

Efficient Control of Logistic Processes Using Multi-criteria Performance Measurement

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Abstract: Supply chain management (SCM) is a dynamic-developing and rapidly changing phenomena supported by companies and researchers throughout the world. Supply Chains are getting more and more complex, longer and complicated, making them hard to measure and control. Extended Supply Chains have large amount of capital invested and high level of inventory that makes control, measurement and optimization an important issue for the world economy. This particular article encompasses the necessity of possessing knowledge of supply chain complexity and length.

Keywords: modelling, Supply Chain Performance, Supply Chain length, complexity

1. Introduction

The term 'Supply Chain Management' (SCM) was first introduced by consultants in the early 1980s. The concept was mainly used to discuss the benefits of integrating a firm's internal business functions: purchasing, manufacturing, sales, and distribution [1, 2]. The original view of supply chains had an intra-organisational focus and concentrated primarily on the firm's internal supply chain and how different functions could be integrated in order to smooth the material flow within the company. This view of the supply chain is closely related to what [2] labels the firm's 'value chain'. From this intra-organisational focus the scope of the supply chain was later extended beyond the boundary of the (manufacturing) firm to include 'upstream production chains' and 'downstream distribution channels'. This complementary perspective gave inter rather than intra-organisational focus to SCM.

To be able to control a supply chain a performance measurement tool is inevitable. To be able to choose the right tool for the right Supply Chain we need to characterise the supply chain according to various characteristics [11]. Complexity and length are key characteristics of Supply Chains that is why a very deep research was needed in these fields.

2. Need for operational feedback and identification

On Fig. 1 the strategic vision of supply chains can be seen. According to this figure, for the time being, mainly strategic view is dominant in planning, thus a good strategy will always result in customer satisfaction. This principle is questionable because of the lack of feedback from strategic level to operational level. Problems and barriers on operational level can hold back strategic level goal fulfilment: a decision on strategic level can be excellent but maybe it cannot be accomplished on operational level. That is why an operational feedback was added to the following figure. This feedback is to check the operational feasibility of strategic decisions.

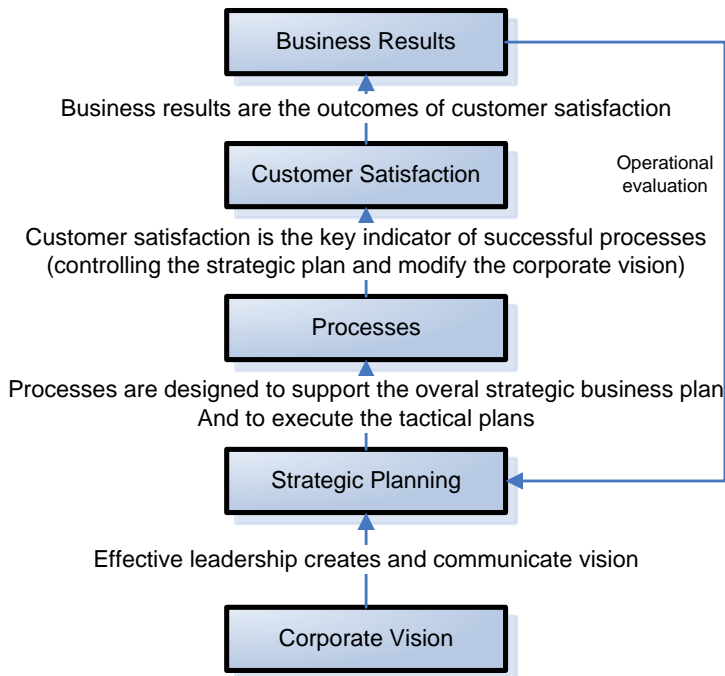


Figure 1. Strategic vision of Supply Chains

To be able to evaluate a strategic decision on operational level the identification of the particular supply chain is inevitable. The proper recognition of two main supply chain characteristics, complexity and length, is an important step in this process.

3. Supply Chain complexity

Complexity is a key managerial issue that supply chain managers should address. Although its meaning has been discussed by a large number of authors, a broad range of definitions still exists. Much of this definitional work has been incorporated into the organisational theory literature, with a focus on studying, predicting and controlling chaotic systems.

Within operations management, the concept of complexity has been linked to operational processes and manufacturing strategy [3]. In our case complexity has other links witch – by using the same concept – can be used to describe supply chain complexity.

According to literature, supply chain complexity depends on several drivers:

- Number of supplier relationships that must be managed. In fact, adding suppliers necessarily increases the complexity, due to the greater number of information flows, physical flows and relationships that must be managed.
- Degree of differentiation among these suppliers, in terms of size, technology, etc.
- Delivery lead time and reliability of suppliers.
- The extent of global sourcing, since global linkages potentially expose companies to a wide range of complicating factors (e.g. import/export laws, cultural differences).
- Level of inter-relationship among the suppliers, since the greater their level of interaction, the greater the operational “load” borne by the main company in managing its supply base. For example, a supply base with two independent suppliers is less complex than a supply base with two inter-related or linked suppliers [3].

Later I will use this and other drivers to define supply chain length which has large effect on performance measurement problems and possible solutions.

4. Length of Supply Chains

As found in various logistics-related books and papers [3,4] the length of a supply chain is the number of tiers, or intermediaries, that materials flow through between source and destination. We might imagine a supply chain with raw material suppliers, main operators, wholesalers and retailers. Some supply chains are shorter than this when, for example, producers sell directly to final customers through a Website.

Usually, though, supply chains are much longer with many intermediaries, perhaps including several stages of manufacturing, and several stages in the distribution of finished products. This can be particularly noticeable when exporters use a series of logistics centres, transport operators, agents, freight forwarders, brokers to move materials through different parts of their journey.

Obviously, the length of supply chains in the world economy is growing. Main drivers of this process are the production complexity, growing importance of economies of scale in production – and in determining economic batch size, and the frequent use of cheap labor force – mainly thousands of kilometers away from the home of the company.

It is of no doubt that the operation and working capital flow of transnational companies is having great effect on world economy. These companies produce approx. 10 percent of the world GDP and 30 percent of the world export. The main part of world production is produced by a small amount of companies [5].

Determining Supply Chain Length

Summarizing the statements of the reference works cited above and considering the aforementioned facts it can be stated that so far mainly the material flows have been taken into consideration, and very little attention have been paid to the information flows that are the framework of commercial and legal acts and give the basis of planning and managing operation is time. A more sophisticated method is to count beside the material flow: the information flow. In this article an extended definition of supply chain length is presented, using graph theory methodology.

Many important optimization problems can best be analyzed by means of a graphical or network representation. A graph, or network, is defined by two set of symbols: nodes and arcs. We define a set (call it V) of points, or vertices. The vertices of a graph or network are also called nodes. We also define a set of arcs A . An arc consist of an ordered pair of vertices and represent a possible direction of motion that may occur between vertices. If a network contains an arc (j,k) , motion is possible from node j to node k .

A sequence of arcs such that every arc has exactly one vertex in common with the previous arc is called a chain.

A path is a chain in which the terminal node of each arc is identical to the initial node of the next arc.

In our case:

- V is the vertex set, the participants of the supply chain
- A is the edge set, the material and information flow

Two graphs are considered equal when $V_1 = V_2$ and $A_1 = A_2$.

Order of the graph $n =$ the number of vertices in a graph, denoted $|V(G)|$.

Size of the graph $m =$ the number of edges in a graph, denoted $|A(G)|$.

The minimum number of edges is $n-1$ (see Fig. 1.), but in our case more edges are also possible because the information flow between two vertices is also regarded as an edge.

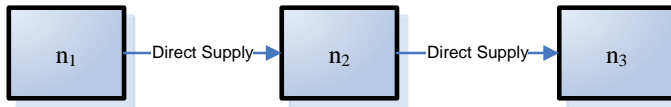


Figure 1: Basic 3 order supply chain graph

The length of a supply chain in most literatures is characterized with the number of vertices (and thus with the number of edges) [1,5]. Our proposal is to also use – besides the aforementioned number of vertices – the number of edges weighted by the complexity of the edges. The reasoning is the following: the main parameters of the supply chain are amongst others the lead-time, the cost of transshipment, the reliability of supply in time and in quality. These parameters are significantly dependent on the actual geographical distances between nodes, the selected transport mode, the necessary legal and commercial actions to be taken in order to transship the cargo from a vertex to another. In this sense the features of edges are at least as important as the nodes where the production processes are taken place. Almost 50% of the total lead-time is devoted to commercial and planning, transport and idle (waiting) time. That is why the control of supply chains must take the edges into consideration as well. In addition there are two types of edges:

- material and information flow parallel from the same origin to the same destination, but not necessarily in the same time,
- information flow without material flow (see Fig.2)

Remark: material flow without information flow is not possible, since in any case some pieces of information are being transferred jointly with the material, recorded either on the packaging and/or on the shipment note.

The term network is a synonym for a weighted graph. In this case a network of raw material suppliers, main operators, wholesalers and retailers build up our supply chain so we have to add weight to the edges. This weight is the complexity of edges – that is:

- Length of the edges: the sum of the physical – geographical distance multiplied with the transport mode parameter and the “resistance” representing the necessary unloading and loading process during the shift between transport modes and the transit warehousing if any.
- Informatics complexity: order placing, respond time, information handling, transmitting and checking data, interpretation and processing ordering and dispatching information.
- Commercial and legal complexity: interpreting and following different regional legislation, obtaining official certificates (e.g. phytosanitary certificate, certificates of origin), arranging custom clearance.

The complexity of informatics in supply chains cannot be disregarded. However pieces of information can be transmitted electronically with the speed of light, information handling and respond times accuse delays. Complex informatics edges in supply chains

can cause the so called “bullwhip effect” [6] which is an often observed phenomenon in forecast-driven distribution channels (see Fig. 2.).

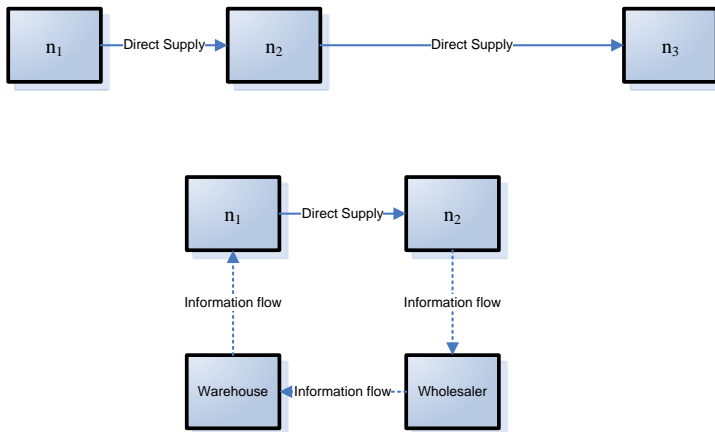


Figure 2. Complex supply chains

As it can be seen in Fig. 2 the material flow can be a simple edge between the two manufacturing actors but the information (order, stock check, etc.) connects commercial actors to the supply chain without material flow.

The various types of network strategies are shown in Fig. 3. Using the same routine as in Fig. 2, the material flow can be a Point-to Point strategy (1) and the information flow can be a Corridor-type (3) or Hub-and-Spoke (5) strategy.

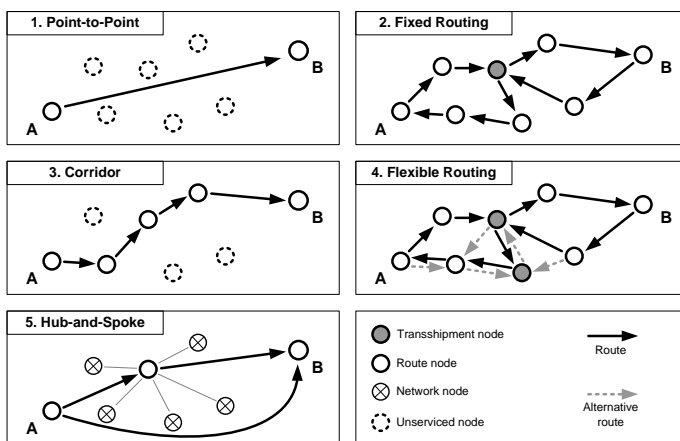


Figure 3: Network strategies

Also the simple summation of number of vertices must be reconsidered. Obviously the different actors represent different “resistance” in the network. On the basis of the activities the following groups can be distinguished:

- Production vertex: where manufacturing processes are taken place
- Transit vertex: hubs and freight forwarding warehouses
- Commercial vertex: where stocks are kept for commercial purposes, mainly in push systems

For the evaluation of logistic networks and supply chains the above listed groups have different weight, since they have significantly different affect on lead-time, distribution cost, reliability etc.

On the basis of the above reasoning the proposed formula of supply chain length (LSC) is:

$$LSC = c_1 \sum_{i \in P} w_s \cdot V_i + c_2 \sum_{(i,j) \in P} f(D_{i,j}) \cdot A_{i,j} \quad (1)$$

where:

- c_1 constant represents the technical and managerial level of vertices
- c_2 constant represents the technical and managerial level of edges
- w_s is the weight corresponding the nature of node (production, transit or commercial)
- P is the path from the origin to the destination
- V_i are the vertices (nodes) in the path
- $A_{i,j}$ are the arcs (edges) in the path
- $D_{i,j}$ distance in logistic terms
- $f(D_{i,j})$ the weight determined by the distance in logistic terms

5. Conclusions

By determining supply chain length so far mainly the material flows have been taken into consideration, and very little attention have been paid to the information flows that are the framework of commercial and legal acts and give the basis of planning and managing operation is time. A more sophisticated method is to count beside the material flow: the information flow. In this article an extended definition of supply chain length is presented, using graph theory methodology. Our proposal is to also use – besides the number of vertices – the number of edges weighted by the complexity of the edges.

With the formula proposed the length of supply chains can be determined and used for choosing the right performance measurement tool.

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