WAREHOUSE PERFORMANCE IMPROVEMENT THROUGH OPTIMAL ORDER PICKING LOCATION: A CASE OF AN OPTICAL LENS COMPANY

By

MONTIRA ITTIMETHAKUL

A Final Report of the Six-Credit Course
SCM 2202 Graduate Project

Submitted in Partial Fulfillment of the Requirements for the Degree of
MASTER OF SCIENCE IN SUPPLY CHAIN MANAGEMENT

Martin de Tours School of Management
Assumption University
Bangkok, Thailand

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I, Montira Ittimethakul

declare that this thesis/project and the work presented in it are my own and has been generated by me as the result of my own original research.

Warehouse Performance Improvement through optimal order picking location: A case of an Optical Lens Company

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ACKNOWLEDGEMENTS

This research could not have been completed successfully without the genuine support and cooperation from many people who offered their time and energy in giving me inspiration, advice, suggestion and comments. It is the right moment for me to think about these people who have contributed to my research.

In the first place, I would like to express my sincerely thanks to A. Thanapat who is my advisor. He provided me with valuable guidance and strong support. His knowledge and expertise guided me in the right direction to final completion of the research. Moreover, I am grateful to all committee members for their time, invaluable suggestions and discussions.

Finally, I would like to thank the management teams of the Optical Lens Company who gave me the opportunity to complete this research. And my thanks also go to members of the company's Supply Chain Department and Finance Department for their kind support in providing relevant and important information.

Montira Ittimethakul
Assumption University
November 2011

ABSTRACT

Picking performance is greatly influenced by the picking location and layout design. Layout plays an important role in determining the expected length of a picker's tour which is itself a relevant component of the time required to complete picking orders. The purpose of this research is to improve picking performance. The research presents the results from data analysis to identify the problem, which is the inappropriate picking location.

There are different traveling times between the fast moving products, the medium moving products, and the slow moving products. A simulation approach is proposed for an efficient layout design of an order picking location. It uses the strategy to classify the frequency of order picking products and to redesign the order picking product locations. The most frequent order picking is A class products, which will therefore be assigned to the closest location, and the lowest frequent order picking which is the C class should be allocated to the farthest location. The new proposed model produces excellent results. The annual traveling time reduction is 5832.14 hours. The new picking performance can increase by 8.50%, from 700 pieces per hour to 759 pieces per hour, which achieves the objective of this research to improve the picking performance.

All data collection, such as sales report, layout, order picking location, and standard traveling time are analyzed by Microsoft Excel to find the existing traveling time and also to determine the new model's result.

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CHAPTER I

GENERALITIES OF THE STUDY

Warehouse management is one of the significant elements in supply chain management because there are many activities to perform in this area since the activity to receive the products, to store the product, to pick the products and to prepare the shipment that affects the customer. It also involves cost for the company.

The order picking process is the critical process in the warehouse that consumes around 60% (Drury, 1988 as cited in De Koster, Le-Duc & Roodbergen, 2007) and it accounts for 55% of the warehouse total expense (Tompkins, White, Bozer, Frazelle, & Tanchoco, 2003). So the order picking process is the primary improvement area in the warehouse. There are four improvable elements of the order picking order process, such as travel time, process time, idle time and administrative time (Caron, Marchet, & Perego, 1998).

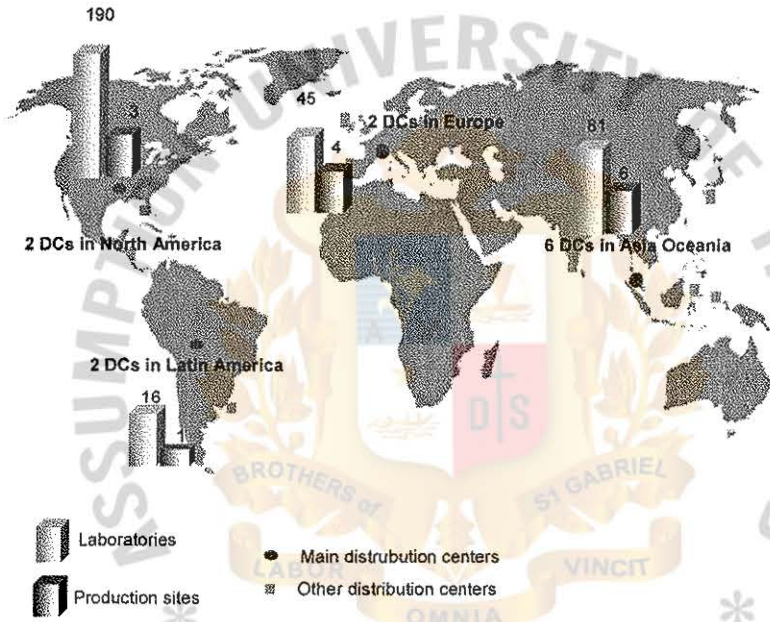
In the picking system, the layout and storage location are influence the picking performance, as traveling time is at the starting point, and the picking location and the stopping point can represent the biggest part of total picking time. As a consequence, there is room for improvement of traveling time. If the traveling time can be reduced, the performance will be increased.

Therefore, this study will focus on how to improve the traveling time of the order picking process in a warehouse. The researcher will find the main factors which create a longer distance for traveling. It will also propose a new model which has the potential benefit of improving performance in the order picking process.

1.1 Background of the Research

The Optical Lens Company group was established in 1972 and now has 14 production sites, 332 laboratories and 12 distribution centers. Figure 1.1 shows all production sites and laboratoriesm, spread around the world, that produce 240 million lenses with 580,000 products.

Figure 1.1: Production sites, Laboratories and distribution center



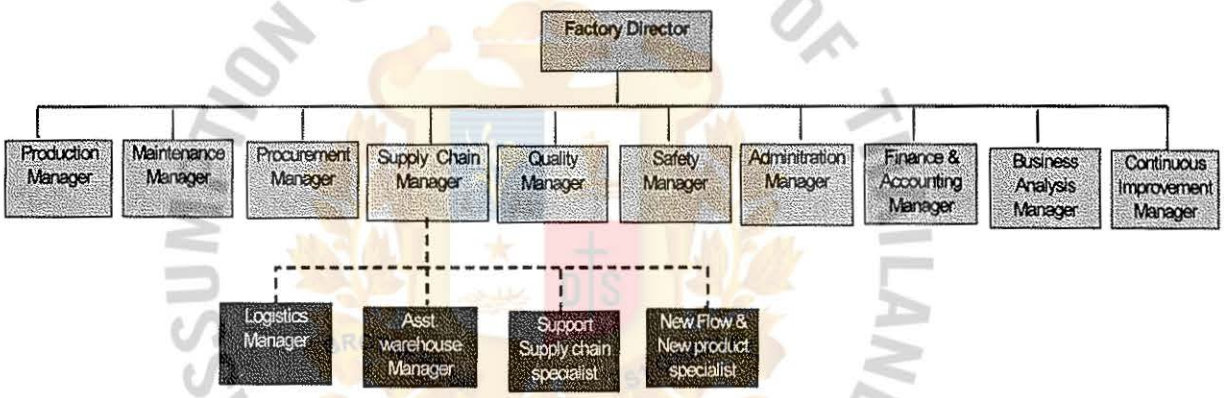
Source: Marketing Department of Optical Lens Company

Optical Lens Company supplies the market and subsidiaries with finished and semi-finished lenses, with 14 manufacturing plants and 12 distribution centers to distribute across more than one continent, which entails a significant number of logistics flows.

Optical Lens Company in Thailand was established in 1990 and now has more than 2,500 employees with approximately production volume of 73.1 millions lenses per year and sales volume of 62.7 millions lenses per year. Optical Lens Company in Thailand is the biggest production site and the main distribution center in Asia because of its high volume of production and sales.

The distribution center of Optical Lens Company in Thailand is the second biggest of the Optical Lens Worldwide Company; the biggest is located in North America. The distribution Center of Optical Lens Company in Thailand stores the finished lens, semi-finished lens, mold and blank mold, with the several business environment types such as make to stock, make to order, assembly to stock and assembly to order. Figure 1.2 shows the Warehouse Section to be one part of the Supply Chain Department, and it is the biggest operation in the Supply Chain Department and also the biggest warehouse and is the only distribution centre in Asia.

Figure 1.2: Organization Chart of Optical Lens Company



Source: Human Resource Department of Optical Lens Company

1.2 Statement of the Problem

Good performance leads to efficiency of the warehouse operation. But the performance of the order-picking process in this warehouse is not efficient when compared with other main activities, as shown in Table 1.1.

Table 1.1: Main activities performance in warehouse

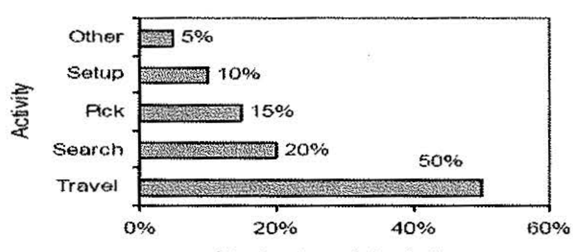
Process	Performance (piece per hr)
Put Away	950
Full box	4800
Order picking	700
Shipment	1000

Source: Warehouse Section of Optical Lens Company

Table 1.1 shows the performance of main processes in warehouse, such as the put away process of 950 pieces of lens per hour, the full box which is the process to move the full box from one location to another, with 4,800 pieces of lens per hour, the shipment preparation process is 1,000 pieces of lens per hour, and the last one is order picking process with the lowest performance at 700 pieces of lens per hour. So it needs to allocate more manpower and to consume more working hours than the other functions in the warehouse as the lowest performance. Moreover it requires overtime on every Sunday to complete the quantity for order picking, to meet the customer's orders. Thus, it is a big problem for this warehouse.

Therefore the critical process is the order-picking process. It needs improvement, and the traveling time is the one component of this process for improvement. It also directly impacts performance and does not create any added value in the process. The travel process substantially contributes to the total order-picking time, as shown in Figure 1.3.

Figure 1.3: Typical distribution of an order picker's time



Source: Tompkins et al. (2003)

The variety and number of products to be stored in the warehouse and increases continuously every year, and is the vital element in the inefficient storage policy which is related to traveling time. Some products have more frequency for order picking but consume a lot of traveling time. The researcher selects some products in each class to determine the traveling time, such as the fast moving product in A class, medium moving product in B class and slow moving product in C class.

Table 1.2: Traveling time for a sample of picking products

Class	Product	No. of order	Traveling time (minute / one order)
A	354710065023400	659	12.20
A	354710070023400	648	14.27
A	352210060016900	495	10.72
A	3547100550314J1	401	13.77
A	354710065060800	222	11.73
A class average		485	12.54
B	3838100700228PP	164	4.85
B	354410070009300	119	6.59
B	396910065000000	141	4.67
B	5555315800NTM00	96	6.54
B	3522100650000BA	83	5.12
B class average		121	5.56
C	3547100600195RP	66	4.78
C	314410070019800	38	6.40
C	352410075060000	14	6.36
C	3297100650305B1	34	6.23
C	5524315750NTM01	12	6.05
C class average		33	5.96

Source: Warehouse Section of Optical Lens Company

Table 1.2 shows the inappropriate traveling times. Products in the A class have the most frequency of order picking with an average of 485 orders but they consume the longest traveling time with an average of 12.54 minutes per picking order of each picking product. In the meantime, the low frequency of order picking in the C class averages 33 orders and consumes traveling time of only 5.96 minutes per picking order.

So the traveling time can be minimized if there is an optimal storage policy, such as Class A, which is the fast moving product, and should be closest to the input and output points and should consume the lowest traveling time.

The aim of this study is to find the main reason for the inefficient performance in the order picking process. It focuses on how to improve the travel time by studying how to redesign the picking location for an optimal solution to solve the problem of inefficient performance. The question, "How does the picking performance improve through the new optimal picking location?" is the focus.

1.3 Research Objectives

This study focuses on the order picking process in a warehouse by considering how to improve the traveling time which directly links with picking performance in the warehouse. The researcher determines the main objectives as follows:

1) To study how to segregate ABC class of order picking products frequency to measure the current situation of picking location.
2) To enhance the knowledge of configuration and layout of the warehouse to find an optimal solution for traveling time improvement.
3) To propose a new picking location for traveling time reduction and picking performance improvement.

1.4 Scope of the Research

This project focuses on the order picking process and selects products of make to stock (MTS) to be stored in the fixed location in the warehouse. The order picking process starts from the allocation of an order picking slip, then the set up process for pickers, the travel between locations from the starting point to the picking location until dropping off at the stopping point, the process of searching for the product and picking the product. But this study has been conducted to focus on the improvement only of travel distance to reduce the traveling time.

1.5 Significance of the Research

The new optimal order picking location would help the company to improve the picking performance because the traveling time saving strongly affects the operational performance. The picking performance can increase due to the elimination of wastes time from the process. So pickers can get more picking orders and the performance can increase. The benefit of picking performance improvement is the important factor for global success of the Supply Chain for this company.

Moreover, this research can enhance the knowledge of supply chain management, especially warehouse management. The researcher can learn how to analyze the data and apply the strategy for the new model that can show be applied in the real situation.

1.6 Limitations of the Research

The limitation of this research is that it studies only one business type which is the make to stock. There are different practices of product to storage in terms of picking process between the make to stock products, the assembly to stock product, the make to order product and the assembly to order product. This study has used Microsoft Excel to calculate the result of distance at the existing picking location to identify the consequence in traveling time. It does not use any other program or a high level of software to analyze the picking location and the layout.

1.7 Definition of Terms

Order picking process	The process to retrieve the product from the picking location according to the customer's order (De Koster, Le-Duc, & Roodbergen, 2007).
ABC Classification	The group of storage product to classify by the frequency of order picking by percentage accumulative calculation (Dekker, De Koster, Roodbergen, & Van Kalleveen, 2004).
Storage Policy	The policy to determine the location to store the product within the forward and reserve specific storage area (De Koster et al., 2007).
Travel time	The element of time during the order picking process (Caron et al., 1998).
Routing Policy	The method how to define the sequence of the item on the pick list for the best route (De Koster et al., 2007).
Zoning	The method how to indicate the specific area to be a smaller zone for the main purpose of travel time reduction Le-Duc (2005).

CHAPTER II

REVIEW OF RELATED LITERATURE

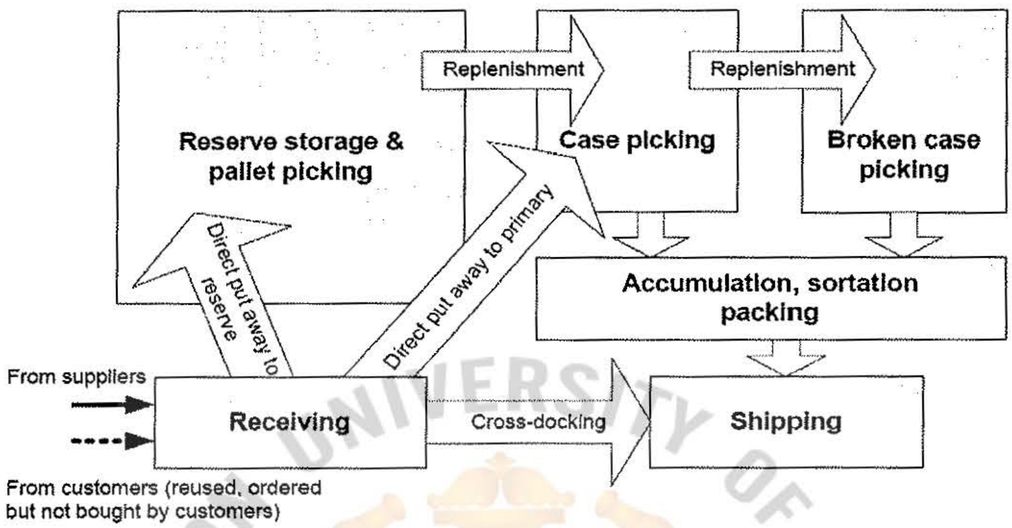
This chapter presents a relevant literature review to enhance the understanding of warehouse management strategy, especially focusing on the travel time process to be related with the optimal order picking location. The researcher has limited the literature review for the topic to be relevant only to warehouse operation management, storage policy, the ABC classification, and the zoning and the routing policy.

2.1 Warehouse operation management

Le-Duc (2005) stated that the warehouse function that can be divided into three main functions: movement, storage and the transfer of information.

1) The movement function consists of several activities. First is the receiving/put away activities that happen after receiving a shipment from the carrier, to move to the inspection process and to update the inventory. After that the put away process is the movement of the shipment from the receiving area to the storage location. Perhaps it needs the process of changing the container to be the standard depending on the individual internal process. Then the order picking process starts with receiving the pick slip, to move the cart through the picking location, to retrieve the product from the storage until being dropped off at the preparation shipment area. Next is the sorting process which depends on the customer's individual requirement to combine and sort at the end of the picking process but before packing process. Then the cross docking process to get the shipment and to move the product or shipment directly to the dedicated area. There is no need for a put away and picking process. The last is the shipping process, to load the ready shipment into the truck or container.

Figure 2.1: Typical warehouse functions and flows



Source: Tompkins et al. (2003)

2) The storage function is the process of putting the product in a storage location with multiple types depending on the size, quantity and the kind of product. And also it is related with material handling to process the product for the storage function.
3) The transfer of information is the function to be performed during the movement and storage functions> Examples are inventory quantity information, the keeping/picking location, the replenishment location, and the customer's information/requirement. All this information is very important for the warehouse operation management and is also significant for the whole supply chain management.

The main functions in the warehouse are receiving, storage, packing, sorting and shipping (Hassan, 2002).

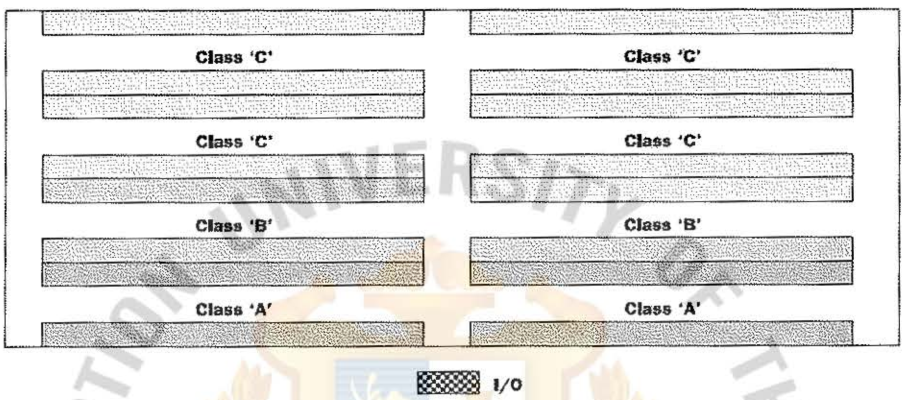
2.2 Storage Policy

This policy is the concept of how to assign the products to the storage location, according to many criteria. De Koster et al. (2007) stated five types of storage assignment:

1) Random storage is used as the method of selecting the available space randomly. It can utilize the space to a high level but it consumes a longer travel distance (Choe & Sharp, 1991). This method needs to be controlled or managed within the computer base.
2) Closest open location storage is the way workers select the storage location by themselves. So the first available storage location will be chosen.
3) Dedicated storage is the method for a fixed location that needs to reserve space capacity to meet the inventory level. It makes for low level of space utilization as all products have to have reserved the space for some products which are dead stock. But this method can help the order picking process as a picker can remember the picking location because normally it is the same place.
4) Full-turnover storage is the policy of assigning products to be stored according to their turnover rate, such as the highest sales rates being stored closest to the input and output locations because of easy access. Obviously, the slow turnover rate products are stored at the farthest end of the warehouse. This type is identified as the cube per order index rule (Heskett, 1963) which uses the ratio of items required for the space to the demand per period. The weak point of this method is to rearrange frequently at storage locations according to the demand in each period. Also, the cube per order index based concept defines the lowest cube per order index values to store at the aisle closest to input and output point Caron et al. (1998) provide an example layout in Figure 2.2
5) The concept of the Class-based storage uses the Pareto method to group the products by class. The concept is to identify the fastest moving class to be about 15% of the stored products but accounting for about 85% of the turnover. The fastest moving group of product is called 'A class', the

medium fast moving group of products is called 'B class' and the slow moving group of products is called 'C class'.

Figure 2.2: COI-based storage policy



Source: Caron et al. (1998)

2.3 ABC Classification

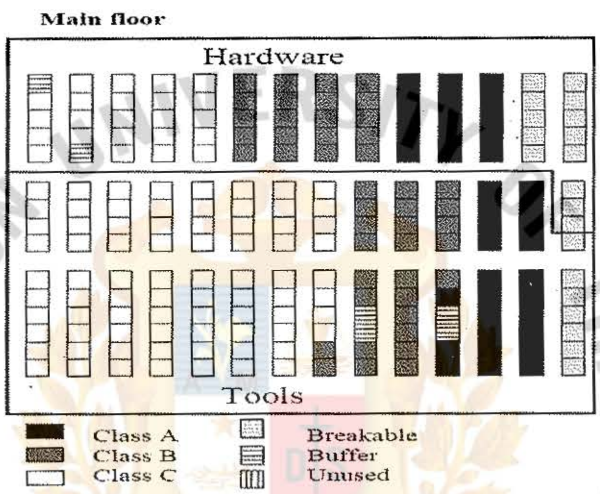
ABC classification is the segregation of class-based storage by defining how fast moving is the picking product. It is one of the vital factors to reduce the travel time as normally the fastest product needs to be stored as close as possible to the input and output point (Le-Duc, 2005).

Dekker et al. (2004) described in their study the ABC-storage classification to perform as Pareto pick-frequency curves. They use the proportion of each class as below:

- A class has the determined frequency of the group product as 70% from the total picks and it can be around 15% of products.
- B class has the determined frequency of the group product as 90% accumulated from the total picks.
- C class is the remaining group of products.

Also, their concept means that products of A class as the fastest moving to store in aisle are stored closest to the starting point. Then B class and C class are stored later at the longest storage location from the starting point. Figure 2.3 shows an example of storage location by ABC classification from their idea.

Figure 2.3: Example ABC storage classification

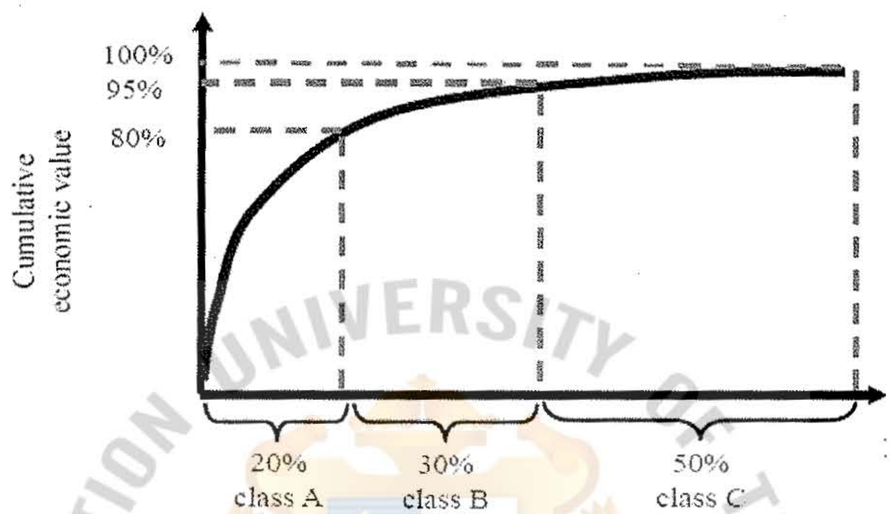


Source: De Koster et al. (2007)

The proportion of ABC classifications by total volume is 5% for A class, 25% for B class and 70% for C class. The most movement is in A class, which needs to be stored in an accommodating location nearest the closest input and output point (Manzini, Gamberi &Regattieri, 2005).

Caputo (2011) described ABC classification as economic value, using the concept of Pareto to identify the A class as 80%, B class as a cumulative 95%, and C class at the 100% cumulative point. A class consumes 20% of components, B class 30%, and 50% for C class.

Figure 2.4: ABC classification by economic value



Source: Caputo (2001)

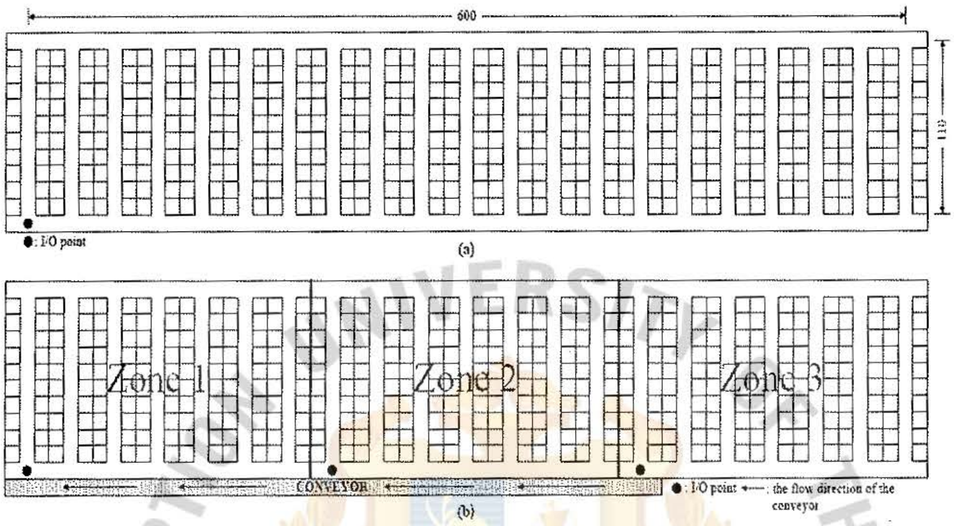
2.4 Zoning

Le-Duc (2005) explained that zoning indicates the specific area to be a smaller zone for the main purpose of travel time reduction in the picking process, enough for the picker to walk around in the zone for one requisition of picking. There are two types of zoning:

- Progressive or sequential zoning strategy is the order picking process by completing one zone at a time.
- Synchronized zoning strategy is the order picking process to travel the entire zone, which thus creates idle time.

Ho and Liu (2005) gave an example to split the picking zone to be three zones with the same equal area instead of one whole area as a picking zone. Also, this has its own input and output point at the individual zone.

Figure 2.5: The layout of an exemplary warehouse as (a) and the layout of exemplary warehouse in three picking zones as (b)



Source: Ho and Liu (2005)

The advantage of zoning is to travel in a smaller area, to reduce traffic jams in the picking location and for pickers to be familiar with the item location. But the disadvantage is to split the order according to the zone, and it needs to have an additional process such as the consolidation process before preparing the shipment for the customer (De Koster et al., 2007).

Hassan (2002) stated that zoning can help the order picking process to be more flexible. If the size of zone is small, it increases the movement between zones. But if it is large, it enlarges the movement within zones.

2.5 Routing Policy

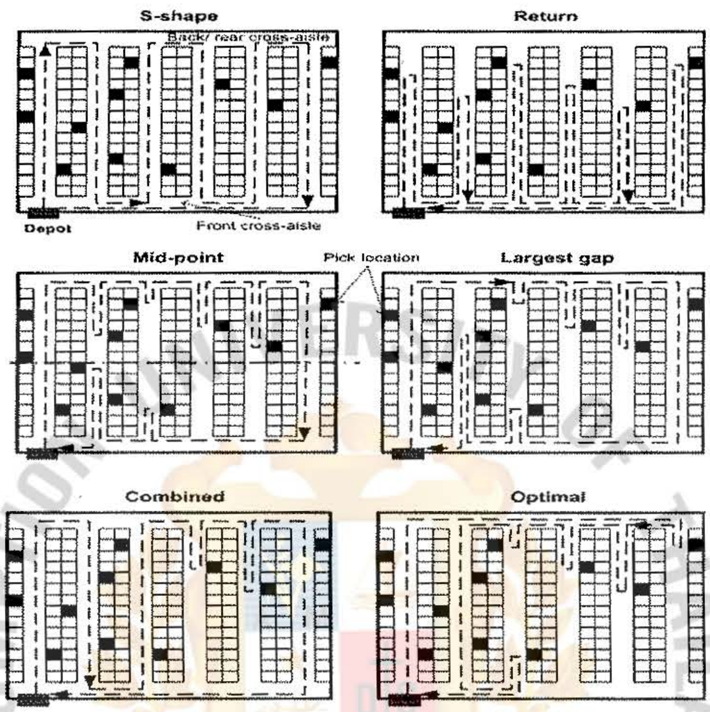
There are several heuristic methods to identify the routing policy in order to solve the problem of the order picking process:

1) S-shape or traversal heuristic is the simplest one. It is the method for the aisle needing to contain at least one pick, with no access to the aisle without a picking requisition. On finishing the last aisle, that order picker needs to go

back to the input and output point (De Koster et al., 2007). Caron et al. (1998) combined the two main objectives for the traversal routing policy to minimize the number of aisles to visit during the order picking trip and to reduce the travel distance.

2) Return heuristic is the method where the order pickers enter and depart each aisle from the same end and also enter the aisle only with a picking order (Le-Duc, 2005). This method is the most popular routing policy as the pickers enter the aisle and pick on the left or right of shelf, then to turn in at the furthest location, to pick on the left or the right again when coming back to the input and output point (Caron et al., 1998).
3) Midpoint heuristic is the method of dividing the area into two parts, the front aisle to enter from the front until the halfway and then back to the aisle to access from the back until the halfway point (De Koster et al., 2007). This method is better than S-shape if the number of order picks is small in each aisle (Hall (1993).
4) Largest gap heuristic is the method by which the picker enters as far as the largest gap from the midpoint. The largest gap is the largest route during travel without the location for picking (Dekker et al., 2004).
5) Composite heuristic or optimal is the method which combines S-shape and the return heuristics, to reduce the travel distance by using S-shape for traveling the entire aisle and using the return for turning in it (Petersen, 1995,1997).
6) Combined heuristic is a method similar to the composite so that order pickers access and depart from the same end (Le-Duc, 2005).

Figure 2.6: Example of routing method of the single-block warehouse



Source: Roodbergen (2001)

2.6 Summary

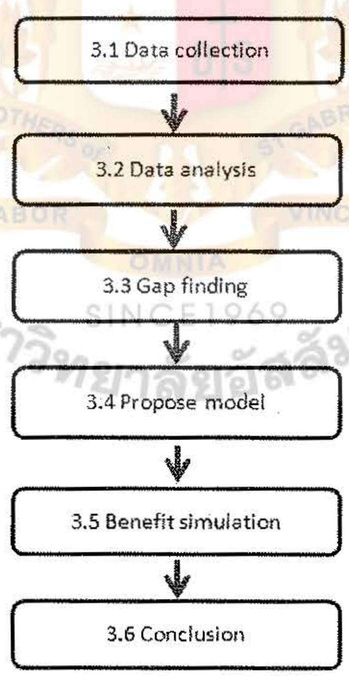
The main purpose of the literature review is to enhance knowledge about the factors related to the topic of reduction of travel time in the order picking process. It can help to find a methodology to support this project. Firstly, it can help to identify the main cause of the inappropriate model in the current situation. Then, it can lead to the optimal solution for a new model to be simulated and proposed according to a result which can improve productivity by reducing the travel time which directly impacts the operating time.

CHAPTER III

RESEARCH METHODOLOGY

In this chapter, the researcher explains the methodology used in this study by the following six steps. Firstly the data collection step determines the technique for gathering the data. Secondly the data analysis is described for how to analyze the data. The next is the gap finding step to identify the gap from the analysis step. After that is the proposed model step to propose the new model, and the benefit simulation step shows the expectation of the new model. The last step is the summary. The tool for the data analysis and simulation model step is Microsoft Excel. The researcher follows the steps in Figure 3.1.

Figure 3.1: Research plan and steps



3.1 Data Collection

In this step, the researcher describes the type and source of data for collection to support the next step of data analysis and also determines the two techniques for collecting the data.

3.1.1 Document Collection

The researcher collects the data of historical sales orders from January 2010 to December 2010 from the Finance department, and the current layout of the warehouse from the Supply Chain department to review the following data.

- Actual sales volume of 2010 which determines the product and frequency of order in each product. It can find the frequency by ABC classification analysis in the step of data analysis.
- The warehouse layout to identify the starting point, picking location and the finishing point which determine the distance of walking. It can help to measure of the distance for the data analysis step to give a clear picture of the current situation.

3.1.2 Data Observation

This technique used observation of the routing of the picking process from the starting point to the aisle of the picking location and the walkway through to the stopping point. The next step is the measurement of walking time, to be compared with the distance in order to identify the average traveling time (second per meter) by performing the observation for 10 pickers, and the result is used in the data analysis step.

3.2 Data Analysis

After all data has been gathered, the first step is to analyze the historical sales orders which defined the group of business category by product to narrow the scope and to focus only on make to stock business, as shown in Table 3.1.

Table 3.1: Sales report for 2010

Business Type	Volume shipped(pcs)	% shipped
ATO	3,014,229	5%
MTO	3,274,696	5%
MTS	53,326,819	90%
Grand Total	59,615,744	100%

Source: Finance Department of Optical Lens Company

Table 3.1 shows a total of 59,615,744 pieces of lens was sold in 2010. So we need to focus only on MTS or make to stock which consumed 90% of the total sales due to the finished goods having been stored on the fixed storage shelves. The other two business types, ATO and MTO, consumed only 5 % each. ATO is the assembly to order and MTO is the make to order, The finished goods from these two business types have been stored at specific locations dedicated by the order number, or at a floating location. Thus, they are outside the scope of this study as they have different methods in the storage and picking process.

Next, we analyze for the frequency of order picking products, the picking location and the measurement of traveling time for MTS or make to stock products.

3.2.1 Frequency of Order Picking Products

For this step, firstly the researcher analyzed the data of the sales report for 2010 by focusing on the business type of make to stock only. The calculation has been made by the ABC classification system, to identify the percentage of picking order frequency and to define ABC classification. The cumulative percentage for A class is

70%, B class is 20% and C class is 10% of picking order frequency, which is presented in Table 3.2.

Table 3.2: ABC product classification of MTS orders

Class	No. of product	Volume sale(pcs)	No. of picking order	% no. of product	% volume sale	% Frequency of order
A	92	25,634,902	47,578	20%	48%	**70%**
B	117	15,047,266	13,605	25%	28%	**20%**
C	254	12,644,651	6,703	55%	24%	**10%**
Total	463	53,326,819	67,886	100%	100%	100%

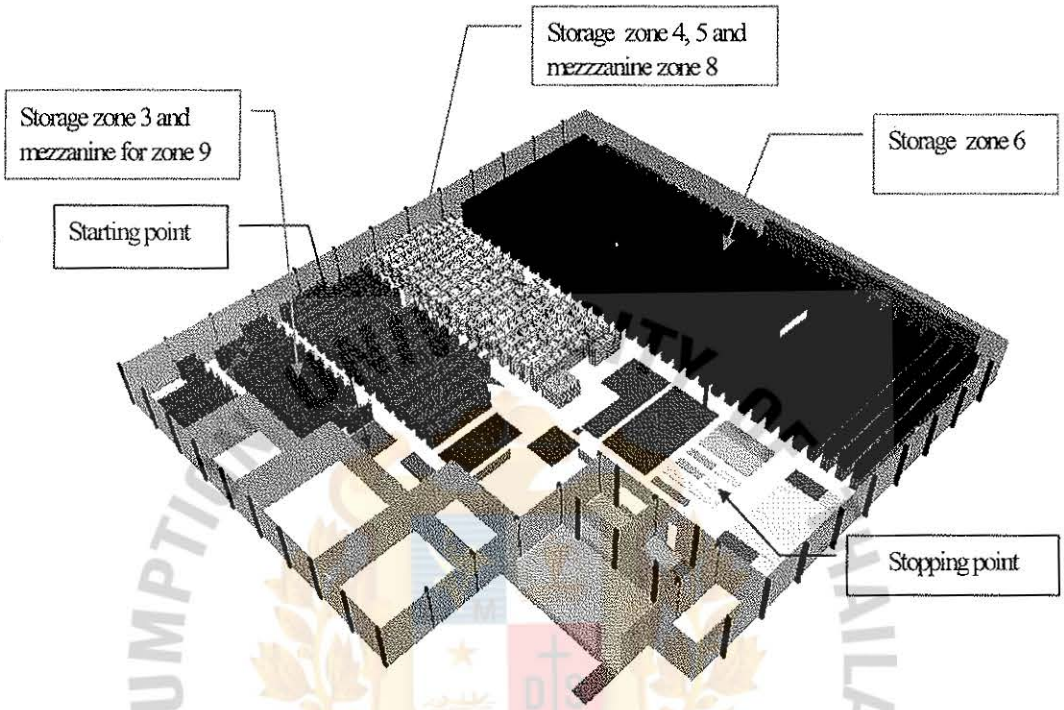
Source: Finance Department of Optical Lens Company

Table 3.2 shows the frequency of picking order of 463 products. The total order picking is 67,886 orders for MTS. The number of order picking can determine the frequency of time to enter the storage location. A class is the most frequent with 70% of order picking for 92 products or 20 % of the number of products. The second is B class with 20% of frequency of order picking for 117 products or 25% of the total number of products. The last is C class with a frequency of only 10% of order picking for 254 products or 55% of the total number of product. This result is then used for the analysis in the next step.

3.2.2 Picking location

After getting the result of products indicating each class from order frequency, the next step is to analyze the current picking location of each class by mapping in the current storage layout. Figure 3.2 displays the current layout as an overview of all the warehouse layout.

Figure 3.2: Existing Warehouse layout



Source: Warehouse Section of Optical Lens Company

The result from this analysis can determine how many picking products need to be stored in each zone of picking location, by the ABC classification approach. After that we need to analyze the distance from the starting point through to the picking location, and from the picking location to the stopping point in the existing current storage location. The picking location to be measured is the fixed location only, as displayed in Table 3.3.

Table 3.3: Table of picking product location and distance

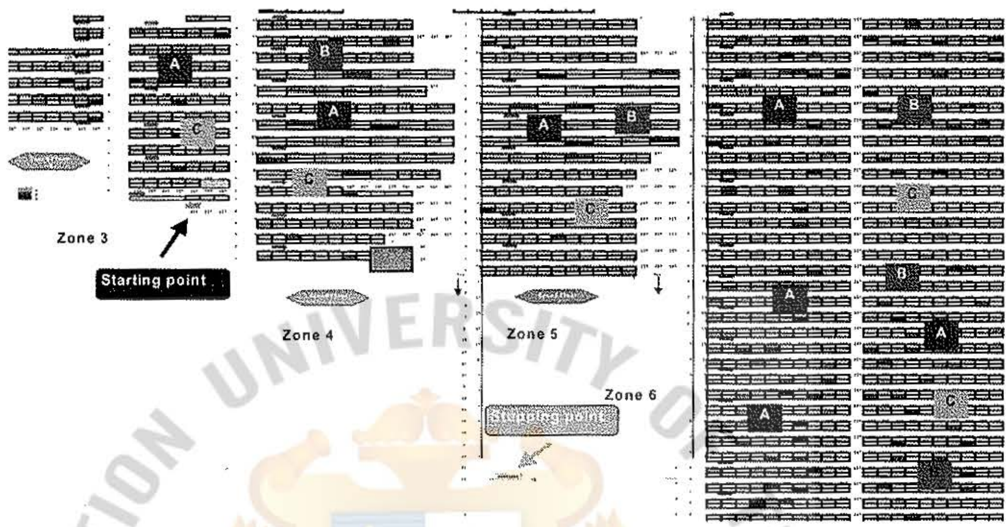
Class	Zone	No. of picking product location	Minimum of distance (meter)	Maximum of distance(meter)	Average of distance (meter)
A	3	8	94.58	131.66	118.26
	4	3	95.54	123.24	112.25
	5	6	74.24	127.78	109.57
	6	49	92.57	161.63	121.21
	8	25	70.88	146.48	106.29
	9	1	154.02	154.02	154.02
A Total		92	70.88	161.63	116.21
B	4	8	72.80	86.39	80.32
	5	4	115.06	130.31	120.15
	6	61	90.74	164.40	125.58
	8	42	70.06	135.40	109.66
	9	2	153.10	157.10	155.10
B Total		117	70.06	164.40	117.09
C	3	7	126.22	149.58	135.27
	4	10	71.72	98.49	80.74
	5	11	91.58	137.12	111.48
	6	115	88.57	170.80	116.31
	8	111	70.88	154.74	104.25
C Total		254	70.88	170.80	109.95
Grand Total		463	70.06	170.80	113.00

Source: Warehouse Section of Optical Lens Company

Table 3.3 shows that all picking products of each class are stored in all the zones of the picking location. For example, the picking products of A class are the most frequent order picking products, but they have been stored at the entire zones in th picking location.

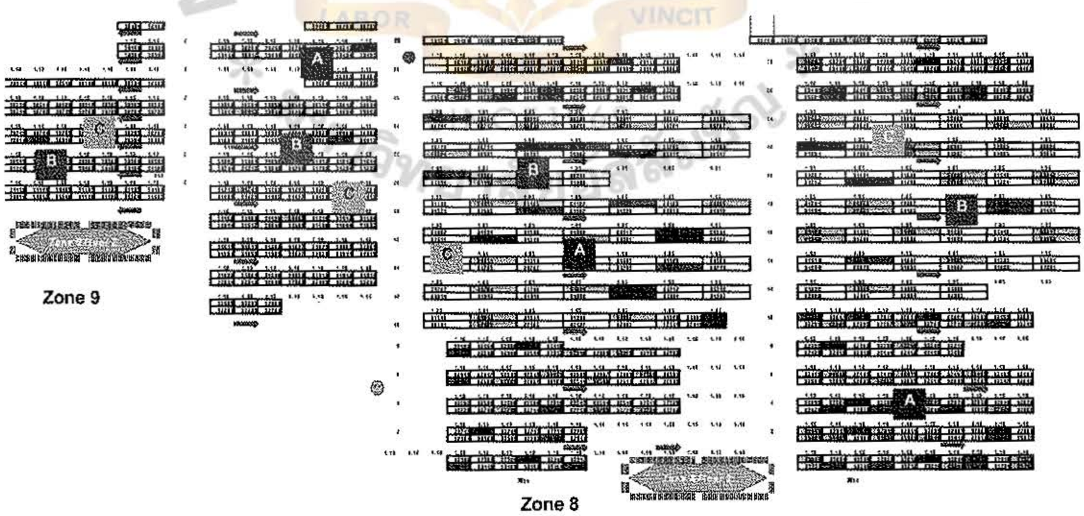
Moreover, the result of minimum, maximum and averages of each ABC product class are not different. For example, the minimum distance of picking product location of A class is 70.88 meter, B class is 70.06 meters, and C class is 70.88 meters. The maximum distance of picking product location of A class is 161.63 meters, B class is 164.40 meters and C class is 170.80. The average distance of picking product location of A class is 116.21 meters, B class is 117.09 meters, and C class is 109.95 meters. The different distance among products of each class has displayed the disadvantage in warehouse management and it directly effects picking productivity due as it is not an appropriate picking location as A class storage location has accommodated the most frequent picking product but it has an average distance higher than the lowest frequent picking products in C class. This is shown in the picking location layout for the entire picking location zone in Figure 3.3 for the ground floor, and Figure 3.4 for the mezzanine floor.

Figure 3.3: Existing layout storage of picking location in ground floor



Source: Warehouse Section of Optical Lens Company

Figure 3.4: Existing layout storage of picking location in mezzanine



Source: Warehouse Section of Optical Lens Company

After finishing the analysis of picking location distance, we need to move on to the next analysis about measuring the traveling time.

3.2.3 Measurement of traveling time

This step is related to the consequence of the picking location distance, to convert it to traveling time. The researcher has measured the traveling time by observation of the picking activity for ten operators with the same picking location for ten locations in five working days, to find the base line of the standard walking time per meter, displayed in Table 3.4.

Table 3.4: Walking time, from observation

Picking location	Total Distance (meter)	Traveling time of each operator (minute)										Average (min)	Time (second) per meter
		Operator 1	Operator 2	Operator 3	Operator 4	Operator 5	Operator 6	Operator 7	Operator 8	Operator 9	Operator 10		
505011	74.24	5.57	5.94	3.09	4.45	4.70	6.81	4.95	3.09	3.71	4.70	4.70	3.80
614393	94.74	4.74	5.21	6.32	6.32	7.58	5.53	5.68	5.53	7.90	7.11	6.19	3.92
809071	119.32	9.94	8.95	7.95	8.95	9.94	7.95	7.95	7.95	8.55	9.94	8.81	4.43
904141	157.1	11.78	11.78	10.47	11.78	11.78	9.16	11.26	10.47	11.78	10.47	11.08	4.23
612191	120.44	8.03	10.04	7.03	9.03	7.63	9.03	10.04	9.03	7.03	7.03	8.39	4.18
401012	123.24	8.22	6.16	5.14	8.22	10.27	8.22	7.19	5.14	8.22	11.30	7.81	3.80
309142	149.58	11.22	9.97	11.22	11.22	11.22	9.97	9.97	11.22	11.22	9.97	10.72	4.30
410142	86.39	4.32	5.04	4.32	6.48	5.76	5.04	5.04	4.32	6.48	5.76	5.26	3.65
626352	96.76	7.18	7.18	6.38	6.38	5.59	7.18	5.59	6.38	6.38	6.38	6.46	4.05
604091	154.18	10.28	11.56	10.28	14.13	11.56	11.56	11.56	14.13	11.56	11.56	11.82	4.60
													4.10

Source: Warehouse Section of Optical Lens Company

Table 3.4 displays that the traveling time or walking time for the picking operators with a cart or trolley has an average of 4.10 seconds per meter.

The next step is to use the standard walking time to be multiplied with the distance in each picking location, to analyze the traveling time in each picking product class, as in Table 3.5.

Table 3.5: Traveling time of each picking product

Class	Zone	No. of picking product location	Minimum of traveling time (minute)	Maximum of traveling time (minute)	Average of traveling time (minute)
A	3	8	6.31	8.78	7.88
	4	3	6.37	8.22	7.48
	5	6	4.95	8.52	7.30
	6	49	6.17	10.78	8.08
	8	25	6.15	13.77	10.13
	9	1	14.27	14.27	14.27
A Total		**92**	**4.95**	**14.27**	**8.62**
B	4	8	4.85	5.76	5.35
	5	4	7.67	8.69	8.01
	6	61	6.05	10.96	8.37
	8	42	4.67	13.03	10.55
	9	2	10.21	10.47	10.34
B Total		**117**	**4.67**	**13.03**	**8.97**
C	3	7	8.41	9.97	9.02
	4	10	4.78	6.57	5.38
	5	11	6.11	9.14	7.43
	6	115	5.90	11.39	7.75
	8	111	6.24	14.32	10.81
C Total		**254**	**4.78**	**14.32**	**9.02**
Grand Total		463	4.67	14.32	8.92

Source: Warehouse Section of Optical Lens Company

Table 3.5 shows that the A class minimum traveling time is 4.95 minutes, but it is still more than B and C classes which have minimum traveling times of 4.67 and 4.78 minutes. The A class also has a maximum traveling time of 14.27 minutes which is longer than B class which has a traveling time of 13.03 minutes and has a few gaps of only 0.05 minutes. The C class has a maximum time of 14.32 minutes. So we can identify some products of A class which are stored longer than the some B class products, from the starting point and stopping point. Even though the average time of ABC classes looks quite good, the A class is 8.62 minutes, the B class is 8.97 minutes, and the C class is the largest one at 9.02 minutes, but the gap is very small.

The analysis result of distance and traveling time shows that the picking product locations are all around the storage location, even though some products have a high pick frequency. The picking location is too away far and it is not easy to access, which leads to long traveling times among ABC picking class products. Thus it can be determined that the problem is inappropriate picking locations in the current situation, with several reasons to explain this, in the next step of gap finding.

3.3 Gap Finding

According to all the results of data analysis, the researcher realized that some products of class A had long traveling times by comparison with products of class B and C, and the result of the existing storage of each product in ABC classes have been displayed in the mixed storage area among ABC classes. So the result from data analysis shows the minimum traveling time, the maximum traveling time and the average traveling time are not much different, with only a little gap. It can be determined that the current layout for picking point to storage does not follow the storage policy in an ABC classification. Also, the researcher considers the starting point and stopping point are far away, and that is not an appropriate layout, which is not conducive to an efficient operation. From these gaps, there is the opportunity for optimization in terms of traveling time improvement.

From the result of all gaps, it has been determined the root causes of the problem are:

- No storage policy for identify the picking location of each product.
- Never reviewed the warehouse layout design to check that it still matches the current situation.
- Inefficiency of coping with increases in new products in the warehouse.
- No reviews of appropriated storage locations related the optimal picking process.
- Lack of knowledge in warehouse management.

These results have come from the storage of product picking locations of ABC class, spread all around the picking location. There is no storage policy applied in the warehouse.

3.4 Model Proposal and Solution

From the literature review, the researcher recognizes the ABC classification is the first factor to study, and it is also the significant influence to improve the operation of the picking process. The researcher has followed the concept of Dekker et al. (2004), to consider the ABC classification, as follows:

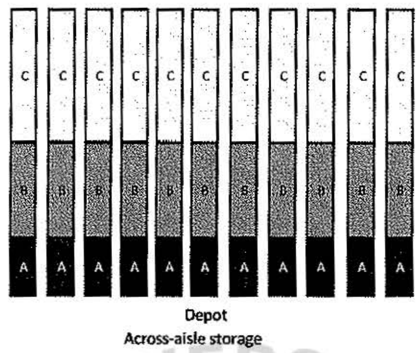
- The A class frequency of order picking at 70 percent.
- The A and B class frequencies of order picking are 90 percent.
- The remaining products are in the C class.

The next step is to calculate the need for total storage space of products in each class: the A class at 70 percent for 92 products, the B class at cumulative 90 percent for 117 products, and the remaining C class for 254 products.

In the warehouse configuration, the researcher considers that the existing layout is not appropriate as the starting point (the input point) and the stopping point (the output point) are too far apart. This does not match with the concept of assigning the fastest moving products in the A class to be closest to the starting point, which has the consequence of affecting the traveling time to reach the stopping point (Dekker et al., 2004).

From this, the researcher selects the concept of Class based storage (Le-Duc & De Koster, 2005) to explain across-aisle storage which is close to the optimal solution in Figure 3.5. The proposed model is the grouping of picking locations by classification.

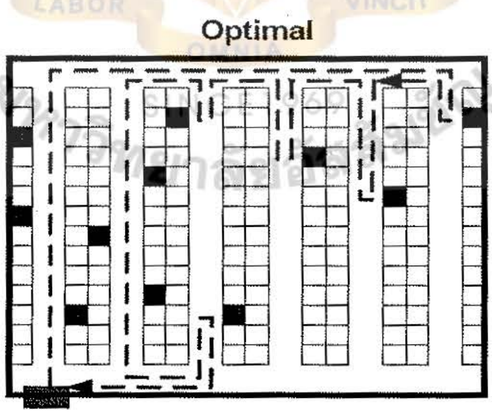
Figure 3.5: Across-aisle storage



Source: Le- Duc and De Koster (2005)

Also, the researcher considered the routing policy, Le-Duc(2005) identified several routing policies and the best one is the optimal heuristic that can reduce the distance between the farthest location and two closed picking locations. Dekker et al. (2004) also supported the optimal heuristic routing policy. It is the best one from their study to show the result that the optimal heuristic can reduce the distance, than over the others, by about 12% -15 %, as in Figure 3.6.

Figure 3.6 Optimal heuristic routing policy



Source: Roodbergen (2001)

The new proposed model uses Microsoft Excel to calculate the traveling time, using the steps below:

1) To assign the new layout of the starting point and stopping point to be closer together (referring to the result of gap finding in 3.3).
2) To use the Excel tool for calculating the traveling time for each location.
3) To analyze the result from the calculations and to select the range of traveling time by referring to the number picking location needed in each ABC classification.
4) To mark the new picking location in the layout.

Figure 3.7: New proposed layout storage of picking locations in ground floor

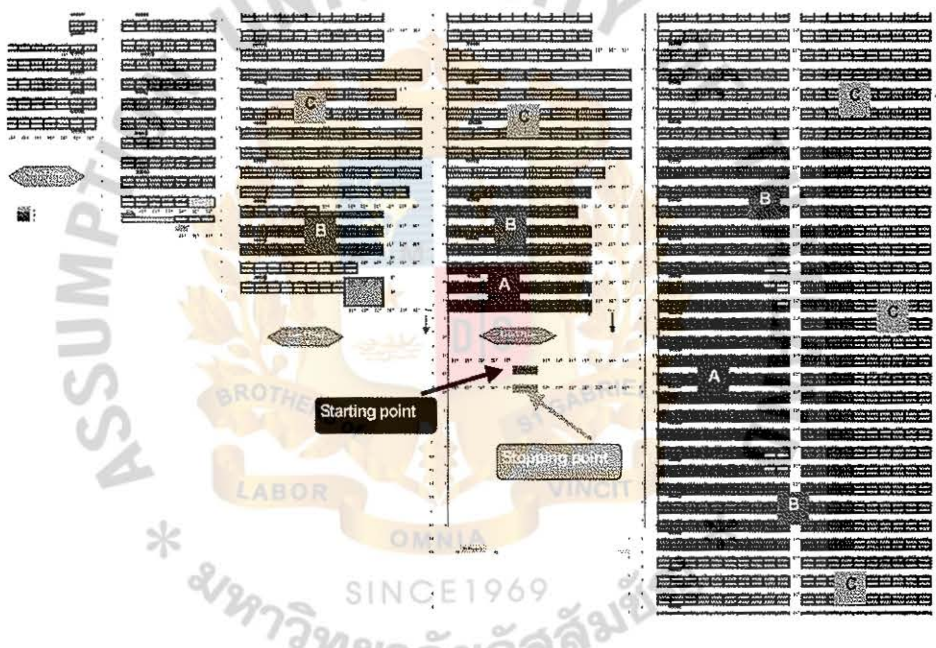
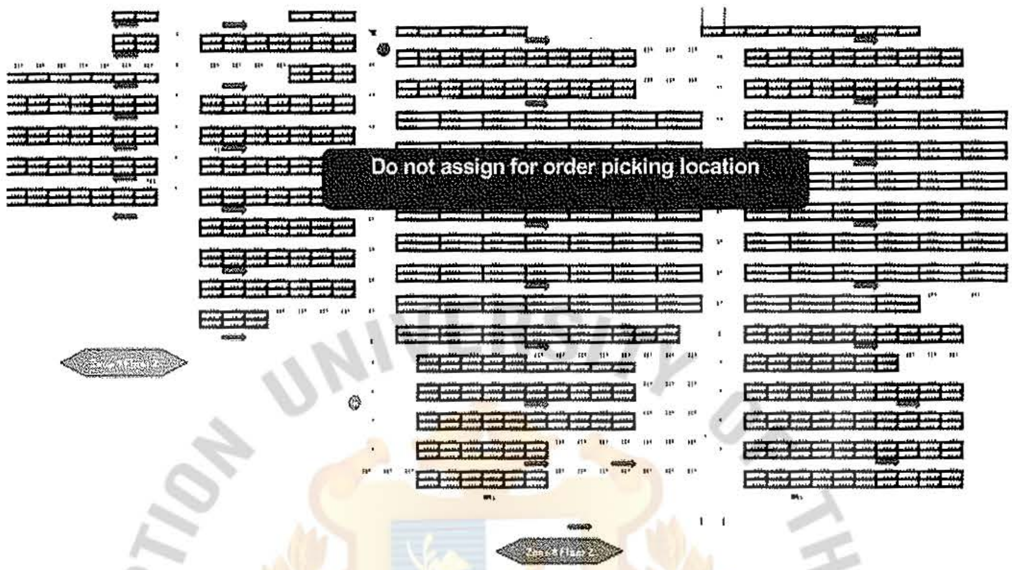


Figure 3.7 displays the grouping zone for picking locations by using the methodology of ABC classification from the frequency of order picking. It reassigns the starting point and the stopping point to be closer. Then it marks the picking product of each ABC classification, by reference to the result in the above step. Figure 3.8 shows the location on the mezzanine to be not an appropriate location to assign as an order picking location at all. This was supposed to be assigned for another purpose, to store such products or items to pick for production only due to the volume of picking a big lot with less frequency, which has less impact in terms of lead time.

Figure 3.8: New proposal layout storage of picking location in mezzanine floor



3.5 Benefit of the New Model

The simulation model can displayed the benefit for time saving by each ABC classification picking location, to show the global benefit at the end of this study. The result of the simulation model can assist the redesign of a new starting point and stopping point to be more appropriate, and to assign a new layout for order picking location by measuring the distance of each location and to convert the traveling time in total from the starting point to the stopping point.

Therefore, the benefit from the new model is presented as a comparison of average traveling time between the current and the new order picking locations. It can show the gap between the current model and the new model. Then the result of traveling time reduction is used to be multiplied with the number of order pickings per year. The most significant benefit can then be shown as performance improvement. The objective of this simulation model is to segregate the importance of each order picking product to be stored in each location, and to approach the new picking location later.

3.6 Summary

The researcher has gathered the data necessary for analysis, and the result from analysis shows the gap to be the primary factor for improvement, such as the inappropriate starting point and the stopping point which are so far away, and the unmatched picking location assigned, especially the high picking frequency products as they are very far from the starting point and stopping point. This has created wasted time in walking through the picking location.

The purpose of the new model is to convert the new picking location to be more effective for the picking process, because if the traveling time is as low as possible, it can gain more productivity. On the other hand, the reduction of traveling time is labor cost saving for picking operators. The next chapter will present the analysis and the benefit from the simulation model by comparing the current model with the new model.

CHAPTER IV

PRESENTATION AND CRITICAL DISCUSSION OF RESULTS

This chapter presents and discusses the comparison result of distance and the traveling time, between the current order picking location and the new model for the picking location. It begins with the result of the distance and traveling time of the existing picking location to identify the current problem such as the most frequent order picking in the A class which involves a long traveling time. Next is the result of distance and traveling time for all storage locations in the warehouse, for the optimal selection in order to assign a new location to each type of order picking. After that the new model of order picking location is presented for implementation for the purpose of traveling time reduction. Then, the comparison of traveling time result and picking performance result, between the current picking location and the new model, is presented to show the advantage after implementation.

4.1 Distance and traveling time of the existing order picking location

The existing order picking location in the warehouse of Optical Lens Company has allowed the order picking products to mix up fast moving products with the medium moving products and the slow moving products, in the same area. Some products of fast moving products are stored very far away and are not easy to access. Some medium and slow moving products are located very close to the input and output point. They involve as much traveling time as the fast moving products. A summary of the distance and traveling time for the existing order picking location is presented in Table 4.1.

Table 4.1: The distance and traveling time of existing order picking location

Class of picking product	Zone	No. of picking product	Minimum of distance (meter)	Maximum of distance (meter)	Average of distance (meter)	Minimum of travel time (minute)	Maximum of travel time (minute)	Average of travel time (minute)
A	3	8	94.58	131.66	118.26	6.31	8.78	7.88
	4	3	95.54	123.24	112.25	6.37	8.22	7.48
	5	6	74.24	127.78	109.57	4.95	8.52	7.30
	6	49	92.57	161.63	121.21	6.17	10.78	8.08
	8	25	70.88	146.48	106.29	6.15	13.77	10.13
	9	1	154.02	154.02	154.02	14.27	14.27	14.27
A Total		92	70.88	161.63	116.21	4.95	14.27	8.62
B	4	8	72.80	86.39	80.32	4.85	5.76	5.35
	5	4	115.06	130.31	120.15	7.67	8.69	8.01
	6	61	90.74	164.40	125.58	6.05	10.96	8.37
	8	42	70.06	135.40	109.66	4.67	13.03	10.55
	9	2	153.10	157.10	155.10	10.21	10.47	10.34
B Total		117	70.06	164.40	117.09	4.67	13.03	8.97
C	3	7	126.22	149.58	135.27	8.41	9.97	9.02
	4	10	71.72	98.49	80.74	4.78	6.57	5.38
	5	11	91.58	137.12	111.48	6.11	9.14	7.43
	6	115	88.57	170.80	116.31	5.90	11.39	7.75
	8	111	70.88	154.74	104.25	6.24	14.32	10.81
C Total		254	70.88	170.80	109.95	4.78	14.32	9.02
Grand Total		463	70.06	170.80	113.00	4.67	14.32	8.92

Source: Warehouse Section of Optical Lens Company

Table 4.1 shows the result of distance and traveling time for the existing order picking product location by the type of frequency of picking orders:

1) Firstly, the fast moving products is the A class, whose total products is 92 are stored in nearly all the locations in the warehouse. They are located in six zones, zone 3, zone 4, zone 5, zone 6 at the ground floor and zones 8 & 9 at the mezzanine. The minimum distance is 70.88 meters, the maximum distance is 161.63 meters and the average distance is 116.21 meters. The minimum traveling time for A class is 4.95 minutes, the maximum traveling time is 14.27 minutes and the average is 8.62 minutes.
2) Secondly, the medium moving products in the B class total 117 products which are stored in five zones, zone 4, zone 5 and zone 6 at the ground floor and zones 8 & 9 at the mezzanine. The minimum distance is 70.06 meters, the maximum distance is 164.40 meters and the average distance is 117.09 meters. Thus, the minimum traveling time is 4.67 minutes, the maximum traveling time is 13.03 and the average traveling time is 8.97 minutes. This result is very close to that of the fast moving products.

3) Finally, the slow moving products in the C class total 54 products which are located in five zones, zone 3, zone 4, zone 5, zone 6 at the ground floor and zone 8 at the mezzanine. The minimum distance is 70.88 meters, the maximum distance is 170.80 meters and the average distance is 109.95 meters. Thus, the minimum traveling time is 4.78 minutes, the maximum traveling time is 14.32 minutes and the average traveling time is 9.02 minutes. Even though this result is higher than that for the fast moving products and the medium moving products, the gap is very close, at only 0.40 minute with the fast moving products and 0.05 minute with the medium moving products.

So the main problem is the inefficient picking location because the most frequent order picking products in the A class is stored in every zone of the warehouse. Even though some zones are located in the mezzanine floor and involve a lot of traveling time, it makes the average traveling time to be very close to the low frequency order picking products in the C class.

What is needed is to find the appropriate picking location by finding the result of distance and traveling time for all storage locations. The appropriate picking location will be selected for each type of order picking product. It needs to allocate fast moving products as the first priority, then the medium moving products followed by the slow moving products.

4.2 Current distance and traveling time for all storage locations

The storage location is divided into six small zones, zone 3, zone 4, zone 5, zone 6 at the ground floor and zones 8 & 9 at the mezzanine. All storage picking locations are fixed locations that are normally assign picking products in the same location. The result of distance and traveling time for all picking location is shown in Table 4.2.

Table 4.2: The result of distance and traveling time for all picking locations

Area	Picking zone	Minimum of distance (meter)	Maximum of distance (meter)	Average of distance (meter)	Minimum of travel time (minute)	Maximum of travel time (minute)	Average of travel time (minute)	No. of location
Ground floor	3	95.20	165.88	133.63	6.35	11.06	8.91	211
Ground floor	4	52.32	148.84	102.19	3.49	9.92	6.81	265
Ground floor	5	34.36	153.20	85.75	2.29	10.21	5.72	310
Ground floor	6	26.86	141.32	81.52	1.79	10.65	5.48	1360
Mezzanine	8	54.68	151.22	97.29	9.65	16.08	11.93	478
Mezzanine	9	104.68	201.28	149.69	10.98	17.42	13.98	196

Source: Warehouse Section of Optical Lens Company

Table 4.2 shows the result of distance and traveling time for all picking locations by each picking zone. The lowest result of minimum distance and traveling time is zone 6 as it has a minimum distance of 26.86 meters and traveling time of 1.79 minutes. It is has the lowest average distance and traveling time. Its average distance is 81.52 meters and the average traveling time is 5.48 minutes. Next is zone 5 that also has a low minimum distance and traveling time at 34.36 meters and 2.29 minutes. The average distance in this zone is 85.75 meters and traveling time is 5.72 minutes. Next is zone 4, whose average distance and traveling time are 102.19 meters and 6.81 minutes. The average result of distance and traveling time for zone 3 are 133.63 meters and 8.91 minutes.

Next, the average distance and traveling picking location are located at the mezzanine, at 97.29 meters and 11.93 minutes in zone 8. This result is very high. But the highest average distance and traveling time is zone 9 with 149.69 meters and 13.98 minutes.

Regarding these figures, the two zones that are the target for the fast moving products are zone 6 and zone 5 because of their lowest distance and traveling time. The minimum distance is 26.86 meter for zone 6 and 34.36 meter for zone 5, and the minimum traveling time is 1.79 minutes for zone 6 and 2.29 minutes for zone 5.

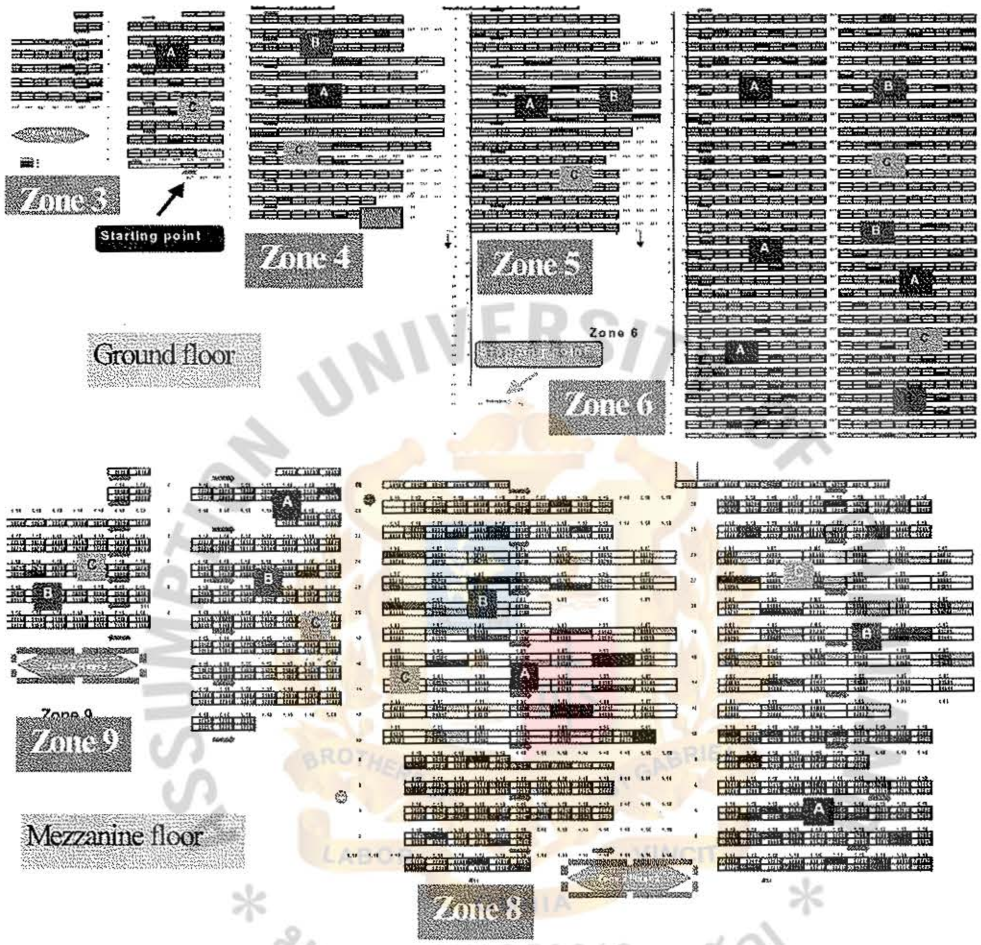
The result of distance and traveling time for all picking locations can help to make the decision how to redesign for the order picking location for the purpose of time reduction.

4.3 New model of the order picking location

The results of distance and traveling time for the existing order picking location and all picking locations have been presented. It is now possible to redesign the order picking location because the distance and traveling time for all picking locations reveals that some locations have shorter distance and lower traveling time. They are therefore appropriate for the fast moving products in the A class. Thus, the new model of order picking location is proposed by using Microsoft Excel to produce the result of traveling times for all storage locations. The new storage locations are assigned from the lowest result of traveling time to cover all fast moving products in the A class. Then, the medium moving products in the B class are allocated their new picking locations. Next to be assigned locations are the slow moving products in the C class.

To compare the current order picking location and the new order picking location, Figure 4.1 shows that in the existing order picking location, the fast moving products in the A class are stored in all picking zones in the warehouse, both on the ground floor and the mezzanine floor. This is the main problem, the long traveling time for these fast moving products. The medium moving products in the B class and the slow moving products in the C class are also located throughout all the picking zones in the warehouse, but their average traveling times are different.

Figure 4.1: The current order picking location



Source: Warehouse Section of Optical Lens Company

Figure 4.2: The new model of order picking location

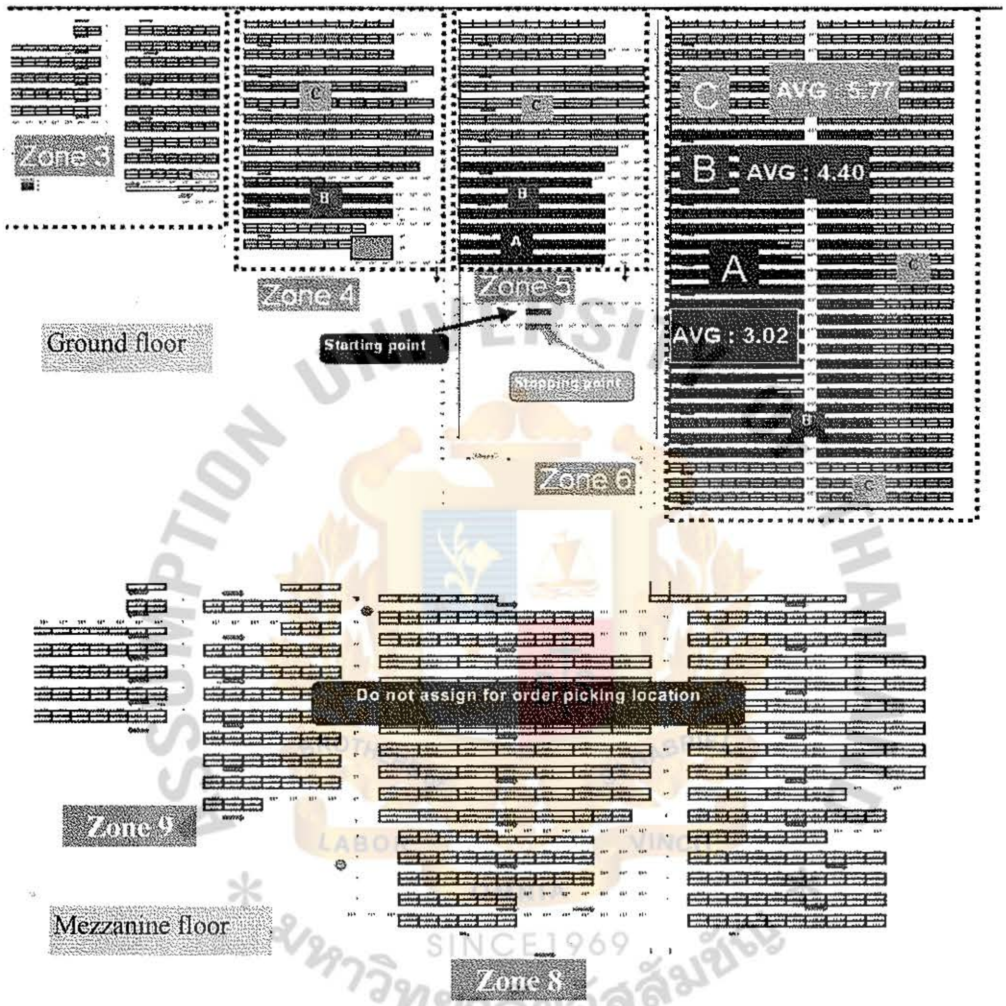


Figure 4.2 presents the new model of order picking location, in which the fast moving products in the A class are to be located at the closest location, the medium moving products in the B class to be stored next, and the slow moving products in the C class to be located at the farthest location. It does not need to assign any order pick product to the mezzanine floor. Figure 4.2 shows the current order picking locations to store the fast moving products in the A class, the medium moving products in the B class and the slow moving products in the C class, using all zones from zone 3, zone 4, zone 5 and zone 6 at the ground floor and zones 8 and zone 9 at the mezzanine floor. That directly causes long traveling times.

Table 4.3: Distance and traveling time of new model picking locations

Class of picking product	Zone	No. of order picking product	No. of lcoation	Minimum distance (meter)	Maximum distance (meter)	Average distance (meter)	Minimum travel time (minute)	Maximum travel time (minute)	Average travel time (minute)
A	5		55	34.36	52.5	46.10	2.29	3.50	3.07
	6		221	26.86	61.2	45.20	1.79	3.94	3.01
A Total		92	276	26.86	61.2	45.38	1.79	3.94	3.02
B	4		45	52.32	71.44	64.64	3.95	4.76	4.34
	5		45	60.32	71.44	66.84	4.02	4.76	4.46
	6		262	50.86	71.88	65.92	3.97	4.79	4.40
B Total		117	352	50.86	71.88	65.88	3.95	4.79	4.40
C	3		5	95.2	99.92	98.36	6.35	6.66	6.56
	4		71	72.16	101.44	87.15	4.81	6.76	5.81
	5		112	72.12	101.4	86.65	4.81	6.76	5.78
	6		574	58.86	101.96	86.41	4.79	6.80	5.76
C Total		254	762	58.86	101.96	86.59	4.79	6.80	5.77
Other	3		206	102.28	165.88	134.49	6.82	11.06	8.97
	4		149	102.16	148.84	120.70	6.81	9.92	8.05
	5		98	102.42	153.2	115.67	6.83	10.21	7.71
	6		303	66.86	141.32	112.21	6.80	10.65	7.68
	8		478	54.68	151.22	97.30	9.65	16.08	11.93
	9		196	104.68	201.28	149.69	10.98	17.42	13.98
Other Total		0	1430	54.68	201.28	116.69	6.80	17.42	10.19
Grand Total		463	2820						

Table 4.3 presents the new model for order picking locations. The total storage location in the warehouse is 2820 locations. One picking order product needs three locations.

1) Firstly, the fast moving 92 products in A class need a total of 276 locations, and the new picking locations assign them only to zone 5 and zone 6 because of their lowest traveling times. The average distance is 45.38 meters and the average traveling time reduces from 8.62 minutes to 3.02 minutes. It is the lowest average result.
2) Secondly, the 117 medium moving products in B class are allocated 352 locations in zone 4, zone 5 and zone 6. The average distance is 65.88 meters and the average traveling time reduces from 8.97 minutes to 4.40 minutes.
3) Lastly, the 254 slow moving products in C class need 762 locations. The average distance is 86.59 meters and the average traveling time reduces from 9.02 minutes to 5.77 minutes. Even though this result has the highest average result, it is also reduced, because it needs to move the picking location from the mezzanine floor which is over 10 minutes of traveling time to the ground floor only.

The new model is very appropriate because the fast moving products which are the highest order picking frequency are assigned to the shortest locations. So the traveling time is the lowest. The slow moving products which are the lowest order picking frequency are allocated to the farthest location. Their traveling time is the highest. The appropriate new model has now been presented. The result comparison of the current picking location and the new picking location, for traveling time and picking performance, is presented in section 4.4 to show the effectiveness of the new picking locations.

4.4 Comparison of the traveling time and picking performance

The new model is proposed by needed the fast moving products to be closest to the input and output point, and the slow moving products to be farthest from the input and output point. The purpose of the new model is traveling time reduction and performance improvement. The comparison is presented in section 4.4.1 for the traveling time between the existing locations and the new locations. The comparison of current picking performance and new picking performance is described in section 4.4.2.

4.4.1 The comparison of traveling time

Now the new model has been proposed for order picking locations, the comparison between the existing order picking location and the new order picking location shows the minimum, maximum and average traveling times for each product class. The result of traveling time reduction per year has been shown by using the different values of average traveling time. This has been multiplied with the number of order picking per each class and summarized in the total time reduction per year. The comparison between the existing and new order picking locations is shown in Table 4.4, and the formulas are displayed below:

Table 4.4: Comparison of total time reduction

Class	As-Is			To-Be						
	Min traveling time (min)	Max traveling time (min)	Avg traveling time(min) [a]	Min traveling time(min)	Max traveling time(min)	Avg traveling time(min) [b]	Average time reduction (min) [c]	No. of order picking per year [d]	Annual travel time saving (hr) [e]	%Average travel time reduction per order [f]
A	4.95	14.27	8.62	1.79	3.94	3.02	5.59	47,578	4,434.03	65%
B	4.67	13.03	8.97	3.95	4.79	4.40	4.57	13,605	1,036.03	51%
C	4.78	14.32	9.02	4.79	6.80	5.77	3.24	6,703	362.08	36%
									5,832.14	

- **Average time reduction** (c) = Average traveling time (a) – Average traveling time (b)
- **Total annual reduction time** (e) = Average time reduction (c) * No. of picking order per year (d)
- **% Average travel time reduction per order** (f) = Average time reduction (c)/Average traveling time (a)

Table 4.4 presents the comparison of traveling time between existing and new picking locations by separating the types of order picking frequency.

1) For the fast moving products in A class, the average traveling time is 8.62 minutes for the existing picking location, but the new traveling time is only 3.02 minutes. Thus it can reduce by 5.59 minutes per order which is a 65% reduction in traveling time. The total number of picking orders is 47,578, so it can save 4,434.03 hours per year which is a major time saving.
2) For the medium moving products in B class, the average traveling time is 8.97 minutes for the existing picking location, but only 4.40 minutes for the new picking location. Thus, the time is saved 4.57 minutes per order, or 51%. The total time saving is 1,036.03 hours per year.
3) For the slow moving products in C class, the average traveling time is 9.02 minutes for the existing picking location. But it is 5.77 minutes

for the new picking location. So it can save 3.24 minutes per order, or 36%. The total time saving is 362.08 hours per year.

From the comparison result, the total time saving for all picking orders is 5,832.14 hours per year. The best time reduction is for the fast moving products, with a 65% reduction from the average of 8.62 minutes to 3.02 minutes. The next step is the comparison of the picking performance, presented in section 4.4.2.

4.4.2 Comparison of the picking performance

In the next step, the calculation for the new picking performance uses the result of time saving which is 5,832.14 hours per year. That is multiplied by the current picking performance of 700 pieces per hours in order to identify the benefit of improved performance per year. Then, we add the current picking volume per year, 48,048,000 pieces. We can then find the new picking performance per hour. The result is presented in Table 4.2 and the formula for calculation is shown below:

Table 4.5: Comparison of the picking performance

(a) Total normal working time per year (hour)	(b) Normal performance per year (piece)	(c) Total time saving per year (hr)	(d) Performance benefit per year (piece)	(e) New performance per year(piece)	(f) Current performance per hr (piece)	(g) New performance per hr (piece)	(h) %Performance improvement
68,640	48,048,000	5,832.14	4,082,499	52,130,499	700	759	8.50%

- **Performance benefit (piece)**(d) = Total time saving per year (hour)(c) * the current picking performance per hour (piece)(f)
- **New performance per year (piece)**(e) = Normal performance per year (piece) (b) + Performance benefit per year (piece)(d)
- **New performance per hour (piece)**(g) = New performance per year (piece) (e) / Total normal working time per year (hour)(a)

- **Percent of performance improvement**(h) = (New performance per hour (piece)(g) – Current performance per hour (piece)(f)) / Current performance per hour (piece)(f)

Table 4.5 presents the performance benefit from the traveling time saving per year, at 4,082,499 pieces. The new performance per year is 52,130,499 pieces, because it adds 4,082,499 pieces of performance benefit to the normal performance of 48,048,000 pieces. The normal annual performance is calculated from the total working time of pickers per year for 68,640 hours, multiplied with the current picking performance per hour at 700 pieces. The result of the new performance is 759 pieces per hour. This number is derived from 52,130,499 pieces of new performance per year divided by total normal working time of 68,640 hours. This is a 8.50 % performance improvement.

4.5 Summary

The result from analysis shows the opportunity for improvement, and the new model is proposed for its benefit of time reduction that leads to picking performance improvement. The comparison calculations between the existing and the new order picking locations were executed by Microsoft Excel.

The simulation shows a very good result for time reduction. The annual time reduction is 5,832.14 hours and the major time saving comes from the fast moving products in the A class. The average traveling time id reduced from 8.62 minutes to 3.02 minutes per order, a 65 % reduction in traveling time. Another important result is the picking performance, which improves by 8.50 %, an increase from 700 pieces to 759 pieces per hour.

CHAPTER V

SUMMARY FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

The new proposed model and the result expectations have been presented. The next step now is to present a summary of the findings, conclusions, theoretical implications, managerial implications, and the limitations and recommendations for future research.

5.1 Summary of the Findings

The inappropriate order picking location produces an inefficient picking performance because the fast moving products in the A class has a long traveling time, with an average traveling time of 8.62 minutes per order. This result is very close to the medium moving products in the B class whose travel time is 8.97 minutes per order, and the slow moving products in the C class which take 9.02 minutes per order. So a new model is proposed by redesigning the fast moving products in the A class to be located at the closest location, and to store the slow moving products in the C class at the farthest location.

Also, the starting point and the stopping points are relocated to be close together, for the purpose of traveling time reduction. This produces a very good result in traveling time reduction. The fast moving products in the A class can have their traveling time reduced by 5.59 minutes per order, or 65%. The medium moving products in the B class can reduce their traveling time by 4.57 minutes per order, or 51%. The slow moving products in the C class can reduce their traveling time by 3.24 minutes per order, or 36%. This traveling time reduction result can lead to the benefit of performance improvement. It can help the picking performance to be more efficient because efficient picking location is the important factor for operation performance in the warehouse. The findings in each step, such as the data analysis, the new proposed model and the result expectations, are calculated by Microsoft Excel. The key benefits are summarized below.

- The total traveling time reduction per year is 5,832.14 hours because of the result of the average traveling time reduction for the new picking location.
- The performance improvement is 8.50 % because of the result of 759 pieces per hour due to the total traveling time reduction.

If the new model of order picking location is implemented, the picking performance can be improved, as shown in the simulation.

5.2 Conclusions

Low performance of the picking process is the problem for the Optical Lens Company, and it needs to find a strategy to improve its picking performance. Thus, the order picking location was examined and analyzed to find a likely solution.

This research analyzed the order frequency for picking products, the existing order picking location, and the current layout in the warehouse. Then, the relevant data was collected, such as the sales report, the picking location and the standard traveling time. The analysis result showed the disadvantage of the existing order picking location and inappropriate layout, because the picking locations do not separate the classification of picking products between the fast moving products, the medium moving products and the slow moving products. The fast moving products are stored throughout all picking zones even though some areas were very far away, and meant long traveling time. Yet the traveling time is very low for some slow moving products that are located throughout all the picking zones, and some are very close. Therefore, a new model is proposed to redesign the order picking location in order to reduce the traveling time and improve the picking performance.

Comparison was made of the analyzed results of distance and traveling time between the existing and the new picking location. The expected benefits from the new picking location are linked to the objective of this research which is to propose a new picking location for the purpose of traveling time reduction and picking performance improvement.

5.3 Theoretical Implications

The most significant objective of this research is greater understanding in knowledge of warehouse management in terms of strategy, such as the storage policy, the routing policy and zoning. The knowledge gained from appropriate theory assisted this researcher to find the root cause of the problem, and to identify a new model regarding picking location.

The main theory in this research is the Class-based storage policy. Dekker et al. (2004) identified that the picking product frequency of fast moving products need to be stored at the closest point, and the slow moving products need to be located at the farthest point, to enable traveling time reduction, which is the major target of this research.

5.4 Managerial Implications

The benefit of this research is in finding a way to make picking performance more efficient in the warehouse of the Optical Lens Company. The company can improve its picking performance by redesigning the order picking location in line with the new proposed model. The company needs to group the fast moving products in the A class to be stored at zones 5 and zone 6 for 276 locations, the medium moving product in the B class to be store at zone 4, zone 5 and zone 6 for 352 locations, and the slow moving products to be stored at zone 3, zone 4, zone 5 and zone 6. It also needs to allocate the locations at zone 8 and zone 9 in the mezzanine floor to be used for other purposes, as these zones should not be used for order picking products because the average traveling time would be more than ten minutes. The result of the simulation model reveals the great advantage of traveling time reduction after the order picking location is redesigned. The benefit of improved picking performance is a factor to make improve the efficiency of the warehouse operation. As the sales volume is continuing to increase very year, effective picking performance is very important for the company.

5.5 Limitations and Recommendations for Future Research

The limited scope of this research is a limitation, because this research focused only on the make to stock products. It excluded other types of order picking products, such as the make to order and the assembly to order products. They are stored by different processes.

Recommendations for future research are that it should find other factors which make for low performance in the picking process, such as process time, idle time and administrative time. Also, future research could study other strategies for improving the picking performance. It may it need to find other computer programs, especially software for the layout calculation and analysis. Also, it should study the Warehouse Management System or WMS. All these recommendations could help to discover more appropriate solution to improve the picking performance.

BIBLIOGRAPHY

Caputo, A.C., & Pelagagge, P.M. (2011). A methodology for selecting assembly system feeding policy. *Industrial management and Data Systems*, 111(1), 84-112.

Caron, F., Marchet, G., & Perego, A. (1998). Routing policies and COI-based storage policies in picker-to-part systems. *International Journal of Productions Research*, 36(3), 713-732.

Caron, F., Marchet, G., & Perego, A. (2000). Layout design in manual picking system: a simulation approach. *Integrated Manufacturing Systems*, 11(2), 94-104.

Choe, K., & Sharp, G. P. (1991). *Small parts order picking: design and operation*. Retrieved August, 25, 2011 from http://www.isye.gatech.edu/logisticstutorial/order/article.htm

De Koster, R., Le Duc, T., & Roodbergen, K.J. (2007). Design and control of warehouse order picking: a literature review. *European Journal of operational Research*, 182(2), 481-501.

Dekker, R., De Koster, M.B.M., Roodbergen, K.J., & Van Kalleveen, H. (2004). Improving order-picking response time at Ankor's warehouse. *Interfaces*, 34(4), 303-313.

Hall, R.W. (1993). Distance approximation for routing manual pickers in warehouse. *IIE Transactions*, 25(4), 77-87.

Hassan, M.D. (2002). A framework for the design of warehouse layout. *Facilities*, 20(13/4), 432-440.

Heskett, J.L. (1963). Cube per order index-a key to warehouse stock location. *Transport and Distribution management*, 3, 27-31.

Ho, Y.C., & Liu, C.F. (2005). A design methodology for converting a regular warehouse into a zone picking warehouse, *Journal of the Chinese Institute of Industrial Engineering*, 22(4), 332-345.

Le-Duc, T., & De Koster, R. (2005). Travel distance estimation and storage zone optimisation in a 2-block class-based storage strategy warehouse. *International Journal of Production Research*, 43(17), 3561-3581.

Le-Duc, T. (2005). *Design and control of efficient order picking processes*, PhD thesis, *RSM Erasmus University*.

Manzini, R., Gamberi, M., & Regattieri A. (2005). Design and control of flexible order-picking systems (FOPS). *Journal of Manufacturing Technology Management,* 16(1), 18-35.

Petersen, C.G. (1995). Routing and storage policy interaction in order picking operations. *Decision Sciences Institute Proceeding,* 3, 1614-1616.

Petersen, C.G. (1997). An evaluation of order picking routing policy. *International Journal of Operations &Production Management,* 17(11), 1098-1111.

Roodbergen, K.J. (2001). Layout and routing method for warehouses, PhD Thesis. *RSM Erasmus University, the Netherlands,*

Tompkins, J.A., White, J.A., Bozer, Y.A., Frazelle, E.H., & Tanchoco, J.M.A. (2003). *Facilities Planning*. NJ: John Wiley & Sons.

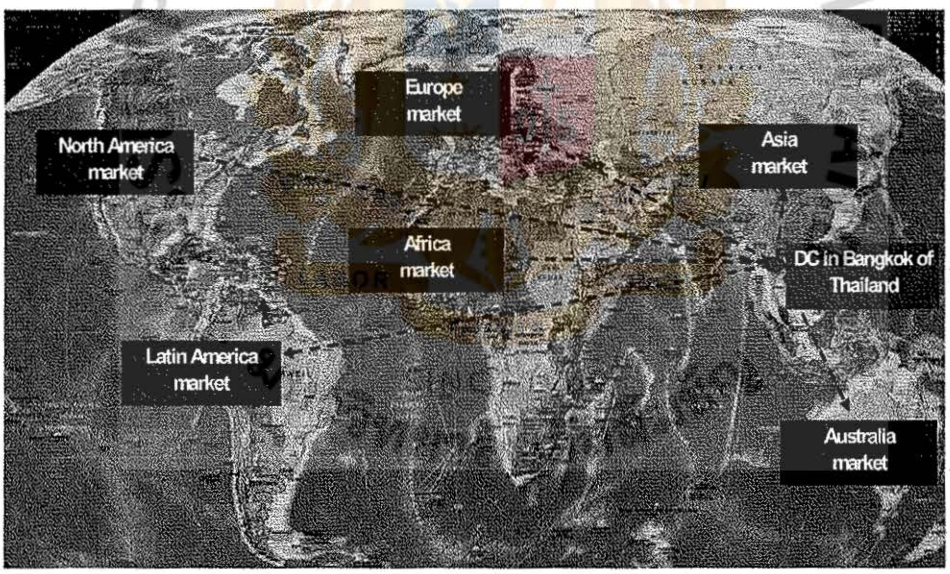
APPENDICES

APPENDIX A

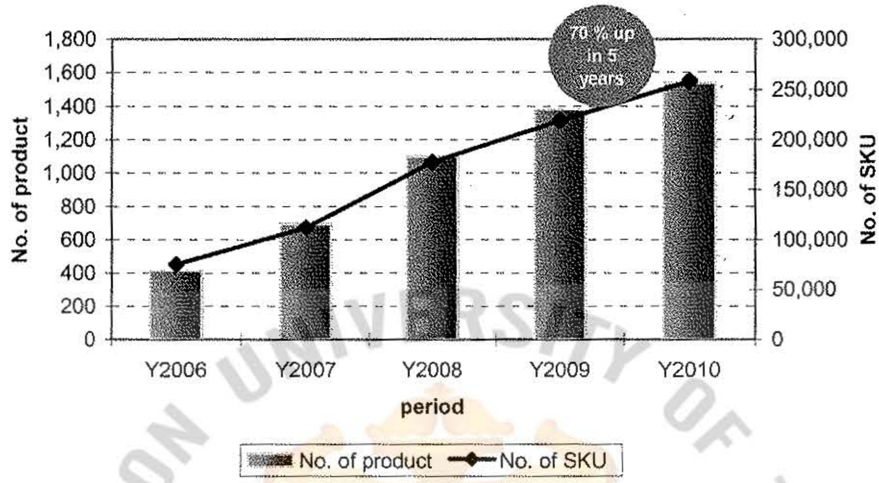
Background of the Optical Lens Company

The distribution centre or warehouse in Thailand manages with 5,919 square meter of space including the space in the mezzanine. The average storage inventory is 16.2 million lenses per month, the total number of product is 1,540 products, the number of storage SKU is 99,744, the number of commercial SKU is 258,111, the average throughput of all activities in the distribution center is 16 million pieces per month, the total production volume in 2010 is 73.1 million pieces or an average production volume of 6 million pieces per month. The total sales of 2010 are 62.7 million pieces or an average sale of 5.2 million pieces per month. The company's market is world-wide. The trend of an increasing number of products and SKUs is around 70%, and the growth trend of sales and production volume is 22% in five years for 2006-2010.

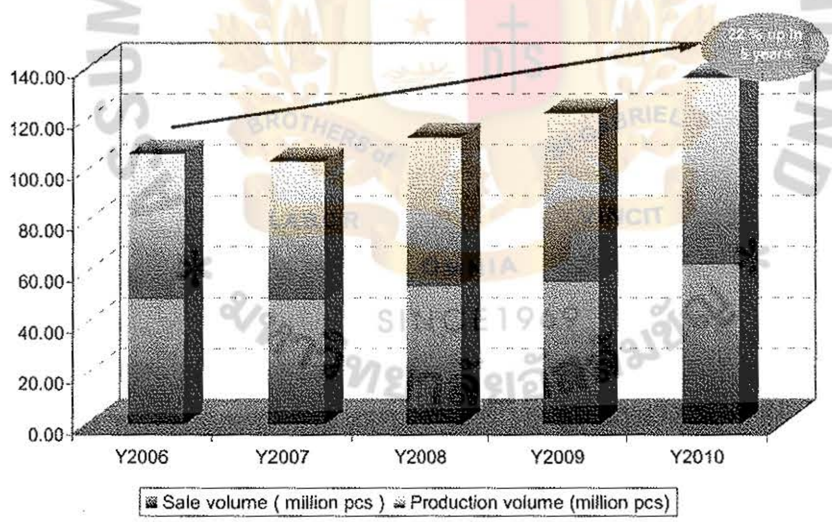
Market location of the Optical Lens Company



Increasing products and SKUs of Optical Lens Company



Growth of Sales and Production of Optical Lens Company



APPENDIX B

Shipment Process of the Optical Lens Company

Flow chart of shipment preparation