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Linking supply chain configuration to supply chain performance: A discrete event simulation model

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ABSTRACT

This paper aims to analyse the dependencies between supply chain performance, i.e. stock and stock-outs, and both supply chain management decisions and supply chain configuration parameters, i.e. the number of sources, the inventory capacity at a given node and the number of nodes that share the considered inventory capacity, the distance between nodes and the number of levels of the supply chain. The relationships among these variables have been studied by means of a scenario design technique and the discrete event simulation together with statistical analysis. Models of Economic Order Quantity (EOQ)-based and forecast-based supply chains have been developed.

Results suggest some managerial implications potentially useful in field: intermediaries and specialized actors (either global or local – since the distance proved to be irrelevant) can be added for the sake of product quality and cost, without adversely affecting service level performance at the retailer stage. Collaborative practices are proved to be very helpful, especially when the number of sources increases. However, retailers' performance enhance, while distributors' one and manufacturers' one worsen, thus raising hurdles to collaborate.

1. Introduction

Supply Chain (SC) performance is one of the fields of research that have attracted the attention of both academicians and industrial practitioners in the recent years. SC performance is tightly linked to SC configuration and to SC management [13,44,25] (Lee et al., [26]) [5,41]. SC configuration tackles decisions concerning the topological structure of the SC: Persson and Olhager [38] include in SC configuration all the decisions concerning the definition of the structure of the SC, therefore SC configuration does not include planning and control related decisions.

SC management concerns the policies to manage materials and information across the entire supply network [36] at the strategic, operational and tactical level (e.g. lot sizing, forecasting methods, see [9]). Indeed, SC management is focused on what to do once a SC has been designed and configured, to achieve cost-related and service-related objectives [42]. SC performance is strongly affected by SC management, particularly with reference to strategy definition [12,35], inventory planning (Ganeshan et al., [14]), customers–suppliers relationship [40], business process connection (Krajewski et al., 2005), internal integration [23] and order policy [28].

While the impacts of SC management policies on SC performance have been extensively investigated (e.g. [12,42,14]; [40,24]; [23,6,28]), the literature devoted to study the link between SC configuration and SC performance is almost sparse

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and even not-existent [41]. Therefore, this paper investigates the effects of SC configuration on SC performance. Since a SC without a material management policy cannot be effectively run, the relationships between configuration-related and management-related parameters have been studied under different material management policy, i.e. Economic Order Quantity (EOQ)-based and forecast-based policy. Under a forecast-based policy, the actors of a given SC place their purchasing (or production) orders on the basis of the forecasted demand, while under an EOQ-based policy, the process of purchasing (or production) is triggered by the inventory level, in that when the inventory level drops below a given threshold (usually called Re-Order Point, ROP), an appropriate amount is ordered from either the upstream SC layer or the production system.

Discrete event simulation has been used as a methodological tool. Indeed, given a set of independent variables, which are expected to impact on a set of dependent variables, simulation appears as the most effective tool to outline the actual relationships when the environment is plagued by variance. Variance in SCs is represented by e.g. time dynamics and uncertainty (e.g. [33]): in such contexts, the models based on Linear Programming (LP) algorithms are proved to be weak [43,9] By contrast, the ability of simulation to support "what-if" analyses and to quantify benefits and issues is well known [46] and, for these reasons, simulation is successfully used in business processes re-engineering projects [32].

The paper is structured as follows: Section 2 presents the literature review. Section 3 introduces the model, while Section 4 highlights the experimental campaign. Finally, in Section 5 the main results are discussed and Section 6 reports some concluding remarks and suggestions for future research.

2. Background

SC performance can be classified into efficiency and/or effectiveness (Tan et al., [45]) [2] (Holmberg, [19]) [29]. Effectiveness refers to the ability of a firm to fulfil customers' requirements, while efficiency refers to the ability (of a firm) to maximize the use of internal resources, being the output the same. Efficiency is therefore traditionally related to costs, inventory levels, machine utilization and resources productivity, while effectiveness is measured in terms of stock-out (or backlog) occurrence (probability) and stock-out quantities [50]. Both efficiency and effectiveness are important: Beamon [2] stated that, when defining a SC performance measurement system, the main trade-off between costs and service level should never be neglected. The determinants of SC performance (efficiency and effectiveness) can be found both in the realm of SC management – e.g. lot-sizing policies, forecast errors – and of SC configuration [25] (Lee et al., [26]) [5,44].

Studies about SC configuration can be classified in three major areas (Shapiro, 2001): (i) SC composition, which means the identification of entities (firms, etc.) that should join the (constituent) logistic network; (ii) network structure, related to the number of stages, the sourcing strategies (e.g. multiple vs. single) of each entity and nodes' capacity and location [42]; (iii) collaboration level among the nodes [18]. Certain authors (Jagdev and Thoben, [21]) [31] consider collaboration a SC configuration decision, while others (e.g. [42,17]) believe that collaboration results from decisions taken at SC configuration stage, i.e. once the network structure is assessed: according to this viewpoint, collaboration is part of the SC management area.

SC performance is strongly affected by SC configuration: Simchi-Levi et al. [42] stated that nodes' capacity and location are determinant factors of the performance of a SC, but they did not formalize their assumptions, so they did not demonstrate its validity. Helbing and Lammer [17] proposed a model focused on the dynamical property and linear stability of SCs in dependence of the network topology, which is given by the number of stages of the SC and by the sourcing strategy of each node. They demonstrate that the topology of the logistic network has a direct influence on either damped or overdamped system's oscillations. However, their study neither links the dynamical behaviour of the network with SC performance nor it considers other SC configuration elements than the number of stages and the sourcing strategies of each node. Later, Sezen [41] demonstrated that SC configuration significantly impacts resources and output performance: SC configuration is measured in terms of (i) proximity to suppliers, (ii) number of suppliers, (iii) capacity planning along the chain and (iv) coordination of the logistic flow.

On the whole, despite the proven importance of SC configuration in determining SC performance, little work has been done to investigate the relationships between SC configuration decisions and SC performance [3]: Beamon [1] outlined that few scholars study how the number of stages and the definition of which plant of the network will serve which customer affect SC performance, and none of those scholars studies both variables jointly.

3. Research framework

This paper aims to investigate how SC configuration affects SC performance under different materials management policies. The research framework is presented in Fig. 1. The independent variables are the SC configuration decisions. In line with Lambert et al. [22], Simchi-Levi et al. [42] and Pero et al. [36], SC configuration is described by the following parameters:

i. the number of sources each node buys from; this parameter is called "multiple sourcing" and – from a management-related perspective – it leads to decide whether adopting a multiple or a single sourcing strategy;
ii. the amount of inventory capacity available at each node and the number of nodes at each level; this parameter is called "splitting";
iii. the distance between nodes; this parameter is called "distance" and it represents the location of SC nodes or the SC footprints;