AN ANALYSIS OF KEY WAREHOUSE RESOURCES

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This study explores key warehouse resources. A typology consisting of six key warehouse resources is proposed. An empirical study is used to validate the typology and determine the level of constraints at the key warehouse resources in present-day warehouses. The findings pave the way for future research focusing on methods to manipulate the key warehouse resources for higher performance.

INTRODUCTION

This is a conceptual study exploring key resources used in warehouse operations. The need for the study stems from this industry's changing role and size and recent challenges that academic literature on warehousing has not adequately addressed.

The role of warehousing has been changing on both macroeconomic and microeconomic levels. In an empirical study using social network analysis of archival panel data for two decades, Iyengar et al. (2012, p. 373) demonstrated that, "over time, logistics and warehousing have not only become more powerful, but have gone from being peripheral activities to being increasingly central and important in the larger economy." CSCMP's ***Annual State of Logistics Report*** calls warehouses the heart of the supply chain (A.T. Kearney, 2017). In 2017, there were over 17,000 establishments in the Warehousing and Storage subsector, code 4931 in the North American Industry Classification System (NAICS); and the employment in this subsector for the first time exceeded 1 million people (Bureau of Labor Statistics, n.d.). Many more warehouses are auxiliary parts of companies that fall under different NAICS codes based on their primary activities. CSCMP's ***Annual State of Logistics Report*** estimated the total US expenditures on public and private warehousing in 2016 at $143.5 billion (10% of the total logistics costs), with a 3% annual growth forecast in the next five years (A.T. Kearney, 2017).

On the microeconomic level over the past three decades, warehousing has gone through fundamental changes driven by rising costs of money and labor, rapid development of technology and information technology in particular, fierce global competition, rising customer expectations, and a transition of supply chain control from manufacturers to retailers (Dadzie and Johnston, 1991; Raney and Walter, 1992; Faber et al., 2002; Richards, 2017). Warehouses have experienced a dramatic increase in productivity and throughput rate, level of automation, reliance on information technology systems, expanded menus of services, improved service quality, and reduction of lead times and order processing costs (Dadzie and Johnston, 1991; Stank et al., 1994; Faber et al, 2002; Richards, 2017). However, the most important changes have been at the strategic level.

After the influential work of Porter (1985) on competitive advantage of firms and business strategies and adaptation of his work to warehousing by McGinnis et al. (1987) and McGinnis and Kohn (1988), warehousing started to be viewed as a part of a broader business strategy, both in business and in research (Murphy and Poist, 1992). It has been recognized that warehouses are not merely cost centers, but they are part of the value creation chain and can contribute to the cost leadership strategy through advantages in operating costs and the differentiation strategy through improved service quality (McGinnis and Kohn, 1988; Murphy and Poist, 1992; Stank et al., 1994; Richards, 2017).

However, on both fronts, cost and service, warehouses are increasingly experiencing major challenges. With the thin, three to six percent profit margins, warehouses find it hard to invest in new technologies or deal with rising labor costs, while customer expectations of ever-faster deliveries and exploding omnichannel ordering add complexity and put further pressure on limited warehouse resources (A.T. Kearney, 2017). Warehouse managers are expected to accomplish more with less (Frazell, 2002; Peschke, 2001) and turn for help to academics.

Academic research linking competitive advantage and resources has been potent. One of the most popular management theories used in supply chain research is the Resource Based View (RBV) proposed by Barney (1991) (Carter et al., 2017; Defee et al., 2010; Zimmerman and Foerstl, 2014)**.** RBV's main original tenet is that a firm can gain a sustained competitive advantage over other firms if it possesses resources that are valuable, rare, imperfectly imitable, and nonsubstitutable. Over the years, several extensions of RBV have emerged and have transitioned from identifying resources of the firm to focusing on their use (Fawcett and Waller, 2011).

One such approach to resources is the resource management theory (RMT) (Esper and Crook, 2014). RMT contends that possession of valuable, rare, inimitable, and nonsubstitutable resources is important, but not sufficient, for obtaining a competitive advantage over other firms (Sirmon et al., 2007). It is critically important how resources are created, deployed, combined, managed, and exchanged by the management of the firm (Lippman and Rumelt, 2003).

Unfortunately, academic research stops at this very general level – there is no specific theory applicable to warehousing that will suggest how warehouse managers should deploy and manipulate available warehouse resources. In fact, there is not even an agreement about what those resources are. Thus, the first order of business to deal with this problem is to identify what resources are available and which of them matter (Wernefelt, 1989). Therefore, the research question of the study becomes: *What are the key warehouse resources?*

This study undertakes a comprehensive review of warehouse resources with a goal to develop classification principles and a *key warehouse resource* typology that is useful in practical operations and provides a more cogent basis for further theoretical and empirical research that will explore possible resource manipulations and their effects.

The structure of the paper is as follows. In the next section, a key warehouse resource is defined conceptually. Based on a focused literature review, a conceptual framework is selected for further theory development leading to a typology of key warehouse resources. Next, survey data are reported as empirical validation of the proposed typology. The concluding section of the paper summarizes the findings, details theoretical and practical contributions of the study, addresses its limitations, and proposes directions of future research.

THEORY DEVELOPMENT

Key Warehouse Resources: Definition and Tests

Current academic literature on warehousing looks at warehouses as systems comprised of processes, resources, and organization, e.g., Rouwenhorst et al. (2000). This study focuses on the resources portion. Before any study of the influence of warehouse resources on its performance can be undertaken, a conceptual understanding of what constitutes a warehouse resource must be developed. While there is abundance of academic literature on warehousing, most papers deal with narrow, well-defined problems (Rouwenhorst et al., 2000), so general classifications of warehouse resources and processes can only be found in academic papers whose main purpose is literature review, such as Gu et al. (2007, 2010), Cormier and Gunn (1992), and Rouwenhorst et al. (2000), or in practitioners' handbooks, such as Frazell (2002), Tompkins and Smith (1998), and Richards (2017).

Warehouse resources are frequently understood to include personnel, material handling equipment, an information technology system, and a storage system (Hackman et al., 2001; Rouwenhorst et al., 2000). However, there is no full agreement on what constitutes a warehouse resource. For example, some view bar code scanners and carton boxes as resources (Rouwenhorst et al., 2000). The inclusion or exclusion of resources from the warehouse resource lists seems to be arbitrary. An argument can easily be made to consider pen and paper as warehouse resources, as well as the lighting and ventilation systems. There does not appear to be a conceptual definition of warehouse resources based on their attributes which would allow grouping them into a useful typology. Besides, a nominal possession of a resource may not be sufficient for higher performance or a competitive advantage; given the modern challenge of warehouses to do more with less, the quantity, or capacity, of a resource must be taken into consideration (Peschke, 2001).

Drawing on the mission of the warehouse in the supply chain and the critical need to have sufficient level of resources to address the modern challenges of warehousing, we propose the following definition of a critical, or key, warehouse resource: *it is a component of a warehouse design or operation that is critical to the mission of the warehouse, is not easily acquirable or modifiable, and has a finite or limited capacity at least in the short term.*

To clarify specific parts of the definition, the mission of the warehouse is commonly understood as a combination of storage and throughput of products at a desired level of quality and minimum resource cost (Gu et al., 2007; Frazell, 2002). Only those resources that support the required level of storage capacity and throughput directly may qualify as key warehouse resources. In other words, key warehouse resources have a critical bottleneck potential that will affect the flow of goods or related information directly and have an impact on quality and cost. We will refer to this statement as the inventory flow impact test (IFIT).

In this definition of a key warehouse resource, "not easily acquirable or modifiable" refers to the fact that a change in the resource, such as an acquisition of additional quantity of this resource or a modification of its characteristics, is not possible to accomplish within the routine processes of the day-to-day operations. It requires substantial waiting time, incurrence of a substantial cost, being subject to a hierarchical management review process, or being simply not available (or no longer available), or any combination of the above. It is also not easily substitutable within the routine processes of the day-to-day operations. For short, we will call this the cost-effort-time test (CETT).

Finite capacity refers to the attribute of a key warehouse resource that cannot be increased infinitely within the existing warehouse organization and process design. In other words, a key warehouse resource has the potential to become a long-term bottleneck in the warehouse operations if the demand for it has outgrown its capacity and management has not been proactive to implement a plan to alleviate the problem, such as increasing the capacity of the resource. A key warehouse resource may reach its maximum capacity, and then it will become a permanent constraint until the existing warehouse design or process is changed.

It should be noted that this research looks at resource capacity from the perspective of its potential to fall behind the demand for it due to growth of the regular operations, not the situation when a resource is out of order or broken and just needs to be restored to its normal capacity to stop being a bottleneck in the warehouse operations.

To summarize, every warehouse uses a broad variety of inputs that may be treated as key resources. Lack of capacity of some of them may present only a trivial problem, whereas a shortage of some other resources may be difficult to overcome. The important attribute of a key warehouse resource is that it has a strong potential to limit warehouse capacity and throughput by becoming a big problem that cannot be fixed quickly and easily.

Typology of Key Warehouse Resources

The proposed formal definition of a key warehouse resource and two tests can be used as tools to create a useful typology of key resources in a typical warehouse. But first, we turn to academic literature to briefly examine already available classifications of warehouse resources. It provides several lists of various warehouse resources. The most succinct list is comprised of four resources: labor, space, equipment, and warehouse management system (Hackman et al., 2001).

The most comprehensive list is found in the work of Rouwenhorst et al. (2000).

1. Storage unit, e.g., pallets, carton boxes and plastic boxes;
2. Storage system, e.g., shelves;
3. Pick equipment, e.g., a reach truck;
4. Orderpick auxiliaries, e.g., bar code scanners;
5. Computer system, e.g., warehouse management system;
6. Material handling equipment for sorting, packing and loading into transportation vehicles, e.g., sorter systems, palletizers and truck loaders;
7. Personnel.

Applying the cost-effort-time test (CETT) of a key warehouse resource to the latter typology, we can eliminate Items 1 and 4 since their representative examples (pallets, boxes and bar code scanners) can be acquired relatively easily and inexpensively. Items 3 and 6 represent material handling equipment used for the picking operation and the steps following it. Separating these into two different categories seems illogical for two reasons: (1) the same piece of equipment, such as a counterbalance forklift, can be used for both picking a pallet and loading it into a truck, even on the same move; and (2) this division ignores operations preceding picking, such as goods unloading and putaway, which, coincidentally, can also be performed by that same forklift. So it makes sense to aggregate material handling equipment into one category. Finally, this research emphasizes traditional warehousing operations that are less likely to use sorter systems and palletizing machines found in high-velocity warehouses that rely on substantial automation. Thus, we can replace the broader term of material handling equipment simply with lift trucks, a general term for warehouse machines such as forklifts, reach trucks, order pickers, etc.

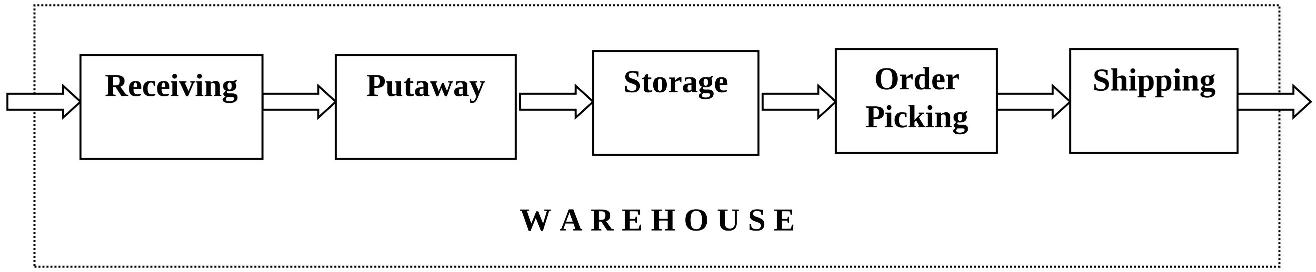
The arguments above reduce the list of warehouse resources to just four items: storage system, lift trucks, personnel and warehouse management system (WMS). Each of them meets the inventory flow impact test (IFIT) in that the capacity of the resource directly affects the capacity and throughput of the warehouse. In case of a WMS, it concerns the information flow. However, the flow of goods and information is synchronized at least periodically and a warehouse management system lagging in speed or deficient in functionality negatively impacts the flow of goods in the end.

The four identified resources also meet CETT. Adding more storage racks, buying more lift trucks, hiring and training more warehouse workers, or upgrading the existing warehouse management system are projects that may take months and substantial investment or spending and are likely to be presented by warehouse managers to their superiors for capital approval before any implementation is initiated. Moreover, all four resources can be viewed as potentially finite, the first three due to spatial limits (as well as possibly others), and the WMS may not be able to be modified to include new functionalities or increased processing speed due to the internal limitations of the software.

However, the list of key warehouse resources identified above appears to be incomplete. Some resources have been overlooked by researchers and need to be added to this list. They can be discovered by identifying potential bottlenecks in the typical inventory flow of a warehouse as shown in Figure 1. This illustration reflects a common approach of warehouse managers and warehouse management system designers as well as some authors who wrote for practitioners (Frazell, 2002; Keller and Keller, 2014); in academic research, the putaway operation (moving goods from the receiving area to storage locations) tends to be viewed as part of another step: receiving (Gu et al., 2007) or storage (Rowenhorst et al., 2000).

Figure 1.

Flow of goods in a warehouse.



It is clear from this figure that the four previously identified key warehouse resources have a direct impact on the goods flow in putaway and picking and on capacity in goods storage by becoming a constraint, should the demand for a particular resource exceed the resource capacity. Receiving and shipping deserve a more detailed analysis.

Examples of receiving activities are unloading, checking for discrepancies, and repacking (Gu et al., 2007; Rowenhorst et al., 2000). Shipping may involve goods preparation for transportation (palletizing, stretch-wrapping), quality control, and loading into a transport conveyance such as a truck (Rowenhorst et al., 2000).

In their comprehensive review of research on warehouse operations, Gu et al. (2007) classify assigning trucks to docks (doors) and scheduling of loading and unloading trucks as part of the receiving and shipping operation. They also note that research on receiving and shipping is scarce (four papers out of 124 reviewed). Most work that deals with receiving and shipping concerns cross-docking operations, particularly the truck-to-dock assignment problem, e.g., Tsui and Chang (1990, 1992). More recently, retailers started to increasingly implement cross-docking in their distribution centers to reduce inventory and achieve other efficiencies (Waller et al., 2006) by relying on automated sorting operations. Automation severely limits the flexibility of the warehouse manager to manipulate warehouse resources (Richards, 2017) and is not considered in this study.

Now that we have defined receiving and shipping for the purposes of this research, we can consider the role of the four key warehouse resources. Labor, lift trucks and warehouse management system are essential for receiving and shipping. However, the storage system does not apply as receiving and shipping occur outside it. This means that we are missing an important spatial component. Space is a primary, finite resource of any warehouse (Smith and Peters, 1988). It is critically important to allocate the right amount of space for receiving and shipping activities that occur on the dock (Smith and Peters, 1988). It is clear that the shortage of that space may severely constrain the goods flow. This space cannot be easily added to within the context of routine operations, i.e., keeping the existing warehouse organization and process design fixed. We will use the term *dock space* to designate this key warehouse resource that meets both tests: IFIT and CETT.

According to Gu et al. (2007), receiving and shipping are the two warehouse interfaces for incoming and outgoing material flow. However, a careful look at Figure 1 will reveal that the goods have to pass through the warehouse wall twice: first, to get into the receiving area and second, when leaving warehouse from the shipping area. They go through a warehouse door. The number of doors, and sometimes their specific characteristics (size, availability and length of dock-leveler, etc.), can put a physical constraint on the inventory flow in and out of the warehouse if the demand for the doors or specific type of doors is higher than their availability.

There is practically no academic literature on warehouse doors that considers the supply and demand relationship within the traditional warehouse operations. The scarce cross-docking literature considers the optimum door layout for truck assignments (Gue, 1999) or travel and waiting time minimization due to congestion (Bartholdi and Gue, 2000) and is not applicable to the insufficient door capacity problem in an existing traditional warehouse operation. Existing handbooks and textbooks, e.g., Tompkins and Smith (1998) and Ballou (2007), provide instructions for engineers on design and calculations of doors to match initial desired throughput requirements, but they do not address the need to accommodate an increase in the actual throughput over time. Ackerman (1999) suggests designing new warehouse buildings with depressed footers to allow future installation of dock doors as necessary. This great advice is, unfortunately, a missed opportunity for companies conducting warehouse operations in existing regular buildings, but his suggestion of moving away from dedicated door assignments to flexible arrangements (Ackerman, 1999) could be a feasible practical recommendation to implement.

Warehouse dock doors meet both tests of a key warehouse resource. Even with wall breaking, the number of doors is finite; adding this resource is very difficult and costly; and it definitely has the potential to become a constraint and slow down the inventory flow.

In a way, doors as a resource are similar to labor or lift trucks: they have capacity measured in numbers (number of people in the shift, number of working (available, not broken) lift trucks and number of working doors) and productivity (units of output per unit of time per person or per lift truck, and number of trucks served per unit of time per door). Just like warehouse workers' skills and lift trucks, doors may be more specialized or more universal. This provides insight into the similarity of constraints that doors can impose on warehouse operations.

What about lighting, temperature control, or fire safety systems (such as sprinklers)? Do they fall under our definition of key warehouse resources? No, they do not. They are a precondition to a normal warehouse operation. They can become a constraint if there is a change in the content of the operation but not the volume. For example, switching to storing and handling a different product in the warehouse may require a change in lighting, ventilation, fire safety systems, etc. However, as part of the normal operation, these systems do not affect the goods flow and are not considered key warehouse resources for the purposes of this research. To emphasize, this research does not consider situations when something is broken; justifying fixing a broken piece of equipment does not need a new theory.

Thus, analyzing previous research and the flow of goods through the warehouse we have identified a total of six key warehouse resources. They are:

1. dock doors;
2. dock space (staging area);
3. a storage system;
4. labor;
5. lift trucks (MHE);
6. warehouse management system (WMS).

They are critical for the mission of the warehouse and any one of them can potentially become a serious bottleneck, or constraint, in regular warehouse operations.

EMPIRICAL VALIDATION

As has been known for some time, the proof of the pudding is in the eating (Camden, 1623). A survey of warehouse managers was conducted to determine if the key warehouse resources in the typology are recognized and used by warehouse managers in practice, as well as to compare which key warehouse resources appear to be more constrained.

The Survey Instrument

The survey questionnaire was prepared using a popular survey software application. Most questions were in the form of a 7-point Likert scale (from "Strongly agree" to "Strongly disagree"). The survey was administered online by a commercial service using online panels. As recommended in online survey methodological literature (Bethlehem and Biffignandi, 2012; Callegaro et al., 2014, 2015), collected data were screened for cases of satisficing (careless respondents' behavior) and misrepresentation fraud, and such responses were eliminated. Data cleaning resulted in retaining 215 responses. It has been noted in online survey methodological literature that a response rate for nonprobability online panel surveys is nearly impossible to estimate and is less useful (Bethlehem and Biffigandi, 2012), so it is recommended that the term "response rate" should be avoided in reference to online panel surveys (Baker et al., 2010).

The survey instrument collected basic information about the respondent and the respondent's warehouse. Warehouses with a high degree of automation and non-traditional operations (value-added, cross-docking) were excluded to maintain focus on traditional warehouse operations. After the demographics section, the respondent was asked to select resources available in the respondent's warehouse and indicate for each selected resource if the warehouse has experienced a shortage of it in the past three years. The period was chosen following an industry survey conducted by Sale and Inman (2003). Respondents were then asked to rate the severity of the shortage on a scale from 1 ("Not severe at all") to 7 ("Extremely severe"). To determine if the list of the six warehouse resources is exhaustive, an option to select an additional resource and name it was given.

The modern challenge of warehousing, an expectation of higher performance with the same or fewer resources may be perceived by warehouse managers as a condition of operating with constrained resources. It is interesting to compare warehouses on the degree to which their key resources are constrained. To do this, a special resource constraint index (RCI) was developed. Since multiple selections were possible and expected in the constrained resources matrix, the difficulty for the researchers was to combine multiple constraints of different severity into just one variable in order to effectively measure the overall level of constraint of operations within the warehouse. No prior literature was found applicable to constructing a measure of how badly constrained multiple resources were in a warehouse, but a literature search for similar scenarios in other fields yielded a few cases, the most applicable of which is briefly discussed below.

In a situation similar to this, Geri and Ahituv (2008) applied the theory of constraints to joint IT systems implementation in the supply chain. They used a 7 by 11 cell matrix with 3 levels to choose from in each cell. They assigned numerical values of 0, 1, and 2 for each of the cell choices and constructed an index based on the sum of all numerical values plus an arbitrary 50 points for another condition considered to be very important. This simple summation approach plus an arbitrary correction for another condition was deemed inappropriate for our study. Clearly, seven resources mildly constrained at the level of 1 are not the same condition as having one level-7 severely constrained resource. Instead, a common statistical practice of squaring values and summing them was chosen. This resulted in a resource constraint index (RCI) with the range of potential values from 1 to 343 (for six plus one resources).

Sample Overview

Profiles of a typical respondent and warehouse in the sample are presented in Table 1 and discussed in more detail further.

Table 1.

Profiles of a typical respondent and warehouse

Category	Value
Warehouse	
• Size (employees)	45
• Years operated	17
• Growth of business over 3 years (%)	26
• Place in supply chain	distributor or wholesaler
• Primary goods stored	finished
• Industry by primary product	consumer
• Predominant picking type	by case
Manager	
• Scope of responsibility, warehouses	1
• Years in charge, period	3 to 6

While respondents were specifically requested to respond to all questions about one warehouse, they were also asked to select how many warehouses they managed. More than half of the respondents (57%) were in charge of just one warehouse, but 21% were in charge of two, and the remaining 22% of respondents were responsible for more than two warehouses.

One survey question asked respondents about how many years they were responsible for their warehouse. In addition to simply collecting demographic information, respondents who selected the answer “0 – 2 years” were shown an additional question asking if they were familiar with the operations of their warehouse for the past three years, and those answering negatively were automatically disqualified from the survey because it covered a three-year period of warehouse operations. This affected the demographic distribution of respondents to this question by reducing the share of those who had been responsible for their warehouses for less than three years (but had a good knowledge of operations there for the full three year period) to 11%. The largest category of managers (39%) were in charge of their warehouses from 3 to 6 years, the next largest (30%) – from 7 to 10 years, with the remaining 20% having managerial responsibility for their warehouses for more than 10 years.

In addition to questions about warehouse managers, the survey collected basic information about the warehouses as well. The average warehouse employed 45 people, not counting management, with a standard deviation (SD) of 73 and was operated by the respondent's company for 17 years (SD = 14). Over the three years, an average warehouse experienced a 26% growth of business (SD = 31; the question was in the format of a sliding scale allowing a decline as well as growth).

The warehouses were split into four categories. When respondents were involved in more than one type of business, they were asked to indicate the one most applicable. Fifteen (7%) were for profit third-party logistics providers, 72 (33%) were primarily manufacturers, 108 (50%) were wholesalers, and 20 (10%) were predominately retailers. In a binary division by product type, 116 (54%) of the respondents handled primarily industrial goods, and 99 (46%) dealt in consumer products. Another binary category, type of picking (predominantly by pallet or predominantly not by pallet) resulted in a split of 75 (35%) to 140 (65%), respectively. As expected, the largest storage category was finished goods (125 warehouses; 58%).

Warehouse Constraints

Arguably, the most interesting part of the survey data was the warehouse resource constraint index (RCI). We offer a brief discussion of individual constraints data that were used in the construction of the index.

To remind, respondents were asked to identify among the six key warehouse resources the one(s) they were short on for half a year or longer in the preceding three years and rate the severity of their constraint on a 7-point Likert scale, where 7 was the most severe condition. Additionally, respondents had an option of selecting and rating an "other" resource (as well as identifying it in a conditionally activated subsequent question). Table 2 illustrates the distribution of the constraint incidence frequencies and severities among the key warehouse resources.

As seen from the table, the biggest constraint for warehouses in the sample was a lack of storage space, followed in the descending order of severity by a shortage of human resources, dock space, IT resources (WMS), lift trucks, miscellaneous other resources and doors. These rankings agree with evidence from industry. For example, average and peak space utilization statistics are among the most tracked metrics of operational performance of warehouses according to a report published by Warehouse Education and Research Council (Manrodt et al., 2013). Constraints due to lack of the two key warehouse resources, storage space and work force, have always been the primary concern in the business growth scenarios. Our study shows that, not only do these problems occur most frequently (the largest share of warehouses that reported them), but also their negative impact is perceived as the greatest (highest mean severities).

Table 2.

Frequency and severity of constraints

Constrained resource	Number of warehouses	Percentage in sample	Mean severity	SD
Storage	184	86	4.09 [a]	1.93
Personnel	168	78	3.79	1.91
Dock space	162	75	3.55	1.87
Lift trucks	150	70	2.87	1.77
WMS	140	65	3.19	1.94
Doors	133	62	2.30	1.69
Other	101	47	2.63	1.93
Average RCI	215	100	70.64 [b]	56.38

a. On a Likert scale from 1 (lowest) to 7 (highest); only the warehouses that reported a shortage of this resource were included in the calculation of this statistic.
b. Allowed range from 1 (lowest) to 343 (highest).

A close third in the rankings list is dock space, a resource that is barely mentioned in the literature beyond engineering textbooks and handbooks on warehouse layout. However, industry professionals know it is the easiest one to trade off when there is a shortage of storage space by storing some product on the dock. This is likely the reason for its high rank in the hierarchy of constraints.

At the bottom of the list are doors and miscellaneous other resources. More than half of the warehouses in the sample reported that they did experience a shortage of doors in the preceding three years, but its severity appears to be very mild. Doors have been overlooked in academic research, but industry evidence shows that it is easy to increase this resource by simply working overtime or restructuring the shifts (going from one to two, or switching to a six- or seven-day workweek). This trade-off with personnel, the most flexible warehouse resource, may potentially explain the finding.

The respondents' choices of the miscellaneous "other" category, when examined in detail through the supporting text, appeared to contain some external constraints as well as many extensions of the previous six key resources when respondents used it as a way to explain their problem in more detail.

Several respondents mentioned cash or financial resources. There are two types of "cash." The money required to run a regular warehouse operation does not affect the product flow *directly* and is just a necessary condition for an operation, just like electricity. Prolonged lack of operating cash (e.g., not being able to pay workers' wages or perform repairs to forklifts, storage racks or doors) essentially reduces the capacity of the key resources and makes the whole operation unsustainable. However, the negative effect is indirect and manifests itself through the same six key warehouse resources. Similarly, the other type of financial resources, investment capital for resource capacity upgrades, has only indirect influence on the warehouse capacity and throughput through the same key warehouse resources. Thus, cash in itself is not a key warehouse resource.

The lack of a common theme in this category is an indirect supporting evidence of the fact that the six key warehouse resources identified in this study appear to completely cover the typical constraint problems in a warehouse. If the “Other” category is excluded from the average warehouse RCI, it assumes a value of 65.65 (SD = 51.74), only 5 points below the full RCI, thus the “other” category may be completely disregarded.

It is also worth noting that in the three-year period an average warehouse reported experiencing constraints in four different key warehouse resources out of six (Mean = 4.36; SD = 1.92). The average adjusted RCI value of 65.65 is an equivalent of having all six key resources constrained at a medium level (between 3 and 4 on the 7-point Likert scale), or of having two severe constraints (between 5 and 6). Therefore, a conclusion follows that warehouse managers have to deal with constraints in the key warehouse resources on a regular basis, and the challenge of doing more with less is indeed *challenging*.

CONCLUSION

With the supply chain management concept taking a strong foothold, warehouses have moved to a more prominent position in modern economy and business as a high value operation and a strategic factor of competitive advantage that could be potentially gained through warehouse resources manipulation. However, the modern day pressures of business to accomplish more with fewer resources and a lack of specific resource management theories applicable to warehousing make this task difficult to perform. This study made the first step on the way to such theory through a detailed analysis of warehouse resources that may be available for such manipulation. This study contributed both to warehousing research and practice in several ways.

Contributions to Applied Research

This study has made several contributions to applied research in warehousing. First, we offered a definition and two tests of a key warehouse resource. Previous resource classifications in academic literature were not based on a single definition or clearly spelled-out logic.

Second, various warehouse resources have been analyzed, and six that are critical for its mission have been identified. All key warehouse resources were selected based on two important attributes: a) the potential to become a long-term constraint on warehousing operations and b) direct impact on the flow of goods. Thus, this study produced a typology of six key warehouse resources. Development of this typology will be a contribution to the academic literature on warehousing, as well as a tool providing managers with a new perspective of their warehouse operations.

Third, two of the key warehouse resources were not previously identified as such in warehousing research. Dock doors and dock space have been largely ignored in research literature. We include them in the typology because they are part of warehouse interface with transportation, the beginning and ending points of warehouse material flows that create throughput. Doors and dock space have common characteristics with the other four key warehouse resources and pass both the inventory flow impact test and the cost-effort-time test of a key warehouse resource.

Fourth, we attempted to empirically validate the proposed typology. Is the list of six key warehouse resources exhaustive? For most warehouses in the U.S., evidence from our study suggests an affirmative answer. The survey responses to the optional “other” resource choice lacked any common theme and were mostly extensions or specifics of the previous six. It is possible to imagine a different context where another resource, pallets or something else that comes in contact with the goods and is routinely available to most warehouses in the U.S., is in chronic short supply there. But the key warehouse resource definition and the two tests that we offered should provide the right answer for that context as well.

Fifth, a single measure to compare warehouses on the condition of having constrained resources was developed. In a very diverse industry like warehousing, the resource constraint index is a rare exception of a universal metric applicable to any traditional warehouse operation.

Contributions to Practice

Based on this study, we can provide warehouse managers with advice on effectively managing warehouse resources.

Every warehouse can be viewed as a system whose primary dimensions are overall capacity and throughput. They influence logistics and financial performance of the warehouse. As operations grow, most warehouses will experience constraints in their operations. The constraints will limit the system’s throughput and may have a negative effect on overall warehouse performance. This study suggests that six resources are critical to operations of a warehouse: doors, dock space, storage capacity, personnel, lift trucks, and WMS. Our research shows that, in a typical warehouse, more than one resource may be constrained at the same time, and some of the constraints may be severe. Capacity problems with these six resources cannot be solved quickly and easily, thus monitoring them and planning corrective action proactively is the only way to deal with such problems. Actively managing the key resources will allow alleviating and eliminating those constraints.

Limitations and Future Research

This study has a number of limitations. The main comes from the use of the survey method. Surveys are known to introduce bias. Online surveys may introduce additional bias (Boyer et al., 2001). We have taken many precautionary measures to minimize it, yet we cannot guarantee its absence.

The scope of the study was limited. We focused on traditional warehouse operations with little or no automation. Thus, the results may not be generalizable to highly automated warehouses.

In this study, we have found that contemporary warehouses routinely experience multiple and severe shortages (constraints) of their key resources, which prevent them from fully reaching their performance objectives. Knowing the exact problem opens the door to studying potential solutions. When it comes to managing warehouse resources, the purpose of this study was to answer the question of “what to manage;” the “how” question is a natural continuation of this study to be addressed by future research.

It should build on the concept of the key warehouse resources by exploring ways to manage them to alleviate constraints that limit their capacity and throughput. Application of several resource management theories, e.g., theory of constraints, may be explored.

REFERENCES

A. T. Kearney. (2017), **CSCMP's Annual State of Logistics Report**. http://cscmp.org /store/SearchResults.aspx?Category=SOL

Ackerman, K. (1999), "Designing Tomorrow's Warehouse: A Little Ahead of the Times," *Journal of Business Logistics*, (20), pp. 1-5.

Baker, R., Blumberg, S. J., Brick, J. M., Couper, M. P., Courtright, M., Dennis, J. M., Dillman, D., et al. (2010), "Research Synthesis. AAPOR Report on Online Panels," *Public Opinion Quarterly*, (74), pp. 711-781.

Ballou, R. H. (2007), **Business Logistics/Supply Chain Management**, (Pearson Education India).

Barney, J. (1991), "Firm Resources and Sustained Competitive Advantage," *Journal of Management*, (17), pp. 99-120.

Bartholdi, J. J., and Gue, K. R. (2000), " Reducing Labor Costs in an LTL Crossdocking Terminal," *Operations Research,* (48), pp. 823-832.

Bethlehem, J., and Biffignandi, S. (2012), **Handbook of Web Surveys**, (John Wiley & Sons).

Boyer, K. K., Olson, J. R., and Jackson, E. C. (2001), " Electronic Surveys: Advantages and Disadvantages over Traditional Print Surveys," *Decision Line*, (32), pp. 4-7.

Bureau of Labor Statistics. n.d. "Warehousing and Storage: NAICS 493." Accessed April 15, 2018. https://www.bls.gov/iag/tgs/iag493.htm.

Camden, W. (1623), **Remaines Concerning Britaine: But especially England and Inhabitants thereof. Their Languages. Names. Surnames. Allusions. Anagrammes. Armories. Monies. Empreses. Apparell. Artillary. Wise Speeches. Prouerbs. Poesies. Epitaphs,** (London: Nicholas Okes for Simon Waterson).

Carter, C. R., Kosmol, T., and Kaufmann, L. (2017), "Toward a Supply Chain Practice View," *Journal of Supply Chain Management*, (53), pp.114-122.

Cormier, G., and Gunn, E. A. (1992), "A Review of Warehouse Models," *European Journal of Operational Research,* (58), pp. 3-13.

Dadzie, K. Q., and Johnston, W. J. (1991), " Innovative Automation Technology in Corporate Warehousing Logistics," *Journal of Business Logistics*, (12), pp. 63-82.

Defee, C. C., Williams, B., Randall, W. S., and Thomas, R. (2010), "An Inventory of Theory in Logistics and SCM Research," *International Journal of Logistics Management*, (21), pp. 404-489.

Esper, T. L., and Crook, T. R. (2014), “Supply Chain Resources: Advancing Theoretical Foundations and Constructs,” Editorial, *Journal of Supply Chain Management*, (50), pp. 3-5.

Faber, N., de Koster, R. (M.) B. M., and van de Velde, S. L. (2002), ” Linking Warehouse Complexity to Warehouse Planning and Control Structure: An Exploratory Study of the Use of Warehouse Management Information Systems,” *International Journal of Physical Distribution and Logistics Management,* (32), pp. 381-395.

Fawcett, S. E., and Waller, M. A. (2011), “Moving the Needle: Making a Contribution When the Easy Questions Have Been Answered,” *Journal of Business Logistics,* (32), pp. 291-295.

Frazelle, E. H. (2002), **World-Class Warehousing and Material Handling,** (McGraw-Hill, Inc).

Geri, N., and Ahituv, N. (2008), “A Theory of Constraints Approach to Interorganizational Systems Implementation,” *Information Systems and e-Business Management,* (6), pp. 341-360.

Gu, J., Goetschalckx, M., and McGinnis, L. F. (2010), “Research on Warehouse Design and Performance Evaluation: A Comprehensive Review,” *European Journal of Operational Research,* (203), pp. 539-549.

Gu, J., Goetschalckx, M. and McGinnis, L. F. (2007), “Research on Warehouse Operation: A Comprehensive Review,” *European Journal of Operational Research,* (177), pp. 1-21.

Gue, K. R. (1999), ” The Effects of Trailer Scheduling on the Layout of Freight Terminals,” *Transportation Science,* (33), pp. 419-428.

Hackman, S. T., Frazelle, E. H., Griffin, P. M., and Vlasta, D. A. (2001), “Benchmarking Warehousing and Distribution Operations: An Input-Output Approach,” *Journal of Productivity Analysis,* (16), pp. 79-100.

Iyengar, D., Rao, S., and Goldsby, T. (2012), “The Power and Centrality of the Transportation and Warehousing Sector within the US Economy: A Longitudinal Exploration Using Social Network Analysis,” *Transportation Journal,* (51), pp. 373-398.

Keller, S. B., and Keller, B. C. (2014), **The Definitive Guide to Warehousing,** (Council of Supply Chain Management Professionals.)

Lippman, S. A., and Rumelt, R. P. (2003), “A Bargaining Perspective on Resource Advantage,” *Strategic Management Journal,* (24), pp. 1069-1086.

Manrodt, K. B., Vitasek, K. L., and Tillman, J. M. (2013), "DC Measures 2013." In: **WERCwatch. A Periodic Assessment of Industry Trends,** (Warehousing Education and Research Council.)

McGinnis, M. A., Carlson, R. W., Forry, L., and Fong, L. (1987), "Competitive Pressures and Emerging Strategies in Public Warehousing," *Transportation Journal (26),* (4), pp. 43-53.

McGinnis, M. A., and Kohn, J. W. (1988), "Warehousing, Competitive Advantage, and Competitive Strategy," *Journal of Business Logistics,* (9), pp. 32-54.

Murphy, P. R., and Poist, R. F. (1992), " Managing the Human Side of Public Warehousing: An Overview of Modern Practices," *Transportation Journal,* (31), pp. 54-62.

Peschke, R. E. (2001), " Resource Capacity and the Theory of Constraints," *2001 APICS Constraints Management Technical Conference Proceedings,* (March 19-20, 2001, San Antonio, TX), pp. 49-51.

Porter, M. E. (1985), **Competitive Advantage**, (New York: The Free Press).

Raney, M. A., and Walter., C. K. (1992), " Electronic Data Interchange: The Warehouse and Supplier Interface," *International Journal of Physical Distribution and Logistics Management,* (22), pp. 21-26.

Richards, G. (2017), **Warehouse Management: A Complete Guide to Improving Efficiency and Minimizing Costs in the Modern Warehouse,** (Kogan Page Publishers.)

Rouwenhorst, B., Reuter, B., Stockrahm, V., van Houtum, G. J., Mantel, R. J. and Zijm, W. H. M. (2000), "Warehouse Design and Control: Framework and Literature Review," *European Journal of Operational Research,* (122), pp. 515-533.

Sale, M. L., and Inman, R. A. (2003), "Survey-Based Comparison of Performance and Change in Performance of Firms Using Traditional Manufacturing, JIT and TOC," *International Journal of Production Research,* (41), pp. 829-844.

Sirmon, D. G., Hitt, M. A., and Ireland, R. D. (2007), "Managing Firm Resources in Dynamic Environments to Create Value: Looking Inside the Black Box," *Academy of Management Review,* (32), pp. 273-292.

Smith, J. D., and Peters, J. E. (1988), "Warehouse Space and Layout Planning" in Tompkins, J. A., and Smith, J. D., ed., **The Warehouse Management Handbook**, (Tompkins Press).

Stank, T. P., Dittman, J. P., and Autry, C. W. (2011), " The New Supply Chain Agenda: A Synopsis and Directions for Future Research," *International Journal of Physical Distribution and Logistics Management,* (41), pp. 940-55.

Stank, T. P., Rogers, D. S., and Daugherty, P. J. (1994), " Benchmarking: Applications by Third Party Warehousing Firms," *Logistics and Transportation Review*, (30), pp. 55-72.

Tompkins, J. A., and Smith, J. D., ed. (1998), **The Warehouse Management Handbook**, (Tompkins Press).

Tsui, L. Y., and Chang, C-H. (1990), "A Microcomputer Based Decision Support tool for Assigning Dock Doors in Freight Yards," *Computers & Industrial Engineering*, (19), pp. 309-312.

Tsui, L. Y., and Chang, C-H. (1992), "An Optimal Solution to a Dock Door Assignment Problem," *Computers & Industrial Engineering*, (23), pp. 283-286.

Waller, M. A., Cassady, C. R., and Ozment, J. (2006), "Impact of Cross-Docking on Inventory in a Decentralized Retail Supply Chain," *Transportation Research Part E*, (42), pp. 359-382.

Wernerfelt, B. (1989), "From Critical Resources to Corporate Strategy," *Journal of General Management*, (14), pp. 4-12.

Zimmerman, F., and Foerstl, K. (2014), "A Meta-Analysis of the "Purchasing and Supply Management Practice–Performance Link," *Journal of Supply Chain Management*, (50), pp. 37-54.