An AHP-based framework for logistics operations in distribution centres

José Geraldo Vidal Vieira\textsuperscript{a,}\textsuperscript{*}, Milton Ramos Toso\textsuperscript{b}, João Eduardo Azevedo Ramos da Silva\textsuperscript{a}, Priscilla Cristina Cabral Ribeiro\textsuperscript{c}

\textsuperscript{a} Department of Production Engineering - CCGT, Federal University of Sao Carlos, Joao Leme dos Santos, KM 110, Itinga, Sorocaba/Sao Paulo 18072-780, Brazil
\textsuperscript{b} Graduate Program of Production Engineering – PPGEP-So, Federal University of Sao Carlos, Joao Leme dos Santos, KM 110, Itinga, Sorocaba/Sao Paulo 18072-780, Brazil
\textsuperscript{c} Department of Production Engineering, Fluminense Federal University, Passo da Pátria street, 156, office 306, block D, São Domingos, Niterói/RJ 24210-24, Brazil

\begin{abstract}
In retail distribution centres (DCs), the handling and storage of products typically represent the largest share of operational costs and its design depends on a balance between supply and demand processes. As hundreds of options are possible, it is a challenge to plan and run these operations effectively. The objective of this research is to propose a framework for designing operations in DCs based on a joint study of three elements: distribution strategy, internal activities, and the characteristics of the distribution operations. The methodology is developed based on theory-building research using three case studies. The data collection was performed by three top managers at large logistics providers (LPs). The analytic hierarchy process (AHP) method was applied, and the framework was validated by the LPs. This framework was then applied to a sports fashion retail operation and was reported to enable the decision-making process regarding operations at DCs, creating scenarios for evaluation.
\end{abstract}

1. Introduction

A key component in a supply chain (SC) is the distribution centre (DC), which plays the vital role of obtaining materials from different suppliers, performing value-added activities, and assembling (or sorting) products to fulfil customer orders and offer a high level of service (Baker, 2007, 2008; Parikh and Meller, 2008). Warehouse operations (such as storage management and picking) are very complex and involve different activities, and warehouse planning based on experienced knowledge is crucial in achieving the goals of cost efficiency and effectiveness (Lam et al., 2015; Hou et al., 2010).

According to the framework of Baker (2007), the role of DCs depends on the SC strategy, which is derived from the company’s business model (a focus on either supply or demand) and is based on two different objectives: service level and costs (Baker and Canessa, 2009). To perfectly coordinate supply and demand, reliable transportation and a quick response via automation (Baker and Halim, 2007) are necessary. However, this combination results in high costs. Therefore, efficient design of the DC is necessary to provide better flow of materials and reduce facility logistics costs (Parikh and Meller, 2008; Hong, Johnson and Peters, 2012; Pan et al., 2014; Dotoli et al., 2015).

The literature reveals a gap in the contributions made by studies on these issues, which suggests that warehouse design evolves only by continuous improvement. Due to the lack of literature review and analysis, further study of the distribution strategy is necessary to guide companies’ strategies for DC design and influence internal activities depending on its distribution focus: supply or demand (Baker, 2004). Moreover, different configurations and designs (Gu et al., 2007) are available to service the demand and to handle different product types (Lam et al., 2015) using different operating methods, equipment and procedures. Additionally, identifying the “optimum” solution is not possible due to the high number of possibilities (Baker and Canessa, 2009). For Thomas and Meller (2015), this decision includes, among other aspects, the number of pallet locations, the number of stockkeeping units (SKUs), the number of cases per pallet, and the throughput requirements, which are used according to the equipment (automatic or manual) chosen for handling the materials. This environment can be thought of as the characteristics of the distribution operations in a DC, which are interrelated. Costs (Rouvenhorst et al., 2000; Bartholdi and Hackmann, 2011), supply (Koster et al., 2007),

\textsuperscript{*} Corresponding author.

E-mail addresses: jose-vidal@ufscar.br, jgvidal@gmail.com (J.G. Vidal Vieira), miltontosso@yahoo.com (M. Ramos Toso), jesilva@ufscar.br (J.E.A.R. da Silva), priscillaribeiro@id.uff.br (P.C. Cabral Ribeiro).

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items (Tomskips et al., 2003) and orders (Hackman et al., 2001; Petersen, 2002; Koster et al., 2007) are criteria to which special attention must be paid to support practitioners and companies in the design of distribution operations. Therefore, these studies lead to the following research question: How can the design of the logistics operations of a DC be defined from the distribution strategy of a company, the complexity of the internal activities of the DC, and the characteristics of the distribution operations?

The DC framework helps the decision makers (DMs) select suitable equipment and operating methods (Baker and Canessa, 2009) to organize internal activities, which is not a simple task. Regarding this discussion, Thomas and Meller, p 741 (2015) attest that "moreover, the decision variables in warehouse design are interrelated, and this further complicates the design process." Although various studies on DC design have been conducted, resulting in a high position of this subject in the logistics research stream, some authors suggest that its activities demand additional studies to address the common interests of both academics and practitioners (Baker and Canessa, 2009; Koster et al., 2007). Although there appears to be consensus on the overall structure of the approach, there is less consensus on the exact nature of the tools (equipment) to be used for each step (Baker and Canessa, 2009).

The objective of this research is to propose a framework for designing operations in DCs based on a joint study of three elements: distribution strategy, internal activities, and the characteristics of the distribution operations. The main contribution of this research is to propose a decision model for distribution operations in a DC based on strategic, tactical, and operational aspects, which are evaluated by a multi-criteria approach. Hence, the proposed framework may facilitate decisions regarding DC operations because it systematizes the selection of the variety of equipment and defines suitable operating methods for use in the DC.

The article is organized as follows: the introduction is presented first, followed by the literature review, which focuses on strategy in a DC, the internal activities of a DC, and the characteristics of distribution operations. Subsequently, the methodology is presented. Then, the framework for logistics operations is developed, including a practical example of the proposed framework. The article ends with final considerations.

2. Literature review

Although studying a DC’s design and problems during its operations is important, the characteristics of the distribution strategy also influence the DC’s design. Christopher et al. (2006) present a taxonomy of global SC strategies that are distinguishable along two dimensions: supply characteristics (the length of the lead time) and demand characteristics (predictability). The strategies vary from lean to agile and leagile (Mason-Jones et al., 2000) and have implications for the role of warehouses in global SCs, i.e., their location and operations and the value-adding activities performed. Baker (2007) underlines the requirements for safety stocks in international SCs because the supply lead times may be very long and a rapid response is required on the distribution side.

Moreover, warehouse design decisions are strongly coupled and are difficult to separate; the warehouse must be designed before it is built because such tactical decisions can be very expensive or impossible to change after the facility is ready to use (Gu et al., 2010; Gong et al., 2013). Although planning and control have been studied quite thoroughly, there is a lack of discussion on warehouse design (Rouwenhorst et al., 2000). To evaluate a specific warehouse design, Rouwenhorst et al. (2000) define some relevant performance criteria: investment and operational costs, volume and mix flexibility, throughput, storage capacity, response time, and quality of order fulfillment (accuracy). With this purpose, Gu et al. (2007) present a framework to jointly classify research on different, but related warehouse problems: warehouse design and operation.

According to Lin and Lu (1999) “how to determine the type of orders, and then to select a strategy for a DC has become an important task for practice”. For an order-picking system design, there are a variety of design considerations, including order-picking strategies, product storage policy, the picker routing pattern and the levels of decision making (strategic, tactical, and operational) (Lin and Lu, 1999; Rouwenhorst et al., 2000).

Based on this discussion regarding DC design and the internal and external characteristics of a DC (Sandberg, 2013), the following subsections present the three elements, i.e., the distribution strategy, the activities and sub-activities of a DC, and the characteristics of the distribution operations, that are part of the framework for the design of operations in DCs.

2.1. Distribution strategy

Operational excellence in a business environment is the primary goal of companies that offer products and services, and its objectives are to maintain leadership in price, reduce costs and optimize operations (Shavarini et al., 2013). However, due to the uncertainty and speed of changes in this environment, the performance of warehouse operations is affected by the logistics strategy-planning process.

Although some books and articles separate SC from warehousing subjects, the classification of SC strategy (referred to in this paper as “distribution strategy”) joins the two areas, as discussed by Baker (2004). Baker says that the DC strategy classification depends on the focus of the SC: demand or supply, which involve an agile (service-level emphasis) or lean (cost emphasis) SC, respectively.

When strategy focuses on demand (agile concept), the project of a DC aims at quick response operations to seize opportunities in a volatile market. Therefore, its objective is to reduce the response time with a high degree of precision. Here, agility is similar to the concept of volatile market places; thus, the ability to respond quickly to market opportunities is the critical factor (Vonderembse et al., 2006). Consequently, the success of a company’s distribution strategy plays a critical role in supporting the internal operations of DCs. The DC’s mission is to efficiently ship products to the next node in the distribution network without altering its form (Tomskips et al., 2003).

Supply strategies (lean concept) focus on the reduction of SC waste, such as excess resources, high levels of inventory and long lead times (Christopher and Towill, 2002; Vonderembse et al., 2006). Lean SC can speed up inventory turns and reduce inventory throughout the chain (Vonderembse et al., 2006). In addition, once project approval is obtained, the goals of improving quality and flexibility can be pursued in parallel with cost reduction (Booth, 1996).

Supply or demand strategies address different lead times provided by different segments of the service level depending on the use of lean or agile thinking (Baker, 2007). Decisions concerning the DC design and storage capacity are often strategic because they will significantly impact the company’s future profitability (Cormier and Gunn, 1992). These concepts are not mutually exclusive (we can find leagile SC strategies in the literature, but this discussion is not the core of this paper) because the consensus of SC is that inventory must be minimized (Baker, 2004). In agile SC, the inventory is held at very low levels, if at all (Van Hoek et al., 2001). The distribution strategy will influence warehouse design, including detail operating methods, equipment, staffing levels, layout and costs.

The focus of some companies’ strategies have changed from minimizing costs to reducing delivery times to meet demand, which implies that these companies have a demand strategy (agile). Baker and Halim (2007) highlight the importance of warehouse automation (cost, service and flexibility) and recognize that although automation is occurring, the SC must be more agile (i.e., focused demand strategy) to serve rapidly changing markets. The warehouse design does not have to be lean (i.e., with the focused supply strategy) but must provide a
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