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A decision-support system for the design and management of warehousing systems

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ABSTRACT

The issue of material handling involves the design and operative control of warehousing systems (i.e., distribution centres), which allow matching vendors and demands, smoothing with seasonality, consolidating products and arranging distribution activities. Warehousing systems play a crucial role in providing efficiency and customer satisfaction. The warehouse design entails a wide set of decisions, which involve layout constraints and operative issues that seriously affect the performances and the overall logistics costs.

This study presents an original decision-support system (DSS) for the design, management, and control of warehousing systems. Specifically, the proposed DSS implements a top-down methodology that considers both strategic warehouse design and operative operations management. The DSS can simulate the logistics and material handling performances of a warehousing system. Heuristic methods and algorithms address several critical warehouse issues, such as the order picking process, which is responsible for 55% of the overall costs in a distribution centre. The benefits due to the adoption of the proposed decision-support system are summarised as a dashboard of key performance indicators (KPIs) of space and time efficiency that allow logistics providers, practitioners, and managers as well as academicians and educators to face real-world warehousing instances and to find useful guidelines for material handling.

1. Introduction and background

In recent years, enterprises have completely reconfigured their supply chain to address increasing customer service levels and demand variability. Warehouses play a pivotal role in the supply chain, and requirements for warehousing operations have significantly increased. Specifically, the customer needs in terms of the order accuracy and response time, order frequency, order quantity and order size have dramatically changed with the global economy and new demand trends (e.g., e-commerce). The literature has widely debated the issues of warehouse design and management, which is aimed at minimising the operation costs and time and increasing the supply chain performance. Comprehensive surveys on warehouse and industrial storage system topics have been proposed by De Koster et al. [1], Gu et al. [2] and Dallari et al. [3].

The main function of the warehousing systems is to receive products (from inbound or manufacturing lines), to store materials until they are requested, and then, to extract products from inventory and ship them in response to the customers' orders.

Fig. 1 illustrates a conceptual framework for classifying warehouse operations, considering the definitions of entities, processes, activities, and decisions as related to storage systems.

Products typically arrive in large units, such as unit-loads, and standard or custom containers, or pallets, which cause the related labour and handling activities to be less expensive. Incoming products must be put away, which is the most significant warehouse function. The put-away process entails a set of interdependent decisions [2]: given a warehouse configuration (based on the layout parameters of Fig. 1), how much inventory should be held for a generic SKU (the so-called allocation in Fig. 1), and where should it be stored (the so-called assignment in Fig. 1)?

The warehousing system pursues the transformation of the large and relatively homogeneous arrival materials into small, frequent and heterogeneous output quantities in response to customer demands. The small and frequent output quantities result from the fulfilment of the customer order lists.

Order picking is one of the prime components of labour and warehouse-associated costs. Two alternative configurations of layout types are common for picking. One, the so-called multi-level picking (see Fig. 1), executes high-level picking directly from storage locations, which are all accessible by picking equipment (e.g., turret-trucks). The other, the so-called forward-reserve

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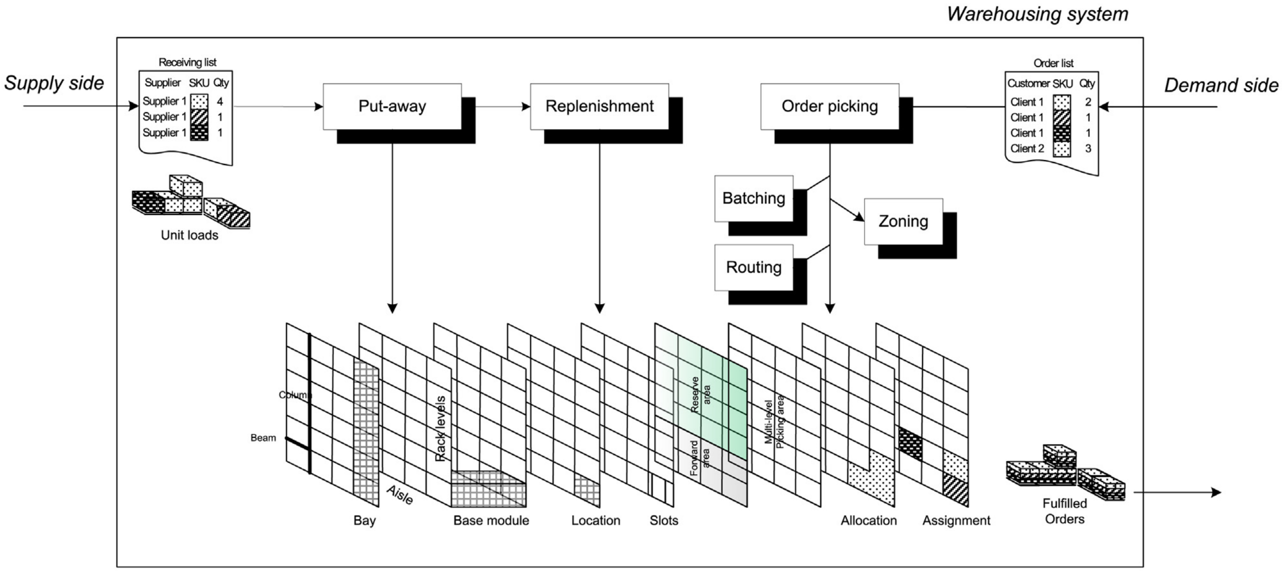

Fig. 1. Framework for warehouse design and operation issues.

(see Fig. 1), executes low-level picking from the easily accessible forward area, which holds the bulk of the inventory for every product in a larger, reserve storage area. When given a product for which the inventory is low in the forward area, replenishment is realised from the reserve. For an exhaustive description of the patterns that are depicted in the proposed framework, a definition of zoning, batching and routing in warehousing is given. The zoning comprises partitioning the warehouse into different zones, which correspond to work stations. Pickers are assigned to zones, and workers progressively assemble each order, passing it along from zone to zone. The batching comprises making a picker retrieve multiple orders in one trip. Even though batching represents a very useful approach to reduce travelling, it requires the retrieved SKUs be sorted into a single order. Lastly, the routing defines an appropriate sequence of items on the order list to ensure a good route through the warehouse.

Overall, two main aspects lead to enhanced performance: the warehouse design (1) and the operations control (2).

The first aspect refers to the layout constraints and parameters (illustrated in Fig. 1), the storage equipment and the high-level strategic decisions on the total inventory of the facility. The second addresses the warehouse operative activities, such as put-away, replenishment and order picking, focusing on models, techniques, and methodologies to enhance the operative performances (e.g., zoning, batching, routing). These two aspects significantly affect warehouse performances and have a direct influence on the level of service of the overall logistic chain (i.e., the steps before and after the warehousing system of Fig. 1).

The literature proposes a wide set of warehouse KPIs that include the throughput capacity (the material flow processed through the warehouse per time unit), the storage capacity, the response time (the time within the order arrival and its shipment), the cost rate, and the cost per unit of material flow shipped by the warehouse. All of these metrics are affected by the management of space and time, which are critical for every logistic process.

Generally, the contributions of the literature address the problem of warehouse design rather than the management of warehouse operations separately. Gu et al. [2] describe inbound/outbound processes and review the literature, classifying the papers on the basis of the scope of analysis, the adopted method and the type of the observed warehouse (e.g., automated, conventional multi-aisle storage systems).

Typically, warehousing problems are non-polynomial (NP) problems and have a very large amount of real-world data to manage. Therefore, user-friendly and timeless solutions for the warehousing issues are ambitious aims for computer-based applications.

The remainder of this study describes the conceptual design and development of a decision-support system (DSS) for the strategic design and the management of operative activities in a warehousing system. Specifically, it supports the design of complex multi-zone forward-reserve picker-to-part storage systems and provides multi-scenario simulation for KPI assessments. The DSS implements sets of heuristic methodologies to support data-oriented analyses and performance enhancement.

The management and control of warehousing system (i.e., industrial storage system) activities and processes range among various design alternatives and involve different expertise. For example, the problem of layout design, the definition of the total storage capacity, the determination of the number of aisles, the types of racks, the locations of the products (i.e., stock-keeping-units or SKUs) within the storage area, the stock per each SKU, and so on, involve interrelated areas and are challenging but can be addressed through a unique modelling formulation. The majority of the contributions reviewed in the literature [1–3] focus on a single aspect of the warehousing problem, thereby ignoring the integration of multi-purpose approaches.

The proposed DSS develops a top-down methodology for the comprehensive design of a warehousing system that allows for the decision-maker to develop and compare different configurations and scenarios in a user-friendly computer environment. It implements multi-scenario simulation techniques to address real-world case studies, to highlight the interdependency among decisions and to identify useful guidelines about warehousing issues.

DSSs are computer-based tools that have been adapted to support and aid complex decision-making and problem solving [4,5]. Research in this area typically highlights the importance of information technology in improving efficiency adopted by users to make decisions, improving their effectiveness [6,7]. Specifically, the literature reveals the benefits of using computer-based systems to support logistics management, especially in the areas of logistics, transportation, and warehousing [8–10].