of the associated planning processes mentioned above. Simulation models are typically fed by release of materials into the system. These input releases, however, are difficult to generate in today's pull-environments with high demand variability and frequent phase-in of new products. The systems represented by the simulation models are ultimately driven by customer demand scenarios. In this setting, the more appropriate term to be used would be "demand fulfillment management" rather than "supply chain management".

The most straightforward way of translating customer demand into feasible input release rates is to integrate the underlying planning and customer order management procedure(s) into the simulation (Lendermann et al. 2002). Current efforts at the Singapore Institute of Manufacturing Technology are focusing on how to even make use of existing (novel types of) business application software as far as possible for order management simulation.

As feasibility of operational execution plans is an issue more that ever before to enable high-fidelity commitments to the customer, this opens up possibilities for simulation-based scheduling methodologies in the supply chain as well.

Last, but not least, discrete event simulation will also allow the assessment of the dynamic behavior of supply chains in a non-steady state, for example a system recovery after perturbations such as breakdowns of critical resources.

Taking these considerations into account, discrete event simulation appears to be particularly feasible for supply chain management in industries that are subject to characteristics as follows:

- A mass production environment which is subject to high variability and stochastic uncertainties across the entire supply chain.
- A lot of complex operational interdependencies between suppliers and customers (e.g. waferfab and semiconductor assembly & test) bear significant potential for optimization and therefore foster the search for collaborative performance improvement.
- The need for optimization of sequence and capacity utilization in manufacturing is high and therefore the flexibility regarding capacity adaptations (e.g. because of high capital costs) is low.
- The logistics content of the value-added operations is significant.
- The non-repetitive labor content of the value added operations is low.

It will be possible to exploit the opportunities for discrete event simulation in supply chain management if we are able to clearly point out what the differences are compared to the challenges that can be tackled with "conventional" supply chain planning systems as described above.

5 MANI MANIVANNAN, VECTOR SCM

In recent years, it is becoming more evident for large and medium size corporations to spin off under-performing operating units, and/or merge with the diversified, cash strapped competitors. The unsettling macro-economic conditions, a huge glut in the supply base, uncertainties in consumer behavior, and stochastic demand patterns further aggravate this situation. Such dynamics impact the entire supply chain and thus it has become a matter of survival for many companies to improve their supply chain efficiency, and reduce costs as a result of mergers and spin-offs.

A supply chain network typically consists of four levels of facilities integrated to accomplish the efficient flow and least-cost supply, manufacture and delivery of products and services. Products flow downstream from vendors to plants, plants to distribution centers (DC's), and distribution centers to final customer or the markets. There can be many other intermediate facilities between any two levels of facilities (see Figure 1).

Moreover, products may sometimes flow upstream when intermediate products are returned to plants for rework, or reusable products are returned back from markets to distribution centers for recycling. Often, large complex supply chains involve multi-commodity, multi-modal, multi-echelon, and multi-periods. All these need to be either decomposed or aggregated to simplify supply chain redesign, analysis, and management.

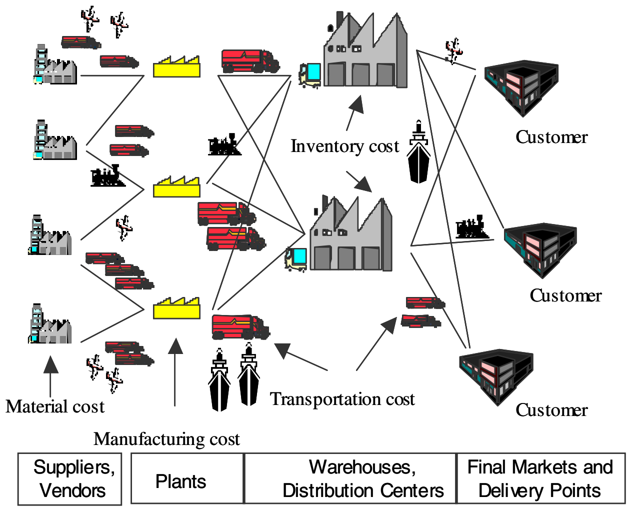

Figure 1: A Typical Supply Chain Network

There are a growing number of opportunities for simulation in providing decision support as part of SCM. Simulation is used in a variety of problem domains within a supply chain to

- Optimize network and materials flows,
- Reduce costs and cash consumption,
- Reduce Transit time and increase velocity,
- Streamline, align, and focus information flow,
- Streamline and refocus the organization from functional and national to process and cross-border, and so on.

Supply chain simulation encompasses the behavior of an integrated logistics and manufacturing networks depicting complex characteristics of both inter- and intra-facilities, physical entities and resources, e.g., finished products, subassemblies, service parts, trucks, airplanes, ships, barges, containers, etc.

In general, simulation is applied to investigate the stochastic impact and variability caused by production schedules, supply base changes, final customer demand, transportation mode shifts, container/packaging changes, etc. The following provides a list of key opportunities for simulation in a supply chain (not exhaustive):

- Perform simulation and scenario analysis to validate existing supply chain(s) to identify the shortcomings and opportunities for redesign.
- Investigate the impact of changes in major demand changes on supply chain components.
- Investigate the impact of new and innovative ways of setting up and operating a large supply chain.
- Investigate the impact of eliminating an existing or adding a new infrastructure component to an existing supply chain.
- Investigate the impact of changing operational strategies within a supply chain, due to major shifts in products, processes, location and use of facilities, etc.
- Investigate the impact of (i) making parts in-house, (ii) outsourcing to existing supply base, (iii) developing a new supply base, or (iv) a combination of (i), (ii) and (iii), based on the tradeoffs between inventory impact and other supply chain metrics.
- Investigate the impact of merging two supply chains or impact of separating a portion of the existing components of a supply chain.
- Investigate the relationships between suppliers and other critical components of a supply chain by rationalizing the number and size of supply points based on total costs, quality, flexibility, responsiveness, etc.
- Investigate the opportunities for postponement, a concept used in reducing product and process variety and achieving standardization across the supply chain.
- Investigate the impact of current and new in-plant and pipeline inventory strategies on the overall performance of a supply chain.

Certainly, other opportunities exist for simulation in support of SCM. In order to investigate the aforementioned opportunities, commercial off-the-shelf (COTS) software packages are often used for modeling and analysis of a supply chain.

Many COTS packages utilize simulation combined with optimization and heuristic/genetic algorithms in the redesign and analysis of large, complex supply chains. Such packages include Extend/SDI, Insight, Simflex, Supply Chain Guru, CAPS Supply Chain Designer, i2 Strategist, Manugistics SC Suite, Logic Net, Synquest, etc. These are loaded with capabilities to capture both the deterministic and stochastic nature of a supply chain.

There are many challenges to applying simulation in solving complex supply chain problems. The reason is that supply chain components are tightly coupled and the simulation model could easily become large and cumbersome to make a variety of decisions. This issue is engorged by the facts that the supply chain simulation involves (i) a long and arduous data gathering and model development process, (ii) evaluation of a large number of alternative scenarios, and (iii) an extensive validation. Therefore, it is critical that a supply chain simulation model not become too large and unwieldy. Adequate levels of aggregation or decomposition of a supply chain are necessary. Again, for simulation experts, these are known facts in extracting the intrinsic value of simulation.

In conclusion, the emergence of SCM is an essential concept underlying the strategy/operations of virtually all companies that manufacture and distribute products. There is torrid pace of improvements in information technology, computer architecture, flexible software for creating user interfaces and managing data, enterprise resource planning (ERP) systems, and e-commerce. Last, but not the least, there is a strong realization by senior management that they must adapt and embrace the entire supply chain improvement and total cost management through redesign and decision support tools. All these definitely point to the fact that there are ever-growing opportunities for simulation in SCM.

6 SUMMARY

Simulation has been used in a variety of problem domains within the supply chain. But, there are many other opportunities where simulation can play a key role. Each of the contributors offers a range of possibilities. But, each contributor also mentions challenges that must be met to turn the possibilities into realities.

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AUTHOR BIOGRAPHIES

JERRY BANKS is an independent consultant. He retired from the School of Industrial and Systems Engineering at Georgia Tech in 1999, then worked for Brooks-PRI Automation for two years as Senior Simulation Technology Advisor. He is the recipient of the 1999 Distinguished Service Award from INFORMS-CS. His e-mail address is <atljerry@earthlink.net>.

STEVE BUCKLEY is a Research Staff Member at the IBM Thomas J. Watson Research Center in Yorktown Heights, NY. He has managed the Supply Chain Analysis department at that facility since 1995. He received his Ph.D. in Computer Science from MIT in 1987. He co-developed a simulation and optimization product called the *Supply Chain Analyzer* that was used both inside and outside of IBM for strategic analysis of supply chain issues. He was one of a group of IBM employees who received the prestigious Franz Edelman award from INFORMS in 1999. His email address is <sbuckley@us.ibm.com>.

SANJAY JAIN is a Research Associate Professor with the Grado Industrial & Systems Engineering Department at Virginia Tech. He is working with the Center for High Performance Manufacturing, a state funded entity with the objective of improving the performance of manufacturers in Virginia. Prior to joining Virginia Tech, he accumulated several years of industrial R&D and consulting experience working at Accenture in Reston, VA, USA, Gintic Institute of Manufacturing Technology (renamed recently as SIMTech), Singapore and General Motors North American Operations Technical Center in Warren, MI, USA. His research interests are in the area of using modeling and analysis techniques in development and operation of supply chains and manufacturing systems. He is a member of the Institute of Industrial Engineers, APICS, The Educational Society for Resource Management and of the editorial board of *International Journal of Industrial Engineering*. His email address is <sanjay.jain@vt.edu> and <www.eng.vt.edu/chpm/Faculty/Dr_Jain.htm>.

PETER LENDERMANN is the Group Manager of the Manufacturing Planning & Scheduling Group at Singapore Institute of Manufacturing Technology (SIMTech). Previously he was a Managing Consultant with agiConsult in Germany where his focus was on the areas of supply chain management and production planning. He also worked as a Research Associate at the European Laboratory for Particle Physics CERN in Geneva (Switzerland) and Nagoya University (Japan). He obtained a Diploma in Physics from the University of Munich (Germany), a Doctorate in Applied Physics from Humboldt-University in Berlin (Germany) and a Master in International Economics and Management from Bocconi-University in Milan (Italy). His research interests include parallel and distributed simulation and advanced methods for supply chain planning and production scheduling. His email address is <peterl@SIMTech.a-star.edu.sg>.

MANI S. MANIVANNAN received his Ph.D. from the Pennsylvania State University in 1988. Currently, he is the Head of Global Engineering in Vector SCM, *A CNF Company*, responsible for logistics, supply chain design, processes/measurement, and advanced technology center (ATC). He has a combined experience of 19 years in both acadame and industry. He specializes in simulation and statistical modeling/analysis of large supply chain networks, artificial intelligence, and large-scale database design. Prior to joining Vector SCM, he held several positions in CNF Inc., including senior staff member of Intelligent Systems at CNF Services Company, General Manager of Advanced Technology at Menlo Logistics, and Director of Quality and Strategic Planning at Emery Worldwide Airlines.

Before coming to CNF, Mani worked as a faculty member in the School of Industrial and Systems Engineering, at Georgia Tech. He has published numerous papers in refereed journals and conference proceedings. He is a recipient of the 1991 Outstanding Young Manufacturing Engineer of the Year Award from SME and the 1996 Raymond F. O'Brien Award of Excellence from the CNF Board of Directors. He has served as an adjunct Associate Professor in the School of Business at Oregon Graduate Institute, a panel member at National Science Foundation, and the Program Chair for the WSC '98 Conference. He is a member of IEEE, ACM, SCS, and SME. His e-mail address is: <manivannan.mani@vectorscm.com>.