A study on Operation Research: Warehouse Designing

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Abstract: Despite the importance of customer service warehousing and cost levels for many companies, a complete, systematic approach to the design of warehouses does not currently exist This paper examines the latest literature on warehouse architecture as a whole and the literature on instruments and techniques for particular analyses. The general literature findings were then checked and reflected in the warehouse design companies. The output is a general steps structure with unique techniques and tools that can be used in each step. This is meant to help practitioners build a more systematic approach for the design of warehouses and help them further study.

Keywords: Facilities planning and design; Warehouse operation planning; Warehouse operation management; Warehouse operation decision support models.

Introduction:

Warehouses are a key part of any supply chain. They play a key role: tamping the material flows in the supply chain to accommodate the variability of variables, including seasonality and/or batching, in manufacturing and transport. They are consolidating goods from different suppliers for joint distribution to the consumers.

Competition in the market requires continuous improvement of production-distribution network design and operation, requiring increased warehouse performance [2]. New management approaches, including tight inventory control, shorter response time and a more comprehensive range of products, are also being introduced in warehouse production systems, for example, Just-in-Time (JIT) or Lean production. Instead, the widespread application of modern IT (Bar Coding, Radio Frequency Communications (RF) and Warehouse Management Systems (WMS) offers new warehouse operation opportunities. This offers real-time warehousing power, simple communications with the other sections of the supply chain and a high degree of automation, but is not limited to these [5].

Warehousing is a central feature of modern supply chains and plays an important role in today's business success or failure. Although numerous companies have investigated the potential for synchronised customer delivery, this still exists in many circumstances. This could be because the supplier's delivery times cannot be cost-efficiently reduced to the customer's short lead times, and consumers must thus be served from the stock instead of the order. At decoupling points in the supply chain, it may also be useful to maintain strategic inventory, separating lean manufacturing activities (which benefit from a smooth flow) from an agile downstream response to volatile markets. The supply and distribution networks can also be so complex that goods must be consolidated at stock holding points so that Multiproduct Orders for consumers, i.e., in break-bulk or make-bulk consolidation centres, may be supplied together. The operations of these warehouses are essential for high levels of service to customers [9]. Many warehouses provide inventory customers with a single or next day lead time, and they need to do this confidently at a high pace, precision and lack of damage tolerances [7].

In addition to these traditional inventory holding roles, warehouses have evolved into cross docking points (where commodities go from internal to external without being stockpiled), value added service centres (e.g., customer products price and labelling), production postponements (specifically configuring or assembling goods to customer demand) [10].

A variety of models for supporting warehouse operations are proposed in the literature, but the application of these models to direct warehouse operations is still very difficult. This paper aims to classify and summarise the previous research findings and the identification of potential research opportunities. The desired result guides the analyst's methodologies and tools to facilitate effective operational planning in the warehouse and a roadmap for academic researchers for future research opportunities [8].

Framework:

Stock Keeping Units (SKUs) receive from manufacturers, store the SKUs, receive orders from customers, collect SKUs, assemble them for sale and send out completed orders to customers are fundamental requirements in warehouse service. In the design and operation of a warehouse, several problems are involved in fulfilling this demand. To meet system specifications with regard to capacities, throughput, operation and at minimum costs of resources, resources such as space, labour, and devices have to be allocated to the various warehouse functions, and each function needs to be carefully implemented, run and organised.

Fig. 1 (the number in parentheses denote the number of papers examined for each problem in the operations plan in this document) provides a scheme for classifying warehouse design and operations plan issues and related literature. This paper focuses on operational planning issues and discusses warehouse architecture and performance assessments in Gu et al. (2005).

The receipt and shipment are the input/outgoing material flow interface of a warehouse. Incoming shipments are taken to the warehouse, unloaded and stored at the receiving docks. Orders are collected from the warehouse, packed and delivered by shipping docks to customers. For example, trucks' assignment to dock and the schedule of loading and unloading activities are involved in receiving and shipping operations.

In order to achieve high space efficiency and promote effective material handling, the storing department organises products stored in the warehouse. Goods may be grouped into various departments of storage. The drivers of departmental organisations may include physical properties of the items (e.g., storage of pallets vs case storage); management requirements, such as a specialised consumer storage area; or handling considerations of material for fast-picking, for example. The products may also be grouped into pick areas within divisions. A selection zone is a group of storage places that are often organised nearby. There is a small selection zone in a specific selection zone, and pickers can select the appropriate items in one or more areas. The picker achieves a high ratio of SKU extraction time to the travel time between sites and an increasing familiarity with SKUs inside the zone thanks to the zone's small physical size. The goods are allocated to storage places in the Department/Zone, and the assignment of the location of the storage has a major effect on storage, stock tracking and order collection. A random, class-based and dedicated storage can also be used in various storage strategies. The choice of storage strategy is considered a design issue and will thus be addressed in Gu et al. (2005) [11]. Therefore, the implementation of each storage strategy is an operational problem (e.g., using a particular rule to assign SKUs to storage locations for dedicated storage).

Order pickup is widely regarded as the costliest warehouse process because it often takes a lot of work or a lot of money. The orders' arrangement to be collected and the material handling operations for the picking process must be regulated [6]. There are various methods of order picking, for example, single-order picking, sort-and-select batching, sort-after picking batching, sequential area picking in a single order, batching in a sequential, simultaneous batching zone, and batching in the concurrent location in the area. The choice of an order collection system is a strategic decision because it affects many other decisions in warehouses' design and operation. For instance, if a sort-after-pick is used, a downstream sorting system is necessary. Gu et al. cover more thoroughly the topic of order collection (2005). The emphasis here is on the level of order collection in operational planning. Some key decisions need to be taken at the active planning stage, including pick wave sizing, batching, routing, and sorting [3].

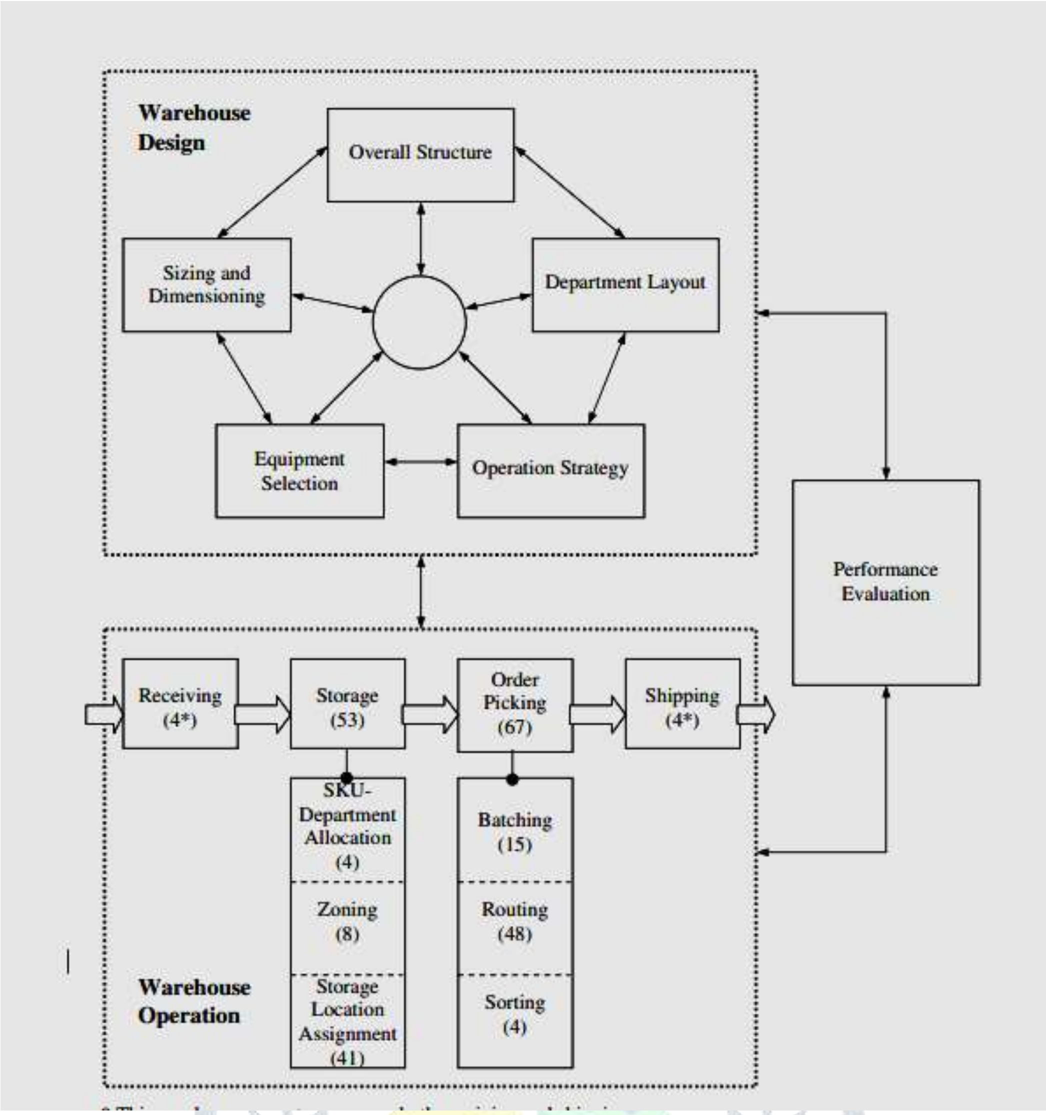

Fig-1: Framework for warehouse design and operation problems.

Receiving and shipping:

Goods are brought into a factory and unloaded at the receiving docks. They are subsequently loaded into a carrier, leaving it through the shipping docks. The goods obtained are sent directly to the shipping docks for docking warehouses. For conventional inventory warehouses, goods obtained are stored and then selected and delivered through shipping docks. In this case, the reception and delivery operations are more complex to administer as they are linked to the storage and picking function [4]. For example, shipping trucks can be planned depending on how orders are loaded and allocated to wave collection and the opposite.

The fundamental decisions for shipping can be defined as -

Given:

(1) Input information such as time of arrival and contents of incoming shipments.

(2) Customer request information, such as orders and their estimated delivery time.

(3) Configuration of the warehouse dock and available tools for material handling.

Determine:

(1) the assignment to the docks of incoming and outgoing carriers determining the aggregate internal flows.

(2) Timetable of the carriers' operation at each port. The assumption of a group of carriers to a shipyard is analogous to a planning issue for the machine, where the incoming companies are planning the work.

(3) Distribution and dispatch of services of material handling, such as labour and equipment for material handling.

Subject to performance criteria and constraints such as:

((1) Resources needed to complete all operations of shipping and receiving.

(2) Service levels, including overall cycle time and carriers load/unload time.

(3) Layout or arrangement of docks and warehouse facilities for the relative location.

(4) Policies of management, e.g., one shipping customer by dock.

(5) All docks' performance criteria.

Storage:

The warehousing role is important. Three essential decisions form the storage role, i.e., how much inventory the SKU should be stored at the warehouse, how often and when the SKU stock should be filled up and where the SKU should be stored the warehouse, distributed and transferred between various warehouse areas. The first two questions refer to the issue of lot size and staggering which are in the conventional field of inventory management, respectively and are not addressed further here. For comprehensive reviews, readers can consult Gallego et al. (1996), Hariga and Jackson (1996). This section focuses on the issue of the allocation of SKUs in different departments and the planning of stock transfers from one department to another, the allocation of SKUs in different zoning zones and the storage location assignment in each department. The storage efficiency corresponding to holding capacity and access effectiveness corresponding to resources consumed through insert (store) and mining (order pick) processes are two main criteria for making such decisions. Table 1 provides a literature review on different problem areas of dynamic storage.

Table 1: Dynamic storage location assignment problem

Citation	Problem statement	Method
Christofides and Colloff (1972)	The collection of things to be relocated and their destinations are provided, and the issue is to route the relocation tour to reduce the overall relocation cost.	Heuristic two-stage, ideal in a narrow case
Muralidharan et al. (1995)	The number of high demand goods to be moved and destined are indicated, and the challenge is to go on the relocation tour in order to reduce the overall cost of relocation	A heuristic closest neighbour and an injection
Jaikumar and Solomon (1990)	Determine the objects to be transferred and their destinations in order to find the least number of relocations, leading to an output that meets the demand in the subsequent busy times.	Optimal ranking algorithm
Sadiq et al. (1996)	Determine the relocation schedule in light of the shifting composition of the order, i.e. relocate objects in clusters in the same order	Thumb rule based on strategies of the cluster
Roll and Rosenblatt (1987)	Through the use of zone storage without dividing, none of the zones could provide enough space for an incoming shipment. The dilemma is how to transfer any stored goods in one area	Rule of thumb procedure

	to other areas to free the inbound shipping room.	

Order picking:

For example, single-order picking, batching, sorting, batching and sorting, zoning, and batching with zoning can be employed with different order picking procedures in a warehouse. The following basic steps are used for each pickup procedure: batching, routing, sequencing and sorting [3].

Batching: The problem with batching is part of the order picking schedule. Orders are received and released for completion after that. The problem with a set of released orders is to divide up the loads, where each load is chosen and collected for packaging and shipping during a given time or "pick-wave" window. The time needed to choose the items in any lot shall not exceed the time window or the duration of the wave. If zone picking is used, the lots should balance pick effort across the zones to achieve high use of pickers, while reducing the time required for picking.

The batching problem can be stated as

Given:

(1) Setup of the warehouse.

(2) Wave pick planning.

(3) A series of commands to be collected during a move.

Determine:

A splitting of waves and pickers assignments.

Subject to performance criteria and constraints such as:

Picker initiative, pickers' imbalances, slots, capabilities and dates of order.

Sequencing and routing:

The decision to sequence and to route for selection decides the best sequence and route of the places where such elements can be selected and/or stored. Usually, the goal is to reduce the overall cost of handling materials. This problem is a travelling salesman (TSP) problem specifically for warehouses, where an object is collected/stored. The problem with multiple candidate locations for retrieval or storage of an item, which often is encountered in practice, is more complicated, and few research findings are available [4]. Due to the aisle arrangement of potential routes, the TSP in the warehouse is special. The research published covers four categories of warehouse systems - traditional multi-parallel alignment systems, AS/RS man-on-board systems, AS/RS unit charge systems and carousel systems.

Sorting:

When several orders are collected together, sorting is essential. This can be done either during picking (sort-and-select) or after picking (sort-after-pick). The selection is very easy and is usually modelled by inflating the extraction time of products. For sort-after selection, the sorting feature is carried over with a separate downstream sorting method. A variety of issues concern the functioning of the method of sorting.

Replenishment:

The refill should ensure the full availability of stocks. The incomplete refill violates a level of service in the form of incomplete orders or additional costs due to pickers re-visiting picking places [1]. For picking, it is recommended that you have smaller forward areas, but more efforts are needed for replenishment to reduce travel costs. The picking and refurbishing efforts are being brokered, according to Rushton et al. (2006). Flow racks that support more stocks in less space will reduce the workload of replenishment. Taljanovic and Salihbegovic (2009) were focused on wave planning and were trying to improve overall warehouse performance, including refilling, picking and shipping. They have improved refuelling costs, pick time, the productivity of workers and labour costs. Some of the solutions (Rushton et al. 2006), where the unit load is empty or the item issued from stock, the next rolls forward and is available immediately for use, have been suggested are realtime computer systems and flow racks In order to reduce the total cost of handling of the materials of the collection and refilling, the companies Hackman and Rosenblatt (1990) proposed a knapsack based heouristic. Frazelle et al. (1994) have further considered the forward zone's size a variable in decision-making and have optimised pick-up and recharging cost by providing an SKU single-tour recharging procedure. Van den Berg et al. (1998) considered a unit charge filling problem where it is possible to fill the forward area with busy and idling times immediately. The number of refilling’s during busy periods can therefore be reduced by refilling in previous idle periods. They have reduced the total estimated time associated with order collection and refilling over a busy period. Taking into account refilling to enhance picking operations is not yet fully explored [6].

Picking productivity and e-fulfilment:

To produce the customer order accurately in a certain period of time, a good information and communication system is required. The pick-up information needed of the picker essentially consists of the pick-up points and their series, the order quantities and the selecting SKUs and their destination. In order to enhance picking processes, numbers of information systems and methods can be implemented [1].

Online ordering now requires more responsive supply chains via Internet technologies and e-commerce businesses. In e-fulfilment systems in which a huge number of small customer orders are required for a wide array, low pricing and good quality products in a short time, pickup workloads are improved, according to Rushton et al. (2006). In order to respond more to demand, companies follow "Pull" supply chain models, where the demand for customers drives production. Online shopping leads to all product varieties being held insufficient amount by retailers and distributors, a failure that reduces service levels and increases opportunities to lose costs. Time, cost and operational efficiency are being combined. Therefore, research should focus on such products (perishable/food) and warehouses (department/distribution), to ensure customer satisfaction and shorter response times [7]. This requires appropriate inventories. High service standards and shorter response times could save costs on the downstream supply network, but they press for lean or JIT philosophy in companies. Shah and Ward (2003) suggested that lean applications can improve productivity and customer lead time. To identify basic structures, lean tools and validate them through factor analysis, Sobanski (2009) proposed an example for lean assessment in the warehouse.

Conclusions:

The distribution of the results between the different warehouse operations is shown in Figure 1, where the numbers in parentheses are the number of documents dealing with the issue in question. Previous research has strongly concentrated on storage and order collection. That is not surprising because they have the two most impacting warehouse functions on the warehouse's overall operational performance, including storage capacity, room usage, and order collection quality.

In contrast, research development is not well-balanced. Some issues received much greater attention than others from the research community. For instance, 32 percent of all surveyed literature is covered by SLAP and routing problems, while less than 6 percent is accounted for by zoning. There is also little direct evidence of the academic research community's cooperation with the industry. Many of the results of research in warehouse practises are not adequately communicated to the industry to have a significant impact. Further communication between the two sides could help identify the real challenges in warehouse operations better and appreciate the possibilities for better operation by working closely with researchers and practitioners.

The issues discussed in this paper are operational, so decisions must be taken quite often and the effects of these decisions are usually short-lived and localised. Usually such decisions must be taken quickly without comprehensive computational tools. This encourages the use of heuristic methods, which are reliable in a reasonable time to find a good solution. Furthermore, from an organizational perspective, a simple, intuitive and reliable solution method should be used in order to minimise warehouse training costs.

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