
Service Science

Publication details, including instructions for authors and subscription information:
http://pubsonline.informs.org

# Driving Supply Chain Transformation Through a Business Process Oriented Approach

Changrui Ren, Miao He, Qinhua Wang, Bing Shao, Jin Dong,

# Driving Supply Chain Transformation through a Business Process Oriented Approach

Changrui Ren, Miao He, Qinhua Wang, Bing Shao, Jin Dong
IBM Research - China
Building 19 Zhongguancun Software Park, Haidian District, Beijing 100193, China
{rencr, hmhem, wangqinh, shaobing, dongjin}@cn.ibm.com



In recent years, clients from various industries have been seeking help from IBM in their supply chain transformation to gain competitive advantage. We have developed a comprehensive tool, SmartSCOR, which integrates the cross-industry process standard SCOR (Supply Chain Operations Reference) model and a variety of operations research techniques to facilitate our clients' end-to-end supply chain transformation. SmartSCOR enables structured supply chain modeling as analysis basis and analyzes both static and dynamic aspects of a supply chain. Static analysis includes benchmarking with best practices, root-cause analysis, etc. Dynamic analysis evaluates the performance and robustness of alternative supply chain designs through simulation. SmartSCOR has been successfully applied in IBM customer projects. We present two cases in this paper.

*Key words*: SCOR; supply chain transformation; business process; simulation
*History*: Received Aug. 8, 2010; Received in revised form Sept. 6, 2010; Accepted Sept. 10, 2010; Online first publication Sept. 16, 2010

## 1. Introduction

In recent years, IBM has faced an increase in demand for *supply chain transformation* from various industries. After the transformation, our clients add more value for their customers by providing more timely and cost effective products/services. Also, better synchronized flows of information, products and cash will ultimately increase their productivity and profitability. However, from the management consulting perspective, the successful delivery of a supply chain transformation project relies heavily on three conditions: 1) strategic, tactical and operational levels are aligned; 2) different models, techniques and tools are integrated; and 3) cross-department cooperation is established. The last condition depends more on communication and transformation vision sharing. Therefore, we do not cover it in this paper.

More specifically, the *strategic level* transformation includes supply chain network reconfiguration, value chain integration, strategic partnership with suppliers, etc. For example, IBM has helped a consumer products company to explore whether reconfiguring the product mix at different sites can release capacity. The *tactical level* deals with inventory policies, staff scheduling, sourcing, production planning, etc. A world-leading home-improvement manufacturer has turned to IBM for quantifying the impact of the base stock level on its order fulfillment cycle, average inventory and on-time delivery rate. The *operational level* concerns bottlenecks in production lines, capacity utilization, etc. An example is that we identified production line bottlenecks in the consumer products company case.

Since the three levels interact with each other nonlinearly, modeling them in a structured way is not easy, let alone redesigning the supply chain and evaluating its performance and robustness before implementation. Furthermore, a single supply chain transformation project often involves multiple models, techniques and tools. The isolation between models/techniques/tools usually results in data format incompatibility, overlap of modeling efforts and frequent synchronization of multiple files generated by different software. For example, modeling business processes in a process modeling tool but simulating or optimizing them in some other tools produces multiple files to manage and require redundant efforts of modeling.

After pinpointing these difficulties in practice, we started the development of SmartSCOR in 2006, aiming to provide end-to-end support to supply chain transformation. We decided that our tool must be *process-centric*, because supply chain management (SCM) lies in "the integration of *key business processes* from end user through original suppliers that provides products, services, and information that add value for customers and other stakeholders" (Global Supply Chain Forum). Hopp (2008) also pointed out that "the fundamental link between a system's objective and its physical operations are the *process flows* that make up a production or supply chain system."

SmartSCOR integrates the cross-industry standard process *SCOR (Supply Chain Operations Reference) model*, proposed by the Supply Chain Council (SCC), and a variety of operations research (OR) techniques. With the integrated platform, users can model supply chains in a structured and streamlined manner. Based on the structured model, they can further conduct *static analysis* such as benchmarking and root-cause analysis to identify directions of improvement and causes of problems. Moreover, the *dynamic analysis* tools, such as system dynamics (SD) and discrete event simulation, allow users to evaluate the performance and robustness of alternative supply chain designs under different strategies, policies and operational decisions.

The remainder of the paper is organized as follows: Section 2 reviews techniques, methodologies and tools relevant to supply chain transformation. We particularly review supply chain simulation because it has addressed a number of dynamic and quantitative problems for IBM clients. Section 3 describes the framework of SmartSCOR and how it supports end-to-end supply chain transformation. While SmartSCOR has been successfully applied to dozens of customer projects, we present two cases of them in Section 4. Lastly, we conclude our paper in Section 5.

## 2. Techniques, Methodologies, and Tools for Supply Chain Transformation

Albeit the term "supply chain transformation" frequently appears in white papers of consulting firms, we can find only a few studies on transformation methodologies or tools in the literature. Chidambaram et al. (2007) proposed a five-step methodology for transformation. The five steps are define the scope of the supply chain, change culture, establish customer-integrated decision making, develop supply chain wide strategy and adopt supply chain wide performance measures. Baramichai et al. (2007) integrated the QFD (quality function deployment) and AHP (analytical hierarchy process) techniques to create a new tool called Agile Supply Chain Transformation Matrix, which could enable a supply chain to create and improve its agility.

Supply chain transformation relies heavily on *key business processes* rationalizations. There are numerous ways to define a business process. Hammer and Champy (2003) stated that a business process is "a collection of activities that takes one or more kinds of input and creates an output that is of value to the customer". Interested readers may refer to Lee and Dale (1998) for more details. Among the existed business process modeling standards, *business process modeling notation* (BPMM) is widely adopted. Wohed et al. (2006) discussed the strengths and weaknesses of BPMN compared with three other standards, i.e. UML2.0 AD, BPEL, and Oracle BPEL PM v.10.1.2.

Business process modeling addresses the process aspect of a business architecture and a good process model enables "comprehensive understanding towards processes" (Aguilar-Savén 2004). Aguilar-Savén (2004) discussed the advantages and disadvantages of nine business process modeling techniques, including flow chart, data flow diagrams, role activity diagrams, role interaction diagrams, etc. The author pointed out *business process modeling techniques* also refers to generic methodologies with process modeling capabilities. Simulation is one such widely applied methodology.

Recognized as a powerful enabler in enterprise management (Kalpic and Bernus 2002), business process modeling requires proper tools to support. However, end users can hardly analyze the dynamics of supply chain processes directly on the process models in most of tools. An IBM product, Websphere Business Modeler (WBM), "enables supply chain analyst to model, simulate and analyze business processes, integrate the new and revised process and define the organization, resources and business items" (Wahli et al. 2006). Note that WBM follows BPMN to model processes.

However, WBM is serving as a generic business modeler without considering supply chain characteristics. SmartSCOR extends WBM modeler and WBM analysis modules to customize offerings for supply chain transformation. In one aspect, SmartSCOR builds SCOR model into WBM to enhance the *supply chain modeling capability*. In the other aspect, SmartSCOR facilitates *supply chain diagnosis and analysis* in WBM with flexible simulation and tailored OR tools.

### 2.1 The SCOR Model

The SCOR model, developed by the Supply Chain Council (SCC), aims to "provide a unique framework that links business process, metrics, best practices and technology features into a unified structure to support communication among supply chain partners and to improve the effectiveness of supply chain management and related supply chain improvement activities" (http://supply-chain.org/about/scor/what/is). With the first version released in 1997

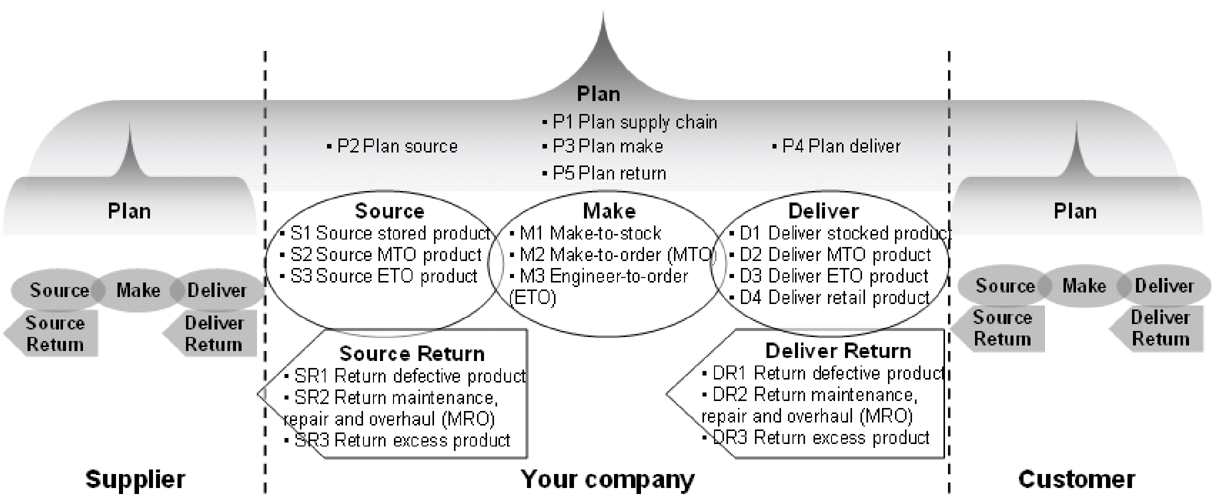
(Steward 1997), SCOR has evolved into version 10.0 by June 2010 and it is well recognized as the cross-industry standard for supply chain management.

The SCOR model describes supply chain processes by three levels. There are five aggregated level-I processes and each one involves a variety of supply chain activities (Bolstorff and Rosebaum 2003).

- PLAN. Assess supply resources; aggregate and prioritize demand requirements; plan inventory for distribution, production, and material requirements; and plan rough-cut capacity for all products\channels.
- SOURCE. Obtain, receive, inspect, hold, issue, and authorize payment for raw materials and purchased finished goods.
- MAKE. Request and receive material; manufacture and test product; package, hold, and/or release product.
- DELIVER. Execute order management processes; generate quotations; configure product; create and maintain customer database; maintain product/price database; manage accounts receivable, credits, collections, and invoicing; execute warehouse processes including pick, pack, and configure; create customer-specific packaging/labeling; consolidate orders; ship products; manage transportation processes and import/ export; and verify performance.
- RETURN. Defective, warranty, and excess return processing, including authorization, scheduling, inspection, transfer, warranty administration, receiving and verifying defective products, disposition, and replacement.

Every level-I process comprises several level-II processes, and each level-II process consists of multiple level-III processes. For example, the level-I process *source* includes three level-II processes, i.e. *S1 source stocked product*, *S2 source MTO (make-to-order) product*, and *S3 source ETO (engineer-to-order) product*. "S1 source stocked product" is further decomposed into five level-III processes, including *S1.1 schedule product deliveries*, *S1.2 receive products*, *S1.3 verify product*, *S1.4 transfer product* and *S1.5 authorize supplier payment*. Figure 1 shows the SCOR framework detailed to level II.

**Figure 1 The SCOR Framework**




Note that *the hierarchical structure plays a critical role in modeling the interactions among strategic, tactical and operational levels*. And as indicated in Figure 1, SCOR can model both the whole supply chain involving multiple participants and the local supply chain within one organization.

SCOR provides more than a standard and structured way to model supply chains. It is composed of four critical elements (Huang et al. 2005):

- Standard descriptions of the individual elements that make up the supply chain processes.
- Standard definitions of key performance measures.
- Descriptions of best practices associated with each of the process elements.
- Identification of software functionality that enables best practices.

Many SCOR-based applications and derivatives have emerged since SCOR released. Wang et al. (2004) adopted the set of level-I performance metrics as decision criteria for supplier selection. Hochstein et al. (2006)

extended the SCOR model for Information System (IS) management by taking the IS value chain and service-oriented computing techniques into consideration. The extended SCOR model benefited an IT service provider in transparency and efficiency. Xiao et al. (2006) proposed a cycle quality chain operations reference (CQCOR) model by adding *reverse manufacturing* to the SCOR process set. SCC members have applied the SCOR model across various industry sectors, such as consumer foods, electronics, software and planning, aerospace and defense, etc.

Companies and organizations have developed support tools to make better use of the SCOR model. For example, *ProcessWizard* by Xelocity is a tool that computerizes the SCOR model and helps users to configure their supply chain in a hierarchical way (http://supply-chain.org/scor-software-processwizard).

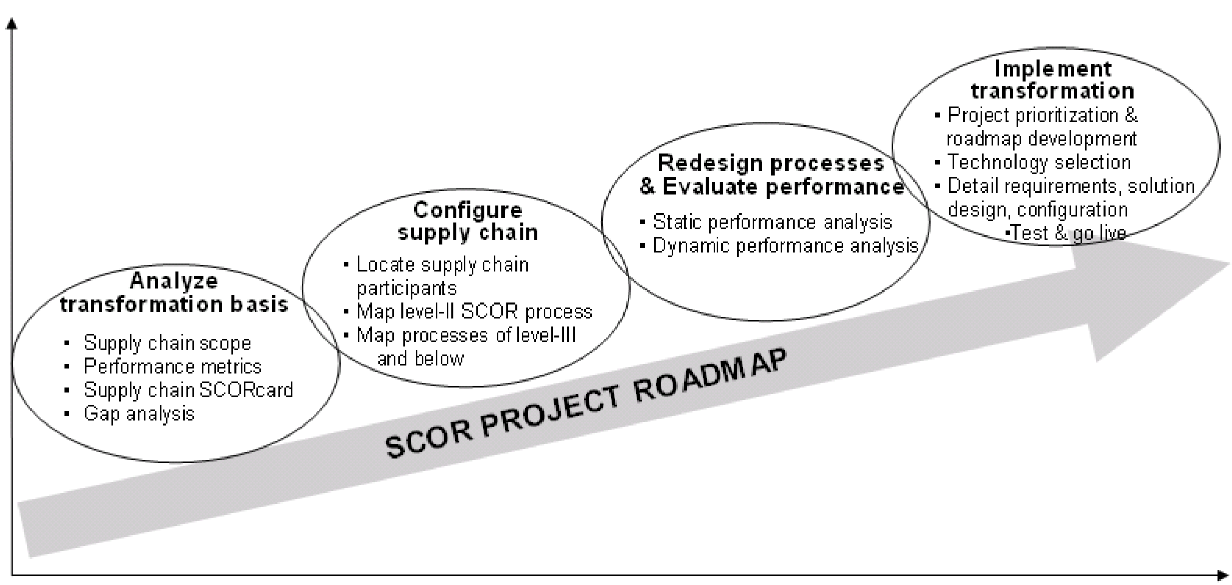
## 2.2 Supply Chain Simulation

Supply chains are very complicated due to the interrelation among multiple participants as well as the interweaving of product, information and cash flows. Complicated supply chains often associate with a plethora of data, stochastic factors and decisions, resulting in problems intractable by optimization techniques. Therefore, it is common to adopt simulation to conduct what-if analysis, policy evaluation and sensitivity analysis in a dynamic context. This will eventually ensure the robustness of SCM solutions.

Supply chain studies using simulation are readily available in the literature. Petrovic et al. (1998) studied a multiple-echelon supply chain with uncertain customer demand and supply of raw materials. They used simulation to evaluate different combinations of stock level and order quantity to attain acceptable fill rate with reasonable total costs. Persson and Olhager (2002) conducted a case study in the mobile communications industry. They used simulation to quantify the performance of alternative supply chain designs with respect to quality, lead time and cost. They also characterized the relationship between the three performance metrics via simulation. Gaag et al. (2004) used a state-transition simulation to model the spread of Salmonella along the pork supply chain. They analyzed the sensitivity of Salmonella spread against 26 external variables through simulation. These are only two examples among many supply chain researches that employ the simulation approach (Fleisch and Tellkamp 2005, Albino et al. 2007).

As pointed out by Albores et al. (2006) after a case investigation, the SCOR-based simulators are more advantageous than general-purpose and business process simulators in launching the supply chain improvement initiatives. There exist several simulators that support simulation on SCOR process models, such as *ARIS (EasySCOR)* by IDS Scheer, *e-SCOR* by Gensym, and *Business Studio* by TIBCO. Also, some researchers linked the SCOR model to a general-purpose simulation software ARENA (Persson and Araldi 2009). Section 3 introduces SmartSCOR, which offers not only SCOR-based simulators, but also a set of qualitative, semi-quantitative and quantitative tools to enhance end-to-end supply chain transformation.

**Figure 2 Supply Chain Transformation Roadmap with SmartSCOR**

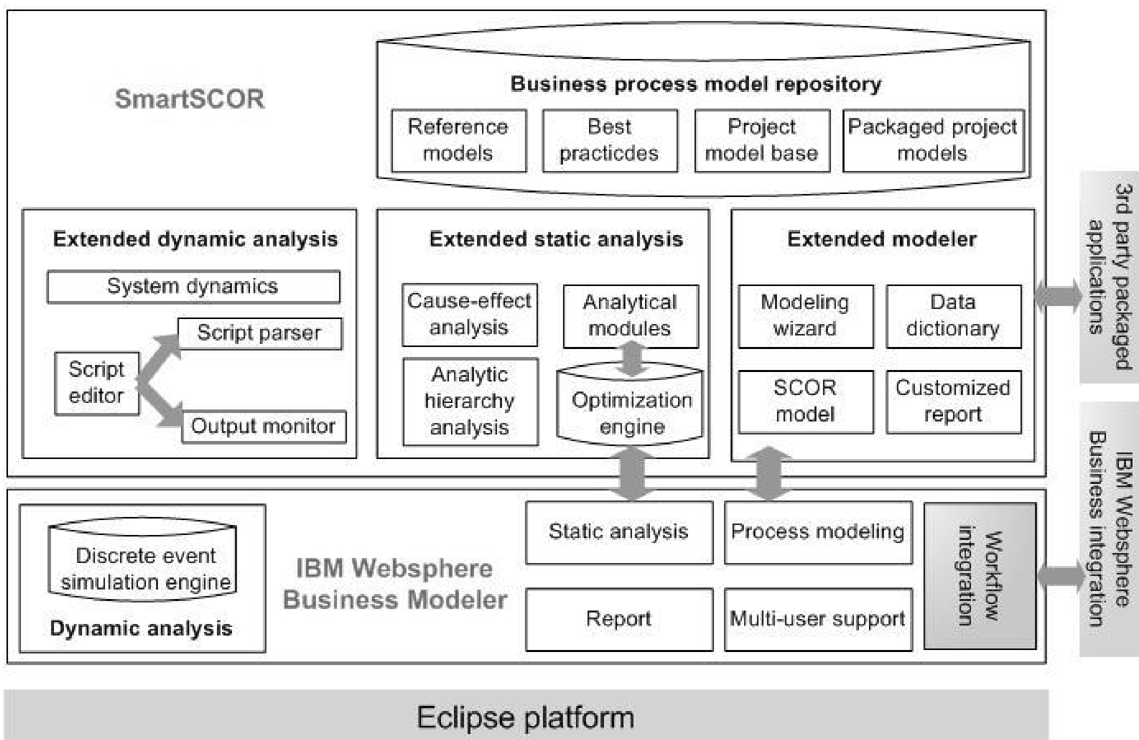


## 3. SmartSCOR

SCC has proposed a four-step SCOR project roadmap, based on which we have developed a four-phase enhanced version, *SmartSCOR project roadmap*, to better match the demand of supply chain transformation. Figure 2 shows the SmartSCOR project roadmap. In the first phase, we identify the supply chain scope, define key performance metrics, and conduct gap analysis on key performance metrics. These activities identify and prioritize the potential improvements. Second, we configure the baseline supply chain according to the hierarchical SCOR model. Through hierarchical modeling, our clients usually gain more insights into the interactions among strategic, tactical and operational levels. The third phase works in an iterative way. Every time after we have modified the processes or changed the operation policies, we evaluate the performance to ensure those modifications benefit the supply chain. The "redesign processes - evaluate performance" pattern repeats until satisfactory configurations are obtained. The final phase involves project prioritization and roadmap development, technology selection, detailed solution design, test and implementation.

SmartSCOR seamlessly plugs in IBM Websphere Business Modeler (WBM), a business process modeling and simulation tool as introduced in Section 2. Aside from WBM functions, SmartSCOR also computerizes the comprehensive framework of the SCOR model and embeds carefully chosen OR tools to facilitate supply chain diagnosis and analysis. Figure 3 shows the SmartSCOR framework.

**Figure 3 SmartSCOR Framework**



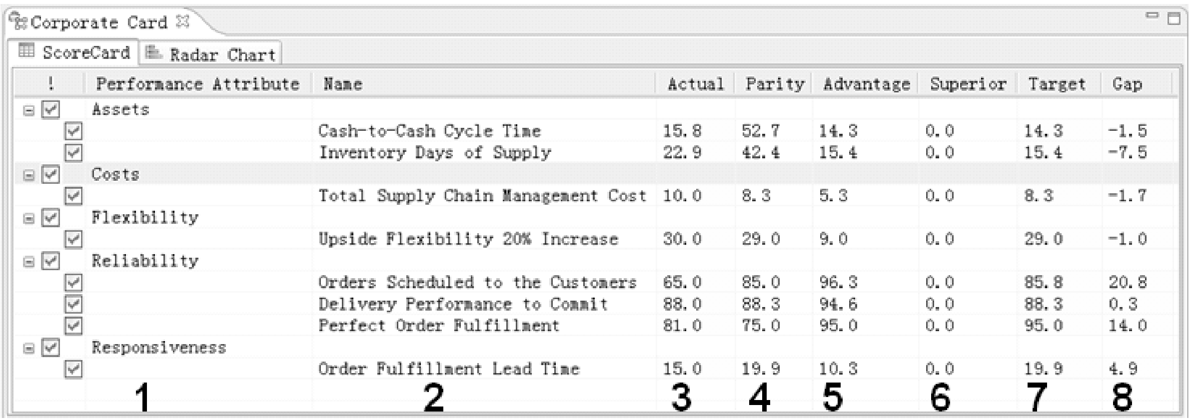

Note that SmartSCOR manages all the models and analysis automatically *within one "project"*, hence eliminating the trouble of managing multiple files produced by multiple tools. In this section, we will further describe how SmartSCOR supports the supply chain transformation lifecycle as shown in Figure 2.

### 3.1 Phase I: Analyze Transformation Basis

In a SmartSCOR-enabled supply chain transformation, we usually first identify key performance metrics and conduct gap analysis between the current and the target performance. SCOR model has summarized the most important supply chain performance metrics in its *SCORcard* for users' reference. SCORcard defines five performance attributes, i.e. supply chain reliability, supply chain responsiveness, supply chain agility, supply chain costs and supply chain asset management. Each performance attribute governs one or more strategic metrics. Figure

4(a) is a sample SCORcard in SmartSCOR. The first and second columns are the performance attributes and strategic metrics, respectively. Columns 3-6 are the *current performance* of the company under concern, the *parity*, *advantage* and *superior* performance of the whole industry, respectively. We set our target performance in the seventh column, and calculate the gap between current and target performance in the last column. SmartSCOR can intuitively illustrate the gap by visualizing current and target performances by radar chart, see Figure 4(b). Note that columns 4-6 are filled with benchmark data and SmartSCOR users are supported by *IBM benchmarking program* to obtain those data in their industries. This program partners with dozens of relevant institutions, including Supply Chain Council, American Productivity and Quality Center (APQC), etc. We stress that defining performance metrics calls for in-depth study and discussions, while benchmarking requires solid data support. Efforts required in phase I are far more than simply manipulating support tools.

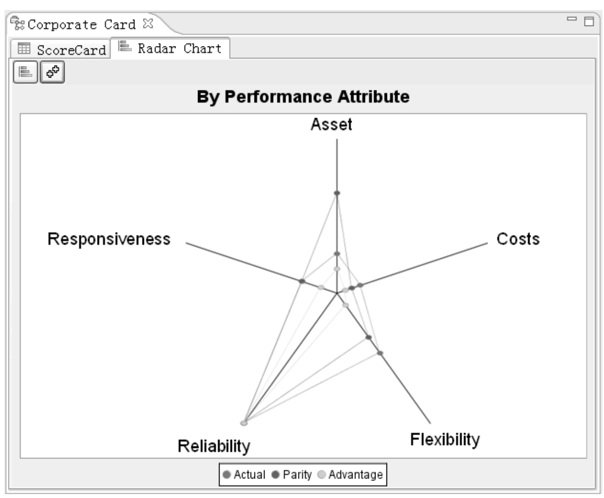
**Figure 4 Computerized SCORcard in SmartSCOR**



Corporate Card
ScoreCard | Radar Chart

| Performance Attribute | Name | Actual | Parity | Advantage | Superior | Target | Gap |
|---|---|---|---|---|---|---|---|
| Assets | | | | | | | |
| | Cash-to-Cash Cycle Time | 15.8 | 52.7 | 14.3 | 0.0 | 14.3 | -1.5 |
| | Inventory Days of Supply | 22.9 | 42.4 | 15.4 | 0.0 | 15.4 | -7.5 |
| Costs | | | | | | | |
| | Total Supply Chain Management Cost | 10.0 | 8.3 | 5.3 | 0.0 | 8.3 | -1.7 |
| Flexibility | | | | | | | |
| | Upside Flexibility 20% Increase | 30.0 | 29.0 | 9.0 | 0.0 | 29.0 | -1.0 |
| Reliability | | | | | | | |
| | Orders Scheduled to the Customers | 65.0 | 85.0 | 96.3 | 0.0 | 85.8 | 20.8 |
| | Delivery Performance to Commit | 88.0 | 88.3 | 94.6 | 0.0 | 88.3 | 0.3 |
| | Perfect Order Fulfillment | 81.0 | 75.0 | 95.0 | 0.0 | 95.0 | 14.0 |
| Responsiveness | | | | | | | |
| | Order Fulfillment Lead Time | 15.0 | 19.9 | 10.3 | 0.0 | 19.9 | 4.9 |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |

(a) SCORcard

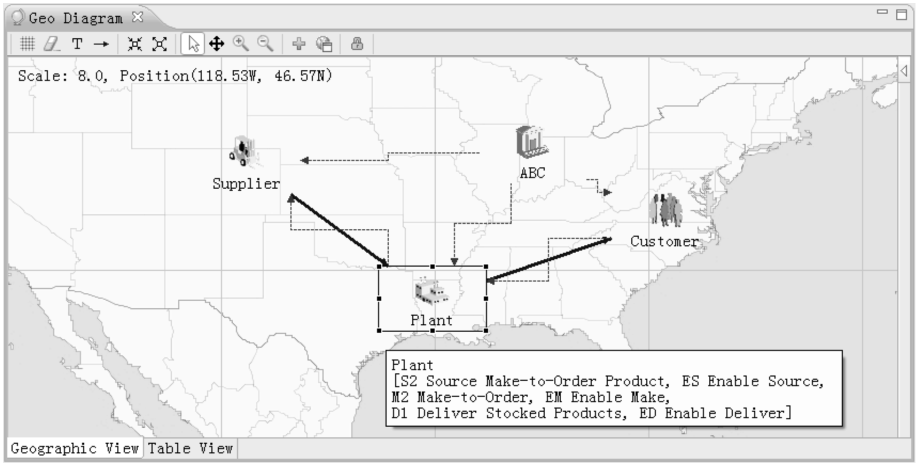



(b) Radar chart of the SCORcard

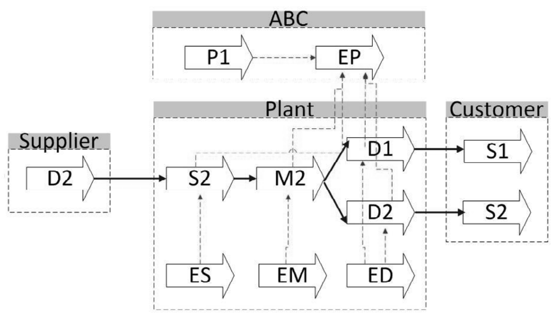
### 3.2 Phase II: Configure Supply Chain

SmartSCOR models supply chain processes in a hierarchical way. First, we geographically locate supply chain participants on a map. Then, we outline the level-II SCOR processes of each participant by a thread diagram. Following that, we model processes at finer levels (level III and below) in the WBM process editor. Figure 5(a) depicts a sample supply chain formed by a company named ABC, its plant, supplier and customer. Figure 5(b) shows the sample thread diagram. For the ABC company, we consider how it plans its supply chain (P1 & EP), sources from its suppliers (S2 & ES), makes products (M2 & EM) and delivers its products (D1, D2 & ED). We are only concerned with the deliver process of its supplier (D2) and the source process of its customer (S1 & S2). In our integrated platform, double clicking a SCOR level-II process will navigate the user to process models at level III and below. Figure 5(c) is an example of a process that can be opened by double clicking P1 (plan supply chain).

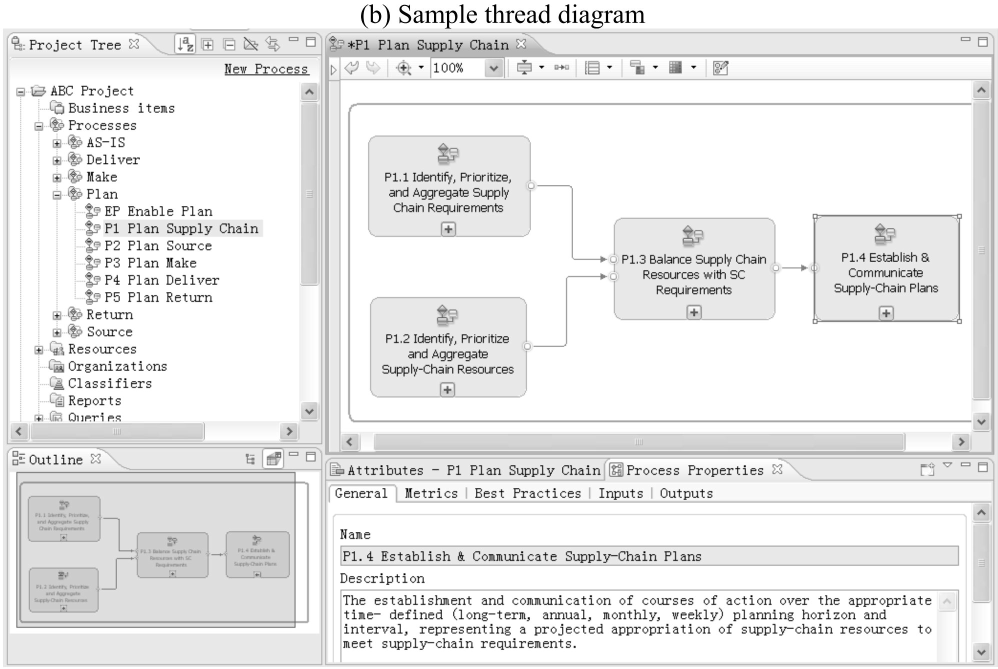
**Figure 5 Hierarchical Supply Chain Modeling in SmartSCOR**




(a) Sample geographic diagram




(b) Sample thread diagram



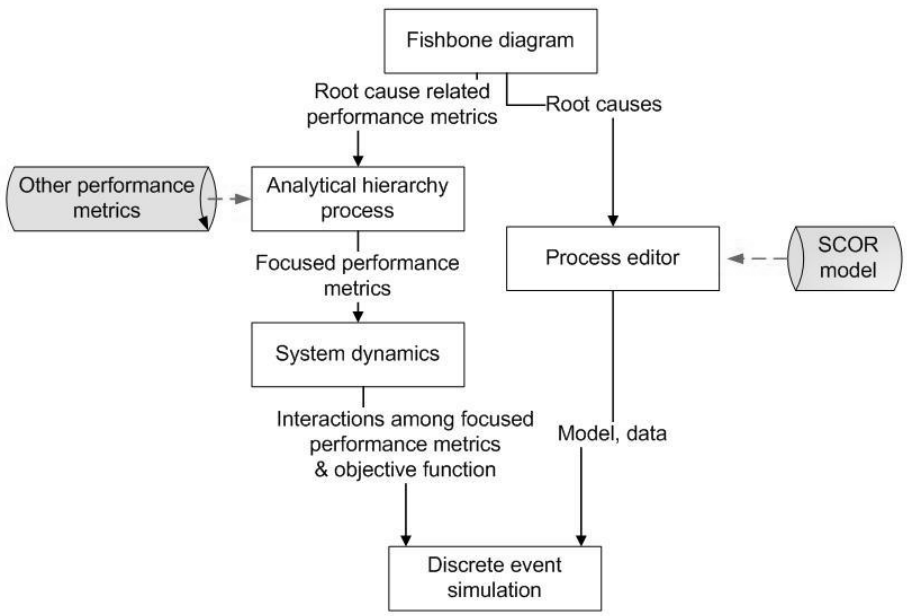

(c) Sample process

Our process modeler provides predefined modeling elements such as task, decision fork, merge fork, while loop, etc. Users can easily build a model by dragging and dropping predefined elements.

### 3.3 Phase III: Redesign Processes and Evaluate Performance

Phase II streamlines baseline supply chain processes by hierarchical modeling. In phase III, we iteratively redesign the supply chain and evaluate its performance to eventually obtain a satisfactory configuration. The integrated SmartSCOR platform offers a bunch of tools to help users redesign and evaluate their supply chain with insights. Figure 6 shows how tools work together in this phase.

**Figure 6 Redesign and Evaluate a Supply Chain in SmartSCOR**




Before proposing any new supply chain designs, we need to pinpoint the origins of current problems at the *first* step. SmartSCOR provides the well-known *fishbone diagram* to support the qualitative root-cause analysis, see Figure 7(a). The output of fishbone diagram includes the root causes and their corresponding performance metrics.

The *second* step learns the weight that decision makers put on each performance metric, namely, prioritize performance metrics to find the focused ones. Taking the root cause related and unrelated performance metrics as input, SmartSCOR offers analytical hierarchy process (AHP, semi-quantitative) to model all the performance metrics in a systematic and hierarchical way. And then, AHP converts the extent to which decision makers value each performance metric to numerical values. Figure 7(b) shows the user interface of AHP in SmartSCOR.

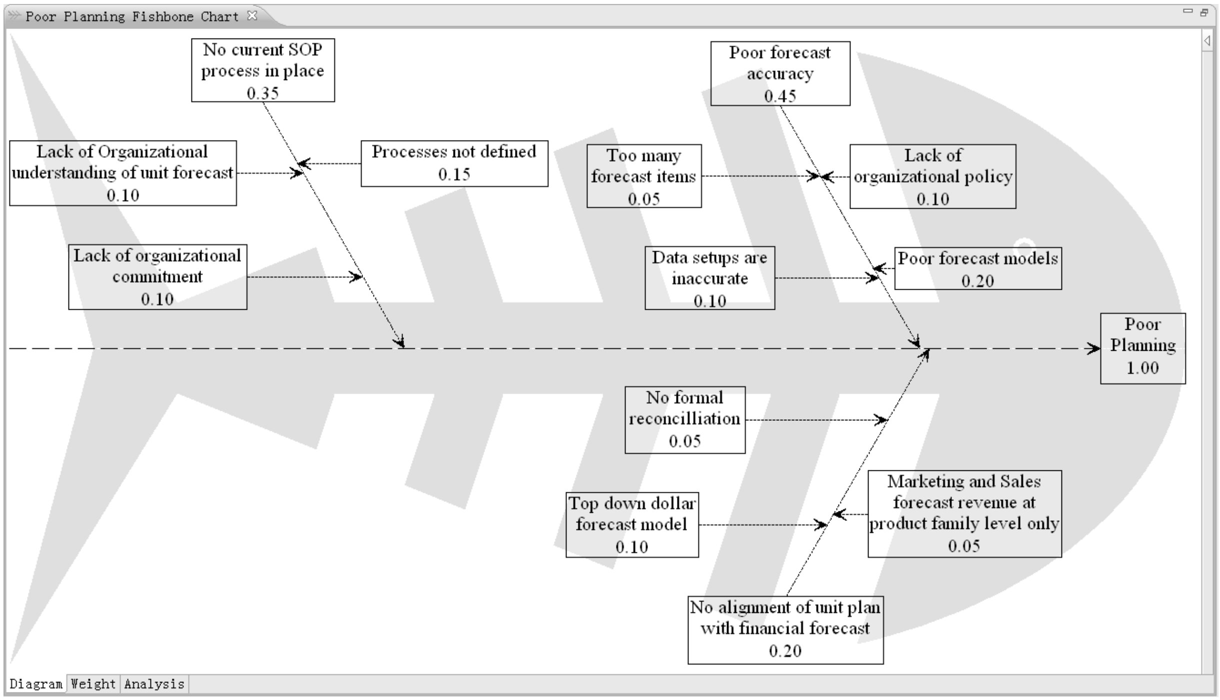
In the *third* step, we can use system dynamics (SD, quantitative) to quantitatively characterize the relationship of the focused performance metrics identified in step two. Step three applies because it is difficult to improve performance in one aspect without damaging other aspects in quite a lot instances. For instance, ensuring a 100% delivery within 24 hours will cost greatly for the express industry since marginal cost increases exponentially with service quality. Understanding the interactions among performance metrics will help our clients set appropriate expected improvement, namely, reasonable objective function.

To drive a correct-running SD model, we specify the feedbacks among elements define equations to link elements and finally run the dynamic simulation. Note that exact equations may not be available for complicated systems, but can be substituted with *empirical* or *approximate* equations. Figure 7(c) displays a sample SD model in SmartSCOR.

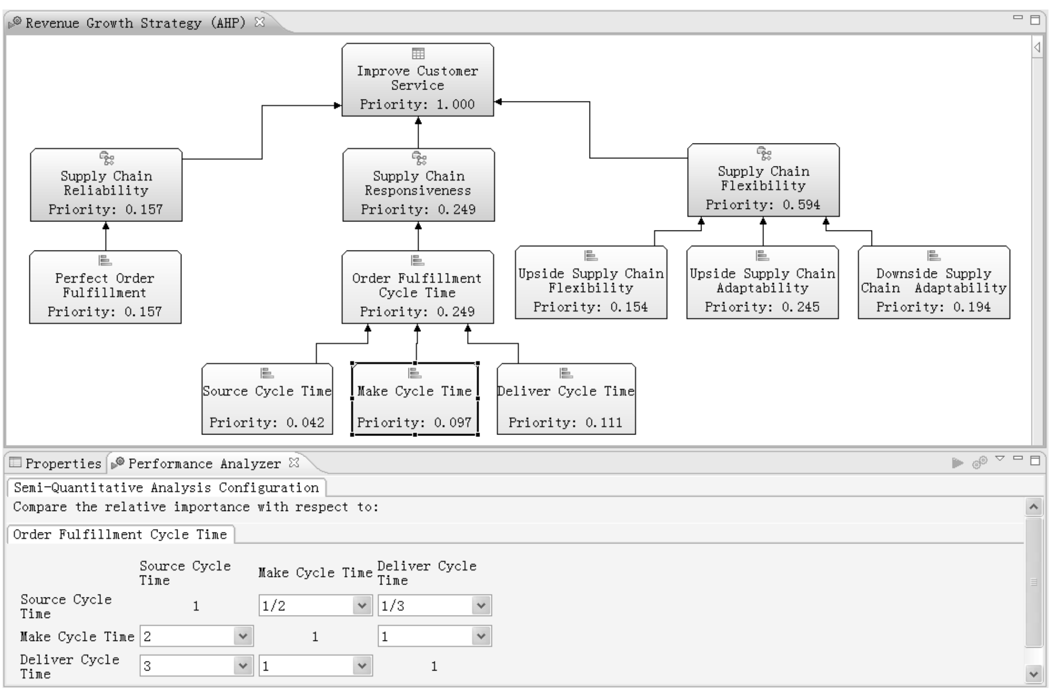
The *forth* step is to design new supply chain processes in the SmartSCOR process editor. The new processes are supposed to eliminate, or at least release, the impact of root causes pinpointed in the first step.

The *fifth* step is to simulate the new processes (modeled in step four) and estimate the objective function (defined in step three) for performance evaluation. SmartSCOR provides two major enhancements to the WBM discrete event simulation engine: *script programming* and *standard business process library*. Script programming allows users to flexibly program in a java-like language. The script-based simulator allows user-specified operations before and after the task execution. It also accepts customized delay, cost, revenue and duration of each task. The embedded script greatly enhances the WBM ability in modeling complicated systems, incorporating complex decision rules and even calling for external components such as optimization engines. These benefits eventually result in a highly extensible tool.

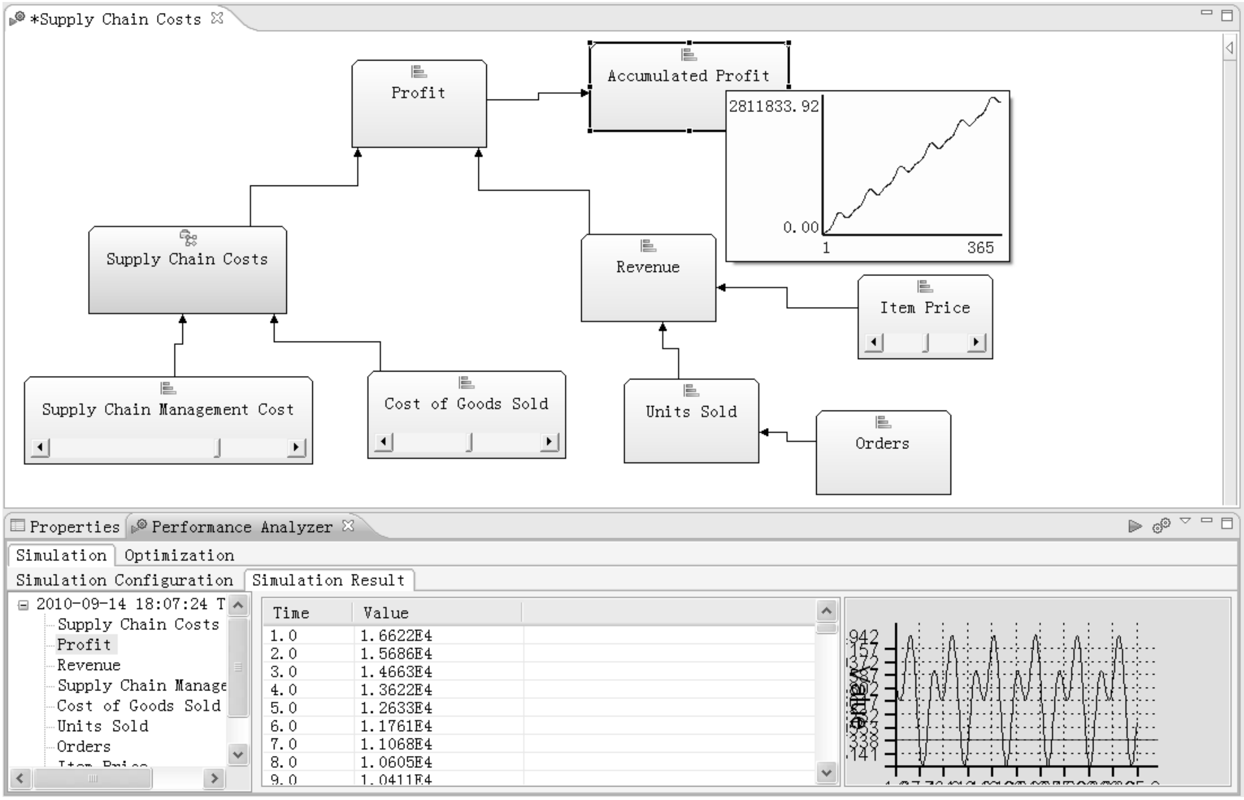
**Figure 7 Tools for Supply Chain Transformation in SmartSCOR**




(a) Root-cause analysis




(b) Analytical hierarchy process




(c) System dynamics

In addition, SmartSCOR provides a standard business process library that stores the most common business components in a supply chain. Each standard business component can be treated as a subprocess, or a module, in a model. We have embedded the standard operations of the components through scripts. For instance, the *inventory control system with (s, S) policy* provides operations such as increase the inventory, decrease the inventory, set the reorder point and order-up-to point, etc. Users can either specify the input parameters or extend our components to meet their own needs. Table 1 lists some standard process components in SmartSCOR now.

**Table 1 Standard Business Component in SmartSCOR**

| **Component** | **Description** |
|---|---|
| Order arriving process | Specify arriving process, label the priority. |
| Inventory control system with ($s$, $S$) policy | Increase inventory, decrease inventory, order up to $S$ when inventory position falls to $s$. |
| Inventory control system with ($r$, $Q$) policy | Increase inventory, decrease inventory, order $Q$ items when inventory position falls to $r$. |
| FIFO (First in first out) queueing system | Record queueing time, record number of queueing tasks, record server status (busy/idle), maintain the FIFO rule. |
| FILO (First in last out) queueing system | Record queueing time, record number of queueing tasks, record server status (busy/idle), maintain the FILO rule. |
| Priority queueing system | Record queueing time, record number of queueing tasks, record server status (busy/idle), maintain the queue according to priority labels. |
| Random variate generation | Generate common random variate from probability distribution, e.g., Bernoulli, binomial, triangular, exponential, normal, Poisson, etc. |

### 3.4 Phase IV: Implement Transformation

In phase IV, SmartSCOR assists implementing the transformed supply chains in two ways. On one hand, SmartSCOR has well-organized catalogs to preserve models and analysis results, which provides data-driven, evidence-based support for our clients to make the implementation plan. For example, the priority of taking different measures depends on the identified priority of performance metrics. On the other hand, after our clients decide which technologies to employ, they can set accurate parameters in reusable models in SmartSCOR and run them again to gain up-to-date insight of their new system.

## 4. Case Studies

We use two real client cases to demonstrate how SmartSCOR enables successful supply chain transformation following the project roadmap (Figure 2). The first case studies a leading manufacturer of home improvement and construction products. The second case studies a first-class consumer products company.

### 4.1 Case 1: Improving the "Source" Process

The client in case 1 is a leading manufacturer of home improvement and construction products, which has 15 *original design manufacturers* (ODMs). An original design manufacturer (ODM) is a company which designs and manufactures a product that is specified and eventually branded by another firm for sale.

***Phase I: Analyze transformation basis***

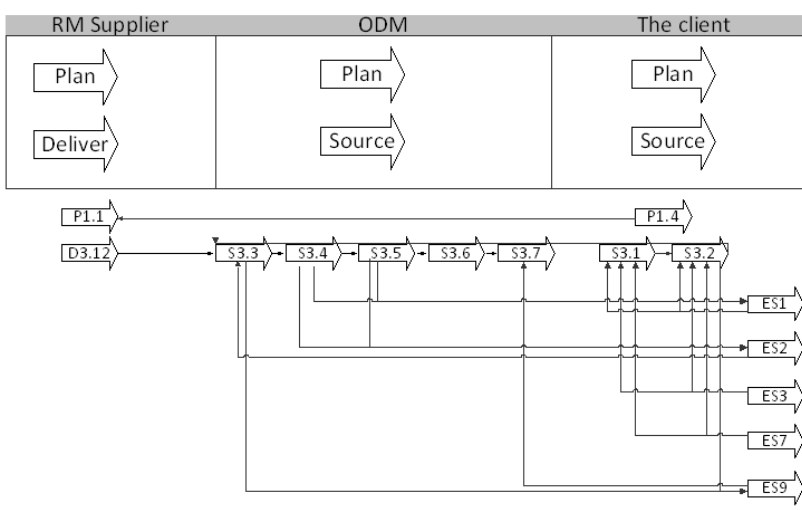
The client planned to enhance its control over raw material procurement in order to improve the supply chain *reliability* and *responsiveness* as well as cut *costs*. Before the supply chain transformation, ODMs ordered independently from multiple raw material suppliers without involving our client. After the transformation, the client selected raw material suppliers and directly negotiated with them for a lower price due to economies of scale. Then raw materials were shipped to the ODMs with the agreed-upon price. Switching from decentral to central procurement, the client expected not only *procurement cost* reduction, but also shorter *source cycle time*, lower *defective product rate* because bigger orders should drive raw material suppliers to improve their service quality.

Our client also wanted to identify how much raw material safety stock to keep in the central procurement, considering the order fulfillment cycle time, average raw material inventory level and *on-time delivery rate*. They preferred a safety stock level that can achieve high on-time delivery rate with accepted inventory costs. In this project, we used SCORcard to conduct gap analysis on all the strategic metrics. However, we cannot release the numeric values because of confidentiality agreement.

***Phase II: Configure supply chain***

Using the SCOR modeling framework, SmartSCOR successfully translated the cost-cutting measure into detailed and streamlined processes. We located the raw material suppliers, ODMs, and the client on a geographical map, and then configured the improved source process in a thread diagram (level II) as shown in Figure 8. We specified processes at level III and below in our process editor, which looked like Figure 5(c) but are not shown due to the paper length limit.

**Figure 8 Thread Diagram of the Improved Source Process**



***Phase III: Redesign processes - evaluate performance***

The origin of high sourcing costs, too many raw material suppliers with non-economic price, had been identified before our client initiated the project. Therefore, we did not apply fishbone diagram to conduct root-cause analysis. Also, decision makers at this company articulated their focused performance metrics are reliability, responsiveness and costs. Hence, there was no need to apply AHP to learn decision makers' focused performance metrics. We employed simulation analysis immediately after configuring the baseline supply chain.

With negligible setup costs of issuing a purchase order, we decided to use the approximately optimal *base stock* inventory control policy, or order-up-to policy, with *periodic review*. Under this policy, our client would order up to the base stock level as soon as the inventory position dropped below that. We modified the inventory control policies and evaluated the policy performance iteratively.

Figure 9 shows that the order fulfillment cycle time decreased as the base stock level rose. However, Figure 10 implies that providing immediate products to customers incurred high inventory costs. The average inventory level was not sensitive when the base stock level varied between 1,250 units and 11,250 units. But more than 11,250 units caused an exponential increase in inventory and hence inventory costs.

**Figure 9 Order Fulfillment Cycle versus Base Stock Level**

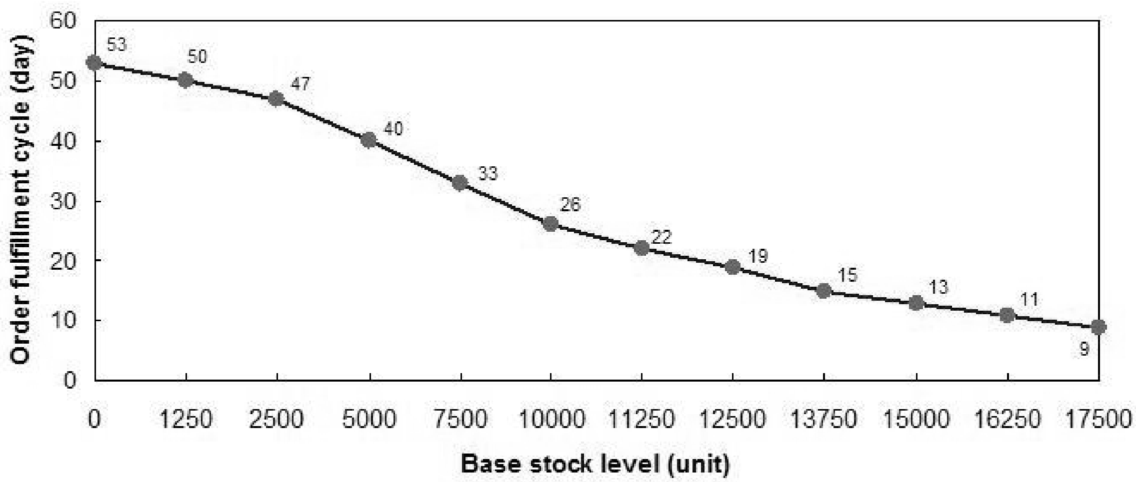



**Figure 10 Average Inventory Level versus Base Stock Level**

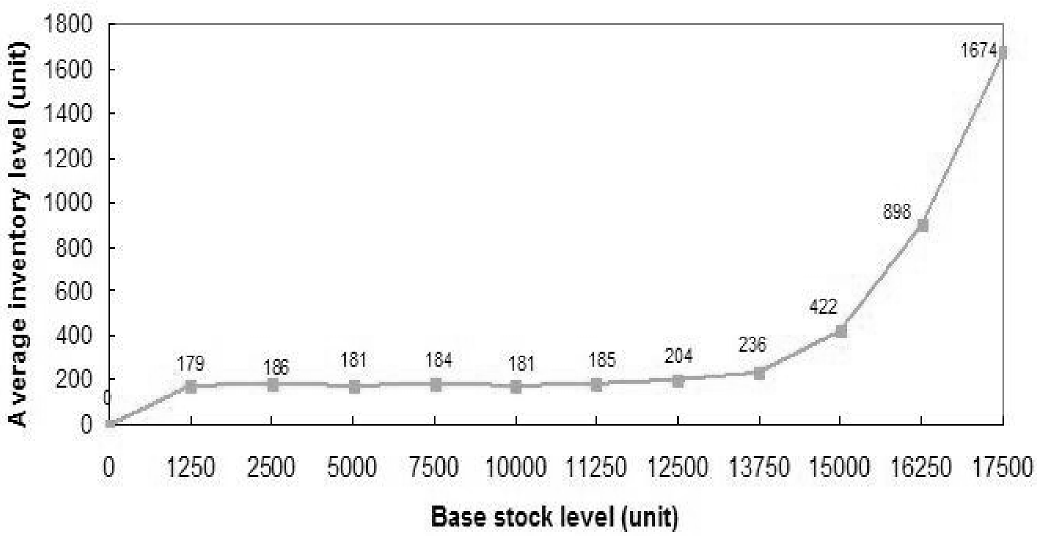
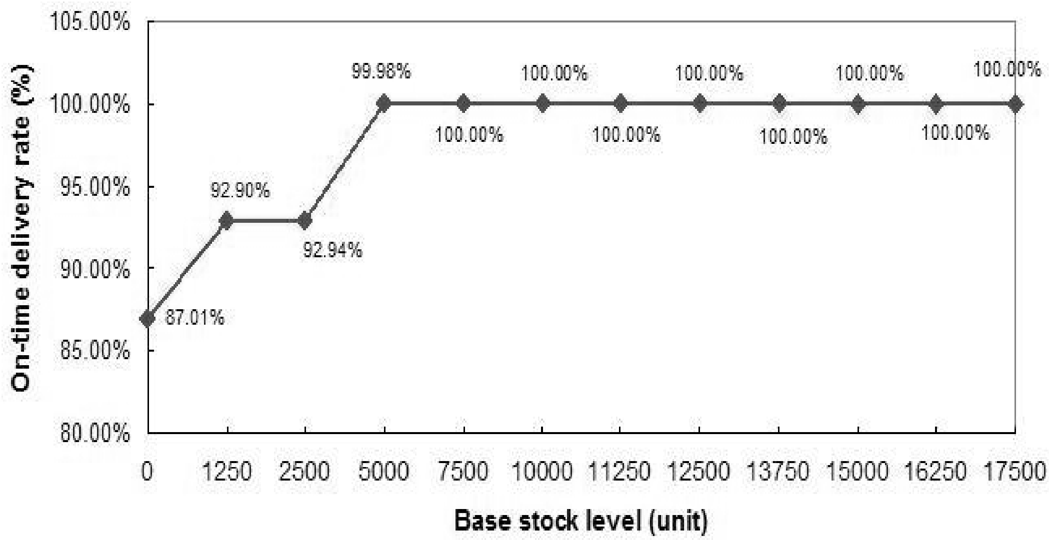


Figure 11 shows that when the base stock level was higher than 7500 units, the on-time delivery rate would become a hundred percent. Combining Figures 10 and 11, we would recommend an 11,250-unit base stock level. This optimized base stock level not only cut order fulfillment cycle time by one half, but achieve a 100% on-time rate without dramatic increase in the inventory holding costs.

**Figure 11 On-time Delivery Rate versus Base Stock Level**




***Phase IV: Implement transformation***

The models and analysis results in SmartSCOR were supporting our client's decision-making during the transformation process. Significant benefits were obtained by applying the central procurement policy and adopting the suggested base stock level for even only one production line. Table 2 shows the results. By centralizing the procurement, our client reduces the defective product rate by 5%, shorten the source cycle time by 7 days, and save \$0.5 million for the raw materials under concern. Using the base stock level as we had suggested brought the on-time delivery rate up from 90% to 98%. We did not attain the 100% on-time delivery rate as suggested in Figure 11 because we could only cover the most important stochastic factors but not all of them in the simulation model.

**Table 2 Improvements by Supply Chain Transformation**

| Performance metrics | Strategic metrics | Improvement |
|---|---|---|
| Reliability | On-time delivery rate | Improved from 90% to 98% |
| | Defective product rate | Reduced by 5% |
| Responsiveness | Source cycle time | Reduced by 7 days |
| Costs | Annual procurement cost | Saved \$0.5 million |

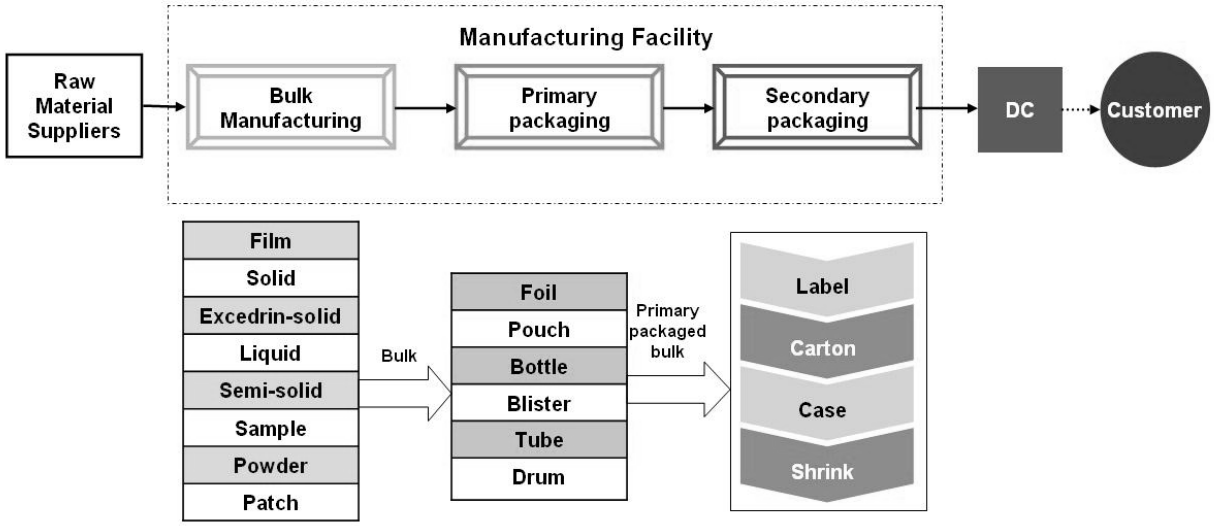
### 4.2 Case 2: Promoting the "Make" Process

The second case focused on a global consumer products company that operates in 140 countries. Expecting a significant rise in demand in the next five years, our client initiated a program to identify potential improvement for their current manufacturing processes.

***Phase I: Analyze transformation basis***

The study involved three factories at different locations and with different product mix. Each product would go through three phases as depicted in Figure 12, i.e. bulk manufacturing, primary packaging and secondary packaging. In the first phase, all ingredients are compounded to create products according to their formulas. Then, products are put into unit packages in primary packaging. Finally in secondary packaging, unit packages will be put into boxes with labels.

**Figure 12 The Manufacturing Process**




After executive interview, site visiting and SCORcard gap analysis, we decided to focus on the manufacturing process. We planned a comprehensive study on how the manufacturing process affect product cycle time, service level (measured by customer waiting time) and inventory level.

***Phase II: Configure supply chain***

For conciseness, we do not put too many words on modeling details here. The modeling process is quite like what we did in the first case, i.e., using the SCOR model to hierarchically model the inter-level interaction.

***Phase III: Redesign processes - evaluate performance***

Our client proposed four hypotheses for us to validate. Table 3 summarizes the four hypotheses and corresponding test scenarios. Using SmartSCOR, we not only tested and verified those hypotheses, but also *quantified* the benefits of manufacturing process redesigns through simulation.

**Table 3 Hypotheses and Test Scenarios**

| **Hypothesis** | **Test Scenario** |
|---|---|
| H1: Optimizing run strategies will improve performance | • Vary customer service level by product segment or region<br>• Vary reorder point and safety stock policy<br>• Vary batch sizes, production scheduling |
| H2: Reducing complexity will lower costs and improve service | Consolidate product mix by forms such as liquid, solid, powder, etc. |
| H3: Postponement provides supply chain efficiency as well as flexibility in meeting customer demands | Postpone the secondary packaging till order arrivals |
| H4: Implementing S&OP will improve net cash flow and service | • Increase demand forecasting accuracy<br>• Enhance cooperation with suppliers |

Due to the confidentiality agreement with our client, we cannot disclose too many details but to provide some sample results. Figure 13 shows numeric results on Hypothesis 3 (H3). Before the postponement, our client had adopted make-to-stock policy (the AS-IS system). After the postponement, it used make-to-stock policy for bulk manufacturing, while it adopted make-to-order policy for primary and secondary packaging phases (the TO-BE system). Figure 13(a) compares order waiting time distribution between the AS-IS and TO-BE system. The AS-IS system could satisfy approximately 50% of the orders upon their arrival. However, it has a fat tail, which means some of the orders would suffer extremely long waiting time. For example, more than 10% orders had to wait 5000 hours or longer. In contrary, the service level of the TO-BE system would be relatively stable, which would concentrate in the bar of 0-1000 hours. Figure 13(b) analyzes the TO-BE system with finer granularity, which demonstrates that the TO-BE system could satisfy more than 80% of orders within 50 hours and all orders within 250 hours.

**Figure 13 Analyses on Postponement**


(a) Waiting time distribution comparison


(b) Waiting time distribution in the TO-BE system

## 5. Conclusion

In this paper, we introduce SmartSCOR, a tool that effectively enables successful supply chain transformation. By integrating the well-recognized SCOR model and a variety of OR techniques, SmartSCOR overcomes two major difficulties in delivering supply chain transformation project from management consulting perspective. More specifically, SmartSCOR can hierarchically model the interactions among strategic, tactical and operational levels. Its embedded analysis tools are also practical in supply chain analysis. Moreover, SmartSCOR systematically manages each transformation project as a whole, eliminating the disconnection among different tools.

**References**

Aguilar-Savén, R. S. 2004. Business Process Modelling: Review and Framework. *International Journal of Production Economics* **90**(2) 129-149.

Albino, V., N. Carbonara, H. Giannoccaro. 2007. Supply Chain Cooperation in Industrial Districts: A Simulation Analysis. *European Journal of Operational Research* **177**(1) 261-280.

Albores, P., D. Love, M. Weaver, J. Stone, H. Benton. 2006. An Evaluation of SCOR Modelling Techniques and Tools. *Proceedings of 2006 International Association for Management of Technology(IAMOT) Conference* 1-9.

Baramichai, M., E. W. Zimmers Jr, C. A. Marangos. 2007. Agile Supply Chain Transformation Matrix: An Integrated Tool for Creating an Agile Enterprise. *Supply Chain Management: An International Journal* **12**(5) 334-348.

Bolstorff, P., R. Rosenbaum. 2003. *Supply Chain Excellence: A Handbook for Dramatic Improvement Using the SCOR Model*. New York: AMACOM.

Chidambaram, S., L. Whitman. S. H. Cheraghi. 1999. A Supply Chain Transformation Methodology. *The 4th Annual International Conference on Industrial Engineering Theory, Applications and Practice* 1-6.

Fleisch, E., C. Telljamp. 2005. Inventory Inaccuracy and Supply Chain Performance: A Simulation Study of a Retail Supply Chain. *International Journal of Production Economics* **95**(3) 373-385.

Hammer, M., J. Champy. 2003. *Reengineering the Corporation: A Manifesto for Business Revolution*. New York: HarperBusiness Essentials.

Hochstein, A., F. Uebernickel, W. Brenner. 2006. Operations Management and IS: Using the SCOR-Model to Source, Make and Deliver IS Services. *Proceedings of 12th Americas Conference on Information Systems* 32-39.

Hopp, W. J., 2008. *Supply Chain Science*. New York: McGraw-Hill.

Huang, S. H., S. K. Sheoran, H. Keskar. 2005. Computer Assisted Supply Chain Configuration based on Supply Chain Operations Reference (SCOR) model. *Computers & Industrial Engineering* **48**(2) 377-394.

Kalpic, B., P. Bernus. 2002. Business Process Modelling in Industry - The Powerful Tool in Enterprise Management. *Computers in Industry* **47**(3) 299-318.

Lee, R. G., B. G. Dale. 1998. Business Process Management: A Review and Evaluation. *Business Process Management Journal* **4**(3) 214-225.

Persson, F., M. Araldi. 2009. The Development of a Dynamic Supply Chain Analysis Tool - Integration of SCOR and Discrete Event Simulation. *International Journal of Production Economics* **121**(2) 574-583.

Persson, F., J. Olhager. 2002. Performance Simulation of Supply Chain Designs. *International Journal of Production Economics* **77**(3) 231-245.

Petrovic, D., R. Roy, R. Petrovic. 1998. Modelling and Simulation of a Supply Chain in an Uncertain Environment. *European Journal of Operational Research* **109**(2) 299-309.

Steward, G. 1997. Supply-Chain Operations Reference Model (SCOR): The First Cross-Industry Framework for Integrated Supply Chain Management. *Logistics Information Management* **10**(2) 62-67.

van der Gaag, M. A., F. Vos, H. W. Saatkamp, M. van Boven, P. van Beek, R.B. M. Huirne. 2004. A State-Transition Simulation Model for the Spread of Salmonella in the Pork Supply Chain. *European Journal of Operational Research* **156**(3) 782-798.

Wahli, U., L. Leybovieh, R. Scher, A. Venancio, S. Wiederkom, N. MacKinno, N., 2007. *Business Process Management: Modeling through Monitoring Using WebSphere V6.0.2 Products*. Available via http://www.redbooks.ibm.com/abstracts/sg247148.html (accessed June 29, 2010).

Wang, G., S. H. Huang, J. P. Dismukes. 2004. Product-Driven Supply Chain Selection Using Integrated Multi-criteria Decision Making Methodology. *International Journal of Production Economics* **91**(1) 1-15.

Wohed, P., W. M. P. van der Aalst, M. Dumas, A. H. M. ter Hofsted, N. Russel. 2006. On the Suitability of BPMN for Business Process Modelling. In: *Business Process Management*. Springer Berlin / Heidelberg, 161-176.

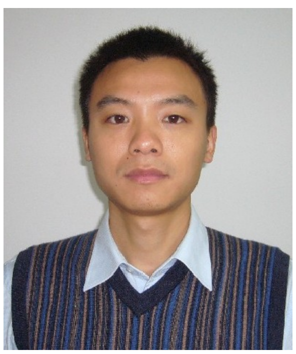
Xiao, R., Z. Cai, X. Zhang. 2009. An Optimization Approach to Cycle Quality Network Chain Based on Improved SCOR Model. *Progress in Natural Science* **19**(7) 881-890.




Changrui Ren is a manager at IBM Research - China. He joined IBM in 2005 after receiving his Ph.D. degree in Control Science and Engineering from Tsinghua University in Beijing, P. R. China. He is now leading the supply chain optimization team to work on applying business analytics and optimization techniques in solving real supply chain management and logistics problems. His SmartSCOR project won both 2008 Supply-Chain Council Global Award for Supply Chain Excellence and Award for Supply Chain Academic Excellence. His research interests include supply chain management and logistics, business process management, and Internet-of-Things.

Miao He is a Researcher at IBM Research - China. She joined IBM in 2009 after receiving her M.S degree in Industrial Engineering from Tsinghua University in Beijing, P. R. China. Her research interests include supply chain management, business process management, clinical decision making and stochastic dynamic programming.

Qinhua Wang is a Staff Researcher at IBM Research - China. She joined IBM in 2007 after receiving her Master degree in Supply Chain Management from Tsinghua University in Beijing, P. R. China. Her research interests include supply chain management, business process management and business analytics and optimization. She is currently working on a process-centric enterprise information system implementation tool.



Bing Shao is a Staff Researcher at the IBM Research - China. He joined IBM in 2006 and has been driving activities to integrate industry process standard models with end-to-end supply chain transformation. He holds a Master degree in Computer Science from Harbin Institute of Technology, Harbin, P. R. China.

Jin Dong is the senior manager of Supply Chain Management and Customer Relationship Management Research in IBM Research - China. He received his Ph.D. degree in Tsinghua University from P.R. China in 2001. Before joined IBM, he was the Research Assistant Professor in Industrial Engineering Department of Arizona State University in USA.