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A framework for designing backroom areas in grocery stores

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Abstract
Purpose – The design of retail backroom storage areas has great impact on in-store operations, customer service level and on store life-cycle costs. Moreover, backroom storage in modern retail grocery stores is critical to several functions, such as acting as a buffer against strong demand lifts yielded by an ever-increasing promotional activity, stocking seasonal peak demand and accommodating e-commerce activities. The purpose of this paper is to propose a framework to design retail backroom storage area. Furthermore, the authors aim to draw attention to the lack of literature on this topic, while clarifying the relationship between this promising research stream and the considerable body of research regarding the design and operations of conventional warehouses, as well as retail in-store operations.
Design/methodology/approach – The key literature on backrooms, grocery retail, in-store operations, warehouse design and operations was reviewed. This allowed an understanding of the gap in the literature regarding the design of backrooms. Moreover, a case study methodological approach was conducted in a Portuguese retailer to extend the literature review.
Findings – Despite having functions similar to conventional warehouses, backroom storage facilities have particularities that deserve a distinct analysis. Thus, the authors stress these differences and demonstrate how they influence the development of a novel backroom design framework.
Originality/value – This paper fills a gap by proposing a framework to design backroom areas. Furthermore, this research may help practitioners to better design backroom areas, since this process currently lacks a formal and standardized procedure.

Keywords Warehousing, Backroom design, Grocery retail

Paper type Research paper

1. Introduction
The ongoing transformation in the retail industry is significantly impacting its operations, requiring ever greater operational efficiencies, namely regarding the optimization of the store scarce resources, such as the store space (Fernie *et al.*, 2010).

In the retail supply chain (SC) inventory may be placed at several stages. These might be warehouses, distribution centres (DCs) or retail stores (backrooms and sales area). Despite the fact that backrooms have several functions similar to DCs, they have particularities that deserve a distinct analysis (Pires *et al.*, 2015). This link of the SC has been often neglected by academics and practitioners, and it is currently seen as a poorly designed transition point between the DCs and the retail store shelves. However, they are a critical link that is used for much more than just store replenishment (Tompkins International, 2014).

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Backroom storage is essential in grocery retail stores since the replenishment orders for a given item that arrives at a retail store, coming directly from suppliers or from DCs, may not fit on the allocated shelf space, making this area indispensable (Buttle, 1984; Eroglu *et al.*, 2013; Aastrup and Kotzab, 2010). Moreover, nowadays, backroom storage in grocery stores is becoming more vital to act as a buffer against strong demand lifts yielded by an ever-increasing promotional activity, to stock seasonal peak demand for particular categories of products and also on weekends, as well as to accommodate other activities, such as e-commerce (Fernie *et al.*, 2010; Mckinnon *et al.*, 2007).

Backrooms are part of retail stores that have operations which are more complex and unorganized than in DCs (Trautrims *et al.*, 2009; Bruzzone and Longo, 2010). These operations include handling the flow of products between shelves and storing in temporary, promotional and backroom areas (Eroglu *et al.*, 2013; Mckinnon *et al.*, 2007; de Koster *et al.*, 2007). Furthermore, on a store level, order packaging units are smaller and more heterogeneous, and customers exhibit higher variability in consumer spending. Stores also have to stock a high range of products with specific characteristics (such as perishability, sensitivity to temperature and shelf-turnover), and problems stemming from shrinkage and theft (Van Zelst *et al.*, 2009; Li *et al.*, 2012). Due to the aforementioned reasons, logistics processes in retail stores represent 40 per cent of the total working hours and 40 per cent of total logistics retail costs due to the manual activities and due to the limited possibilities for using technology (Reiner *et al.*, 2013). In addition to the previously mentioned topics, backroom design faces further challenges, such as the sales area restriction.

In the store designing process, sales area design is the priority since it is the space that creates value to the store. Thus, it should have a regular shape and be attractive to customers. In contrast to the selling area, the remaining space is dedicated to the backroom storage the design of which is often neglected. Nevertheless, the main problems in grocery stores are related to constructional defects, inappropriate architecture and the non-existence of standardized guidelines for backroom storage facilities, proving the importance of the design of these areas (Kotzab and Teller, 2005; Reiner *et al.*, 2013). Also, retail store shelving and replenishment practices are the causes for about 25 per cent of out-of-shelf (OOS) situations, which reflect inefficient in-store operations that are very much influenced by the backroom design (Gruen and Corsten, 2002).

The design of backrooms is a strategic decision that is focused on the last stage of the retail SC planning framework (Hübner *et al.*, 2013; Schneeweiss, 2003; Miller, 2001), as illustrated in Figure 1. This is a complex decision and both retail literature and practice lack a structured framework to design backroom storage areas. Currently in practice, these complex areas are the result of ad hoc methodologies, mainly established on the perception of the architect who compares the new store with similar ones.

Therefore, our contribution focuses on answering the following research questions:

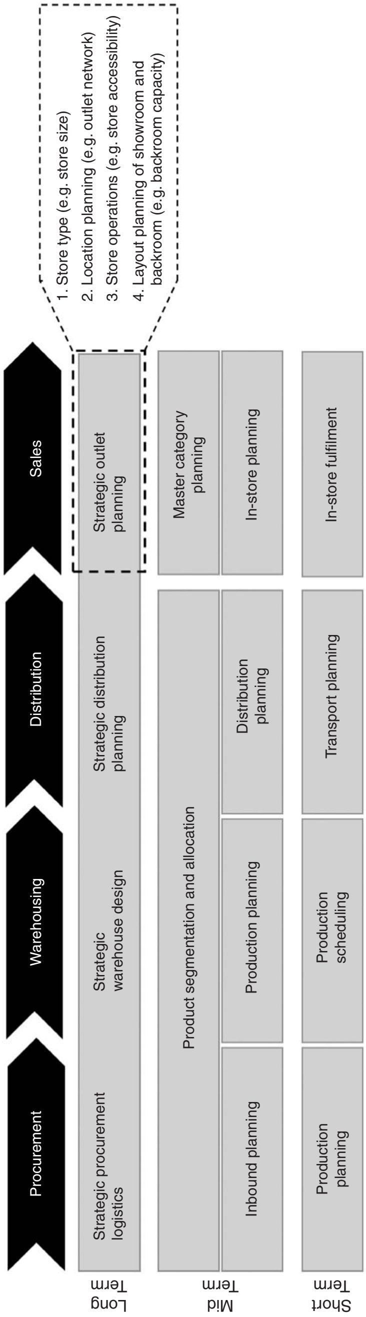
RQ1. What is the importance of backrooms in grocery retail SC?

RQ2. What are the main decisions to make when designing a grocery backroom?

Answering these questions will help practitioners and researchers to understand what aspects to consider while designing these areas and which methodologies to use when solving this problem.

This paper combines knowledge and insights from the literature on backroom design-related topics, namely, conventional warehouses design, and from an exploratory research conducted on a case study company. This builds the foundation for the development of the framework to design backroom areas.

The case study methodological approach was conducted between October 2014 and April 2015 in a Portuguese grocery retail chain, branded SONAE (Voss *et al.*, 2002). SONAE is the leader retailer in Portugal and has three segments of stores: convenience stores,



Sources: Adapted from Hübner *et al.* (2013) and Stadtler and Kilger (2008)

Figure 1.
Backroom design in the supply chain design framework

supermarkets, and hypermarkets. In 2015 this company held a total of 746 grocery stores worldwide and achieved a volume of sales of €3.490 M (SONAE, 2016).

The case study had two phases. First, several retail stores of the Portuguese retail company were visited. These are described in Table I. Our unit of analysis was the in-store operations. This field research allowed us to understand the real context of retail in-store operations as well as to notice operational in-store problems and inefficiencies regarding backrooms. Moreover, with this qualitative and observational-based information we were able to map the products' flow within the stores which is fundamental for the layout definition and department organization within the backroom area. Second, non-structured interviews were conducted with three members (two engineers and one architect) of the department responsible for designing and managing the stores' space. Our unit of analysis was the store design standard process.

In order to ensure the validity of this study, we have observed the operations of several stores ranging from north to south of Portugal, both in urban and rural areas, thus assuring sample diversity. Moreover, the proposed framework (cf. Section 4) was reviewed by the key members of the company.

The remainder of this paper is organized as follows. The following section describes the review of backroom roles, related literature as well as the particularities of backroom storage captured in the exploratory research. Section 3 covers the literature review on warehouse design approaches that will help in proposing the framework for designing backroom storage facilities described in Section 4. Finally, Section 5 concludes the research paper and indicates future works and further research areas.

2. Backroom role, related literature and backroom particularities

In order to help defining the backroom role and its particularities, a literature review was undertaken searching a range of electronic databases, including Science Direct, Google Scholar, Springer and Scopus. These databases were searched using combinations of relevant keywords, such as "backroom", "back store", "wareroom", "stock-room", "back-office", "grocery retail", "design", "layout", "warehousing", "dimensioning" and "operations". Relevant documents were then selected based on the abstracts analysis. From this initial selection, the search was extended by accessing the relevant books and cited papers. It should be referred that no relevant literature existed in the design of retail backroom storage areas *per se*.

2.1 Backroom role

In most retail stores, inventory is held in two locations: retail shelves, in the sales area, and in the backroom. Storing inventory in two locations has disadvantages because it requires permanent attention to real time sales in order to prevent OOS situations and lost sales.

Backroom storage, highlighted in grey in Figure 2, is a requirement in the retail business. Retailers manage these facilities for many reasons. One main factor is the limited shelf space that makes it often impossible to fit a complete replenishment order on the allocated shelf space (Eroglu *et al.*, 2013). By storing some inventory in the backroom, shelf space is freed

Type of stores	Number of stores visited	Total number of stores in Portugal	Average sales area (m^2)	Average backroom area (m^2)	Average number of stock keeping units (SKUs)	Monthly average of full time equivalent (FTEs)
Conventional stores	8	53	1,100	660	25,000	37
Supermarkets	15	130	2,100	1,400	40,000	59
Hypermarkets	5	40	7,500	5,400	70,000	186

Table I. Characterization of the stores visited

Figure 2.
Example of a grocery store layout, with the backroom area highlighted in grey

for displaying a wider product assortment, potentially increasing sales (Eroglu *et al.*, 2013; Reiner *et al.*, 2013). Moreover, backrooms enable retailers to keep stock in anticipation of, or to react to, demand of products. Lastly, backrooms allow a space apart from customers to perform activities such as in-store picking, breaking-bulk of transportation units to end-user units, transforming products before being put to sales, packing, labelling, cross-docking between stores and returning merchandise to the suppliers.

Besides being crucial to retail stores, backrooms impact the whole SC. First, they relieve some of the capacity pressure of DCs by allowing them to (early) transfer stock downstream to the stores. Also, they permit wider delivery windows, which greatly benefit route planning decisions and therefore, transportation costs. Moreover, by providing additional storage space, multiple daily deliveries from the DCs to the stores are avoided which also reduces transportation costs. Backrooms may also play an important role in retail services by enabling new omnichannel needs. For instance, backroom provides retailers with an opportunity to consolidate and fulfil online home delivery and click and collect at the store orders (Aastrup and Kotzab, 2010). Regarding the administrative tasks, backrooms support the link between the stores and the upstream SC departments, enabling sorting and processing of paperwork activities. Finally, backrooms accommodate the social areas, intended to the store employees. For all of the above reasons, backrooms merit attention and focus as they are a key link in the SC and a crucial support to the store.

As mentioned before, backroom storage area is usually divided into two major areas: storage areas and social areas. Storage areas (primary departments) are generally separated into three major departments: food, non-food, and chilled areas. At a more detailed level, each department is organized into several subdepartments, with their own layout established. The number of subdepartments is influenced by the type of store (hypermarkets, supermarkets or convenience stores). This happens because the services performed, assortment and volume of stock stored vary with the type of store. Stores have to stock a high range of products with specific and different characteristics, requiring different storage temperatures. Moreover, the number of required departments depends on the legal constraints of this sector.

2.2 Related literature

Backroom storage design involves several research areas and it has been overlooked in the literature. The research areas interrelated with the backroom design are very diverse and concern the conventional warehouse design and operations, grocery retailing, store operations and logistics (Gruen and Corsten, 2007; Raman *et al.*, 2001).

The design and operation of a warehouse comprise many challenging decision problems that have been studied in the literature in many sectors, such as grocery distribution, manufacturing or health care. These problems are usually divided into storage capacity models, warehouse design models and throughput capacity models (Cormier, 2005). Storage capacity models are typically strategic problems that aim to find the optimal warehouse size or else how to maximize space utilization. On the other hand, warehouse design problems deal with questions such as rack orientation, space allocation and overall building configuration. Throughput capacity models are usually in the operational level and comprise order picking policies as well as storage and assignment policies. Furthermore, warehouse performance has also been addressed in the literature, where travel-time models are often used to compare both alternative operating scenarios and warehouse designs.

Despite the research on warehouse design and operations, backroom design has been neglected. Nonetheless, there exists some literature covering backroom design-related topics. Eroglu *et al.* (2013) have looked over in-store operations and have introduced the backroom effect in-store operations, which is a consequence of misalignment of case pack size, shelf space and reorder point. In this paper, the authors assess the impact of the backroom effect on optimal inventory policy and total costs. This work supports the interconnection between backroom design, upstream SC planning and sales area design. Moreover, Milicevic and Grubor (2015) have analysed the effect of backroom size on product availability and concluded that in grocery stores, with the increase of backroom size, OOS on a store level decreases while in hypermarkets the opposite was observed, i.e., with the increase of backroom size, OOS increases as well. Therefore, these results opened several issues concerning the differences between smaller and larger stores.

A very important backroom-related topic is grocery retailing which allies customer profiling, products profitability (Kumar *et al.*, 2006), category management (Hübner and Kuhn, 2012), store layout (Van Zelst *et al.*, 2009) and shelf management (Dreze *et al.*, 1994). The impact of case pack quantities on the store level has also been addressed in the literature (Van Zelst *et al.*, 2009; Kuhn and Sternbeck, 2013; Waller *et al.*, 2008). Two opposing effects influence the expected levels of backroom activity. While larger case pack sizes increase the probability of excess inventory in the backroom (higher handling and inventory costs), orders will be placed less often and therefore new merchandise will arrive less frequently at the store (lower handling and transportation costs) (Kuhn and Sternbeck, 2013; Waller *et al.*, 2008).

As mentioned before, store operations is a crucial topic compared to backroom design as it addresses the flow of operations within the store (process chain), and how it affects the backroom area planning (Reiner *et al.*, 2013; Raman *et al.*, 2001). Concerning this topic, the process of replenishing products from the backroom to the sales area (refilling shelves) has been considered by several authors as not efficient, leading to poor service. Corsten and Gruen (2003) have confirmed that between two-thirds and three-fourths of OOS are caused in the store. Also, Kuhn and Sternbeck (2013) have stated that nearly 50 per cent of the entire logistics costs in grocery retailing occur in retail stores. Some of the raised factors are the incongruence between shelf capacity and replenishment frequencies, large assortment, insufficient staffing, congested backroom and poor design (Waller *et al.*, 2008; Corsten and Gruen, 2003; Fernie, 1994). The subject of SC planning, which encompasses inventory management (e.g. reorder points), retail supply networks and delivery patterns, has a significant impact in the overflow inventory in the backroom, affecting its storage requirements (Gudehus and Kotzab, 2012; Teo and Shu, 2004). Kuhn and Sternbeck (2013) have addressed the implications of planning issues such as store delivery arrival times, replenishment lead times and roll-cage sequencing and loading carriers to the store.

Lastly, RFID technology has also been addressed in the backroom context, showing great value for retail in-store operations and a great promise to reduce OOS situations (Gruen and Corsten, 2007; Condea *et al.*, 2012; Piramuthu *et al.*, 2014). The underlying idea is to automatically monitor inventory in order to trigger replenishments from the backroom to the sales area based on RFID data in real time (Gruen and Corsten, 2007; Condea *et al.*, 2012).

Despite the work undertaken in these distinct areas, the link between these subjects in light of backroom design is missing. For instance, the models for designing conventional warehouses and DCs do not completely adjust to the necessities of backroom storage facilities, such as being robust against an intense promotional activity stress and coping with in-store operations (Aastrup and Kotzab, 2009).

2.3 Backroom particularities

The particularities of backrooms *vis-à-vis* DCs can be divided into design and operational particularities. One of the main design differences is the position and function of backrooms and retail stores in the SC. Retailers are positioned in the last stage of the SC while DCs are located upstream. Since retailers operate at the closest point to the client they can serve as an input to the upstream planning areas. Also, the decoupling point that separates planning tasks into forecast driven and order driven is typically located at the store (Hübner *et al.*, 2013; Gudehus and Kotzab, 2012). Another important characteristic is the low and irregular shape of backrooms caused by the construction space as well as selling area restrictions (cf. Figure 2). These warehouses are integrated in stores which are frequently located in residential areas that are more expensive. For this reason, the storage capacity of backrooms is more limited. Additionally, backrooms coexist with the selling area, which competes for the same space. Another particularity is the low level of automation of backrooms, which rely on manual operations. Furthermore, the layout organization of backrooms is completely different when compared to DCs. Although the layout is generally divided into different areas depending on the category of the products, they all serve the same client, which is the sales area.

Regarding operational particularities, a significant distinction between DCs and backrooms is that the latter are not as organized as the former. The differentiating factor is that often store personnel are responsible for both backroom and sales area management. This causes disorder in the backroom since it is not considered a priority as most of the efforts are attributed to the availability of products in the sales area and on assisting clients. For these reasons, backroom storage areas are often neglected. The in-store operations are summarized in Figure 3. In this process, store employees travel from the backroom to the sales area, with the products about to miss, or missing, in the shelves. During this process, employees may interact with the store clients, assisting them if necessary. Since in grocery retail delivery frequencies are high, stock is needed to meet the demand for a short period of time, in contrast with most DCs. Nevertheless, days of inventory in conventional warehouses or DCs are usually shorter than in retail stores. This is caused by several aspects such as the case pack size, excess inventory from promotional campaigns, presentation needs, discontinued products, among others. This is

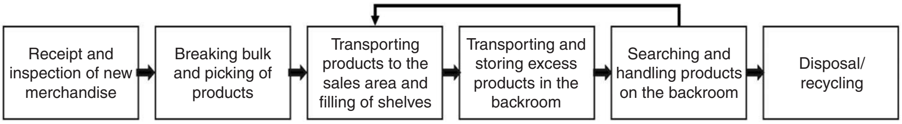


Figure 3.
In-store operations

Sources: Adapted from Reiner *et al.* (2013) and Kotzab and Teller (2005) a critical aspect since one may consider that inventory in the stores is more valuable than in DCs because the merchandise was already transported from DCs to stores, which results in additional logistic costs.

3. Literature review on warehouse design approaches

As previously referred, literature on backroom design is missing. Thus, an extensive review on warehouse design was conducted that will later be used on the definition of the backroom design framework, presented in the forthcoming section.

Efficiently designing a warehouse is crucial since it is known that warehouse costs are, to a large extent, determined at this phase. The design process of DCs is usually described by a series of steps. Some authors group the activities within these steps into a hierarchical framework based on a top-down approach, identifying strategic, tactical and operational decisions (Rouwenhorst *et al.*, 2000). Other authors divide the warehouse design into a set of sequential steps (Hassan, 2002; Baker and Canessa, 2009) and, alternatively, in further approaches warehouse design is presented in non-sequential groups of decisions (Gu *et al.*, 2010).

The literature review on this topic included publications concerning "warehouse design", the earliest publication being that of year 1974 and the most recent of 2016. From the literature review, it was possible to identify three general approaches to design conventional warehouses and DCs. These approaches are summarized in Table II, with a description of the methodologies commonly used to tackle the different design stages. In this table, the decision sequence takes place from the left to the right side, as the left-side decisions are previously made and influence the decisions that follow. This table allows parallel visualization and comparison of the distinct frameworks. From the left to the right side of the table, decisions progress from a higher to a lower level of detail.

In the first approach, Rouwenhorst *et al.* (2000) define the warehouse design process as a structured approach of decision making at the strategic, tactical and operational levels, representing long- (five years), medium- (two years) and short- (one year) term decisions. In this top-down approach decisions are divided into hierarchical levels which reflect the time horizon. Thus, solutions chosen at a higher level provide the constraints for the lower level decision problems, starting with a rough design that will be refined at the subsequent stages until a final design is defined. At the strategic level, the authors consider decisions that have a long-term impact, mostly those concerning high investments. At this level, decisions are made regarding the design of the process flow and the selection of the type of warehousing systems. Medium-term decisions are made at the tactical design level and generally have a lower impact when compared to strategic decisions. Tactical decisions typically concern dimensioning the resources (such as storage size and the number of employees) and the layout definition. At the operational level, processes have to be carried within the constraints settled at the higher levels. The main decisions at this level concern the assignment and control problems of both personnel and equipment. However, in this research we are not tackling the operational level because it is beyond the backroom design problem scope.

In the second approach, Baker and Canessa (2009) propose a framework for the warehouse design by combining the results from the literature review on works such as Rowley (2000), Hassan (2002) and Rushton *et al.* (2006), as well as warehouse design companies. The proposed framework consists in a set of eleven steps which are organized as follows. The first step consists in defining the system requirements, referring to the overall system, and therefore includes business strategy requirements and relevant constraints, such as planning and environmental issues. The second and third steps involve obtaining and analysing data, which results in warehouse activity profiling that includes aspects such as customer orders, characterization of items and investment profiling. The next step (Step 4) consists in establishing unit loads, by taking into account supplier and customer considerations. Step 5 involves the determination of the operating procedures

Table II.
Comparison between the various approaches

Strategic Level	Macro										Micro
Authors: Rouwenhorst *et al.* (2000)	• Design of the process flow • Selection of types of technical systems								• Equipment selection • Dimensioning of the resources • (storage systems, employees, etc.) • Layout design		
Authors: Baker *et al.* (2009)	Define system requirements	Define and obtain data	Analyse data	Establish unit loads to be used	Determine operating procedures and methods	Consider equipment types and characteristics	Calculate equipment capacities and quantities	Define services and ancillary operations	Prepare possible layouts	Evaluate and assess	Identify the preferred design
Authors: Gu *et al.* (2010)	Determine overall structure		Operational strategy			Equipment selection		Sizing and dimensioning		Determination of the layout	
Methodologies used	• Business and supply chain strategy • Scenario analysis • Benchmarking (simulation and data envelopment analysis) • Checklists and spreadsheet models		• Database models • Activity profiling techniques • Warehouse flow charts • Analytic and simulation approaches			• Flexibility frameworks • Spreadsheet models and decision trees • Heuristic, analytic and simulation methods • Checklists		• Multi-attribute value functions • Warehouse relationship activity charts • CAD software (generally used by practitioners)		• Analytic and simulation models • Quantitative (e.g. financial business case) and qualitative (e.g. SWOT analysis) methods • Multi-criteria decision making	

Source: Adapted from Baker and Canessa (2009) and methods. The authors consider an important part of this step the decision of the zones into which the warehouse should be divided, depending on the different product groups, temperature regimes or Pareto classifications. Step 6 regards the decision on the equipment types and their characteristics. Further, Step 7 comprises the calculation of equipment types, capacities and quantities. The goals include the development of optimum rack lengths and space utilization. Step 8 consists in defining the services and ancillary operations. In Step 9 possible layouts are prepared. This is considered by the authors a key and complex step due to the range of different objectives to be optimized. The last steps consist in evaluating and assessing the possible layouts by validating the operational and technical feasibility. The final step involves identifying the preferred warehouse layout by drawing together all of the above elements into a coherent design.

Finally, Gu *et al.* (2010) present a detailed survey on warehouse design, describing it into five non-sequential major stages: determining the overall structure; sizing and dimensioning of the warehouse and its departments; determining the detailed layout within each department; selecting warehouse equipment; and selecting operational strategies. The overall structure determines the material flow pattern within the warehouse, the specification of functional departments and the spatial relationship between departments. The warehouse sizing problem determines the warehouse storage capacity. In addition, the warehouse dimensioning problem translates capacity into floor space and determines the space allocation among warehouse departments. This decision has important implications on such costs as construction, inventory holding and replenishment, and material handling. Department layout is the detailed configuration of the warehouse departments. The equipment selection problem's purpose is to determine the appropriate warehouse automation level, and specify the equipment types for storage, transportation, order picking and sorting. The operation strategy selection problem is to determine how the warehouse will be operated, for instance, with regard to storage and order picking.

In this section, the literature on warehouse design was reviewed. Conventional warehouses and DCs operate in different conditions from backrooms, which are reflected in the design process. We hereby indicate four areas in which standard frameworks for conventional warehouses differ from those aimed at designing backrooms:

(1) As opposed to the process of designing conventional warehouses, while designing retail backrooms there are large amounts of data available that are generated with the current stores. It is important that backroom design profits from this information while defining the backroom requirements. Therefore, a step concerning backroom activity profiling should be part of the backroom design process.

(2) Retail in-store operations can be characterized by a great task complexity, due to the high product assortment as well as the variety of services provided in the store (e.g. counters of "to-be-prepared" products or e-commerce activities) that depend on the store type and influence the backroom departmentalization. Therefore, a step in which the functional requirements are defined is required in the backroom design framework.

(3) In terms of resources, namely, equipment and personnel, backrooms are much more restricted. Actually, backrooms are characterized by a low level of automation, mainly due to budget constraints. For this reason, a step intended to the selection of equipment is not relevant in the backroom design process, as it is in conventional warehouses.

(4) Finally, backrooms are highly conditioned by the sales area, mostly due to the replenishment operations during the day, and by the physical constraints (irregular shapes and limited space) caused by operating a store in urban areas, for example. Therefore, the definition of the layout and its assessment has an enhanced relevance in backroom design.

4. Framework for designing the backroom

Backrooms are a very specific type of warehouse and therefore deserve a particular design framework (cf. Section 2). However, since there is a lack of literature on backroom design and operations, the methodology chosen by the authors consisted of an extensive review of warehouse design (Section 3) and adapting it to the backroom design, benefiting from the practical insights described in Section 2.

Figure 4 presents the framework proposed. It illustrates the design steps sequence as well as the necessary inputs, outputs and external data required for each step. It often occurs that one step requires information from several preceding steps, which is illustrated by dark circles.

In this section, we present a framework for the design of backroom areas that consists in a sequence of interrelated steps. In each step of the framework, we present the problem description, generically in warehouses and more specifically in the backroom context, the methodologies and techniques applied in the literature to solve each of the individual problems and the tools usually applied in practice. Each subsection ends with the description of the department responsible for this decision in the case study company.

4.1 Storage requirements

This step aims to define the general requirements of the backroom. Backrooms are part of retail stores, and for that reason their design is directly related to the type of store. In this step, it is important to identify which of the typical types of stores the new store is going to be, i.e., a hypermarket, a supermarket, a convenience store or another typology (e.g. drugstores, freeze stores or organic POS). Seidel *et al.* (2016) have analysed the selling concepts in France and Germany and have defined the sizes of convenience stores to be generally less than or equal to 400 m^2, supermarkets between 400 and 2,499 m^2, and hypermarkets dimensions' to be more than 2,500 m^2. Moreover, it is worth mentioning that general merchandise stores have historically dedicated about 15-20 per cent of their store space to the backroom (Dunne *et al.*, 2013). Then, a forecasting analysis should be performed in order to understand the expected levels of store activity, product assortment, sales volume and demand profiling. Usually, practitioners compare the store in project phase with the existing stores in order to provide estimates that will result in the requirements for capacity, throughput, budget and space that the store should meet. The following decisions in the backroom design will be built on these estimates and assumptions.

Data envelopment analysis has been used in order to assess the retail productivity of outlets in a retail firm (Donthu and Yoo, 1998). Defining the storage requirements of the backroom is interconnected to the forecast analysis of demand, which plays an important role in manufacturing and retail operations. In that area, there is the work of Kumar and Patel (2010), who have proposed a new method of combining forecasts using the concepts of clustering. Another important decision regards the definition of product assortment. In this topic, there are works that aim to aid retailers to define which products to stock (product assortment) and how much shelf space to allocate to those (Cachon *et al.*, 2005; Borin *et al.*, 1994; Hariga *et al.*, 2007; Hübner and Kuhn, 2011).

The methods used for this step in practice are scarce and unstructured. Usually ad hoc database/spreadsheet tools on backroom roles and functions (e.g. storage and treatment zones required) are used (Baker and Canessa, 2009; Gu *et al.*, 2010).

The decision of opening new stores is often the Executive committee's responsibility. Then, the planning Department performs market studies to predict the characteristics of the store based on available data (e.g. the client profile). This information allows to decide, for instance, the best location for the new store.

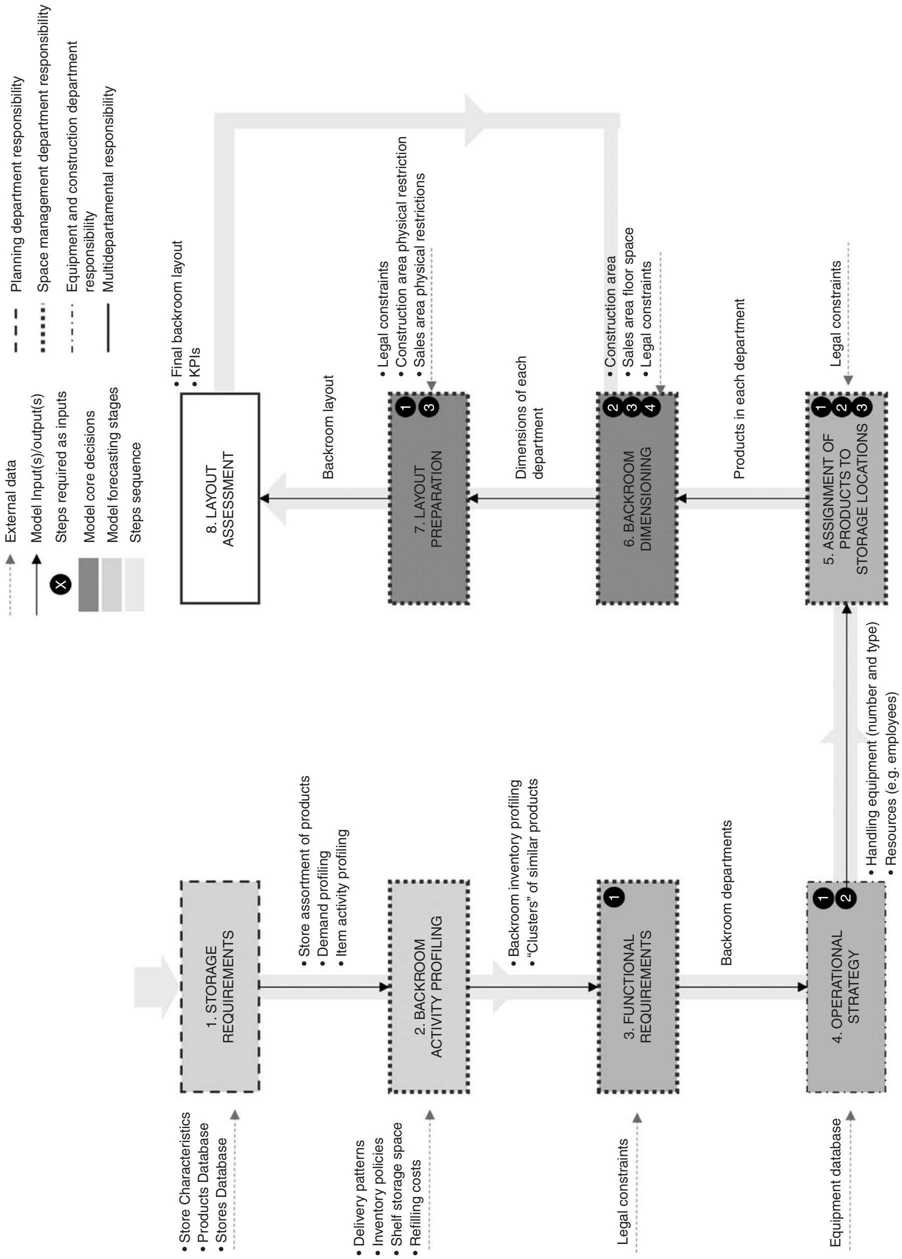


Figure 4.
The proposed framework for the backroom design

4.2 Backroom activity profiling

Generally, warehouse activity profiling includes topics such as – topic 1: customer order profiling (e.g. pallet, carton, etc.), topic 2: item activity profiling (e.g. item popularity and demand variability distributions), topic 3: inventory profiling (e.g. Pareto inventory distribution), topic 4: calendar clock profiling (e.g. seasonality and daily activity distributions), topic 5: investment profiling (e.g. wage rates and the required return on investment), and topic 6: activity relationship profiling, i.e., importance of certain functions being located near other functions (Baker and Canessa, 2009). Topics 2, 3, 4 and 6 are especially important in backroom design.

Depending on the product assortment of the store, storage classes can be made, considering the family of products, their demand and characteristics (e.g. sizes, weights, shapes, temperature regimes and expiration dates). Besides the product assortment, the identification of the inventory (topic 3) to store in the backroom takes into account the shelf space of each product in order to assess if it is enough to store the inventory needed to meet the estimated demand. In this decision, aspects such as product demand forecast, shelf space, inventory policies, delivery patterns, and shelf refilling and handling costs of different products should be considered. Other important aspect concerns topic 4 and is the seasonality of products, which may affect subsequent steps on space requirements and storage assignment. There are products the demand of which is relatively low during all year with the exception of one specific period (e.g. summer, Christmas). Another crucial aspect is the promotional campaigns, which can have, for instance, a weekly or biweekly periodicity, that influence the sales area and the backroom, as well as the store resources. Finally, regarding topic 6, it is very important to keep in mind the relationship between activities within the backroom in order to allocate better the departments and arrange their location concerning the corresponding sales area. For example, the chilled areas for fish and meat should be near their respective treatment zones (in the backroom) and the attendance service (in the sales area). This is a very important aspect for efficient and smooth flow of products.

There is some research concerning the topic of in-store operations and inventory management. Lin *et al.* (2008) have used simulation to investigate shelf replenishment policies used in retail stores. The policies' impact on the efficiency of the retail SC was analysed and compared. Furthermore, Van Zelst *et al.* (2009) have developed a conceptual model for shelf-stacking in stores, which was derived using the analogy based on order picking models for warehouses. This model demonstrates the impact of the most important drivers for stacking efficiency that are case pack size, number of case packs stacked simultaneously, the filling regime and the working place of the employees. Moreover, benchmark examinations are also used to consider efficient stores as reference to design the new store (Reiner *et al.*, 2013). Within the context of food SC, authors such as Van Donselaar *et al.* (2006) have studied the design of perishable inventory management systems.

At this step, as well as in the previous, tools used in practice are ad hoc checklists, flow charts and spreadsheet (Rushton *et al.*, 2006). Data profiling techniques are used to understand the product details, demand profiles, arrival patterns and site information (Baker and Canessa, 2009).

The data required in this step belong to several business departments of the company, such as marketing, sales and logistics. However, the data analysis is often the responsibility of the space management department that combines the relevant information for defining the backroom activity profile.

4.3 Functional requirements

Defining the functional departments consists in determining how many departments will be required in the backroom and their characteristics (e.g. storage temperature). The functional departments are defined based on the zones into which the warehouse should be divided (e.g. zones for different product groups, temperature regimes or Pareto classifications). This decision is based on the backroom inventory profiling in which the products to store in the backroom were defined. In the specific case of backrooms, items are generally stored in departments depending on their temperatures and categories. Nevertheless, there is a set of common departments to all types of stores (e.g. food warehouse).

Backrooms are generally divided into two major areas: storage areas and social areas. The storage areas include the food and non-food warehouses, chilled and frozen rooms, and technical and maintenance areas (ancillary operations). Additionally, there are important legal constraints to follow regarding food security and hygiene issues (e.g. home cleaning products, which contain chemicals, should not be stored close to food products). In a more detailed level, each department is organized into several subdepartments, with their own internal layout established. Social areas, also referred as secondary departments, are intended for the employees of the store in order to provide them working conditions and areas to perform administrative activities. These areas include administrative offices, restrooms, and meeting and living rooms. Furthermore, in some stores there are also external areas including the unloading dock, where products arriving at the store are unloaded.

In warehousing, authors generally consider a warehouse with five functional areas, i.e., receiving, shipping, cross-docking, reserve and forward areas (Heragu *et al.*, 2005). Furthermore, Le-Duc and De Koster (2005) aimed to determine the optimal number of zones such that the overall (picking and packing) time to finish a batch is minimized using exact and approximate methods.

The set of tools utilized in practice in this step is also empirical and includes warehouse flow charts as well as database and spreadsheet models on warehouse roles (e.g. cross-docking) and functions (e.g. storage) (Mantrala *et al.*, 2009; Baker and Canessa, 2009).

These decisions are often taken by the space management department. Here, legal constraints are important to make sure that every product is stored in adequate conditions. Nevertheless, suggestions from the operations department (e.g. store managers) may be taken into consideration.

4.4 Operational strategy

Once the main departments and operations are identified, warehouse flow diagrams can be used to describe the daily flows passing through the various zones of the backroom as a basis for the subsequent steps. The selection of the operational strategy is also a high-level decision with high impact on backroom life-cycle costs and include defining the storage, order picking, material handling systems and personnel.

Regarding storage, it is important to understand what serves better the backroom: dedicated, randomized or class-based storage. Since a quick and efficient service is essential to the quality of shelf-stacking, employees should be familiarized with the location of products in the backroom. For this reason, the strategy usually chosen is dedicated and class-based storage, which also allows the division of the areas by family of products. However, within each subdepartment items can be allocated randomly or by their demand (hybrid storage). Further decisions regarding DCs include determining the depth and height of storage, the type and dimensions of unit loads, the type, number and capacity of handling equipment and the assignment of equipment to particular areas of the warehouse. Backrooms are characterized by a low level of automation in storage systems, making use of labour-intensive systems (e.g. shelving systems). The common material handling systems include palletizers and truck loaders. In backrooms, the simplicity and accessibility of products are crucial requirements for the operation. Moreover, as retailers may have hundreds or thousands of stores, the available financial resources for backroom systems and equipment are very scarce. In addition, there are space constraints which do not allow voluminous systems. In regular retail stores, products are generally separated by categories that are assigned to the store personnel. For this reason, a common picking strategy in backrooms is zone picking.

An important particularity of backrooms is that pickers *per se* do not usually exist, since the employees of the store perform activities in both sales area and backroom. It is also important to note that in DCs there exists a list of products to meet a specific order, which tends to be very clear and available at established timetables. However, in backrooms this cannot be assumed because the replenishment from the storage areas is unpredictable and triggered by the absence of products in the sales area (i.e. OOS) and conditioned by the availability of resources. At this decision level, the necessary resources for a smooth store operation should also be calculated, namely the number of employees (full and part time).

In the literature, operational strategy appears to be divided into storage and order picking strategies (Gu *et al.*, 2007). Berg and Zijm (1999) discussed warehousing systems and presented a classification of warehouse management problems. Regarding storage strategy, Graves *et al.* (1977) and Schwarz *et al.* (1978) compared random storage, dedicated storage and class-based storage using both analytical and simulation models. In respect to order picking strategies, Petersen (2000) simulated five different order-picking policies: single order picking, batch picking, sequential zone picking, concurrent zone picking and wave picking. Naish and Baker (2004) described a step-by-step approach to equipment evaluation and, lastly, Park and Webster (1989) assumed the functions are given, and select equipment types, storage rules and order picking policies to minimize total costs. In practice, the role of the designer in this process is of great importance and is often supported by checklists with the operational requirements. Nonetheless, the research in this topic considering the backroom's characteristics is very scarce.

The definition of technological requirements, such as store equipment, is decided by the equipment and construction department. These decisions are then communicated to the space management department that incorporates it in the design.

4.5 Assignment of products to storage locations

Once the departments are defined, one needs to determine which items are assigned to each department. As it happens in conventional warehouses, the assignment of items to storage locations is an important step in the design due to its impact on movement time, throughput, productivity of store employees and congestion. Thus, rules for the assignment of items to storage locations have to be carefully defined in order to improve in-store operations.

In the specific case of backrooms, these decisions include the assignment of groups of items into storage locations and their arrangement within each location. The assignment decisions rely on information obtained from previous steps concerned with the analysis of demand, class formation, backroom departmentalization, legal constraints and storage systems. For instance, highly demanded items or classes should not be all stored in one place in order to reduce congestion. Thus, highly demanded items are distributed throughout the backroom. As referenced before, zone picking is a common strategy in backrooms. For that reason, effort is made to assign products that are picked in the same route in the same, or adjacent, department.

Regarding the assignment problem, there are some relevant works in the literature. Hackman and Rosenblatt (1990) solved the problem of which SKUs to assign to the forward area by proposing a heuristic that attempts to minimize the total costs for picking and replenishment activities. Moreover, Frazelle *et al.* (1994) have provided a framework for determining the size of the forward area together with the allocation of products into that area. Finally, Heragu *et al.* (2005) considered an optimization model and a heuristic algorithm to determine the assignment of SKUs to the different storage areas as well as the size of each functional area in order to minimize the total material handling and storage costs. However, the departmentalization of the warehouse and the complexity of the products stored are not consonant with the reality of backrooms.

In practice, the space management department uses the information regarding food safety and legal constraints to guide the products assignment to each department. Usually, no detailed assignment is performed.

4.6 Backroom dimensioning

The warehouse dimensioning problem translates capacity into floor space. Space requirements in a conventional warehouse depend on various factors such as inventory levels, storage units, number of aisles, number of storage levels, departmentalization and storage equipment that have already been discussed in earlier steps. Warehouse dimensioning is crucial since it has important implications on construction, inventory holding and operational costs. Sizing is much related to the inventory policies and decisions, which rely on the forecasting and analysis of demand. This step must be carefully executed because an oversized estimate of space needs could lead to wasted space, while an undersized estimate may lead to crowded conditions.

Assuming that the backroom has little control over inventory, which is often managed centrally by the commercial and supply chain departments, backroom dimensioning determines the appropriate storage capacity in order to cope with the stochastic demand. At this stage, the impact of demand variability may be assessed by organizing several scenarios for space requirements. Moreover, it is important to consider buffers for promotional campaigns and returns to the supplier.

In the literature, some authors propose optimization models considering alternative situations: warehouses are responsible for controlling their inventory (Levy, 1974; Cormier and Gunn, 1996), and warehouses that have no control over the inventory policy and are subject to single-product or multi-product deterministic demand (Goh *et al.*, 2001). Heragu *et al.* (2005) have addressed simultaneously the product allocation and functional area size considering a warehouse with several functional areas resorting to an optimization model and a heuristic algorithm. Simulation models were also applied to understand the effects of inventory control policies on the total required space capacity (Rosenblatt and Roll, 1988). Lastly, Pliskin and Dori (1982) proposed a method to compare alternative space allocations among different warehouse departments based on multi-attribute value functions. However, none of these models include multi-products with the diversity of storage requirements that backrooms face (e.g. multi-temperature) while considering promotional and seasonal demand and, most importantly, the arrangement of two competing areas such as the backroom and sales area in the same confined space.

This decision is taken by the space management department that often makes use of recent and similar stores to use as a reference for the new store.

4.7 Layout preparation and assessment

Finally, the possible layouts can be prepared and assessed. This step consists in allocating the departments in the backroom by considering several aspects, such as the product flow. This is a complex problem since different objectives can be desired simultaneously, such as the minimization of space, costs related to walking distances, as well as maximization of the products accessibility and resources utilization. However, backrooms have additional goals such as OOS minimization.

Usually, computer-aided design software is used to assist in the layout drawing (e.g. AutoCAD). Material flow plays an important role in this step since it allows understanding the best organization within the warehouse in order to simplify and streamline the material flow. Designing the backroom layout requires the consideration of several aspects. For instance, the distance between sales area of a specific category of product and its storage space in the backroom should be minimized. Moreover, it is important to consider the adjacencies between the departments, i.e., which department is required to be located together due to, for instance, construction issues. Lastly, the backroom area has often irregular shapes which lead to several iterations until the final layout is defined. At this step the designers' know-how and expertise may be very valuable. The final layout is chosen considering the indicators selected to measure the performance of the backroom (e.g. travelled distances).

There is a reasonably robust research literature on the general facility layout problem, which is also a relevant approach to this step and regards the physical organization of the departments. In this area several works were published, including the application of genetic algorithms. For example, Hernandez *et al.* (2011) have used a multi-objective interactive genetic algorithm to support the decision-maker's decision. Another example is the work of Amaral (2006), who proposed a mixed-integer linear programming model to the resolution of this problem. Gray *et al.* (1992) have proposed a multistage hierarchical approach that uses simple calculations to evaluate the trade-offs and prune the design space to a few superior alternatives.

The layout definition is usually defined by the space and management department. However, it is evaluated by all the stakeholders and modifications are often required.

Despite the sequential manner in which the design steps were presented, a degree of iteration is necessary in order to achieve the best suiting design for a given backroom.

5. Conclusions and future research

This paper presents a general framework for the design of backroom storage areas while drawing attention to backrooms and emphasizing their importance to the store and their impact at in-store logistics and customer service level. This framework is unique in view of the fact that backroom storage as a type of warehouse has never been addressed in the literature. Additionally, at each step of the framework a parallel between warehouse and backroom design is established while highlighting the dissimilarities. A limitation of our research concerns the external validity of our framework that was performed using one grocery retail Portuguese (leading) company. Therefore, future research may test the framework on different contexts/companies.

After this analysis we could conclude that the current literature focusing on warehousing is a very small fraction of the overall SC papers and backroom design is not discussed. Another important issue that we would like to stress is the evident lack of contributions of practical cases demonstrating the potential benefits and application of academic research to real problems in this field. Thus, cross-fertilization between groups of practitioners and researchers appears to be limited and should be encouraged to face this challenging problem. It was also observed that the design of the backroom areas is mainly established on the perception of the architect and on similar stores, when it should be carefully studied based on in-store logistics and operations, expected orders' volume of the regular activity as well as seasonal and promotional activity. To prevent these situations, the designers should also rely on formal means to assist the design process, rather than follow ad hoc procedures.

In the course of our discussion, we have outlined various aspects that deserve attention but have been barely addressed by retail practitioners, consultants or academics. Thus, this discussion will, hopefully, stimulate future research in this very promising area, both from a theoretical and a practical perspective, having a strong potential for improving the current practices. Further research opportunities lie in performing further empirical studies regarding backroom operations and using them in quantitative studies concerning backroom design. With the proposed framework we aim to create a basis for discussion around this relevant topic as well as to encourage further research in this topic. The future research opportunities identified were grouped by planning areas, i.e., steps of the framework, and are the following:

- Storage requirements and backroom activity profiling – retail companies store large-scale data sets in their databases. There is a need to develop and extend the research on business data mining in order to capitalize on this information by not only presenting the current results, but also capturing tendencies. In this research context, companies should be able to determine the new stores' storage requirements based on data regarding, for instance, clients' demand, product characteristics, inventory policies and store location.
- Functional requirements and operational strategy – with so many technological developments, studies regarding the best automation level for backroom storage systems are missing. In confined and constrained spaces, such as backrooms, new systems (e.g. compact storage systems) could allow for an improvement in retail practices. These studies should encompass, for instance, the impact of different transportation and storage units in the retail SC.
- Assignment of products to storage locations – the assignment of products within backroom departments has great influence on in-store operations. Therefore, it would be interesting to study the backroom departments' micro-layout considering aspects such as product characteristics (e.g. volumes, density), replenishment frequency (considering sales area storage capacity and product demand) and promotional and seasonal policies. Allying this research with the potential use of RFID technology would also be very relevant to practice due to the potential improvement in picking efficiency. By taking advantage of the information provided by the RFID, real time sales and product location within the backroom departments, it would be possible to determine order picking strategies and prevent OOS, increasing sales and, consequently, customer satisfaction.
- Backroom dimensioning – in the literature, sizing of DCs has been tackled and discussed. However, the number of departments considered and the assortment of products stored do not encompass the complexity of retail operations. Moreover, the backroom sizing needs to consider the sales area as a storage space as well, making this an even more complex problem.
- Layout preparations and assessment – DCs layout configuration is very different from backrooms. For example, backrooms have irregular shapes caused by the limited construction space in urban areas, which yield a very hard layout problem. Also, backrooms make little use of aisles, as opposed to DCs, since they usually consume valuable storage space, affecting the overall layout. Hence, new layout models and methods are necessary for tackling the overall backroom design problem. Furthermore, the allocation of the departments in the backroom should consider not only the products' flow in the backroom, but also the position of the corresponding products in the sales areas.

The integration of the sizing and layout problems described above is promising. Connecting the capacity allocation among departments with their distribution in the available space is a complex and innovative research direction. Moreover, it would be interesting to extend the mentioned integration with other planning decisions that impact the backroom. These decisions may include not only the inventory and delivery policies to the stores (determining the optimal delivery strategy and inventory levels), but also decisions regarding the sales area space (analysing the optimal distribution of inventory between the backroom and sales area).

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