FACTORS AFFECTING THE EFFICIENCY OF WAREHOUSE PICKING OPERATION IN RETAIL INDUSTRY

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ABSTRACT

Covid-19 pandemic has changed people's buying behavior and most of retail supermarkets are in a great challenge of fulfilling customer requirements due to "Panic buying" behavior. Since the current trend has become an e-commerce market, the necessity of well-working warehouse operation has increased. Therefore, to move with the customer changes and to increase customer satisfaction, improvements should be added for warehouse activities. Order-picking has the highest priority in warehouse operation in terms of improving the warehouse efficiency.

This research was conducted to determine the factors that affect efficiency of warehouse picking operation in retail industry with a comprehensive literature study. Following factors were identified as the influential factors for the efficiency of warehouse picking operation such as training on warehouse workers, technology, incentive payments for labor, picking methodology, safety of the operation etc. Further analysis was conducted for factors identified from literature review using a self-administered questionnaire which was developed and distributed among warehouse people to get their opinions. 207 responses were collected, and consistency analysis test confirmed that the collected data set is consistent and in an acceptable level. Using Analytical Hierarchy Process (AHP) it was concluded that "Training on warehouse workers", "Technology" and "Machine maintenance plan" were the top 3 factors that affect the efficiency of warehouse picking operation. Therefore, rather than focusing on one area, management should give a priority for all three areas simultaneously. Such as, there should be a mechanism to train the workers which should not be only a one-time training, management should invest on technology based on the volume and complexity of the operation they have and finally rather than waiting for a machine breakdown, people should have a proper machine maintenance plan.

Because of the pandemic situation, it was difficult to have many participants for the survey and total number of respondents was limited. Future studies can be conducted with another level of AHP by considering sub factors under each prominent factor and it can also be suggested to analyze the challenges going to face when implementing these factors within a warehouse. Same study can be done for other operations within the warehouse such as put-away, repacking, loading etc.

Key words: Warehousing, Warehouse Management, Picking, Efficiency

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LIST OF ACRONYMS

AHP – Analytical Hierarchy Process

AI - Artificial Intelligence

KPI – Key Performance Indicator

MIS – Management Information System

RFID – Radio-Frequency Identification

WMS – Warehouse Management System

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1 CHAPTER – INTRODUCTION

1.1 Background of the Research

Efficient logistic management allows business to have competitive advantage over other competitors and also help to increase customer satisfaction (Sooksai, n.d.). Improvements in warehouse activities are needed to keep up the customer satisfaction with the continuous changes in customer demand. With the current trend of e-commerce market, the importance of well-working warehouse operation has increased (Timo, 2016). To increase warehouse performance and satisfy customer requirements in a speedy way, it is important to have an efficient warehouse (Jermsittiparsert, 2019). Thus, the objective of this research is to identify factors that affect the efficiency of warehouse picking operation in retail industry.

1.2 Problem Statement / Need for the Study

As the covid-19 pandemic directly affecting to people health, demand for the consumer goods has been increased rapidly with more and more people live indoors and practicing social distancing. This is mainly because of sudden quarantine or substantial supply interruptions (Martin et al., 2020). While the demand goes high, on the other hand employees have been uncertain on continue working and companies had to reduce staffing to keep social distance and keep the operation ongoing with safety precautions to not getting suspended (Overstreet, 2020).

One of the key elements for material flow efficiency in supply chain is the warehouse processes. It is difficult to find literature and scientific research on the evaluation of warehouse process efficiency. (Kolinski & Sliwczynski, 2015).

Recent trends such as reducing of customer lead time, volatility of market, and demand fluctuations has brought more attention on designing and operating practices of warehouses in order to manage warehouses more efficiently and effectively (Fernando, 2016).

Traditional warehouses find it difficult to meet the requirements with competitive market conditions. As a result, smart logistic concept evolves all over the world to eliminate the

drawbacks of warehouse management. However, In Sri Lanka, most of the warehouses are labor-intensive and labor shortage issue is a potential challenge in future (Karunarathna et al., 2019).

Both effective and efficient in logistic management, brings competitive advantage to be well ahead from business competitors in terms of speed, quality, reliability and lower cost (Sooksai, n.d.).

When analyzing company profitability, warehouse activities have become more frequently under the microscope over the past decade. This has led the company to a conclusion that they need to improve warehouse efficiency and cut off unnecessary warehouse activity costs. Also, since the current trend more over become an e-commerce market, the importance of well-working warehouse operation has increased. Therefore, to move with the customer changes and increase customer satisfaction, improvements should be needed for warehouse activities (Timo, 2016).

Order picking has the highest priority in warehouse operation in terms of improving the warehouse efficiency (K.L. et al., 2017). One of the key factors that affect warehouse performance is order picking (Lu et al., n.d.).

Therefore, the objective of this research is to identify the influencing factors that affect the efficiency of warehouse picking operation in retail industry.

1.3 Research Question

- What are the influencing factors that affect the efficiency of warehouse picking operation in retail industry?

1.4 Research Objectives

1.4.1 General Objective

- To identify factors affecting the efficiency of warehouse picking operation in retail industry

1.4.2 Specific Objectives

- To analyze the importance of warehouse picking operation
- To determine the variables that affect the efficiency of warehouse picking operation
- To identify how those variables correlated to efficiency of warehouse picking operation

1.5 Research Scope

Supermarkets are in a great challenge in fulfilling the customer requirements with the increase of e-commerce market (Hamza, 2020). Warehouse is one of the key elements for material flow efficiency in supply chain (Kolinski & Sliwczynski, 2015). In terms of improving the warehouse efficiency, order picking has the highest priority(K.L. et al., 2017). The research scope is to identify the factors that affect the efficiency of warehouse picking operation in retail industry.

1.6 Significance of the Study

Coronavirus disease has changed buying behavior of people and most of the retail supermarkets are in a great challenge of fulfilling customer requirements due to “Panic buying” behavior. Moreover, with the current situation, there is a possibility that people may get absent due to quarantine condition and warehouses need to operate with available employees while trying to output the same as earlier. Identifying the factors that affect efficiency of warehouse picking operation in retail industry will help people

to identify gaps they currently have in their warehouses and take necessary actions to correct them to make sure to keep the customer satisfaction in a constant level while keeping the company profitable.

1.7 Time Plan

Description \Week	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
Select the Research Topic															
literature Study															
Preparation of Research Proposal & Presentation															
Identification of Data and Preparation of Questionnaire															
Collection of Data from Questionnaires															
Data analysis & preparation of report															
Submission of report															

Table 1.1 Time Plan

One Column represents 2weeks.

Activities finished	Activities being performed	Planned Activities	Buffer time

1.8 Key Terminology

Warehousing - This is the process of storing physical goods before they move out or distributed from a storage facility. These products are safely and securely organized to track item location and quantity on hand. In ecommerce market, products are shipped directly to consumer from the storing facility once the order is placed online. On other hand in traditional retail, products are stored temporarily in a warehouse before it shipped to a store (Lopienski, 2020).

Warehouse Management – Warehouse management includes organizing and controlling everything within the warehouse such as arranging inventory, maintaining appropriate equipment, managing new stock coming to warehouse, picking, packing and shipping orders etc. (Glover, 2020)

Picking Process

The process of picking individual products from a fulfillment facility in order to gratify customer orders (Gomez, 2020).

Efficiency – This is defined as achieving highest amount of output with the least amount of input. Efficiency should be required to decrease unwanted resources to yield the output. This can be measured using the ratio of output to total input (Banton, 2020).

1.9 Chapter Breakdown

Chapter 1: Introduction

Consists with research background, significance of the study, research question, research objectives and key terminologies.

Chapter 2: Literature Review

Primarily comprised of studies related to efficiency of warehouse picking operation. This chapter delivers a detail approach to conducting the empirical study.

Chapter 3: Research Methodology

The methodological approach of the study was delivered by this chapter. This involves research design, variable identification, conceptual framework, questionnaire design, population and sample design, data collection methods and statistical approach of data analysis.

Chapter 4: Research Findings

A Comprehensive analysis of the data set was done in this chapter. As the initial step, reliability test was done to measure the reliability and acceptability of data. Then mean, median, standard deviation and variance was calculated as descriptive statistics. Finally, Pareto Analysis and AHP was conducted to prioritize the identified factors.

Chapter 5: Conclusions and Future Research Directions

This chapter shows the overall conclusion that can be formed based on the analysis done in preceding chapter. Limitations of the study and recommendations for future research potential have also been addressed in this chapter.

1.10 Chapter Summary

This introduction chapter gives a basic understanding of background of the research, significance of the study, research questions, research objectives and time plan of the study.

2 CHAPTER – LITERATURE REVIEW

2.1 Importance of Warehouse Picking Operation

One of the key process in warehouse outbound operation is picking which collects products to fulfill customer orders. It is also defined as the costliest process in the warehouse as it covers about 55% of total working expense (Sunol, 2021). To reduce the cost considerably and to increase warehouse efficiency, process optimization need be done. As human errors create direct impact on customer satisfaction, streamlining these processes need to be done in order to achieve higher accuracy (Sunol, 2021).

One of the costliest activities in warehouse operation is the order picking. Therefore, by improving the order picking efficiency, warehouse can increase the customer satisfaction level as well as minimize cost (Timo, 2016).

Compared to receiving, storage and shipping, picking is an important part as it forms 55% of operation costs within any warehouse and it is directly impacting to customer satisfaction level (Hinz, 2013). Delivering the customer orders both quickly and accurately is a crucial part of doing business (Hinz, 2013).

According to studies and reports picking covers around 50% of warehouse labor cost and the number can be high as 63% (Bowles, 2021b). Order picking become more and more important with the rise of ecommerce. This is mainly because, while other operations can be automated in the warehouse, picking operation largely remains manual (Bowles, 2021b).

2.2 Challenges in Warehouse Picking Operation

Space utilization is one challenge warehouse people currently having. It is not how much space people have; it is about optimizing the space so that people can avoid unnecessary labor. Warehouse should keep the fast-moving inventory near front of the warehouse loading bay to reduce the labor movements within the warehouse. Warehouses that continue with manual processes, add unnecessary time to processes like picking as there is no common route to be taken to pick goods for shipments (Blanchard, 2013).

With the Covid-19, health risk is becoming a major challenge as traditional warehouses touch the products several time. One of the critical success factors in warehousing in 2021 is efficient use of space where people try to do more with less. Insufficient storage space leads to poor warehouse facility layout. As pickers are engaged in a rush environment to deliver the goods as early as possible, most of the problems in warehouses are occur from picking process. Barcode technology streamline the processes and maximize the resource utilization. Warehouse layout should increase the resource utilization, safety to staff and enable to access fast moving products easily. Replacing labor with automated system is a one strategy to address labor related problems (Sudding, 2021).

Performing same operation more than once accidently creates repetitive works and increase the labor cost and time as it takes another extra time to reverse the mistake. Since there is more space and more inventory, this can be happening often in large warehouses. Repetitive works is mostly happening in picking as there are multiple people working together to pick goods from different locations in the warehouse to fulfill a single order. Mistakes like picking too many of products can be happen since the same order is passed around multiple people. On other hand not having sufficient storage because of unproductive use of space is a common pain that warehouse people have (Natarajan, n.d.).

Travel distance and workers discomfort are main drivers for order picking time and workers well-being. Long term health saving will positively impact to order picking time. This study also showed that the value of data stored in Warehouse Management System (WMS) and direct inquiry from pickers is an effective way to get insights for determine their preferences on level of discomfort (Larco et al., 2017).

Flexibility is a one challenge warehouses are currently facing to have a greater responsiveness. Picking strategies should be developed to allow changes to the picking list while doing the picking (Lu et al., n.d.).

Warehouse labor planning is an essential step as inaccurate labor planning has negative effects on labor productivity. Study shows that average daily efficiency is higher for picking with a positive labor forecast. Planned workload forecast can lead to have a smooth workflow in warehouse and eventually result in higher labor efficiency (Heij et al., 2018).

Space allocation and reducing of travel distance are two key factors to improve the warehouse performance. To further improve the warehouse efficiency and performance with less costly in long term, warehouse should be integrated with smart logistic such as Artificial Intelligence (AI) (Lee et al., n.d.).

Order picking has the highest priority in warehouse operation in terms of improving the warehouse efficiency. Major factor that affects efficiency in the order picking process is storage policy which assign incoming products to storage locations to reduce material handling cost and maximize space utilization. Generally, staff members with weak AI tend to rely on experience when assign storage locations to incoming products, thus the quality of decision making not guaranteed. Radio-Frequency Identification (RFID) based storage assignment system was proposed to support decision making in storage assignment in warehouse. The system is implemented in a manufacturing warehouse and results show that the proposed system can improve the efficiency of order picking in the warehouse (K.L. et al., 2017).

Fulfil customer needs fast and increase firm's performance is a one ability that efficient warehouse is having. By fulfilling customer needs quickly, a well-designed layout of a warehouse increases the efficiency. Also warehouse operation has a key role to play when increase the efficiency. One of the facilitating attributes among supply chain warehouse efficiency and its attributes is Management Information System (MIS) (Jermsittiparsert, 2019).

Some techniques which can use to increase efficiency of moving goods in warehouse are Why-Why analysis and Fishbone along with ABC analysis theory. Four reasons that found to delay the picking goods are, lack of expertise staff in the operation, insufficient equipment, inaccurate process, and diversity of goods. It is not enough to have the technology only but also to identify the correct location of a product in the warehouse. To increase the picking efficiency, employees must have the knowledge on location and symbol of each product. As personal factors like age, gender, and education level etc. are matters in warehouse work, people need a training before starting the real work (Sooksai, n.d.).

2.3 Techniques use to Improve the Efficiency of Warehouse Picking Operation.

Major percent improvement in labor productivity can be bring by a properly planned incentive payments for performance. This process should be start from pick and pack as more than 50% labors are in there (Barry, 2020). Critical KPI should be capture and manage in order to identify the current performance level and regular feedback should be given to employees. Voice enabling technology should be applied to all processes in warehouse in order to have a better inventory control and to have a higher productivity (Barry, 2020).

WMS would improve warehouse outbound logistic operational performance. Using safety stock formulas will help to not to keep too much of stock in the warehouse and reduce the inventory cost. Also cross docking approach help business to have less warehouse space and reduce material handling (Bowles, 2021a).

KPI should be established and track and make notes on the cause and effect when shortfall occurred which help to increase labor performance. Training for warehouse staff, increase worker morale, incentive and reward system to staff should be well in placed in order to have better performance (Saad, n.d.).

Introducing right technology is one way to optimize the picking process. Mobile and wearables helps streamline the picking by allowing picker to view picking list wirelessly, access system in real and allow them to scan anywhere in the warehouse. Also, doing ABC analysis which improve warehouse layout, choosing the right picking methodology and having software that guide clerks properly to execute tasks will also help to improve the warehouse efficiency. Packing process can be optimized by using a software to guide people for executing tasks with proving necessary data such as dimension, weight, type and amount of packaging material needed to keep the product safe while minimizing the packing cost. Having a labor management system helps to assign right amount of people to prevent under or over allocation (Sunol, 2021).

Lean Management can improve order picking efficiency by identifying wastes. These wastes can be unnecessary storing of products and unnecessary travel distance to pick products. When improving picking efficiency, inventory reduction is a key factor (Timo, 2016).

Automated system is an ideal solution to eliminate the inefficiencies of warehouse practices and to overcome the labor shortage issue. Digitalization is an effective strategy to increase the output from available labor force. This study mainly focuses on intra processes of the warehouse and in the analysis of the study found some critical factors that affecting to implementation of logistic 4.0. Top management commitment, aligning with competitive strategies and coordination with existing business processes are some of them (Karunarathna et al., 2019).

Performance analysis helps managers to make decisions. Study presents both direct and indirect indicators where direct indicators treat quantitative measures like order cycle time, fill rate, and labor productivity while indirect indicators treat qualitative measures like perception of customer satisfaction and loyalty. Direct indicators consider as basis for warehouse performance measurement. With having high number of outbound indicators, it is showed that activities in a warehouse are more customer oriented. (Francielly et al., 2015).

Most important factor in warehouse design is cube utilization and therefore people should ensure that design allows accessibility and reduce damage while applying the space efficiently. There are more innovative technologies has developed to improve the efficiency of the warehouse. Up-to date technologies must be implemented to reduce the bottlenecks while increasing warehouse efficiency. Technology implementation related decisions should be taken only through a detailed evaluation on its trade-offs (Fernando, 2016).

One of bus manufacturing organization's motto is "Do more with less" with the intention of meeting the needs of their customers. A study has done to improve logistic operation of the warehouse. Brainstorming sessions has done to get suggested solutions for identified problems. Reducing employee travel distance, increase space utilization and increase safety of the operation results in greater availability to work and increase confidence of workers which ultimately reflected in a high-quality work done. Employee involvement and sense of responsibility become high with implementation of 5S and increase employee motivation in the workplace. With 35mins faster picking process they reduced 25% from initial consumed picking task time (Freitas et al., 2019). Application of Lean methodologies is considered as a high priority as it gains productivity and

benefits to the environment with improving waste management in the warehouse (Freitas et al., 2019).

To improve performance, people need to measure the performance. Therefore, it's important to identify necessary Key Performance Indicator (KPI) for managers to determine corrective actions on warehouse efficiency. Most important KPIs can be identified using the Analytical Hierarchy Process (AHP). By comparing performance with best performance peer groups, warehouse performance can be improved (Kusrini et al., n.d.).

Both operational data relating to technological process and data generated by an information system are required to do a comprehensive analysis of efficiency. Warehouse processes need to concentrate on factors that have crucial impact to the continuity of material flow. Also, efficiency of warehouse processes depends on following factors like use of modern equipment and technology of warehouse, the efficiency and utilization of warehouse resources. Analysis of warehouse efficiency should be based on both operational indicators such as effectiveness of realization orders (number of completed orders/ total number of orders), average duration of material receipt (lead time of material receipt / number of material receipt) etc. and as well as financial indicators such as return on equity (net income after tax/ shareholder equity), ratio of worker productivity (net sales/ salary costs) etc. (Kolinski & Sliwczynski, 2015).

Implementing barcode system in the warehouse will give accurate data in real time as well as it helps to reduce human errors. Warehouse processes that has been equipped with barcodes can do the operation much faster. Therefore, implementing of barcodes in the warehouse will provide the facility to increase the efficiency in the warehouse (Istiqomah et al., 2020).

A research has conducted to study the benefits of RFID to reduce the inefficiency in supply chain under inventory reduction and misplacement in a nonprofit scenario. Following two scenarios has considered, 1st optimizing the operation only with recognizing the inventory inaccuracy in system and 2nd improves the system with RFID technology along with theft preventing support equipment. The introduced framework model considers both operational cost and deprivation cost. Here deprivation cost is defined as economic value of human suffering. Assuming the demand is consistently distributed, and compare total cost with and without RFID, result showed that when the

shrinkage and misplacement is critical, RFID creates more value even at a higher tag price (Biswal et al., 2017).

Reduction of total inventory levels improves efficiency of the warehouse operation. Also, total travel distance of put-away and picking can be minimized by effective storage space planning. Congestion can be reduced by putting fast moving products close to the dock doors and other slow-moving products putting at back of the warehouse which leads to increase the output capacity (Arunyanart et al., n.d.).

In order to improve warehouse efficiency, employee training should be done by focusing on technology and how they utilize the tools. Also, analyze the effectiveness of the resources, effective communication with workers, design for incentive pay or reward system, improve employee comfort by music, invest in quality equipment rather than cheap products where regular break disturb to the work been done, allow WMS to add data verification and alerts to picking operation, schedule maintenance plan to reduce downtime at machine breakdown points, minimizing safety issues by labeling safety hazards, allow system to guide the order picking process, avoid mixing more than one SKU in a single bin should be implemented within the warehouse in order to increase the efficiency (Hanks, 2018).

Labor productivity can be improved by introducing proper incentive payment for performance and providing training sessions regularly. Unproper safety practices allow to happen accidents and leads to inefficiency and profit loss. Training the people to perform different tasks or build cross-train workforce can boost the productivity in a warehouse. Steps in a process should be examine and streamline to reduce number of touches involved which help workers to reduce their unnecessary time and increase productivity. Organizations that use WMS have accurate warehouse processes and lower logistic cost and perform higher perfect order performance. Putting SKUs in wrong storage locations can reduce the order picking productivity by 20% (Dunakin, 2021).

Time that takes to pick, pack and shipping orders will affect to overall productivity. Optimizing warehouse routes is a one way to reduce travel time. Training helps people to identify opportunities and it should not be a one-time thing rather an on-going process that increase the efficiency. Having maintenance plan for essential machineries will help to prevent failures at the operation and leads to increase the efficiency as operation runs smoothly (Hill, 2020).

ABC analysis is one of the best methods to understand the efficiency of inventory controlling. In order to have less strolling time and total the picking operation in less time, quick moving stock ought to bring to front of the distribution center whereas the slow-moving stock go to back. One of the wasteful approaches in picking strategies is pick-to-order approach. In pick-to-order strategy, laborer mindful for collecting all things that incorporate in an order. Pick-to-order approach is more effective when the orders have low number of SKU, otherwise it is very inaccurate and inefficient. Cluster picking technique is more proficient than pick-to-order as it allows to pick more than one order same time. Zone picking is another useful methodology for a large warehouse. Here items are partitioned into numerous zones and committed pickers are doled out to zones. In this manner, numerous picking lists are made for numerous orders and allocated to each zone for specialized pickers to choose them. On other hand, Wave picking methodology group the orders and released them to pickers at specific times across different zones. This makes a difference to adjust the picking handle with other operations such as filling fixed bins, shipping planning, etc. Technology is another aspect to focus when optimizing picking process. One of the best and compelling way to move forward distribution center operation is utilizing standardized identification scanners. Combination of picking list and barcode scanners allow the picker to pick the right product from right location to the right customer. Wearable computers, voice picking, RFID, Pick by Light and Wearable Glasses are some advanced technologies that increase efficiency (Sunol, 2020).

Frequently picked items should locate closely to each other and picking the orders directly into a shipping carton rather than going through a consolidation zone helps to reduce the walking time of pickers while saving time. Also frequently picked items should be in waist-high and training should be done on how to lift and handle loads in-order to reduce risk of injuries. Creating a safe place is cheaper than getting a worker injured. Voice directed or Light directed picking systems helps to find the right product more quickly with the right quantity. Technology like RF scanners help to validate an item based on its barcode and reduce human picking errors will speed up the picking process. To reduce the picker idle time on standing for an item to be re-stocked from high rack, replenishment should be scheduled throughout the day. KPIs should use to measure and benchmark the operation and improve identified areas. Capacity utilization, in each time frame how many orders are picked, accuracy of picks, cost of the labor required to fulfill the tasks are the most order picking KPIs. Wave picking, Batch picking and zone

picking are good strategies to speed up order fulfillment process. Batch picking group several orders that have same items whereas in zone picking different workers assign to different location. Wave picking helps to release orders based on priorities (Tarr, n.d.).

Order picking supports the core functionality of warehouse and accounts for 55% of cost of operating expenses (Glynn, 2021). Fast moving products should locate in easily accessible racks which are near to loading dock. Picking routes depend on picking methodology and should eliminate issues such as backtracking aisles that already walked through. Foundation to have effective picking is having accurate inventory data. Keeping the inventory stock at the right place in easily identifiable manner will help to increase picking efficiency. Error picking data should be collected and analyze to identify where the error typically occurring and get corrective actions. One strategy that warehouses use to increase awareness among workers is posting individual or group error rates and have a good incentive plan to get a positive reinforcement. Augment the work of humans is one of best automation solution for warehouses to increase picking accuracy and efficiency (Glynn, 2021).

Horizontal picking is quicker than vertical picking. Therefore, Slow moving products should store vertically while keeping the fast-moving products horizontally. WMS helps to increase picking speed and allocate labor correctly while reducing human errors (Neuhaus, n.d.).

Minimizing touches is one way to improve warehouse picking where picked orders directly go to the truck without repacking or checking. Verifications need to be done while picking to increase picking accuracy. Should reduce walking distance as when employees not get tired, it reduce picking mistakes and increase the speed of the process (Wheeler, 2017).

Top four warehouse picking strategies are batch picking, zone picking, and wave picking. A WMS should have a pick list that is auto generated, display availability of product, provide real-time order status, automatic replenishment forecast, and also assist with planning labor staff (Lopienski, 2020).

2.4 Literature Summary

No.	Study	Year	Study Area	Variables affect to Warehouse Picking Efficiency
1	Warehouse challenges	2013	Outbound operation	• Space utilization
2	Warehouse management challenges	2021	Outbound operation	• Space utilization • Technology
3	Warehouse management problems	-	Outbound operation	• Picking methodology
4	Warehouse management problems and solutions	2017	Outbound operation	• Space utilization • Employee comfort level
5	An algorithm for dynamic order-picking in warehouse operations	-	Outbound operation	• Picking methodology
6	Improve warehouse efficiency using RFID	2018	Inbound and outbound operation	• Labor planning
7	Internet of things-based warehouse management system	-	Outbound operation	• Technology • Picking methodology • Space utilization
8	Improve order picking efficiency with RFID based storage assignment.	2017	Outbound operation	• Space utilization • Technology

9	Warehouse layout	2019	Outbound operation	• Space utilization
10	Warehouse space management	-	Outbound operation	• Training on warehouse workers
11	Warehouse efficiency	2020	Outbound operation	• Incentive payments for labor • KPIs • Technology
12	Increasing inbound and outbound logistics	2021	Inbound and outbound operation	• Technology
13	Improve warehouse management	-	Outbound operation	• KPIs • Training on warehouse workers
14	Optimization of warehouse processes	2021	Outbound operation	• Technology • Picking methodology
15	Improving efficiency of the order picking process in the case company warehouse	2016	Outbound operation	• Space utilization
16	Logistics 4.0 in future warehousing.	2019	Inbound and outbound operation	• Technology
17	Warehouse performance measurement: A literature review	2015	Outbound operation	• KPIs
18	Increasing efficiency through ergonomic warehouse design: A review	2016	Inbound and outbound operation	• Space utilization • Technology

19	Improving efficiency in a hybrid warehouse: a case study	-	Outbound operation	• Space utilization • Safety of the operation
20	Key performance indicators for warehouse performance measurement.	-	Inbound and outbound operation	• KPIs
21	Warehouse efficiency - comprehensive analysis	2015	Inbound and outbound operation	• Technology
22	The implementation of barcode on WMS for warehouse efficiency	2020	Inbound and outbound operation	• Technology
23	RFID for improve warehouse efficiency	2017	Inbound and outbound operation	• Technology
24	Efficiency improvement on warehouse management	-	Inbound and outbound operation	• Space utilization
25	Improve warehouse operation	2018	Inbound and outbound operation	• Training on warehouse workers • Technology • Incentive payments for labor • Worker comfort level • Machines maintenance plan • Safety of the operation

26	Improve warehouse efficiency and productivity	2021	Inbound and outbound operation	• Incentive payments for labor • Training on warehouse workers • Safety of the operation • Cross train workforce • Technology • Maintenance of product slotting
27	Maximize efficiency and productivity of warehouse operation	2020	Inbound and outbound operation	• Space utilization • Training on warehouse workers • Machines maintenance plan
28	Optimizing warehouse picking operation	2020	Outbound operation	• Space utilization • Picking methodology • Technology
29	Optimizing order picking operation	-	Outbound operation	• Space utilization • Training on warehouse workers • Integrating processes • Safety of the operation • Technology • KPIs • Picking methodology
30	Improve order picking accuracy	2021	Outbound operation	• Picking methodology • Space utilization • Incentive payments for labor • Technology
31	Improve warehouse productivity by	-	Outbound operation	• Space utilization • Technology

	optimizing picking process			
32	Improve picking and packing efficiencies	2017	Outbound operation	• Integrating processes • Space utilization
33	Warehouse order picking strategies	2020	Outbound operation	• Picking methodology • Technology

Table 2.2 Literature Summary

3 CHAPTER - RESEARCH METHODOLOGY

3.1 Introduction

The chapter describes the research methodology and research design in descriptive manner. This chapter explains the conceptual framework with a set of determinants that affects the efficiency of warehouse picking operation. Further this chapter gives a brief introduction on target population and sample, justification of the sampling approach, methods used for collecting and evaluating the figures.

3.2 Research Design

This study utilized quantitative and qualitative approach to identify the factors affecting the efficiency of warehouse picking operation in retail industry.

As a qualitative method, Literature review was done on surveys that published by other authors on same area to understand the variables relating to efficiency of warehouse picking operation.

Then a quantitative plan was implemented with the intention of explore and describe the findings of the literature. The research design is cascade to the category of causal research as the main objective is to verify the level of degree on cause and effect relationship between variables. The research evaluates the degree of changes on one variable which is called dependent variable and the variations in-other factors which is called as independent variables.

The aim of this study to identify factors affecting the efficiency of warehouse picking operation in retail industry. The researcher was interested in defining the important variables related with the problem. Thus, this study is called a factor analysis. The factors affected in warehouse picking operation are considered as unit of analysis.

3.3 Conceptual Framework

The conceptual framework suggests what is anticipated to be locate inside the studies. It portrays the related factors for the think about and outline how it gets relate to each other. The framework was developed before collecting the information and usually based on a literature review of the study. This appears more often visually. In the causal relationship where there are usually several independent variables that affect the dependent variable, the basic design components of arrows and boxes can be used for visualization. The variable appears in the box indicates the causality by starting an arrow from the impartial variable and point to the dependent variable (Swaen, 2015).

The researcher was proposed a conceptual framework which shows the relationship between efficiency of warehouse picking operation and factors affecting the efficiency of warehouse picking operation in retail industry.

3.4 Identification of Variables

3.4.1 Dependent Variable

Dependent variable was the efficiency of warehouse picking operation in retail industry which was my research question and represents the outcome of the study.

3.4.2 Independent Variable

Factors that have an effect for the efficiency of warehouse picking operation were taken as independent variables and these are mentioned in the conceptual framework (Figure 3.1). These variables were obtained from literature review to evaluate the efficiency of warehouse picking operation. Identified independent variables are;

1. Space utilization
2. Technology
3. Picking methodology
4. Incentive payments for labor
5. KPIs
6. Worker comfort level
7. Training on warehouse workers

8. Labor planning
9. Safety of the operation
10. Machines maintenance plan
11. Cross train workforce
12. Maintenance of product slotting
13. Integrating processes

The following model was developed to explain the variables in the conceptual framework to identify the cause-and-effect relationship.

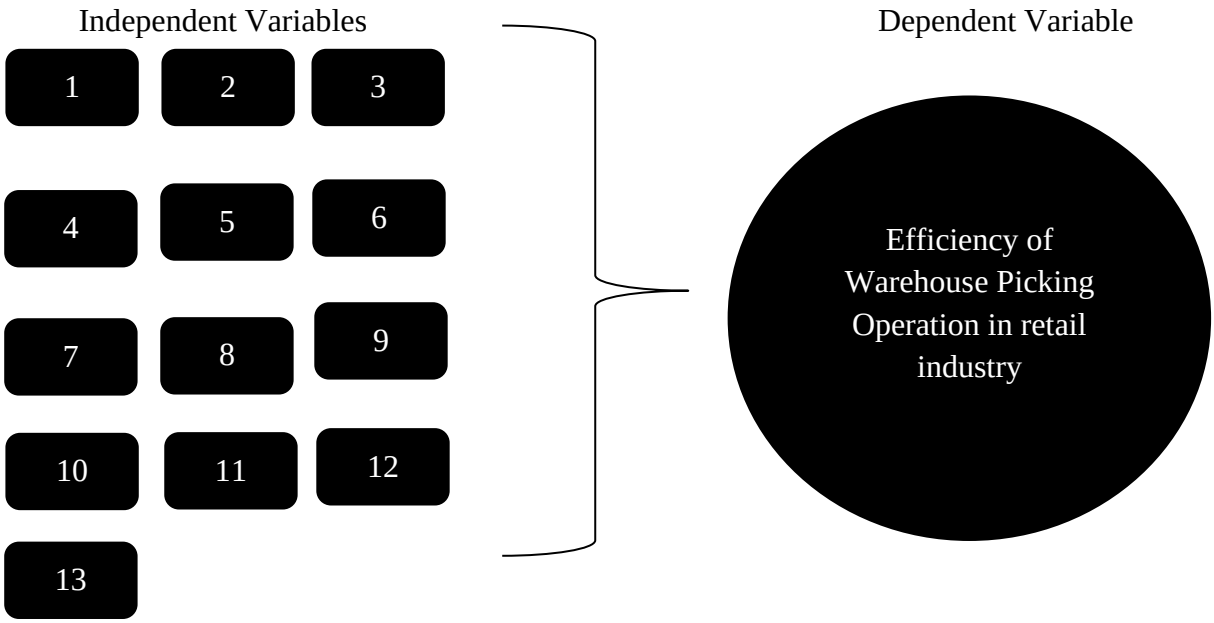

Figure 3.1 Conceptual Framework

3.5 Questionnaire Design

In surveys, Likert scale rating is popular as they allow people to put their opinion easily. To collect data, a researcher can present Likert type statements or questions and a range of possible selections. Then a numerical score will be given to those selections to analyze the data quantitatively. Likert scales typically have 5 to 7 reaction items and each called reaction anchors. Middle item is usually neutral, with negative objects on one side and positive objects on the other aspect. A score from 5 to 7 is given for each response item. Most used types of Likert scales are agreement, quality, likelihood and experience. To find greater detail about one attribute (e.g. satisfaction) researcher should go with

unipolar items and to measure two attributes (e.g. satisfaction and dissatisfaction) researcher should go with bipolar scale (Bhandari, 2020).

On this study, a web questionnaire was developed to gather main records required to look how diagnosed elements affect to efficiency of warehouse picking operation. The questionnaire was structured properly, and simple wordings were used to prepare the questionnaire to make sure that respondents will answer with less difficulty. The questionnaire is included in Appendix.

Likert scale rating was used to evaluate the opinions of the respondents to the questionnaire. It includes six general questions and variables were defined with Likert scale rating with an example in order to give a better understanding.

3.6 Selection of Population and Sample

3.6.1 Target Population

Employees who were working in warehouses of retail industry.

3.6.2 Sample

Distributing the online questionnaire was focused on employees who were currently working at warehouses of one of the leading supermarket chains in 2021.

3.6.3 Sample Size

Sample size for the research was 300 employees who were currently working at warehouses in retail industry.

3.6.4 Sampling Method

Convenience sampling was used as the sampling method as participants were selected based on availability and willingness to take part.

Inclusion criteria – Employees who had more than 3 months' working experience in the current warehouse.

Exclusion criteria – Employees more than 60 years old, Employees with mental disorders (such as short-term memory loss, depression), Employees who had less than 3 months' work experience in the current working company.

3.6.5 Duration of the Study

Answers for the questionnaire were collected within two weeks of the study.

3.6.6 Justification of the Sampling Approach

Sri Lanka supermarket sales have dramatically increased subsequently with new cases of coronavirus reported within the country. After closing schools on March 12, 2020, Sri Lanka has felt the 'Panic buying'. The selected company which is the top retail chain in Sri Lanka 2021, got three times the normal sales on March 12, 2020 (Hamza, 2020). Covid-19 pandemic gave extraordinary challenges to retail companies in Sri Lanka. With these challenges the above selected company was able to be the 7th in the overall ranking in brand value and number one in supermarket chain in Sri Lanka in "Brand Finance Sri Lanka 100 2021". The research was conducted to analyze how these factors related to their operation and how they continue the good work further.

3.7 Data Collection

3.7.1 Primary Data Sources

The research was conducted based on primary data collected through the questionnaire and it was distributed among 300 people followed by a pilot survey to confirm the validation of the questionnaire.

3.7.2 Secondary data sources

A literature survey conducted to collect data on factors affecting the efficiency of warehouse picking operation. 40 to 50 literature surveys were analyzed and then started to narrow down the topic and finally came up with 33 literature surveys.

3.8 Data Analysis

Collected data sets were first fed into an excel in order to convert them into numbers. Then the converted data set was fed into SPSS to do the validity test for data obtained by the questionnaire. Mean, median, variance and standard deviation were used as descriptive analysis for the study. Then Pareto analysis carried out to perceive the 20% of reasons that impact 80% of the outcome. Finally, AHP was conducted to prioritize the identified factors.

Each response item is given a numerical value as showed in below (Table 3.1) to analyze the data quantitatively.

Response Item	Score
Strongly agree	5
Agree	4
Neither	3
Disagree	2
Strongly disagree	1

Table 3.1 Response Values

3.8.1 Validity and Reliability

Cronbach's alpha is a coefficient of reliability test to identify and measure internal consistency of a group of variables as a group of closely related degrees. This is an indicator of the reliability of the scale. A high alpha coefficient is considered a highly acceptable questionnaire for collecting survey-related data. Conventionally, coefficient of 0.7 or higher is considered that the data is reliable, and variables have relatively high internal consistency. Cronbach's alpha can be calculated by following formula (Equation 3.1) and the reliability test was carried out in this study to verify the reliability of variables (Bruin, 2006).

$$\alpha = \frac{N \cdot \bar{c}}{\bar{v} + (N-1)\bar{c}}$$

Equation 3.1 Cronbach's alpha

N= Total no. of items.

$\bar{c}$ = Average covariance between items.

$\bar{v}$ = Average variance.

3.8.2 Descriptive Analysis

Descriptive statistics will be used in research analysis and it describes the basic features of the data set and provides a simple summary about the sample. With the use of simple

graphics analysis, it forms the basis for every quantitative data. Descriptive statistics are different from inferential statistics. Descriptive statistics describes what the data shows while inferential statistics describes conclusions by analyzing the direct data. Descriptive statistics helps to recognize large amount of data simply and sensible way by reducing the data into a simple summary. Most of the time following characteristics will be described in a study; distribution, central tendency and dispersion. The distribution is a summary of the occurrence or frequency of values for a variable. For example, describing the gender by showing the percent or number of males and females who participated to the study. The central tendency of a data set describes the "center" of the distributed values. Mean, Median and Mode are the three main types of estimating central tendency. Among those three, mean is the most used method for describe the central tendency and it's the average of the data set. The median is the exact value placed in the middle of a data set while mode shows the most frequently occurring value in the data set. The dispersion illustrates the distribution of values from the calculated central tendency. Standard deviations is the most accurate and detailed estimation of dispersion (Trochim, n.d.).

In this study, mean, median, and standard deviation were used as descriptive analysis. Formula for each measure has shown in below.

$$M = \frac{sum\ of\ the\ terms}{number\ of\ items}$$

Equation 3.2 Mean

$$\text{Med (x) if n is even} = x\left[\frac{n}{2}\right]$$

Equation 3.3 Median when n is even

$$\text{Med (x) if n is odd} = \frac{x\left[\frac{n-1}{2}\right]+x\left[\frac{n+1}{2}\right]}{2}$$

Equation 3.4 Median when n is odd

x = Ordered list of values in data set

n= Number of values in data set

$$s = \sqrt{\frac{\sum(x_i - \bar{x})^2}{n-1}}$$

Equation 3.5 Standard Deviation

x_i= The value of one observation

$\bar{x}$ = The mean value of all observations

n = The number of observations

3.8.3 Pareto Analysis

Pareto analysis technique is based on the 80-20 rule. It shows that 80% of effects arise from 20% of the causes. This technique is used to get the essential facts needed for setting priorities. This technique statistically separates the input factors that have high impact on an outcome. This is a powerful decision-making tool and it is useful to get required facts needed to setting priorities. Here first step is to identify the problem. Then need to list down the causes of the problem. Each identified cause will get assigned a number based on the impact to the problem. A Pareto chart can be used to evaluate the identified causes. In this chart, individual values are illustrated in descending order by bars and then a cumulative total is represented by a line. Causes that impact to the problem are represented in descending order with showing number of times its occurrence and its cumulative impact. Highest priority will be given for the causes with top scores and lowest priority goes for the causes with lowest scores (Kenton, 2021).

3.8.4 Analytical Hierarchy Process (AHP)

AHP is a technique that could assist to procedure all the facts and make choices by way of ranking specific selections towards every other primarily based on importance. This is extra helpful when making selections without clear great choice. It combines mathematics and psychology to compare selections and pick out the excellent with the concept of pairwise comparisons. Here its compare two at a time that is less complicated to make the selection. Each variable gets its own importance weight and to evaluate the

results of every pairwise comparison, Linear algebra will be used. When weight becomes better, variable turn out to be more vital to the general selection. This approach of assessment can be used to observe many choices such as selecting products, services, processes, and routes etc. (Jagoda et al., 2020).

AHP technology is used to make decision in complex situations where many variables are considered when prioritizing alternatives. First, the selected variables are compared in pairs. These comparison results are then converted into mathematical values, and then process further and compare to determine relative importance between variables. Then one can give relative weights to each variable by doing normalization for the comparison matrix. This normalization will be performed by dividing every value through the sum of the column value. Then calculate the weight to determine the contribution of each variable to the goal. Weight will be obtained by calculating the mathematical average of all variables. The final step to calculate consistency index and consistency ratio. Formula for calculating the consistency index and consistency ration is given in below. To calculate consistency ratio, random consistency index (RI) will be used and it's a fixed value based on the number of evaluated variables. If consistency ratio is less than 0.1, it says that the matrix is considered as consistent (Vargas, 2010).

$$(CI) = \frac{\lambda \max - n}{n-1}$$

Equation 3.6 Consistency Index (CI)

$$(CR) = CI/RI$$

Equation 3.7 Consistency Ratio (CR)

N	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Table 3.2 Random Consistency Indices

4 CHAPTER – RESEARCH FINDINGS

4.1 Introduction

This chapter describes the findings of the data analysis. This part contains both descriptive statistics and inferential statistics. Descriptive statistics provide a simple summary of the sample with mean, median, variance and standard deviation which were calculated using excel. Then Pareto analysis was conducted to identify the factors that have high impact to the efficiency. To identify the most influencing factors that affect the efficiency of warehouse picking operation, AHP analysis was used.

Finally, the AHP analysis was conducted to identify the top 3 factors that affect the efficiency of warehouse picking operation.

In this study, two questionnaires were developed. First one was developed for warehouse people to identify the factors affecting the efficiency of warehouse picking operation. It was a self-administered questionnaire and people filled it without any intervention of the researcher, and to get a more insight on the variables, some interviews were held with people through online using the same questionnaire randomly. From those online interviews it was cleared that these variables have significant impacted to their day to day picking efficiency of the warehouse. Second questionnaire was developed for industry experts and it was a word document which was shared via an email. The second questionnaire was an interviewer administered questionnaire and it was filled using the data collected over the phone.

4.2 Reliability Statistics

The Cronbach's Alpha is a statistical technique to measure the internal consistency of a psychometric test. If the Cronbach's Alpha value is higher than 0.7, it indicates that the variable has high internal consistency (Bruin, 2006).

Case Processing Summary

		N	%
Cases	Valid	207	100.0
	Excluded[a]	0	.0
	Total	207	100.0

Figure 4.1 Case Processing Summary

Reliability Statistics

Cronbach's Alpha	N of Items
.822	13

Figure 4.2 Reliability Statistics

According to the outcome of the above table, the value of Cronbach's Alpha is 0.822. Therefore, the reliability of the variables is in a consistent level and data set can be accepted.

4.3 Descriptive Analysis

Distribution of demographic profile of people who participated for the questionnaire were illustrated using a graphical view for easy understand. These were gender, age, level of education, work experience at a warehouse, experience in WMS and types of technologies used. Then mean, median, variance, and standard deviation were calculated using excel.

4.3.1 Demographic Profile and Preferences Analysis

Gender

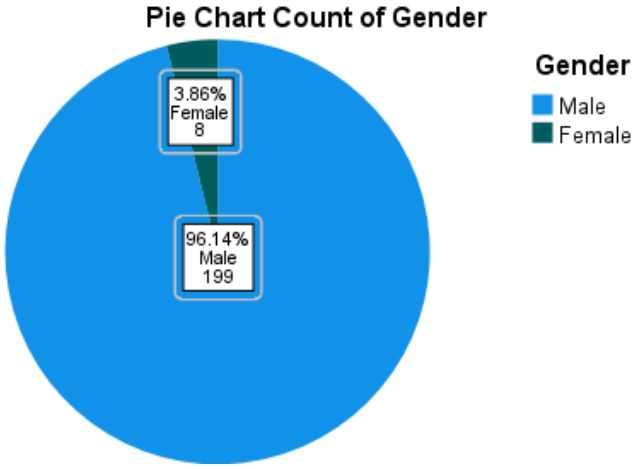

Figure 4.3 Gender

It was cleared that most of the participants were male with the percentage of 94.14% and the rest was female with percentage of 3.86%.

Age Group

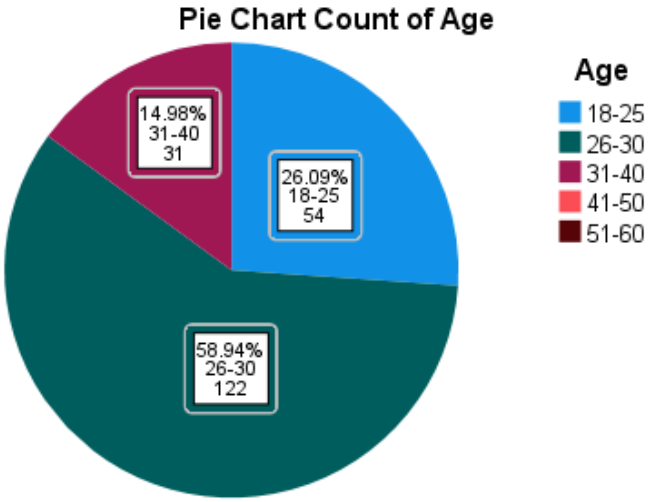

Figure 4.4 Age

Most of the participants were in the 26-30 age group with a percentage of 58.94%. Secondly 18-25 age group was noted with the percentage of 26.09% and the least number of participants belonged to the age group of 31-40 with percentage of 14.98%.

Level of Education

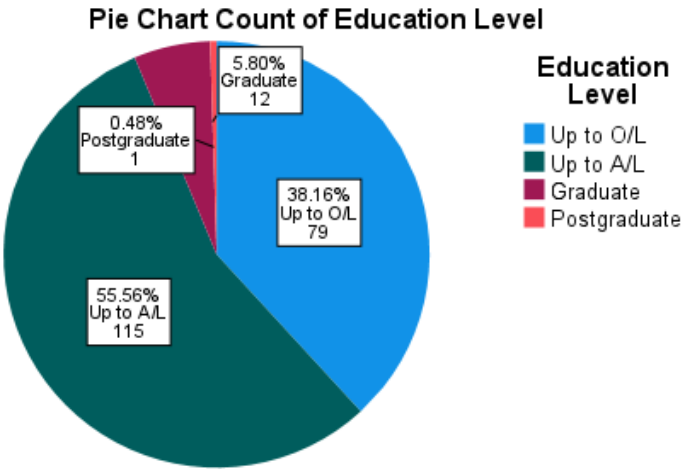

Figure 4.5 Education Level

Most of the participants had learned up to A/L with the percentage of 55.56%. And 38.16% participants had learned up to O/L. Graduate and Postgraduate level of education showed percentages of 5.8% and 0.48% respectively.

Work Experience at a Warehouse

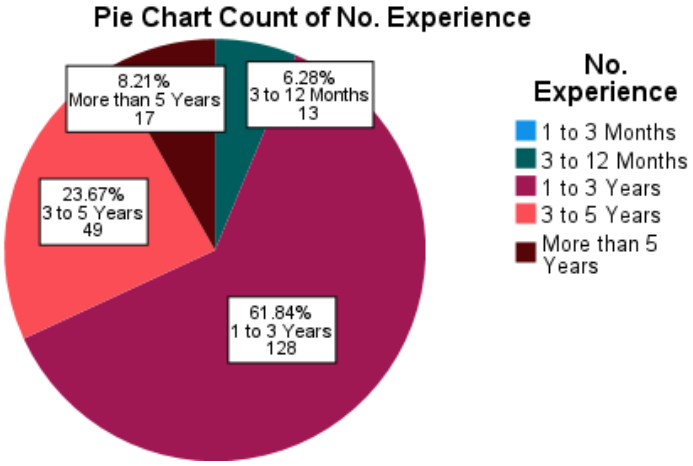

Figure 4.6 No. of Experience

The questionnaire was mostly filled by people who had 1 to 3 years of experience which represented a percentage of 61.84%. A percentage of 23.67% had 3 to 5 years' experience. Percentages of 8.21% and 6.28% was obtained for participants with more than 5years experience and participants with 3-12 months respectively.

Experience in WMS

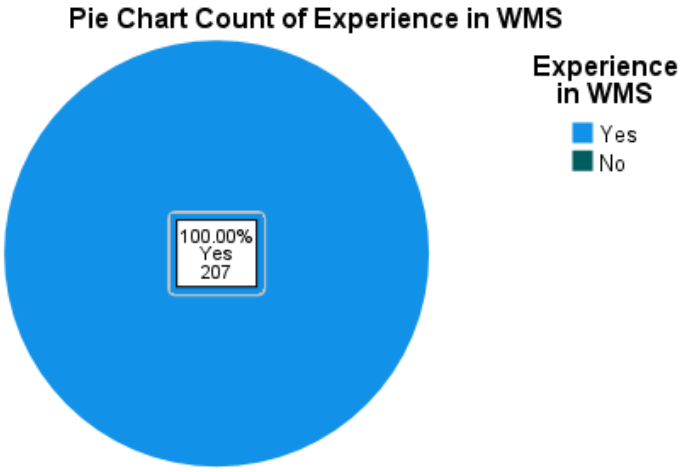

Figure 4.7 Experience in WMS

All the research participants had experience in WMS.

Type of Technologies Used

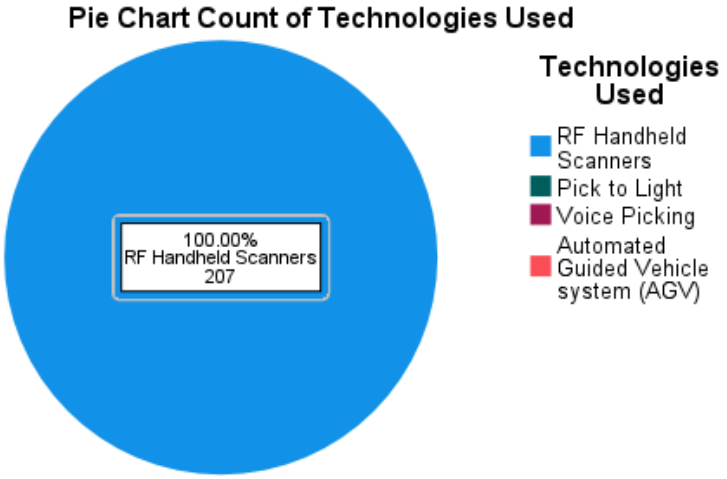

Figure 4.8 Type of Technologies Used

The whole sample of research participants had experience in using RF handheld scanners.

4.3.2 The Central Tendency and Dispersion

Variables	Mean	Median	Standard Deviation	Variance
Training on warehouse workers	4.84	5.00	0.35	0.12
Labor planning	4.28	4.00	0.57	0.32
Technology	4.75	5.00	0.48	0.23
Space utilization	4.53	5.00	0.65	0.43
Worker comfort level	4.14	4.00	0.60	0.35
Cross train workforce	4.25	4.00	0.57	0.32
KPIs	4.35	4.00	0.60	0.36
Incentive payments for labor	4.79	5.00	0.41	0.17
Maintenance of product slotting	4.58	5.00	0.58	0.34
Picking methodology	4.21	4.00	0.55	0.30
Integrating processes	4.15	4.00	0.60	0.36
Safety of the operation	4.34	4.00	0.57	0.32
Machine maintenance plan	4.72	5.00	0.47	0.22

Table 4.1 Descriptive Analysis Summary

According to the above table (Table 4.1) mean value is greater than 4 for all 13 variables. Training on warehouse workers, incentive payments for labor, technology, machine maintenance plan, maintenance of product slotting and space utilization are the top 6 variables which have higher mean value which is more than 4.5. KPIs, safety of the operation, labor planning, cross train workforce, picking methodology, integrating processes and worker comfort level have a mean value between 4 and 4.5 which also considered as a high value. Therefore, we can consider that all 13 variables have an impact on the efficiency of warehouse picking operation.

Standard deviation explains the variance or how the observed data are spread around its mean value. The top 6 variables which have higher mean value also have smaller standard deviation which is close to zero. Similarly, the standard deviation of next 7 variables are also close to zero.

From above descriptive analysis we can consider that training on warehouse workers, incentive payments for labor, technology, machine maintenance plan, maintenance of product slotting and space utilization factors have a significant impact to the efficiency of warehouse picking operation.

4.4 Pareto Analysis

Pareto analysis technique is based on the 80-20 rule. It shows that 80% of effects arise from 20% of the causes. Identified top factors were later used for the AHP analysis to get more insight on data and prioritize the factors.

Factor	Total Score	Cumulative Score	Cumulative %
Training on warehouse workers	1005	1005	8%
Incentive payments for labor	995	2000	17%
Technology	990	2990	25%
Machine maintenance plan	983	3973	33%
Maintenance of product slotting	958	4931	41%
Space utilization	950	5881	49%
KPIs	909	6790	56%
Safety of the operation	907	7697	64%
Labor planning	893	8590	71%
Cross train workforce	887	9477	78%
Picking methodology	878	10355	86%
Integrating processes	868	11223	93%
Worker comfort level	866	12089	100%
	12089		

Table 4.2 Calculation of Pareto Analysis

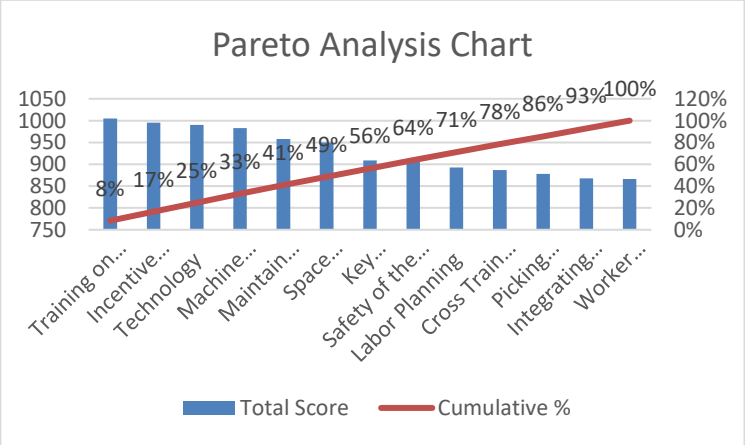

Figure 4.9 Pareto Analysis Chart

From the above table (Table 4.2) and figure (Figure 4.9) it shows that 80% of impacts is due to 10 factors identified from the literature review. These 10 factors are training on warehouse workers, incentive payments for labor, technology, machine maintenance plan, maintenance of product slotting, space utilization, KPIs, safety of the operation, labor planning, and cross train workforce.

4.5 AHP Analysis

To reduce the complexity in pair wise comparison proceedings and to ensure the accuracy of pair wise comparison in AHP analysis, the top 6 factors were selected out of 10 factors which were identified from Pareto analysis. These top 6 factors were training on warehouse workers, incentive payments for labor, technology, machine maintenance plan, maintenance of product slotting and space utilization. To get the industry expert opinions on pair wise comparison, a questionnaire was developed, and it is attached in the appendix. This second questionnaire was an interviewer administered questionnaire and it was filled using data collected over the phone.

TWW	Training on warehouse workers
IPL	Incentive payments for labor
T	Technology
MMP	Machine maintenance plan
MPS	Maintenance of product slotting
SU	Space utilization

Table 4.3 Code Description

	TWW	IPL	T	MMP	MPS	SU	Total	Weights
TWW	0.41	0.26	0.52	0.41	0.34	0.26	2.21	0.37
IPL	0.10	0.06	0.08	0.03	0.03	0.04	0.34	0.06
T	0.17	0.16	0.22	0.35	0.34	0.28	1.51	0.25
MMP	0.11	0.20	0.07	0.11	0.18	0.18	0.85	0.14
MPS	0.10	0.20	0.05	0.05	0.08	0.18	0.66	0.11
SU	0.11	0.12	0.05	0.04	0.03	0.07	0.42	0.07
Total	1.00	1.00	1.00	1.00	1.00	1.00	6.00	1.00

Table 4.4 Weight Calculation

As per the below table (Table 4.5), the consistency ratio is 0.08 and it is less than 0.1. Therefore, it is confirmed that data collected for the weight calculation are consistent.

	l	l-h	n-1	CI	RI	CR
	6.69	0.47	5	0.093	1.24	0.08
	6.30					
	6.87					
	6.54					
	6.24					
	6.16					
λmax	6.47					

Table 4.5 Critical Ratio Calculation

Factor	Weight
Training on Warehouse Workers	0.37
Technology	0.25
Machine Maintenance Plan	0.14
Maintenance of Product Slotting	0.11
Space Utilization	0.07
Incentive payments for labor	0.06

Table 4.6 AHP Result

Based on the AHP weight calculation which is mentioned in above table (Table 4.6), Top 3 factors that have high impact to the efficiency of warehouse picking operation were “Training on Warehouse Workers”, “Technology” and “Machine Maintenance Plan” with the value of 0.37, 0.25, and 0.14 respectively.

5 CHAPTER – DISCUSSION CONCLUSION AND FUTURE RESEARCH DIRECTIONS

5.1 Introduction

This chapter provides results and discussion, conclusion, limitations and the capabilities of future research. The study was carried out to determine the factors affecting the efficiency of warehouse picking operation.

5.2 Results & Discussion

Research findings were analyzed along with the objective of the study in order to get a clear idea about the research area. According to literature study, picking operation is one of the key processes in warehouse management and it is also defined as the costliest process. It covers 50% of warehouse labor cost and the number can be high as 63% which highlights the importance of warehouse picking operation. Further, space utilization, technology, picking methodology, incentive payments for labor, KPIs, worker comfort level, training on warehouse workers, labor planning, safety of the operation, machine maintenance plan, cross train workforce, maintenance of product slotting and integrating processes were identified as variables that affect the efficiency of warehouse picking operation with a comprehensive literature study on challenges and technologies used in warehouse picking operation from literature study.

Self-administered questionnaire was developed and distributed among warehouse people. 207 responses were collected and in the demographic analysis, most of the them accounts for male category and age group of 26-30 years. Further, 55.56% of the respondents have education level up to A/L and 61.84% have 1-3 years of working experience at a warehouse. Also, all the respondents had experience in using a WMS and RF handheld scanners in a warehouse.

Cronbach’s Alpha method was used to measure the consistency of the data set and with the value of 0.822 it showed that internal consistency of the research instrument was within satisfactory level and data set can be accepted.

As a descriptive analysis, mean and standard deviation were calculated and the top 6 factors that have higher mean value and a smaller standard deviation were training on warehouse workers, incentive payments for labor, technology, machine maintenance plan, maintenance of product slotting, and space utilization.

Pareto analysis technique was used to determine the factors that have significance impact to the warehouse picking efficiency and based on the outcome it is showed that 80% of impact is due to 10 factors. These 10 factors were training on warehouse workers, incentive payments for labor, technology, machine maintenance plan, maintenance of product slotting, space utilization, KPIs, safety of the operation, labor planning and cross train workforce.

AHP analysis was conducted to prioritize the factors identified from Pareto analysis. To reduce the complexity in pair wise comparison and to ensure the accuracy of pair wise comparison in AHP, the top 6 factors of Pareto analysis were selected. Based on the AHP weight calculation, top 3 factors that affect the efficiency of warehouse picking operation were “Training on Warehouse Workers”, “Technology”, and “Machine Maintenance Plan” with the value of 0.37, 0.25 and 0.14 respectively.

5.3 Conclusion

With the Covid-19 pandemic, supermarkets are in a great challenge of fulfilling customer requirements due to “Panic buying” behavior. Demand for the consumer goods has been increased rapidly with more and more people live indoors and practicing social distancing. Moreover, with the current situation, there is a possibility that people may get absent due to quarantine condition and warehouses need to operate with available resources while trying to output the same as earlier. As most of the warehouses in Sri Lanka are labor intensive, labor shortage issue is a potential challenge in future. Therefore, to keep the customer satisfaction in a constant level, this study is highly important to analyze the current gaps within the warehouse and to increase the efficiency while keeping the company profitable. As per the results shown in below table (Table 5.1), “Training on Warehouse Workers”, “Technology” and “Machine Maintenance Plan” were the most influential factors for the efficiency of warehouse picking operation.

Rank	Factor	Weight according to AHP analysis
1	Training on Warehouse Workers	0.37
2	Technology	0.25
3	Machine Maintenance Plan	0.14

Table 5.1 Conclusion

5.4 Research Limitations

- Research was carried out for one level of factors and not considered the sub factors among those. For example, technology can be further analyzed by what kind of technologies that affect efficiency of warehouse picking operation.
- Due to the pandemic situation it was difficult to have many participants. Therefore, total number of respondents were limited to 207 in the survey.
- There are other operations within the warehouse that can help to increase the efficiency. With the limited time duration, the study was carried out only for the picking operation.

5.5 Future Research Directions

- To gain more insight for the efficiency of warehouse picking operation, future studies can be conducted with another level of AHP by considering sub factors under each prominent factor.
- It can also be suggested to analyze the challenges going to face when implementing these factors within a warehouse.
- There are other operations within the warehouse that can help to increase the efficiency and further studies can be conducted for those as well.

5.6 Chapter Summary

Picking is defined as one of the key processes in warehouse management and the costliest process. 13 influencing factors were identified from literature study such as space utilization, technology, picking methodology, incentive payments for labor, KPIs etc. 207 responses were collected for the primary data collection and with the Cronbach's Alpha value of 0.822 it showed that the data set can be accepted. To identify the most influencing factors that have significant impact to warehouse picking operation, Pareto analysis was used. With the result of AHP analysis, the top 3 factors that affect the efficiency of warehouse picking operation were training on warehouse workers, technology and machine maintenance plan. Future studies can be conducted with another level of AHP by considering sub factors under each prominent factor and it can also be suggested to analyze the challenges going to face when implementing these procedures within a warehouse. Same study can be done for other operations within the warehouse such as put-away, repacking, loading etc.

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7 CHAPTER – APPENDIX

7.1 Questionnaire Template 1 (Primary Data Collection)

Factors affecting the efficiency of warehouse Picking Operation in Retail Industry / භාණ්ඩ තෝරා ගැනීමේ මෙහෙයුම් කාර්යක්ෂමතාවයට බලපාන සාධක

Dear Sir/Madam,

I am K. Waruna Chathuranga Peiris reading for the MBA in Supply Chain Management at University of Moratuwa.

As a requirement of the program students are required to conduct a research and collect responses for the questionnaire. Responses will be highly confidential and will only be used for study purposes.

I appreciate your support by spending few minutes to fill this questionnaire.

හිතවත් මහත්වරුනි / මහත්මයාණෙනි,

කේ. වරුණ චතුරංග පීරිස් වන මා මොරටුව විශ්ව විද්‍යාලයේ සැපයුම්දාම කළමනාකරණය පිළිබඳ උපාධිය හදාරමින් සිටියි.

එම වැඩසටහනේ අවශ්‍යතාවයක් ලෙස පර්යේෂණයක් සිදු කර ප්‍රශ්නාවලිය සඳහා ප්‍රතිචාර එකතු කිරීම අවශ්‍ය වේ. ප්‍රතිචාර ඉතා රහස්‍ය වන අතර එය භාවිතා කරනු ලබන්නේ අධ්‍යයන කටයුතු සඳහා පමණි.

මෙම ප්‍රශ්නාවලිය පිරවීම සඳහා මිනිත්තු කිහිපයක් ගත කිරීම වෙනුවෙන් ඔබගේ සහයෝගය මම අගය කරමි.

Section 1 / 1 කොටස

01. Gender / ස්ත්‍රී පුරුෂ භාවය
    a. Male / පිරිමි
    b. Female / ගැහැණු

02. Age / වයස
    a. 18-25
    b. 26-30
    c. 31-40
    d. 41-50
    e. 51-60

03. Current Level of Education / වත්මන් අධ්‍යාපන මට්ටම
    a. Up to O/L / සාමාන්‍ය පෙළ දක්වා
    b. Up to A/L / උසස් පෙළ දක්වා
    c. Graduate / උපාධිය දක්වා
    d. Postgraduate / පශ්චාත් උපාධිය දක්වා

04. No. of Experience working at a Warehouse / රැකියා ස්ථානයේ පළපුරුද්ද
    a. 1 to 3 Months / මාස 1 සිට 3 දක්වා
    b. 3 to 12 Months / මාස 3 සිට 12 දක්වා
    c. 1 to 3 Years / අවුරුදු 1 සිට 3 දක්වා
    d. 3 to 5 Years / අවුරුදු 3 සිට 5 දක්වා
    e. More than 5 Years / අවුරුදු 5 කට වඩා

05. Do you experience any WMS (Warehouse Management System) in your organization? (Example - SAP EWM, Oracle, Infor, Tradegecko) / ඔබ කිසියම් භාණ්ඩ කළමනාකරණ පද්ධතියක් සම්බන්ධයෙන් පළපුරුද්දක් ලබා තිබේද ? (උදාහරණය - SAP EWM, Oracle, Infor, Tradegecko)
    a. Yes / ඔව්
    b. No / නැත

06. What type of technologies you are experiencing in your current organization for the picking operation / භාණ්ඩ තෝරා ගැනීමේ මෙහෙයුම සඳහා ඔබගේ රැකියා ස්ථානය තුළ ඔබ අත්විඳින්නේ කුමන ආකාරයේ තාක්ෂණයන් ද?

a. RF Handheld Scanners / අතින් ගෙනයන ස්කෑනර් තාක්ෂණය
b. Pick to Light / ආලෝක සලකුණු තාක්ෂණය
c. Voice Picking / හඬ තාක්ෂණය
d. Automated Guided Vehicle system (AGV) / ස්වයංක්‍රීය මඟ පෙන්වන වාහන පද්ධති

Section 2 / 2 කොටස

Please select your opinion to rate the following factors (**Bold highlighted**). For Better understanding, an example is mentioned for every factor within the brackets. / කරුණාකර භාණ්ඩ තෝරා ගැනීමේ මෙහෙයුම් කාර්යක්ෂමතාවයට පහත සඳහන් සාධක සඳහා ඔබේ මතය පවසන්න.වඩා හොඳ අවබෝධයක් සඳහා, සෑම සාධකයක් සමඟම උදාහරණයක් වරහන් තුළ සඳහන් වේ.

07. **Training on Warehouse Workers** / රැකියා පුහුණුව (A Quality training of processes will help to increase my confidence level while working / ක්‍රියාවලි පිළිබඳ ගුණාත්මක පුහුණුවක් ලබාදීම රැකියාව කිරීමෙදී මගේ විශ්වාසනීය මට්ටම ඉහළ නැංවීමට උපකාරී වේ)

a. Strongly Agree / තදින්ම එකඟයි
b. Agree / එකඟයි
c. Neutral / අදහසක් නැත
d. Disagree / එකඟ නොවෙමි
e. Strongly Disagree / තදින්ම එකඟ නොවෙමි

08. **Labor Planning** / මිනිසුන් කලමනාකරණය (Having enough no. of workers for the picking operation will increase the speed of the picking / භාණ්ඩ තෝරා ගැනීමේ ක්‍රියාවලිය සඳහා ප්‍රමාණවත් තරම් මිනිසුන් සිටීම එම ක්‍රියාවලියේ වේගය වැඩි කිරීම සඳහා උපකාරී වේ)

a. Strongly Agree / තදින්ම එකඟයි
b. Agree / එකඟයි
c. Neutral / අදහසක් නැත
d. Disagree / එකඟ නොවෙමි
e. Strongly Disagree / තදින්ම එකඟ නොවෙමි

09. **Technology** / තාක්ෂණය (Verifications like scanning barcodes of products and bins will help to reduce picking errors / ලබා ගන්නා භාණ්ඩය සහ භාණ්ඩය ගන්නා ස්ථානය පද්ධතිය විසින් ස්වයංක්‍රියව පරීක්ෂා කිරීම භාණ්ඩ තෝරා ගැනීම් ක්‍රියාවලියේ දෝෂ අවම කිරීමට උපකාරී වේ)

a. Strongly Agree / තදින්ම එකඟයි
b. Agree / එකඟයි
c. Neutral / අදහසක් නැත
d. Disagree / එකඟ නොවෙමි
e. Strongly Disagree / තදින්ම එකඟ නොවෙමි

10. **Space Utilization** / ඉඩකඩ භාවිතය (Keeping fast moving products near to loading bay will reduce picker walking distance and it will increase the speed of picking operation / නිතරම ඉවත්වෙන භාණ්ඩ, භාණ්ඩ පටවන ස්ථානය ලඟින් තැබීමෙන් ඇවිදීමේ දුර අඩු කරන අතර එය භාණ්ඩ තෝරා ගැනීමේ මෙහෙයුම් ක්‍රියාවලි වේගය වැඩි කරයි)

a. Strongly Agree / තදින්ම එකඟයි
b. Agree / එකඟයි
c. Neutral / අදහසක් නැත
d. Disagree / එකඟ නොවෙමි
e. Strongly Disagree / තදින්ම එකඟ නොවෙමි

11. **Worker Comfort Level** / සේවක සුවපහසු මට්ටම (Keeping the warehouse clean while doing the work help to reduce the stress level and help to do more work / වැඩ කරන අතරතුර වැඩ කරන ස්ථානය පිරිසිදුව තබා ගැනීම ආතතිය අඩු වීමට සහය වන අතර එය වැඩිපුර වැඩ කිරීමටද උපකරී වේ)

a. Strongly Agree / තදින්ම එකඟයි
b. Agree / එකඟයි
c. Neutral / අදහසක් නැත
d. Disagree / එකඟ නොවෙමි
e. Strongly Disagree / තදින්ම එකඟ නොවෙමි

12. **Cross Train Workforce** / බහු පුහුණු ශ්‍රම බලකාය (Training people on several activities (Example – Picking, Loading, Shipping etc.) will help to assig them for those activities when labor shortage arises. ක්‍රියාකාරකම් කිහිපයක් (උදාහරණ - Picking, Loading, Shipping etc.) පිළිබඳව පුද්ගලයින් පුහුණු කිරීම ශ්‍රම හිඟයක් ඇති වූ විට එම ක්‍රියාකාරකම් සඳහා ඔවුන්ව යොමු කිරීමට උපකාරී වේ)

a. Strongly Agree / තදින්ම එකඟයි
b. Agree / එකඟයි
c. Neutral / අදහසක් නැත
d. Disagree / එකඟ නොවෙමි
e. Strongly Disagree / තදින්ම එකඟ නොවෙමි

13. **Key Performance Indicators (KPI)** / ප්‍රධාන කාර්ය සාධන දර්ශක/KPI (If I am the picking supervisor of a warehouse, displaying KPIs like throughput (how many picks or orders are completed in a given time-frame by a user) will help me to assign skillful pickers for high volume of orders. / මම ගබඩාවක භාණ්ඩ තේරීම් මෙහෙයුමේ අධීක්ෂක නම්, KPI ප්‍රදර්ශනය කිරීම (උදාහරණයක් ලෙස- පුද්ගලයෙකු විසින් ලබා දී ඇති කාල රාමුව තුළ කොතරම් ඇණවුම් ප්‍රමාණයක් සම්පූර්ණ කර ඇත්ද යන්න) දක්ෂ පුද්ගලයින් හඳුනා ගැනීමට උපකාරී වන අතර ඔවුන්ට ඉහළ පරිමාවක් සහිත ඇණවුම් පැවරීමටද උපකාරී වේ)

a. Strongly Agree / තදින්ම එකඟයි
b. Agree / එකඟයි
c. Neutral / අදහසක් නැත
d. Disagree / එකඟ නොවෙමි
e. Strongly Disagree / තදින්ම එකඟ නොවෙමි

14. **Incentive Payments for Labor** / සේවක දිරි දීමනා (Errors should be monitored during picking and a good reward or incentive pay system should be developed based on picker performance to motivate people / භාණ්ඩ තෝරා ගැනීමේදී සිදු කරන දෝෂ නිරීක්ෂණය කළ යුතු අතර දෝෂ අඩුවෙන් සිදු කරන පුද්ගලයින් හඳුනා ගෙන ඔවුන්ට දිරි දීමනා ගෙවීමේ ක්‍රමයක් සකස් කිරීම ඔවුන්ගේ වැඩ කිරීමට ඇති කැමැත්ත වැඩි කිරීමට උපකාරී වේ)

a. Strongly Agree / තදින්ම එකඟයි
b. Agree / එකඟයි
c. Neutral / අදහසක් නැත
d. Disagree / එකඟ නොවෙමි
e. Strongly Disagree / තදින්ම එකඟ නොවෙමි

15. **Maintenance of Product Slotting** / භාණ්ඩ නිවැරදි ස්ථානයේ තැබීම (During rush hour people put items in the most convenient area to save time without putting the product in the right bin. When product is not in the right bin, picking speed get reduced / කාර්යබහුල වේලාවේදී භාණ්ඩය නිවැරදි ස්ථානයට නොගෙන කාලය ඉතිරි කර ගැනීම සඳහා වඩාත් පහසු ප්‍රදේශයක තබයි. භාණ්ඩය නිවැරදි ස්ථානයේ නොමැති විට, එය භාණ්ඩය තෝරා ගැනීමේ වේගය අඩු කරයි)
a. Strongly Agree / තදින්ම එකඟයි
b. Agree / එකඟයි
c. Neutral / අදහසක් නැත
d. Disagree / එකඟ නොවෙමි
e. Strongly Disagree / තදින්ම එකඟ නොවෙමි

16. **Picking Methodology** / භාණ්ඩ තෝරා ගැනීමේ ක්‍රමවේදය (Picking strategy should eliminate issues such as backtracking aisles that already walked through. This will increase picking speed / භාණ්ඩ තෝරා ගැනීමේ ක්‍රමෝපාය මඟින් දැනටමත් ගමන් කර ඇති භාණ්ඩ-ගබඩා ස්ථාන වලට නැවත ගමන් කිරීම වැනි ගැටළු ඉවත් කළ යුතුය. මෙය භාණ්ඩ තෝරා ගැනීමේ වේගය වැඩි කරයි)
a. Strongly Agree / තදින්ම එකඟයි
b. Agree / එකඟයි
c. Neutral / අදහසක් නැත

d. Disagree / එකඟ නොවෙමි
e. Strongly Disagree / තදින්ම එකඟ නොවෙමි

17. **Integrating Processes** / ක්‍රියාවලියන් ඒකාබද්ධ කිරීම (Picking orders directly into the final shipping carton without going to repack or consolidate the items again will help to reduce overall time between picking and loading the products / භාණ්ඩ නැවත ඇසුරුම් කිරීමේ ක්‍රියාවලියකට නොයවා, කෙලින්ම අවසාන ඇසුරුම් පෙට්ටියටම දැමීමෙන් භාණ්ඩ එකතු කිරීමේ සිට පැටවීම දක්වා සමස්ත කාලය අඩු කර ගැනීමට උපකාරී වේ)

a. Strongly Agree / තදින්ම එකඟයි
b. Agree / එකඟයි
c. Neutral / අදහසක් නැත
d. Disagree / එකඟ නොවෙමි
e. Strongly Disagree / තදින්ම එකඟ නොවෙමි

18. **Safety of the Operation** / මෙහෙයුම් ක්‍රියාවලියේ ආරක්ෂාව (Safety equipment (Eg: hard hats) should be worn by every worker inside the warehouse to minimize workplace injuries and help people to work more confidently / ආරක්ෂිත හිස් වැසුම් වැනි උපකරණ රැකියා ස්ථානයේ සිටින සෑම සේවකයෙකුම භාවිතා කිරීම තුලින් සේවා ස්ථානයේ ඇති වන අනතුරු සහ ආපදා අවම කර ගැනීමටත්, වඩාත් විශ්වාසයෙන් වැඩ කිරීමටත් උපකාරී වේ)
a. Strongly Agree / තදින්ම එකඟයි
b. Agree / එකඟයි
c. Neutral / අදහසක් නැත
d. Disagree / එකඟ නොවෙමි
e. Strongly Disagree / තදින්ම එකඟ නොවෙමි

19. **Machine Maintenance Plan** / යන්ත්‍ර නඩත්තු කිරීමේ සැලසුම් (Having ensure that machines are serviced regularly according to the maintenance plan, help to identify problems before they become too serious and it will reduce the impact to the operation / නඩත්තු සැලැස්මට අනුව යන්ත්‍ර නිරන්තරයෙන් නඩත්තු

කිරීම තුලින්, යන්ත්‍ර දෝෂ ඉක්මනින් හඳුනා ගැනීමට උපකාරී වන අතර එමගින් භාණ්ඩ තෝරා ගැනීමේ මෙහෙයුමට සිදුවන හානිය අවම වේ

a. Strongly Agree / තදින්ම එකඟයි
b. Agree / එකඟයි
c. Neutral / අදහසක් නැත
d. Disagree / එකඟ නොවෙමි
e. Strongly Disagree / තදින්ම එකඟ නොවෙමි

Thank you for your valuable cooperation. ඔබගේ වටිනා සහයෝගයට ස්තූතියි.

7.2 Questionnaire Template 2 (Data Collection for AHP)

Factors Affecting the Efficiency of Warehouse Picking Operation in Retail Industry

Dear Sir/Madam,

I am K. Waruna Chathuranga Peiris reading for the MBA in Supply Chain Management at University of Moratuwa. As a requirement of the program students are required to conduct a research. For my research I wish to get your support and your responses will be highly confidential and will only be used for study purposes. I appreciate your contribution by spending few minutes to fill this questionnaire.

Based on the responses got from the 1st questionnaire, following 6 factors have been identified as most affecting factors for the efficiency of warehouse picking operation.

1. Training on Warehouse Workers

2. Incentive Payments for Labor

3. Technology

4. Machine Maintenance Plan

5. Maintenance of Product Slotting

6. Space Utilization

To conduct an AHP analysis, you are supposed to give a rating on pair wise comparison between above mentioned top 6 factors. The main goal is to fill the questionnaire, based on your knowledge and experience on importance of one main factor over the corresponding other factor. In other words, considering the importance of one factor on efficiency of warehouse picking operation over the other factor.

By considering the below scale, compare the left-side factor with respect to the right-side factor and rate the importance level of each row.

Scale	Meaning	Explanation
1	Equally Important	Both factors are equally important for the decision
2	Slightly Important	Decision slightly favors towards one factor

3	Important	One factor is important than other
4	Very Important	One factor is very important than other
5	Extremely Important	One factor is extremely important than other

Instructions: Compare the factors mentioned on left side and right side of the same row and then make your response based on the scale mentioned above. Please follow the below example.

Example:

1. If you think “Training on Warehouse Workers” is very important for efficiency on warehouse picking operation than “Incentive payments for labor” then select 4 in the left-hand side.
2. If you think “Incentive payments for labor” is very important for efficiency on warehouse picking operation than “Training on Warehouse Workers” then select 4 in the right-hand side.

LHS Factor	5	4	3	2	1	2	3	4	5	RHS Factor
Training on Warehouse Workers	☐	☐	☐	☐	☐	☐	☐	☐	☐	Incentive payments for labor
Training on Warehouse Workers	☐	☐	☐	☐	☐	☐	☐	☐	☐	Technology
Training on Warehouse Workers	☐	☐	☐	☐	☐	☐	☐	☐	☐	Machine Maintenance Plan
Training on Warehouse Workers	☐	☐	☐	☐	☐	☐	☐	☐	☐	Maintenance of Product Slotting
Training on Warehouse Workers	☐	☐	☐	☐	☐	☐	☐	☐	☐	Space Utilization

Incentive payments for labor	☐	☐	☐	☐	☐	☐	☐	☐	☐	Technology
Incentive payments for labor	☐	☐	☐	☐	☐	☐	☐	☐	☐	Machine Maintenance Plan
Incentive payments for labor	☐	☐	☐	☐	☐	☐	☐	☐	☐	Maintenance of Product Slotting
Incentive payments for labor	☐	☐	☐	☐	☐	☐	☐	☐	☐	Space Utilization
Technology	☐	☐	☐	☐	☐	☐	☐	☐	☐	Machine Maintenance Plan
Technology	☐	☐	☐	☐	☐	☐	☐	☐	☐	Maintenance of Product Slotting
Technology	☐	☐	☐	☐	☐	☐	☐	☐	☐	Space Utilization
Machine Maintenance Plan	☐	☐	☐	☐	☐	☐	☐	☐	☐	Maintenance of Product Slotting
Machine Maintenance Plan	☐	☐	☐	☐	☐	☐	☐	☐	☐	Space Utilization
Maintenance of Product Slotting	☐	☐	☐	☐	☐	☐	☐	☐	☐	Space Utilization