Hierarchical Warehouse Design Approach for Distribution Centres

Dr. Ismail Karakis, Prof. Dr. Mehmet Tanyas, Assoc. Prof. Dr. Murat Baskak,

Industrial Engineering Department, Istanbul Technical University, Istanbul, Turkey
International Trade and Logistics Management Department, Maltepe University, Istanbul, Turkey,
Industrial Engineering Department, Istanbul Technical University, Istanbul, Turkey,
Corresponding Author: Dr. Ismail Karakis

ABSTRACT: Warehouses are essential components of supply chains with regard to customer service and cost levels. As a result of a comprehensive literature review, this paper asserts the need for systematic warehouse design methodology that considers the different and interrelated decision points. The purpose of the study is to develop a systematic methodology for warehouse design problems in order to make a more efficient and cost effective warehouse design. This purpose is realized through a comprehensive systematic literature review that addresses warehouse design problems and solution approaches, and detailed interviews with both logistics service providers and key fast moving consumer goods and retail industry companies in Turkey. The described methodology that provides an end-to-end, holistic approach for warehouse design problems by proposing a systematic flow for each design parameter and taking into consideration their interrelations. The methodology enables to conduct more effective and efficient warehouse design. The proposed methodology is easy to use and helpful since it provides a systematic and intelligible way of completing an end-to-end warehouse design project. The methodology covers all the necessary steps of warehouse design and provides a better, more efficient and cost effective way of managing warehouse design project. This methodology provides a holistic and systematic approach for warehouse design. Therefore, the methodology can be treated as a roadmap / guideline for both academicians and practitioners.

KEYWORDS: Warehouse design, Facility planning, Conceptual framework

I. INTRODUCTION

Warehouses are essential components of the supply chain (Guet et al., 2007), playing an important role in the success or failure of a business from both a customer service level perspective and a cost perspective (Baker and Canessa, 2009). Warehouses have several major roles, such as enabling a buffer for material flow along the supply chain when altered by seasonality, batching, or transportation and providing a location for value-added services such as kitting, labelling, and stamping. When market competition is added to this situation, warehouses, as important players in supply networks, need to show continuous improvement in design and operations in order to achieve ever-higher performance (Guet et al., 2007). A recent literature review study on warehouse performance evaluation conducted by Staudt et al. (2015) revealed all key performance indicators with clear definitions.

Because of the increase in labour costs, allocating more people for any warehouse performance problem is not a viable solution (Grayet et al., 1992). Therefore, these improvement efforts typically result in the adoption of new management philosophies, such as tighter inventory control and shorter response times, and implementation of new technology, like bar coding, radio frequency communications, warehouse management systems (WMS), automatic storage and retrieval systems (AS/RS), and automated vehicle storage/retrieval systems (Grayet et al., 1992; Guet et al., 2007; Marchet et al., 2013). Because these solutions have a very significant cost impact, warehouses need to function cost effectively (Baker and Canessa, 2009). These cost drivers are in fact determined during the design phase (Rouwenhorst et al., 2000).

Warehouse design involves making decisions about different design parameters in order to satisfy cost and performance objectives. This paper proposes a warehouse design methodology for ensuring that all required parameters and factors are accounted for and that the best-fit design alternative is developed according to economic and technical expectations and performance targets by considering different design elements and their dependencies. Thus, the following questions should be answered regarding the warehouse design:

- Is this design correct? (i.e. Are any parameters missing or forgotten? Is the design consistent through the different parameters?)

www.ijbmi.org 69 | Page
• Is this the “correct” design? (i.e. Are warehouse performance targets achieved by this design or not?)
In the literature, one of the structured design approaches is proposed as Rouwenhorst et al. (2000) stated by which multiple interrelated decisions are made at the strategic, tactical, and operational levels. For each level, problems are defined using three axes: processes (receiving, storage, picking, shipping, etc.), resources (storage unit, storage system, picking equipment, WMS, etc.), and organization (process flow, storage policy, order picking policy, etc.) (Rouwenhorst et al., 2000). For instance, selection of a storage strategy is a strategic decision that affects the warehouse design (Guet et al., 2007). Overall warehouse design is a different problem from warehousing systems design, which is another critical strategic-level subject related to sizing problems. Conceptual models and systematic approaches can be found within the literature regarding the sizing topic (Keserla and Peters, 1994; Rollet et al., 1989).
As clearly seen in the literature, the systematic layout planning (SLP) developed by Muther (1987) is one of the most used methodology for especially facility layouts. On the basis of the definition of overall warehouse design stated above, this paper asserts that SLP approach is not appropriate for warehouse design, although it is widely used in practice. The reasons for this assertion are as follows:

• SLP provides a good view of analysis (flows, products, time, etc.). However, while flows are important for warehousing, the number of materials, loads, units, storage types, and sizes of the storage types over time are also crucial. Analysis of these other factors is not explicitly addressed by the SLP framework.
• SLP is helpful for layout planning of the warehouse, but layout is only one of the key components of overall warehouse design, as stated by Gu et al. (2010).
• SLP design does not use a system choice perspective, including combined selection of storage equipment, a material handling system for transport from/to the storage areas, and order picking and storage methods. These decisions are not able to be taken in isolation since they are part of a complete system choice. For instance, one may have to choose between an operation with wide aisle pallet racks using low-level order pick trucks with reach trucks for pallet storage and retrieval versus a pallet storage system with narrow aisle pallet racks and semi-high bay combi trucks.
• SLPlacks the ability to address the procedure steps regarding order picking system design, according to Dallari et al. (2009).

The third point is one of the core aspects of warehouse design which is not addressed by SLP: therefore, this method is not a best-fit solution for warehouse design projects. Moreover, all these decision points are interrelated and dependent on each other, which mean that iteration is required to achieve the most appropriate design solution. This aspect is also not covered by SLP.

On the other hand, there is another framework for warehouse design problems that involves five major decisions as stated by Gu et al. (2010). 1) Determining the overall structure requires a conceptual design that determines the material flow pattern within the warehouse, specification of the functional departments, and the flow relationships between them. 2) Sizing decisions determine the size (capacity) and dimensions (translation of capacity into floor space). 3) Department layout involves details about such things as aisle configuration in the retrieval area and configuration of AS/RS. 4) Equipment selection determines the automation level of the warehouse in terms of storage, transportation, order picking, and sorting. 5) Operation strategy determines how the warehouse will be operated in terms of whether randomized storage or dedicated storage will be used and whether or not to use zone picking (Guet et al., 2007, 2010). Besides, a step-wise approach, a kind of decision support system developed by Duve and Mantel (1996) for warehouse design. Goetschalckx et al. (2001) provided a framework for systematic warehouse design in terms of developing a mixed integer mathematical model.

Ina conceptual warehouse design, the strategic level includes data acquisition regarding the warehouse and functional and technical high-level descriptions of the warehouse. The tactical level involves equipment selection and internal layout determination on the basis of technical details determined at the strategic level. The operational level includes planning and control policies for daily warehouse processes. Because order picking is one of the most important operations in terms of time and cost effectiveness, several studies that focus only order picking system design in the literature (Bryzner et al., 1994; Yoon and Sharp, 1996; de Koster et al., 2007). Moreover, Thomas and Meller (2015) recently developed design guidelines for case-picking warehouse by using statistical based methodology and analytical models. Recently, the optimum design of warehousing systems for a specific sizing has been asserted to be independent from storage policies (Zaerpour et al., 2013).

Two different approaches are used for warehouse design. The first is a top-down approach with limited details, which can be described roughly as design at first glance and subsequent branching into the details. The second approach is the reverse of the first, namely a bottom-up approach (Rouwenhorst et al., 2000). This paper proposes top-down approach as well.

For the purposes of this paper, 243 studies were reviewed, and 170 of these were classified according to the method(s) used for warehouse design. It is obvious from the results of this review that many studies have been done regarding the operational level. Fewer studies have been conducted regarding the tactical level, and
significantly fewer strategic-level studies have been done in comparison to tactical level research papers. Therefore, this paper asserts that there is a need to focus on warehouse problems at the strategic level. Furthermore, only a few studies have been conducted on warehouse design methodology (Karakiset al., 2011). The key studies including the literature review papers regarding warehouse design is given in Table 1.

<table>
<thead>
<tr>
<th>Citation</th>
<th>Focus</th>
<th>Method</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muther (1987)</td>
<td>Facility layout planning</td>
<td>Systematic Planning (SLP)</td>
<td>Layout</td>
</tr>
<tr>
<td>Gray et al. (1992)</td>
<td>Overall warehouse design</td>
<td>Analytical Model</td>
<td>Mathematical Model</td>
</tr>
<tr>
<td>Duve and Mantel (1996)</td>
<td>Overall warehouse design</td>
<td>Conceptual Model</td>
<td>Step-wise approach</td>
</tr>
<tr>
<td>Goetschalckx et al. (2001)</td>
<td>Overall warehouse design</td>
<td>Analytical Model</td>
<td>Mixed Integer Programming</td>
</tr>
<tr>
<td>Bryner et al. (1994)</td>
<td>Order picking system design</td>
<td>Analytical Model</td>
<td>Zero-based Analysis</td>
</tr>
<tr>
<td>Yoon and Sharp (1996)</td>
<td>Order picking system design</td>
<td>Conceptual Model</td>
<td></td>
</tr>
<tr>
<td>Thomas and Meller (2015)</td>
<td>Order picking system design</td>
<td>Analytical Model</td>
<td>Statistical Methodology, Mathematical Models</td>
</tr>
<tr>
<td>Ashayeri and Gelders (1985); Rouwenhorst et al. (2000); Baker and Canessa (2009)</td>
<td>Warehouse design methodologies</td>
<td>Literature Review</td>
<td></td>
</tr>
<tr>
<td>de Koster et al. (2007)</td>
<td>Order picking system design</td>
<td>Literature Review</td>
<td></td>
</tr>
<tr>
<td>Gu et al. (2007)</td>
<td>Warehouse Operations</td>
<td>Literature Review</td>
<td></td>
</tr>
<tr>
<td>Gu et al. (2010); Staudt et al. (2015)</td>
<td>Warehouse Performance Evaluation</td>
<td>Literature Review</td>
<td></td>
</tr>
</tbody>
</table>

The warehouse design issue is crucial since it is the base for further execution of operations and, if neglected, it may necessitate costly design modification efforts later. Because no overall design methodology has been defined in the literature as well as in practices in the industry, this paper proposes a systematic approach to the warehouse design process. From a review of the literature, it is obvious that although there is a general consensus on the overall structure of the approaches to warehouse design, there is less consensus on the tools to be used for warehouse design (Baker and Canessa, 2009).

With regard to methodologies, analytical models are widely used, appearing in 77 studies for warehouse design and validated with heuristics and simulation models. Heuristics and metaheuristics are the second most common method used (51 studies). Conceptual models, including literature reviews, are mentioned in 25 studies, mainly related to strategic-level topics. Seventeen studies use simulation models as a primary tool (Karakiset al., 2011). According to Ashayeri and Gelders (1985), the combination of analytical models and simulation is the most practical approach for topics related to warehouse design optimization. Moreover, Ashayeri and Gelders (1985) state that very few papers deal with the general warehouse design problem. This view is supported by Rouwenhorst et al. (2000), who emphasize the need for research oriented towards a synthesis of currently isolated models and techniques as a basis for decision support in designing complete warehousing systems. Recent research papers agree as well; Baker and Canessa (2009) describe the lack of a comprehensive and science-based methodology for the overall design of warehousing systems and the absence of a procedure for systematically analysing the requirements for and design of a warehouse. Baker and Canessa (2009) also assert that there appears to be only some consensus on the overall design approach across the warehouse design companies within the UK.

Simple, validated models that actually give useful results for guiding overall structural design is identified as one of the key research needs in a recent literature review paper by Gu, Goetschalckx, and McGinnis (2010).

As a result of the comprehensive literature review, it is asserted that the systematic warehouse design approach is poorly represented. In light of this gap in the literature, this paper aims to develop a systematic and hierarchical warehouse design approach, especially for distribution centres (Karakiset al., 2011). The methodology proposed provides an end-to-end, holistic approach for warehouse design problems, suggesting a systematic flow for each design parameter by taking into consideration interrelations with other parameters. Both academicians and practitioners can use the proposed methodology as a guideline for warehouse design projects.

www.ijbmi.org
II. PURPOSE

The purpose of the study was to develop a hierarchical methodology for warehouse design problems in order to make a more efficient and cost effective warehouse design. This purpose is realized by developing a conceptual methodology through a comprehensive systematic literature review and detailed interviews with both logistics service providers and key fast moving consumer goods (FMCG) and retail industry companies in Turkey (Karakis et al., 2011, 2012). As stated before, despite the fact that there are several studies regarding the problems of warehouse design as seen in the appendix with the details, there is a lack of research on systematic approaches or methodology for addressing these problems (Karakis et al., 2011, 2012; Rouwenhorst et al., 2000).

Elements, issues, and parameters related to warehouse design are dependent on the type of warehouse. Thus, the type of warehouse for which the methodology will be valid was first determined. Distribution centres for the FMCG industry were selected for several reasons:

- The importance of balancing speed and volume compared to other warehouse types (e.g. raw materials warehouses)
- The possibility and probability of storage of different types of products within the same warehouse location, implying usage of different types of equipment and rack systems
- The existence of specific processes and applications (e.g. cross docking, value-added services, etc.)

III. METHODOLOGY

A comprehensive literature review of journal articles was conducted using library facilities. A range of electronic databases were searched, including Emerald Insight, EBSCO Host, Science Direct, Springer Link, and Taylor & Francis Journals. These databases were searched using relevant keywords, especially “warehouse” combined with “design” of those details regarding the classification of the existing topics investigated and the methods used in the existing studies in the literature are stated in Karakis et al. (2011). Moreover, detailed interviews were conducted with executives of two global and four local leading logistics service provider companies as well as one local logistics consulting company in Turkey. These logistics service provider companies are the top companies in the Turkish market in terms of client base, especially among FMCG companies, and in terms of projects and service variability and use of leading practices in warehousing function. In addition, executives of three leading global FMCG companies and two local retail companies were interviewed (Karakis et al., 2011). The interviews were performed with sales, business development, and warehousing executives of logistics companies and distribution centre managers and supply chain managers of the industrial companies. The interviews covered current approaches and tools used for warehouse design projects, main critical decision points, improvement areas for the warehouse design process, and so forth. The studies conducted by Muther (1987), Gu et al. (2007, 2010), Rouwenhorst et al. (2000), and Baker and Canessa (2009), and Baker (2010) were theoretical background of this study and taken as starting points. Moreover, the need of such an overall design methodology is treated as the main future research area by Baker and Canessa (2009). Thus, the systematic methodology stated in this paper is also aimed to address the gaps identified by Baker and Canessa (2009).

All the information gathered from the different resources was used for the development of the hierarchical warehouse design approach, illustrated in Figure 1.

---

**Figure 1. Approach for development of warehouse design methodology.**
3.1 Hierarchical Warehouse Design Approach

Effective and efficient warehouse management requires sustainable cost and service performance. The factors that affect cost and service level performance are determined during the warehouse design phase. Both fixed costs like rent and depreciation, which average 30–50% of total warehousing costs, and variable costs like personnel, heating, cooling, and lighting are all determined during the design phase. The economic life of a warehouse is 25–30 years, and equipment life averages 5–10 years. Therefore, a warehouse that is not flexibly designed according to expected performance criteria can negatively affect company performance for many years (Baker, 2010).

As stated above, the warehouse design process takes a large number of interrelated decisions into consideration (Rouwenhorst et al., 2000). Therefore, this paper asserts that warehouse design should be evaluated according to three hierarchical levels: strategic, tactical, and operational. The approach in this paper assumes that the outcomes of each level are used as inputs for the next level and that the various steps or tasks are interrelated.

3.1.1 Strategic Level

The reasons for warehouse design include the building of a new warehouse, migration to a larger/smaller warehouse, and modification of an existing warehouse. The first step in the strategic level is to determine the strategic goals in order to be able to define the warehouse design problem in more detail. These goals are determined according to the following points:

- Warehouse type and purpose
- The industry the warehouse will serve
- The number of product groups in the warehouse (one or multiple)
- The number of floors in the warehouse (one, two, etc.)
- Goals related to desired sustainability of the warehouse
- The number of customers that the warehouse will serve (one or multiple)

The second step is to make a decision regarding the warehouse location. At this stage, such aspects as territory limitations due to topography and legal regulations should be examined. This step will be visited again after dimensioning of the warehouse is completed in order to determine a suitable location for the warehouse. The third step includes a comprehensive data analysis in order to determine the general design principles of the warehouse. Data analysis should have two phases, including a current state analysis (material flow, quantities, and movements) and a future state design (future goals, new products). This is the most time-consuming step. Two basic data collection tasks are always applicable: storage analysis and movement analysis (Baker, 2010).

A key decision point in warehouse design involves the need to balance speed and volume. Because speed and volume requirements are often conflicting, the optimization of this balance is crucial. Besides storage and movement analysis, volumetric analysis should be conducted as well. The results of this analysis are particularly critical for warehouse management systems. For this analysis, products that have large physical volume with fast movements should be the focus (Baker, 2010). According to the outcomes of these analyses, material flow diagrams are developed for each different type of product through different lines. After this, a Pareto analysis can be conducted to provide input for a warehouse sizing study in terms of determining warehouse units, volume, and dimensions.

The next step is to decide whether the warehouse will be conventional or automated. There are advantages and disadvantages to automated warehouses (Baker and Halim, 2007). Recent research has indicated that scale (pallets stored) and throughput (pallet movements per hour) are key factors in the choice of automation by retailers, manufacturers, and logistics service providers (Baker, 2010). A study by Dallari et al. (2006) shows that automated warehouses tend to be selected when storage location values are higher than 5,000–7,000 pallets and the pallets moved per hour are greater than 50–60. Since this is one of the key strategic decisions, it is advised that not only the current situation but also the future state of the warehouse be taken into account before taking the final decision. At this stage, hybrid solutions (e.g., a partly automated warehouse) can be evaluated if the movements and storage volumes differ among the various product groups.

The next step is to determine the warehouse flow type (e.g., S type, I type, or U type), depending on the inputs from the previous steps. Moreover, this step also involves identification of general process flow principles that affect the tactical and operational level steps. During this step, receiving, bulk stock, dispatch, and picking should be considered as the main flows (Baker, 2010). The purpose of this step is to determine the high-level area requirements.

As the final step of the strategic level, the high-level warehouse layout should be developed by taking into consideration basic processes as well as some special processes relevant to distribution centres, like value-added services and special storage conditions. At the end of this step, the main deliverable is the high-level layout with a rough estimation of the total storage area; the estimate will be matured on the basis of the decisions made during the following levels.
3.1.2 Tactical Level

The first step of the tactical level is to determine storage policies, including selection of a storage method and an order picking method. Dedicated storage, random storage, class-based storage, and product-group-based storage are the main methods that should be evaluated and decided on during this step (Rouwenhorst et al., 2000). For determination of the storage location, cube-per-order index (COI) rule can also be considered (de Koster et al., 2007).

In the second step, aisle configuration should be determined based on storage policies. The third step includes racking system selections and equipment selections. After these outcomes are fully determined, warehouse aisles should be reviewed and aligned with the racking systems and equipment selected. At this stage, warehouse sizing will be translated into floor space in order to assess construction and operating costs (Gu et al., 2010). Lastly, the detailed warehouse layout should be decided upon, with determination of the warehouse dimensions as the last step in the tactical level.

3.1.3 Operational Level

The operational level starts with the detailed design of the warehouse processes, with the outcomes of the high-level design of the processes conducted during the strategic level treated as inputs.

For receiving, the number of docks and doors of the warehouse should be determined, and putaway and order picking processes should be designed in greater detail during this step. With regard to putaway and storage, department or rack dispersion will be determined. The order picking process is the most important process from a work force perspective since this process requires around 60% of all work force used within the warehouse (de Koster et al., 1999). During picking process design, suitable picking methods (batching, single order picking, zone picking, etc.) should be determined for each product group. A cross docking process should be designed, if necessary. This special process is crucial for FMCG and retail industry companies that have many distribution centres. One process that should receive special attention is batching, which is the grouping of orders during the picking process (Gu et al., 2007). The key tasks are to determine whether batching will be used and, if so, to define the most suitable batch method and batch quantities. Value-added services, such as sorting, storing, routing and sequencing, and shipping, are other processes that should be designed with an eye towards the future requirements of the warehouse. All these processes will be designed at the task level on the basis of principles set during the strategic design level. After all processes are designed for execution in daily operational life, the number of staff needed for carrying out these operations within the warehouse is calculated.

3.1.4 Evaluation and Implementation

The purpose of this stage is to evaluate the possible different design alternatives and figure out the implementation details resulting from all of the steps stated above. Sample evaluation techniques and key indicators are listed below (Baker, 2010):

- Determining the costs for equipment and staffing as well as the budgets for the design alternative(s)
- Evaluation of alternative(s)
  - Financial evaluation (calculation of total cost of ownership with consideration of investment costs and operational costs, net present value (NPV) analysis, return on investment (ROI) calculation, etc.)
  - Technical evaluation (customer service level, throughput rate, environmental analysis, risk analysis, simulation, etc.)

At this stage, the following key performance indicators are proposed, with the breakdown for each thread shown in Table 2.

<table>
<thead>
<tr>
<th>Thread</th>
<th>Performance Indicator</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1 – Strategic Goals &amp; Investment Planning</td>
<td>Return on Investment (ROI)</td>
<td>Net Profit/Investment Cost</td>
</tr>
<tr>
<td>S1 – Strategic Goals &amp; Investment Planning</td>
<td>Energy Consumption per m²</td>
<td>Total Energy Consumption/m²</td>
</tr>
<tr>
<td>S4 Conventional/Automated Warehouse</td>
<td>Cost per Storage Unit</td>
<td>Total Costs/Total Number of Storage Units</td>
</tr>
<tr>
<td>S4 Conventional/Automated Warehouse</td>
<td>Ratio of Operational Costs to Total Costs</td>
<td>(Operational Costs/ Total Costs) × 100</td>
</tr>
<tr>
<td>S4 Conventional/Automated Warehouse</td>
<td>Cost per m²</td>
<td>Total Costs/Net m²</td>
</tr>
<tr>
<td>S4 Conventional/Automated Warehouse</td>
<td>Order Picking Time</td>
<td>Total Time Between Start and Finish of Picking an Order</td>
</tr>
</tbody>
</table>

Table 2. Performance indicators for hierarchical warehouse design.
After all of these steps are completed at the three different hierarchical levels, the warehouse design should be evaluated and realized in terms of building the warehouse, implementation of equipment and warehouse management systems, and recruitment of the required staff. After all steps are completed, the warehouse will start to operate according to the design. It is advisable to monitor the performance of the warehouse to enable continuous improvement.

Figure 2 shows the hierarchical warehouse design approach for distribution centres that covers the design topics and related activities described above.
IV. FINDINGS AND IMPLICATIONS

The proposed methodology was validated with top management executives of two out of seven logistics service provider companies interviewed (as described above). Iterated deep interviews were conducted with a focus on the validity, usability, and applicability of the methodology for real life cases. This conceptual approach was validated by one of these leading logistics service providers that has operations across EU region as well through a recent real life warehouse design project. The outcomes of the proposed approach were compared with the actual results of an existing warehouse project named “Project Esenyurt 1” with a 22,000 m² area and a capacity of 14,000 pallets, 400,000 hanging garments, and 90,000 cases. The warehouse is a multi-purpose distribution centre that serves FMCG and textile companies. The warehouse project team reworked the warehouse design on the basis of business requirements by utilizing the systematic methodology proposed in this paper. The outcomes of this application in terms of realized benefits are stated by the head of business and system development as follows:

- The proposed methodology is easy to use and helpful since it provides a systematic and intelligible way of completing an end-to-end warehouse design project.
- The methodology covers all the necessary steps of warehouse design and provides a better and more efficient way of managing the impacts of different phases on each other. In this application, it enabled mistake-proofing and reduced human errors by providing a standard approach for the entire design process. Therefore, the design phase duration of the project decreased from four months to three months. In other words, the model improved the total design phase duration by 25% since it reduced re-work efforts significantly compared to the period of time required for the original design of this distribution centre.
- The methodology was used as a reference model or checklist for the project team and provided for better monitoring and coordination across the whole project team, including third parties. For that reason, the seniority level of the project team decreased, and this resulted in a decline in the allocated human resources budget for the design phase from $98,500 to $49,250. This means an improvement of the human resources budget of 50%.
- The proposed model helped in figuring out and evaluating different design alternatives in a more rapid, robust, and consistent way.

The company has also stated that they will institutionalize the utilization of this methodology for their warehouse design projects in the future since the methodology is also useful for managing corporate intelligence for these types of projects.

Moreover, this methodology was utilized in another warehouse design project by another local key logistics service provider that runs their operations not only in Turkey but also several countries. The Strategic Planning and Marketing Manager of the company stated that it is highly significant in warehouse design to have a systematic method because many decision points and tasks need to be undertaken, so the proposed design approach was useful in terms of providing a framework for designing more efficient warehouses. The
methodology enabled positive outcomes with regard to human resource costs, duration of the design phase of the project, and efficiency of equipment and helped in making decisions during the warehouse design process. This company has also confirmed that they will utilize this approach as a reference model on their future projects.

V. CONCLUSIONS

Warehouses are essential for any supply chain. Since most of the parameters that affect warehouse operations in terms of both costs and performance are determined during the design phase, warehouse design is becoming more crucial day by day.

It is obvious from the findings of the literature review that although there is a general consensus on the overall structure of approaches to warehouse design, there is less consensus on the tools to be used or on a systematic warehouse design approach (Baker and Canessa, 2009; Karakis et al., 2011, 2012). In light of this, a design methodology called a hierarchical warehouse design approach was developed for distribution centres in the FMCG industry, as described in this paper.

The warehouse design process includes many tasks and decision points, some of which are interrelated. Therefore, it is hard to determine the optimum results for each decision since the results may be altered by factors encountered in real life situations (Rouwenhorst et al., 2000). A conceptual model was therefore developed for systematic warehouse design with the purpose of making warehouse design more efficient and cost effective. In addition, there is an enormous gap between published warehouse research and the practice of warehouse design and operations, and effectively bridging this gap would improve warehouse design methodology (Guet et al., 2010).

Because of the gaps between academic work and real life practices, deep interviews were conducted with seven key logistics service providers during the development of this hierarchical warehouse design methodology. The described methodology provides an end-to-end, holistic approach for warehouse design problems by proposing a systematic flow for each design parameter and taking into consideration their interrelations. This methodology can be treated as a roadmap for warehouse design projects by both academicians and practitioners because these gaps are not only stated for Turkey by Karakis et al. (2012) but also stated for the UK by Baker and Canessa (2009). Therefore, the methodology can be a key guideline for warehouse design projects of companies across the Europe, as it is already validated two logistics companies which both have international operations.

The benefits of this methodology are the following:

- An end-to-end, holistic approach for overall warehouse design problems
- A systematic approach that covers all the key steps of warehouse design
- Addresses the sequence and steps of warehouse design tasks along with sub-problems/sub-tasks
- Assists in determining the relationships of these tasks with each other and the impacts of one task on others

VI. RESEARCH LIMITATIONS

For further research, this conceptual model should be extended to other types of warehouses. Moreover, it was realized during the development of the methodology that the steps and/or the tasks under the steps correspond to different issues to be solved by different techniques or methods. Further research can focus on these problems separately and determine the appropriate solutions in order to reveal the implications of that specific problem for overall warehouse design.

REFERENCES


Hierarchical Warehouse Design Approach for Distribution Centres


