Transportation Cost Improvement for an Electric Appliance Manufacturer

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วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรมหาบัณฑิต
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จิรฐา ถิรดานน : การปรับปรุงต้นทุนการขนส่งของบริษัทผลิตเครื่องใช้ไฟฟ้า (Transportation Cost Improvement for an Electric Appliance Manufacturer) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: ดร. พิศิษฏ์ จารุมณีโรจน์, 224 หน้า.

ในปัจจุบัน ประเทศไทยถูกพัฒนาให้เป็นประเทศอุตสาหกรรมมากขึ้น ดังที่ปรากฏจากการที่บริษัทต่างๆ ตัดสินใจลงทุน สร้างโรงงานการผลิต และกระจายสินค้าไปยังกลุ่มลูกค้าที่กระจายตัวอยู่ทั้งในและต่างประเทศ ทำให้การขนส่งสินค้ามีบทบาทสำคัญในภาคธุรกิจเนื่องจากค่าใช้จ่ายของการขนส่งนับเป็นประมาณ 30% ของค่าใช้จ่ายโลจิสติกส์ทั้งหมด ดังนั้นงานวิจัยนี้จึงมีวัตถุประสงค์เพื่อพัฒนาการจัดการการขนส่งของบริษัทที่ศึกษาซึ่งส่งผลให้เกิดการปรับปรุงค่าใช้จ่ายในการขนส่ง

งานวิจัยฉบับนี้มุ่งเน้นไปที่การศึกษา และพัฒนาระบบช่วยตัดสินใจในการขนส่งสินค้าตามเวลาจริงของบริษัทที่ผลิตและจัดส่งเครื่องใช้ไฟฟ้าแห่งหนึ่งในประเทศไทย ที่มีรูปแบบการจัดส่งแบบการขนส่งโดยตรงจากคลังสินค้าหลักของบริษัทไปยังลูกค้าที่กระจายตัวอยู่ตามจังหวัดต่างๆ รอบจังหวัดสมุทรปราการ ทั้งนี้ระบบช่วยตัดสินใจที่ถูกพัฒนาขึ้นประกอบไปด้วยระบบย่อย 2 ระบบ คือ ระบบการจัดกลุ่มลูกค้า และระบบการจัดเส้นทางการเดินรถที่เหมาะสมในแต่ละวัน

ระบบการจัดกลุ่มลูกค้านั้นมีวัตถุประสงค์เพื่อลดความซับซ้อนในการออกแบบเส้นทางเดินรถ โดยจะทำการรวบรวมกลุ่มลูกค้าที่มีคุณลักษณะเหมือนกันเข้าด้วยกัน เช่น กลุ่มลูกค้าที่อยู่ในเขตเดียวกัน กลุ่มของลูกค้าดังกล่าวจะถูกนำส่งไปยังระบบการจัดเส้นทางการเดินรถเพื่อคัดเลือกรถ และวางแผนเส้นทางการเดินรถให้เป็นไปตามข้อกำหนดของบริษัทและการขนส่ง เพื่อให้บรรลุวัตถุประสงค์ของงานวิจัย ระบบช่วยตัดสินใจที่ถูกพัฒนาขึ้นนี้ได้อาศัยหลักการการจัดลงตัวครั้งแรก (First-Fit Algorithm) และวิธีการค้นหาเพื่อนบ้านที่ใกล้ที่สุด (Nearest Neighbourhood Algorithm) ตามลำดับ

ผู้วิจัยได้ทำการทดลอง และวิเคราะห์ความสามารถของระบบช่วยตัดสินใจที่ถูกพัฒนาขึ้น โดยเปรียบเทียบกับผลลัพธ์การดำเนินการในอดีตเป็นเวลา 7 วันทำการ มีคำสั่งซื้อทั้งสิ้น 1,004 คำสั่งซื้อ ทั้งนี้ผู้วิจัยพบว่า ระบบที่พัฒนาขึ้นสามารถเพิ่มอรรถประโยชน์ของการใช้รถได้ถึง 14.80% และลดการส่งของช้าได้ทั้งหมด ดังนั้นจึงส่งผลต่อ ค่าใช้จ่ายในการขนส่งรวมลดลง 8.24% อย่างไรก็ดี ผลลัพธ์ที่ได้จากระบบช่วยตัดสินใจที่ถูกพัฒนาขึ้นนี้เป็นเพียงผลการทดลองเบื้องต้น ซึ่งจำเป็นต้องทำการปรับแต่งให้เหมาะสมกับการนำไปใช้งานจริงต่อไป

ภาควิชา	ศูนย์ระดับภูมิภาคทางวิศวกรรมระบบการผลิต	ลายมือชื่อนิสิต ....
		ลายมือชื่อ อ.ที่ปรึกษาหลัก ....
สาขาวิชา	การจัดการทางวิศวกรรม	
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Nowadays, Thailand has developed itself to become a more industrial country. There are many companies who decide to invest and establish their manufacturers here and distribute their products to customers domestically and internationally. Transportation discipline plays an important role in many organisations as 30% of logistics cost goes to transportation cost. Thus, this research aims to improve the studied company's transportation management which also results in transportation cost improvement.

This research is a study and development of a heuristic which helps manage the transportation discipline using online orders, of an electrical appliance manufacturer in Thailand. It focuses on delivering products from the company's main warehouse to customers which are located in other provinces around Samutprakarn. This research has developed 2 systems which are customer clustering system and route designing system, with an objective to improve transportation cost, as well as improve vehicle utilisation and delivery performance.

The customer clustering system is designed to reduce the complexity when designing a delivering route. The system will cluster the customers which have similar characteristic together into the same group, for example; group of customers which are located in the same province. This group of customer will be used in route designing system in order to select a suitable vehicle and create a travelling route plan which conform to the transportation conditions and regulations. In order to achieve the objective, the proposed systems applied the First-Fit Algorithm and the Nearest Neighbourhood Algorithm respectively.

The researcher has experimented and analysed the abilities of the proposed systems by comparing the results of the experiment and the company's actual recorded data of 7 operating days. There are 1,004 order lines in total. As a result, the proposed systems are able to improve 14.80% of vehicle utilisation and reduce any delayed delivery. Therefore, it leads to 8.24% reduction of overall transportation cost. However, these proposed systems only provide initial solutions which need to be adjusted when implementing to a company.

Department:	Regional Centre for Manufacturing Systems Engineering	Student's Signature	....
		Advisor's Signature	....
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CHAPTER 1

INTRODUCTION

1.1 Background of Research

Nowadays, Thailand has developed itself to be an industrial country. As a result, there are many industrial parks located in Thailand. Various companies use Thailand as their base to manufacture products and distribute them domestically and internationally, such companies, that are well-known are Electric appliance companies like Sharp, Panasonic, Electrolux, and Hitachi. Thansettakit (Thansettakij, 2016) mentioned that the economic growth of electronic appliances was only two to three percent in 2015 due to external factors such as a flat economic, which led to individuals' lower buying power. However, the market has tended to grow in 2016. According to the Marketeer (MARKETEER, 2016), the low economic growth did not affect the purchasing power of premium customers. The report showed that those premium customers had dominated twenty five to thirty percent of the overall electric appliance market in 2015. As for the economic forecast for 2016, the premium customers segment is foreseen to grow more than seven percent. The government anticipated a channel to improve domestic economic from the mentioned groups of customers. Therefore, the government is trying to push the economy forward by investing more in big projects. The reason for the push is to increase the income distribution and restore domestic economy. Once people get more buying power, it would positively affect the electric appliance market, as it is involved in the daily lives for every level of customers.

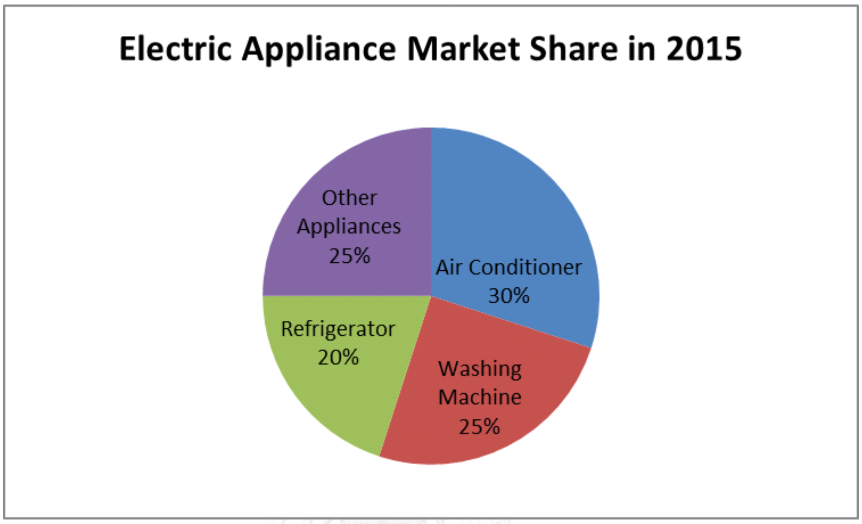

Figure 1: Electric Appliance Market Share in 2015

Source: Adapted from MARKETEER (MARKETEER, 2016)

In a supply chain, the logistics plays an important role in every process. An effective logistics discipline within a company can improve the company’s efficiency and help reduce inessential costs. To improve logistics efficiency, everyone in an organisation should understand the reason why it needs to be changed and what are the benefits they would receive. Once they realise the importance of functional logistics, they would be willing to change and improve. However, there is no specific solution to the problems that a company could be facing. The company ought to evaluate its current situation, then research the most suitable method and strategy that can be chosen and applied to achieve the most effective outcome.

Transportation is a part of logistics discipline. It plays the most important role in the business of logistics systems; how well a company can manage this discipline reflects its efficiency of moving products. Effective management and principles help improve the overall system such as product allocation, speed of delivery, service quality, transportation costs, facility of usage management, and conservation of energy. Moreover, Tseneg, Y. et.al (Tseng et al., 2005) stated that two third of business costs are invested in transportation. Chang, Y.H. (Chang, 1998) defined that, on average, six point five percent of market revenue and twenty nine percent of logistics costs go to transportation cost.

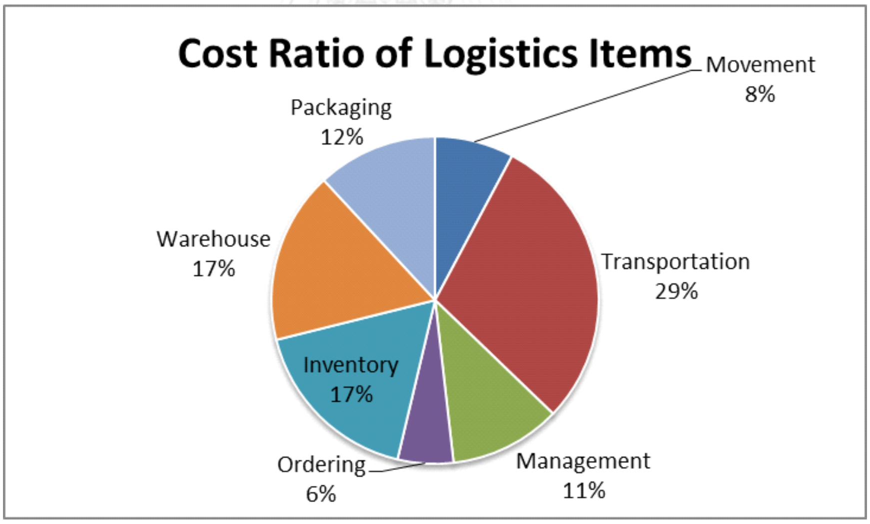

Figure 2: Cost Ratio of Logistics Items

Source: Adapted from Chang, Y.H. (Chang, 1998)

1.2 The Company Overview

The studied company is an electric appliance manufacturer located in Samutprakarn, Thailand. The company's main operation consists of manufacturing goods, storing products, and delivering products to customers. All finished goods are moved from the manufacturer to the company warehouse located in Samutprakarn. There are six different product categories that are to be delivered from this warehouse; (a) air conditioner, (b) air purifier, (c) microwave oven, (d) refrigerator, (e) vacuum cleaner, and (f) washing machine. Each product category consists of its sub models, which differ in size and capacity.

Figure 3: The Company's Products

Source: SHARP (SHARP, 2016)

All products will be delivered from warehouse to customers by the company's own vehicles. According to many real life situations, which are relevant to the sustainability of the business for both the company and customers, the company has agreed with the customers to deliver goods within twenty four hours (excluding days off). Every delivery schedule, therefore, has to be completed within twenty four hours (excluding days off) after receiving delivery order (DO) from sales department. There are reasons behind the fact why all orders need to arrive at the customers' sites within specific of time. For the company, there are a number of competitors in the market that are willing to deliver goods within one day or at least as soon as they possibly can. The sooner the company is able to deliver their goods, the more opportunity to gain more customers and increase the company's reputation. On the other hand on the customer side, it appears that some customers do not have their own warehouses. Therefore, they are not able to store a lot of products at their shops. As a result, they prefer to order products and have them delivered to the shop to avoid any storage conditions such as warehouse rental cost. It reduces inventory and increases the company's ability to respond to a higher number of customer demands (Lee et al., 2006). In this research, the company only pays attention to the competition among the same business only.

The warehouse is a start point and terminal point for every vehicle. There are six types of vehicle that the company owns; (a) 4-wheel Pick Up (6 m^3), (b) 4-wheel Big

(10 m^3), (c) 4-wheel NKR (10 m^3), (d) 6-wheel (30 m^3), (e) 6-wheel Big (75 m^3), and (f) 18-wheel (60 m^3), while cubic meter is a volume unit used for calculating vehicle and product capacity.

Figure 4: The Example of Company Vehicles

Source: Adapted from CARRY BOY (CARRY-BOY, 2016)

In this study, the overall transportation processes will be focused and analysed. All nine processes are shown in figure 5, followed by the explanations.

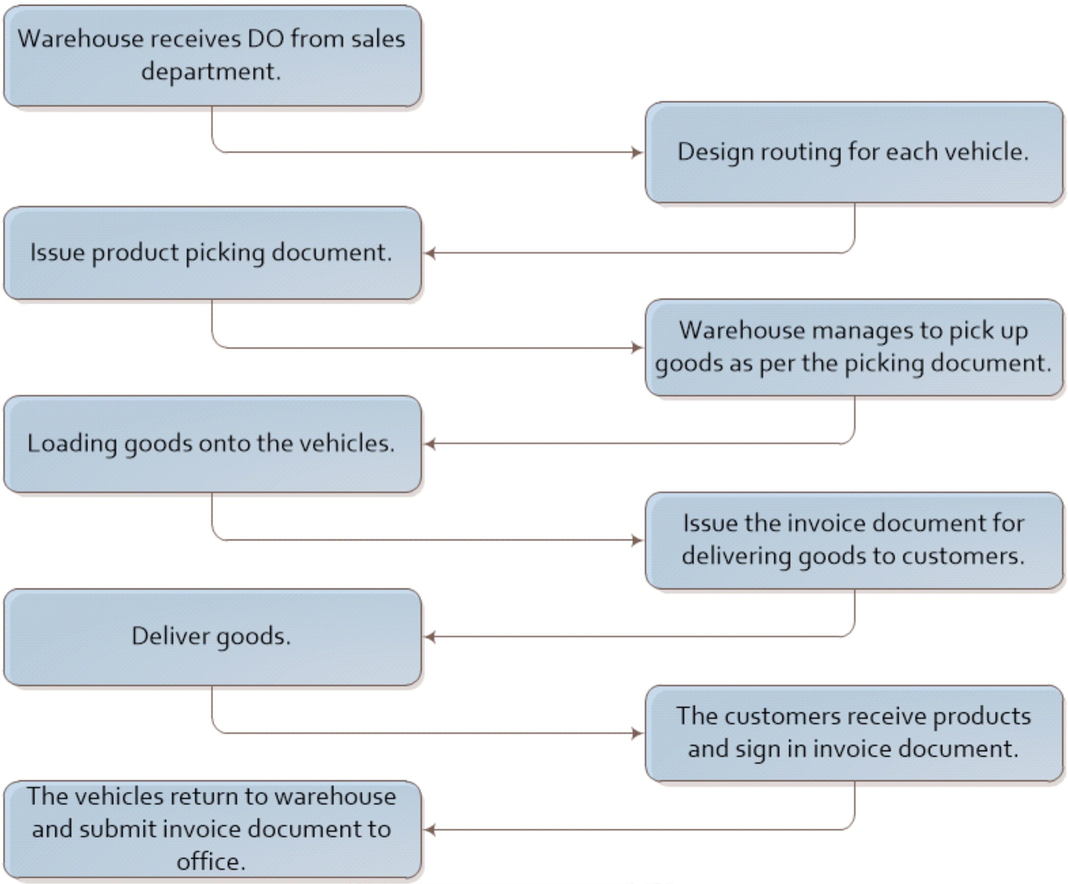

Figure 5: The Company's Transportation Processes Flow Chart

1.2.1 Company’s Transportation Processes

- **Sales department**

The sales representative from the sales department is responsible for communicating with customers. When the customers purchase products, the sales department will check the product's availability in stock, then confirms their orders with said customers.

- **Warehouse receives DO from sales department**

After the sales department confirms orders with customers, a sales representative will issue the delivery order (DO) to the warehouse. The essential details shown in the DO are: product category including its sub models, product quantity, customer name and address, order receiving time, and terms and conditions. The DO will be submitted to the warehouse from 8.30 to 18.00 daily, excluding lunch time and Sundays. Any document that is received after working hours will be considered in the following day (excluding days off).

- **Design routing for each vehicle**

After receiving the DO from their sales department, the warehouse will group the customers together and design a delivering path. Customer grouping is done based on customers' locations. The decision of the number of orders and quantity of products to be allocated onto each vehicle will be made along with the most suitable travelling route for the vehicle will be designed. All decisions are made by the warehouse manager. Normally, the customers with the same postcode are grouped together; but, this depends on the capacity of goods which already occupies the vehicle. The orders are allowed to be split onto many vehicles. The warehouse manager has to ensure that the product quantity that will be loaded onto the vehicle must not exceed the its capacity. However, the company sometimes assigns overloaded work to a vehicle due to the limitations of time and vehicle availability.

- **Issue product picking document**

Once the warehouse manager has decided which orders will be loaded into the vehicles, the warehouse document controller will issue a document called "picking document", for the warehouse's workers to pick the needed products.

- **Warehouse workers manage to pick up goods as per picking document**

The picking document shows all product types and quantities. The workers will access the storage area to pick up goods according to the document and move them to the loading area. All items must be ready at the loading area before the vehicle arrives to the warehouse's dock to avoid any waiting.

- **Loading goods onto the vehicles**

When all goods are placed at the loading area, the vehicle driver is called to pick them up. There are seven loading docks, which are compatible with all existing sizes of vehicles. According to route design, the sequence of loading products matters. The products of the last customer on the route will be loaded first and the product of first customer on the route will be loaded last. This helps avoid any damage caused by unloading at customers' sites. In addition, the loading time for each vehicle is different. Loading and unloading activities are done by workers without any help of special equipment.

- **Issue the invoice for delivering goods to customers**

An invoice is an important document which provides essential information about customers and their orders. The vehicle is able to leave the warehouse when the invoice is ready. The document controller is responsible for this task and has to hand over this document to the driver. Each invoice indicates customer's name and address, and product details; such as, name, quantity, weight, price per unit, and total price. Customers will use this document to confirm that they have received the corrects order or to have the right to refuse to accept products if they are damaged or are incorrect products.

- **Deliver Goods**

Once the products are loaded onto the vehicle and the invoice is ready, the vehicle may leave the warehouse for delivery. The starting point is the warehouse and also the termination point. Delivery time is set from 05.00 – 20.00, Monday to Saturday, except Sundays and public holidays. The first vehicle leaves the warehouse at 5.00 and no vehicle is allowed to return after 20.00 to avoid over-time working hour. For the vehicle which leaves at 5.00, goods might be loaded onto the vehicle the day before. However, even though each vehicle gets its designed route, the driver sometimes does not follow the plan due to traffic condition, driver's routing experience and other unexpected conditions.

- **The customers receive products and sign the invoice**

When the driver reaches a customer location, the driver and assistance are responsible for unloading the products. This process is done by manpower. There is no special equipment involved. The customer then checks any mistakes of orders, as well as inspects for any damage on the newly arrived products. If the products conform to the statement in the invoice and there are no unsatisfied conditions, the customer will then sign the invoice as confirmation of the delivery.

- **The vehicles return to the warehouse and submit invoice to the office**

When the driver completes the delivery of goods to all customers, s/he has to return to the warehouse immediately. The invoice must be returned to the warehouse office to confirm that all assigned goods are delivered to the customers accurately. The travelling time back to warehouse from customer site should not be later than the time indicated in the schedule provided.

Notes:

- The company has a policy that all orders must be delivered to the customers within twenty four hours after receiving the DO. According to the company's KPI, it states that all products must be delivered to customers more than ninety eight percent on time of the overall DOs. Any delay will directly affect the KPI. There will be a penalty that will be taken into account as per company's and customer's agreement.

- The delivery areas are Ayutthaya, Bangkok, Chachoengsao, Nonthaburi, Pathumthani, and Samutprakarn, Thailand.

1.3 Statement of Problem

This research aims to study the company's transportation management which affects the department transportation performance and cost. In this context, the transportation management includes customer clustering, vehicle utilisation planning, and delivery route planning. The transportation management will focus on the electric appliance manufacturer's goods delivery system from the company's warehouse to customers in Ayutthaya, Bangkok, Chachoengsao, Nonthaburi, Pathumthani, and Samutprakarn, Thailand. It also includes the methods to cluster customers, select vehicle, and design travelling path, in order to deliver goods effectively.

As the recent situation in the electric appliance business, there are a great number of competitors in the market. It is not only about the product quality but also the company’s after sales service. This research is mainly focused on the company's vehicle selection and travelling route design processes. Therefore, the activities in this discipline are investigated to identify the overall problems.

The relationship in the transportation process is a link between the company's warehouse and customers. Moreover, it is also about the management within the department itself. As per the agreement between the company and customer, it states that all orders must be delivered to customers' site within twenty four hours after receiving the orders (except days off), otherwise a penalty fee will be charged. From the agreement, the company needs to manage their process, in order to deliver goods in time. The process begins with the DOs, that are submitted by sales department to the warehouse. There is no cut off time to submit the document; therefore, the warehouse has to standby for any orders that might come in. Once the DOs have reached the warehouse, the customers are clustered by using their locations, vehicles are selected, and then delivery paths are designed. Products are loaded onto the vehicle once the plans are completed. The plans consist of group of customers and their orders on each vehicle and their delivery sequence. However, the orders sometimes do not fill the whole vehicle and the vehicle has to wait until it is fully filled to its maximum capacity. Because the company does not have standard waiting time, the manager can decide to release the vehicle to deliver goods, even though there is some empty space left. In the point of view of manager, the reason he might do this action is to avoid any late delivery that might cause penalties to the company. But as a result, there is some empty space inside the vehicle that could be used properly if the vehicle had got better management. From the collected data, it shows that some vehicles contain goods less than fifty percent of their overall capacity. And there are also a few vehicles that are used to deliver goods more than their capacity. In addition, there are vehicle round trip cost which occurs to every vehicle that leaves warehouse to deliver products. This cost will be used to calculate the overall transportation cost. Therefore, the empty space on a vehicle does not create any value to the company besides the achievement to meet the lead time agreement with customers. On the other hand, the vehicle which carries goods more than its capacity would be able to create more value. But, it is quite risky to do so, because exceeding its capacity may result in an increasing of maintenance cost. Moreover, when there is an accident which is related to this issue, it would have greater effects and cause greater damage. Therefore, the company has lost an opportunity cost to an empty space on each vehicle and responsible for unnecessary of maintenance cost according to company's poor vehicle utilisation management,

Besides the vehicle utilisation management, the company's delivery performance is also an issue that needed to be considered. A performance measurement is used to measuring how good a transportation management is. The transportation KPI is set in place to measure this performance. Only 2% of delayed delivery is allowed, otherwise there will be a penalty that a company could be charged. As the company's current transportation performance (from collected data from 3^{rd} May 2016 – 11^{th} May 2016), only 55.68% of overall orders are able to be delivered to customers' sites within twenty four hour (excluding days off). This number is below the company KPI but the performance could be better if the company has applied a suitable management to operate it. From the data analysis, it appears that 44.32% late deliveries may be caused by a lack of vehicle which is a consequence of poor vehicle utilisation management mentioned above. The vehicles sometimes leave to deliver goods before its leaving time even though there is some empty space. This refers that the manager decided not to wait until they are fully filled in order to deliver goods within the lead time. As a result, most of the vehicles are released and when they are needed, there is no available vehicle at warehouse. The orders have to wait until an available vehicle returns but by that time it might almost meet the delivery lead time and cause a delayed delivery. As a result, the company will be charged for any orders that could not reach customer on time. The penalty that a company has to bear depends on an agreement made between customer and a company. It is calculated from value or delayed orders by percentage. According to the collected data, it shows that during considered operating days, the company could be charged for a penalty of up to 100,000 baht. In addition, delayed delivery may be caused external factors such as traffic, weather, or vehicle break downs.

According to the results, vehicle utilisation management and delivery performance lead to transportation cost of overall system. Company transportation cost consists of vehicle round trip cost and penalty cost. The vehicle round trip cost is calculated from number of vehicle used for delivering products each day. As per the collected data, the company has spent 589,344.23 baht on vehicle round trip cost while penalty is not yet considered. It could cost more if the company does not consider to improve a management of utilisation. Moreover, the company has to suffer from burden of penalty cost when the transportation does not success as plan. This would result in higher transportation cost. As a consequence, the net revenue that the company would receive is less than it is expected to be.

In conclusion, this studied company is facing a problem of high transportation cost which result from the company's recent operation behaviour. Poor vehicle utilisation causes an empty space which could create more value if manage wisely or cost greater maintenance cost when containing goods more than vehicle's maximum capacity. A number of vehicle which are assigned to deliver products has direct effects to total vehicle round trip cost. In addition, company's delivery performance is below the KPI due to warehouse not being able to deliver goods within lead time so that the penalty cost is taken into account. Thus, with those mentioned issues, with a suitable and effective managements, they could help reduce unnecessary and unexpected costs which will also lead to an improved transportation cost.

1.4 Assumption of Research.

1.4.1 Customer Clustering System Assumptions

1. Customer location, province, is a criterion to cluster the customers.
2. The distance between two locations is symmetrical.

1.4.2 Route Designing System Assumptions

1. Vehicle capacity threshold is 80%.
2. Maximum vehicle waiting time at warehouse is 60 minutes.
3. The travelling time consists of travelling time without traffic plus additional thirty percent of insurance time of traffic, loading, and unloading goods.
4. DO is able to be split. Order lines of the same DO can be delivered separately by separated vehicles.
5. Thailand's regulation of vehicle speed and travelling time allowance is neglected.
6. Route is designed based on order receiving time after clustering groups of customers.

1.5 Restrictions of Research

1.5.1 Customer Clustering System Restrictions

1. The sales department submits DOs to warehouse from 8.30 to 18.00.
2. The company delivery time and the customer's order receiving time is any time between 5.00 to 20.00.
3. There are one hundred and forty nine customers.
4. The customers are able to have more than one product in one order.
5. Products capacity is determined by volume (m^3).
6. The distance between two locations is symmetrical, determined by kilometre (km).

1.5.2 Route Designing System Restrictions

1. The number of vehicles is limited at 31 vehicles.
   - 4-wheel pick up: ten units
   - 4-wheel big: two units
   - 4-wheel NKR: three units
   - 6-wheel: ten units
   - 6-wheel big: three units
   - 18-wheel: three units

2. Each type of vehicle has different capacity loads and consumes different amount of resources.
    - 4-wheel pick up: six cubic metres
    - 4-wheel big: ten cubic metres
    - 4-wheel NKR: ten cubic metres
    - 6-wheel: thirty cubic metres
    - 6-wheel big: seventy five cubic metres
    - 18-wheel: sixty cubic metres
3. The vehicle round trip cost consists of fixed cost and variable cost.
4. Transportation cost consists of vehicle round trip cost and penalty cost.
5. Products are delivered on Monday to Saturday (except Sundays and holidays) from 05.00 – 20.00.
6. The vehicle's speed is limited at 60 km/ hr.
7. Route is designed based on order receiving time after clustering groups of customer.
8. The distances between two locations are represented in real distances. Unit is in kilometre (km).

9. There is no outsourcing strategy to cover when the vehicles are insufficient.

10. The distance between two locations is considered symmetrical.

11. The different sizes of goods are able to be delivered together.

1.6 Parameters

1. Distance between the warehouse and customers.
2. Distance between customers.
3. Delivery history from 3rd May 2016 to 11th May 2016 (excluding 7th to 8th May 2016).
4. Customer order history from 3rd May 2016 to 11th May 2016 (excluding 7th to 8th May 2016).
5. Vehicle characteristics including volume capacity and cost.
6. Order information: customer name, customer location, and demand.
7. Number of vehicles used in the system.
8. Distance that each vehicle travels each day and each trip.
9. Number of orders and product quantity that the vehicle contains to deliver each trip.
10. Vehicle capacity threshold is set at eighty percent.

1.7 Inputs

In order for the systems to operate effectively, the detailed inputs are required. Those detailed inputs could be used for one or two systems. In addition, the outputs of customers clustering systems are used as the inputs of the route designing system. Both systems inputs are shown in table 1.

Table 1: The Systems' Inputs

Customers Clustering Inputs	Route Designing Inputs
DO number.	Feasible sequences from customer clustering system.
Customer code.	DO number
Customer names.	Customer code.
Customer addresses.	Customer names.
Order receiving time.	Customer addresses.
Product code.	Order receiving time.
Product name.	Product code.
Product quantity (unit).	Product name.
Customer working hours.	Product quantity (unit).
Vehicle average speed.	Product capacity: volume (m^3).
Distance between locations.	Customer working hours.
Travelling time between locations.	Type of vehicle in the system.
	Number of vehicle (unit).
	Vehicle capacity: volume (m^3).
	Vehicle average speed.
	Vehicle's working hours.
	Vehicle's capacity threshold.

Customers Clustering Inputs	Route Designing Inputs
	Distance between locations.
	Travelling time between locations.
	Logistics time regulations.
	Logistics speed regulations.
	Transportation cost per delivery trip of each vehicle.

1.8 Outputs

This research is separated into two systems which are cluster the group of customers, and vehicle assignment as well as design routing plan. Each system has its own objectives and outputs as shown in table 2.

Table 2: The Objectives and Outputs of the Systems

System	Objective	Output
Customers clustering	To group the customers together by using their locations.	A group of similar customers along with their order lines.
Route designing	• To increase the vehicle utilisation by creating more value of the empty space within vehicles. A suitable vehicle is selected. • To improve transportation management. The most effective travelling route shall be planed.	• Type of vehicle that is assigned to deliver goods to customers. • Feasible plans of travelling route for each vehicle for delivering goods.

1.9 Constraints

The constraints refer to any factor which may cause working limitations in the system and provide various outputs depending on type of constraint. Some constraints affect both systems depending on how important they are to each system. Some constraints impact only one system as it is not relevant to another system at all. The constraints of both systems are shown in table 3.

Table 3: The System's Constraints

Customers Clustering Constraints	Route Designing Constraints
Product capacity: volume (m^3)	Product capacity: volume (m^3)
Delivery lead time	Vehicle capacity: volume (m^3)
Order receiving time	Order delivery time
	Customers' working hours
	Vehicle working hours

1.10 Objective of Research

To develop a heuristic for improving transportation cost for an electric appliance manufacturer, including improving the vehicle utilisation and delivering performance.

1.11 Scope of Research

Firstly, the company actual data of operating days is collected from 3rd May 2016 11th May 2016 (except 7th – 8th May 2016). This data will be used for analysing a company's actual performance. Moreover, it will also be used in this thesis in order to analyse the effectiveness of the proposed systems.

Secondly, all vehicles belong to the company. They deliver goods from the company's warehouse to customers. In this research, there are thirty one vehicles involved in the system. The vehicles are divided into six types which are 4-wheel pick up, 4-wheel big, 4-wheel NKR, 6-wheel, 6-wheel big, and 18-wheel. Every vehicle starts and stops its route at the company warehouse. There are one hundred and forty nine customers that the company serves, the temporary customers are ignored. More specifically, customers are located in Ayutthaya, Bangkok, Chachoengsao, Nonthaburi, Pathumthani, and Samutprakarn, Thailand.

The system starts when the warehouse receives a DO. The process flow is based on real time. There is no cut off time but the DO has to be submitted during office hours only (8.30 – 18.00). The goods uploading management and routing design are done by warehouse manager. The delivery time starts from 05.00 to 20.00.

In conclusion, the author considers the area of vehicle routing problem with the constraints of vehicle capacity, customer location, delivery lead time, and travelling routes. Therefore, the result of vehicle utilisation and delivery performance are being considered. The factors which will not be considered are traffic, weather, and product shortage.

1.12 Expected Results

When a heuristic is generated and applied to the system, it is expected to be an effective tool for improving the customers clustering and route designing processes which will lead to a reduction of overall transportation cost. The method to manage the goods uploading process is created. As a result, the vehicle utilisation is expected to increase. Moreover, the tool to choose the most suitable type of vehicle to deliver goods is generated. It aims to provide the tool to design the most effective travelling path and customer sequence.

1.13 Expected Benefits

1. The vehicle utilisation is increased.
2. The number of vehicles being used each day is decreased.
3. The number of vehicles being used does not exceed the limits of company own vehicle.
4. The distance that the vehicle could travel is extended.
5. The complexity of routing design is decreased.
6. The travelling time for each delivery trip is decreased.
7. The cost of transportation is reduced.
8. The company is able to deliver goods on time as states in the agreement.
9. The company is able to achieve the KPI goal.

1.14 Research Methodology

The research methodology is the overall steps from the beginning until the end of this research. The processes, methods, and the outcome are shown in table 4.

Table 4: Research Methodology

Process	Methodology	Outcome
• Collect the company data	Request previous relevant data (seven working days, except public holidays) such as customer data, customer orders, delivery schedule as well as their vehicle information.	• Company previous delivery data • Relevant company transport information • Lists of customers and products • Lists of orders
• Study company structure, including transportation processes	Study how the company operates its transportation discipline and analyses its recent performance	• The company performance evaluation • The lists of activities that shall be improved
• Study relevant information and regulation	The logistics regulations are being observed. This includes speed, and size of the vehicle, as well as the time regulation. This is to understand the external constraints which affect the company activity.	• The constraints which relevant to the regulations

Process	Methodology	Outcome
• Data analysis	The previous data is studied to identify what are the good and bad situations that the company is recently facing.	• The performance of company transportation management
• Identify problems	The observed data is analysed to identify the problems which occur in the transportation process.	• Statement of problem
• State the scope of research	The objective of research is clearly identified in order to set the research direction. Then frame the scope of research and state the research assumption.	• Objective of research • Scope of research • Assumptions of research • Restrictions of research

Process	Methodology	Outcome
• Study relevant theory	The articles, journals, and literatures are studied to collect information which relevant to the research. The area of study is listed below: • The vehicle routing problem (VRP) • Travelling salesman problem • Bin packing problem • Bin packing algorithms • Heuristic • Two-phase heuristic • Greedy algorithm • The nearest neighbourhood algorithm • Early due date method	• The appropriate knowledge to apply to the research
• Identify the concept design of research	A heuristic is identified to use in the proposed systems. The core concept and frameworks have to be clarified.	• Heuristic concept • Heuristic framework
• Identify the detailed concept design of research	A two-phase heuristic is applied to the research. The thoroughly details is interpreted according to research concept design.	• Detailed heuristic for the systems

Process	Methodology	Outcome
• Create tool to evaluate the heuristic	The tool for examining the heuristic is developed. This is to ensure that the proposed heuristic is suitable for the system.	• A tool to experiment the heuristic • Pros and cons of heuristic
• Heuristic implementation	The heuristic is applied to system to obtain the results then evaluate them.	• Improved system
• Research conclusion	The overall research is written as a report. The report consists of five chapters which are introduction, related theories, and literature reviews, methodology, proposed systems measurements and discussion, and conclusion and suggestion.	• Research printout

CHAPTER 2

RELATED THEORIES AND LITERATURE REVIEWS

2.1 Supply Chain and Value Chain

A definition of supply chain is a process which starts from transforming initial raw materials into finished goods by flowing across the links between suppliers and users. It also refers to the internal and external activities of manufacturers which helps add value to the value chain by manufacturing products and providing services. The supply chain does not consist of only the goods' physical movements between companies, but also the information flow amongst them as well (Fredendall and Hill, 2016). Figure 6 shows the idea of the overall supply chain. A supply chain is operated and concerned by the company in order to reduce any costs. The manufacturer will evaluate their production line and adjust its production's efficiency in each step until the products reach the customers (Supadilok, 2012).

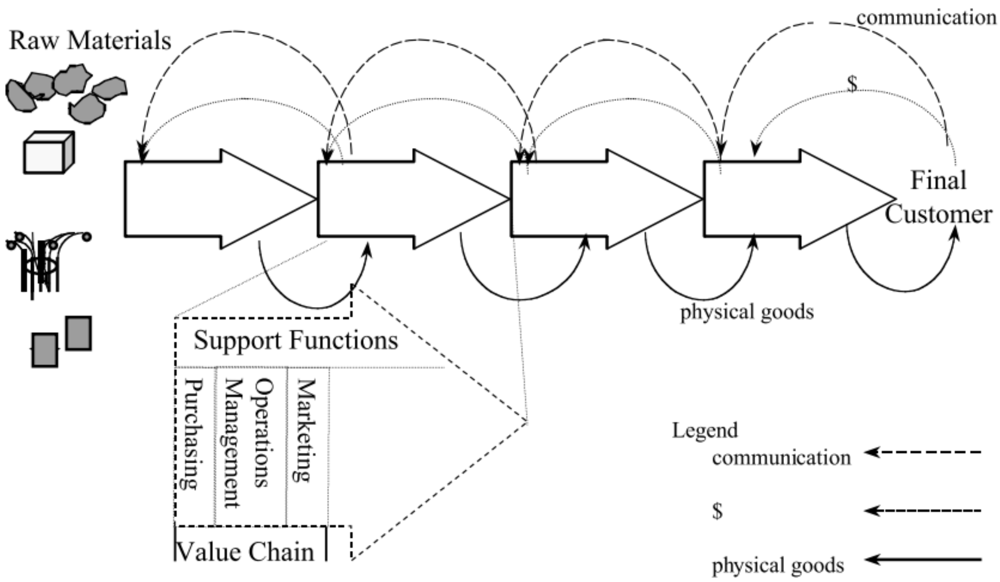

Figure 6: Supply Chain

Source: Fredendall, L. D. & Hill, E. (Fredendall and Hill, 2016)

Value chain signifies the value added functions which are added to the company's products or services, which in the end, the company aims to sell to customers and earn an income from it. In figure 6, functions of one of the companies' are enlarged to illustrate more detailed information of adding value into the supply chain (Fredendall and Hill, 2016). Moreover, in a value chain, the value is seen through the customers' point of view. It is also to determine how customers value a company's products and how to encourage them to purchase the company's products or services (Supadilok, 2012).

2.2 Logistics System Management

Logistics is an activity flow of materials within the organisation. The activity starts from the origin of raw materials or suppliers until the final end of delivering the finished goods to customers. The logistic term was firstly used in the military. It was a study of methodology which ensures that the supplies were allocated effectively and that the right resources were used correctly. The activities flow of materials and information are included in the logistics system management, but those are not all of them. The logistics system management also contains the information of essential and inessential infrastructures, equipment, and resources which are involved in the logistics activities (Ghiani et al., 2013).

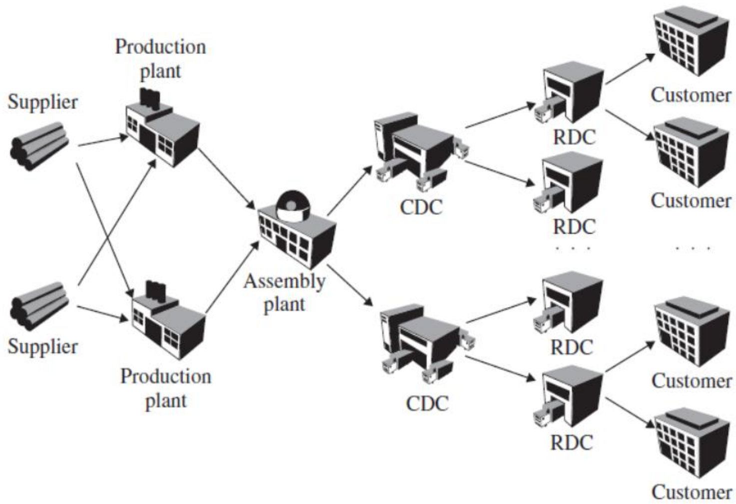

Figure 7: Example of Logistics

Source: Ghiani, G. et al (Ghiani et al., 2013)

Logistics are consisted of the 4R operating tasks. Providing the required quantities of product at the right time are the key concepts of logistics. Moreover, if the goods are able to be provided in the right order as well as at the right place where they are needed, they would make logistics more effective. The objects of logistics could refer to many items; for example, raw materials, finished and unfinished goods, parcels, or even scraps. Livestock, animals, or human are also counted as objects of logistics. Source of logistics is divided into two point: source and final sink. The source refers to suppliers, plants, and storages or warehouses. The receivers or destinations are defined as the final sinks, which are the malls, markets, or points of consumption. The transport elements are to link the sources, intermediate stations, and final sinks together and create a logistic network. In summary, logistics is a discipline where the initial sources and final sinks are variable but the product orders, manufacturing procedures, and consumable quantities are given (Timm and Herbert, 2009). Figure 8 has illustrated the basic functions of logistics.

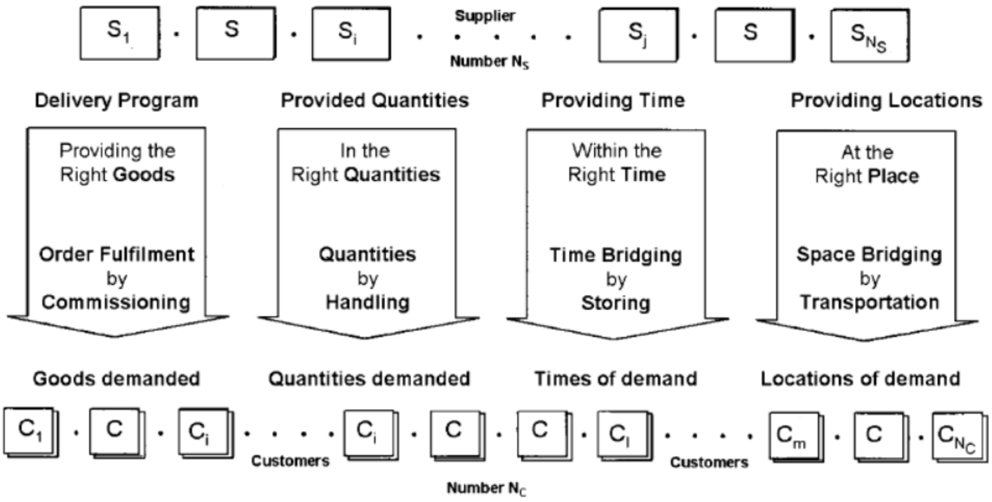

Figure 8: Functions and Tasks of Operative Logistics

Source: TIMM, G. & HERBERT, K. (Timm and Herbert, 2009)

2.2.1 Logistic Activities

According to Ballou, R.H. (Ballou, 2007) and Akaramanee, R. (Akaramanee, 2010), the logistics activities within each organisation which form up the business logistics are varied depending on type of business they are. Mostly, the activities are divided into two main parts which are physical supply (material management) and physical distribution. The activities under those disciplines are shown in figure 9

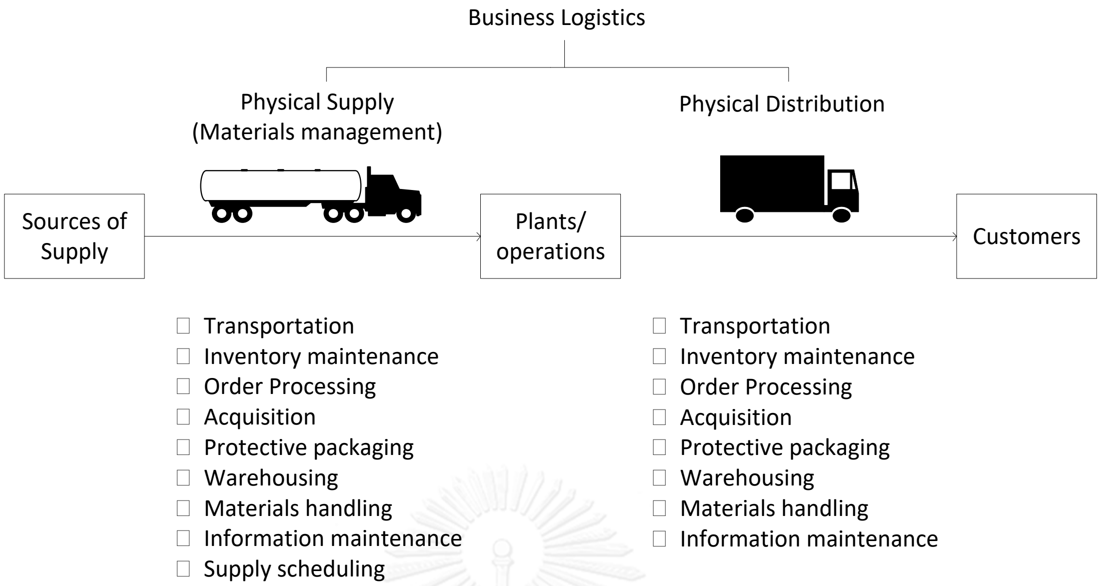

Figure 9: Logistics Activities in a Firm's Immediate Supply Chain

Source: Adapted from Ballou, R.H. (Ballou, 2007)

2.3 The Vehicle Routing Problem (VRP)

In supply chain and logistics, the vehicle routing problem (VRP) is brought up for consideration as it is one of the simplest transportation problem which many companies have to take into account when delivering goods from place to place. The transportation service includes picking up and delivering goods from the depot to the customers located at different places. It is aimed to optimise delivering routes, and/or to collect routes from warehouses to customers or other concerned location (Laporte, 1992). In these operations, there are constraints affecting the vehicle and route planning which are vehicle capacity, customer time window, delivery sequence, and other service constraints. In logistics settings, the vehicle capacity refers to the available capacity a vehicle is able to contain products. The loaded products must not violate the vehicle capacity. A time window is a delivery time limitation. If a vehicle arrives at the customer location before an appointment, the driver has to wait until it is the time to unload the goods. On the other hand, if the vehicle arrives after the schedule, it must return to deliver goods on the next day. The delivery sequence is relevant for the customer's time window.

The VRP is the simplest routing problems for a company operating multiple vehicles. The factors which are included in the problem are the depot and the customer. The exact number of customers is known along with their locations. The amount of goods required by customers is the demand. The vehicle used are identical and their exact numbers is known. Every vehicle starts and ends at the depot. Each customer will be visited by only one vehicle per day. The objective of this problem is to deliver goods as per demand to customers by using the shortest distance at the lowest cost. The cost that the company spends is proportional to the distance that the vehicle has to travel. This includes all vehicles in the system. The travelling distance of the transportation is based on Euclidean distance norm. It must satisfy a triangle inequality and is symmetrical. The triangle inequality guarantees that the travelling distance between two locations is the shortest path (Golden et al., 2008, Goetschalckx, 2011).

2.3.1 Elements of Vehicle Routing

1. "Depot" refers to location(s) where the vehicle starts and terminates.
2. "Vehicle" refers to any freight transport; for example, pick-up, truck, which is use for serving service, delivery goods. The vehicle capacity is brought for consideration.
3. "Customer" refers place or node which has the interaction with the company. This could be a product dealer, factory, or office. The product size and quantity are involved.
4. "Route" refers to the travelling path which is used for serving service or delivering goods to customers (nodes). Number of customer might or might not be different depending on type of company and customer. Route and customer are connected by their locations and by using the information of traffic.

The elements of vehicle routing are shown in figure 10.

In figure 10, it shows a vehicle routing problem with a single depot (d1), eight customers (c1 – c8), and three vehicles. The vehicle routine starts at the depot, then delivers goods, and ends at the depot.

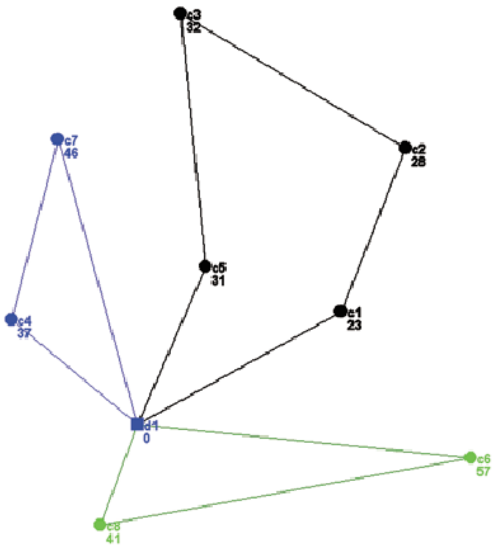

Figure 10: Example of a Vehicle Routing Problem with a Single Depot

Source: Goetschalckx, M. (Goetschalckx, 2011)

Table 5: Characteristics of Routing and Scheduling Problems

Characteristics	Possible Options
1. Fleet size	One vehicle Multiple Vehicles**
2. Fleet type	Homogeneous (only on vehicle type) Heterogeneous (multiple vehicle types)** Special vehicle types (compartmentalised, etc.)
3. Depot	Single depot (domicile)** Multiple depots
4. Demands	Deterministic demands** Stochastic demand requirement Partial satisfaction of demand allowed

Characteristics	Possible Options
5. Demand locations	At nodes** At Route Mixed
6. Vehicle capacity restriction	All the same Different vehicle capacities** Unlimited capacity
7. Maximum route time	Same for all route Different for different route Not imposed
8. Operations	Pick ups only Deliveries only** Pick ups and deliveries Pick ups or deliveries
9. Costs	Variable routing costs** Fixed operation vehicle acquisition costs Common carrier costs
10. Objectives	Minimise total routing cost** Minimise sum of fixed and variable costs** Minimise number of vehicles required** Maximise utility function based on service Maximise utility function based on customer priorities

** refers to the problems which are being considered in this research.

Source: Adapted from Bodin L.D. (Bodin et al., 1983)

According to table 5, the studied company uses 6 types of vehicle to deliver products to customer. Within this research, on 31 heterogenous vehicles are used to serve customers from 6 provinces. They have different ability to contains products, as well as they require different amount of resources. There is only depot concerned which is a company's main warehouse. It is both the start and termination point. Demand refers to orders which a warehouse receives from sales department. However, the orders are the online orders. Neither warehouse nor sales department would know in advance of when and how many orders will be purchased. Within this research, a main operation which will be considered is delivering products to customers at different locations only. Transportation cost involves in this research are vehicle round trip cost and penalty cost. A vehicle round trip cost is determined by a studied company and consists of variable cost and fixed cost. Lastly, an objective of this research is to develop a heuristic which is able to help reduce overall transportation cost and improve vehicle utilisation and delivery performance.

Supakdee K. et al. (Supakdee et al., 2012) had studied on vehicle routing problem of transportation for Medical Experiment Maintenance in Ubon Ratchathaini province, Thailand. An objective is to decrease overall transportation cost. Reduction of total travelling trip and travelling distance are expected benefits. A modified saving algorithm is applied. The results of experiment will be compare with current routing method, district routing method, and saving algorithm technique. As a result of experiment, a transportation cost of modified saving algorithm was reduced about 40% of when compared with current method while the district clustering and saving algorithm technique were able to reduce cost approximately 8% and 3 % respectively. Moreover, the travelling distance and total trip were also decreased. However, the Nearest Neighbourhood Algorithm should be applied in order to create a suitable travelling route.

Another case study was introduced by Akaramanee, R. (Akaramanee, 2010) to develop a vehicle routing problem of Thailand's Provincial Electricity Authority to distribute the electrical parts from company's main warehouse in Bangkok to other domestically warehouses around Thailand. The Nearest Neighbor Heuristic and Saving Algorithm were applied to achieve the objectives of reducing transportation cost and increase vehicle utilisation management. The results of two mentioned methods would be compare with results from a company's actual method. The best method which provided satisfactory result was a saving algorithm. A transportation cost was reduced by 19% from an actual cost. However, this research had used Microsoft Excel to operate the experiments. To code the algorithms in an appropriate program may provide more accurate results.

When it comes to a large-scale of customer, more application shall be taken into account. Tan, L. et al. (Tan et al., 2016) had studied clustering method for a large-scale TSP. The researchers of this research believed that a Genetic Algorithm was an effective toll to solve a TSP, but yet, it was not suitable when it came to a large-scale TSP. Therefore, an Improved Genetic Algorithm was applied to solve the problem altogether with a GA, which are a K-means Clustering and Affinity Propagation. Each method would give results of sub-clustered group of customers. The GA was then applied to identify the shortest travelling path of each sub-clustered group. Lastly, those sub-clustered groups will be connected together by appropriate method to generate the shortest route. Results of the experiments are an effectiveness and efficiency of each improved algorithm. As a result, when comparing results with a classic GA, it turned out that both K-means Clustering was able to provide effective and competitive results, as well as an Affinity Propagation method. In addition, Du, L. and He, R. (Du and He, 2012) has studied methods to solve a large-scale and scattered customers of tobacco company. An objective of this research was to design a travelling route with the least cost. The Nearest Neighbor Search and Tabu Searh (intra-route and inter-route) were applied as an initial solution and solution improvement respectively. The results of proposed algorithms would be used to compare with a standard benchmark data and real data. As a result, the experiments showed that a combination of the Nearest Neighbor Search and intra-route & inter-route improvement gave the best result. It was not only able to reduce a transportation cost but also delivering performance.

2.4 Travelling Salesman Problem (TSP)

According to Goetschalckx, M. (Goetschalckx, 2011), the travelling salesman problem or TSP is the simplest travelling problem. It consists of two components, salesman and set of cities or locations. A salesman has to start from one origin point (e.g. depot), then visit N customers or N locations only once, and lastly return to the original point. To travel on one route and able to visit all customers or locations are the challenge of this problems. Moreover, how to minimise the overall travelling must be considered. Nevertheless, this problem becomes more severe when there are many customers and they locate in scattered locations (Kiatnukul, Pitakaso, Gutin and Punnen, 2006). In summary, the TSP is only considered about travelling costs and how to minimise the total travelling distance while the customer demands and vehicle capacity is ignored (Jaillet, 1985).

The Travelling Salesman Problem (TSP) is always mentioned as it is the simplest problem of VRP. The routing includes only one vehicle. But in this case, the vehicle capacity is ignored. The salesman has to visit each city only once on his travelling path. The starting point and ending point are the same city. The problem which is found in TSP is how to travel by using the shortest distance, stated by Ropke, S. (Ropke, 2005). To solve the TSP problem, the route establishment algorithm is applied. The shortest path is generated for the vehicle to visit all customers once in one cluster. However, as per Lin, S. and Kernighan, B.'s (Lin and Kernighan, 1973) study, they used TSP to identify the shortest path to travel and the result turned out to be satisfactory. Even though the algorithm gave an approximated result but the optimal solution was quickly produced. All processes are repeated until all orders are delivered. A travelling salesman problems with profits is a part of TSP. Profits are generated from each visited vertex but it is not necessary for all vertexes to be visited (Feillet et al., 2005). In addition, considering the large size problems, when there are more than one vehicles and there are a great number of customers or locations, the problem moves on to the next stage which is cluster-first, route-second and route-first, cluster-second (Miranda-Bront et al., 2015). Other VRPs which require multiple vehicles to deliver and pick up goods at different customers' sites are studied by Hasle, G. (Hasle, 2003)

In reality, there are a number of restrictions which unable the transport to operate effectively. The complexities and limitations which are often found are customers' time window, vehicle types (homogeneous and heterogeneous), vehicle capacity, multi-dimensional capacity of goods loading, many different locations of start and termination point, transportation costs, vehicle and goods relevance, and routing restrictions. Furthermore, these limitations are rarely solved by one single solution. Therefore, Goel, A. and Gruhn V. (Goel and Gruhn, 2008) had studied the possible approaches to improve and adjust neighbourhood structure.

The vehicle routing problem with time window (VRPWT) is another kind of classical VRP. There is an additional time constraint where the additional specified delivery time is given by customers.

In order to solve the VRP, the Route Generation Algorithms is one of the methods that is being used widely. When using the algorithms, the information that are necessary are the problem data and partial/ full set of routes. There are two route-generation algorithms which are route-construction and route-improvement. Firstly, route-construction divides to nearest neighbour and saving algorithms by Clarke G. and Wright J.W. (Clarke and Wright, 1964). In the nearest neighbourhood algorithm, every new route starts from the depot and visit the closest unvisited customers first. The vehicle capacity is also significant. Any unvisited customers are continuously added to the route as long as it does not violate the vehicle capacity. Once the capacity is violated, the vehicle has to return to the depot and a new route will be commenced. For Clarke G. and Wright J.W. (Clarke and Wright, 1964) and as stated in a research of Hemmelmayr et al. (Hemmelmayr et al., 2009), it is a procedure that extends the original route. Both endpoints of the original route are extended. Secondly, route-improvement is another algorithm that is considered. As per Goetschalckx, M. (Goetschalckx, 2011), there are a number of route-improvement algorithms such as 2-opt, 3-opt, intra-route improvement, and inter-route improvement.

According to the study of Yu, B. et al. (Yu et al., 2011), it is stated that the meta-heuristic should be the most effective algorithm to solve VRPWT. To that extent, the hybrid approach has been proposed. It consists of an Ant Colony Optimization (ACO) and Tabu Search (TS). Moreover, a neighbourhood search is used for improving the ACO performance. In the process, the initial solutions are searched by ACO. Then, the Tabu search is applied as to maintain the solutions from ACO and then to generate new solutions. When comparing the results of meta-heuristic and the hybrid approach, the results show that the ACO-Tabu (hybrid approach) is suitable for solving VRPWT.

2.5 Bin Packing Problem

The bin packing problem is closed to the company's actual problem when selecting a suitable vehicle. Its solution is aimed to provide a method to pack a group of items together while using the least bins. Likewise, to the mentioned problems, the company would like to cluster similar customers together in one vehicle. Moreover, the number of vehicles that are being used should be as few as possible. The first - fit algorithm of bin packing problem seems to be the most suitable. The items are placed in a bin. Any first available bin will be filled first until there is no empty space. It then moves to the next new bin. The product capacity is a factor that has to be considered when selecting which vehicle is being used. Second method of bin packing algorithm is first – fit decreasing. The orders will be rearranged by their size, from the biggest to the smallest. They are then placed into the first available vehicle/ container until there is not enough room. They shall move on to next available vehicle. Lastly, full – bin algorithm, the orders will be arranged into size of vehicle/ container. Then, they will be added to the vehicle/ container.

According to Korf, R.'s research (Korf, 2002), a new algorithm for optimizing the bin packing problem is proposed. The Martello, S. & Toth, P.'s (Martello and Toth, 1990) algorithm is developed and leads to the creation of the Bin Completion algorithm. Instead of considering the given items first and then secondly considering where to place the items, this method's processes must firstly consider the bin and then the feasible item sets that are being considered in order to fit items into the bin. In summary, the given items are rearranged into decreasing order. The largest items are placed into the bin, then followed by placing the second largest orders into another bin.

From the experiment of Korf R. (Korf, 2002), the result indicates that the solutions which are obtained from the bin completion are faster than the solutions from Martello and Toth's algorithm (Martello and Toth, 1990). The solutions are equal in the lower bound which is also an optimal solution. Therefore, the bin completion gives an advantage when it is implemented. Comparing to the best existing algorithm, it is simpler.

N	Optimal	L2 bound	% Optimal		Martello + Toth		Bin Completion		Ratio
			FFD	BFD	Nodes	Time	Nodes	Time	Time
5	3.215	3.208	100.000%	100.000%	0.000	7	.013	6	1.17
10	5.966	5.937	99.515%	99.541%	.034	15	.158	13	1.15
15	8.659	8.609	99.004%	99.051%	.120	25	.440	19	1.32
20	11.321	11.252	98.570%	98.626%	.304	37	.869	27	1.37
25	13.966	13.878	98.157%	98.227%	.741	55	1.500	36	1.53
30	16.593	16.489	97.790%	97.867%	2.146	87	2.501	44	1.98
35	19.212	19.092	97.478%	97.561%	7.456	185	4.349	55	3.36
40	21.823	21.689	97.153%	97.241%	39.837	927	8.576	73	12.70
45	24.427	24.278	96.848%	96.946%	272.418	6821	20.183	103	66.22
50	27.026	26.864	96.553%	96.653%	852.956	20799	57.678	189	110.05
55	29.620	29.445	96.304%	96.414%	6963.377	200998	210.520	609	330.05
60	32.210	32.023	96.036%	96.184%	58359.543	2153256	765.398	2059	1045.78
65	34.796	34.598	95.780%	95.893%			11758.522	28216	
70	37.378	37.167	95.556%	95.684%			16228.245	41560	
75	39.957	39.736	95.322%	95.447%			90200.736	194851	
80	42.534	42.302	95.112%	95.248%			188121.626	408580	
85	45.108	44.866	94.854%	94.985%			206777.680	412576	
90	47.680	47.428	94.694%	94.832%			1111759.333	2522993	

Figure 11: The Bin Completion Experiment Result

Source: Korf, R. (Korf, 2002)

2.6 Route Generation Algorithms for the VRP

2.6.1 Exact Approach

Exact approach is able to provide the most suitable solutions for the problem and does not oppose any conditions. However, the operation of exact approach requires a lot of time. Therefore, it is not suitable for big size problems. Example of exact approach are listed below.

- Branch and Bound
- Branch and Cut

2.6.2 Heuristics

Heuristic is a method to provide the most suitable solution at that period of time. It must not oppose any conditions as well. One heuristic only suitable for one specific problem, therefore, it cannot be used with other problem. The examples of heuristic which are widely used are as followed.

- Constructive methods

  Constructive method is suitable for solving the problems which consider cost saving as a first priority.

  1. Clark and Wright’s savings algorithm
  2. Matching based
  3. Multi-route improvement heuristics

- Two-phase algorithm

  1. Clustering of vertices into feasible routes
  2. Actual route construction
     - Cluster-first, route-second algorithms
     - Route-first, cluster-second algorithms

2.6.3 Meta-heuristics

Meta-heuristic is a development of a standard heuristic. It is mainly used and able to provide in depth and width resolution of solutions at the same time. Moreover, the acquired solutions have more quality than standard heuristics. The examples of meta-heuristic which are widely used are as followed.

- Ant colony algorithms
- Genetic algorithms
- Tabu search

2.7 Greedy Algorithm

Srichanthongsiri, G. (Srichanthongsiri, 2013) had explained the use of a greedy method which provides the solution that seems to be the best and possible for the next step of other algorithm. It might be the most suitable solution at that specific time only and it might not be feasible when time has moved on. However, that obtained solution might not be the optimal solution for the problem. As a result, it might not always answer the strategic objective of organisation. Goetschalckx, M. (Goetschalckx, 2011) stated that the greedy algorithm's main objective is on the next step, therefore, it is also called myopic algorithms.

2.8 Savings Algorithm

The savings algorithm or Clark and Wright's algorithm is firstly introduced by Clark and Wright in 1964. The main objective is to minimise cost which is a result from minimising distance and vehicle used within the system. All customers must be visited once and the exact demand quantities must be delivered while the demand capacity on the same vehicle must not violate the vehicle capacity or must not exceed the delivery lead time (Lysgaard, 1997). Its construction procedure is to extend an original partial rote at its end points. The depot is always a starting point and it is also where the route ends after deliver goods to customers. When there is one customer to be served, the vehicle would leave warehouse to deliver goods then comes back. Once there are more orders come in, the next vehicle will be assigned to transport products to customers. Therefore, two vehicles might be used at the same time as shown in figure 12.

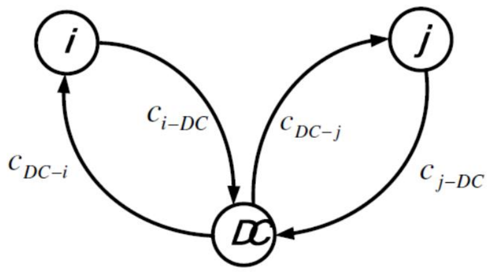

Figure 12: Initial Savings Algorithm

Source: Srimuang, K. (Srimuang, 2007)

The saving algorithm aims to reduce the distance to deliver goods to more than one customer by consolidating them together within one vehicle. The saving can be calculated by the total travelling distance from depot to each customer (from figure 12 represent two customers) minus the travelling distance between two customers. Once the saving algorithm is applied to the problems, the feasible route which contains two customers in the same vehicle shall be provided (Goetschalckx, 2011, Srimuang, 2007), as shown in figure 13. However, the combination of two routes together into one route does not guarantee that the transportation cost of both directions will be the same (Lysgaard, 1997).

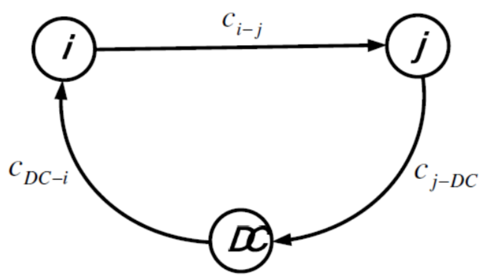

Figure 13: Final Savings Algorithm

Source: Srimuang, K. (Srimuang, 2007)

2.9 Heuristic

The heuristic is brought for consideration when the problem's size becomes greater. It is possible to use an algorithm, but when there is more complexity in the problem, it would require longer time to solve the problem. The time consumption when finding the solutions is proportional to the size of problems. Heuristic is a method that is used for determining a set of feasible solutions. Nevertheless, the heuristic may not provide the best solution but it is also effective. The feasible solution from it can be sufficient enough to be used in any planning processes, as stated by Pitakaso, R. (Pitakaso, 2011).

2.10 Two-Phase Heuristics

2.10.1 Cluster-First, Route-Second

The cluster-first, route-second is the preferred method, and is applied with the help of the sweep algorithm proposed by Wren, A. & Holliday, A. (Wren and Holliday, 1972) and Gillett, B. E. & Miller, L. R. (Gillett and Miller, 1974).

The cluster phase is aimed to group customers together. There are criterions which are used when evaluating each customer's characteristic. As a result, the common characteristics of customers are likely to be grouped together. Customer's location is one of the criterions that many organization uses for clustering their customers. Moreover, customer demand, customer time window, or vehicle capacity could also be the factors which would affect the clustering phase. Result of cluster phase may vary depending on what criterion is used at that time. Once the cluster-first phase is complete, the route-second approach shall be begun. The travelling route plan will be generated for those customers within the same cluster. Its delivery sequence is also identified. However, when the vehicle capacity is also brought for consideration,the cluster shall end when its capacity is violated (Goetschalckx, 2011, De Grancy and Reimann, 2015).

2.10.2 Route-First, Cluster-Second

Cordeau, J. F. et al (Cordeau et al., 2007) and Goetchalckx, M. (Goetschalckx, 2011) had explained this two phase heuristic operation based on TSP. The route-first phase starts by generating a single travelling which contains all customers inside. The customer demand will not be used for any consideration at this step. Afterward, in the clustering phase, customer demand will be observed along with the vehicle capacity. However, this method is not widely used since it does not provide good performance.

Lau, H. C. (Lau et al., 2003) has defined a two-phase heuristic as a standard two-phase method. The two-phase approaches are consisted of a construction heuristic and iterative improvement heuristic. In a construction heuristic, the possible suitable initial solutions are identified. For the vehicle routing problem with time window, this stage may refer to the step of rearranging the new customers into any feasible sequences of the existing vehicles in the system. The feasible sequences should provide the least travelling cost and distance. An iterative improvement method is the practice of those initial solutions. They will be applied to the system. The feasible solutions are repeatedly operated under the feasible neighbourhoods. Once a certain condition is achieved, the system is ended.

In 1981, Fisher, M. L. & Jaikumar, R. (Fisher and Jaikumar, 1981) proposed an algorithm to solve the clustering problem, Generalized Assignment Problem (GAP). A minimum cost assignment of items is paired with a number of bins. Each bin has a set weight assigned. To be beneficial, the assignment cost of a customer to a vehicle is equal to its distance to that customer.

Another two-step method would be to find an amount of seeds equal to an amount of vehicles. Once the routes to the different seeds are initialised, the remaining customers are inserted in the already existing routes. With this method, we can control the total number of routes from the beginning, whereas with the sweep algorithm we cannot.

Petal algorithm is another two-phase method that generates a massive amount of possible route to finally select a final subset as the most feasible route. The performance of this method is superior to that of the sweep method, as mentioned by Cordeau, J.-F. et al. (Cordeau et al., 2007) .

2.10.3 Initial Solution

Fisher, M. L. & Jaikumar, R. (Fisher and Jaikumar, 1981) had introduced a GAP (Generalized Assignment Problem) to form the clusters. However, it showed the limitation of a number of vehicles that are being used in the system. The cluster-first, route-second is a part of sweep algorithm. The route will be created by the connection of each customer.

The cluster-first, route-second method provides the initial solution to solve problems. Even though the initial solution is suitable, it is able to be improved for better solutions. It is called the solution improvement phase.

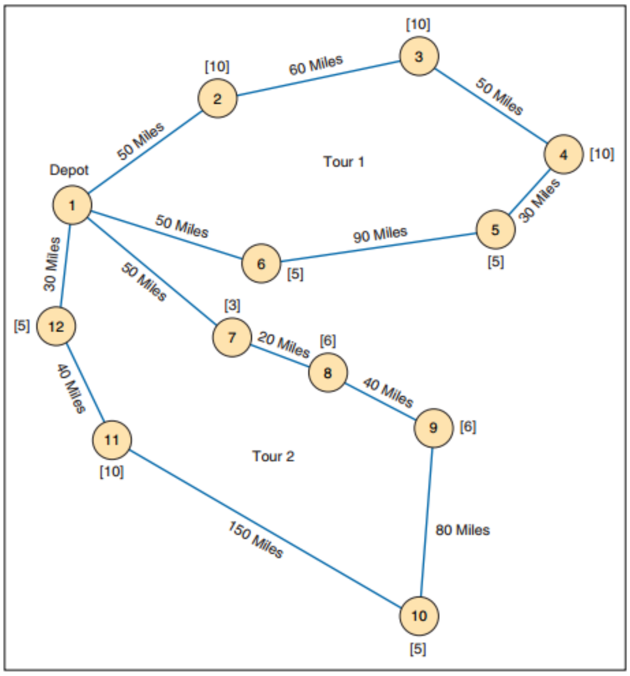

Figure 14: Vehicle Routing Problem: Initial Solution

Source: Heizer, J. et al. (Heizer et al., 2016)

2.10.4 Solution Improvement

In the second phase, the initial feasible solution is improved by the improvement algorithm. When there are additional constraints such as time window, only the TSP or 2-phase heuristic themselves from the first phase may not solve the problem effectively.

The local algorithms are used to improve the initial solution. A simple modification of local search is applied to current solution, such as customer movement, to obtain a better solution. Therefore, if the improved solution is found, it then becomes new current solution for the problem.

In this research, the neighbourhood structures are being studied. According to Hartl, R. F. & Parragh, A. N. (Hartl and Parragh, 2012) and Cordeau, J.-F. et al. (Cordeau et al., 2007), the neighbourhood structure is subdivided into two categories which are (a) intra-route neighbourhood and (b) inter-route neighbourhood. When the improvement operates on single route at a time, it is called intra-route. On the other hand, if there is an operation on more than one route, it is considered as inter-route.

1. **Intra-route neighbourhoods**

   - **λ -opt: 2-opt, 3-opt**

The procedure is to create a new travelling route by using the nearest neighbour algorithm. The λ nodes are possible to be exchanged. The remaining nodes on the path are reconnected in any possible ways. The routing path shall be reversed. As a result, the total distance should decrease. It will show that the improvement algorithm is effective (Fleszar et al., 2009, Kytöjoki et al., 2007, Cordeau and Laporte, 2005, Cordeau et al., 2005).

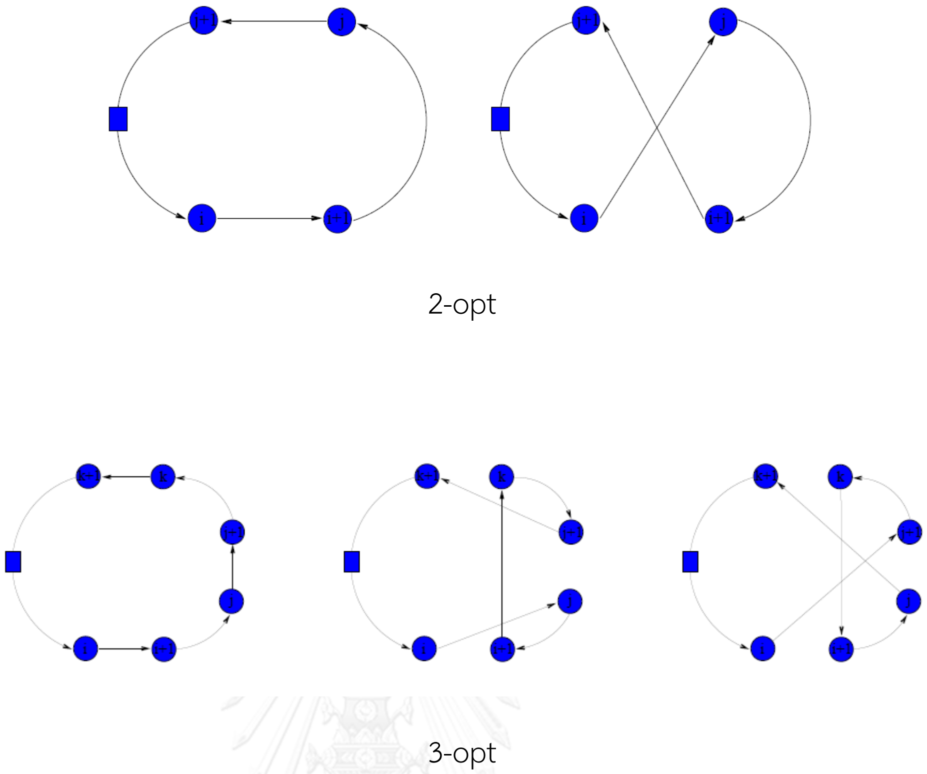

Figure 15: Intra-route neighbourhoods

Source: Chiarandini, M. (Chiarandini)

2. **Inter-route neighbourhoods**

The inter-route improvement aims to reduce the total length of the travelling paths by allocating the facility(s) from one route to another route. Any allocation is possible when the quantity that is moved does not violate the vehicle capacity on the other route. The inter-route improvement consists of two algorithms which are (a) move and (b) swap. The move aims to allocate only one facility to new route which result in the length reduction. The moved facility is placed on any suitable route without violating the vehicle capacity.

For the swap, two facilities from different route are allocated to the other route. It is also aimed to reduce the overall travelling length (Cordeau et al., 2005, Cordeau and Laporte, 2005).

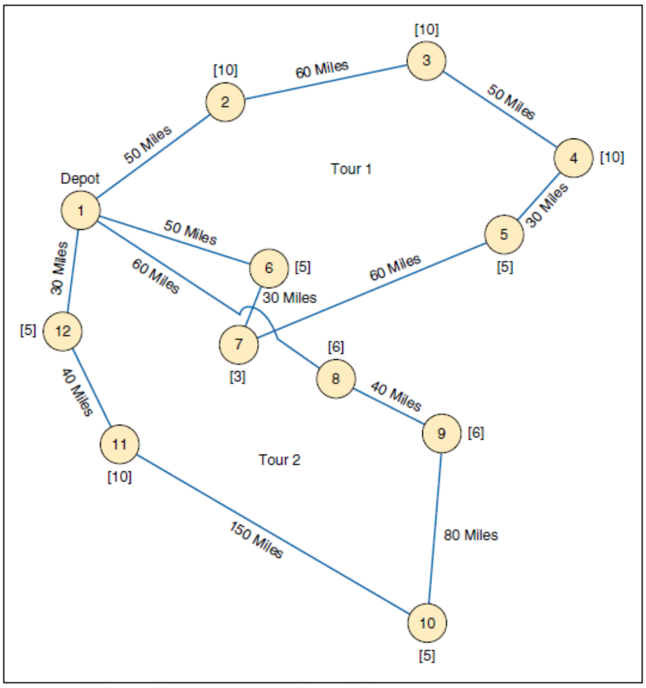

Figure 16: Vehicle Routing Problem: Revised Solution

Source: Heizer, J. et al. (Heizer et al., 2016)

Nigro, M. et al. (NIGRO et al., 2013) had studied a heuristic of cluster-first, route-second in order to solve Many-to-many Dial a Ride problem of Roma Tre University. The factors which were included in clustering phase are vehicle capacity and time constraint. The routing phase was initiated from a travelling salesman problems (TSP). In addition, the travelling path was specified that it could only serve the customers in a one way path. The vehicle cannot travel back and forward (i to j and j to i). The heuristic was implemented in a real situation. The result was satisfactory. It was able to optimise the boarding time, travelling distance, and increase the users when compared to the standard bus service. Moreover, it was able to reduce the time consumption. For future studies, the innovation should be concerned and added to the method.

There was a study of Miranda-Bront, J. et al. (Miranda-Bront et al., 2015), a cluster-first, route-second that was also applied to solve the Swap Body Vehicle Routing Problem (SBVRP). This problem consists of a classical VRP but it is quite new for VRP literature. The objective of this study was to solve the logistics problem in a real world situation. The trucks which were used in the system are considered. They could carry only one swap body or carry an extra trailer but has to have an extra swap body as well. In this study, a swap location plays the role as a special depot for dropping and picking up the swap bodies. The constraint of this study was time. The process of the heuristic starts from dividing the sample problems into smaller problems. Then, the problems are optimised within a period of time. Finally, integrating the obtained solutions together. If there is remaining time, it could be wisely used to find a better solution. After the implementation, the result was satisfactory, it was effective in a practical sense. For future studies, it is able to be extend as to use an Integer Linear Programming in order to generate the solution of larger neighbourhoods.

Csiszar, S. (Csiszár, 2007) had studied on two-phase heuristic algorithm which aimed to solve the vehicle routing problem with time windows (VRPWT). It focused on the industry that would like to reduce the number of travelling path. Moreover, as a consequence from the first objective, it aimed to decrease the travelling distance of each travelling trip by using Tabu search (TS). The first phase was an initial solution. The study proposed a seed selection by probability density function. The Guide Route Elimination was also concerned for developing and was applied to be used along with the mentioned method. A two-phase algorithm was developed by using a computer program, Delphi. Once the solution was generated, it would be tested on the Solomon Problem set. The outcomes which were used for comparing and evaluating, were the number of vehicles and cumulative travelling distances. After the experiment, the result turned out to be better than problem set sample. The number of route was significantly decreased. The efficiency of delivery process was increased. The experiment showed that within one delivery trip, it was able to visit more customers. However, this method had neglected the time consumption which should be taken into account for future researches.

Bunthao, J. (Bunthao, 2015) had studied “Heuristics for the Vehicle Routing Problem with Time Windows” based on the transportation of automotive parts. The limitations of this study were the limited number of vehicles and various customer demands. The objective of this research was aimed to identify the most suitable routes which were able to decrease the studied company's transportation cost. There were three heuristics which were used within this study, saving algorithm, nearest heuristic, and max – nearest heuristic. The saving algorithm was a method which aggregated the start and termination points together in the same route. Each distance would be calculated to find the transportation costs. Then, those costs would be arranged in increasing orders. The cheapest transportation cost of each distance shall be grouped together and it shall then provide the suitable routing with minimum transportation cost. However, the number of goods must not violate the vehicle capacity. This algorithm was quite simple but it was only suitable for a small and medium sized problem. The nearest heuristic was a simple method to design routing. The main idea was to travel to the nearest destination from the origin point. The vehicle capacity and travelling time were used for considering the next destinations. Lastly, the max – nearest, which was a modification of the nearest algorithm. The first stop was the furthest location from the beginning point, then followed by the nearest one. After applying the mentioned heuristics to the system, the max – nearest heuristic was able to provide more satisfying results than the saving algorithm and nearest heuristic.

In VRP, the heterogeneous fleet may occur when the manufacturers have many sizes of products or different size of customer types. The "Meta-Heuristic Algorithms Comparison for Heterogeneous Fleet and Split Delivery of Vehicle Routing Problem with Time Windows" was introduced by Mungwattana, A. and Manisri, T. (Mungwattana and Manisri, 2012). The main objective was to discover the shortest total traveling time of each algorithms. The algorithms which were being studied were (a) the Tabu Search (TS), (b) the First Best with Tabu Search (FBTS), and (c) the Global Best with Tabu Search (GBTS). The system would measure the performances of the algorithms by using their solution's quality and the system analysing time. Numbers of customer which were involved in this study were twenty five, fifty, and one hundred customers. The λ – LSD was used in FBTS and GBTS to search for the best solutions. After that, the TS was applied to improve the obtained solutions. The TS itself was also used for to search for the best solutions. MATLAB was developed to be used as a tool for this study. As a result, the FBTS was able to provide the shortest total travelling time and serve up to one hundred customers.

2.11 The Nearest Neighbourhood

Goetchalckx, M. (Goetschalckx, 2011) described that the nearest neighbourhood is one of greedy algorithm. The route will start at one specific originating point (depot) and it then start to travel to the nearest unvisited customers or locations. The nearest unvisited points are continuously visited until they are all reached. The origin point could be any specific point depending on how the company defines them. But as the consequence, the different travelling path and customer visiting sequence could occur. When applying the nearest neighbourhood to the problem, the most customers or locations are most likely to be visited then move on to another neighbourhood. The distances when travelling from one neighbourhood to another neighbourhood are greater than travelling in the neighbourhood itself. Unvisited customers or locations outside the current neighbourhood is called the orphans.

In conclusion, the studied company is now facing problems of high transportation cost which is a result of poor vehicle utilisation and delivery management. For poor vehicle utilisation, the warehouse is not able to fill a vehicle until it to its maximum capacity. As a result, there are some empty space within a vehicle which could create more value if management is improved. Moreover, a vehicle is sometimes forced to contain products exceeding its capacity. Vehicle violation could lead to more cost via vehicle maintenance. As for poor time management, the studied company does not have a standard vehicle stand by time. This causes a delay of delivery when time is not managed properly. More importantly, every order that are purchased are online orders, that neither the sales department nor warehouse can know in advance whether there will be orders in the near future or not. As a result, this will be brought into consideration when selecting suitable algorithms to apply to the company's problems, to be precise on the problems that the studied company is facing. The literature reviews shall be proceeded. In the first system, customer clustering system equals to Vehicle Routing Problem (VRP). In the second system, route designing system, it is divided into 2 problems which are Bin Packing Problem when selecting a suitable vehicle, and Travelling Salesman Problem (TSP) when it comes to the point of delivering route design. From the literature reviews, there are a number of methods that could be appropriate. The two-phase heuristic of "Cluster-first, Route-second" is identified as the most appropriate heuristic to solve the problems. The first phase is cluster-first which, in this thesis, is defined as "customer clustering system". Customer orders are aimed to be clustered into groups by using the similar characteristics. In this case, customer location, province is set as a criterion. A Saving Algorithm is considered as well as classic clustering algorithm. Since there are 6 provinces that are considered within this thesis, therefore, there will only 6 possible groups of clustered customers, thus, a classic clustering algorithm is appropriate enough. In the second-phase, route designing system, there are Bin Packing Problem and Travelling Salesman Problem. Due to the online orders, which both sales department and warehouse cannot receive advance notices from customers, the only possible method for solving the Bin Packing Problem is First-fit algorithm. The reason that the other two, First-fit Decreasing Algorithm and Full-bin Packing algorithm are not suitable due to a requirement of a known number of orders. An order line which is considered at specific of time will be assigned to an available vehicle. If that added order line causes an excess to the capacity of the vehicle assignment or existing vehicle assignment, it will then be removed and assigned to another available vehicle assignment in the system. Once the order lines are assigned onto a suitable vehicle, the process of travelling route design shall begin to solve a Travelling Salesman Problem. There are many possible algorithms which are able to provide satisfactory solutions for the system. In this studied company's case, there is a delivering agreement that the company makes with customers: all product must be delivered to the customer's site within 24 hours (excluding days off) after order lines are confirmed by a sales representative. When time is involved as a system constraint, the Nearest Neighbourhood Algorithm (NNA) and Early Due date (EDD) are suitable for these systems. The NNA is based on customer receiving time. The delivering sequence for each assignment shall be arranged by monitoring the soonest delivering time, EDD is also involved. Therefore, the first order line in the delivering sequence is the one which has the earliest order receiving time. It shall then be followed by the order line which has the second earliest order receiving time, and then so on. Finally, when loading goods onto a vehicle, the loading sequence will follow First-in, Last-out method. This is to avoid any wasted time and any damages when unloading goods at customers' points.

CHAPTER 3

METHODOLOGY

3.1 Data Collection

3.1.1 Collecting Past Data from the Company

According to this thesis, the study of a company's performance requires past company data to be analysed on how well or bad the company did in the past. To ensure that the data that is used in this research is sufficient for analysing, seven operating days of data is collected. The date is from the 3rd May 2016 to the 11th May 2016 while the holidays (7th May 2016 and 8th May 2016) are ignored. Note that all the data which are used in this research are collected from the company's database of their actual work and performance.

- **WO number**: this refers to 'work order number' that the warehouse manager assigns once similar DOs from sales department are clustered together. One assigned vehicle will have only one WO number. This number has 12 digits and it contains the information that is used for sequencing the orders; for example, "W411605030127", "41" refers to headquarter hub number which means that this order is delivered to customers from the company's main warehouse. "160503" refers to the date of the order when the DO has reached the warehouse and put into the system. Lastly, “127” is the sequence number that the order is assigned.

- **Date:** there are four dates information which are the current day’s date, the date that the warehouse plans to deliver goods, the actual date that the goods are being delivered, and the actual date that the goods have arrived at the customer site.
- **Time:** the time is divided into three parts which are the time that the goods are expected to leave warehouse, the actual time that the vehicle leaves the warehouse, and the time that the vehicle arrives at customers’ location.
- **Vehicle license plate and vehicle type:** each vehicle has its vehicle license plate and number. Moreover, the number shown on the plate directly tells the vehicle type.
- **Mileage:** this information consists of two parts, beginning mileage and ending mileage. It shows how much distance each vehicle travels, each time it goes out to deliver goods. Mileage summary is also given.

Table 6: Example of Company Data (1)

No.	WO No.	Date	Delivery Plan Date	Actual Delivery Dat	Actual Arrival Date	Vehicle License Plate	Vehicle Type	Mileage Start	Mileage End	Mileag
3307	W411605060011	06-05-2016	06-05-2016 9:38AM	06-05-2016 9:38AM	06-05-2016 5:59PM	ฒง-8308	4-wheel pick up	175873	176050	177
3308	W411605060011	06-05-2016	06-05-2016 9:38AM	06-05-2016 9:38AM	06-05-2016 5:59PM	ฒง-8308	4-wheel pick up	175873	176050	177
3309	W411605060011	06-05-2016	06-05-2016 9:38AM	06-05-2016 9:38AM	06-05-2016 5:59PM	ฒง-8308	4-wheel pick up	175873	176050	177
3310	W411605060011	06-05-2016	06-05-2016 9:38AM	06-05-2016 9:38AM	06-05-2016 5:59PM	ฒง-8308	4-wheel pick up	175873	176050	177
3311	W411605060011	06-05-2016	06-05-2016 9:38AM	06-05-2016 9:38AM	06-05-2016 5:59PM	ฒง-8308	4-wheel pick up	175873	176050	177
3312	W411605060011	06-05-2016	06-05-2016 9:38AM	06-05-2016 9:38AM	06-05-2016 5:59PM	ฒง-8308	4-wheel pick up	175873	176050	177
3313	W411605060011	06-05-2016	06-05-2016 9:38AM	06-05-2016 9:38AM	06-05-2016 5:59PM	ฒง-8308	4-wheel pick up	175873	176050	177

- **DO number:** or 'delivery order number'. This is a document number that the warehouse receives from sales department.
- **Invoice number:** this number is stated in the invoice that the driver brings along when delivering products to customers.
- **Customer code:** the number is assigned to each customer by the company's numbering system.
- **Customer name and address:** this information shows details about customers and their locations. Note that this obtained address is a shipping address, not a billing address.
- **Product code:** the product code in the company's system reveals its model and type.
- **Quantity, capacity, and weigh:** it shows the product quantity of each product code. In addition, the information of its volume and weigh are provided in order to calculate the feasibility when loading products onto a vehicle.

Table 7: Example of Company Data (2)

DO No.	Invoice No.	Customer Code	Customer Name	Product Code	Quantity	CBM	Weight	Province
3010000513	3010000513	515940	A	SJ-Y22T-SL	2	0.63	60.00	Bangkok
3010000570	3010000570	355176	B	R-299	18	0.07	25.00	Bangkok
3010000570	3010000570	355176	B	R-299	3	0.07	25.00	Bangkok
3010000571	3010000571	355176	B	R-299	1	0.07	25.00	Bangkok
3010000667	3010000667	756226	C	R-287	15	0.07	22.00	Bangkok
3010000767	3010000767	355176	B	R-220	10	0.08	12.00	Bangkok
3010000437	3010000437	756226	C	R-299	10	0.07	25.00	Bangkok

- **Vehicle detail:** this table shows all the details about the vehicles that the company owns. The dimension is determined, including its capacity.

Table 8: The company own vehicles' dimensions

Type	Capacity (m^3)	Width (m)	Length (m)	Height (m)
4-wheel pick up	6	1.73	2.3	1.53
4-wheel big	10	1.73	2.37	2.44
4-wheel NKR	10	2.1	3.021	1.58
6-wheel	30	2.38	6.5	1.94
6-wheel big	75	2.38	6.8	2.32
18-wheel	60	2.5	10.91	2.2

3.1.2 Study the Company's Structure

The basic company background is already mentioned in chapter one. As the studied company is an electric appliance manufacturer, not a purely logistic company, the transportation discipline is not its core competency. The company is required to analyse its transportation performance and how to continuously improve it in order to achieve the most effective outcome. The information which is required for the analysis are customer detail, deliver history, and its current working processes of decision making of customer clustering, vehicle selection, and routing design.

3.1.3 Study Company Transportation Process

In this study, the second process of overall transportation process of design routing for each vehicle is considered. It consists of ten steps and is as follow;

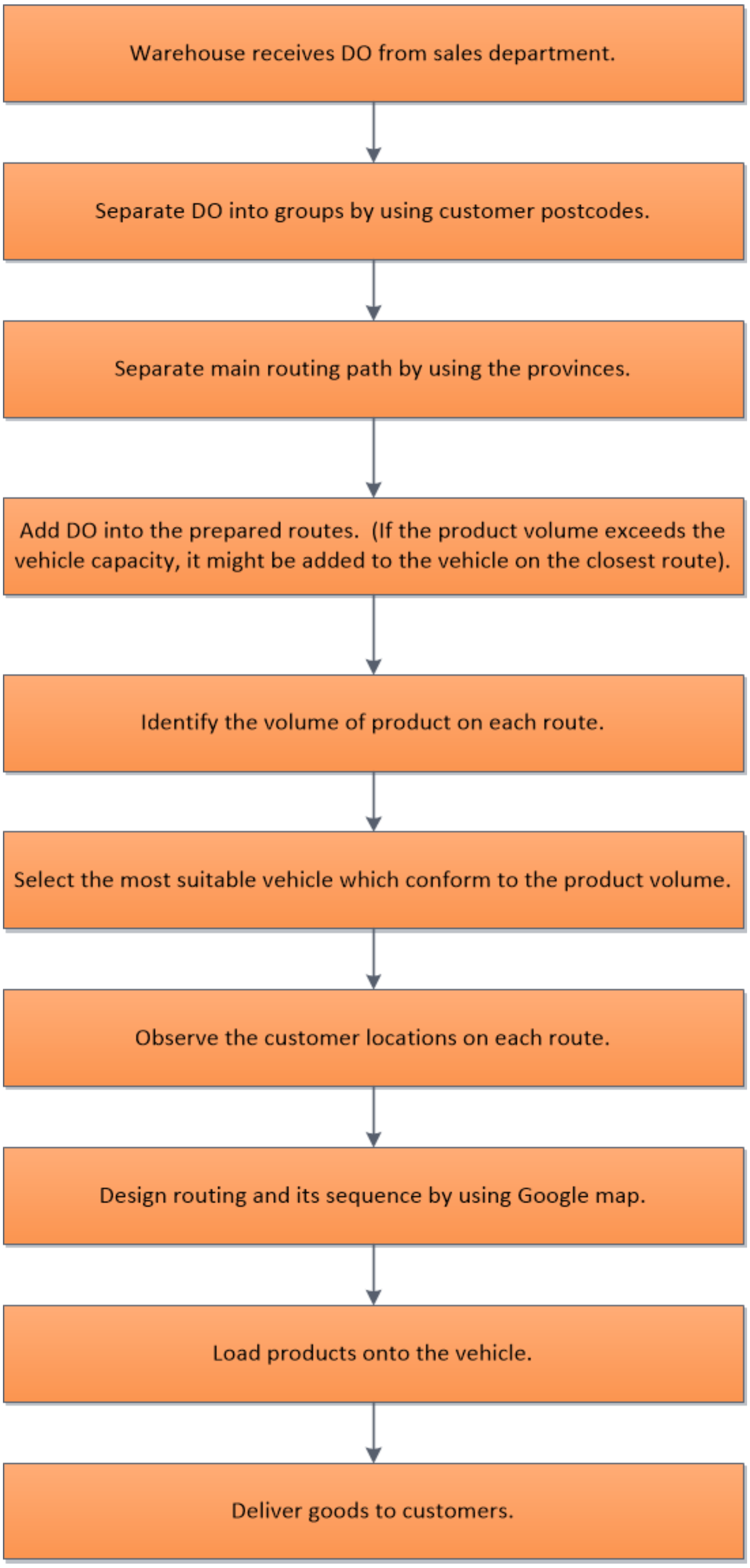

Figure 17: The Studied Company's Transportation Process

- **Warehouse receives DO from sales departments.**

After the sales department receives orders from the various customers, they will then issue the delivery order (DO) and submit it to the warehouse. It can only be submitted during the working hours (8.30 – 18.00).

- **The warehouse separates DO into groups by using customer postcodes.**

Once the DOs have reached the warehouse, they will be examined to know their location, according to the customer information stated in the document. The DOs are clustered into groups by using the postcode. The customers with the same postcode are likely to be grouped together because it is easy for the company to design a travelling path. However, there might be a chance that the same postcode customers are not grouped together. This may be caused by the lack of vehicle in hand or an order quantity which is too large to assign into a single vehicle.

- **The main routing is distinguished by using the province.**

As mentioned earlier in chapter one, this study focuses on product delivery from the company warehouse in Samutprakarn to customers which are located in six other provinces; Ayutthaya, Bangkok, Chachoengsao, Nonthaburi, Prathumthani, and Samutprakarn. Therefore, the main routes are roughly separated into six main paths. Nevertheless, the routes might be subdivided due to the product quantity and volume which will be discussed later in this chapter.

- **The DOs are added into the main designed routing.**

In this step, groups of separated DO will be added into the main routes. The product volume capacity is not yet considered.

- **The volume of product on each route is identified.**

Once all DOs are added into the routes, the capacity of customers in each province is determined. The overall product volumes are calculated in order to use this information to choose the most suitable vehicle in the next step.

- **The most suitable vehicle is selected according to the product volume.**

After determining the product quantity and volume, it then comes to the stage of selecting a suitable vehicle to deliver goods. There may be many suitable vehicles but only the best is chosen. All orders may be contained in the same vehicle or separated into many vehicles within the same province. The criterions are based on customer locations, time constraint, product capacity, and vehicle availability.

- **The customer locations on each route are observed.**

This step is to observe customer locations within the same vehicle assignment. The objective is to measure the distance between places and produce the customer delivering sequences.

- **The delivery route is designed including its sequence.**

The distance calculation which is done from the previous step will be used for the routing design. The customer sequence is based on the distance between two nodes and time limitation. As mentioned that all orders must be delivered within twenty four hours (excluding days off) after the sales department receives orders from customers, otherwise the company will have to be held responsible for the penalty.

- **Goods are loaded onto the vehicle.**

When the vehicle is assigned and the route is designed, the warehouse then prepares the products to be delivered. Goods are loaded onto the vehicle in the opposite sequence of the delivery sequence. The last customer's order will be taken care of first, followed by the sequenced orders, and end with the first customer's order that must be delivered.

- **Goods are delivered to customers.**

The vehicle leaves the warehouse when the products are completely loaded onto the vehicle as per DO and when an invoice is ready. Once the delivery is completed, the vehicle has to immediately return to warehouse to be able to deliver other orders as per the schedule.

3.1.4 Study the Relevant Information

The research of relevant information to the transportation discipline is quite important due to the possibility that it might affect the delivery routine or that it has to conform to the national logistics regulation.

According to Ministerial Regulations (Naewmalee, 1979, Jarusombat, 1999), the “Vehicle” refers to car, motorcycle, freight car, bus, and trailer. “Freight car” refers to the vehicles which are made for containing goods or animals.

- **Vehicle size regulation**

According to the report of Thailand Automotive Institute (Thailand-Automotive-Institute, 2010), the freight vehicle is divided into nine types which are; (1) freight truck, (2) freight van, (3) freight car containing liquid object, (4) freight car containing hazardous object, (5) specific freight car, (6) trailer, (7) semi-trailer, (8) semi-trailer containing extensive object, and (9) cabin.

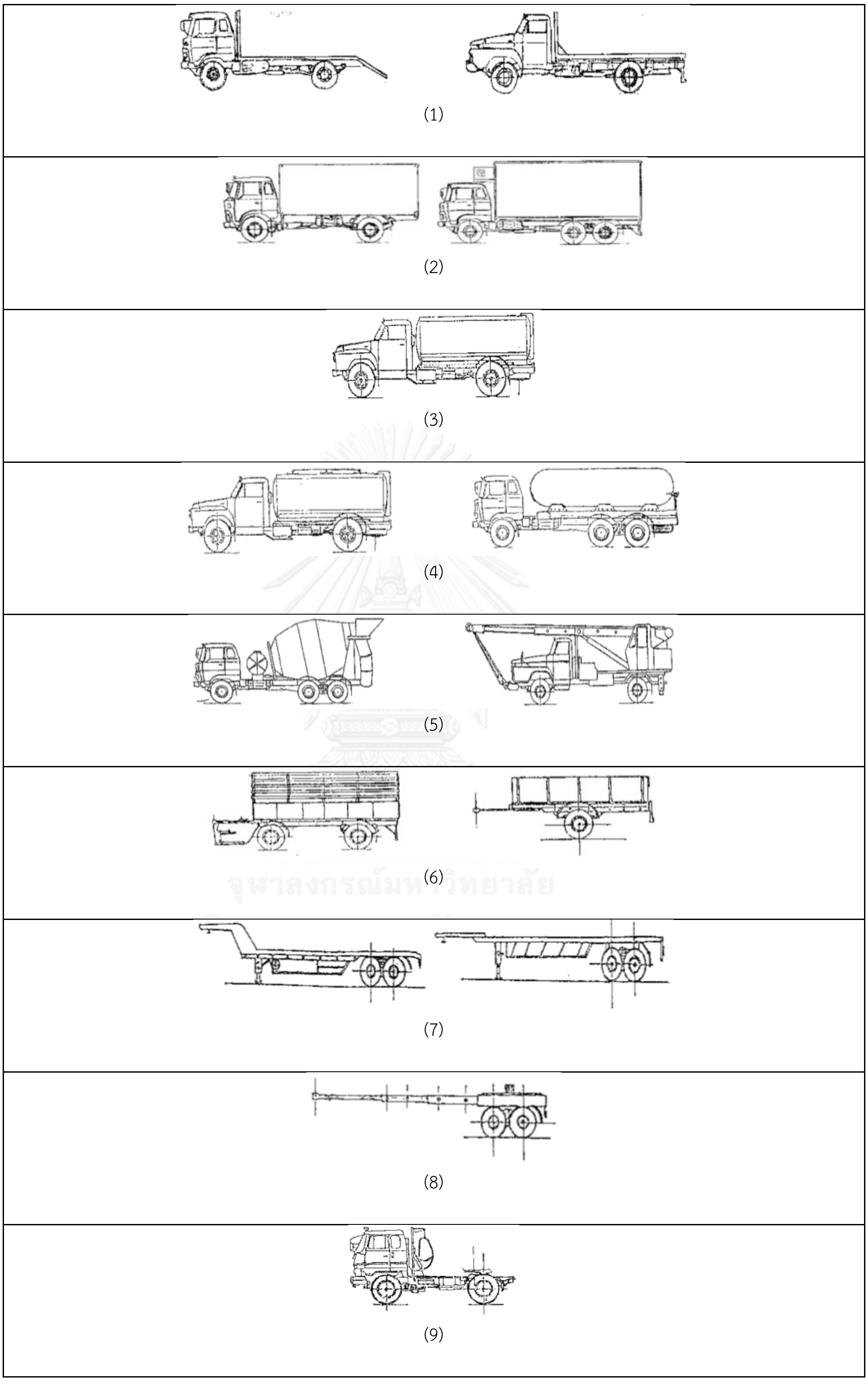

Figure 18: Type of Vehicle Defines by Act of Parliament of Road Logistics

Source: Thailand Automotive Institute (Thailand-Automotive-Institute, 2010)

Table 9: Dimension of Vehicle Defines by Act of Parliament of Road Logistics

Dimension	Vehicle (1), (2), (3), (4), (5), and (9)	Vehicle (6)	Vehicle (7) and (8)
Width (metres)	2.55	2.55	2.55
Length (metres)	12.00	8.00	13.60
Height (metres)	4.00	4.00	4.00

Source: Thailand Automotive Institute (Thailand-Automotive-Institute, 2010)

- **Vehicle speed regulation**

A freight car which weight, including carry on weight, more than one thousand and two hundred kilograms is allowed to drive no more than sixty kilometres per hour when travelling in Bangkok and Pattaya, Thailand. It is allowed to drive no more than eighty kilometres per hour in the other areas, beside those mentioned above.

Other vehicles, excluding the freight cars, mentioned above are allowed to drive up to eighty kilometres per hour in Bangkok and Pattaya, Thailand, and one hundred kilometres per hour in other areas (Naewmalee, 1979, Jarusombat, 1999)

- **Logistics time regulation**

In this research, the delivery process is done by using roads, main roads, and public highways, excluding toll ways or roads that has to pay a toll. By all means, the company prefers all vehicles to deliver goods by using regular roads in order to avoid any extra cost of paying toll fees. However, by using the regular public roads, there is logistics time regulations that vehicles have to follow. These regulations affect the logistic activities in Bangkok, Thailand only.

A vehicle with equal or more than six wheels which contains gas container and flammable material is not allowed to travel on Bangkok roads from 6.00 to 22.00, every day, except Sunday.

A vehicle with equal or more than six wheels is not allowed to travel on Bangkok road between 6.00 to 9.00 and 16.00 to 20.00, every day, except on weekends and public holidays.

A vehicle with equal or more than ten wheels is not allowed to travel on Bangkok roads between 6.00 to 10.00 and 15.00 to 21.00, every day, excluding weekends and public holidays.

A vehicle which contains logs or foundation piles is not allowed to travel on Bangkok roads from 6.00 to 21.00, every day.

A 4-wheel vehicle which overall weight does not exceed one thousand and six hundred kilograms is allowed to travel on Bangkok roads anytime (Manager, 2014)

Table 10: A Table of Losgistics Time Regulation

Vehicle Type	Prohibited Time	
4-wheel	-	
4-wheel big	-	
4-wheel NKR	-	
6-wheel	6.00-9.00	16.00-20.00
6-wheel big	6.00-9.00	16.00-20.00
18-wheel	6.00-10.00	15.00-21.00

3.2 Data Analysis

3.2.1 Data Analysis

The data received from the previous section will be used for analysing the company transportation discipline in order to acknowledge its current performance. The following are the results of the data analysis.

- **Vehicle Utilisation**

According to the vehicle capacity, each vehicle has different abilities to carry goods. Once the warehouse receives the DOs from the office, they then manage to cluster DOs. The cluster process is managed by using product capacity and customer location as criterion. After monitoring seven days of operations (3^{th} May 2016 to 11^{th} May 2016), figure 19 shows the comparison between the maximum capacity that each vehicle carries and the average 7-day capacity that they use each trip. From the obtained data, in some vehicle types, the loaded product capacity (volume, m^3) are mostly less than the actual capacity of the vehicle. There are some empty spaces on every vehicle due to poor vehicle utilisation management and time constraint. The time constraint forces the vehicle to leave the warehouse before it is filled to its maximum capacity which leads to low vehicle utilisation. Nevertheless, some types of vehicle are assigned to carry goods by violating its capacity. This matter enables the company to increase a number of delivery orders. The larger number of deliver orders leads to a larger number of customers that the company is able to serve, but violating the vehicle capacity may lead to many drawbacks later. These issues shall be discussed later it this chapter.

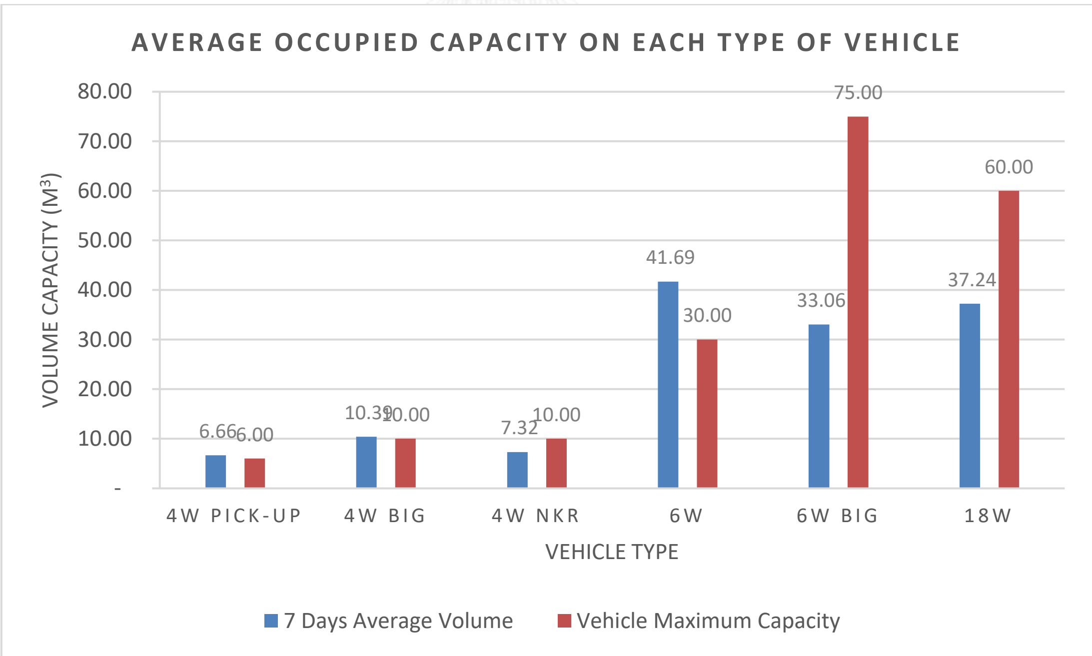

Figure 19: The Comparison of Vehicle Capacity Utilisation

The numbers of order assigned to each vehicle trip also affects the company's efficiency performance. This refers to the number of customers that the vehicle has to visit each round it goes out. Each round the vehicle goes out, there are round trip cost, which consists of fixed cost and variable cost. The company profit is calculated based on the income and transportation cost. This means that the more customers the vehicle visits, the more profit the company gains. Figure 20 shows average orders which are assigned to each vehicle trip on average. An average number of order on all vehicle is 3.88 orders. However, the number of orders on the vehicle varies due to the customer type and his order size.

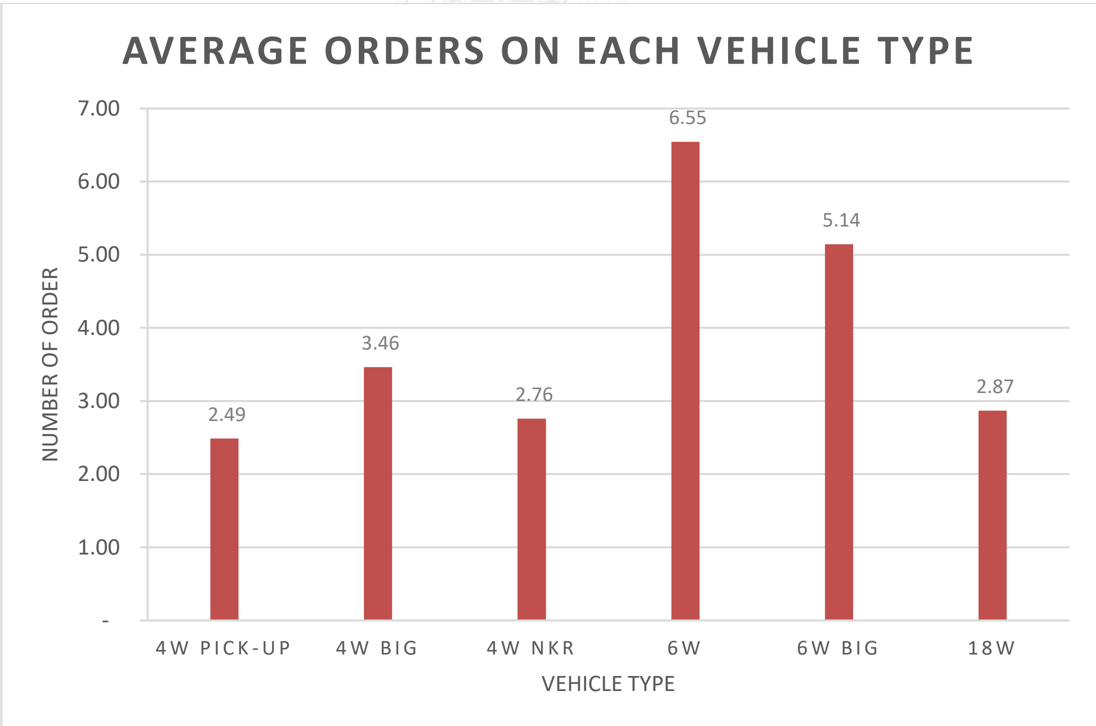

Figure 20: The Average Number of Orders on Each Type of Vehicles

Table 11: Calculation of Average Utilisation, Standard Deviation, and Coeffective of Variation of Each Vehicle Type

Vehicle type	4-wheel Pick-Up	4-wheel Big	4-wheel NKR	6-wheel	6-wheel Big	18-wheel
Average utilisation (m^3)	6.66	10.39	7.32	41.69	33.06	37.24
Standard deviation	1.42524	2.27597	1.66478	10.77146	7.76156	11.74917
Coefficient of variation	0.29752	0.36804	0.29981	0.45464	0.18445	0.31546

According to a coefficient of variation of vehicle utilisation as shown in table 11, it states that a company's variation of vehicle utilisation is moderate. A 6-wheel big has the best variation while a 6-wheel is the worst.

In addition, the distance that each vehicle could travel is based on the number of orders loaded as well. Each vehicle type has different abilities to travel. The factors that affect the travelling distance are vehicle capacity, number of order, product quantity, fuel consumption, and time constraint. Figure 21 shows the average distance that each vehicle could travel each trip. All vehicles are able to travel to any provinces according to the work assignment. According to the figure 20 and figure 21, the 4-wheel big and 4-wheel NKR has the same capacity at 10 m^3, but the average distance that both vehicle have been travelling are largely different. It implies that the company did not manage vehicle utilisation effectively enough.

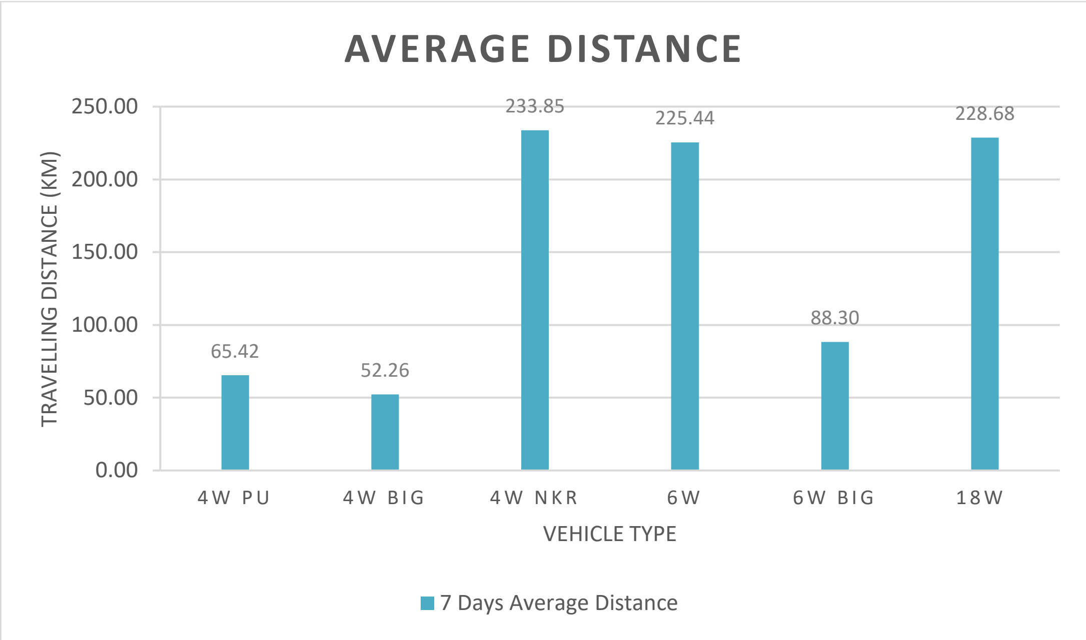

Figure 21: The Average Travelling Distance for Each Vehicle Type

- Order Management

The order size that the warehouse needs to deliver also varies. The product quantity in each order depends on the size of customers. The company's customers are divided into three main groups; dealers, distribution centres, and modern trades. Different types of customers imply different purchasing powers and different size of orders. The company does not require a minimum size of order, neither a maximum sized one. Previous data shows that some customers only order one item at a time. This situation usually occurs with small dealers. However, the customer demands may fluctuate due to the economy and seasonal periods. The distribution of order size is shown in figure 22.

The delivery orders (DO) that the warehouse receives from sales department are uncontrollable. Those orders are real timed and the warehouse is responsible for managing all orders itself. As per the agreement between the company and the customers, the company has to deliver products within twenty four hours after receiving the DO (excluding days off). The receiving time is stated in the DO. However, sometimes the company is not able to deliver goods within the specific delivery lead time. The errors may be caused by lack of transportation management or unpredictable external factors. From the deliveries of the past seven-day record, it is shown that approximately 44.32% percent of all orders are not able to reach customers' locations on time, as shown in figure 23.

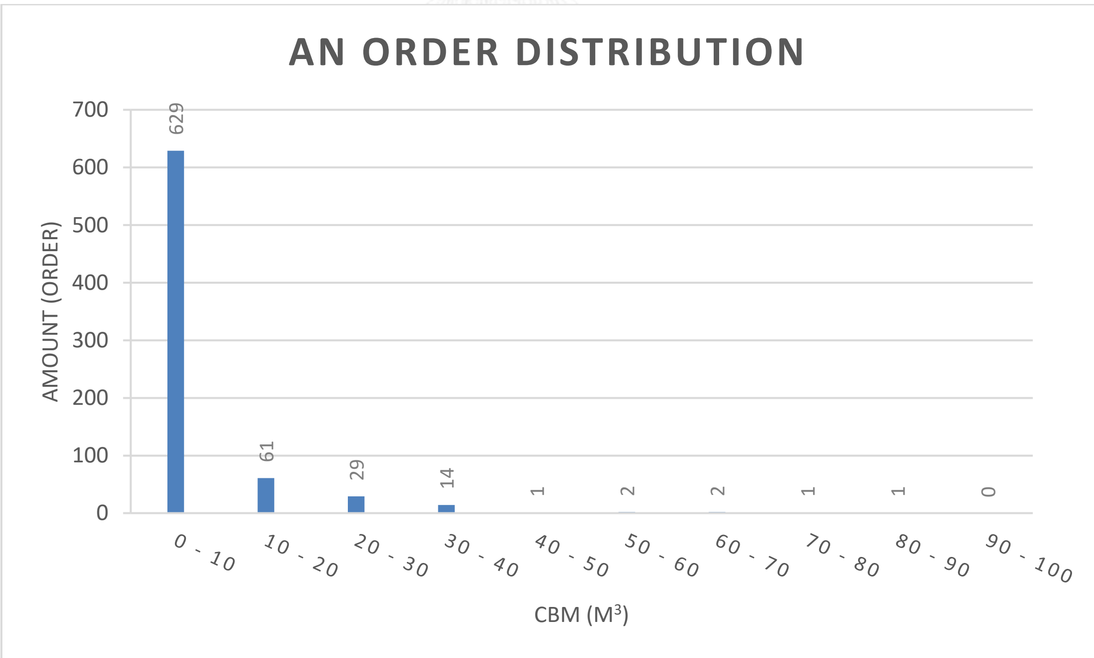

Figure 22: The Distribution of Order by Size

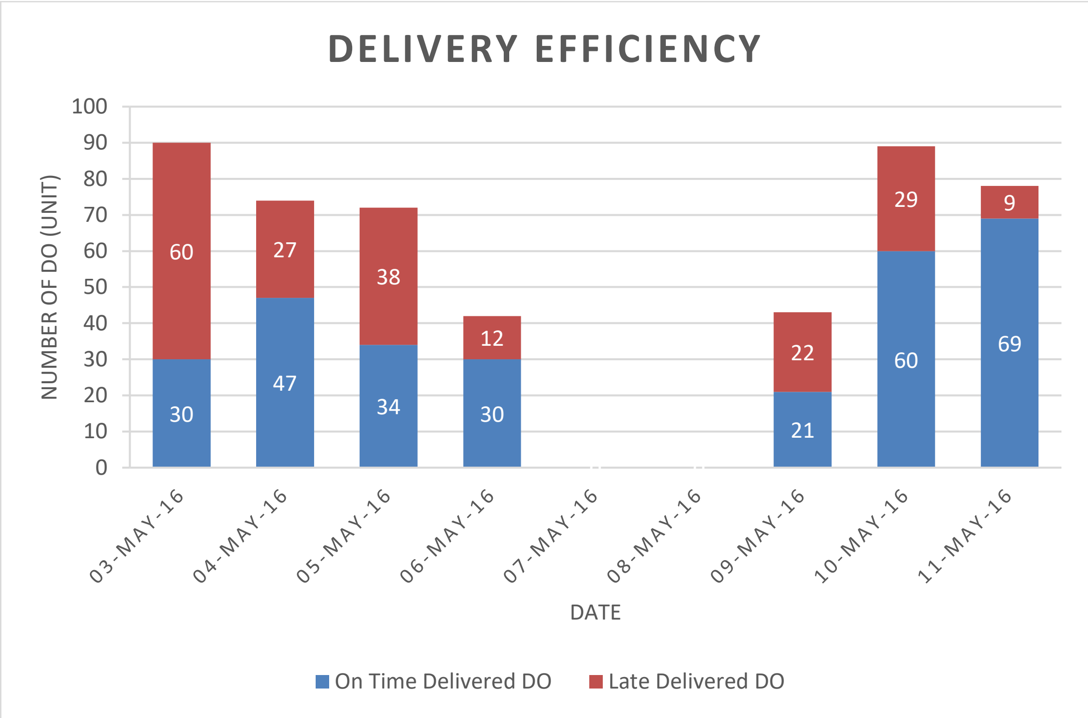

Figure 23: The Delivery Efficiency

3.2.2 Identify the Current Problems

- **Vehicle Utilisation**

As per the company's current performance, it appears that the company does not manage vehicle utilisation effectively. According to the delivery policy, the delivery is expected to be completed within twenty four hours after receives the DO from sales department (excluding days off). The vehicle could leave the warehouse on the same day or the next day depending on the number of orders on the vehicle at that time, including time constraint. The warehouse manager is responsible for this matter. However, the company sometimes is not able to fill the vehicle to its maximum capacity due to limited delivery time. And as a result, there is some empty space on vehicles that the company could have gained more value in them. On the other hand, if the company decides to wait for more orders until it reaches its maximum capacity, the company may not be able to deliver the goods within the specified lead time. A delay in delivery directly affects the company's KPI (two percent of late delivery is allowed).

As a result, the problem of the vehicle utilisation is brought into consideration that needs to be improved. With good vehicle utilisation management, the company should be able to reduce any unnecessary cost and gain more profit with better delivery performances.

- **Company's Delivery Performance**

According to the KPI that at 2% of overall orders are allowed to be delayed. The company's current delivery performance is quite poor. Only 55.68% of all orders are able to be delivered at customer's location on time. The rest of them are marked as delayed due to various conditions. First factor that causes any delays is that there is no standard vehicle waiting time at the warehouse. The vehicle is stood by and waits for future orders to fill in more space, but sales department or warehouse does not know for how long in advance. By the time the vehicle is demanded to leave to deliver goods, it might already be too late to be in time. In addition, the driver's behaviour also affects the delivery performance. Normally, the warehouse would plan the travelling route and assign it to the driver. He is expected to follow the plan but in reality, he barely does. Some of the drivers believe in their driving experience, and think that they could make a faster delivery. However, experience might not guarantee that the orders will be 100% delivered on time.

In conclusion, the study in this research is about the daily vehicle routing plans. The objective of vehicle routing plan is to design a suitable path that the vehicle could travel each trip to deliver goods. Moreover, vehicle utilisation, such as daily product loading management, shall be brought into consideration. We aimed to find out how to carry the maximum quantity of products onto one vehicle without violating its capacity. This part is relevant to the first part. Therefore, the overall objective is to design travelling paths that each vehicle should be able to visit the maximum number of customers, while the maximum number of order is loaded without violating the vehicle capacity. As a result of those objectives, an improved transportation performance can be achieved, as well as transportation cost reduction.

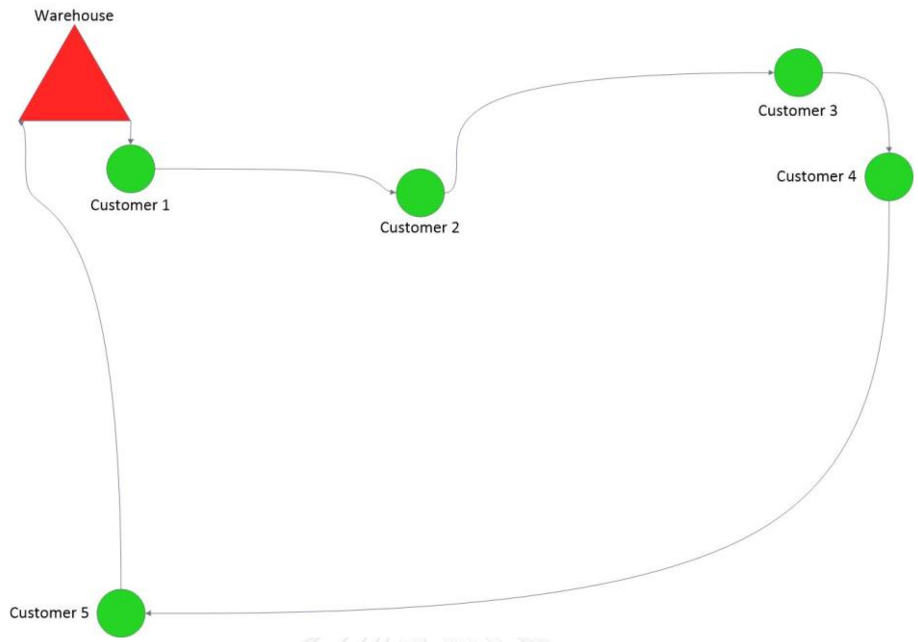

Figure 24: The Company's Designed Route

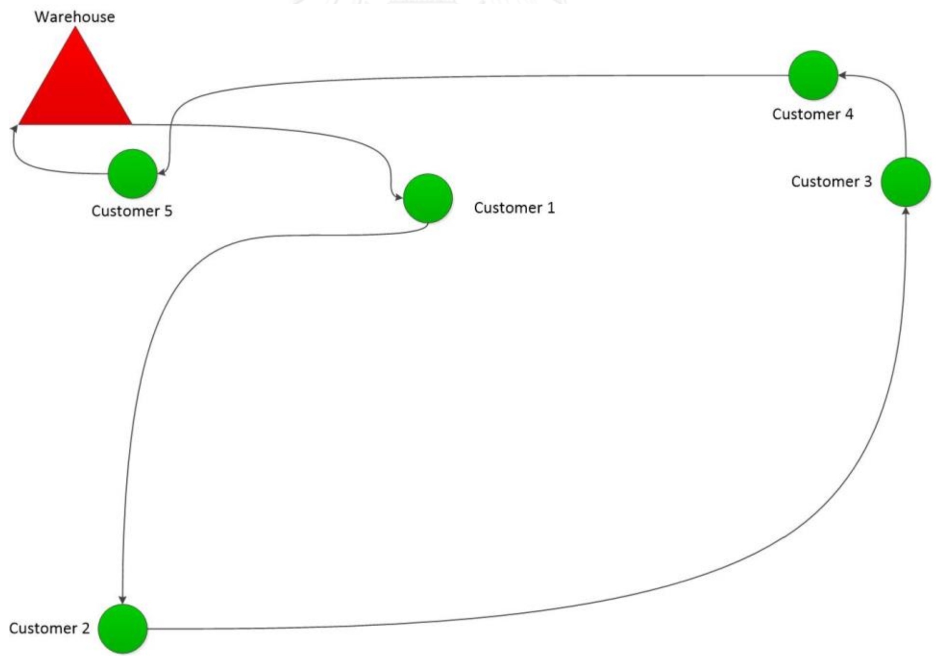

Figure 25: The Company's Actual Route by Driver

3.3 Solution Development

In this section, the algorithm that is being used in the system will be discussed. According to the study of relevant information and researches, a “Two-Phase Heuristic” is applied as a role model for this research. Therefore, as mentioned in chapter one, this research is divided into two systems, which are customers clustering system and route designing system.

The first phase heuristic is “customer clustering system”. This system focuses on how to group similar characteristic of customers together, such as having a common province location. The groups of customers are not permanently set. They depend on the customers who order products on each day. Output of this system shall be the order line which has already been clustered into appropriate group.

The second phase heuristic is “route designing system”. This system consists of two sub-system which are vehicle selection and travelling route design. The vehicle assignment is designed by using the output of the first system as an input. In vehicle selection sub-system, product volume (m^3) will be evaluated then assigned into the most suitable vehicle size which must be able to contain order lines without violate the vehicle capacity. The route designing sub-system takes place to ensure that all products will be delivered to customers in the right sequence while delivering goods within the lead time. The number of vehicle used each day is not the same due to the different number of customers on each day, as well as the product quantities that they order. However, this step is aimed to increase vehicle utilisation, which results in reducing the number of vehicle used in the system.

3.3.1 Customer Clustering System

The customer clustering system in this research refers to the procedure of separating the customer DOs, which are received from sales department, into groups by using customer location as a criterion to cluster them. Then, the process of separating each DO into the detailed order lines shall be followed. The concept of this system is to group the most similar and appropriate customers together because this will have a consequence on the travelling route design in the second system. The most appropriate group of customers could imply that the customers are located in the same province. A clustering algorithm is also applied for clustering similar customers into the same group. The input of this system is the DO which the warehouse receives from sales department. After proceeding through all processes, an order line which already has been labelled with its location will be provided as an output of this system. As a result of this system, the transportation discipline could obtain the customers' order lines which might be put together in the same vehicle. This would help improve the company transportation management. An order line size affects the selection assigned vehicle size. If the overall order lines are able to fit in a specific vehicle size to its maximum capacity (or in this research, the available capacity is to meet the capacity threshold), this means that the company is able to utilise the vehicle effectively.

This chapter part consists of four sub-parts; the system explanation, system concept design, system detailed design, and example of system. The system explanation contains the objective, output, scopes, assumptions, constraints, and inputs. The system concept design illustrates core processes of the system and then followed by the detailed system design. Lastly, an example of this system shall be exhibited with the explanation.

<u>Explanation of System</u>

Objective of System

The system objective is to group similar characteristic customers together. A welled group of customer leads to the reduction of vehicle usage and increasing vehicle utilisation.

Output

The output of this system is a group of similar customers along with their order lines.

Scopes of System

1. The customer clustering system is the system that separates the customers into an appropriate group for delivering goods together in the same vehicle.
2. An order line of clustered customer is an output of this system.

3. The customers who are involved in customer clustering process are ones who actually confirm their orders on that day.

4. The warehouse receives orders (DOs) from sale department.

5. The customer types are dealers, distribution centres, and modern traders.

6. The customer locations are in Ayutthaya, Bangkok, Chachoengsao, Nonthaburi, Pathumthani, and Samutprakarn, Thailand.

Restrictions of Research

1. The sales department submits DOs from 8.30 to 18.00.

2. The company delivery time and customer's order receiving time are any time between 5.00 to 20.00.

3. There are one hundred and forty nine customers.

4. The customers are able to have more than one product in one order.

5. Product capacity is determined by volume (m^3).

6. The distance between two locations is symmetrical, determined by kilometre (km).

Assumptions of Research

1. Customer location, province, is a criterion to cluster the customers.

2. The distance between two locations is symmetrical.

Constraints of System

1. Customer locations.

2. Order delivering time.

Inputs of System

1. DO numbers.

2. Customer code.

3. Customer names.

4. Customer address consists of individual postcode, province, city, district, village, lane, and house number.

Table 12: Example of Customer Information

Province	Customer Code	Customer Name	Address
Bangkok	756226	C	10/3-4 Soi 89 Ladproa Road, Klong Jao Khun Norasingha, Wangthonglang, Bangkok, 10310
Bangkok	515940	A	1 Narathiwatrachanakarin Road, Thungwatdon, Sathorn, Bangkok, 10120
Bangkok	355176	B	111 Moo 6, Phahontothin Road, Klong Thanon, Sai Mai, Bangkok, 10220

5. Order received time indicates the time that the sales representative confirmed the order with the customer. This is for the system to schedule the delivery time.
6. Product code.
7. Product type.
8. Product quantity (unit).
9. Customer working hours.
10. Vehicle average speed.
11. Distance between locations.
12. Time between locations.

System Concept Design

In this section, the overall concept of this system will be defined. There are four main processes in the customer clustering system which are (a) receive DO from sales department, (b) check province of DO, (c) cluster DO by province, and (d) divide DO into separate detailed order line.

The customer clustering system starts the process when the warehouse receives DO from sales department. Sales representative is responsible for communicating with customers. There is no submission cut off time but the DO has to be submitted between 8.30 to 18.00. Therefore, the warehouse has to be prompted at all time. Then, the DO shall be examined for its location. In this research, province is used as a criterion. As a result, each DO will be clustered into six main of provinces which are Ayutthaya, Bangkok, Chachoengsao, Nothaburi, Pathumthani, and Samutprakarn. Lastly, the DO will be separated into the order lines, which are already grouped under the same province. This order line with province labelled is an output of customer clustering system and will be used as an input at route designing system. The core processes of customer clustering system are illustrated in the figure 26.

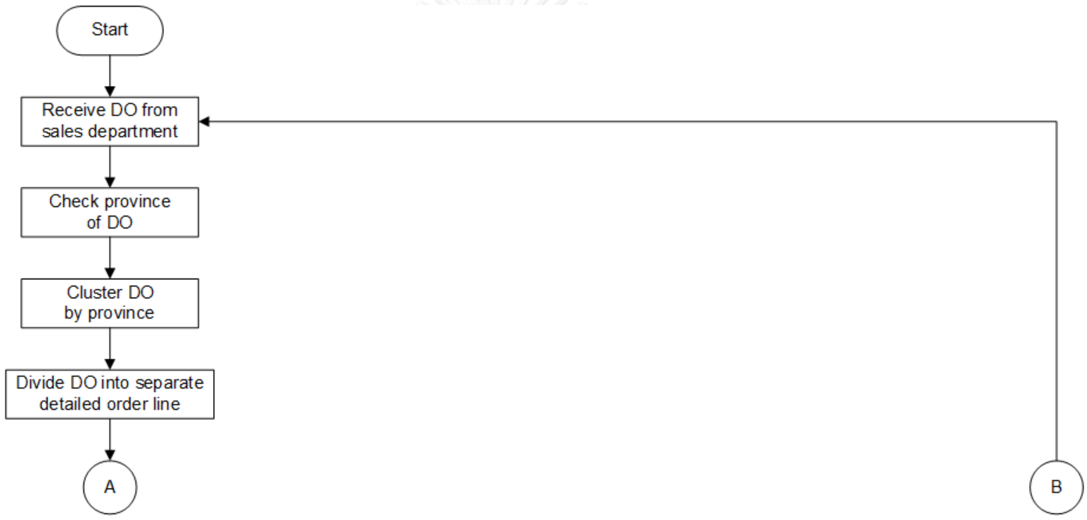

Figure 26: Flow Chart of Customer Clustering System

System Detailed Design

“DO” refers to “delivery order” which the warehouse receives from sales department. Each DO represent only one customer. Within a DO, there could be more than one order line. There is no minimum or maximum quantity required by the researched company. One number of DO is given to the customer each time they confirm their order with the company. Therefore, when one customer purchases products more than once a day, a different DO number will be given to each time they order. Order date, time, customer code, customer name, all product codes, and all product quantities (unit) are indicated in a DO.

“Order line” refers to detailed order within individual DO. There could be more than one order line in one DO. Every order line consists of order date, time, DO number, customer code, customer name, product code, and product quantity. Order line is different from DO as DO contains all orders which customer requests at one time while the order line considers only one product type at a time. Product quantity is neglected as long as it is the same product type within the same DO number.

“Assignment” is a set of order lines which are sequenced in the assigned vehicle. Each new order line will be added to the sequence which are already in the assignment.

“Product volume” means the capacity of product in cubic metre, m^3 unit. Each product type and model have different capacity as well as dimensions.

“Vehicle capacity” refers to the company’s own vehicles’ capacity which are used for delivery goods to customers. There are six types of vehicle in the system and each of them has differences in their capacity ability.

“Vehicle capacity threshold” refers percentage of vehicle capacity ability to contain goods. A hundred percent of containing ability is possible in theory but it hardly occurs in real situation. A limitation goes to the dimension (width x length x height) of both goods and vehicle (Wei et al., 2015, Junqueira and Morabito, 2015). However, there is no exact percentage of threshold. Therefore, the vehicle capacity threshold will be set as a parameter at eighty percent throughout this research.

In this section, the core processes of customer clustering system will be thoroughly explained. For an ease of understanding, they will be demonstrated in an example, which will be illustrated in intensive steps. Note that, the system is considering one DO at a time. However, steps in this section will show complete results of all DOs.

Receive DO from sales department

The DO is submitted to the warehouse from 8.30 to 18.00. There is no cut off time; therefore, the warehouse should be prepared at all time. The DO contains information of the customers and their orders. The details which appear on DO are: DO number, date, order receiving time, customer code, customer name, billing address, customer delivering address, product code, product name, and product quantity. However, the customer is able to order more than once a day. And there is no restriction to the number of order as well as to the quantity of an order. Each time they order, they will be given different DO number that represents this order sequence. Refer to table 13, it shows the essential information which will be used later in the system. It also shows that customer number 517541 (Power Buy) ordered three times on that day but are given a different DO number, depending on the time that sales department receives an order from them. Moreover, as shown in table 13, sales department received order from customer number 517541 at the same time for several DOs, this could occur when the orders were requested to different sales representatives.

Table 13: Example of DOs

Date	Time	DO Number	Customer Code	Customer Name	Product Code	Quantity (Unit)
3-May-16	13.27	3010000002	353073	Kor. Saengfah Air Cooling	SJ-Y22T-SL	1
3-May-16	13.27	3010000045	321547	AV Plus Air and Service	AH-PR19	5
					AU-PR19	5
					AZ-185	5
3-May-16	13.27	3010000064	354806	Mida Assets	AH-R13	100
					AU-R13	100
					AZ-125	100
3-May-16	13.30	3010000069	356863	Salaya Electronics Plaza	AH-R13	20
					AU-R13	20
					AZ-125	20
3-May-16	14.22	3010000077	517541	Power Buy	SJ-C19E-WMS	7
3-May-16	14.22	3010000078	517541	Power Buy	SJ-Y22T-SL	25
3-May-16	14.30	3010000079	517541	Power Buy	SJ-C19E-WMS	13
3-May-16	14.30	3010000080	510276	The Mall Group	SJ-S28EV-SL	1
					SJ-S28EV-SL	2
					SJ-S32EV-SL	7
3-May-16	14.33	3010000093	556494	Big C Super Center, Bangna Branch	SJ-M15S-SL	3

Check province of DO

The DOs which are sent from sales department come together with mixed provinces. Therefore, in this process, the DOs' provinces shall be checked since it is set as a criterion to cluster DOs into groups. Along with the DO, there will be a customer code and its name which are able to be used to obtain its address in the system. As a result of received DOs, each DO will be numerically listed and defines its province as shown in table 14.

Table 14: Process of DO Province Checking

DO Number	Time	Customer Code	Customer Name	Province	Address
3010000002	13.27	353073	Kor. Saengfah Air Cooling	**Bangkok**	161/17 Moo 3 Kamnunman Rd. Bangkhuntien Chomthong Bangkok
3010000045	13.27	321547	AV Plus Air and Service	**Bangkok**	145/8 Moo 3 Eakachai Rd. Bangbon Bangkok
3010000064	13.27	354806	Mida Assets	**Bangkok**	267 Charansanitwong Rd. Bangaor Bangplad Bangkok
3010000069	13.30	356863	Salaya Electronics Plaza	**Pathumthani**	54/59-70 Moo 13 Nawanakorn Villa Phaholyothin Rd. Klong 1 Klongluang Pathumthani
3010000077	14.22	517541	Power Buy	**Pathumthani**	152 Rangsit - pathumthani Rd. Bangpoon Muang Pathumthani

DO Number	Time	Customer Code	Customer Name	Province	Address
3010000078	14.22	517541	Power Buy	**Pathumthani**	152 Rangsit - pathumthani Rd. Bangpoon Muang Pathumthani
3010000079	14.30	517541	Power Buy	**Pathumthani**	152 Rangsit - pathumthani Rd. Bangpoon Muang Pathumthani
3010000080	14.30	510276	The Mall Group	**Bangkok**	144 Ramkhumhang Rd. Huamark Bangkapi Bangkok
3010000093	14.33	556494	Big C Super Center, Bangna Branch	**Samutprakarn**	498/1 Sukhumvit Rd. Paknam Muang Samutprakarn

Cluster DO by Province

A clustering algorithm is applied during this process. It is aimed to cluster a similar characteristic of customers into the same group. As a result, the algorithm helps ease other processes within overall system.

In this process, each DO is congregated into groups by using its location. According to how the system works, customer province is the main criterion. Thus, newly added DO will be clustered into provinces. There should be maximum six groups of provinces in this research. The same customer provinces will be grouped together. The DO size, quantity number, and order volume are neglected throughout the entire system. As mentioned in the process of receiving DOs from sales department, there is one customer who has requested three orders on the same day. The DOs of that customer are grouped together in the same group of provinces but the orders within each DO will not be grouped together. They will still be numerically separated by their DO numbers and order receiving time. Table 15 shows the results of cluster DOs by province process.

After the province clustering process, all DOs will be operated and considered within its province only. The main purpose is to limit and narrow down the boundary of travelling route which will be discussed later in the next system.

Table 15: Process of Clustering DOs by Province

Province	DO Number	Time	Customer Code	Customer Name	Address
Bangkok	3010000002	13.27	353073	Kor. Saengfah Air Cooling	161/17 Moo 3 Kamnunman Rd. Bangkhuntien Chomthong Bangkok
	3010000045	13.27	321547	AV Plus Air and Service	145/8 Moo 3 Eakachai Rd. Bangbon Bangkok
	3010000064	13.27	354806	Mida Assets	267 Charansanitwong Rd. Bangaor Bangplad Bangkok
	3010000080	14.30	510276	The Mall Group	144 Ramkhumhang Rd. Huamark Bangkapi Bangkok
Pathumthani	3010000069	13.30	356863	Salaya Electronics Plaza	54/59-70 Moo 13 Nawanakorn Villa Phaholyothin Rd. Klong 1 Klongluang Pathumthani
	3010000077	14.22	517541	Power Buy	152 Rangsit - pathumthani Rd. Bangpoon Muang Pathumthani
	3010000078	14.22	517541	Power Buy	152 Rangsit - pathumthani Rd. Bangpoon Muang Pathumthani

Province	DO Number	Time	Customer Code	Customer Name	Address
	3010000079	14.30	517541	Power Buy	152 Rangsit - pathumthani Rd. Bangpoon Muang Pathumthani
Samutprakarn	3010000093	14.33	556494	Big C Super Center, Bangna Branch	498/1 Sukhumvit Rd. Paknam Muang Samutprakarn

Divide DO into separate detailed order line

As mentioned above, one DO may consists of one or many order lines. There is no restriction of minimum or maximum number of order that the customer could purchase. In order to avoid the complexity of order which will result in the vehicle selection process in the next system, the whole DO will not be considered but individual order lines will be. Therefore, every order lines within each DO will be individually listed by number of DOs and order receiving time. An obtained order line is an output of customer clustering system and will be an input for route designing system. The result of dividing DOs into detailed order line is shown in table 16.

Table 16: Detailed Order Lines

DO Number	Date	Time	Customer Code	Province	Product Code	Quantity (Unit)
3010000002	03-05-16	13:27	353073	Bangkok	SJ-Y22T-SL	1
3010000045	03-05-16	13:27	321547	Bangkok	AH-PR19	5
3010000045	03-05-16	13:27	321547	Bangkok	AU-PR19	5
3010000045	03-05-16	13:27	321547	Bangkok	AZ-185	5
3010000064	03-05-16	13:27	354806	Bangkok	AH-R13	100
3010000064	03-05-16	13:27	354806	Bangkok	AU-R13	100
3010000064	03-05-16	13:27	354806	Bangkok	AZ-125	100
3010000069	03-05-16	13:30	356863	Pathumthani	AH-R13	20
3010000069	03-05-16	13:30	356863	Pathumthani	AU-R13	20
3010000069	03-05-16	13:30	356863	Pathumthani	AZ-125	20
3010000077	03-05-16	14:22	517541	Pathumthani	SJ-C19E-WMS	7
3010000078	03-05-16	14:22	517541	Pathumthani	SJ-Y22T-SL	25
3010000079	03-05-16	14:30	517541	Pathumthani	SJ-C19E-WMS	13
3010000080	03-05-16	14:30	510276	Bangkok	SJ-S28EV-SL	1
3010000080	03-05-16	14:30	510276	Bangkok	SJ-S32EV-SL	7
3010000080	03-05-16	14:30	510276	Bangkok	SJ-S28EV-SL	2
3010000093	03-05-16	14:33	556494	Samutprakarn	SJ-M15S-SL	3

In summary, the customer clustering system focuses on grouping the characteristically similar customers into the same group to ease the vehicle assignment and travelling route design. The system starts with the process of receiving delivery orders (DO) from sales department. Each DO represents orders from only one customer. The submission time is between 8.30 to 18.00 on company operation day. It is able to contain either single or multiple order lines. The DO will be checked for its location by using the customer's address which states the province in the DO. After that, it will be placed into the same provincial group. This process helps set the boundary and limit the travelling route zone. The final process for this system is to divide each DO into detailed order lines. To reduce the complexity when analysing the data, the whole DO will not be considered, but instead, the individual order lines will be considered each time. As a result, the order lines will be given as an output of the customer clustering system. It will also be used as an input of the next system, route designing system.

3.3.2 Route Designing System

The route designing system is the second system. It will start to operate after the customer clustering system. Its input are the detailed order lines which result from the first system's output. This system's main purposes are to maximize vehicle utilisation and design the most appropriate travelling route and its sequence for delivering products. Vehicle utilisation management is significant and brought for consideration by selecting the most suitable vehicle for each order line. The right capacity and vehicle size which conform to the capacity and size of each order line leads to the effectiveness of the company's vehicle utilisation management. The capacity volume (m^3) is a criterion for determining the order line to the right vehicle. In theory, it is possible to carry one hundred percent of capacity load on a single vehicle but in practice, there are many factors that would affect that ability. The vehicle and product dimensions are examples of which would make the theory impossible in reality. Therefore, the loading capacity threshold of the vehicle should be set. As in this research, it will be set at eighty percent of overall vehicle capacity. However, there is no specific threshold percentage which can be confirmed to be the most suitable for the system. Once the vehicle is selected, delivery lead time will be considered respectively. Good delivery management must be able to provide product delivery on each DO within specific lead time. According to the company and customer's agreement, all customer order must be delivered to customer's site within twenty four hour after they have made their order to sales department (excluding days off). Moreover, the delivery sequence is also important but to ensure that all goods are delivered in time, the sequences will be arranged based on Early Due Date (EDD) time. However, the delivery time could be anytime between order receiving time plus twenty four hours of delivery leading time but under company delivery hour (5.00 – 20.00). The vehicle ought to wait at the warehouse until its earliest delivery order time is almost due, then it should leave the warehouse. However, it might not be reasonable for a vehicle to wait until its leaving time if it is already loaded to its maximum capacity. In this case, maximum capacity means the eighty percent of vehicle capacity threshold. Once loaded goods on the vehicle have reached that point, the vehicle should be allowed to leave the warehouse as well. Decisions of releasing vehicles to deliver goods are not only limited to two reasons mentioned above. The vehicle waiting time must be calculated. Sixty minutes is the maximum time that a vehicle is allowed to wait for more orders at the warehouse. When there is no more orders coming in, it might be a waste of time for vehicle to stand by. It might be more effective if the vehicle goes out and deliver goods for the group of customers on that vehicle, then come back to be ready to be assigned to another group of customers. All vehicle assignment are designed by the system. Once the system decides that one vehicle is ready to leave the warehouse, warehouse workers will be informed in order to prepare the goods for delivery. The vehicle will then be called for loading. The vehicle returning time will be checked before leaving warehouse. The system ends when time is later than 20.00. After 20.00, all undelivered orders will be transferred and considered as the following day's delivery schedule.

This section consists of the system explanation, system concept design, system detailed design, and example of system. The system explanation includes its objectives, outputs, scopes of research, restrictions, assumptions, constraints, and input. The system core processes are described in the system concept design. The detailed system design is described along with an example.

Explanation of System

Objective of System

There are two objectives in this system. The first objective is to increase the vehicle utilisation by creating more value by using the empty space within vehicles. A suitable vehicle is selected. Secondly, the transportation management is improved. The most effective travelling route shall be planed.

Outputs of System

The outputs of this system are feasible plans of travelling route for each vehicle for delivering goods and type of vehicle that is assigned to deliver goods to customers.

Scopes of System

1. The route designing system consists of two sub - operations.
2. First sub-operation is responsible for selecting the most suitable vehicle for individual order lines by using the volume capacity (m^3).
3. Second sub-operation is to design a delivery sequence for each vehicle based on order delivery time.
4. Inputs of route designing system are outputs from customer clustering system.
5. Individual order lines from each DO are considered one at a time respectively.
6. There are one hundred and forty nine customers in the system.
7. The customer locations are in Ayutthaya, Bangkok, Chachoengsao, Nonthaburi, Pathumthani, and Samutprakarn, Thailand.

8. The assignments that were not delivered the previous day are to be considered on the current day.
9. The vehicles which are used for delivering goods are owned by the company.
10. There are thirty one vehicles in the system.
11. There is no outsourcing strategy when vehicles are insufficient.
12. The deliveries take place any time between 5.00 – 20.00 on Monday to Saturday, except Sundays and holidays.

Restrictions of Research

1. The number of vehicles is limited at 31 vehicles.
    - 4-wheel pick up: ten units
    - 4-wheel big: two units
    - 4-wheel NKR: three units
    - 6-wheel: ten units
    - 6-wheel big: three units
    - 18-wheel: three units
2. Each type of vehicle has different capacity loads and consumes different amount of resources.
    - 4-wheel pick up: six cubic metres
    - 4-wheel big: ten cubic metres

- 4-wheel NKR: ten cubic metres
- 6-wheel: thirty cubic metres
- 6-wheel big: seventy five cubic metres
- 18-wheel: sixty cubic metres

3. The vehicle round trip cost consists of fixed cost and variable cost.
4. Transportation cost consists of vehicle round trip cost and penalty cost.
5. Products are delivered on Monday to Saturday, except public holidays (except Sundays and holidays) from 05.00 – 20.00.
6. The vehicle's speed is limited at 60 km/ hr.
7. The distances between two locations are represented in real distances. Unit is in kilometre (km).
8. There is no outsourcing strategy to cover up for insufficient vehicles.
9. The distance between two locations is considered symmetrical.
10. The different sizes of goods are able to be delivered together.

Assumptions of Research

1. Vehicle capacity threshold is 80%.
2. Maximum vehicle waiting at warehouse is 60 minutes.
3. The travelling time consists of travelling time without traffic and additional thirty percent of insurance time of traffic, loading, and unloading goods.

4. DO is able to be split. Order lines of the same DO can be delivered separately by separated vehicle.
5. Thailand's regulation of vehicle speed, vehicle size, and travelling time allowance is neglected.
6. Route is designed based on order expected delivering time after clustering groups of customers.

Constraints of System

1. Vehicle capacity: volume (m^3).
2. Product capacity: volume (m^3).
3. Customers' working hours.
4. Vehicles' working hours.
5. Order delivery time

Inputs of System

1. Order line from customer clustering system.
2. DO number.
3. Customer code.
4. Customer name.
5. Customer address.
6. Order receiving time.

7. Product code.

8. Product name.

9. Product quantity (unit).

10. Product capacity: volume (m^3).

Table 17: Example of Product Details

Product	Product Code	Width (m)	Length (m)	Height (m)	CBM (m^3)
Air Conditioner	AH-PBX10	0.27	0.95	0.35	0.0898
Vacuum Cleaner	EC-LS18-R	0.31	0.51	0.33	0.0522
Washing Machine	ES-U80GT-A	1.04	0.65	0.62	0.4191
Air Purifier	FP-E50TA-W	0.66	0.44	0.28	0.0813
Microwave Oven	R-29D1(GL)	0.33	0.53	0.44	0.0770
Refrigerator	SJ-C19E-BLU	1.46	0.62	0.57	0.5160

11. Customer working hours.

12. Type of vehicle in the system.

13. Number of vehicle (unit).

14. Vehicle capacity: volume (m^3).

15. Vehicle average speed.

16. Vehicle’s working hours.

17. Vehicle capacity threshold.

18. Distance between locations.

19. Travelling time between locations.

20. Logistics time regulation.

21. Logistics speed regulation.

22. Vehicle size regulation

23. Transportation cost per delivery trip of each vehicle.

<u>System Concept Design</u>

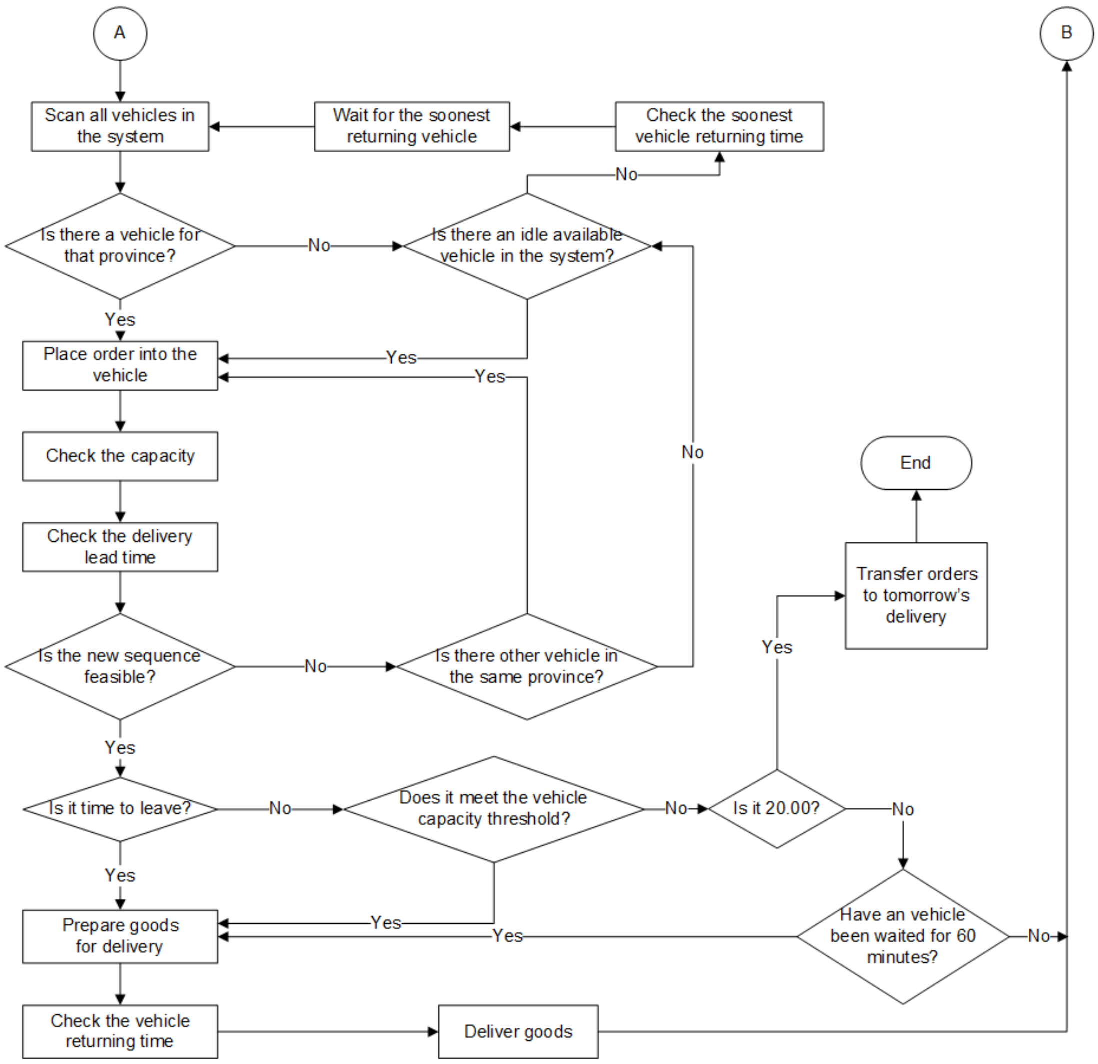

Figure 27: Route Designing System Flow Chart

In this section, the system will be divided into two sub - system which are the vehicle selection and travelling route plan.

The first operation is selecting the most suitable vehicle for delivering goods as per customer requests. An appropriate vehicle will be chosen by comparing the vehicle volume capacity with the volume capacity of the order line. An input of this system is the detailed order line which is already labelled with its location (province). The system would check the status of all vehicles first, whether they are available at the warehouse or have already left for goods delivery. The system will read the order line's province, then search within the system to spot the vehicle assigned to the same province. If there is one, the order line shall be added onto that vehicle. However, if there is no vehicle assigned to that province the system is looking for, the system will search for an idle vehicle in the system to serve the order. The order line will then be added to new vehicle as its first order. Once the order line is added onto the vehicle, its capacity will be checked as well as the vehicle's available capacity. After that, the order expected delivery time shall be analysed. Not only the newly added order's time has to be checked, all orders' time within that vehicle must also be analysed. Once information of both capacity and time are obtained, they will be used in the system to evaluate assignment feasibility. The assignment is feasible when vehicle capacity is not violated after adding new order lines. Moreover, all orders on that vehicle must be delivered to customer sites within the twenty four hours of delivery lead time (excluding days off) and the vehicle has to be back at the warehouse by the latest delivery hour (20.00). If those two criterions are met, the assignment is feasible and shall be proceeded to the next step. However, if either factor is not met, this means that the new order line makes the existing assignment unfeasible. Therefore, the system shall search again for another vehicle assigned to that province. If there is another one, the order will be added and then checked for the feasibility again. On the order hand, if there are no more vehicles of the same province, an idle vehicle shall be thoroughly searched again. Afterward, the system will proceed as described earlier. When the assignment on the vehicle is feasible, it will be checked for the vehicle's latest leaving time. The latest leaving time is calculated from the soonest order delivery time of orders on that vehicle and travelling time from warehouse to the first soonest unvisited customer. If it is time for the vehicle to leave, all goods which belong to that assignment will be prepared for loading. After the loading is completed, that vehicle shall be checked for its returning time. Knowing the returning time helps the warehouse easily plans for next delivery schedule. The vehicle is expected to leave warehouse and deliver goods as plan. Nevertheless, after calculating the vehicle's latest leaving time and it is not yet time to leave, the vehicle capacity threshold will be determined. Eighty percent for capacity threshold is set. Therefore, if the threshold is met, that vehicle is ready to leave warehouse. If not, warehouse delivery time is checked. If the system runs after 20.00, all orders will be transferred to the following day's delivery schedule. But if it is not yet 20.00, the vehicle waiting time in the warehouse will be brought for consideration. When there is no new order added to the existing vehicle assignment and the total waiting time has reached up to sixty minute, the vehicle is no longer allowed to stand by at the warehouse. The system will proceed to prepare the goods for delivery and the ensuing processes will be continued. On the other hand, the system will return to the customer clustering system to receive more DO if the vehicle has waited at the warehouse for less than sixty minutes after the latest order has been placed. The process of receiving DOs from the sales department will begin again after the vehicle leaves warehouse to deliver goods and returns.

System Detailed Design

Scan all vehicle in the system

At this point of the process, all thirty one vehicles will be checked for their statuses. It is to ensure that the system and on site workers have the same status of the vehicles. There are three status for these vehicles, which are (a) vacant and available (V/A), (b) occupied but available (O/A), and (c) not available (N/A). A vacant and available vehicle refers to the vehicle which is not been assigned to any order lines. It is available at the warehouse and ready to be used any time. An occupied but available vehicle refers to the vehicle which already been assigned with one or more order lines but there is available space for more order lines. It has to stand by at all times. A not available vehicle refers to a vehicle which is not ready to use or is not at the warehouse. It may leave warehouse for delivering goods. For this point, result of example one is shown in table 18.

Note that the results which are shown in table 18 are the given results after the system operation has thoroughly been completed. The vehicles which have already been occupied are 4-wheel pick up no. 1, 2, 3, 4, 5, 4-wheel big no. 1, and 6-wheel no. 1, 2, 3. However, some of them have already been commanded to deliver goods and result is “not available”. They are 4-wheel pick up no. 1, 3 and 6-wheel no. 1, 2.

Table 18: Result of Scan All Vehicle in the System Process

		Vehicle Status					**Vehicle Status**		
Vehicle Type	**No.**	**V/A**	**O/A**	**N/A**	**Vehicle Type**	**No.**	**V/A**	**O/A**	**N/A**
4-wheel pick up	1			X	6-wheel	1			X
4-wheel pick up	2		X		6-wheel	2			X
4-wheel pick up	3			X	6-wheel	3		X	
4-wheel pick up	4		X		6-wheel	4	X		
4-wheel pick up	5		X		6-wheel	5	X		
4-wheel pick up	6	X			6-wheel	6	X		
4-wheel pick up	7	X			6-wheel	7	X		
4-wheel pick up	8	X			6-wheel	8	X		
4-wheel pick up	9	X			6-wheel	9	X		
4-wheel pick up	10	X			6-wheel	10	X		
4-wheel big	1		X		18-wheel	1	X		
4-wheel big	2	X			18-wheel	2	X		
4-wheel NKR	1	X			18-wheel	3	X		
4-wheel NKR	2	X			6-wheel big	1	X		
4-wheel NKR	3	X			6-wheel big	2	X		
					6-wheel big	3	X		

Is there a vehicle for that province?

After receiving the province labelled order lines, this system would search for an existing vehicle which contains order lines from the same province. Therefore, the decision making of “is there a vehicle for that province?” shall be questioned. However, the type of vehicle as well as its occupied capacity will not be considered as long as there is a vehicle of that province of interest. The possible results are as followed:

1. When there is no available vehicle, the system will proceed to next decision making of “is there an idle available vehicle in the system?”.
2. However, if the system has to the desired vehicle, the process of “place the order into the vehicle” shall be considered next.

Table 19: System Analysis of "Is There a Vehicle for That Province?"

			Vehicle Status						Vehicle Status		
Vehicle Type	No.	Province	V/A	O/A	N/A	Vehicle Type	No.	Province	V/A	O/A	N/A
4-wheel pick up	1	Bangkok			X	6-wheel	1	Bangkok			X
4-wheel pick up	2	Pathumthani		X		6-wheel	2	Bangkok			X
4-wheel pick up	3	Pathumthani			X	6-wheel	3	Pathumthani		X	
4-wheel pick up	4	Bangkok		X		6-wheel	4		X		
4-wheel pick up	5	Samutprakarn		X		6-wheel	5		X		
4-wheel pick up	6		X			6-wheel	6		X		
4-wheel pick up	7		X			6-wheel	7		X		
4-wheel pick up	8		X			6-wheel	8		X		
4-wheel pick up	9		X			6-wheel	9		X		
4-wheel pick up	10		X			6-wheel	10		X		
4-wheel big	1	Bangkok		X		18-wheel	1		X		
4-wheel big	2		X			18-wheel	2		X		
4-wheel NKR	1		X			18-wheel	3		X		
4-wheel NKR	2		X			6-wheel big	1		X		
4-wheel NKR	3		X			6-wheel big	2		X		
						6-wheel big	3		X		

According to the analysis from table 19, it shows that there are several vehicles which have already been assigned for delivery goods to different provinces. As from the DOs of example one, the system would find the assigned vehicles of Bangkok, Pathumthani, and Samutprakarn. Once the DOs are analysed through, the existing and available vehicles are 4-wheel pick up no. 2, 4, 5, 4-wheel big no. 1, and 6-wheel no. 3. The rest of vehicles are not available since they are off for deliver goods. In addition, when it appears to have many vehicles for that searching province, the searching priority will be as followed.

1. The assignment of vehicle which contains orders of the same customer will be considered first.
2. The vehicle which has been assigned to the province as same as the considered order line will be considered secondly.

When the existing vehicle assignment meets at least one of the above criterions, then it is eligible to be considered at the next process, “place order into the vehicle”.

Is there an idle available vehicle in the system?

This decision making occurs when the answer to the “is there a vehicle for that province?” is no. When there is no vehicle for that searching province, other idle vehicles in the system will be brought for consideration instead. The possible results are as followed:

1. If there is/ are the idle vehicle(s) in the system, the system then continues to the process of “place order into the vehicle”.
2. If not, the system would proceed to “check the soonest vehicle returning time” because the order has to stand by in system and wait for the vehicle to return before it is being reconsidered again.

Table 20: Consideration Table of “Is There an Idle Available Vehicle in the System?”

			Vehicle Status						Vehicle Status		
Vehicle Type	**No.**	**Province**	**V/A**	**O/A**	**N/A**	**Vehicle Type**	**No.**	**Province**	**V/A**	**O/A**	**N/A**
4-wheel pick up	1	Bangkok			X	6-wheel	1	Bangkok			X
4-wheel pick up	2	Pathumthani		X		6-wheel	2	Bangkok			X
4-wheel pick up	3	Pathumthani			X	6-wheel	3	Pathumthani		X	
4-wheel pick up	4	Bangkok		X		6-wheel	4		X		
4-wheel pick up	5	Samutprakarn		X		6-wheel	5		X		
4-wheel pick up	6		X			6-wheel	6		X		
4-wheel pick up	7		X			6-wheel	7		X		
4-wheel pick up	8		X			6-wheel	8		X		

			Vehicle Status						Vehicle Status		
Vehicle Type	No.	Province	V/A	O/A	N/A	Vehicle Type	No.	Province	V/A	O/A	N/A
4-wheel pick up	9		X			6-wheel	9		X		
4-wheel pick up	10		X			6-wheel	10		X		
4-wheel big	1	Bangkok		X		18-wheel	1		X		
4-wheel big	2		X			18-wheel	2		X		
4-wheel NKR	1		X			18-wheel	3		X		
4-wheel NKR	2		X			6-wheel big	1		X		
4-wheel NKR	3		X			6-wheel big	2		X		
						6-wheel big	3		X		

Table 20 shows the results of this process. The idle vehicle refers to the vehicle which is unoccupied and available at the warehouse at the processing time. The vehicles which are labelled with V/A are the result the system are looking for. The idle vehicles for example one after analysing are 4-wheel pick up no. 6, 7, 8, 9, 10, 4-wheel big no. 2, 4-wheel NKR no. 1, 2, 3, 6-wheel no. 4, 5, 6, 7, 8, 9, 10, 18-wheel no. 1, 2, 3, and 6-wheel big no. 1, 2, 3. The first idle vehicle which the system would bring out for serving and containing the order line is the vehicle which its volume capacity (m^3) is the closest product volume capacity (m^3).

Check the soonest vehicle returning time

The soonest vehicle returning time shall be declared in the system at the process of "check the vehicle returning time" which will be describe later in this system. Every vehicle will be checked for its returning time before it leaves for delivering goods. This process shall be proceeded when there is no idle vehicle to serve the order line at the time it is required.

Table 21: Process Results of "Check the Vehicle Soonest Returning Time"

Date	Vehicle Type	no.	Province	Leaving Date	Leaving Time	Travelling Time (min)	Returning Time
03-May-16	4-wheel pick up	1	Bangkok	4-May-16	14.27	153	17.00
03-May-16	4-wheel pick up	3	Pathumthani	4-May-16	14.30	167	17.17
03-May-16	6-wheel	1	Bangkok	4-May-16	14.27	104	16.11
03-May-16	6-wheel	2	Bangkok	4-May-16	14.27	104	16.11

These results from table 21 are based on the example one analysis from the process of "check the vehicle returning time". This information will be used when there is order line needed to be served but there is no idle vehicle available within the system. In table 21, the soonest returning vehicles are 6-wheel 1, 2. They will return to warehouse and are available again at 16.11.

Wait for the soonest returning vehicle

After the system acknowledge the returning time of the outgoing vehicle, an unassigned order line shall wait in the system. Meanwhile, there will not be any activity occurs to this order line. The system would start to analyse this order line again when there is at least one idle vehicle returns and is available at the warehouse.

Place order line into the vehicle

In order to place order lines onto the vehicle, the bin packing problem is brought into consideration. As mentioned that the warehouse receives DOs from sales department by real time, therefore, the most suitable algorithm goes to first – fit algorithm. The order line is assigned to possible and available vehicle in the system.

This process will be operated after the decision making of (a) “is there a vehicle for that province?”, (b) “is there an idle available vehicle in the system?”, and (c) “is there other vehicle in the same province?”. Once the system is able to find an available vehicle, the order line shall be placed into that vehicle. The adding sequence is at the end of the latest order line within that vehicle assignment. The capacity and time are neglected at this stage but shall be considered at the next processes.

Table 22: Results of "Place Order into the Vehicle" Process

Date	Vehicle Type	no.	Province	DO Number	Customer Code	Product Code	Quantity (Unit)
03-May-16	4-wheel pick up	1	Bangkok	3010000002	353073	SJ-Y22T-SL	1
			Bangkok	3010000045	321547	AH-PR19	5
			Bangkok	3010000045	321547	AU-PR19	5
			Bangkok	3010000045	321547	AZ-185	5
03-May-16	4-wheel pick up	2	Pathumthani	3010000069	356863	AH-R13	20
			Pathumthani	3010000069	356863	AZ-125	20
			Pathumthani	3010000077	517541	SJ-C19E-WMS	7
03-May-16	4-wheel pick up	3	Pathumthani	3010000069	356863	AU-R13	20
03-May-16	4-wheel pick up	4	Bangkok	3010000080	510276	SJ-S28EV-SL	1
			Bangkok	3010000080	510276	SJ-S28EV-SL	2
03-May-16	4-wheel pick up	5	Samutprakarn	3010000093	556494	SJ-M15S-SL	3
03-May-16	4-wheel big	1	Bangkok	3010000080	510276	SJ-S32EV-SL	7
03-May-16	6-wheel	1	Bangkok	3010000064	354806	AH-R13	100
			Bangkok	3010000064	354806	AZ-125	100
03-May-16	6-wheel	2	Bangkok	3010000064	354806	AU-R13	100

Date	Vehicle Type	no.	Province	DO Number	Customer Code	Product Code	Quantity (Unit)
03-May-16	6-wheel	3	Pathumthani	3010000078	517541	SJ-Y22T-SL	25
			Pathumthani	3010000079	517541	SJ-C19E-WMS	13

As shown in table 22, the order lines from each from the first system are now separately assigned into the vehicle. According to the discussion earlier that each order line will be individually considered at a time and then added at the end of the existing sequence. No capacity and delivery lead time are involved.

Check the capacity

After a new order line has been assigned to the vehicle, the overall product volume on that vehicle shall be calculated. As mentioned earlier that the system has set the containing ability at eighty percent of overall vehicle capacity. Therefore, at this process, the order line capacities shall be checked then compared with the vehicle capacity to find out whether they do or do not exceed the vehicle capacity threshold. The volume calculation is created by using each product’s dimension (width x length x height) then altogether added to obtain each order line’s volume capacity (m^3). After that, the total volume capacity is summarised. Each vehicle type has different ability to contain goods. Therefore, it is necessary to always check those two capacities. The result of this process shall be used for making decision whether the new order line is appropriate to assign into the selected vehicle or not.

Table 23: Process of "Check the capacity"

Date	Vehicle Type	no.	DO Number	Customer Code	Total (m^3)	80% Vehicle Capacity (m^3)
03-May-16	4-wheel pick up	1	3010000002	353073	0.6366	
			3010000045	321547	0.6989	
			3010000045	321547	1.7424	
			3010000045	321547	0.1500	
					3.2279	4.87
03-May-16	4-wheel pick up	2	3010000069	356863	3.5218	
			3010000069	356863	0.6000	
			3010000077	517541	0.7211	
					4.8428	4.87
03-May-16	4-wheel pick up	3	3010000069	356863	1.9710	
					1.9710	4.87
03-May-16	4-wheel pick up	4	3010000080	510276	0.8709	
			3010000080	510276	1.7417	
					2.6126	4.87
03-May-16	4-wheel pick up	5	3010000093	556494	1.2604	
					1.2604	4.87

Date	Vehicle Type	no.	DO Number	Customer Code	Total (m^3)	80% Vehicle Capacity (m^3)
03-May-16	4-wheel big	1	3010000080	510276	6.6366	
					6.6366	8.00
03-May-16	6-wheel	1	3010000064	354806	17.6088	
			3010000064	354806	3.0000	
					20.6088	24.01
03-May-16	6-wheel	2	3010000064	354806	9.8550	
					9.8550	
03-May-16	6-wheel	3	3010000078	517541	15.9153	
			3010000079	517541	1.3391	
					17.2544	24.01

As shown in table 23, the results of product volume compared with eighty percent vehicle capacity are satisfactory. The product volume on each vehicle assignment does not exceed the vehicle capacity which enables the assigned order line to remain on the selected vehicle. However, it is possible that the assigned order line shall make the overall product volume exceed the vehicle capacity. If that situation occurs, the system would keep the calculation data and use it when the system reaches the "is the new sequence feasible?" decision making process.

Check the delivery lead time

The algorithm of the nearest neighbourhood algorithm and early due date method shall be applied to create the delivery sequence for each vehicle. Once the system receives the order line and assigns it to the selected vehicle, the sequence shall focus on the delivery lead time. The nearest neighbourhood which is applied in this system is based on delivery time only. The order line which its order receiving time comes first means that it must be delivered before any other order lines which comes after it. This is to ensure that the customer would receive their orders within twenty four hours as per agreement after they place orders with the sales representative (excluding days off).

At this step, each order line's order receiving time shall be checked then indicate its latest time to be delivered. However, when calculating the time, it must include order loading time, order travelling time, and order unloading time. Therefore, the system shall use the travelling time between two locations as a base time then add another thirty percent of time for loading and unloading. Once the system obtains the information of all order lines on one vehicle assignment, its travelling time from warehouse to first customer, from customer to customer, and from last customer back to warehouse are noted and summarised up together. Travelling time to each location tells that what time the vehicle is expected to arrive at that point to ensure that customer order will arrive by the time as per the agreement. The summarised travelling time is used for forecasting the vehicle returning time to warehouse after leaving for delivering goods. According to the company's delivery hour, every vehicle must return to warehouse no later than 20.00.

Table 24: Result of "Check the Delivery Lead Time" Process

Date	Vehicle Type	no.	Province	DO Number	Customer Code	From	To	Travelling Time (Minutes)
03-May-16	4-wheel pick up	1	Bangkok	3010000002	353073	0	353073	62
			Bangkok	3010000045	321547	353073	321547	14
			Bangkok	3010000045	321547	321547	321547	0
			Bangkok	3010000045	321547	321547	321547	0
						321547	0	78
								<u>153</u>
03-May-16	4-wheel pick up	2	Pathumthani	3010000069	356863	0	356863	84
			Pathumthani	3010000069	356863	356863	356863	0
			Pathumthani	3010000077	517541	356863	517541	18
						517541	0	74
								<u>176</u>
03-May-16	4-wheel pick up	3	Pathumthani	3010000069	356863	0	356863	84
						356863	0	84
								<u>167</u>
03-May-16	4-wheel pick up	4	Bangkok	3010000080	510276	0	510276	26
			Bangkok	3010000080	510276	510276	510276	0
						510276	0	26
								<u>51</u>

Date	Vehicle Type	no.	Province	DO Number	Customer Code	From	To	Travelling Time (Minutes)
03-May-16	4-wheel pick up	5	Samutprakarn	3010000093	556494	0	556494	42
						556494	0	42
								84
03-May-16	4-wheel big	1	Bangkok	3010000080	510276	0	510276	26
						510276	0	26
								51
03-May-16	6-wheel	1	Bangkok	3010000064	354806	0	354806	52
			Bangkok	3010000064	354806	354806	0	52
								104
03-May-16	6-wheel	2	Bangkok	3010000064	354806	0	354806	52
						354806	0	52
								104
03-May-16	6-wheel	3	Pathumthani	3010000078	517541	0	517541	74
	6-wheel	3	Pathumthani	3010000079	517541	517541	517541	0
						517541	0	74
								148

The travelling time calculations of the DOs from example one are shown in table 24. Each travelling time indicates the time which the vehicle will be at the specific location. Zero (0) represents company warehouse. The vehicle starts its route at the warehouse and also terminate there. The result of each vehicle shows that goods are able to be delivered to customer site by delivery lead time. It is also able to return to warehouse by 20.00 of warehouse working hours. The result of this process will be used for analysing in “is the new sequence feasible?” decision making process.

Is the new sequence feasible?

The new sequence refers to the vehicle assignment after adding a new order line to the sequence. The feasibility of sequence bases on two factors which are capacity and time. The result data from “check the capacity” and “check the delivery lead time” will be analysed altogether at this process to decide whether the newly added order line is suitable for the selected vehicle and the existing sequence on the vehicle.

There are two criterions to be considered. The sequence must meet both of the following criterions to be a feasible assignment otherwise, it will be denied.

1. Volume capacity: the volume capacity of all order lines on the vehicle must not exceed eighty percent threshold capacity of that vehicle assignment.
2. Time: after adding new order line into the sequence, it must be able to be delivered within its twenty four hours leading time. It also must not affect the delivery time of other order lines in the same assignment. All order lines ought to arrive at customer sites within the delivery lead time as well. Lastly, overall travelling time from warehouse to customers and return to warehouse must be before 20.00.

The system would analyse the above two criterions. After analysing the data, there are two possible options which lead to two different processes.

1. The new sequence is feasible when the new sequence meets the above two criterions. It shall then proceed through the process to “is it time to leave?”
2. If the sequence is not able to meet one of the above criterions, the system shall proceed to the decision making of “is there other vehicle in the same province?” to search for other available vehicle within the system.

Table 25: An Analysis of “Is the New Sequence Feasible?”

Date	Vehicle Type	no.	Province	Total Product Capacity (m^3)	80% Vehicle Capacity (m^3)	Travelling Time (Minutes)
03-May-16	4-wheel pick up	1	Bangkok	3.23	4.87	153
03-May-16	4-wheel pick up	2	Pathumthani	4.84	4.87	176
03-May-16	4-wheel pick up	3	Pathumthani	1.97	4.87	167
03-May-16	4-wheel pick up	4	Bangkok	2.61	4.87	51
03-May-16	4-wheel pick up	5	Samutprakarn	1.26	4.87	84
03-May-16	4-wheel big	1	Bangkok	6.64	8.00	51
03-May-16	6-wheel	1	Bangkok	20.61	24.01	104
03-May-16	6-wheel	2	Bangkok	9.86	24.01	104
03-May-16	6-wheel	3	Pathumthani	17.25	24.01	148

The analysed data from “check the capacity” and “check the delivery lead time” process is shown in table 25. The results of example one turn out that there is no sequence assignment that violate the vehicle capacity. Moreover, all vehicles are able to deliver goods by their delivery lead time and are able to return to warehouse within the operating hours. However, all sequences are not always feasible. Some of them may not, depending on their order size and order receiving time.

Is there other vehicle in the same province?

This is a consequence decision making when the new sequence assignment from “is the new sequence feasible?” is not feasible. This means that the considered order line does not suit the selected vehicle properly and it is needed to search for other vehicle in the system to serve it. Therefore, the system is looking for other vehicles which contain order lines from the same province. The results from this decision making are as followed;

1. If there is other vehicle in the same province, the system then proceeds to “place order into the vehicle” and continue the processes as described earlier.
2. If the system does not have any vehicle in the same province for the considered order line, the system would look for other idle vehicle within the system in “is there an idle available vehicle in the system?”. Then, the system will proceed.

Is it time to leave?

Time to leave in this process is the vehicle latest leaving time for delivering goods so that the products will reach the customer location as planned. If there are order lines from only one customer on the vehicle, the customer latest leaving time could be calculated by the order receiving time plus twenty four hours and minus with travelling time from warehouse to customer and return to warehouse. When there are order lines from more than one customer on the vehicle assigned, the travelling time between customers shall be added. This is to ensure that all customers will receive their order on time. The calculation of vehicle expected leaving time is shown in table 26.

Table 26: Calculation of Vehicle Expected Leaving Time

Date	Vehicle Type	no.	Customer Code	DO Number	Order Receiving Time	Travelling Time (min)	Latest Leaving Date	Latest Leaving Time
03-May-16	4-wheel pick up	1	353073	3010000002	13.27	153	4-May-16	10.54
			321547	3010000045	13.27			
03-May-16	4-wheel pick up	2	356863	3010000069	13.30	176	4-May-16	10.34
			517541	3010000077	14.22			
03-May-16	4-wheel pick up	3	356863	3010000069	13.30	167	4-May-16	10.43
03-May-16	4-wheel pick up	4	510276	3010000080	14.30	51	4-May-16	13.39
03-May-16	4-wheel pick up	5	556494	3010000093	14.33	84	4-May-16	13.09
03-May-16	4-wheel big	1	510276	3010000080	14.30	51	4-May-16	13.39

Date	Vehicle Type	no.	Customer Code	DO Number	Order Receiving Time	Travelling Time (min)	Latest Leaving Date	Latest Leaving Time
03-May-16	6-wheel	1	354806	3010000064	13.27	104	4-May-16	11.43
03-May-16	6-wheel	2	354806	3010000064	13.27	104	4-May-16	11.43
03-May-16	6-wheel	3	517541	3010000078	14.22	148	4-May-16	11.54
			517541	3010000079	14.30			

According to the results from table 26, all vehicles are scheduled to leave to deliver goods on the following day after receiving orders from customers on the current day. The latest leaving time is also identified. As example one is being considered on current day (3 May 2016), therefore; all orders will remain in the system and will not be delivered until the following day. The result of this analysis could be two ways as followed

1. When the system finds that it is time for the vehicle to leave warehouse for delivering goods, the system would continue to the process of "prepare goods for delivery".
2. If it is not yet time for the vehicle to leave warehouse, the system then proceeds to the decision making of "does it meet the vehicle capacity threshold?".

Does it meet the vehicle capacity threshold?

As mentioned earlier that a one hundred percent ability to contain goods on the vehicle is only practical in the theory. In reality, there are limitation of vehicle and product shape which may lead to some dead space when uploading goods into the vehicle. Therefore, the capacity threshold shall be set so the system could operate as close as the reality. However, there is not a specific threshold that is suitable for the problem. Therefore, the vehicle capacity threshold is at eighty percent throughout the system. The objectives of this decision making are (a) to make sure that the vehicle containing ability is conform to real life situation and not violate the vehicle capacity, and (b) the vehicle does not waste its time standing by at the warehouse. The vehicle may already contain a great number of products but has not yet reached the leaving time. The management is not productive and the company does not gain any benefits when the vehicle has to stand by until its leaving time but it is unable to contain any more goods.

At this decision making step, the system would check the selected vehicle which contains newly added order line for it containing capacity. Then, that value will be used to compare with the eighty percent capacity of vehicle. From example one, the value analysis is performed in table 27. After analysing those two values, the results shall be as followed;

1. If the current volume capacity of order lines on the vehicle meet the vehicle capacity threshold, the system will proceed to “prepare goods for delivery”.
2. If not, the vehicle may able to contain more order lines. Therefore, the system will bring time for consideration at “is it 20.00?”.

Table 27: Capacity Threshold Analysis

Date	Vehicle Type	no.	Province	Total Product Capacity (m^3)	80% Vehicle Capacity (m^3)	Status
03-May-16	4-wheel pick up	1	Bangkok	3.23	4.87	No
03-May-16	4-wheel pick up	2	Pathumthani	4.84	4.87	No
03-May-16	4-wheel pick up	3	Pathumthani	1.97	4.87	No
03-May-16	4-wheel pick up	4	Bangkok	2.61	4.87	No
03-May-16	4-wheel pick up	5	Samutprakarn	1.26	4.87	No
03-May-16	4-wheel big	1	Bangkok	6.64	8.00	No
03-May-16	6-wheel	1	Bangkok	20.61	24.01	No
03-May-16	6-wheel	2	Bangkok	9.86	24.01	No
03-May-16	6-wheel	3	Pathumthani	17.25	24.01	No

As a result from table 27, it shows that all product capacities on individual vehicle are not yet reach the vehicle threshold capacity. Therefore, all vehicle assignments are remained in the system. They will be considered at “is it 20.00?” afterward.

Is it 20.00?

As mentioned at the beginning of this section, the company delivery hour is in between 05.00 to 20.00. As it is real time operation, DOs will be submitted from sales department until 18.00 and after that both customer clustering system and route designing system still continue to operate until 20.00. After the system has checked the current time, the followings are the results;

1. If the current time is 20.00, all vehicle assignments which are remained in the system will be transferred to next operating day's consideration.
2. If the current time is not yet reached 20.00, the system shall continue to proceed to the decision making of "have a vehicle been waited for sixty minutes?".

As sales department and warehouse operates according to real time orders, timing has to always be checked throughout the process. The result of this process from example one is all vehicle assignments are remained in the system because time is not 20.00 yet. Therefore, the next process is "have a vehicle been waited for sixty minutes?"

Has a vehicle been waiting for sixty minutes?

The objective of this decision making to search for the vehicle assignment waiting time in the system. The vehicle which has been standing by in the system for too long only provides an available opening for more orders from the same province when they come in. But the company does not know in advance about incoming orders, so the longer the vehicle waits, the more orders it will contains. However, there is no guarantee that there will be new order lines from the same province later in the day. Time might be wasted without any benefits gain. It could be more productive when the vehicle leaves warehouse for delivering goods and returns to serve more assignments. Therefore, the vehicle maximum waiting time in the system will be sixty minutes. There are two alternative results of this decision making.

1. If the vehicle has already been waiting in the system for sixty minutes, the selected vehicle and its order lines will be continued at "prepare goods for delivery".
2. The system will continue back to the first system, customer clustering system, to receive new DO from sales department when the vehicle has already not been waited for sixty minute.

Table 28: Results of Sixty Minutes Waiting Time Analysis

Date	Vehicle Type	no.	Province	Customer Code	DO Number	Order Receiving Time	Capacity (m^3)
03-May-16	4-wheel pick up	1	Bangkok	353073	3010000002	13.27	3.23
				321547	3010000045	13.27	
03-May-16	4-wheel pick up	2	Pathumthani	356863	3010000069	13.30	4.84
				517541	3010000077	14.22	

Date	Vehicle Type	no.	Province	Customer Code	DO Number	Order Receiving Time	Capacity (m^3)
03-May-16	4-wheel pick up	3	Pathumthani	356863	3010000069	13.30	1.97
03-May-16	4-wheel pick up	4	Bangkok	510276	3010000080	14.30	2.61
03-May-16	4-wheel pick up	5	Samutprakarn	556494	3010000093	14.33	1.26
03-May-16	4-wheel big	1	Bangkok	510276	3010000080	14.30	6.64
03-May-16	6-wheel	1	Bangkok	354806	3010000064	13.27	20.61
03-May-16	6-wheel	2	Bangkok	354806	3010000064	13.27	9.86
03-May-16	6-wheel	3	Pathumthani	517541	3010000078	14.22	17.25
				517541	3010000079	14.30	

After all DOs from example one have been considered throughout the system, the 4-wheel pick up no. 1, 3 and 6-wheel no. 1, 2 have been waited and stood by for sixty minutes already. Therefore, those vehicle assignments shall be sent to the process of “prepare goods for delivery”. Other vehicle assignments are remained in the system and shall continue to be considered in the first system.

Prepare goods for delivery

This process is a result from three decision making, which are (a) “is it time to leave?”, (b) “does it meet the vehicle capacity threshold?”, and (c) “have a vehicle been waited for sixty minutes?”. At this process, the only vehicle assignment which is ready for delivering goods will be considered. All order lines within the assignment will be arranged for their sequence. As mentioned that the sequencing method is based on the nearest neighbourhood and early due date algorithms. Therefore, the order lines which its order receiving time comes first will be arrange as the first order of the sequence and follows by the order lines which their order receiving time come after respectively. From the beginning since the first system, the processes are operated within the system while there is no real activity takes place until the vehicle, the order lines, and the travelling route are finalised. Therefore, once the selected vehicle is finalised and order lines on it are identified, goods will then be prepared for loading. The delivery sequence is planned. Therefore, goods arrangement sequence on the vehicle will be opposite to the delivery sequence, First-in, Last-out method. This is a protection for any damages that could occur during delivering and unloading goods at customer sites.

The vehicle leaving time shall also be declared at this process. However, the leaving time of each vehicle depends on which decision making it comes from. If the vehicle has meet the condition of "is it time to leave?", its leaving time is calculated from the earliest order delivery time minus overall travelling time from one location to another. For "does it meet the vehicle capacity threshold?" condition, the vehicle leaving time will base on the earliest order delivery time on that vehicle minus overall travelling time from one point other another point. Lastly, the leaving time for the vehicle of condition “have a vehicle been waited for sixty minute?” will be sixty minutes after the latest order line receiving time.

The conclusion of order lines and the vehicle are shown in table 29-30.

Table 29: Result of Process “Prepare Goods for Delivery” (1)

Date	Vehicle Type	no.	Province	DO Number	Customer Code	
03-May-16	4-wheel pick up	1	Bangkok	3010000002	353073	A ->
			Bangkok	3010000045	321547	
			Bangkok	3010000045	321547	
			Bangkok	3010000045	321547	
03-May-16	4-wheel pick up	3	Pathumthani	3010000069	356863	B ->
03-May-16	6-wheel	1	Bangkok	3010000064	354806	C ->
			Bangkok	3010000064	354806	
03-May-16	6-wheel	2	Bangkok	3010000064	354806	D ->

Table 30: Result of Process “Prepare Goods for Delivery” (2)

	Product Code	Total (m^3)	Travelling Time (min)	Leaving Date	Leaving Time
<- A	SJ-Y22T-SL	0.6366	153	4-May-16	14.27
	AH-PR19	0.6989			
	AU-PR19	1.7424			
	AZ-185	0.1500			
<- B	AU-R13	1.9710	167	4-May-16	14.30
<- C	AH-R13	17.6088	104	4-May-16	14.27
	AZ-125	3.0000			
<- D	AU-R13	9.8550	104	4-May-16	14.27

As shown in table 29 - 30, there are four vehicles are assigned to deliver goods at a current time. These vehicle assignments are results from “have a vehicle been waited for sixty minutes?”. Thus, their leaving time is based on the receiving time of the latest order line on that vehicle plus sixty minutes of waiting time in the system.

To arrange goods on the vehicle, according to first-in, last-out method, the latest delivery order line in the sequence will be uploaded first. Let see on 4-wheel pick up no. 1 which contains order line from two customers. Customer number 353073 will be visited first then followed by customer number 321547. Therefore, order lines of customer number 321547 will be loaded onto the vehicle first and followed by order lines from customer number 353073 respectively. After all goods are prepared, the system would proceed to “check the vehicle returning time”.

Check the vehicle returning time

The vehicle returning time is important for warehouse to keep track on the outgoing vehicle. It also tells when the vehicle will be available for serving new DOs again. The data from the process of “check the soonest vehicle returning time” is also used to predict the soonest vehicle that would return to warehouse when there is no idle vehicle to serve the order line at the considering time. From example one, the 4-wheel pick up no. 1, 3 and 6-wheel no. 1, 2 have left warehouse for delivering goods to customers. Their retuning time are calculated and shown in table 31.

Table 31: Vehicle Returning Time Calculation

Date	Vehicle Type	no.	Province	Leaving Date	Leaving Time	Travelling Time (min)	Returning Time
03-May-16	4-wheel pick up	1	Bangkok	4-May-16	14.27	153	17.00
03-May-16	4-wheel pick up	3	Pathumthani	4-May-16	14.30	167	17.17
03-May-16	6-wheel	1	Bangkok	4-May-16	14.27	104	16.11
03-May-16	6-wheel	2	Bangkok	4-May-16	14.27	104	16.11

Deliver goods

After the order lines are loaded onto the selected vehicle and vehicle leaving and returning time are checked, the vehicle is ready to deliver goods to customers. It shall leave warehouse and visit customers as per schedule plan. Every route starts at the warehouse and return to warehouse after deliver orders to customers. After this process, the system would start over again at "receive DO from sales department" in customer clustering system.

Transfer orders to tomorrow's delivery

All order lines which still remain in the system after operating hour (05.00 – 20.00) will be transferred for considering again on the next operating day. There will not be any changes to the existing order lines and assigned vehicle. Everything shall remain the same. But on the following day, there might be new order lines added to the vehicle assignment.

3.4 Project Risk Assessment and Mitigation plans

The proposed systems provide low risk methods to solve the company's recent problems. The possible risks which could occur are as followed.

3.4.1 Vehicle Utilisation

According to the proposed systems, the vehicle's capability to contain goods is set at eighty percent threshold of maximum vehicle capacity. The vehicle containing ability may not be one hundred percent due to the shape of material. However, there is a possible chance that the boxes are arranged and occupied more than percentage threshold. Therefore, there is an opportunity cost that the company would lose if the vehicle is able to contain more goods.

In addition, the maximum vehicle stand by time at the warehouse is sixty minutes. There might be an empty space on the vehicle that would create more value if the vehicle has waited longer.

To initially solve this issue, a smaller size vehicle might be considered. All orders on selected vehicle might be transferred to smaller and available vehicle in the systems.

3.4.2 Transportation Cost

Transportation cost in this research consists of vehicle round trip cost and penalty cost. The vehicle round trip cost is calculated based on number of the vehicles used and the location they are heading to. The more vehicle is assigned, the more cost the company has to response. As soon as the vehicle leaves warehouse for delivering goods, the round trip cost occurs. After applying the vehicle's stand by time at sixty minute, it is possible that there will be more vehicle released. As a result, that would increase the overall transportation cost.

The proposed systems are design to selected the vehicle based on product in order line's volume and vehicle capacity. According to the previous collected data, the order's size is congested between 0.0015 m^3 – 10.00 m^3, therefore, vehicle with small capacity is tend to be chose the most. As a result, an often-used vehicle would have shorter life time and require more maintenance.

A possible way to reduce the transportation cost caused by number of outgoing vehicle is to use smaller size of vehicle in the systems (if available). Small size of vehicle usually cost less than big size. However, it only works when small size of vehicle is able to contain all order lines from bigger vehicle without violating the smaller vehicle's capacity.

3.4.3 Employees

The employees' cooperation could bring a huge successful to any changes within the organisation. But in reality, an employee's resistance might occur and cause an obstacle or difficulty to the proposed system implementation. As a result, final solution may not one hundred percent satisfactory. Therefore, the reasons of change, including the expected outputs should be clarified for everyone in the company for understanding.

The proposed systems are designed for the vehicle to be fully used during operating hours (05.00 – 20.00). This implies that the driver who stations to each vehicle has to work long shift, 15 hours. In company's perspective, the more hours the driver can work during a day implies the more revenue the company can make that day. On the other hand, this does not conform to working human ethic. Some regulation should be applied in order that the driver should have a break after each successful delivery of a various duration depending on the delivery time.

3.5 Discussion

Currently, the studied company does not have any proper standards of transportation management. According to an interview, the warehouse manager operates based mostly on experiences. However, they have set some rules that everyone has to follow but they rarely do so. Their transportation process starts with 6 main routes that are designed based on customers' location. DOs from customers of those provinces shall be roughly assigned to the earlier routes. They will then group customers which are located near one another together and select a vehicle for them. Lastly, travelling route shall be designed. These recent methods may be suitable when the number of customers is not high. When it comes to high demand, their current methods might not be able to provide any effective outputs. As a result of poor transportation management, it causes the company many problems. Firstly, vehicle utilisation is not very effective. According to the analysis, there are vehicles which contain products less than their maximum capacity. Furthermore, there are vehicles which are forced to carry products more than their available capacity. Empty spaces do not create any value, moreover, the company still has to spend cost on every vehicle which has to leave to deliver goods with empty spaces. In the same way, when exceeding a vehicle capacity, the transportation cost would increase due to the vehicle might require more maintenance than usual. In addition, time management is also an important point for this company to improve. As there is no standard stand by time, many vehicles have to stand by for more orders while not knowing in advance when would they arrive. Once a vehicle is fully filled, there may be some orders on that vehicle that has their delivering time almost at its deadline. And that would cause a delayed delivery. When the company does not achieve to deliver products on time as stated in the agreement, a penalty fee shall occur. Penalty cost is charged from the company and it would rise the total transportation cost of the company. Once all plans are set, groups of products are then loaded onto selected vehicles and are delivered to customers.

Because of those mentioned points, an objective of this research is to develop a heuristic to improve transportation cost, as well as to improve vehicle utilisation and delivering performance. The proposed systems are aimed to provide better standards for the studied company in order to improve their overall transportation management. A clustering system is used for cluster customers with similar characteristic into the same group. There will not be crossed-province of order on the same vehicle. Once DOs are divided into detailed order lines, they will be individually assigned to a suitable vehicle by using first-fit algorithm. The first-fit algorithm is suitable because every order are online orders that no one can know in an advance when they will come. They have to be assigned onto an existing and available vehicle in the system, on the first one that has not violated the vehicle capacity. If capacity is exceeded, then it shall be assigned to the next available vehicle. Another reason why first-fit algorithm is suitable is that it helps increase a vehicle utilisation. A vehicle will be filled until it cannot take any more order line. It ensures that every vehicle is occupied to its maximum capacity. After knowing which vehicle is going to deliver which order lines, the Nearest Neighbourhood Algorithm is applied to create a delivering sequence or travelling route path. In this case, order receiving time is considered along with order expected delivery time. An Early Due Date (EDD) is also involved. An order line which has the earliest order receiving time will be marked as the first order line in the sequence. It shall then be followed by an order line which has the second earliest order receiving time. However, arranging the delivering sequence could be done by considering travelling distance between two points. But, according to delivery lead time and agreement between company and customer, timing is the first thing that should be considered in order to avoid any delayed deliveries. Moreover, to rearrange order lines from time based to distance base would result in more complications to the systems. Therefore, it might consume longer operating time and may cause delayed deliveries. In addition, these proposed systems are aimed to be implemented to the studied company, therefore, arranging by time helps enable and fasten the overall process. Once knowledge of which order lines are assigned to which vehicles and travelling routes are designed, actual order lines will be prepared to be loaded onto the vehicle by First-in, Last-out method to ease the unloading and to avoid any damages.

CHAPTER 4

PROPOSED SYSTEMS MEASUREMENTS AND DISCUSSION

In chapter 4, the proposed systems shall be measured to analyse and evaluate its performance. To measure the proposed systems performance, the company's actual data from 3rd May 2016 to 11th May 2016 (except 7th – 8th May 2016) is used to perform an experiment as it conforms to real life situation. The experiment's objective is to evaluate the effectiveness of the proposed systems which result the company transportation cost.

As mentioned in chapter 3, the proposed systems are based on the two-phase heuristics of cluster-first, route-second. The systems start with receiving the DOs from sales department and they will be clustered into groups of customers, based on their locations. Clustering algorithm is involved. Then, each DO will be subdivided into the order lines and they will be individually considered throughout the system. The first-fit method is applied for the vehicle selection procedure. First order line is assigned to a suitable vehicle and followed by order lines which will be considered by receiving time respectively. Capacity and time are analysed as constraints. If either one of them is violated, the latest added order line shall be removed and assigned to the next available and suitable vehicle. Once the order lines are assigned into their suitable vehicle, a vehicle assignment is created. The delivery sequence is generated by the nearest neighbourhood algorithm based on the order receiving time. Goods are ready to be delivered to customers when the suitable vehicle is assigned along with its travelling route. The system ends after warehouse operating hours. All order lines which are not yet delivered will be reconsidered again on the next operating day.

The algorithms which are presented in chapter 3 were written in MATLAB Code (MATLAB R2015b) to facilitate the experiments. The experiments are operated on a HP laptop with Intel Core i7 2.50GHz 8.00 GB and Window 10. The inputs are obtained from a studied electric appliance manufacturer. Data used are from 3rd May 2016 to 11th May 2016, except 7th and 8th May 2016. To evaluate the algorithms' performances, the inputs are entered into MATLAB, to obtain expected outputs. The results from experiments are compared with the company's actual performance which will be intensively discussed later in this chapter.

Inputs which are used in MATLAB are order receiving date and time, DO number, customer code, product code, and product quantity. The algorithms are expected to provide the outputs of clustered groups of customers together with their suitable vehicle. It should also be able to provide the effective travelling customer sequence. The number of customers and number of DOs are as shown in table 32. The company's number of vehicle and its capacity remain the same as recent situation as shown in table 33.

Table 32: Number of Customer and number of DO of Each Operating Day

Date	Number of Customer	Number of DO
3 May 16	14	90
4 May 16	37	74
5 May 16	27	72
6 May 16	19	42
9 May 16	11	43
10 May 16	41	89
11 May 16	40	78

Table 33: Vehicle Used in the System

Type	Quantity	Capacity (m^3)	80% Capacity (m^3)
4-wheel pick up	10	6.09	4.87
4-wheel big	2	10.00	8.00
4-wheel NKR	3	10.02	8.02
6-wheel	10	30.01	24.01
6-wheel big	3	75.09	60.08
18-wheel	3	60.01	48.00

The objective of this research is to improve the transportation cost for the electric appliance manufacturer, as well as to improve a vehicle utilisation and delivery performance. The wanted results of the experiment are: suitably assigned vehicles that serve all customer orders along with the delivering route for the vehicles. This obtained data will be used to calculate the transportation cost resulting from the proposed systems, which will be compared, later, with the company's current cost.

$$Percentage\ of\ cost\ reduction\ (\%) = \frac{actual\ cost - proposed\ systems\ cost}{actual\ cost}\ x\ 100$$

Equation 1: Percentage of Cost Reduction

$$Percentage\ of\ vehicle\ utilisation\ improvement\ (\%) = \frac{proposed\ systems\ vehicle\ utilisation - actual\ vehicle\ utilisation}{actual\ vehicle\ utilisation}\ x\ 100$$

Equation 2: Percentage of vehicle utilisation improvement

The following list consists of the restrictions and assumptions of this experiment.

1. The experiments measure the performance of proposed systems vehicle utilisation, delivery route plan, and delivery performance.
2. The customers are allowed to request orders from 8.30 – 18.00. And sales department submits DOs from 8.30 to 18.00. There is no minimum and maximum product quantity.
3. The delivery working days are from Monday to Saturday, and days off are on Sundays and public holidays. The warehouse delivery time is from 5.00 to 20.00. as well as the customer's order receiving time. Goods are able to be delivered at any time. DO is able to be split. Order lines of the same DO are able to be delivered separately. Every vehicle starts and terminates at the company warehouse.

4. There are one hundred and forty nine customers from six different provinces in Thailand.
5. Product capacity is determined by volume (m^3).
6. The distance between two locations are represented in real distances and are symmetrical and determined by kilometre (km).
7. The number of vehicles is limited at thirty one vehicles. Each type of vehicle has different capacity loads and consumes different amount of resources.
8. The vehicle loading ability is a parameter and is set at eighty percent of actual maximum capacity.
9. The vehicle's average speed is sixty kilometres per hour (60 km/ hr).
10. The travelling time consists of travelling time without traffic plus additional thirty percent of insurance time of loading, and unloading goods. Time unit is in minute.
11. Transportation cost includes delivery cost and penalty cost.
12. There is no outsourcing strategy to cover when the vehicles are insufficient.
13. Maximum vehicle stand by time at the warehouse is sixty minutes.
14. The external factors are considered as uncertainties which will not be considered.
15. Thailand's regulations of vehicle size, vehicle speed, and travelling time allowance are neglected.

The proposed systems' constraints are listed in table 34

Table 34: Proposed Systems' Constraints

Customers Clustering Constraints	Route Designing Constraints
Product capacity: volume (m^3)	Product capacity: volume (m^3)
Deliver lead time	Vehicle capacity: volume (m^3)
Order receiving time	Order delivery time
	Customers' working hours
	Vehicle working hours

Table 35 shows the basic information which is used for analysing in the proposed systems. This information is an actual data from the studied company itself. Once the results from the proposed systems are obtained, they will be used to be compare with the actual ones.

Table 35: Experiment Basic Inputs

Date	Number of Customer	Number of DO	Number of Order Line
3 May 16	14	90	207
4 May 16	37	74	143
5 May 16	27	72	141
6 May 16	19	42	85
9 May 16	11	43	95
10 May 16	41	89	173
11 May 16	40	78	160

4.1 Experiment Results

4.1.1 Revenue

The transportation department also has its own activities to earn income. The transportation fee is charged to the customer and that would become another source of revenue of the company. It will be calculated based on the number of product and its volume capacity (m^3) when customer purchases the orders. In the experiment, the transportation revenue is an actual number given from the company which will be used for calculating the net income after achieving all the results from proposed systems. Once the customer has placed their orders to the sales department, the DO containing details of the purchasing orders will be stated, including the overall volume capacity (m^3). The volume capacity will be used for calculating the transportation fee from warehouse to the customer by using equation (3). Note that, each calculation represents the fee for an individual order line only. The total fee is a sum of all order lines from the same DO. The revenue results are shown in table 36.

$$Transportation\ fee = \frac{product\ dimention}{5000}\ x\ province\ factor\ x\ quantity$$

Equation 3: Transportation fee calculation for each order line

Where; Product dimension = width x length x height. Unit is centimetre (cm).

Province factor = multiplier number defined by the studied company.

Table 36: The Company's Revenue from Transportation Fee

Date	Total order volume (m^3)	Revenue (Baht)
03-May-16	641.44	383,281.85
04-May-16	411.28	239,494.96
05-May-16	478.13	255,221.35
06-May-16	379.27	215,492.40
07-May-16	-	-
08-May-16	-	-
09-May-16	243.44	139,093.73
10-May-16	593.76	322,390.05
11-May-16	532.74	318,372.70
Total	3,280.07	1,873,347.04

According to table 36, total volume that the customer purchased between 3rd May 2016 to 11th May 2016 is 3,280.07 m^3 which result in the total revenue of 1,873,347.04 baht. This revenue is a raw data which will be used for calculating the net revenue after obtaining the transportation cost.

4.1.2 Transportation Cost

The transportation cost within this research consists of the delivery cost and penalty cost. The delivery cost is defined by the studied company. It is a round trip delivery cost which already includes fixed and variable cost. The round trip delivery cost is determined based on vehicle size and location it is travelling to. Therefore, when measuring the transportation cost, number of vehicle used, vehicle size and customer location must be considered altogether.

Table 37: The Transportation Round Trip Cost (Baht)

Province/ Vehicle Type	4-wheel pick up	4-wheel big	4-wheel NKR	6-wheel	6-wheel big	18-wheel
Ayutthaya	1,964.70	1,964.70	2,554.10	4,134.52	8,269.04	5,545.80
Bangkok	1,527.50	1,527.50	1,985.75	2,900.82	5,801.64	3,771.30
Chachoengsao	1,265.18	1,265.18	1,644.74	2,160.60	4,321.20	2,706.60
Nonthaburi	1,601.49	1,601.49	2,081.93	3,109.60	6,219.20	4,071.60
Pathumthani	1,736.01	1,736.01	2,256.81	3,489.20	6,978.40	4,617.60
Samutprakarn	1,520.77	1,520.77	1,977.01	2,881.84	5,763.68	3,744.00

The penalty cost will be brought for consideration when the studied company is not able to deliver goods to customers within lead time. The company will be charged for the penalty which has a direct effect to the transportation revenue. According to the collected data from the company, there is no specific penalty charging rate. The company and customers would state the fee in their agreement case by case. Nevertheless, the value of late delivery orders will be used for penalty charging calculation. In this experiment, the penalty rate is varied from zero percent to fifty percent of value of delayed order.

Transportation cost without penalty

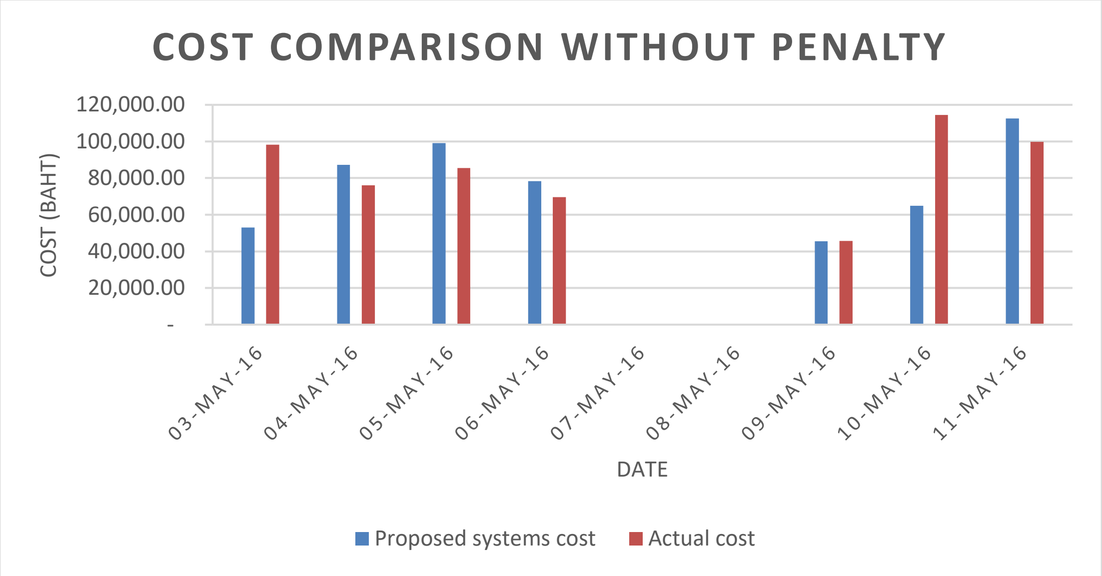

Figure 28: Cost Comparison Without Penalty Between Proposed Systems and Actual System

Table 38: Transportation Cost Without Penalty

Date	Proposed systems cost	Actual cost
03-May-16	53,053.25	98,250.83
04-May-16	87,275.79	76,026.89
05-May-16	99,183.26	85,531.63
06-May-16	78,369.36	69,682.47
07-May-16	-	-
08-May-16	-	-
09-May-16	45,565.76	45,617.91
10-May-16	64,941.61	114,434.38
11-May-16	112,470.73	99,800.12
Total	540,859.77	589,344.23

According to the results of proposed systems, none of the order lines are delayed to be delivered. Thus, there will no penalty added to the proposed systems cost. To make the comparison of the proposed systems and the actual results looks reasonable, the costs without any penalty are demonstrated.

From figure 28 and table 38, the transportation costs of both proposed system and actual system are illustrated. The total cost of each day is fluctuated because of the number of vehicles used to serve a different number of order lines each day. For the day that the proposed systems cost is higher than the actual cost will be further explained in a section of vehicle used and vehicle utilisation. However, when monitoring the overall transportation cost, it appears that the cost of proposed systems is lower than the current cost. The proposed systems cost is 540,859.77 baht. While the actual cost is 589,344.23. A cost difference is 48,484.47. Therefore, the proposed systems are able to decrease the total transportation cost by 8.23%. As per the decrease, it implies that the proposed systems are suitable and effective in order to improve the transportation cost which successfully answers this research's objective.

Transportation cost with various penalties (10% - 50%)

Delayed delivery does not only affect the company's KPI but also the transportation cost. The penalty is brought for consideration when the company is not able to deliver goods to customers on time as per the agreement. In this experiment, various penalty percentages are considered. According to the company's actual performance, approximately 48.32% of overall orders are not able to be delivered on time and this causes an increase of transportation cost due to the penalty. Moreover, delayed delivery might affect the company's reputation in the future.

The possibility of penalty that the company would be charged is forecasted from 10% to 50% of total value of the delay orders as shown in figure 29. It is obvious that the value of the penalty has a direct variation relevant to the percentage. If the company is charged according to the percentage calculation costs, it would be a burden that the company has to carry. Moreover, it would affect the net revenue which shall be discussed later.

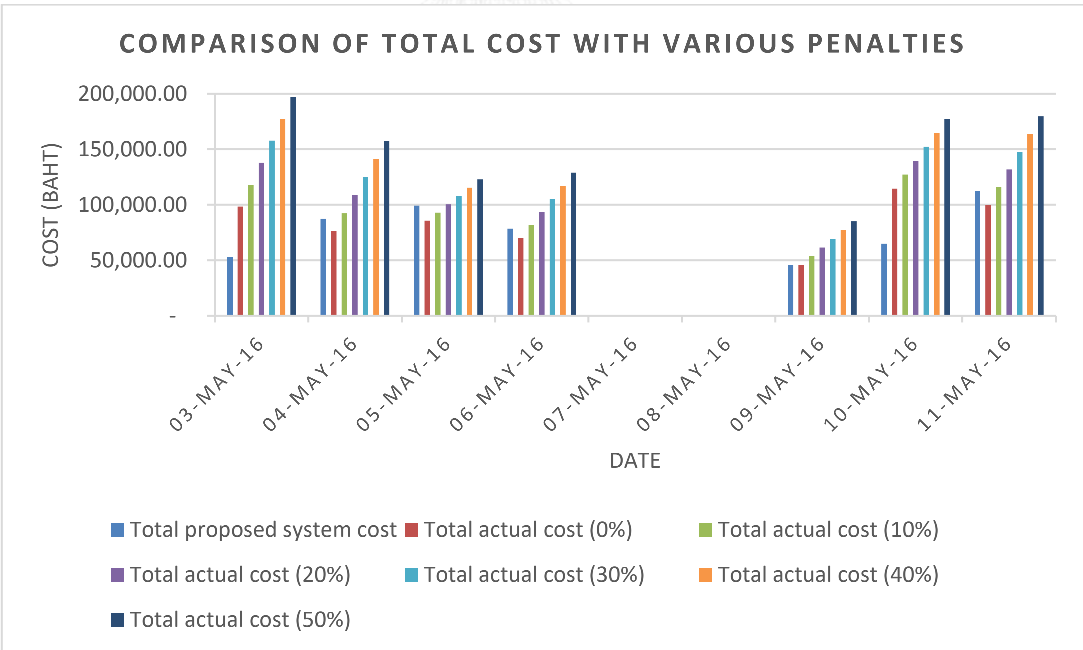

Figure 29: Comparison of total transportation cost with varieties of penalty

From the comparison in figure 29, the transportation cost with penalty on 3rd May 2016 could be charged up to nearly 200,000 baht which is about 51.45% of the total revenue on that day. While the lesser of the transportation cost, with penalty, is about 38.46% of overall revenue on the 9th of May 2016. If the company continues this poor transportation management, it will not do any good to the company. The company reputation will be on a downslide when compared with other rivals of the same business field. The calculation value of the company' transportation cost with different percentage of penalty is demonstrated in table 39. Note that these values are predictions based on the company's current situation.

Table 39: The Calculation of Possible Penalty Cost (Baht) with Various Percentage for Actual System

Date	Delay order value	10% Penalty	20% Penalty	30% Penalty	40% Penalty	50% Penalty
03-May-16	197,860.71	19,786.07	39,572.14	59,358.21	79,144.28	98,930.35
04-May-16	162,842.71	16,284.27	32,568.54	48,852.81	65,137.08	81,421.35
05-May-16	74,295.01	7,429.50	14,859.00	22,288.50	29,718.00	37,147.50
06-May-16	118,171.08	11,817.11	23,634.22	35,451.32	47,268.43	59,085.54
07-May-16	-	-	-	-	-	-
08-May-16	-	-	-	-	-	-
09-May-16	78,840.70	7,884.07	15,768.14	23,652.21	31,536.28	39,420.35
10-May-16	125,803.35	12,580.33	25,160.67	37,741.00	50,321.34	62,901.67
11-May-16	159,606.98	15,960.70	31,921.40	47,882.09	63,842.79	79,803.49

Date	Delay order value	10% Penalty	20% Penalty	30% Penalty	40% Penalty	50% Penalty
Total	917,420.53	91,742.05	183,484.11	275,226.16	366,968.21	458,710.27

4.1.3 Net Revenue

In this experiment, there are only two costs that are considered to finalise the net revenue. They are vehicle round trip cost and penalty cost. To calculate the net revenue of the system, these two costs are deducted from the initial revenue, equation (4).

$$Net\ Revenue = Revenue - round\ trip\ cost - penalty\ cost$$

Equation 4: Net Revenue Calculation

Net revenue without penalty

Referring to the discussion above about transportation cost without the penalty cost, this section aims to compare and illustrate the different outcomes when the proposed systems are applied. Firstly, the experiment would assume that the warehouse's current operation has a one hundred percent on time delivery performance, as same as the result of the proposed systems. The comparison of both proposed systems' net revenue and actual's net revenue is shown in figure 30.

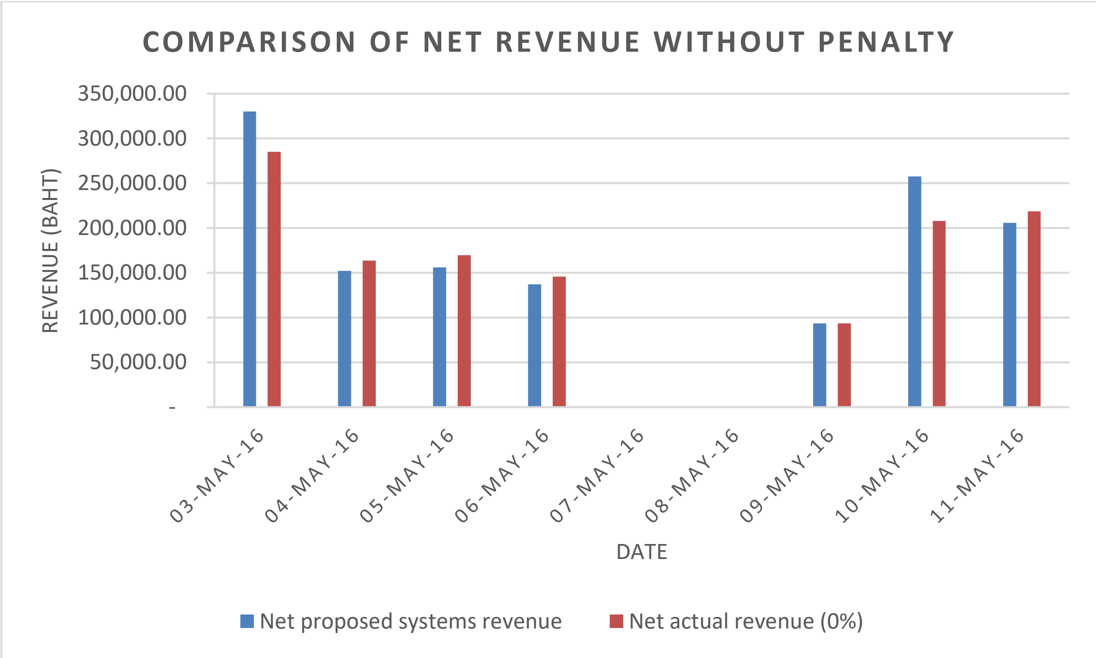

Figure 30: The Comparison Between Proposed Systems and Actual Net Revenue Without Penalty

The net revenue comparison of both proposed systems and actual one is not quite obvious, it barely shows that the proposed systems are able to provide better solution. Daily net revenue is fluctuated because it is a result from number of vehicle used each day, as well as number of order line which has been considered in one day. This matter shall be discussed in detail in the vehicle utilisation discussion later. Only three out of four days (3rd, 9th, 10th May 2016) of proposed systems results appear to gain net revenue more than the actual system. But when summarised up, the net revenue for all seven operating days turns out to be that the proposed systems net revenue is better than the actual systems. The proposed systems' net revenue is 1,332,487.27 baht while the net revenue of actual system is only 1,284,002.80 baht.

Which mean that the proposed systems are able to improve the transportation management and provide 3.78% better net revenue. The net revenue calculation is demonstrated in table 40.

Table 40: The Results of Net Revenue (Baht) Calculation

Date	Proposed systems net revenue	Actual net revenue (0%)
03-May-16	330,228.60	285,031.02
04-May-16	152,219.16	163,468.06
05-May-16	156,038.09	169,689.72
06-May-16	137,123.04	145,809.93
07-May-16	-	-
08-May-16	-	-
09-May-16	93,527.98	93,475.82
10-May-16	257,448.43	207,955.66
11-May-16	205,901.96	218,572.58
Total	1,332,487.27	1,284,002.80

Net revenue with various penalties (10% - 50%)

When products are not able to be delivered to customer sites on time as per the agreement, the penalty cost shall be a matter that the warehouse/company should bear in mind. As mentioned, the penalties are varied, based on the statement in the company and customer agreement. As there is no specific number of percentage charged, this experiment is aimed to provide a view of the burden that the company has to carry when the delivery management is not efficient. The actual net revenue of actual system will be compared with the net revenue of the proposed systems. There is no penalty taken into account for the proposed systems because the results do not appear to have any delayed deliveries.

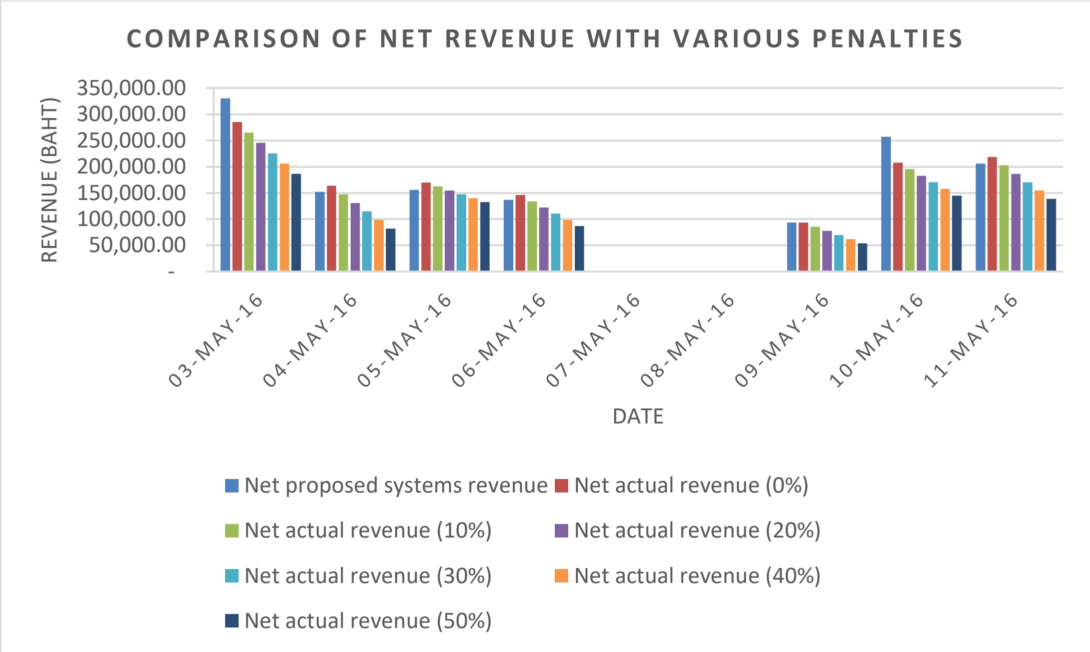

Figure 31: The Net Revenue Comparison of Proposed Systems and Actual Systems with Various Penalties

The possible net revenue when applied with the different percentage of penalty is shown in figure 31. The total amount is decreasing proportional to the percentage, as the latter is increasing. On the 3rd May 2016, actual net value without penalty is 285,031.02 baht. When the warehouse is charged for the penalty up to fifty percent of delay order value, the revenue loss is 98,930.35 baht. As a consequence, a poor management causes the loss of revenue of the warehouse of about 48.55% of overall income on that day. Let's take a look at the 9th May 2016, the net revenues of proposed systems and the actual system are quite similar. But when there is a fifty percent penalty considered, the warehouse may lose about 85,038.26 baht. In the other word, the company shall lose about 38.86% of total revenue of that day. Table 41 demonstrates the calculation of net revenue after penalty charging cost and round trip cost.

Table 41: Calculation Results of Net Revenue with Round Trip Cost (Baht) and Various Penalty Costs (Baht) for Actual System

Date	Net actual revenue (10%)	Net actual revenue (20%)	Net actual revenue (30%)	Net actual revenue (40%)	Net actual revenue (50%)
03-May-16	265,244.95	245,458.88	225,672.81	205,886.74	186,100.67
04-May-16	147,183.79	130,899.52	114,615.25	98,330.98	82,046.71
05-May-16	162,260.22	154,830.72	147,401.22	139,971.72	132,542.22
06-May-16	133,992.82	122,175.72	110,358.61	98,541.50	86,724.39
07-May-16	-	-	-	-	-
08-May-16	-	-	-	-	-
09-May-16	85,591.75	77,707.68	69,823.61	61,939.55	54,055.48
10-May-16	195,375.33	182,795.00	170,214.66	157,634.33	145,053.99
11-May-16	202,611.88	186,651.18	170,690.48	154,729.78	138,769.09
Total	1,192,260.75	1,100,518.70	1,008,776.64	917,034.59	825,292.54

4.1.4 Vehicle Utilisation and Vehicle Used

Vehicle utilisation is one of the considered factors of this research. Due to ineffective management of vehicle utilisation, it has a direct effect on the transportation cost. Therefore, in order to improve the company's transportation cost, a proper vehicle utilisation management should be considered.

According to the proposed systems, they aim to increase the vehicle utilisation of the studied company. The inputs which will be used in the experiment are the same as the current inputs that the company uses. Those inputs are the customer DOs, which the warehouse receives from the sales department.

Table 42: Daily Vehicle Volume Used Comparison

Date	Total order volume (m^3)	Total proposed systems vehicle volume (m^3)	Total actual vehicle volume (m^3)
03-May-16	641.44	288.03	771.90
04-May-16	411.28	524.47	469.38
05-May-16	478.13	686.03	627.25
06-May-16	379.27	419.98	470.04
07-May-16	-	-	-
08-May-16	-	-	-
09-May-16	243.44	281.36	325.44
10-May-16	593.76	448.54	807.11
11-May-16	532.74	780.67	553.72
Total	3,280.07	3,429.08	4,024.84

The total volume of order line is shown in table 42. The total volume of vehicles used to complete the product delivery to customers are also demonstrated. As the data shows, the seven-day total volume of the order lines is 3,280.07 m^3. The actual system total volume is 744.77 m^3 larger than the total products volume This means that about 18.50% is wasted on an empty space. On the other hand, when analysing the proposed systems' total volume of vehicles, it turns out that it is only 148.38 m^3 larger than the total product volume or 4.35%. In conclusion, the proposed systems are more effective to the overall system. The vehicle utilisation has increased 14.80% from the actual system's.

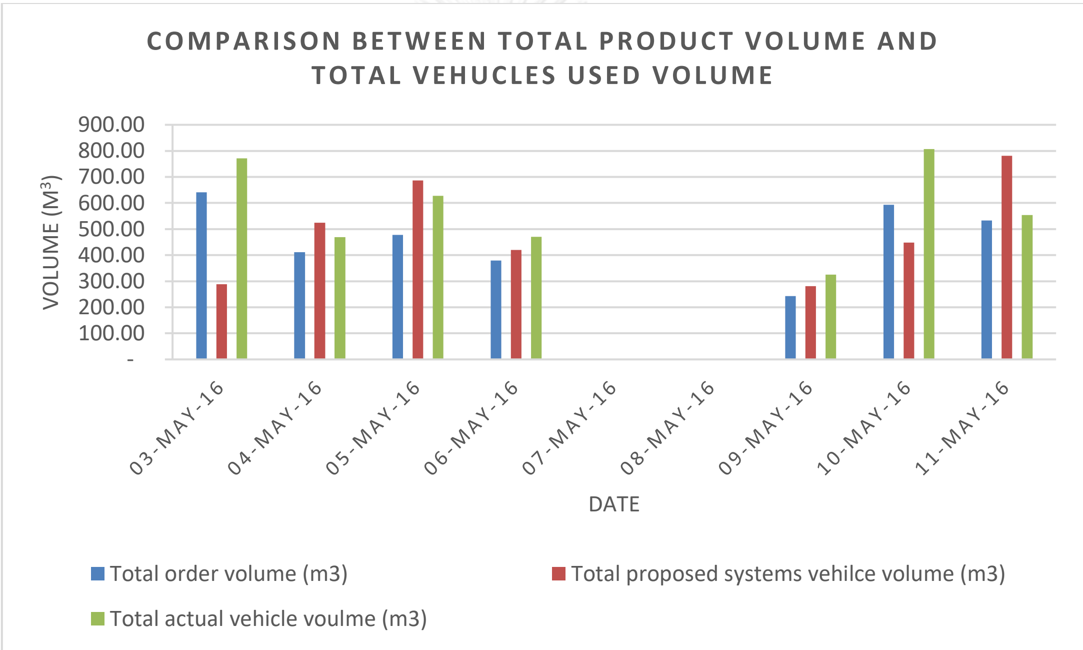

Figure 32: Comparison Between Total Product Volume and Total Vehicle Volumes Used

Table 43: Calculation of Average Utilisation, Standard Deviation, and Coeffective of Variation of Each Vehicle Type of Proposed Systems

Vehicle type	4-wheel Pick-Up	4-wheel Big	4-wheel NKR	6-wheel	6-wheel Big	18-wheel
Average utilisation (m^3)	3.83	6.18	6.69	19.72	50.57	40.59
Standard deviation	1.2485	1.4944	1.5081	4.5578	8.5853	6.7677
Coefficient of variation	0.3261	0.2417	0.2255	0.2311	0.1698	0.1667

As a data shows in table 43, from a calculation of coefficient of variation, it implies that a result of proposed systems' vehicle utilisation management has a low variation. The proposed systems are able to increase value for an empty space inside a vehicle. Moreover, it appears that both 6-wheel big and 18-wheel have the lowest variation while all 4-wheel's variation is quite low but not yet very well managed.

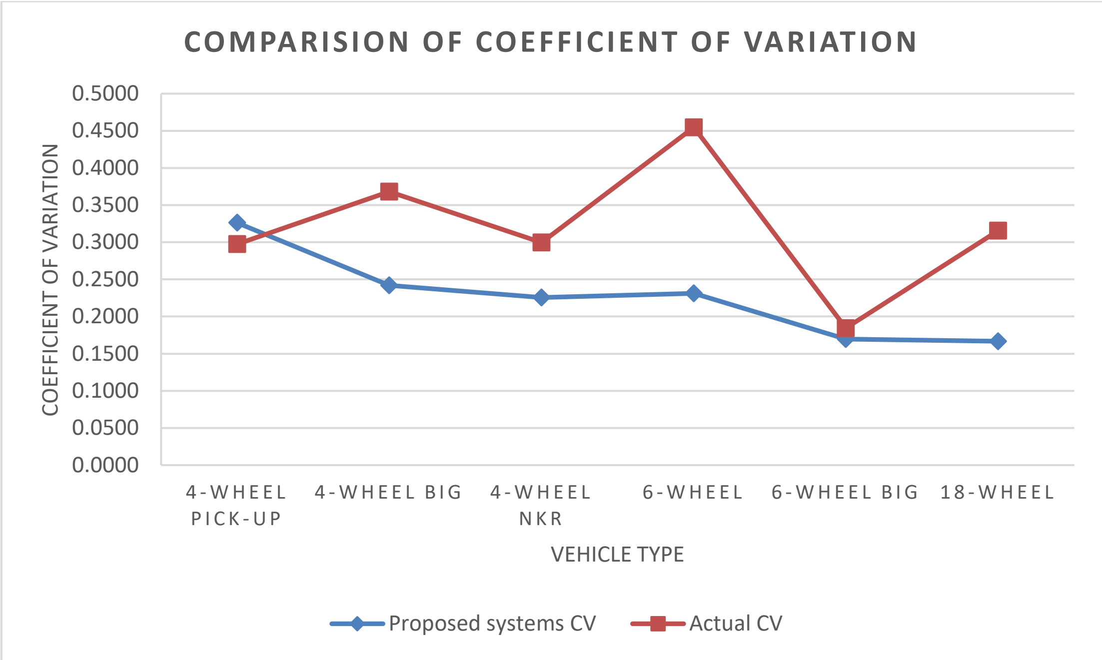

Figure 33: Comparison of the Proposed Systems' Coefficient of Variation of Each Vehicle Type

The graphs shown in figure 33 compare a coefficient of variation of proposed systems and a company's actual system. It illustrates that the proposed systems are able to reduce a variation of vehicle utilisation which mean that the vehicle utilisation is positively improved. There are 5 out 6 types of vehicle tend to have better management expect a 4-wheel pick up. This may due to there is not enough number of order from the same customer of that province to fill a vehicle until it reaches its maximum capacity. In addition, this number also implies that vehicle utilisation management is consistent. However, it does not guarantee that a utilisation is effective.

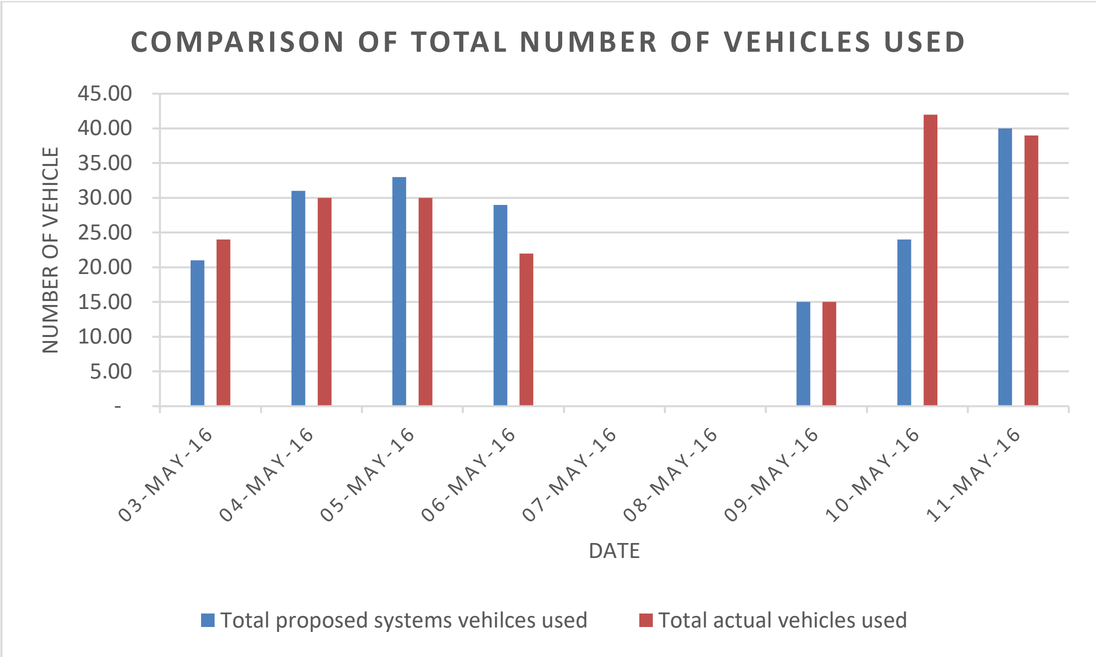

Figure 34: Comparison of Total Number of Vehicles Used in the System

The proposed systems are designed in order to improve the vehicle transportation cost for the studied company. The vehicle utilisation managed to be improved, and transportation management is expected to be better than current situation. Therefore, the proposed systems, once applied, provide results that may be either similar or different to the current one. In figure 34, there are some days that the total volume of vehicles used is less than the total volume of products ordered on that day. This does not mean that the warehouse is not able to deliver goods but it refers that only specific amount of order lines is worth to be served on that day. Other products could be served on other days. However, all goods must be delivered under the twenty four hours only.

Detailed explanation

The number of vehicles used each day, as shown in figure 34, is relevant to the daily transportation cost. On the 3rd May 2016, the proposed systems decide to serve only 226.33 m^3 out of 641.44 m^3. Therefore, it requires only twenty one vehicles while the actual system requires twenty four. The less vehicle used by the systems, the less transportation cost shall occur as shown in figure 28 on the 3rd of May 2016. The transportation cost of the proposed system is 45,197.58 baht less that the actual system. As for vehicle utilisation, when vehicle type and number are different, the management of vehicle utilisation is also different as shown in figure 35. On this day, the proposed systems decide to reduce number of vehicle. An 18-wheel is eliminated while a number of 4-wheel pick up and 6-wheel are reduced (figure 36). Therefore, when analysing and comparing the transportation cost without penalty for both proposed systems and actual, it clearly shows that the proposed systems cost is lower than the actual one. In addition, when the mentioned information is used for calculating the net revenue, the proposed systems are able to provide better solutions to the company. The 4-wheel big, 4-wheel NKR, and 6-wheel big of proposed systems are able to increase the vehicle utilisation for 4.28%, 17.07%, and 33.01% respectively.

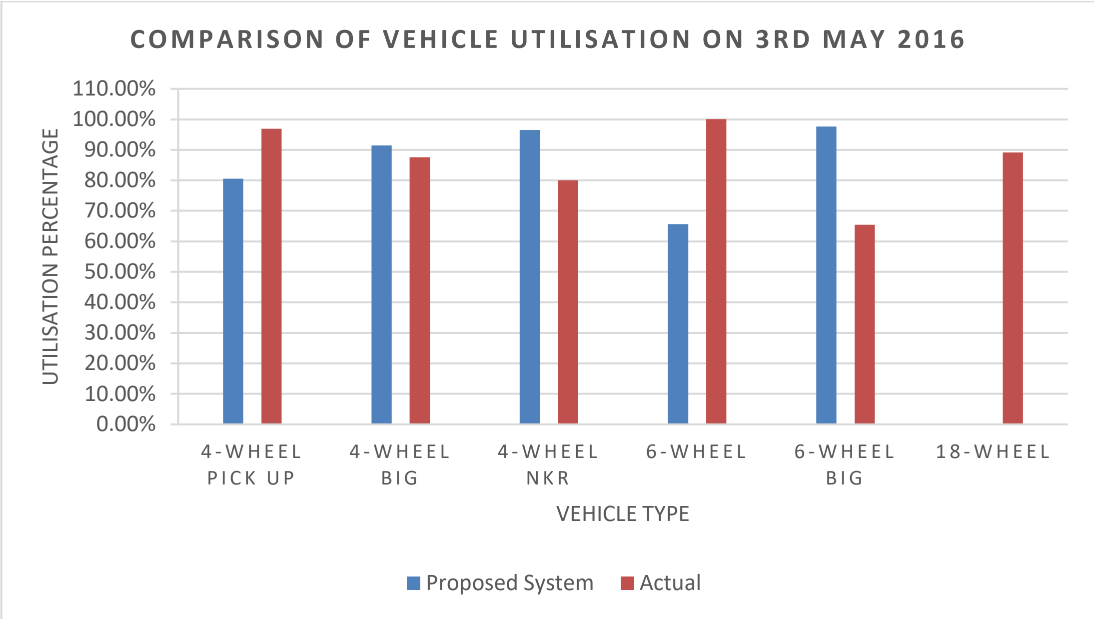

Figure 35: Comparison of Vehicle Utilisation on 3rd May 2016

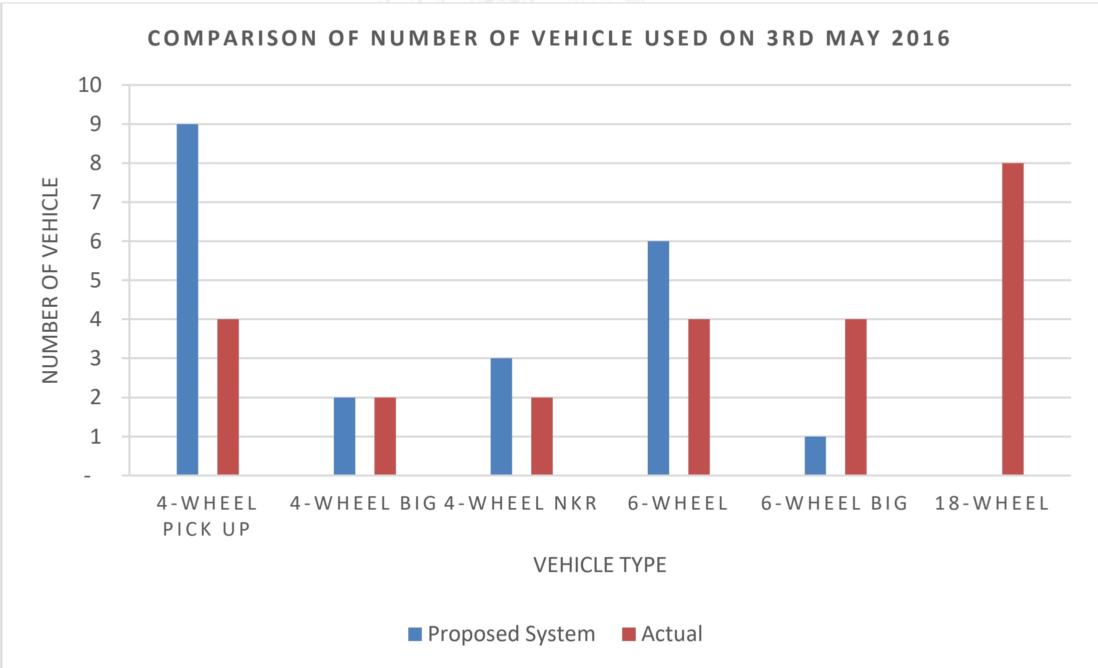

Figure 36: Comparison of Number of Vehicles Used on 3rd May 2016

Same analysis takes place for the results of the 4th of May 2016. On this day, the total volume of order lines which were purchased by customers is 411.28 m^3 while the volume which is assigned on all proposed systems' vehicle is 453.12 m^3. This day's delivery also includes the undelivered order lines from previous day. The proposed systems assigned thirty one vehicle to deliverer goods, while the actual system assigned only thirty vehicles (figure 38). Therefore, the transportation cost of proposed system would be higher and result in lower net revenue when comparing to the actual system, refer to figure 28. The transportation cost of the proposed systems is 87,275.79 baht while an actual transportation cost is 76,026.89. Since the number of vehicles used between the two systems are different, therefore, their vehicle utilisation is also different as shown in figure 37. The proposed systems are able to increase this day's vehicle utilisation for 4-wheel NKR and 6 wheel big (3.54% and 11.99% respectively).

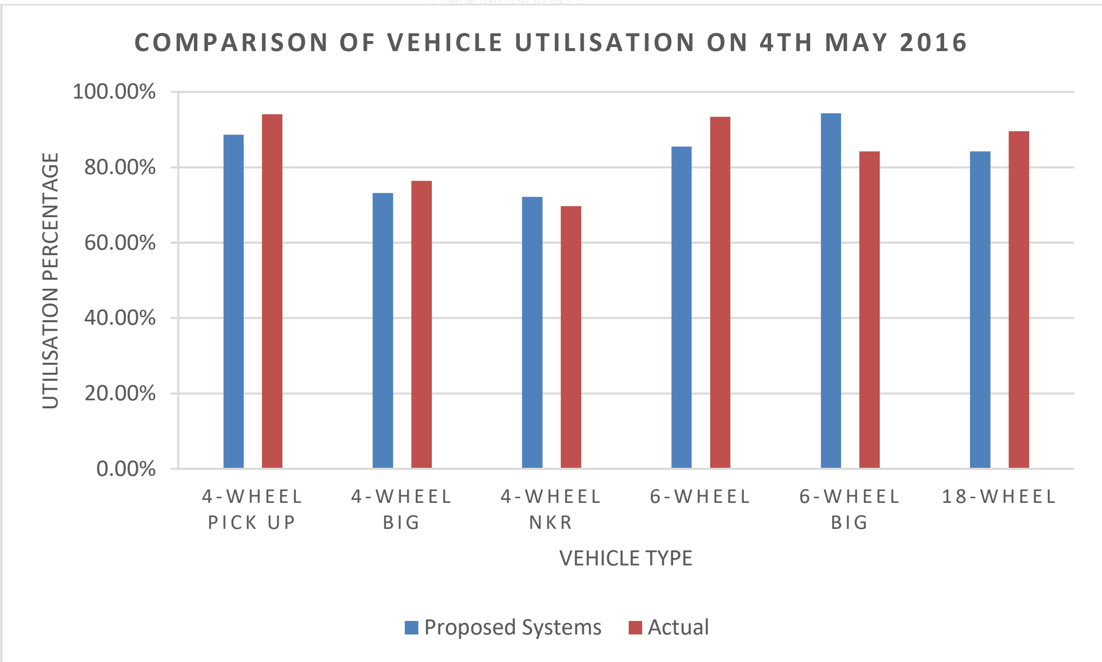

Figure 37: Comparison of Vehicle Utilisation on 4th May 2016

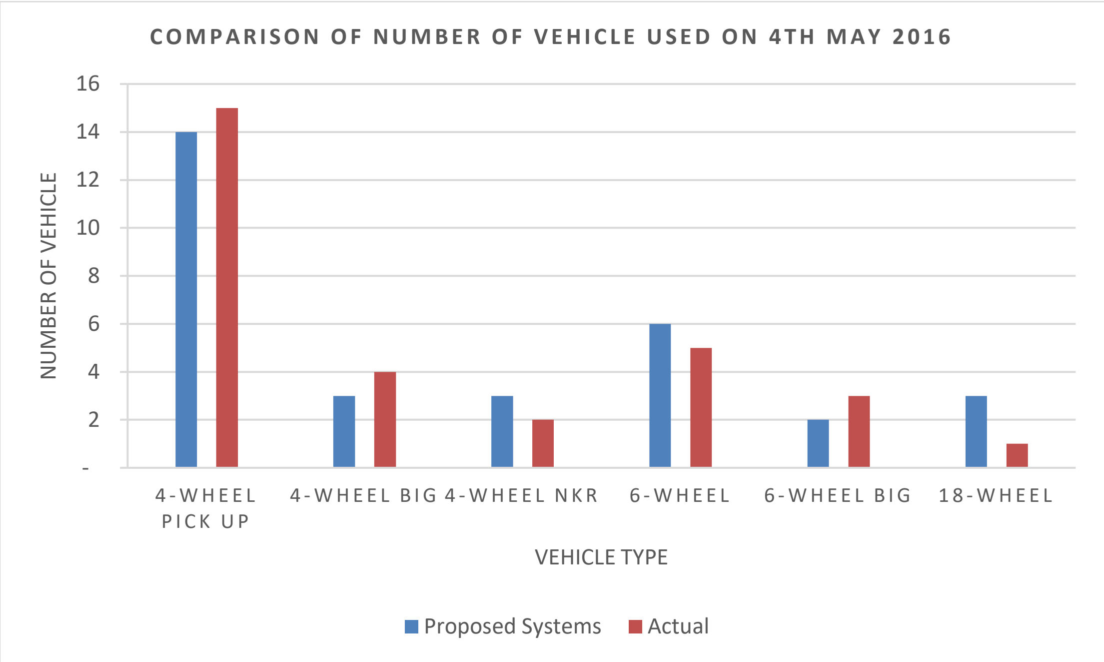

Figure 38: Comparison of Number of Vehicles Used on 4th May 2016

The total transportation cost of proposed systems on the 5th of May 2016 is higher than the actual system. This is due to an increasing number of vehicles assigned by the proposed systems. The actual system uses only thirty one vehicles to deliver 478.13 m^3 while the proposed systems assigned thirty three to deliver order lines of that day and previous day, which contained more volume. The differences of vehicle type and their number lead to different transportation cost (figure 40). Total numbers of 4-wheel NKR, 6-wheel, and 18-wheel have decreased while the others have increased. The cost for the proposed systems is 13,651.63 bath higher than the actual one. However, even though the number of vehicle used and type of them are different. The vehicle utilisation of proposed systems is still improved for 4-wheel big, 6-wheel big, and 18-wheel as illustrated in figure 39.

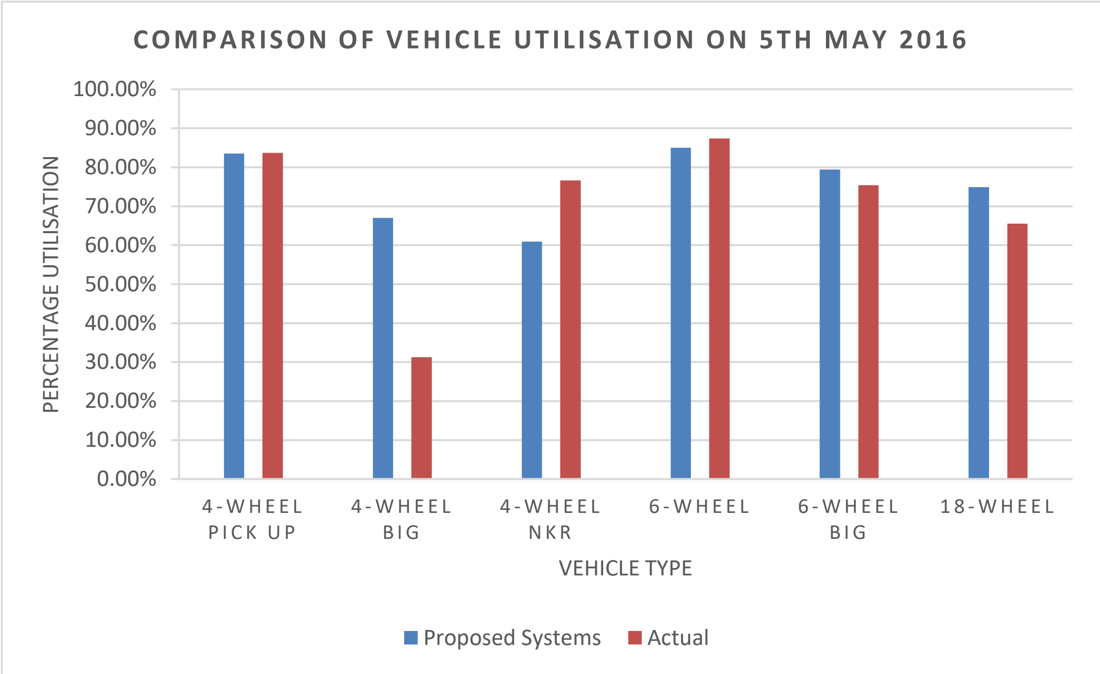

Figure 39: Comparison of Vehicle Utilisation on 5th May 2016

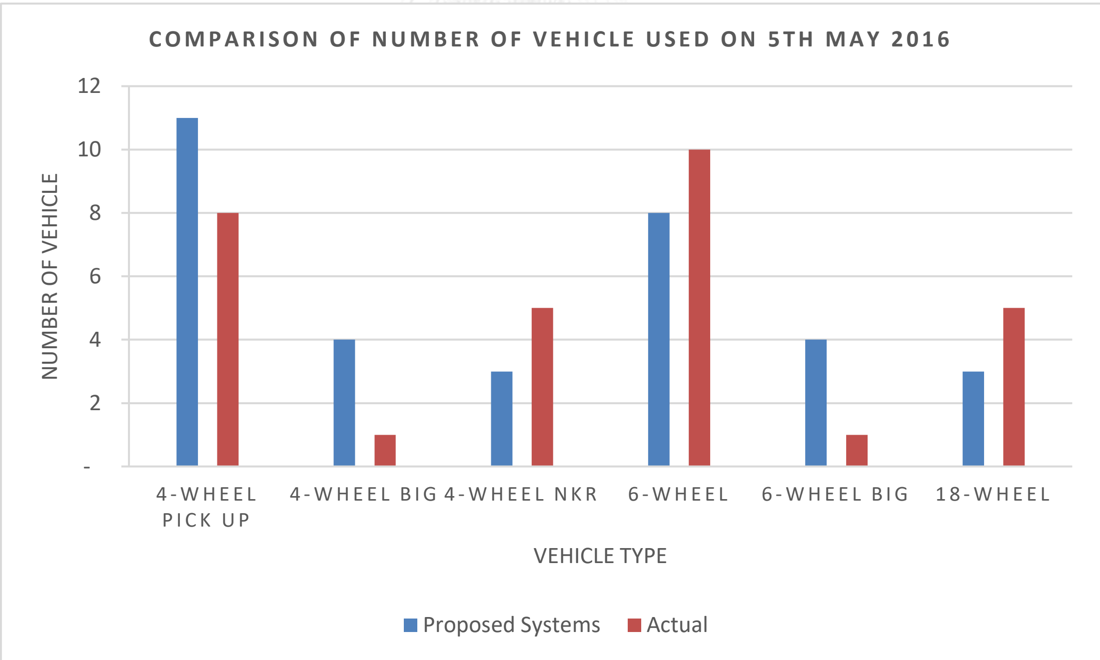

Figure 40: Comparison of Number of Vehicles Used on 5th May 2016

On the 6th of May 2016, the proposed systems' transportation cost still higher than the actual system around 8,686.89 baht. Due to larger number of vehicles used and the difference of vehicle type. Twenty nine vehicles are assigned to deliver 329.57 m^3 of order line, which is more than the vehicle assigned by the actual system (figure 42). Number of 4-wheel pick up of proposed systems is steeply high, in consequence, it affects the total transportation cost. Nevertheless, the number of 4-wheel NKR, 6-wheel, 6-wheel big, and 18-wheel have decreased. Therefore, the transportation cost of each type of vehicle have cancel each other out. However, the total volume of the order lines which the proposed systems plan to deliver is still less than the new order lines' volume that come in on that day. This could imply that the vehicles assigned today have to be responsible for the order lines from the previous day. As a result, there is no order lines from the 5th of May 2016 that remains undelivered. When considering the vehicle utilisation, the proposed systems provide a quite effective improvement for 4-wheel big, 4-wheel NKR, and 6-wheel big. From figure 41, their utilisation is increased by 1.38%, 39.59%, and 55.66% respectively from the current actual system.

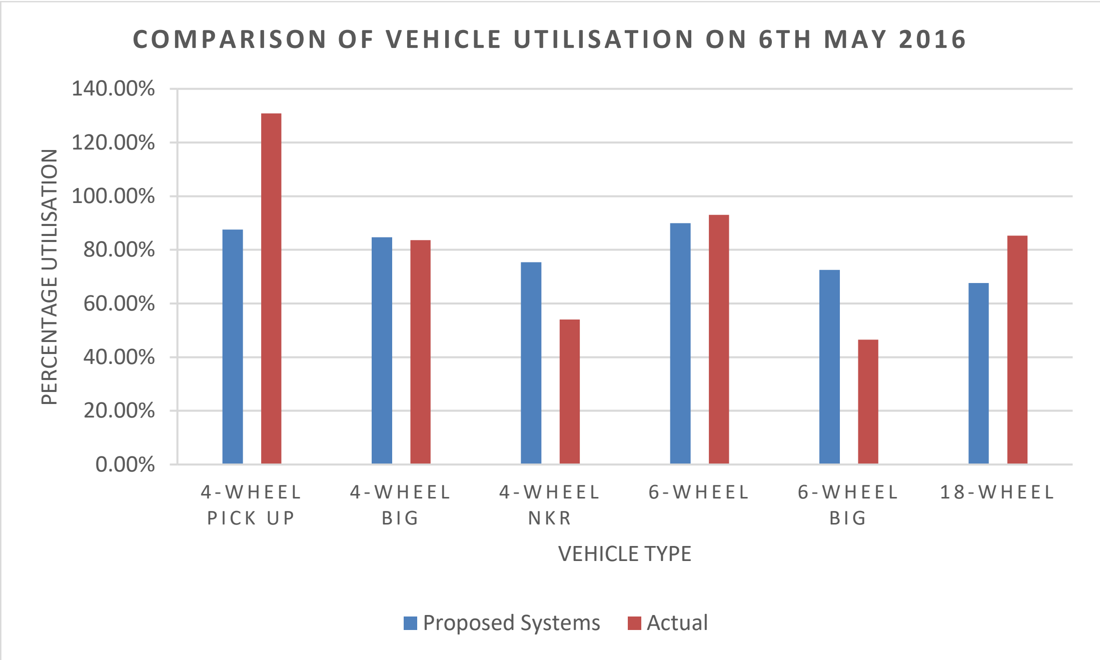

Figure 41: Comparison of Vehicle Utilisation on 6th May 2016

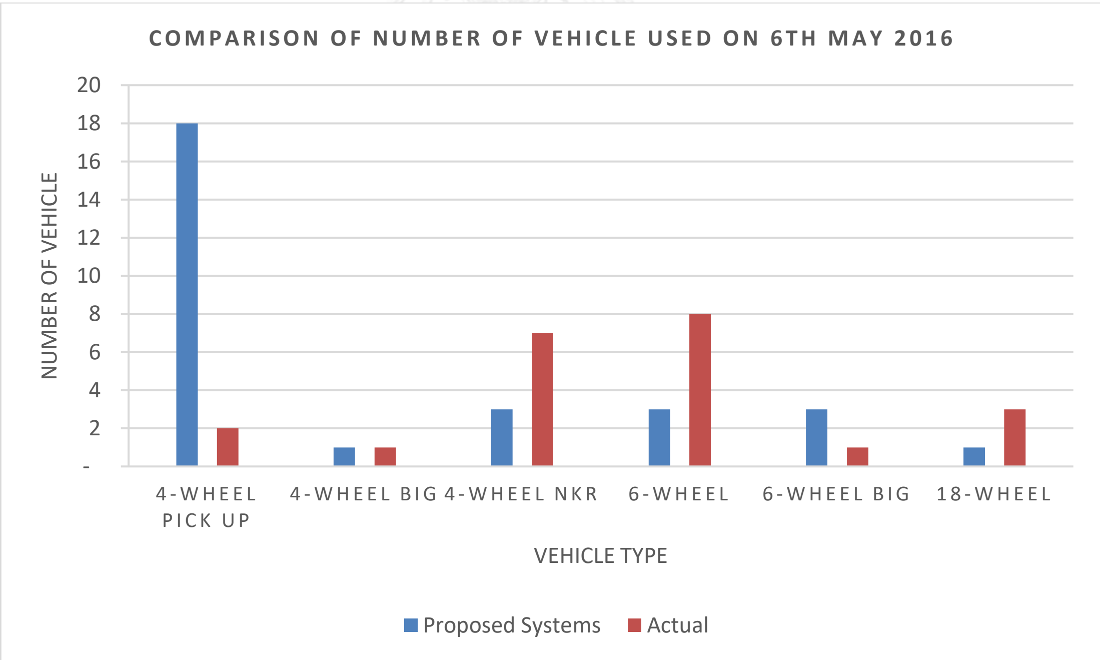

Figure 42: Comparison of Number of Vehicles Used on 6th May 2016

The proposed systems result of the 9th of May 2016 is similar to the result of actual system. Firstly, total number of vehicles used for both system is fifteen vehicles, but the assigned vehicle types are different, two 4-wheels big are assigned while the actual system is not. As a result, transportation cost will be different as well. Transportation cost between two systems are not much different, 52.15 baht.

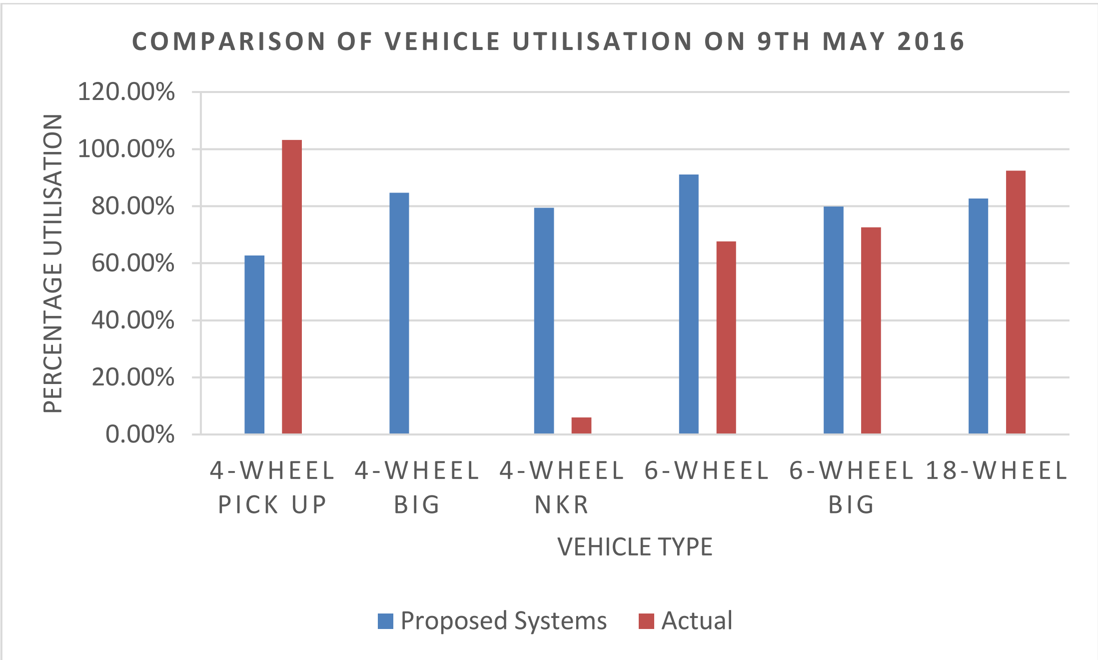

Figure 43: Comparison of Vehicle Utilisation on 9th May 2016

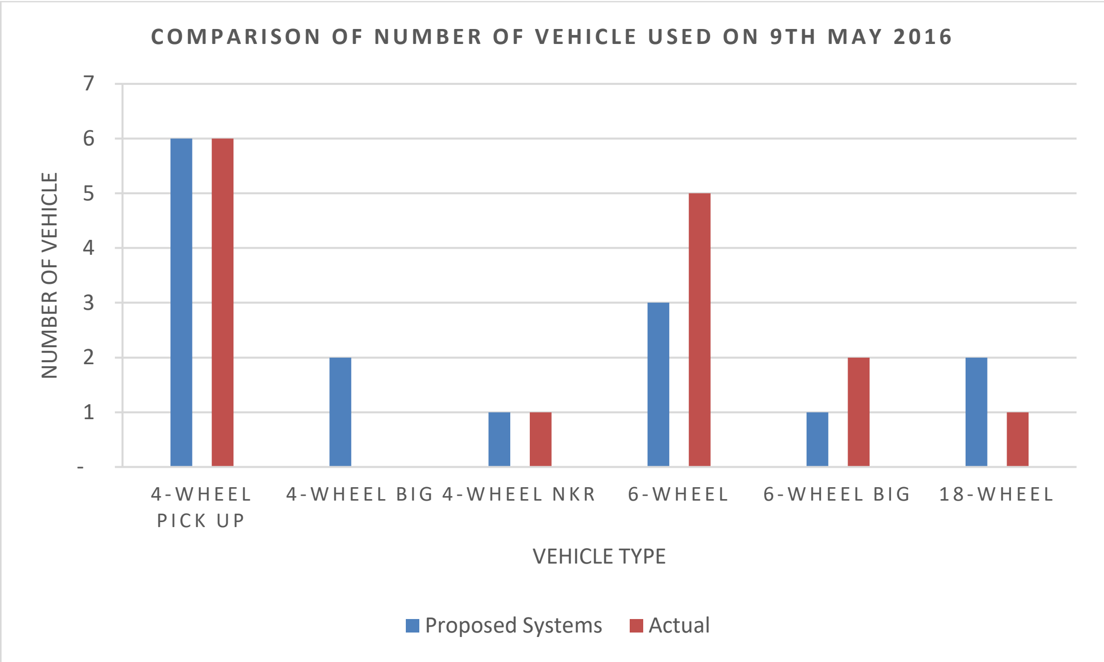

Figure 44: Comparison of Number of Vehicles Used on 9th May 2016

The experiment result of 10th May 2016 shows an extremely different on number of vehicles used and transportation cost without penalty. On this day, 359.67 m^3 of order line is delivered to customers by twenty four vehicles in total but, the actual system has used forty two vehicles, as illustrated in figure 46. Therefore, the transportation cost comparison shows that the results of the proposed systems provide a better cost. The actual transportation cost is 114,434.38 baht while the proposed systems' is 64,941.61 baht, which is better by about 43.25%. As for the vehicle utilisation part, as shown in figure 45, the percentage of 4-wheel big, 4-wheel NKR, and 18-wheel are increased.

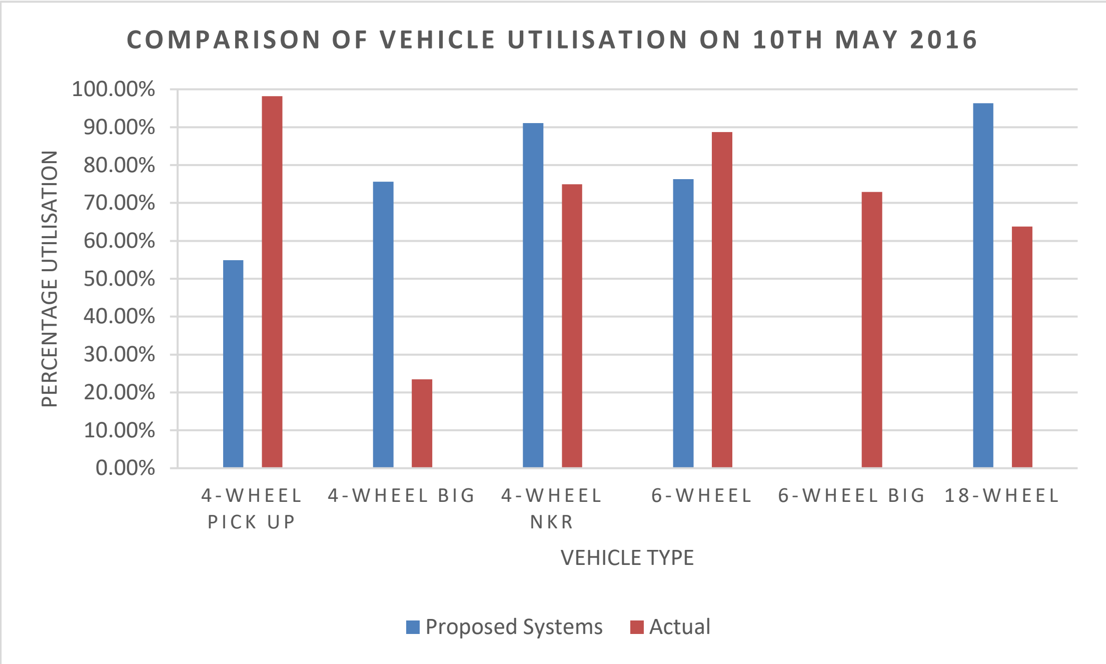

Figure 45: Comparison of Vehicle Utilisation on 10th May 2016

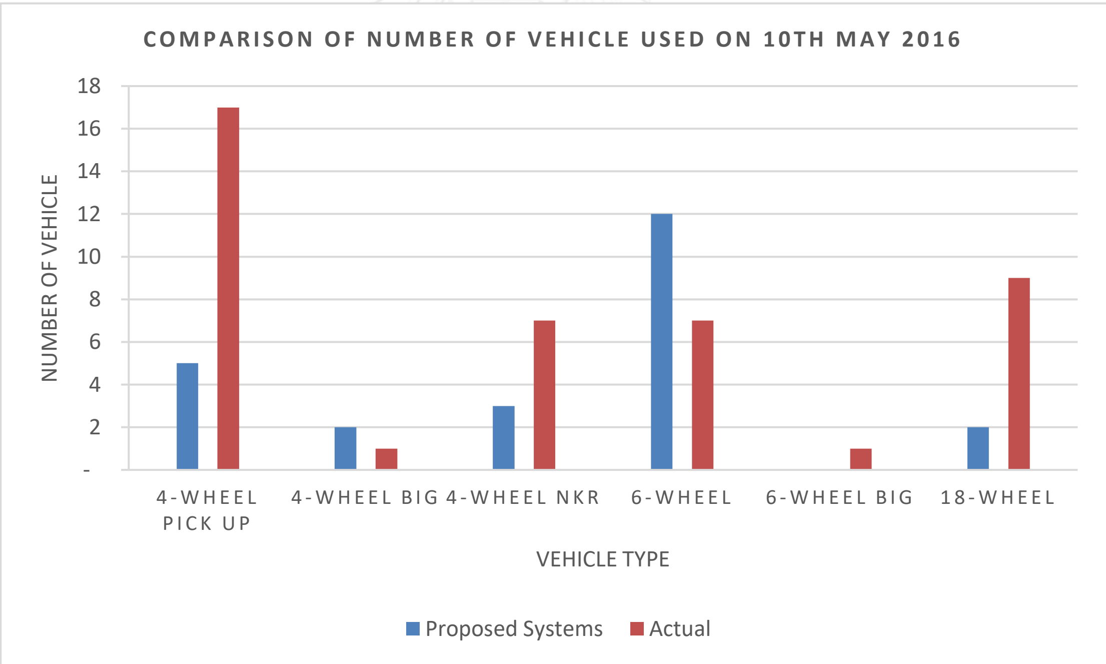

Figure 46: Comparison of Number of Vehicles Used on 10th May 2016

Lastly, on the 11th of May 2016, transportation cost of the proposed systems is higher by 12,670.61 baht. On this day, the proposed systems designed to deliver goods which came on that day, including partial orders from the previous day. Therefore, it would require more different type of vehicles to be able to do so (figure 48). However, today's vehicle utilisation is not as good as expected. Only 6-wheel big and 18-wheel's utilisations were increased. The vehicle utilisation of actual system of 4-wheel pick up and 6-wheel is above one hundred percent because, according to the warehouse manager interview, they allow to contain goods by violating the vehicle capacity.

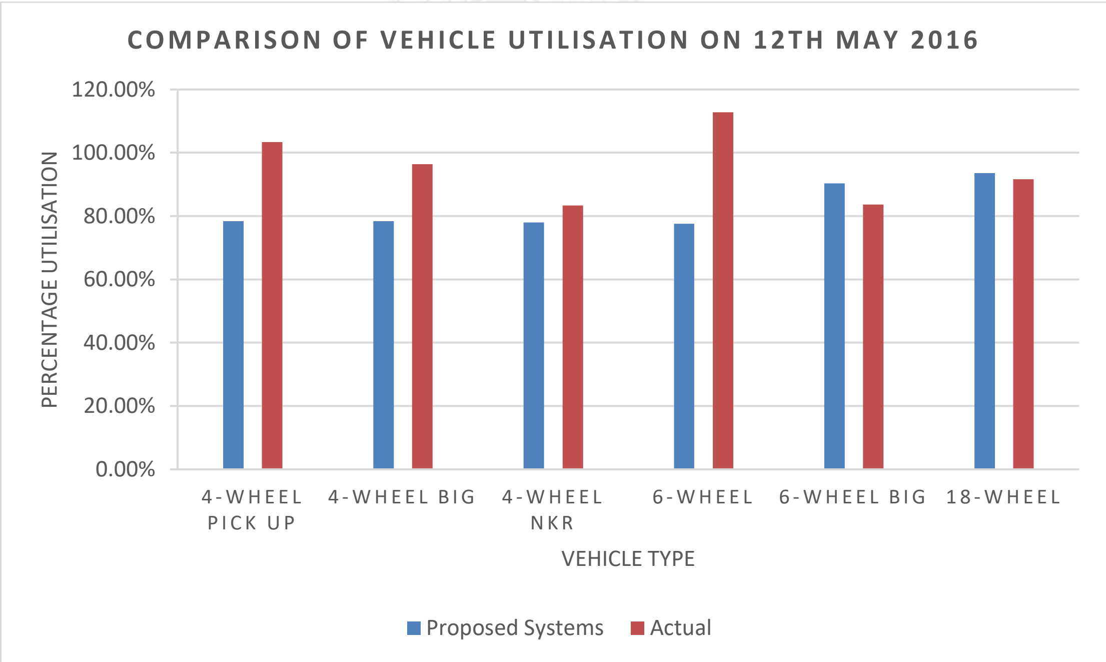

Figure 47: Comparison of Vehicle Utilisation on 11th May 2016

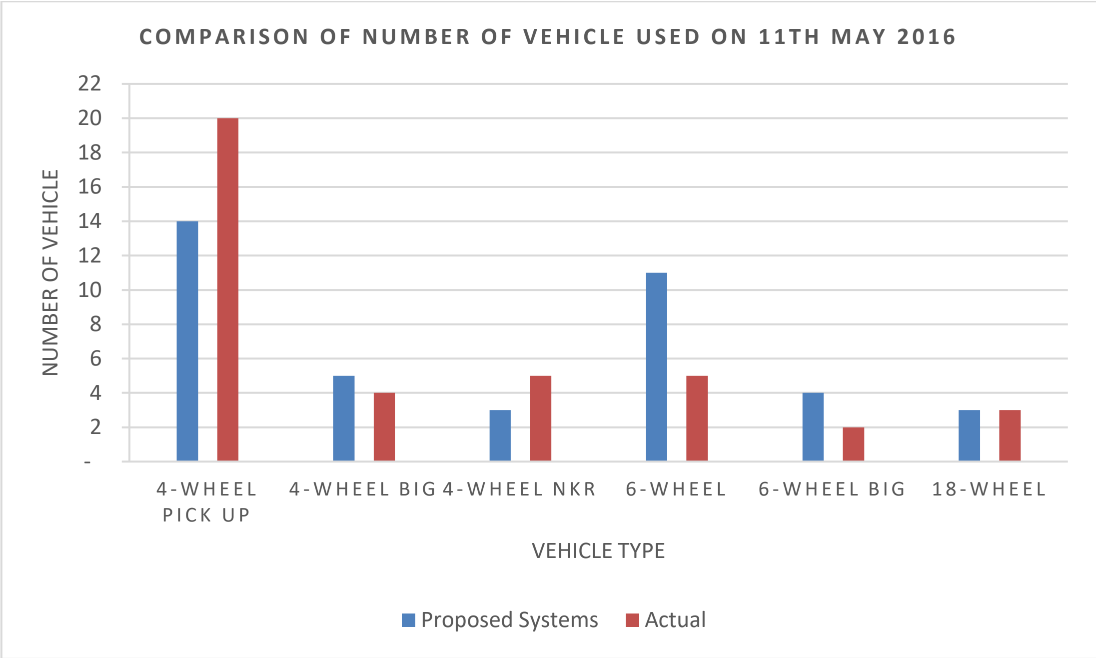

Figure 48: Comparison of Number of Vehicles Used on 11th May 201

4.1.5 Delivery Performance

The delivery performance is a key to evaluate the company's KPI. Currently, the delivery KPI is set at ninety eight percent of all orders must be delivered within the twenty four hours lead time. Otherwise, they would be marked as delayed deliveries, which affects the transportation penalty cost and company's reputation.

The proposed systems are designed to improve to the studied company's delivery performance. From the collected data of studied company record, it shows that only 55.68% of overall orders are able to be delivered on time. The rest of them are delayed due to poor transportation management. Therefore, the proposed systems are expected to improve the delivery performance by reducing and eliminating the delayed orders.

Table 44: Comparison of Delivery Performance

	Actual delivery performance (unit)			Proposed systems delivery performance (unit)		
Date	On Time	Late	Total	On Time	Late	Total
03-May-16	61	146	207	122	-	122
04-May-16	98	45	143	193	-	193
05-May-16	56	85	141	132	-	132
06-May-16	62	23	85	115	-	115
07-May-16	-	-	-	-	-	-
08-May-16	-		-	-	-	-
09-May-16	36	59	95	91	-	91
10-May-16	102	71	173	150	-	150
11-May-16	144	16	160	144	-	144
12-May-16	-	-	-	57	-	57
Total	559	445	1,004	1,004	-	1,004

According to the results of the proposed systems, all of the order lines from 3rd May 2016 to 11th May 2016 are able to be delivered to customer sites on time. There are some order lines that are delivered on the 12th but they are still under the condition. The delivery performance of proposed systems is 79.61% increased from a current situation. Therefore, the proposed systems would be good solutions for improving the delivery performance in order to achieve the company's KPI goal, as well as reducing the penalty cost from delayed delivery.

4.2 Discussion

The objective of this research is to improve the transportation cost for the electric appliance manufacturer. The studied company's data is used for analysing the transportation department's current situation. As a result, there are two problems that the company is facing right now and they have direct effects on the company's transportation cost.

Firstly, the vehicle utilisation is brought into consideration. The analysed data shows that the vehicle sometimes contains goods, less than 50% of its overall capacity. However, there is also a chance that it may carry goods that exceeds its maximum capacity. The proposed systems are designed to increase the percentage of vehicle utilisation including to decrease any risks that would occur when the vehicle capacity is violated. The total volume of order lines between 3rd May 2016 to 11th May 2016 is 3,280.07 m^3. The company's current management is assigned to deliver goods by using total 4,024.84 m^3 volume of vehicle. The exceeded volume is accounted for 18.50% over which could be converted into value, if the company has good vehicle utilisation management. The result of proposed systems is more satisfactory. Only 3,429.08 m^3 of vehicle volume is occupied which is accounted for 4.35% over. In overall, the proposed systems are able to provide better management as expected. The daily's vehicle utilisation of the proposed systems is sometimes better than the actual system but sometimes the opposite is true. This might be due to the number of order lines that the proposed systems design to be served daily are not the same as the actual one does. Moreover, it might request the usage of different vehicle which might result in the differences of vehicle type and amount which might affect the transportation cost of each day.

Secondly, the studied company's deliver performance is not quite effective. The delivery KPI is set at 2% of overall orders are allowed to be delayed deliveries. Yet, the current delivery performance is only 55.68% of overall orders are able to be delivered to customer sites on time. The delayed deliveries are caused from poor transportation management. The vehicles are released before they are supposed to, when it is not yet fully loaded, but has to deliver goods to avoid any delay. And as a result, when the vehicle is really needed on site, none of them are available. As a consequence, it costs the company, as a penalty costs, which will be charged as per the agreement between company and customer. Therefore, the proposed systems are designed to improve the company's delivery performance. From the experiment, the performance is very much improved. There is no delayed delivering orders which helps eliminate the penalty cost.

In conclusion, when comparing the transportation cost without any penalty, the proposed system could reduce 48,484.47 baht or 8.23% from the company's current transportation cost. The overall result is effective and satisfactory. In addition, when considering the delayed delivery, more penalty cost will be added to the transportation cost which make it higher than it is supposed to be. Lastly, when calculating the net revenue that the company would receive, the proposed systems would give a 3.78% higher value than the current one.

CHAPTER 5

CONCLUSION AND DISCUSSION

5.1 Conclusion

Thailand's economic is growing and developing itself to be an industrial country. It appears that there are a number of various companies which use Thailand as their manufacturing base and distribute their products domestically and internationally. The studied company is an electric appliance manufacturer which is also one of business that tends to grow lately. In many companies, supply chain, especially logistics, has played an important role in every process. An effective logistics discipline helps improve company's efficiency and reduce an inessential cost. Transportation is also one part of logistics. Twenty nine percent of logistics cost goes to transportation cost. An effective transportation management would help improve product allocation, speed of delivery, service quality, transportation cost, facility of usage management and energy conservation.

The studied company is electric appliance manufacturer which is located in Samutprakarn province, Thailand. Its main operation is manufacturing goods, storing goods, and delivering final products to customers. This manufacturer has many final products, but within this research, only six of them are considered, which are (a) air conditioner, (b) air purifier, (c) microwave oven, (d) refrigerator, (e) vacuum cleaner, and

(f) washing machine. Each product has its sub model with the individual product code. The delivering area which are covered in this research are Ayutthaya, Bangkok, Chachoengsao, Nonthaburi, Pathumthani, and Samutprakarn, Thailand.

As for the company's current situation, there are a few problems that the company is facing and it would be advantageous for the company if these problems are dealt with. As a result, the company's performance can be improved and transportation cost could be reduced. Vehicle utilisation is the first issue that is brought into consideration. Presently, the warehouse is operated based on real time receiving of DOs from sales department. These DOs will be analysed throughout the company's transportation process. The final outcome is that the DOs are grouped together and their products will be loaded onto the selected vehicles and be delivered as plan. However, there is an agreement between customer and the company that all products must be delivered within twenty four hours lead time (considering operating days only). Altogether with the real time orders, the warehouse sometimes does not know in advance that there will be new orders that come in or not. If so, they still do not know how long it has to take until new orders come in. Therefore, the recent orders are, sometimes, not able to be filled in the selected vehicle until reaching its maximum containing ability. And since the company does not have any standard or rule on standby time, the warehouse manager sometimes has to decide to release the vehicle to deliver goods even though there is some empty space left. This action may avoid any late deliveries which might cause any penalties, but on the other hand, with better vehicle utilisation management, the company should be able to create more value from that empty space. The company's previous data states that some vehicle have been loaded with less than fifty percent of its overall capacity. However, the data also shows that vehicle capacity is sometimes violated. The vehicle has to contain more goods than its maximum capacity. When it comes to the stage of transportation cost, which results from vehicle utilisation, it is dependant of the number of vehicles used and their types. The round trip cost of each vehicle type is different, and the destination affects the transportation cost as well. The round trip cost, which is used for calculation, is provided by the company and already included as a fixed cost and variable cost. The second considered issue is delivery performance. The transportation KPI is set to measure the performance. Two percent of delayed delivery is allowed. According to the collected data of seven operation days, only 55.68% of all orders are delivered on time as per the agreement, of twenty four hours delivery lead time. It appears that 44.32% of late deliveries may be caused by a lack of vehicle, driver's performance, or other external factors. A lack of vehicle is a consequence from vehicle utilisation. The vehicles are sometimes released before the time they are supposed to, therefore, when they are needed to be assigned, they may not be available at the warehouse. The orders have to wait until there is a vehicle back, and it might almost exceed the delivery lead time and cause a delay. When the warehouse is not able to deliver goods on time, the penalty shall be taken into account. The penalty rate depends on the agreement between the company and each customer.

The objective of this research is to develop heuristics from improving the transportation cost for an electric appliance manufacturer, as well as, to improve a vehicle utilisation and delivery performance.

The proposed systems are designed by using suitable algorithms for improving and developing the processes within transportation discipline which would lead to a better management. As a result, when the management is more effective than usual, it would help reduce the overall transportation cost. After reviewing several theories and literatures, the appropriate heuristics which can be applied to the company's current situation is the "cluster–first, route-second" of two–phase heuristics. The customer clustering system is considered as Vehicle Routing Problem (VRP). The route designing system is considered as Bin Packing Problem and Travelling Salesman Problem (TSP). The clustering algorithm is used for clustering similar customers together. In the first proposed system, the outputs are the order lines which have already been grouped together by province. The second proposed system consists of vehicle selecting and route designing processes. To select a suitable vehicle for each order lines, the order line's volume and vehicle capacity are considered together. The bin packing algorithm, first-fit method, is applied when assigning order line onto the vehicle. The order line would fill the vehicle as much as possible until it is not able to contain anymore. Then, it will consider other available vehicle in the system. Once possible order lines are assigned onto the vehicle (system assigned, not yet practical), the traveling plan will be designed. To arrange the delivering sequence for all order lines on the same vehicle, the Nearest Neighbourhood Algorithm and Early Due Date method (EDD) are adapted to use with the order receiving time. The first order line that will be delivered is one with the earliest received order time and followed by the order lines of the same customer. The next earliest received order time lines are considered respectively. When loading products onto a vehicle, the First-In, Last-Out method is applied.

The proposed systems are written in MATLAB code to facilitate the experiment. As a result, the transportation cost improvement is satisfactory. When considering transportation cost without penalty, the proposed systems are able to reduce the cost by 8.24% or 48,484.47 baht, which will increase the net revenue by 3.78%. Furthermore, vehicle utilisation is also improved. The proposed systems have decreased 14.80% of empty vehicle space compared to the company’s actual vehicle utilisation. In addition, the delivery performance is significantly improved. The results of the proposed systems indicate that there is no delayed delivery which help eliminate penalty costs. Effective management and improvement lead to transportation cost reduction as well as increasing the company reputation.

5.2 Discussion

5.2.1 Research Limitations

1. The proposed systems are designed based on the given data between 3rd May 2016 – 11th May 2016. In case of any information changes may lead a complication to the proposed system. For example, an increasing or decreasing number of customers would require more analysis of distance and travelling time between locations. To continue using the proposed systems without any revises may cause ineffective results. However, a data given from the studied company is only 7 operating days. An analysis of that data may be limited and only provide initial information.

2. Most of company's financial data is confidential, for example; penalty cost. Therefore, values which are used within this research is limited to that. Some calculation, such as penalty cost, is from a percentage estimation which applies with company's given calculation method.

3. A round trip transportation cost is already consisted of fixed cost and variable cost which is calculated based on previous company data. Detailed cost explanation is not available for future studied.

4. In this thesis, a vehicle travelling speed and time regulations are neglected for an ease of analysing. When the proposed systems are applied with a company system, it might not operate effectively due to these limitations. However, these

proposed systems are good enough to be used for the studied company as they are able to provide basic improved solutions.

5.2.2 Academic Contribution

Many organisations, including the studied company, do not have a transportation discipline as a core competency, but is a part that could provide benefit as well as an income to the company. It is useful to understand the company's capabilities and be able to identify any problems that the company is facing. For the studied company, the overall problem would be compared to the vehicle routing problem (VRP). To solve the studied company's problems, many heuristics are studied. A two–phase heuristics of cluster–first, route–second seems to be proper solution. The new transportation system is designed to make a working process more conform to the current situation. A clustering algorithm, a bin packing algorithm, and the nearest neighbourhood algorithm are used to support the proposed systems. The company conditions when designing new system are 24-hour deliver lead time, a limited number of vehicle and type, delivery KPI, and no outsourcing strategy. This research could be useful for ones who are seeking the ideas to solve the vehicle routing problem (VRP), bin packing problem, and travelling salesman problem (TSP) for their studies or organisations. However, the algorithms used here may not be fully be effective for every problem but they are at least able to provide initial solutions. Further studies on each organisation's nature, current situation, and current problems are a must.

5.2.3 Future Researches

1. In proposed route designing system, a symmetric distance and travelling time are applied to “point A” to “point B’ and vice versa. To make the system become more realistic, an asymmetric distance and travelling time should be considered.

2. The proposed systems are only the initial solutions for the problems, the solution improvement such as intra – route improvement and inter – route improvement might lead to a more effective system.

3. If the business is expanded in the future, new strategy such as outsourcing shall be applied to support the business growth.

4. The capacity constraint in this research considers only one dimension, which is volume, whereas weight and material shape are not considered. The system could become more practical with two dimensions (volume and weight) and/ or three dimensions (volume, weight, and dimension).

5. The proposed systems have neglected the travelling speed and time regulations. It would be very useful for the company if the proposed systems could consider those regulations so that the studied company could actually use them. Moreover, if there are other companies which have similar situation, they could use these proposed systems as an initiator to improve their internal system.

6. The proposed systems used the nearest neighbourhood algorithm and early due date method to design delivery sequence and travelling route for order lines on the same assigned vehicle. To apply the nearest neighbourhood algorithm by travelling distance between locations and analyse, it would provide alternative solutions.

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