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# IMPLEMENTING PERFORMANCE-BASED ANALYSIS IN SUPPLY CHAIN MANAGEMENT: REVIEW AND EXTENSION

Elgharably, Nayera[1,4], Easa, Said[2] and El-Damatty, Ashraf[3]
[1,3] Western University, Canada
[2] Ryerson University, Canada
[4] nelghara@uwo.ca

**Abstract:** Supply chain is the integration of processes where raw materials are converted into final products, then delivered to customers. Supply chain management (SCM) consists of two basic processes: (a) production planning and inventory control process and (b) distribution and logistics process. The SCM objective is to maximize competitiveness and profitability not only for the company but the entire supply chain network, including the ultimate-customer. This is achieved by synchronizing customer requirements with the flow of materials from suppliers, while causing a reduction in inventory investment in the chain, and increasing the customer satisfaction. The selection of appropriate performance evaluation measures for supply chain analysis, given the inherent complexity in SCM, is critical. Traditional SCM performance measures focused on financial measures (e.g. net present value). Such methods are best suited for simple SCM applications. In addition, modeling transportation operations in SCM lacks a concise representation of the transportation cost function. The purpose of this paper is to review current status of SCM and propose a framework that integrates relevant performance measures and decision variables in SCM. The supply chain evaluation system includes resource, output, and flexibility measures. The framework includes a transportation optimization module and a supply chain module for routing decision using private or outsourced fleet. The optimization module incorporates not only transportation cost, but also other relevant performance measures. In addition, the framework includes a decision support system that integrates various measures and the trade-off among them. Finally, risk assessment is implemented to minimize supply chain disruptions and uncertainties. The proposed framework should be a valuable assessment tool for the newer generation of SCM applications.

Keywords: Transportation, Optimization, Supply Chain Management.

## 1 INTRODUCTION

A supply chain consists of multiple firms, both upstream (supply) and downstream (distribution), and the ultimate consumer. It is the network of all organizations involved, in the different processes/ activities that are responsible of adding value in the form of products and services delivered to the ultimate consumer (Mentzer et al 2001). Supply chain can be defined as the integration of manufacturing process where raw materials are converted into final products, then delivered to customers. A supply chain consists of two basic, integrated processes that interact together: (a) production planning and inventory control process, and (b) distribution and logistics process. The production planning and inventory control process includes all the manufacturing and storage processes. Production planning defines the design and management of the manufacturing process including raw material scheduling and purchase, manufacturing process design and scheduling, operations management and material handling. Inventory control deals with managing the raw materials, work in process (WIP) as well as the final products, where the storage and purchase policies are determined. Inventory retrieval and transportation, whether it is a final product or raw material is defined in the transportation and logistics processes. Products might be delivered to customers directly or may be delivered to distribution centers first and then shipped to the customer (Beamon 1998).

This paper will be organized as follows: Section 2 describes supply chain management (SCM) in detail, including SCM vs. logistics, SCM objectives, and SCM components. Section 3 discusses SCM complexity and performance measures. Section 4 shows the transportation operations modelling in SCM. In section 5, the proposed framework is presented to measure SCM performance and to model transportation operations. Finally, conclusions are presented in section 6.

## 2 SUPPLY CHAIN MANAGEMENT

Supply Chain Management is the management of material and information flows through all the members of the chain, such as vendors, manufacturing, assembly, and distribution centers (Thomas and Griffin 1996). The coordination of the traditional business functions and its tactics not only within a specific company but across businesses within the supply chain aiming and a long-term performance of the chain as a whole is the definition of SCM (Li 2014).

### 2.1 Supply Chain and Logistics

In 1986, logistics management was stated by the Council of Logistics Management as “The process of planning, implementing, and controlling the efficient, cost – effective flow and storage of raw materials, in-process inventory, finished goods and related information flow from point of origin to point of consumption for the purpose of conforming to customer requirements” (Lambert and Cooper 2000). SCM is a new term in literature. It appeared in 1982 focusing on inventory reduction through the whole network involved (Cooper et al. 1997). Supply chain and logistics are usually related in academia. They both are related to the product movement during its whole life cycle, and both are considered the central unit of competitive analysis of model management science. Supply chain is a more broadened concept than logistics dealing with a wider range and perspective. as logistics has no relationship with organizations. Moreover, SCM doesn’t aim at reducing costs and improving profits but the general aim is to increase the competitiveness of the whole chain. (Li 2014).

### 2.2 SCM Objectives

The objective of SCM is to maximize competitiveness and profitability for the company as well as the whole supply chain network including the ultimate-customer, aiming at increasing the total process efficiency and effectiveness across members of the supply chain (Lambert et al. 1998). Moreover, reducing the total amount of resources used to provide the necessary customer service level, reducing inventory investment in the whole chain, and increasing customer service (Cooper et al. 1997).

### 2.3 SCM Components

The supply chain involves the combination of three elements (Figure 1): the structure of the chain, its business processes, and SCM components. The supply chain structure is the network of members and the links between them. Business processes, second element in SCM, are the activities needed to produce a specific output to the ultimate customer. The management components, third element in the SCM, are the managerial variables by which the business processes are integrated and managed across the supply chain. The identification of the supply chain members is one of the important points in managing the supply chain, then determining their links with each other and their link to the processes done in the chain (Lambert et al. 1998). According to Thomas and Griffin (1996), the following important elements should be considered in SCM:

- The restructuring of value-added activities may offer great opportunities for improvement Which can be done through co-ordinated modelling.
- A key element is choosing performance measures that correspond with the supply chain goals and objectives.

- Transportation cost accounts for more than the half of the total logistics cost, which is the largest component of the logistics costs.
- Life cycle constraints and costs should be considered in long supply chains. Quick response to customers' requirements can be constrained in long supply chains. With products of short life cycle, a high risk of inventory obsolescence can occur.
- The coordination between stages of the supply chain in the design and modelling is important.
- Decomposition methods fail to solve the se problems as the models becomes too large/complicated to be solved.
- A great attention should be taken to the supply chain activities environmental impact. (Thomas and Griffin 1996).

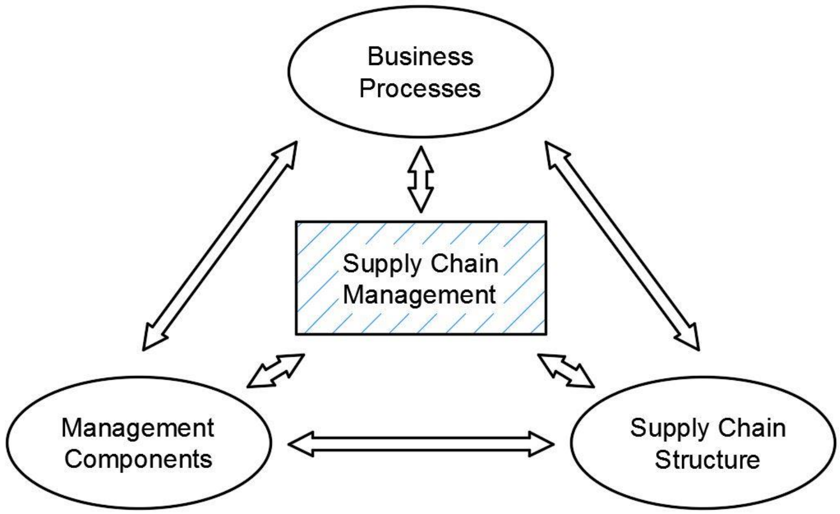


Figure 1: Supply Chain Management Components

## 3 SCM COMPLEXITY AND PERFORMANCE MEASURES

Figure 2 shows a four level Supply Chain consisting of suppliers, manufacturing plants, distribution, and customers. Each level of the supply chain may include several facilities. the complexity of the supply chain depends on the number of levels in the chain and the number of facilities in each level. The selection of the most suitable performance measures of the supply chain is a critical decision, due to the complexity of the Supply Chain (Beamon 1999).

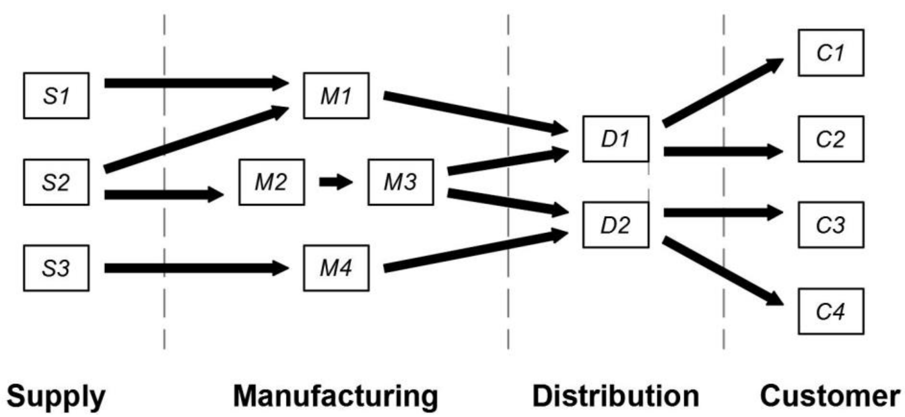


Figure 2: Example of a Supply Chain

Mentzer et al (2001) defined three degrees of supply chain, as shown in Figure 3 which illustrates the complexity of a supply chain system:

- Direct Supply Chain, consists of a company, a supplier, and a customer (Figure 3i),
- Extended Supply Chain, consists of all the suppliers and customers involved in flow of products, services, finances, and/or information (Figure 3ii), and
- Ultimate Supply Chain, includes all the organizations involved in the chain (Figure 3iii). A third party financial provider and a third-party logistics (3PL) exist. Traditional performance measures concentrate on using financial measures such as return on investment (ROI), net present value (NPV), internal rate of return (IRR), and payback period (PBP). Financial measures could be used in evaluating noncomplex supply chains of small sizes although they will not give an overview of the whole chain performance. (Bhagwat and Sharma 2007).

In 1996, Beamon presented several characteristics that can aid in evaluating supply chains These characteristics are:

1. Inclusiveness: measuring all aspects,
2. Measurability: data used could be measured, quantitative not qualitative data,
3. Universality: to allow for comparison under various operating conditions,
4. Consistency: measures meets the organization goals and objectives (Beamon 1996).


Figure 3: Degrees of Supply Chain Complexity.

Supply chain models have mainly used either cost; and or a combination of cost and customer responsiveness. Costs may include inventory costs and operating costs. Customer responsiveness includes lead time, stock out probability, and fill rate. Other performance measures have been identified to measure supply chains, yet they are not used in research due to their qualitative nature. These measures include: customer satisfaction, information flow, supplier performance, and risk management. In 1999, Beamon presented a framework for the selection of performance measurement systems for manufacturing supply chains that include measures for the use of resources, the desired output and flexibility. Each one of these three measures is important and affect each other. Beamon (1999) stated that the supply chain performance measurement system should contain at least one single measure from each of the three identified types that is consistent with the organization's strategic goals and objectives. The three types of measures are listed below:

1. Resources: which are the minimum requirements (quantity) or an efficiency measure, that measures the utilization of the resources in the system. The use of too few resources can affect the system in a negative way affecting the output and as a result affects the systems flexibility and ability to respond to customers' requests.
2. Output: include measures for customer responsiveness, quality, and the quantity of final product produced. Output measures are mainly quantitative measures, however customer satisfaction; and Product quality are qualitative measures that need to be interpreted quantitatively.
3. Flexibility: is a measure of the ability of the system to respond to customer requests by cooping with volume and schedules changes from suppliers, manufacturers, and customers. Flexibility is vital to the success of the supply chain as supply chains exist in uncertain environments. Beamon (1999) developed a quantitative approach to measure flexibility (Beamon 1999).

Gunasekaran et al. (2001) stated that there is a great need to study the performance measures of SCM in the context of following reasons:

- Lack of a balanced approach as most of the approaches in literature focused on financial measures (stakeholders' measures), not giving enough attention to operational measures
- Lack of determining the suitable evaluation measures for SCM and the number of measures used. Good few metrics are better than many measures not related to the goals and objectives.
- Lack of differentiation of the measures required at strategic, tactical, and operational levels (Gunasekaran et al. 2001).

## 4 MODELLING OF TRANSPORTATION OPERATIONS IN SCM

According to the 23rd annual Council of Supply Chain Management Professionals State of Logistics Report, the USA transportation costs represented 64 % of the total logistics costs in 2011, while inventory costs represented 33% and 4% for administrative costs. The use of mathematical programming techniques in SCM is on of the most important techniques in latest decades. A review of historic modeling of the transportation function, from 1974 to 2008, in supply chain optimization models and recent papers, from 2009 to 2012, done by Bravo and Vidal 2013 shows that:

- Integrated models have been frequently used. However, those models did not deal with the stochastic nature of transportation time. As this may result in computational complications.
- The number of vehicles used in the fleet and transportation times were considered as model parameters not as decision variables
- Most of the research used the cost function as the objective function in optimizing the problem. The objectives related to minimizing the travel time, minimizing the distance travelled and, minimizing the order delay were ignored, which means that cost minimization is preferred over customer satisfaction.
- It was found that 10% of the variability in transportation costs is due to the travelled distance, which is calculated using cost per unit shipped or cost per unit distance. This shows that there is a gap in modeling the transportation operations and the modeling of the transportation cost function.
- Recently, transportation models paid attention to service times and considered time windows for serving customers. Moreover, different types of transportation vehicles and modes are considered in the models.
- The speed of the vehicles, its acceleration, the road's topography, and CO2 emissions were rarely considered.
- Transportation fleet in most of the papers is not determined whether it is private or outsourced, and homogeneous or heterogeneous.
- The use of Trade-off considerations between transportation costs and other aspects has decreased rather than increased in research for the recent years (Bravo and Vidal 2013).

## 5 PROPOSED FRAMEWORK

In the past, manufacturers were considered the main drivers of the supply chain. They controlled the way at which products were manufactured and distributed. Today, customers are the main drivers, and manufacturers are competing to meet their demands by manufacturing products that are different in options, styles, features, quick order fulfillment, and fast delivery (Jain et al. 2010). Best value supply chains are the chains most likely to prosper within this today's competition. Best value supply chains are the ones that use strategic SCM in an effort to excel in terms of speed, quality, cost, and flexibility (Muysinaliyev and Aktamov 2014). As shown in literature, Supply chain models have mainly used two different quantitative performances, either cost; and or a combination of cost and customer responsiveness, ignoring important measures such as output measures. The selection of performance measures in supply chain is considered one of the critical steps in the SCM. A Framework (Figure 4) that adopt Beamon's performance Measures in Supply Chain (Beamon 1999) is proposed, emphasizing on the three different types of measures: resource, output, and flexibility measures. These three measures are all interrelated as the output of the supply chain is affected by the resources used and the flexibility of the system is determined by the output whether it is a product or service

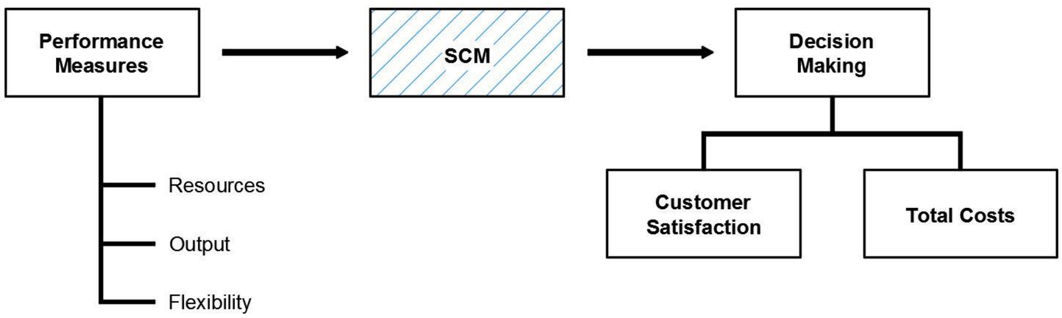


Figure 4: Supply Chain Management Framework

The framework includes developing a transportation optimization model that takes into account not only the transportation cost per unit distance or cost per unit shipped, but also other transportation operations involved and trade-offs between transportation costs and other aspects done using a decision support system. The transportation model (Figure 5) includes routing decisions using private or outsourced fleet, Homogenous or nonhomogeneous fleet. Furthermore, risk assessment is implemented. Supplier poor management, customer orders uncertainties, carrier delays, lack of updated/accurate data, and other external circumstances are considered sources of risk. Implementation of risk management is to minimize supply chain disruptions and uncertainties, where stochastic analytical models are considered. This is done by identifying the sources of risk in the model, their consequences, actions and backup scenarios and finally monitoring risks to detect the them when they occur (Tuncel and Alpan 2010). Some components of the framework are to be validated using Monte Carlo simulation. The proposed framework should be a valuable assessment tool for the newer generation of SCM applications.

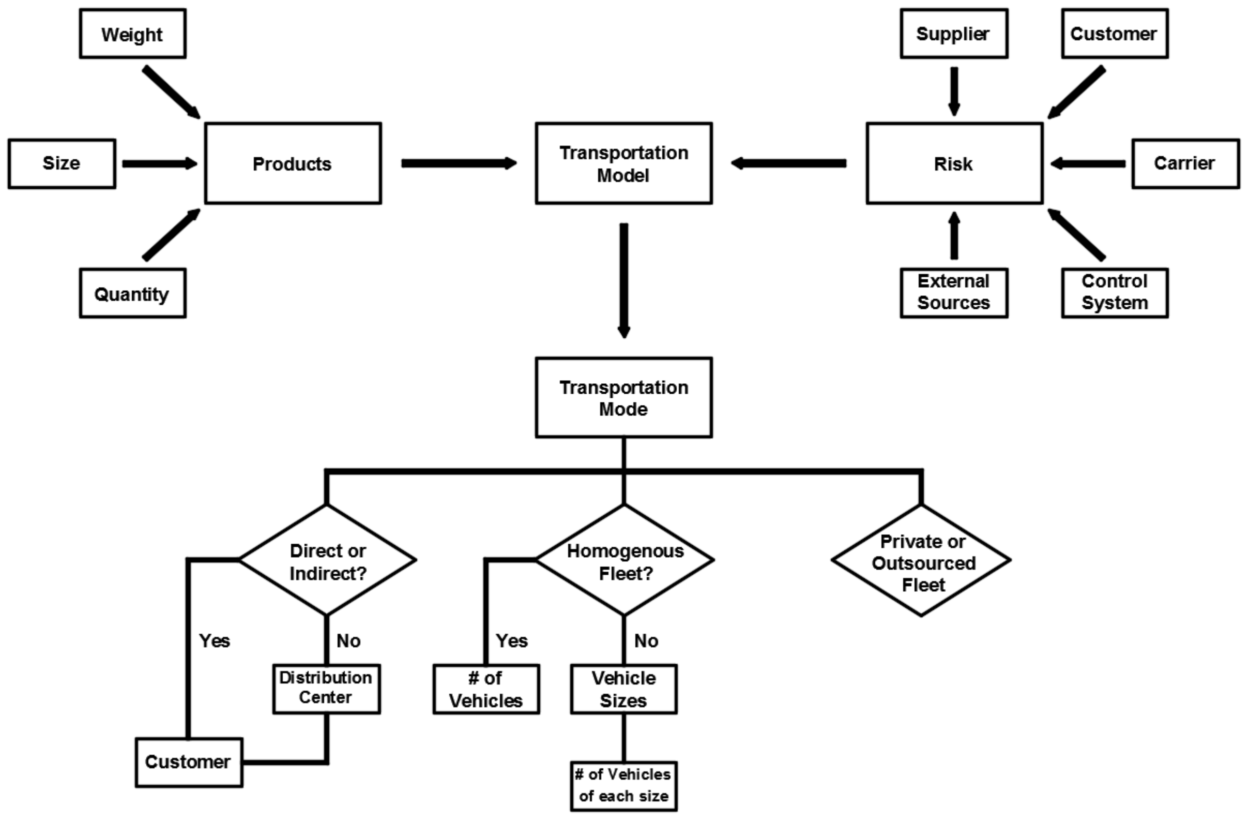


Figure 5: Transportation Model

## 6 CONCLUSIONS

A review of the SCM complexity, objectives, performance measures along with modelling the transportation function is done. It was found that Traditional SCM evaluation methods focus on the well-known financial measures and Such methods are not suited for the new generation of complex Supply Chains. In addition, modeling transportation operations in SCM lacks a concise representation of the transportation cost function. A framework is proposed that integrates relevant performance measures and decision variables that adopts a transportation optimization module and a supply chain module for routing decision using private or outsourced fleet. The optimization module incorporates not only transportation cost, but also other relevant performance measures. It integrates various performance measures and the trade-offs among them using a decision support system. Finally, risk assessment is to be prepared to evaluate the uncertainties in the model.

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