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LINKING STRATEGIC OBJECTIVES TO OPERATIONS: TOWARDS A MORE EFFECTIVE SUPPLY CHAIN DECISION MAKING

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ABSTRACT

Supply chain managers today face an unremitting challenge to their capabilities in both the volume and complexity of factors to be reconciled. In order to achieve more effective decision making, it is very necessary to link strategic objectives to operational actions. However, little is available to guide managers in translating a set of objectives into operations so far. This paper presents a comprehensive methodology to address this gap. In this methodology, strategic objectives are translated into performance metrics by qualitative strategy map and metric network firstly, and then quantitative techniques such as system dynamics simulation and optimization are adopted to take managers through the stages of strategy mapping, action evaluation and decision making. A case study, supported by a software tool, is carried out throughout the paper to illustrate how the method works.

1 INTRODUCTION

Supply chain is a typical complex, adaptive, and dynamic system with nonlinearities, delays, and networked feedback loops. So it is very difficult for supply chain managers to clearly understand supply chain operational mechanisms and thus make appropriate decisions within the limited time to adapt to the ever-changing, competitive, and turbulent business environment. Performance measurement is an effective way to know how a supply chain operations, however, besides the actual value of key performance indicators (KPIs) or performance metrics, managers may often ask questions like below:

- What is the impact of an inventory increase by 5% on total cost?
- What could be the bottleneck causing the revenue decreased by 5% in the last 6 months?
- Which operations should be paid more attention, and which actions should be taken to achieve a 5% revenue growth in the following quarter?

Performance measurement can only help to identify the problems existing in the current supply chain, while it is helpless in exploring the root causes of these problems and thus choosing corresponding actions to improve supply chain performance. So there is a gap between strategic objectives and supply chain operations. To those strategic thinkers, they mainly concentrate on things like “revenue”, “profit”, or “cost”, etc., however, all strategic objectives must depend on actions from operational level to achieve. The conflict between the top-down strategy decomposition and the bottom-up implementation process is serious. Therefore, in order to overcome the above issues, it is very necessary to link strategic objectives to operations, which could help managers, especially those operating at a strategic level, to know more operational mechanism of supply chains, i.e., how various KPIs in supply chains affect each other, and make more effective decisions consequently.

The objective of this paper is to describe our research work conducted on a comprehensive methodology and tool to link strategic objectives to operations, so that enables a more effective supply chain decision making. The remainder of this paper is structured as follows. At first, a literature review on strategy management and the methods of linking strategies to operations is performed in Section 2. Then in Section 3, the framework and methodology for linking strategic objectives to operations is presented. Each step of the process is discussed in detail, and a case study is also used throughout this section to illustrate how each step works. A software tool to support the whole process is introduced in Section 4. Finally, in Section 5, we conclude with some closing remarks.

2 LITERATURE REVIEW

The process of translating strategic objectives into actions is a difficult task. This difficulty is due to the wide range of possibilities and the lack of structured information. Managers must take into account relevant information and generate a range of options before a decision is reached. So far, little is available to guide managers in translating a set of objectives into actions (Tan and Platts 2003). Effective strategy formulation requires the setting of objectives, the identification and evaluation of alternative actions, and the implementation of the selected choice. However, a review of the literature shows that the emphasis of strategy formulation is very much on the setting of strategic objectives. The current strategy frameworks and processes seem to focus on broad directions and the establishment of strategic objectives, but are weak in translating these into actions for further implementation. Garvin (1993) indicated that strategic objectives (cost, quality, delivery, etc.) were too highly aggregated to direct decision making. They are broad and generic categories with a multitude of possible interpretations. For example, "quality" can mean reliability, durability, or aesthetic appeal. Many researchers have indicated that the process of linking strategic objectives to actions is often overlooked and poorly implemented.

The Balanced Scorecard (BSC) (Kaplan and Norton 1992, 1993, 1996, 2000, 2001ab) is not only a performance measurement system, but a strategy management tool that can facilitate managers to find performance drivers, to explore and describe strategic action map precisely, to implement strategy effectively, and to learn from the circular process. The BSC can help to balance strategic focuses on four perspectives (financial, internal business process, customer, learning and growth), complex cause and effect relationships, leading and lagging indicators, and tangible and intangible indicators, and to develop more systemic aligned strategy. Figure 1 (Kaplan and Norton 1996) introduces four management processes to link long-term strategic objectives with short-term actions.

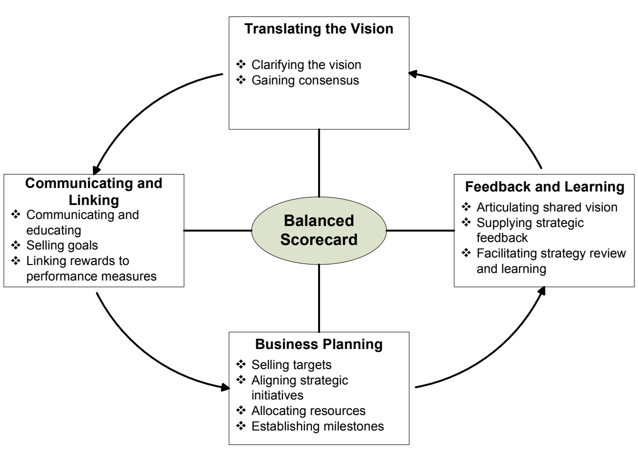


Figure 1: Four Processes for Managing Strategy

However, despite the widespread recognition of the importance of the BSC in strategy management, some literatures show that the BSC theory and practice have some limitations. Akkermans and Oorschot (2002) advocated five limitations to BSC development. The limitations were "unidirectional causality too simplistic", "does not separate cause and effect in time", "no mechanisms for validation", "insufficient between strategy and operations", and "too internally focused". They further proposed the theory of using system dynamics (SD) as a method to overcome the before-mentioned limitations. System dynamics (Forrester 1961) is an approach for exploring the nonlinear dynamic behavior of a system and studying how the structure and parameters of the system lead to behavior patterns. The essential viewpoint of SD is that feedback and delay cause the behavior of systems. In literature, there are many other attempts (Schoeneborn 2003, Wolstenholme 1998, Young and Tu 2004) in developing BSC from a feedback loops perspective to understand and manage the dynamic complexity, which is generated by the complex cause-and-effect relationships, the trade-offs among multiple objectives and measures, the resource and capacity constraints, and the time delays. The introduction of SD could enhance the BSC by adding quantitative and dynamic factors.

From the perspective of performance measurement, it also has an emerging idea to study the relationships between performance metrics. Santos et al. (2002) incorporated SD and multi-criteria analysis to analyze the relationships among performance metrics. Suwignjo et al. (2000) used cognitive map, cause and effect diagram, and analytic hierarchy process (AHP) to build hierarchical model and determine priorities of performance metrics. Malina and Selto (2006) and Banker et al. (2004) made use of statistics and data mining methods to study the "balance" of BSC based on historical data. Linking performance metrics in a logical manner could help much both on performance measurement and decision-making.

In summary, we can learn from literature that "linking" is not a novel idea for strategy management, however, it is still immature and a little far from being effectively applied - the problem and difficulty lie in how to effectively link strategic objectives to operations, i.e., how to model and how to analyze. In literature, the approaches of building linkages can be divided into two main groups, namely qualitative (Tan and Platts 2003, Kaplan and Norton 1996, 2000, 2001ab) and quantitative (Akkermans and Oorschot 2002, Schoeneborn 2003, Wolstenholme 1998, Young and Tu 2004). The qualitative approach, representing by the traditional BSC, is weak in the expression of more accurate and dynamic factors; while the quantitative approach, representing by the adoption of SD, is too rigid in the expression of quantitative relationships, especially to those strategic objectives. No single approach could work well, so it still requires further study if it is to be effective in supporting the supply chain decision making process.

3 THE FRAMEWORK AND METHODOLOGY

We propose a framework (see Figure 2) with comprehensive methodology and tool support for effective supply chain decision making by linking strategic objectives to operations, which incorporates features from both qualitative and quantitative approaches.

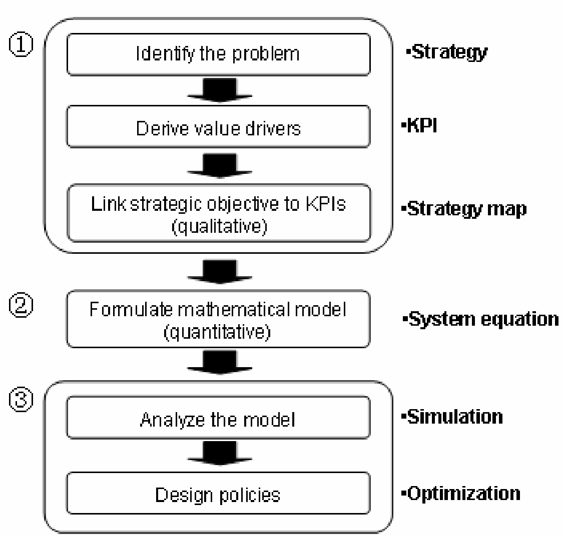


Figure 2: The Decision Making Process by Linking Strategic Objectives to Operations

The following three main processes are identified in the framework:

1. Link strategic objectives to KPIs.
2. Formulate mathematical model.
3. Analyze and decide.

Each of these is described below.

3.1 Link Strategic Objectives to KPIs

In this process, strategy map and metric network are used to link strategic objectives to KPIs (performance metrics) from two different levels respectively. On the top level, we utilize strategy map to express the cause-and-effect links among strategic objectives; while on the bottom level, metric network is used to organize the value drivers of strategic objectives from the operational perspective. Obviously, the linkages between these two levels are also important.

The concept of strategy map (Kaplan and Norton 1996, 2000, 2001ab) originates from the BSC, which provides a visual representation of an organization's critical objectives and the relationships among them that drive organizational performance. The BSC provides a framework for organizing strategic objectives into the four perspectives as below:

1. Financial: The strategy for growth, profitability, and risk viewed from shareholders' perspective.
2. Customer: The strategy for creating value and differentiation from the perspective of the customer.
3. Internal business processes: The strategic priorities for various business processes that create customer and shareholder satisfaction.
4. Learning and growth: The priorities to create a climate that supports organizational change, innovation, and growth.

Figure 3 (Kaplan and Norton 2000) gives a typical example of how the BSC links strategic objectives from different perspectives together.

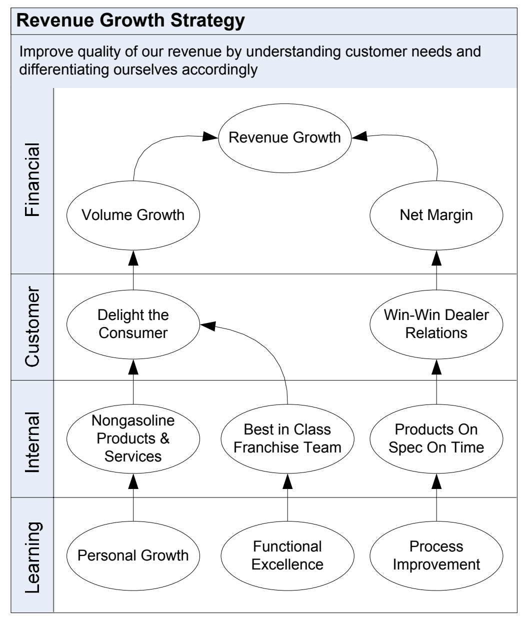


Figure 3: Revenue Growth Strategy Map

The strategy map helps to structure strategic objectives in a logical way, then we have to translate these objectives into operations, which is more important but difficult. Fortunately, the SCOR model provides a framework and a set of metrics that can be used as the starting point for building metric network and decomposing strategic objectives.

The SCOR (Supply Chain Operations Reference) model is a process reference model that was introduced in 1996 through the Supply Chain Council (SCC) and supported by more than 1000 academic and industrial organizations to become an industrial standard for supply chain management. The SCOR model is intended to describe the business activities, operations and tasks corresponding to all levels of satisfying supply chain internal and external customer demands (Supply-Chain Council 2006). Besides the well-known concepts of business process reengineering and benchmarking, SCOR also defines a set of metrics that one can use to evaluate processes at each level of the process hierarchy. The performance attributes and metrics are measured in five different categories, namely supply chain reliability, supply chain responsiveness, supply chain flexibility, supply chain costs, and supply chain asset management. Each SCOR metric is associated with certain SCOR processes.

Based on SCOR, we can construct metric network for each strategic objective, thus achieve the decomposition of strategy into operational metrics at different levels. Figure 4 shows the whole picture of the link from a strategy map to SCOR based metric network. On the left side, the strategy map enables to decompose objectives in the strategic world; while on the right side, SCOR metrics provide a very good foundation for translating strategic objectives into supply chain operations of different levels.

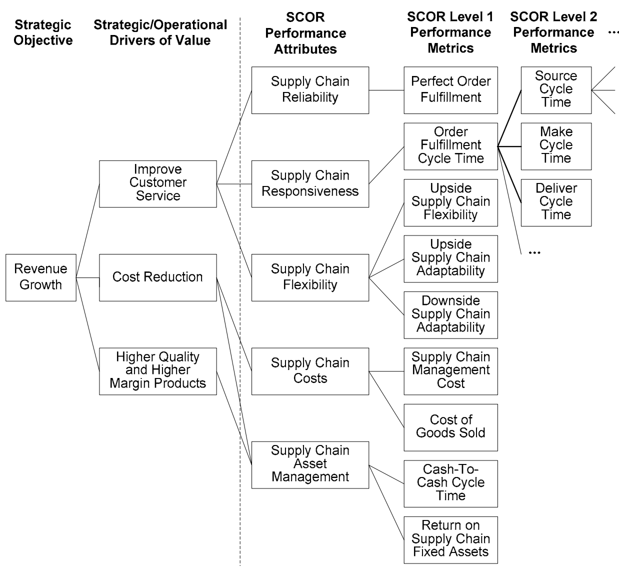


Figure 4: Linking Strategy Map to Metric Network

In fact, based on the framework provided by SCOR metrics, we can further drill down to different levels according to the actual requirements by adding more details beyond SCOR to the metric network. For example, to a pharmacy wholesaler ABC company, its Level 1 metric "Supply Chain Costs" for one of its typical products can be further expressed by the metric network as Figure 5.

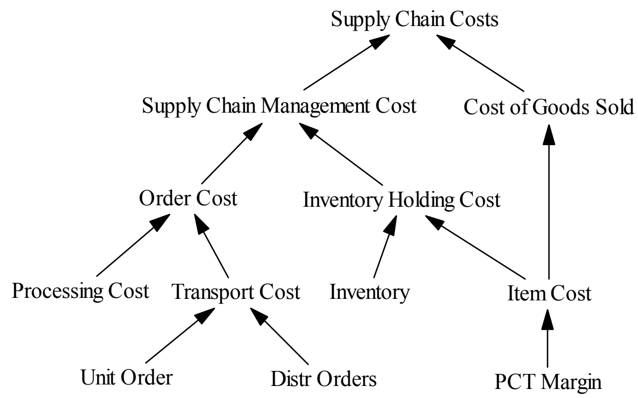


Figure 5: Metric Network for "Supply Chain Costs"

3.2 Formulate Mathematical Model

The strategy map and metric network lay a solid foundation for further decision making, however, the linkages in these maps are all qualitative ones which represent logical or causal dependencies, so the next step is to expand the initial qualitative framework into a series of interlinked mathematical equations that specify how the elements are related quantitatively. Quantitative relationships are not easy to obtain in strategy maps and the links to metric networks. So in this paper, we design a hybrid mechanism that utilizing AHP to weight strategy map and the links to low level metrics, while applying SD to metric networks for exploring supply chain operational mechanisms.

3.2.1 Weighting Strategic Objectives

For the difficulty in directly quantifying, we use AHP to assign weights to each element from strategic objectives to supply chain performance attributes, according to the contribution to its father nodes in the map. The AHP (Saaty 1980) is a commonly used tool for solving multi-criteria decision-making problems, and provides a framework to cope with multiple criteria situations involving tangible and intangible, quantitative and qualitative aspects. It consists of three main steps:

1. Decomposing the complex problem into a hierarchy of different levels of elements.
2. Using a measurement methodology to establish priorities among the elements.
3. Synthesizing the priorities of elements to establish the final decision.

The AHP helps to rank and make decision in a rational and systematic way. Weights can be changed according to different companies or industries, thus it is a flexible kind of data analysis. The AHP allows flexibility to aid the management decision-making process and reduces assessment bias by pairwise comparison.

3.2.2 Quantifying Metric Network

In the operational level, metrics that associated with business processes can be more easily to be accurately quantified, so we introduce SD to quantify metric networks. Supported by SD, dynamic factors and causal loops are allowed in this level, so more details in operations could be addressed.

In general, the structure of a metric network can be divided into two parts: well-defined structure and ill-defined structure. In the well-defined structure, the relationships among metrics can be directly quantified by mathematical equations, which include algebraic equations, differential equations, and logical equations (such as the rules like "IF…THEN…"). However, for the below three reasons:

1. People still know little about the system.
2. The information and data people have are not enough to build the quantitative relationships.
3. Some relationships in the structure are uncertain in nature.

People can only use semi-quantitative or qualitative methods to express the relationships in the ill-defined structure. So in order to apply SD to the whole metric network, we design a process to quantify the ill-defined structure. Figure 6 illustrates the solution to this problem.

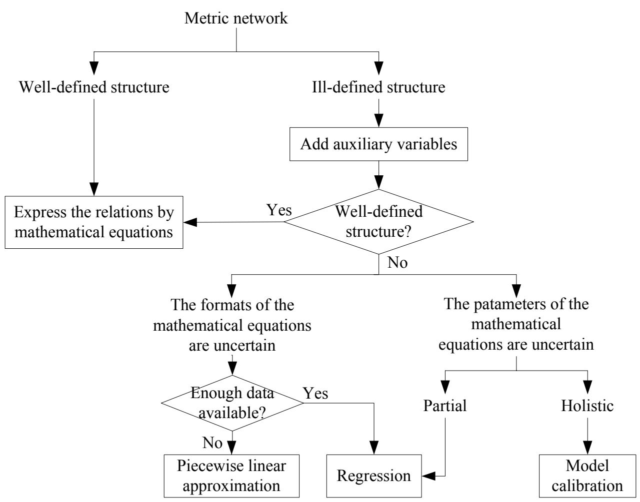


Figure 6: The process of Quantifying Metric Network

We can see from Figure 6 that three main methods are introduced to quantify the ill-defined structure in metric network: piecewise linear approximation, adding auxiliary variables, and model parameters estimation. So to an ill-defined structure, if there is enough data available, the quantitative relationships can be obtained by estimation; piecewise linear approximation, which is similar to the table function in SD, can work when only some limited data is available; while adding auxiliary variables, is a simple but effective means under many conditions.

For example, in Figure 5, "Transport Cost" is determined by "Unit Order" and "Distr Orders", but the quantitative relationship is hard to derive. By using the piecewise linear approximation, we can easily get an approximate expression of the function *f* for equation (1).

$$\text{Transport Cost} = f\,(\text{Distr Orders/Unit Order}) \qquad (1)$$

Figure 7: Piecewise Linear Approximation

3.3 Analyze and Decide

The last step focuses on putting the model to use. The qualitative and quantitative models we have built can help to evaluate, analyze and design policies for supply chain decision making. Under the hypothesis of metric network, designing a new policy for supply chain management is an activity of (1) assigning alternative values for parameters; (2) changing linkages among system elements; or (3) inserting new elements into a model. Therefore, a policy can be expressed by some partial structures in a metric network. For example, we can simply add a periodic review singe item inventory control policy (t, R, M) to the previous model by extending the metric network with the structure in Figure 8.

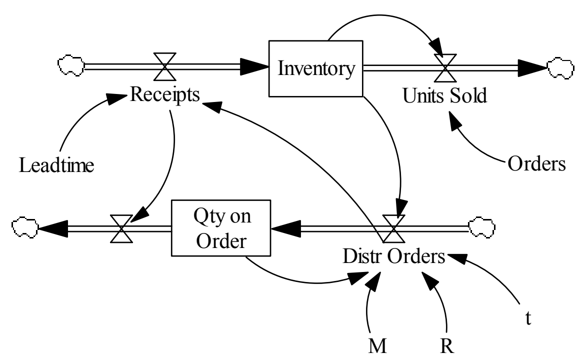


Figure 8: The (t, R, M) Policy

The value of "Distr Orders" can be calculated through the below logical equation (2):

IF Inventory + Qty on Order < R **THEN**
Distr Orders = (M - Qty on Order - Inventory)/t
ELSE
Distr Orders = 0 (2)

3.3.1 Policy Evaluation

The AHP can not only be used for weighting strategy map, but also as a tool for policy evaluation. Based on the strategy map and metric network, we can directly use AHP to evaluate different policy options, just as in Figure 9. This method can be used in different levels of the model, but it is more useful in some strategic decision-makings.

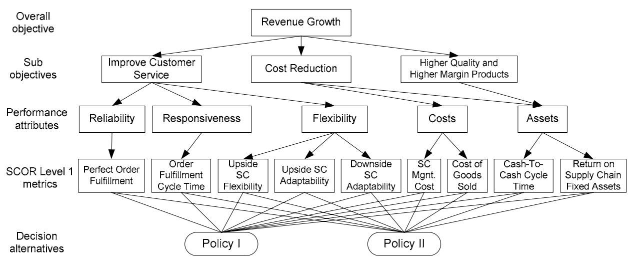


Figure 9: Policy Evaluation Using AHP

3.3.2 Policy Analysis

The quantitative model can be used for answering a broad range of "what if" questions, i.e., given the changes of one or more elements in the model, what are the impacts to other related elements? For example, if we increase "Price" by 10%, what are the impacts to "Sales" and "Total Profit"?

"What if" analysis allows the organization to experiment in advance with the full, long-term consequences of potential policies, actions or changed conditions before committing to action, and in practice, such analyses can help organizations to (Mayo and Wichmann 2003):

- Find policies that produce desired benefits.
- Fine tune the timing and sequencing of strategy implementation.
- Spot and mitigate undesirable consequences that arise under a potential set of actions.

This kind of problem can be solved by SD simulation based on the quantitative models. Additionally, the SD based analysis also brings some other powerful automated analysis capabilities that can enhance the ability of organizations to explore a rich selection of policy options, via for example (Mayo and Wichmann 2003):

- Sensitivity testing: Which actions make the most difference to the desired outcomes?
- Monte Carlo analysis: Given a potential range of action effectiveness, what is the expected value of benefits delivered, and over what expected time frame will they be delivered?

Another kind of analysis is to find the root causes for the existing phenomena. For example, one has observed the "Total Profit" decreased by 10% in the last 5 months, what could be the bottlenecks causing this decrease? Such problems are not easy to solve, and one feasible approach is the trial-and-error method by repeated what-if analyses using the SD simulation. Moreover, the eigenvalue analysis method can also be used to enhance the understanding of the problematic behaviors (Rabelo et al. 2004).

3.3.3 Policy Design

Policy design is actually an optimization problem, i.e., to find the optimal mix of actions (the elements that can be changed as decision variables) to achieve a given goal of obtaining a particular set of benefits within a particular time frame (usually a function of one or several elements in the model). For example, given the objective of achieving a 90% "Perfect Order Fulfillment", how to set the metric "Price" to achieve this goal?

The objective of this optimization problem can either be a payoff function or a target trajectory. When the optimization objective is a payoff function, the problem can be formulated as below:

$$\underset{\boldsymbol{p}}{\text{Min}}\ \ g_1(\boldsymbol{p}), g_2(\boldsymbol{p}), \cdots, g_n(\boldsymbol{p}) \tag{3}$$

$$\text{s.t. } c\,(\boldsymbol{s}_t, \boldsymbol{p})=0,\ \ \mathbf{ll} \le \boldsymbol{p} \le \mathbf{ul} \tag{4}$$

Where

$g_i(\boldsymbol{p})$ - the ith objective (i=1, 2, …, n),
$\boldsymbol{s}_t$ - state variables,
$\boldsymbol{p}$ - decision variables,
ll - lower limit of decision variable feasible range,
ul - upper limit of decision variable feasible range,
c- equations in SD model.

When the optimization objective is a target trajectory, it means that the time factor will be considered. So in this condition, the problem can be formulated as below:

$$\underset{P}{\text{Min}} \sum_{t=t_1}^{t_s} f(y_{1t}-\hat{y}_{1t}), \sum_{t=t_1}^{t_s} f(y_{2t}-\hat{y}_{2t}), \cdots, \sum_{t=t_1}^{t_s} f(y_{nt}-\hat{y}_{nt}) \tag{5}$$

$$\text{s.t. } Y_t=c\,(\boldsymbol{s}_t, \boldsymbol{p}),\ \ \mathbf{ll} \le \boldsymbol{p} \le \mathbf{ul} \tag{6}$$

Where

Y=(y_1, y_2, …, y_n) - objective variables,
$\hat{y}_{it}$ - target trajectory for y_i(i=1, 2, …, n),
t_i(i=1, 2, …, s) - sampling points,
$\boldsymbol{p}$=(p_1, p_2, …, p_m) - decision variables,
ll - lower limit of decision variable feasible range,
ul - upper limit of decision variable feasible range,
c- equations in SD model.

This nonlinear optimization model is difficult to solve, heuristic algorithms need to be developed. Usually, the genetic algorithms (GA) is a choice to this kind of problems.

For the previous example in Figure 8, if we want to design an optimal inventory control policy (t, R, M) to get much higher profit, we can use the model as Figure 10.

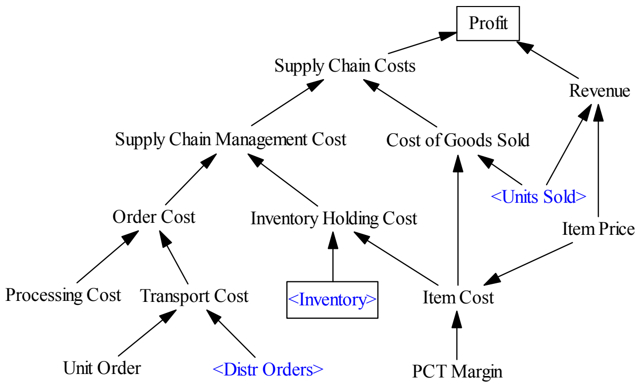


Figure 10: The Model for Policy Design

The objective function of this optimization problem is to maximize the "Profit", while the decision variables are the parameter R and M in the policy. Given the feasible range of 0≤R≤10000 and 100≤M≤10000, we finally derive the optimal policy at R=698 and M=4520 after 364 runs. Figure 11 shows the result of "Profit" under the optimal policy, in contrast to the base condition (R=200, M=1000).

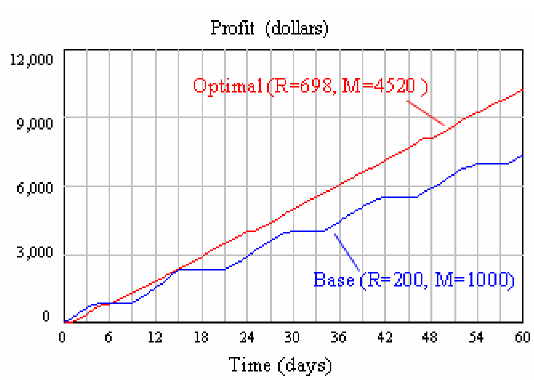


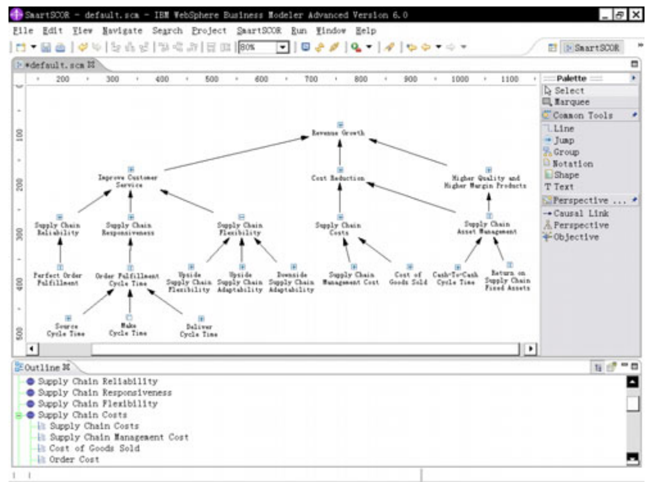
Figure 11: The Optimization Result

4 THE TOOL SUPPORT

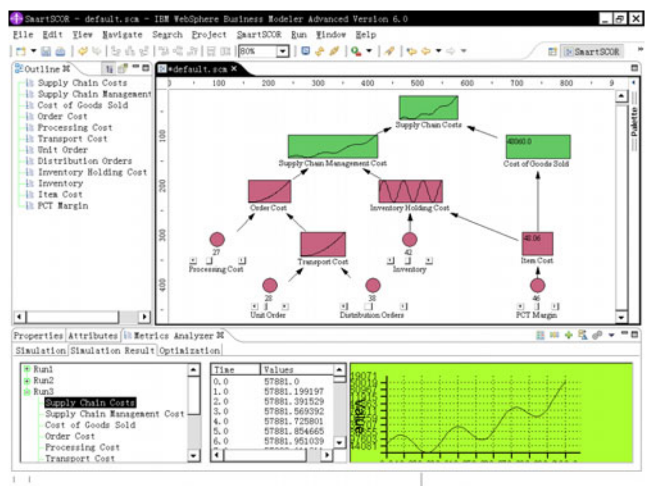
In order to support the whole process we have presented for supply chain decision making, we develop a software tool for strategy and performance modeling and analysis, as part of our supply chain transformation platform - IBM SmartSCOR (Dong et al. 2006). The main functions of this tool include:

- Support dynamic definition and modeling of strategy map and metric network.
- Provide many reusable and extensible templates of industry best practices and benchmarks, such as the SCOR model.
- Build in many analytics capabilities, powered by the SD engine we developed.

The tool has been seamlessly integrated with an IBM standard business process management (BPM) platform - IBM WebSphere Business Modeler (IBM WBM), so all features in IBM WBM can be leveraged. Together with other modules in SmartSCOR, such as business process reengineering, logistics network optimization, and supply chain simulation, an end-to-end supply chain transformation solution can be provided. The tool has easy-to-use graphic user interfaces, see Figure 12.



(a) Strategy and Performance Modeling



(b) Policy Analysis and Design

Figure 12: The Software Tool

5 CONCLUSIONS

This paper presents a comprehensive methodology for supply chain decision making by translating strategic objectives into operations. With the software tool support, this method makes it possible to integrate all of the key environmental and behavioral elements and their interrelationships into a single consistent, explicit, and flexible strategic level analysis system. Furthermore, the framework in this paper can also be used for supply chain diagnosis, supply chain transformation, and the exploration of supply chain operational mechanisms.

This paper is intended to describe the main framework of this methodology, rather than elaborate technical details. Moreover, its contributions would be tested in further practices with necessary adjustments. In future, there are still many issues which require further study if this method is to be more effective in supporting the decision making process and supply chain performance improvement, such as the validation of the quantitative model, the accumulation of reference modes and best practices by industry, and the enrichment of policy optimization methods.

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