Revising the warehouse productivity measurement indicators: ratio-based benchmark

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Abstract

Purpose – The literature on warehouse performance assessments is mainly focussed on the efficiency and effectiveness of an action or activity due to customer demand and tailored fulfilment, with less attention being given to the performance measurement of each function of the warehouse and its overall productivity. Therefore, this study was aimed at revising the key warehouse performance metrics to a set of productivity measurement indicators that can be adopted internationally for benchmarking productivity performance.

Design/methodology/approach – A literature review and semi-structured survey questionnaire were used for this study. The importance of warehouse productivity performance was reviewed to revamp the measurement indicators. Through the use of a directed content analysis and descriptive analysis, an extensive study was carried out to analyze existing warehouse productivity indicators.

Findings – The findings of this study provide comprehensive references for practitioners and academicians for improving the classification of productivity measurements from existing key performance metrics for warehousing. Also, this paper highlights the warehouse resources related to the respective warehouse operation activities.

Research limitations/implications – The study was limited to productivity performance indicators adapted from Staudt *et al.* (2015). Furthermore, the samples for this study comprised Malaysian academicians and practitioners in the related field. The findings can be adapted on a global scale as this study implemented general warehouse operation processes.

Originality/value – Consequently, the contributions of this study are that it provides relevant benchmarks for key productivity performance indicators in the warehousing sector that has worldwide applicability and the developed model provides a conceptual platform from which further theoretical and empirical developments can be carried out.

Keywords Logistics, Content analysis, Supply chain management, Physical distribution, Warehouse performance, Ratio-based productivity

Paper type Research paper

1. Introduction

The expanding globalization, the advancement of the world economy and developing industrialism of consumer orders have prompted an increased demand for logistics, transport, as well as warehousing services. The role of warehouses in the supply chain is very crucial because they contribute significantly to the storage of goods from the time of production until the goods are supplied to consumers on demand. In the highly competitive business environment of today, a warehouse is not just a place to store inventory but also to manage and operate value-added services (Kolinski and Sliwczynski, 2015).

Warehouses are constantly under pressure to increase productivity and accuracy while reducing costs and improving customer service. The measurement of productivity is the most significant dimension for warehousing to monitor the output from the input provided in warehouse operations. This study was prompted to revise the existing literature on warehouse productivity in view of several issues that have been raised regarding the measurement of warehouse productivity. The Asian Productivity Organization (2016) stated that instead of relying on their financial statements alone, small and medium enterprises should consider implementing a productivity measurement system (with value-added and logistics productivity indicators). According to Jacyna-Gołda (2015), the indicators that measure the efficient use of resources must be associated with the performance of tasks and functions to maximize the workload while minimizing the working cost. Johnson and McGinnis (2010) addressed the need to develop a valid model to account for resource inputs and service outputs, which will be useful in the conceptual design of new warehouses. In this context, the ratio method was introduced to measure the productivity of warehouse performance by using all the important warehouse resource inputs (capital and labour) and multiple service outputs (resulting from warehouse operations). Conclusively, productivity performance assessments in warehousing are significant to identify areas of improvement by using the resource inputs.

Hence, this study was aimed at revising the existing 10 warehouse productivity indicators (Staudt *et al.*, 2015) that express the tasks within the work area into one model of warehousing productivity measurement indicators. Apparently, the performances of key metrics can be varied in many companies, but this study generalized the engagement of the results of significant resource inputs and outputs in every basic warehouse activity that can be easily accessible by any warehouse. By

using an appropriate productivity performance measurement, together with the adoption of the latest technologies and innovations, a company can review and reward the productivity performance of its employees.

2. Literature review
2.1 Definition of warehouse
The terms "warehouse" and "distribution centre" are often used interchangeably, but there are a number of differences between the two, as illustrated by other studies. Dawe (1995) stated that a warehouse handles most products in four cycles, namely, receive, store, pick and ship; while, a distribution centre handles most products in two cycles, namely, receive and ship (De Koster *et al.*, 2007). A warehouse is more than just a place where inventory is stored. The role of a warehouse in the supply chain network is essential because it provides temporary storage before the products reach the customers.

In fact, warehousing is integrally involved in four distinct supply chain processes, namely, sourcing/inbound logistics, processing/manufacturing, outbound distribution and reverse logistics (returns, recycling, etc.) Harrington (1998). Faber *et al.* (2013) defined warehouse management as a combination of planning, decision-making and controlling inbound, storage and outbound flows. Figure 1 illustrates the generic warehouse activities that are performed to some degree in all warehousing operations as it is possible that one or more of them do not exist in a given facility or are combined
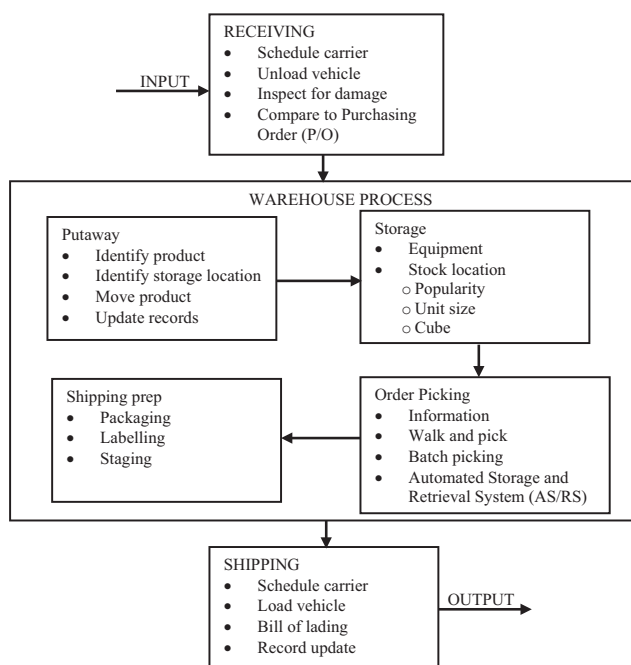
Source: Bowersox *et al.* (2007)

Figure 1.
Basic warehouse operations

with other activities (Gourdin, 2006). Therefore, the word "warehousing" will be used throughout this study.

2.2 Previous studies on warehouse productivity indicators
Liviu *et al.* (2009) analyzed the performance of warehouses by adopting John M. Hill's indicators, which are grouped into three categories, namely, "inventory management", "warehouse performance" and "order fulfilment". The respective authors also defined the measurement elements for the activities under each of these three category indicators. For instance, under "warehouse performance", the indicators include four measurement elements, namely, orders per hour, items per hour, cost per order and cost as a percentage (per cent) of sales.

However, Kusrini *et al.* (2018) analyzed the performance of warehouses using the 25 key performance indicators (KPI) introduced by Frazelle (2002), which include productivity, financial, cycle time, quality and utilization, as shown in Table 1. In addition, Kusrini *et al.* (2018) found that the most important KPI for receiving is productivity, for putaway is cycle time, for storage is utilization, for order picking is cycle time and for shipping is productivity.

In addition, productivity is a subject that has been discussed for many years, and nowadays, there is a growing interest in productivity with regard to performance measurement. Usually, business entities are evaluated on their profitability and operational productivity. Warehouse productivity is measured by the ratio of multiple outputs relative to a specific input (Dowlatshahi, 2000; Kolinski and Sliwczynski, 2015). According to Stainer (1997), the term "productivity" is often ill-defined, but basically, its measurement is that of a prescribed output to the resources consumed and it can be divided into three main types:

(1) Partial productivity is the ratio of output to a single input such as labour, materials or capital.

(2) Total factor or value-added productivity is based on sales less bought-in goods, materials and services.

(3) Total productivity is the ratio of total output to total input.

However, the National Council of Physical Distribution Management (1978) claims that not all the indicators commonly used in logistics to monitor productivity are strictly output and input measures as many relate more to utilization and efficiency. It also suggests that the measurements should be complete and more comparable, covering the use of all resources to be more valid in todays' complex environment.

Warehouse resources consist of space, equipment and personnel (Pirttilä and Hautaniemi (1995); Hackman *et al.*, 2001; Chow *et al.*, 2006; Richards, 2011; Kłodawski *et al.*, 2017). Operational productivity is usually measured as the number of units handled per person (De Vries *et al.*, 2016). It is also inappropriate and inaccurate to call it labour productivity as this would be to neglect other resources, which can result in the performance output being seriously misleading. Therefore, Hackman *et al.* (2001) proposed a productivity benchmark, as shown in Figure 2, by considering all the warehouse resources and outputs from the warehouse operations.

Essentially, Staudt *et al.* (2015) provided a literature review from the dimension of 10 operational performance productivity indicators, namely, labour productivity throughput, shipping productivity, transport utilization, warehouse utilization, inventory space utilization, outbound space utilization, picking productivity, receiving productivity and

| Activity	Financial	Productivity	Utilization	Quality	Cycle time
Receiving	Receiving cost per line	Receipts per man-hour	% Dock door utilization	% Receipts processed accurately	Receipt processing time per receipt
Putaway	Putaway cost per line	Putaway per man-hour	% Utilization of putaway labour and equipment	% Perfect putaway	Putaway cycle time (per putaway)
Storage	Storage space cost per item	Inventory per square foot	% Locations and cube occupied	% Locations without inventory discrepancies	Inventory days on hand
Order picking	Picking cost per order line	Order lines picked per man-hour	% Utilization of picking labour and equipment	% Perfect picking lines	Order picking cycle time (per order)
Shipping	Shipping cost per customer order	Orders prepared for shipment per man-hour	% Utilization of shipping docks	% Perfect shipments	Warehouse order cycle time

Source: Frazelle (2002).

Table 1.
Warehouse key performance indicators

turnover. Meanwhile, Frazelle (2002) defined five indicators under the productivity performance dimension (Table 1). In this context, a study conducted by Karim *et al.* (2018) adopted the 10 indicators of warehousing productivity introduced by Staudt *et al.* (2015) to rank the importance of the indicators affecting the failure of warehouse productivity operations. Besides, Laosirihongthong *et al.* (2018) found in their research that practitioners place more value in the performance resource utilization category on equipment utilization and labour productivity compared to space utilization. Conclusively, Table 2 illustrates the warehousing productivity measurement indicators proposed by Staudt *et al.* (2015), with modifications made by Karim and Abdul Rahman (2018).

Therefore, this study was conducted as an extension of the warehouse productivity measurement proposed by Staudt *et al.* (2015) and took into consideration other indicators within the work area. Two indicators were recognized in this study for the development of

Warehouse Model: INPUT AND OUTPUT SPECIFICATION
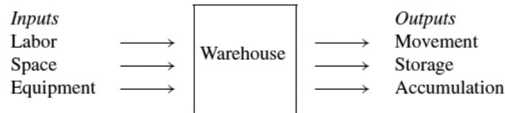
Source: Hackman *et al.* (2001)

Figure 2.
Input and output warehouse model

Indicator	Definitions	Citation
Labour productivity	The ratio of the total number of items managed to the amount of item-handling working hours	Attar *et al.* (2012)
Throughput	Items/hour leaving the warehouse	Mentzer and Konrad (1991); Kiefer and Novack (1999); Altarazi and Ammouri (2018)
Shipping productivity	Total number of products shipped per time period	Mentzer and Konrad (1991); Kiefer and Novack (1999); Cagliano *et al.* (2014); Frazelle (2002)
Transport productivity	Vehicle fill rate	O'Neill *et al.* (2008); Matopoulos and Bourlakis (2010)
Warehouse utilization	The average amount of warehouse capacity used over a specific time	Rimiene (2008); Johnson and McGinnis (2010); Wang *et al.* (2010)
Inventory space utilization	The rate at which space is occupied for storage	Ramaa *et al.* (2011); Rizzi and Zamboni (1999); Frazelle (2002)
Outbound space utilization	Utilization of the area inside the warehouse used for retrieving, order picking, packing and shipping	Johnson *et al.* (2010)
Picking productivity	Total number of products picked per labour hour in picking activity	Kiefer and Novack (1999); Manikas and Terry (2009); Petersen *et al.* (2004); Frazelle (2002)
Receiving productivity	Number of vehicles unloaded per labour hour	Mentzer and Konrad (1991); Wang *et al.* (2010); Faber *et al.* (2002); Frazelle (2002)
Turnover	The ratio of the cost of goods sold to the average inventory	Johnson and McGinnis (2010); Yang and Chen (2012)

Source: Karim and Abdul Rahman (2018)

Table 2.
Warehousing productivity measurement indicators

the warehouse productivity measurement model, namely, equipment utilization and putaway productivity. In addition, Staudt *et al.* (2015) stated that inbound indicators should be considered in future studies, as the inbound performance is as important as the outbound performance and will affect all the warehousing results. Putaway is very crucial as the decision in inbound operations is used to design the storage space (Lam *et al.*, 2010) because of its importance with regard to the stock-keeping units and its direct impact on the picking process in outbound operations. Meanwhile, the equipment should also be considered in productivity performance, as all activities that are performed in the warehouse, especially the movement of goods within the warehouse, make use of internal transport (Govidaraj *et al.*, 2000; Jacyna *et al.*, 2015). The equipment used and the materials handled can be measured in various dimensions, including the cost incurred for advanced equipment and maintenance, the time consumed and the downtime (Staudt *et al.*, 2015), as well as in terms of the efficiency (Pyza *et al.*, 2011). Hence, this study also focussed on picking productivity and equipment utilization, which were considered for the productivity measurement indicators.

2.2.1 Equipment utilization. Equipment can be categorized under vehicles, storage systems and conveyor systems (Hackman *et al.*, 2001). Equipment utilization can be determined by the size of the equipment (material handling) required for a system. Equipment utilization has been extensively defined by several scholars as:

- the average rate of utilization of mechanical equipment in logistics enterprises (He *et al.*, 2017);
- the given volume (or mass) of the load transported by given equipment or means of transport in a given unit of time (Pyza *et al.*, 2011); and
- the ratio of the capacity used to the maximum available capacity (Jothimani and Sarmah, 2014). Beamon (1998) summarized that the utilization value will be greater than one when the vehicle can carry multiple loads.

2.2.2 Putaway productivity. Putaway, which is very crucial for the inbound process in warehouse operations, is a process that requires a strictly determined storage location (Karasek, 2013). The most important concern is the putaway strategy after the incoming items have been received. Therefore, Lam *et al.* (2010) stated that the putaway performance can be measured by the number of trips required and the travelling time for each trip after considering the potential labour resources and the means of internal transport used to move the items from the docks to the designated storage area. In addition, the putaway productivity can be measured as the putaway lines per man hour (Frazelle, 2002; and Lakmal and Wickramarachchi, 2011). Hence, the putaway activity is very crucial during the inbound process to provide a reference as to the availability of stock to customers.

Therefore, this study was aimed at revising the key performance metrics for improving warehousing productivity indicators in terms of ratio-based benchmarks for implementing a warehouse measurement system.

3. Methodology
Face-to-face and semi-structured interviews were conducted in this study. Both closed-ended questions and open-ended questions were used in the survey. For the closed-ended questions, the respondents were required to choose from an offered set of alternatives (Krosnick, 2018). As such, the proposed model for the ratio-based warehousing productivity performance indicators was determined by the degree of

agreement on the classification of the resources, activities, indicators and definitions, respectively. By using closed-ended questions based on a five-point Likert scale ranging from "strongly disagree", "disagree", "neutral", "agree" and "strongly agree", data were collected from the respondents with regard to the proposed indicators (Joshi *et al.*, 2015). This was followed by open-ended questions to provide opportunities for multiple answers (Sabilah and Manoy, 2018) and strategies for discovering new things without being influenced by the researchers (Reja *et al.*, 2003). Thus, this research dealt with open-ended questions for comments and ideas for improving the proposed model.

3.1 Directed content analysis approach

Content analysis is a research technique for making replicable and valid inferences from texts or other meaningful matter within the context of their use to provide knowledge, representation of facts, new insights and a practical guide for action (Krippendorff, 1980). A content analysis is aimed at defining the characteristics of the contents of a document by considering who says what, to whom and with what effect (Bloor and Wood, 2006). According to Elo and Kyngas (2008), the purpose of a study determines the approach to be used for the content analysis that is whether the quantitative or qualitative data are to be used in an inductive or deductive way. In addition, the qualitative method typically involves the use of interviews and natural observations. Mayring (2014) mentioned that texts occur more often within social science, and the method involves analyzing the text materials themselves, including interview transcripts, focus groups, open questionnaires or observations and document analyzes. Meanwhile, there are three approaches to content analysis, namely, conventional, deductive and summative (Hsieh and Shannon, 2005; Hashemnezhad, 2015).

According to Hsieh and Shannon (2005), when an existing study is incomplete or would be of interest with a further explanation with the goal of validating or refining or extending a conceptually theoretical framework or theory, then a directed content analysis will be used. In a directed content analysis, as defined by Kyngas and Vanhanen (1999), the researcher uses a prior or existing theory research to develop the initial coding scheme before beginning to analyze the data. On top of that, Kaid (1989) stated that all approaches to a qualitative content analysis require a similar analytical process of seven steps, which are:

(1) formulating the research questions to be answered;

(2) selecting the sample to be analyzed;

(3) defining the categories to be applied;

(4) outlining the coding process and the coder training;

(5) implementing the coding process;

(6) determining the trustworthiness; and

(7) analyzing the results of the coding.

Table 3 shows the differences between the three approaches to content analysis.

Therefore, this study used the deductive/directed content analysis approach for the proposed model development, which was verified from both the academic and industrial perspectives by using the level of agreement. However, when denoting the qualitative content analysis, the researcher was not allowed to conduct a statistical

analysis to obtain the means of the data; therefore, other methods of analysis were required (Bengtsson, 2016). Hence, the data on the level of agreement was analyzed using the descriptive analysis approach. Then, the open-ended questions were analyzed using the directed content analysis approach to improve the model according to the participants' comments and suggestions.

3.2 Expert survey

An expert survey is a well-known survey-based approach. According to Gemenis (2015), experts are asked to make judgements of party positions based on their knowledge, and these are extended with recommendations. The experts for this study were classified by filtration, as shown in Table 4. The experts who were chosen were professionals with more than 5 years of experience in the industry and academicians who had 10 or more international publications (Da Cruz et al., 2013).

3.3 Research framework

Figure 3 shows the research framework for this study. The study was conducted according to the steps and procedures of the developed research framework to revise the warehousing productivity performance indicators using ratio-based benchmarks.

3.3.1 Step 1: Identify the problem. In this study, the problem was identified as the need to develop logistics (including warehousing) productivity performance indicators. Performance measurement issues are significant and successive to allow managers/ researchers to ratify relevant performance measures. Conventional productivity benchmarking approaches use input and output ratios, where the ratio value corresponds to the "best in class" based on the specific ratio definition (Chen and McGinnis, 2007). In other words, the performance indicator refers to the ratio of an output to an input or an input to an

Type of content analysis	Study starts with	Timing of defining codes or keywords	Source of codes or keywords
Conventional content analysis	Observation	Codes are defined during data analysis	Codes are derived from data
Directed content analysis	Theory	Codes are defined before and during data analysis	Codes are derived from theory or relevant research findings
Summative content analysis	Keywords	Keywords are identified before and during data analysis	Keywords are derived from the interest of researchers or review of literature

Source: Hsieh and Shannon (2005)

Table 3.
Major coding differences among three approaches to content analysis

| Criteria	Industrial experts	Academic experts
Classification	Involved directly or indirectly in warehouse operations management	Background of expert studies in logistics, warehousing and supply chain
Experience	At least more than five years	At least more than five years
Positions/ranks	Operational/ tactical/ strategic management level	Senior Lecturer/Associate Professor/Professor

Table 4.
Classification of experts
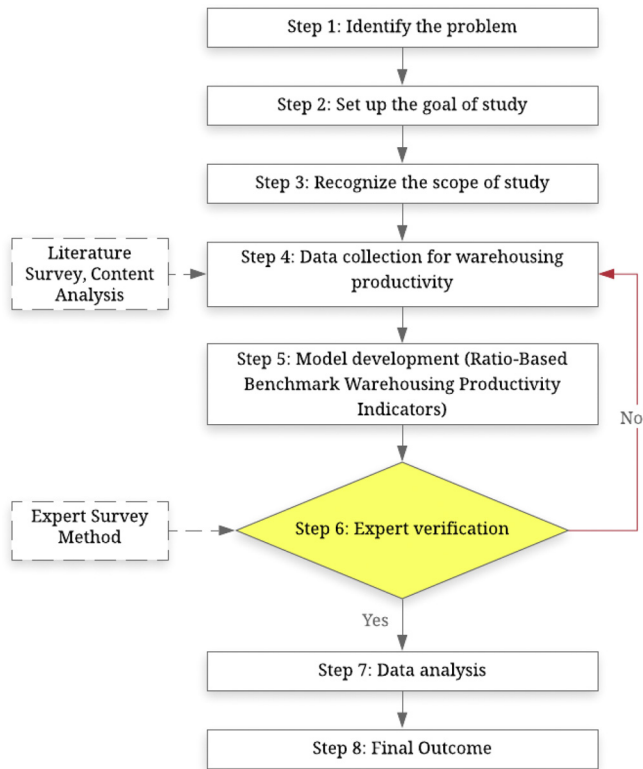
output (Thanassoulis *et al.*, 1996). Therefore, this study implemented the ratio-based productivity indicator measurement introduced by Staudt *et al.* (2015) because of the importance of allocating the warehouse resources efficiently and effectively to enrich productivity and to reduce the production cost of the warehouse (Richards, 2017; Poon *et al.*, 2009; Rama *et al.*, 2012). However, the introduced paradigm was incomplete, where some input resources and activity performances that were not included in the framework may result in an imbalanced and vulnerable productivity performance indicator benchmark. As such, these gaps raised the attention to investigate the necessary definitions of the ratio-based productivity indicators.

3.3.2 Step 2: Set up goal of study. The goal of this study was to revise the warehouse productivity indicators by enhancing the existing paradigm of the ratio-based productivity indicator benchmarks. A ratio-based benchmark was chosen in this study as its significance was in line with current industry practices. Thus, a complete study was conducted to formulate the warehousing productivity indicator model with concrete ratio-based benchmarks that will be applicable universally.

3.3.3 Step 3: Recognize the scope of the study. Warehouse performance is usually measured in terms of economic and technical efficiencies. This study focussed only on technical efficiency to measure the productivity performance according to ratio-based benchmarks. In addition, as discussed earlier, in the existing paradigm of warehouse

productivity indicators introduced by Staudt *et al.* (2015), the definition of each productivity indicator of the ratio-based benchmark is described. However, the model produced by Staudt *et al.* (2015) does not seem to cover all the respective productivity elements, which are the warehouse input resources and the activities involved with warehousing. Hence, this indicated the significance of revising the existing paradigm by considering the measurement of all the input resources (labour, equipment and space) and outputs (movement, storage utilization and accumulation) in terms of the technical efficiency.

3.3.4 Step 4: Data collection process. In this step, the data were collected from both primary and secondary sources. Initially, the data for the construction of the warehousing productivity performance indicators model were obtained from secondary sources (published journals, articles and books), as further explained in Step 5. Then, the constructed model (Table 5) was used to conduct a survey and discussions with experts to gather the first-hand data for analysis. The survey consisted of three parts, namely:

(1) the respondents' profile;

(2) questions based on a five-point Likert scale; and

(3) open-ended questions.

Meanwhile, the probability sampling technique was used to select a random sample of logistics experts from among both Malaysian academics and expert practitioners in the logistics, warehousing and supply chain fields. Table 5 illustrates the details of the selected experts, with their names and respective organizations written under pseudonyms to protect their anonymity and confidentiality.

3.3.5 Step 5: Model development – warehousing productivity performance indicators. As briefly discussed earlier, the input, defined as the warehouse resources, includes labour, equipment, space and cost. However, cost and capital investment was not discussed in the productivity measurement (Frazelle, 2002; Staudt *et al.*, 2015) and was referred to as another dimension of the warehouse cost performance measurement. Therefore, the model showed

Experts	Designation	Organization	Background/experience	Years of experience
Expert 1	Senior Lecturer	Organization A	Logistics management and warehousing/ logistics and warehouse	16 years (practitioner) 13 years (academic in logistics and warehousing)
Expert 2	Warehouse Executive (tactical level)	Organization B	Logistics and warehousing	8 years
Expert 3	Senior Logistic Manager (strategic level)	Organization B	Manufacturing, transportation and logistics	19 years
Expert 4	Warehouse Executive (tactical level)	Organization C	Warehouse	22 years
Expert 5	Warehouse Executive (tactical level)	Organization D	Warehouse	More than 10 years
Expert 6	Associate Professor	Organization E	Logistics and supply chain	25 years

Source: Authors' illustrations

the ratio of the resources to the tasks within the work area. The output of the warehousing activities within the work area was classified as the movement and storage in response to the performance of the input resources.

As shown in Figure 4, the model was developed using the content analysis and expert survey methods. The input resources (labour, equipment and space) were outlined as the key codes for the construction of the model. Then, by refining the ratio-based benchmark of each indicator, as introduced by Staudt *et al.* (2015), the keyword to describe each indictor was categorized into the respective input resource group. For example, the "labour productivity" indicator was the ratio of the number of items managed to the number of items handled during working hours, where the working hours were referred to as the labour input resource.

Meanwhile, this study identified the equipment input resource to be considered in the model, and proposed an indicator referred to as "equipment utilization". This was followed by the "putaway productivity" indicator, where the putaway activity that was performed during the inbound process was considered in the model. Thus, this model took into account the information in Table 2, namely, warehouse input resources (labour, space and equipment) and additional productivity indicators (putaway productivity and equipment utilization).

3.3.6 Step 6: Expert verification – academic and industrial perspectives. The survey data were obtained through personal interviews and electronic interactive media. The experts were selected according to the criteria for respondents, as shown in Table 4. In total, 10 questionnaires were sent to both professional and academic experts. However,
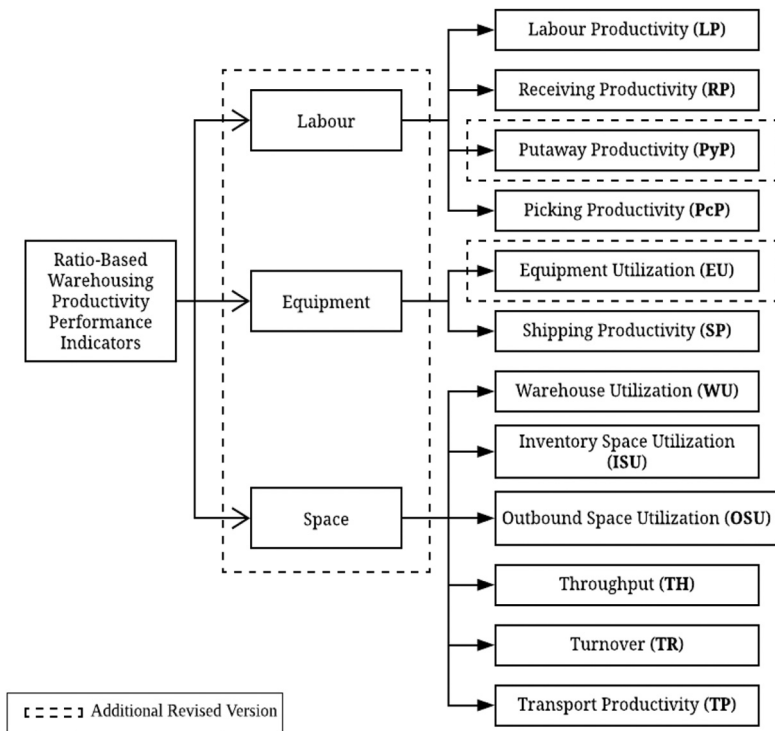

Figure 4.
First version of ratio-based warehousing productivity performance indicators

6 out of the 10 questionnaires were returned. The data for this study, particularly those that were collected through semi-structured interviews with six experts, were analyzed as they surpassed the minimum number of five experts for the expert survey (Davis *et al.*, 2009; Frehe *et al.*, 2017).

Table 6 illustrates the summary of the experts' comments, verification of the proposed model and the action that was to be taken. In this step, the gathered data were analyzed before the development of the warehousing productivity measurement indicators model was finalized.

3.3.7 Step 7: Descriptive data analysis process from experts' verification. The existing warehousing productivity indicators (Table 2) and proposed model development (Figure 4) were reviewed by the experts and their responses are recorded in Figure 5.

Figure 5 illustrates the analysis of the judgement options of the respondents such as strongly disagree, disagree, neutral, agree and strongly disagree. Overall, the respondents agreed with the proposed model (Figure 4), and their judgement options were based on the definition of each of the listed indicators. For instance, for labour productivity, it was recorded that one respondent disagreed, one was neutral, three agreed and one strongly agreed. Then, the experts preferred labour and equipment to be the main resources to be measured in both the inbound and outbound processes in warehousing operations. Meanwhile, under the space resource, the highest preference was for the "inventory space utilization" as this is very crucial, as every square foot available is to store or place goods, which will bring money to the company.

On top of that, all the experts were in favour of the proposed model, which consisted of 12 indicators, with some having been amended to rename the indicators and to clarify the definitions. Moreover, this study also considered the comments of the experts on the inclusion of additional indicators in the warehousing productivity measurement indicators model, and these will be presented as the final outcome of this study.

4. Findings
The final outcome, as illustrated in Table 7, was the revision of a set of ratio-based warehousing productivity measurement indicators. After the information had been gathered from the survey and discussed with the experts, all the suggestions of the experts were taken into consideration and the former indicators, as well as the ratio-based measurement for each indicator were revised. The resources remained as labour, equipment and space, with the inclusion of information system in the model, while the experts agreed that cost should not be incurred for measuring the productivity. Therefore, a comparison between the developed model (Figure 4) and the revised version of the model (Table 7) showed that some amendments were made, including the renaming of the indicators and the inclusion of additional resources, as well as warehouse activities. As such, the suggestions for equipment utilization' and "putaway productivity", that were made in the earlier stage of this study, were accepted. The experts had also suggested that the equipment resource should be expanded and that the productivity performance should be distinguished according to the basic warehousing activities. Meanwhile, the "putaway productivity" was extracted to measure the putaway operation performance in terms of labour and equipment resources, respectively. The labour and equipment resources were conclusively measured into the inbound (receiving and putaway) and outbound processes (picking and shipping).

Also, this model considered the categorization of "manpower productivity" with its definition as value-added services such as kitting, replenishment, packing and labelling,

Expert	Comments	Verification	Action
Expert 1	1. To add two more items or activities, namely: 2. Layout (under the space) Computer usage or IT (under all the three inputs) to ensure the model is complete and the research is done significantly	Agreed to additional indicators	• The layout has been categorized as warehouse utilization (WU), inventory space utilization (ISU) and outbound space utilization (OSU) • To consider the Information System as an additional indicator
Expert 2	1. Unfair to measure LP as it depends on customer orders 2. To consider communication in the model	Agreed, with slight comments	• Analyzing the LP • To consider the Information System as an additional indicator
Expert 3	1. Unfair to measure labour productivity (LP) as an indicator 2. WU indicator to be amended to building/ facility utilization and to be measured as a percentage 3. ISU indicator to be amended to storage space utilization and measurement to vary 4. OSU indicator to be amended to staging/inbound and outbound space utilization and to be measured as item per square foot over time 5. Turnover defined as the ratio of sales revenue to average inventory level 6. Delivery activity to be amended to loading and measurement of TU to vary	Agreed to rename the indicators and amend the definitions	To consider and analyze the comments to finalize and amend the model development
Expert 4	1. Good to measure the throughput indicator in the production warehouse 2. TP is not under warehousing responsibility but acts as an advisor to the customer in filling the container planning 3. Communication through information system is the major means of ensuring the productivity of the warehouse	Agreed, with slight comments	• To analyze the comments • To consider the information system as an additional indicator
Expert 5	1. Those indicators and measurements are to be used in their company and should be remarked as neutral	Overall agreed	To analyze the indicators and measurements
Expert 6	1. Labour can be addressed as manpower (a term that is usually used in industries) 2 Technology shall be included in equipment usage 3. To consider WMS, inventory management system and RFID in the model	Strongly agreed with strong measurement model	To consider the Information System as an additional indicator

Table 6.
Summary of data gathered from experts
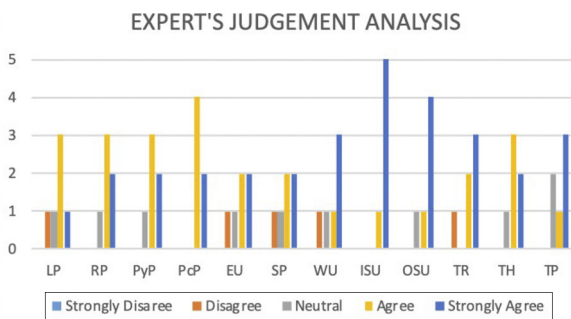
Note: Refer to Figure 4 for the full name of each indicator

Figure 5.
Experts' judgement
analysis

Input (Resources)	Activities	Indicator	Definition
Labour	Receiving[a]	Receiving productivity	Number of vehicles unloaded per labour hour
	Putaway[a]	Putaway productivity	Putaway per man hour
	Picking[b]	Picking productivity	Total number of products picked per labour hour in picking activity
	Value-added services[b]	Manpower productivity	The ratio of the total number of items managed to the amount of item-handling working hours
	Shipping[b]	Shipping productivity	Total number of products shipped per labour hour
Equipment	Receiving[a]	Receiving productivity	Number of vehicles unloaded per equipment
	Putaway[a]	Putaway productivity	Putaway per equipment
	Picking[b]	Picking productivity	Total number of products picked per equipment in picking activity
	Shipping[b]	Shipping productivity	Total number of products shipped per equipment
Space	Layout	Building utilization	The ratio of the number of the square foot used per total square feet capacity of the building
		Storage space utilization	The rate of space occupied by the storage as $\dfrac{\varkappa}{\gamma}$ $\varkappa =$ amount of capacity used by items (pallets, cartons, tons, square feet) $\gamma =$ total amount of available capacity (racking, square feet)
		Staging area utilization[a,b]	The ratio of items per square feet over the amount of time
	Storage	Turnover	The ratio between the number of outgoing items and average items in stock
		Throughput	Items per hour leaving the warehouse
	Loading	Transport utilization[b]	The ratio between weight/volume loaded over the total amount of weight/volume of container capacity
Information system	Communication	Warehouse management system	Optimization of the warehouse as a whole Measurement of the assigned task per hour

Notes: [a]Inbound process; [b]outbound process

Table 7.
The final revised
model development –
warehousing
productivity
measurement
indicators

which depend on customer demand and warehouse availability to provide the value-added services that are usually performed by labour. This was to ensure that the value-added services provided by the warehouse were taken into consideration to magnify the effectiveness and efficiency of the current supply chain management. Meanwhile, the space resource remained the same, except for slight changes, where the indicators were renamed as "building utilization", "storage space utilization" and "staging space utilization", with its categorization as the layout of the warehouse. This was followed by storage group activity, which remained with the same indicators of turnover and throughput. The "delivery" activity was amended to "loading" activity, where the term loading was much more reliable and it was thought best that it be renamed as "transport utilization", as its definition refers to the space capacity of the transport, where productivity is best defined for the movement performance.

After considering the comments and opinions of the experts, it was decided to include the "information system" element in the model as it is one of the most required resources for warehousing (Bartholdi and Hackman, 2014). As such, it was the information technology (IT) revolution that gave access to the specific mechanisms that appeared to increase productivity and profitability (King, 1998). Warehouse efficiency and firm performance are highly influenced by the positive relationship between warehouse operations and warehouse management information system (Mohd Saifudin et al., 2012; Ali and Haseeb, 2019). Some comprehensive integrated information systems in warehouse management systems influence the effective functions of the warehousing process (Klabusayova, 2013) and directly affect employee productivity, overall efficiency and even storage capacity (Ramaa et al., 2011). Therefore, this study proposed to measure the warehouse management system (WMS) productivity performance by the ratio of the assigned tasks per hour to improve the processing speed and time. For example, the assigned task can be referred to as the number of workers involved in the receiving activity per hour with the utilization of an information system in the process, resulting in an improved process and time saved per order. In addition, the information system will be used by the labour force, ranging from the operators to the upper management, to record, monitor and control the products using the available system. To summarize, the information system, which was generally addressed as the warehouse management system, was studied widely with various available inventory management systems to support the warehousing process as a form of effective communication throughout the process from the customer order, stock availability, stock leaving the warehouse and stock traceability.

For a better understanding of the revision process, Figure A1 (Appendix) demonstrates the three different models that had been improved accordingly.

5. Conclusion

In conclusion, the objective of this study, which was to revise the ratio-based benchmarks for warehousing productivity performance indicators, was achieved as the model deviated from the previous findings by Staudt et al. (2015) with the additional inclusion of warehouse input resources that reflected every warehouse activity.

A comprehensive review of warehouse productivity performance indicators for the measurement of the input of major warehouse resources (labour, equipment, space and information system) within the work area to represent the movement and storage output performance was clearly presented in this paper. Apart from that, a major concern among warehouse managers is how to increase productivity and accuracy,

reduce and control the cost of inventory and shipping, while providing good customer service (Richards, 2011). Therefore, the final model developed for warehousing productivity indicators can be adapted for worldwide applicability, as the basic warehouse operations have remained the same. Meanwhile, the model has improvised a variety of ratio-based measurements into packaged items (pallets/cartons/tons) for the movement and storage output performance. Still, researchers Frazelle (2002) and practitioners have cautioned against a high space utilization, which may reduce productivity. As such, this model can be of benefit to warehouse managers in highlighting the use of "turnover" and "throughput" indicators performance measurements to monitor the movement of products in the warehouse, as well as to avoid the congestion that will lead to reduced productivity performance. Productivity has been widely studied as one of the major dimensions in the measurement of warehouse performance that can assist managers in identifying any low productivity together with the adoption of the latest technology and innovations. The best thing a company can do to improve its productivity is to engage with the people as they are the heart of warehousing operations and to be ready to transform the business by revolutionizing its "smart" technology assets. Consequently, an improved internal warehouse operation performance will lead to increased customer satisfaction.

The contributions of this study are as follows: First and foremost, the developed ratio-based warehousing productivity performance indicators model is accessible to any warehouse. The model was constructed by considering significant resources (labour, equipment, space and information system) in every warehouse and the output performance of all the basic warehouse operations (receiving, putaway, storage, picking and shipping). As such, this model can be widely adopted regionally and globally as all warehouses are being run with the same basic warehouse operation activities and general warehouse resources. Secondly, this study also provides a general ratio-based performance measurement to evaluate the productivity performance by indicating the activity indicators and the input resources of the warehouse. Thus, it is important to distinguish between different outputs as different levels of resource commitments may be involved in handling different types of order lines (piece picks, case picks and pallet picks). Thirdly, the indicators of the productivity dimension are meant to support organizations, authorities and researchers in developing a warehouse performance measurement system, as well as to assist warehouse managers in measuring the KPIs of the warehouse. Finally, warehouse managers can re-examine the work area movement and storage output performance with the available input resources. For instance, the measurement of labour and equipment productivity can provide better performance analysis for warehouse management to increase or decrease the number of workers and/ or investments for new equipment.

As such, this study suggested some details for extended studies that can be conducted in future:

- to measure the ranking of importance among the warehousing productivity performance indicators, which will lead to better knowledge and guidance for future planning;
- to conduct a productivity performance measurement assessment case study by using the revised ratio-based method among practitioners;
- as the limitation of the study was that it only focussed on the productivity dimension, a revised study can be carried out on the other dimensions (time, cost

and quality) of existing ratio-based warehouse operation performance indicators;
and

- to construct a general systematic warehouse operation performance indicators
  model that can be used by every type of warehouse both regionally and
  globally.

References

Ali, A. and Haseeb, M. (2019), "Radio frequency identification (RFID) technology as a strategic tool towards higher performance of supply chain operations in textile and apparel industry of Malaysia", *Uncertain Supply Chain Management*, Vol. 7 No. 2, pp. 215-226.

Altarazi, S.A. and Ammouri, M.M. (2018), "Concurrent manual-order-picking warehouse design: a simulation-based design of experiments approach", *International Journal of Production Research*, Vol. 56 No. 23, pp. 7103-7121.

Asian Productivity Organization (2016), "SME warehouse productivity: benchmarking the logistics sector and goals that companies should go for", available at: www.apo-tokyo.org/publications/wp-content/uploads/sites/5/SME-Warehouse-Productivity-2016.pdf

Attar, A.A., Gupta, A.K. and Desai, D.B. (2012), "A study of various factors affecting labour productivity and methods to improve it", *IOSR Journal of Mechanical and Civil Engineering*, Vol. 1 No. 3, pp. 11-14.

Bartholdi, III, J.J. and Hackman, S.T. (2014), "Warehouse and distribution science", Supply Chain and Logistics Institute, School of Industrial and Systems Engineering, Georgia Institute of Technology, available at: www2.isye.gatech.edu/~jjb/wh/book/editions/wh-sci-0.96.pdf

Beamon, B.M. (1998), "Performance, reliability, and performability of material handling systems", *International Journal of Production Research*, Vol. 36 No. 2, pp. 377-393.

Bengtsson, M. (2016), "How to plan and perform a qualitative study using content analysis", *NursingPlus Open*, Vol. 2, pp. 8-14.

Bloor, M. and Wood, F. (2006), *Keywords in Qualitative Methods: A Vocabulary of Research Concepts*, Sage.

Bowersox, D.J., Closs, D.J. and Bixby, C.M. (2007), *Supply Chain Logistics Management*, McGraw-Hill/Irwin, New York, NY, p. 212.

Cagliano, A.C., Mustafa, M.S., Rafele, C. and Zenezini, G. (2014), "Logistics performance measurement for sustainability in the fast fashion industry", *HICL (Hamburg International Conference of Logistics), Next Generation Supply Chains-Trends and Opportunities*, epubli GmbH, Hamburg, pp. 113-135.

Chen, W.C. and McGinnis, L.F. (2007), "Reconciling ratio analysis and DEA as performance assessment tools", *European Journal of Operational Research*, Vol. 178 No. 1, pp. 277-291.

Chow, H.K., Choy, K.L., Lee, W.B. and Lau, K.C. (2006), "Design of a RFID case-based resource management system for warehouse operations", *Expert Systems with Applications*, Vol. 30 No. 4, pp. 561-576.

Da Cruz, M.R.P., Ferreira, J.J. and Azevedo, S.G. (2013), "Key factors of seaport competitiveness based on the stakeholder perspective: an analytic hierarchy process (AHP) model", *Maritime Economics and Logistics*, Vol. 15 No. 4, pp. 416-443.

Davis, D.F., Golicic, S.L. and Marquardt, A. (2009), "Measuring brand equity for logistics services", *The International Journal of Logistics Management*, Vol. 20 No. 2, pp. 201-212.

Dawe, R.L. (1995), "Reengineer warehousing", *Transportation and Distribution*, Vol. 36 No. 1, pp. 98-102.

De Koster, R., Le-Duc, T. and Roodbergen, K.J. (2007), "Design and control of warehouse order picking: a literature review", *European Journal of Operational Research*, Vol. 182 No. 2, pp. 481-501.

De Vries, J., De Koster, R. and Stam, D. (2016), "Exploring the role of picker personality in predicting picking performance with pick by voice, pick to light and RF-terminal picking", *International Journal of Production Research*, Vol. 54 No. 8, pp. 2260-2274.

Dowlatshahi, S. (2000), "Developing a theory of reverse logistics", *Interfaces*, Vol. 30 No. 3, pp. 143-155.

Elo, S. and Kyngas, H. (2008), "The qualitative content analysis process", *Journal of Advanced Nursing*, Vol. 62 No. 1, pp. 107-115.

Faber, N., De Koster, M.B.M. and Smidts, A. (2013), "Organizing warehouse management", *International Journal of Operations and Production Management*, Vol. 33 No. 9, pp. 1230-1256.

Faber, N., de Koster, R.M.B. 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*, Vol. 32 No. 5, pp. 381-395.

Frazelle, E. (2002), *Supply Chain Strategy: The Logistics of Supply Chain Management*, McGrraw Hill.

Frehe, V., Mehmann, J. and Teuteberg, F. (2017), "Understanding and assessing crowd logistics business models – using everyday people for last mile delivery", *Journal of Business and Industrial Marketing*, Vol. 32 No. 1, pp. 75-97.

Gemenis, K. (2015), "An iterative expert survey approach for estimating parties' policy positions", *Quality and Quantity*, Vol. 49 No. 6, pp. 2291-2306.

Gourdin, K.N. (2006), *Global Logistics Management*, Blackwell Publishing, Victoria, p. 133.

Govidaraj, T., Blanco, E., Bodner, D., Goetschalckx, L., McGinnis, L. and Sharp, G.P. (2000), "Design of warehousing and distribution systems: an object model of facilities, functions and information", *Proceeding of the 2000 IEEE International Conference on Systems, Man and Cybernetics, 2000, Nashville, TN*, pp. 1099-1104.

Hackman, S.T., Frazelle, E.H., Griffin, P.M., Griffin, S.O. and Vlasta, D.A. (2001), "Benchmarking warehousing and distribution operations: an input-output approach", *Journal of Productivity Analysis*, Vol. 16 No. 1, pp. 79-100.

Harrington, L.L. (1998), "How to choose a third-party warehouse", *Transportation and Distribution*, Vol. 39 No. 11, pp. 112-115.

Hashemnezhad, H. (2015), "Qualitative content analysis research: a review article", *Journal of ELT and Applied Linguistics (JELTAL)*, Vol. 3 No. 1, pp. 54-62.

He, Z., Chen, P., Liu, H. and Guo, Z. (2017), "Performance measurement system and strategies for developing low-carbon logistics: a case study in China", *Journal of Cleaner Production*, Vol. 156, pp. 395-405.

Hsieh, H.F. and Shannon, S.E. (2005), "Three approaches to qualitative content analysis", *Qualitative Health Research*, Vol. 15 No. 9, pp. 1277-1288.

Jacyna, M., Lewczuk, K. and Kłodawski, M. (2015), "Technical and organizational conditions of designing warehouses with different functional structures", *Journal of KONES*, Vol. 22, pp. 50-58.

Jacyna-Gołda, I. (2015), "Decision-making model for supporting supply chain efficiency evaluation", *Archives of Transport*, Vol. 33 No. 1, pp. 17-31.

Johnson, A. and McGinnis, L. (2010), "Performance measurement in the warehousing industry", *IIE Transactions*, Vol. 43 No. 3, pp. 220-230.

Johnson, A., Chen, W.C. and McGinnis, L.F. (2010), "Large-scale internet benchmarking: technology and application in warehousing operations", *Computers in Industry*, Vol. 61 No. 3, pp. 280-286.

Joshi, A., Kale, S., Chandel, S. and Pal, D.K. (2015), "Likert scale: explored and explained", *British Journal of Applied Science and Technology*, Vol. 7 No. 4, p. 396.

Jothimani, D. and Sarmah, S.P. (2014), "Supply chain performance measurement for third party logistics", *Benchmarking: An International Journal*, Vol. 21 No. 6, pp. 944-963.

Kaid, L.L. (1989), "Content analysis", in Emmert, P. and Barker, L.L. (Eds), *Measurement of Communication Behaviour*, Longman, New York, NY, pp. 197-217.

Karasek, J. (2013), "An overview of warehouse optimization", *International Journal of Advances in Telecommunications, Electrotechnics, Signals and Systems*, Vol. 2 No. 3, pp. 111-117.

Karim, N.H. and Abdul Rahman, N.S.F. (2018), "Warehousing productivity assessment on logistics service sector", *Advances in Transportation and Logistics Research: Proceedings of the Global Research on Sustainable Transport and Logistics Conference, Jakarta*, Vol. 1, pp. 889-903.

Karim, N.H., Abdul Rahman, N.S.F. and Shah, S.F.S.S.J. (2018), "Empirical evidence on failure factors of warehouse productivity in Malaysian logistic service sector", *The Asian Journal of Shipping and Logistics*, Vol. 34 No. 2, pp. 151-160.

Kiefer, A.W. and Novack, R.A. (1999), "An empirical analysis of warehouse measurement systems in the context of supply chain implementation", *Transportation Journal*, Vol. 38 No. 3, pp. 18-27.

King, W.R. (1998), "IT-enhanced productivity and profitability", *Information Systems Management*, Vol. 15 No. 3, pp. 63-64.

Klabusayova, N. (2013), "Support of logistic processes in modern retail chain warehouse", *Applied Mechanics and Materials*, Vol. 309, pp. 274-279.

Kolinski, A. and Sliwczynski, B. (2015), "Evaluation problem and assessment method of warehouse process efficiency", *Proceedings of the 15th International Scientific Conference, Business Logistics in Modern Management, 2015, Osijek, Croatia*, pp. 175-188.

Kłodawski, M., Jacyna, M., Lewczuk, K. and Wasiak, M. (2017), "The issues of selection warehouse process strategies", *Procedia Engineering*, Vol. 187, pp. 451-457.

Krippendorff, K. (1980), *Content Analysis: An Introduction to Its Methodology*, Sage Publications, Newbury Park.

Kusrini, E., Novendri, F. and Helia, V.N. (2018), "Determining key performance indicators for warehouse performance measurement – a case study in construction materials warehouse", *MATEC Web of Conferences*, Vol. 154, pp. 1-4.

Kyngas, H. and Vanhanen, L. (1999), "Content analysis", *Hoitotiede*, Vol. 1 No. 1, pp. 3-12.

Krosnick, J.A. (2018), "Questionnaire design", *The Palgrave Handbook of Survey Research*, Palgrave Macmillan, Cham, pp. 439-455.

Lam, C.H.Y., Choy, K.L. and Chung, S.H. (2010), "Framework to measure the performance of warehouse operations efficiency", *2010 8th IEEE International Conference on Industrial Informatics*, IEEE, pp. 634-639.

Lakmal, A.G.D.P. and Wickramarachchi, W.A.D.N. (2011), "Enhancing the effectiveness and efficiency of warehouse operations in FMCG sector in Sri Lanka", *17th ERU Research Symposium, Faculty of Engineering, University of Moratuwa*.

Laosirihongthong, T., Adebanjo, D., Samaranayake, P., Subramanian, N. and Boon-Itt, S. (2018), "Prioritizing warehouse performance measures in contemporary supply chains", *International Journal of Productivity and Performance Management*, Vol. 67 No. 9, pp. 1703-1726.

Liviu, I. and Ana-Maria, T., E., C. (2009), "Warehouse performance measurement-a case study", *Annals of the University of Oradea, Economic Science Series*, Vol. 18 No. 4, pp. 307-312.

Manikas, I. and Terry, L.A. (2009), "A case study assessment of the operational performance of a multiple fresh produce distribution centre in the UK", *British Food Journal*, Vol. 111 No. 5, pp. 421-435.

Matopoulos, A. and Bourlakis, M. (2010), "Sustainability practices and indicators in food retail logistics: findings from an exploratory study", *Journal on Chain and Network Science*, Vol. 10 No. 3, pp. 207-218.

Mentzer, J.T. and Konrad, B.P. (1991), "An efficiency/effectiveness approach to logistics performance analysis", *Journal of Business Logistics*, Vol. 12 No. 1, p. 33.

Mayring, P. (2014), *Qualitative Content Analysis: theoretical Foundation, Basic Procedures and Software Solution*, Klagenfurt.

Mohd Saifudin, A., Zainuddin, N. and Deraman, N. (2012), "The effect of management information system (MIS) on warehouse operation efficiency in small and medium enterprises (SMEs)", *Proceeding of WASET, Bayview Hotel Georgetown Penang*, pp. 607-616.

National Council of Physical Distribution Management (1978), *Measuring Productivity in Physical Distribution*, NCPD, Chicago, IL.

O'Neill, P., Scavarda, A.J. and Yang, Z. (2008), "Channel performance in China: a study of distribution centres in Fujian province", *Journal of Chinese Entrepreneurship*, Vol. 1 No. 1, pp. 21-39.

Petersen, C.G., Aase, G.R. and Heiser, D.R. (2004), "Improving order-picking performance through the implementation of class-based storage", *International Journal of Physical Distribution and Logistics Management*, Vol. 34 No. 7, pp. 534-544.

Pirttilä, T. and Hautaniemi, P. (1995), "Activity-based costing and distribution logistics management", *International Journal of Production Economics*, Vol. 41 Nos 1/3, pp. 327-333.

Poon, T.C., Choy, K.L., Chow, H.K., Lau, H.C., Chan, F.T. and Ho, K.C. (2009), "A RFID case-based logistics resource management system for managing order-picking operations in warehouses", *Expert Systems with Applications*, Vol. 36 No. 4, pp. 8277-8301.

Pyza, D., Jachimowski, R., Jacyna-Gołda, I. and Richards, G. (2011), *Warehouse Management: A Complete Guide to Improving Efficiency and Minimizing Costs in the Modern Warehouse*, Kogan Page Publishers.

Ramaa, A., Subramanya, K.N. and Richards, G. (2011), *Warehouse Management: A Complete Guide to Improving Efficiency and Minimizing Costs in the Modern Warehouse*, Kogan Page Publishers.

Ramaa, A., Subramanya, K.N. and Rangaswamy, T.M. (2012), "Impact of warehouse management system in a supply chain", *International Journal of Computer Applications*, Vol. 54 No. 1, pp. 14-20.

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

Rimiene, K. (2008), "The design and operation of warehouse", *Economics and Management*, Vol. 13, pp. 136-137.

Rizzi, A. and Zamboni, R. (1999), "Efficiency improvement in manual warehouses through ERP systems implementation and redesign of the logistics processes", *Logistics Information Management*, Vol. 12 No. 5, pp. 367-377.

Reja, U., Manfreda, K.L., Hlebec, V. and Vehovar, V. (2003), "Open-ended vs close-ended questions in Web questionnaires", *Developments in Applied Statistics*, Vol. 19 No. 1, pp. 159-177.

Richards, G. (2011), *Warehouse Management: A Complete Guide to Improving Efficiency and Minimizing Costs in the Modern Warehouse*, Kogan Page Publishers.

Sabilah, I. and Manoy, J.T. (2018), "The use of open-ended questions with giving feedback (OEQGF) for effective mathematic learning", *Journal of Physics: Conference Series*, Vol. 947 No. 1, p. 12032.

Stainer, A. (1997), "Logistics-a productivity and performance perspective", *Supply Chain Management: An International Journal*, Vol. 2 No. 2, pp. 53-62.

Staudt, F.H., Alpan, G., Mascolo, M.D. and Toboada Roddriguez, C.M. (2015), "Warehouse performance measurement: a literature review", *International Journal of Production Research*, Vol. 53 No. 18, pp. 5524-5544.

Thanassoulis, E., Boussofiane, A. and Dyson, R.G. (1996), "A comparison of data envelopment analysis and ratio analysis as tools for performance assessment", *Omega*, Vol. 24 No. 3, pp. 229-244.

Wang, H., Chen, S. and Xie, Y. (2010), "An RFID-based digital warehouse management system in the tobacco industry: a case study", *International Journal of Production Research*, Vol. 48 No. 9, pp. 2513-2548.

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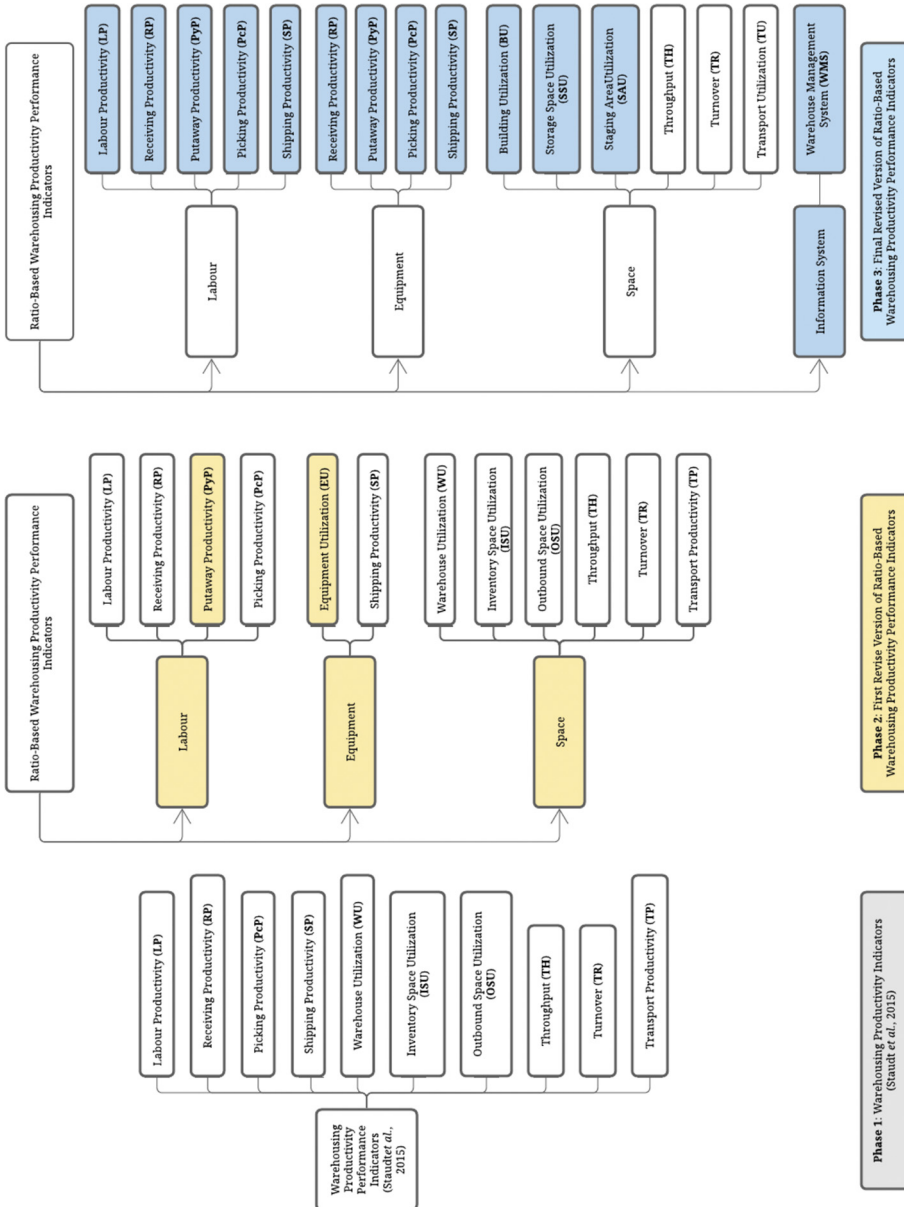Noorul Shaiful Fitri Abdul Rahman can be contacted at: noorul@imco.edu.om

Appendix