STRATEGIC DISTRIBUTION CENTRES LOCATION FOR TRAFFIC SAFETY PRODUCTS

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น.ส.ภคภรณ์ บุญวิทย์

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ภคภรณ์ บุญวิทย์ : กลยุทธ์การหาตำแหน่งของศูนย์กระจายสินค้าสำหรับอุปกรณ์ความปลอดภัยด้านจราจร. (STRATEGIC DISTRIBUTION CENTRES LOCATION FOR TRAFFIC SAFETY PRODUCTS) อ.ที่ปรึกษาหลัก : รองศาสตราจารย์ ดร.วิภาวี ธรรมาภรณ์พิลาศ

การวิจัยนี้มีวัตถุประสงค์เพื่อจัดหาสถานที่ที่เหมาะสมในการสร้างศูนย์กระจายสินค้าให้กับบริษัทหนึ่งที่จำหน่ายผลิตภัณฑ์ความปลอดภัยด้านจราจรให้กับสำนักงานแขวงทางหลวงทั่วทุกจังหวัดในประเทศไทยโดยใช้วิธีการเชิงกลยุทธ์ ในชุดปัญหานี้ จะมีการใช้ข้อมูลตำแหน่งที่ตั้งและความต้องการของลูกค้าที่ได้รับมาจากบริษัท เพราะสถานที่ตั้งของลูกค้านั้นกระจายอยู่ทั่วประเทศไทยงานวิจัยนี้จึงมีวัตถุประสงค์เพื่อค้นหาที่ตั้งของศูนย์กระจายสินค้า ซึ่งจะให้ผลลัพธ์ที่มีต้นทุนการเดินทางภายในกลุ่มของลูกค้ารอบๆศูนย์กระจายสินค้าและจากสำนักงานใหญ่ไปยังศูนย์กระจายสินค้าที่ถูกที่สุด งานวิจัยนี้มีเป้าหมายที่จะทำการแนะแนวให้กับบริษัทในการตัดสินใจลงทุนในศูนย์กระจายสินค้าโดยคำนึงถึงค่าเดินทาง ค่าดูแลรักษารถ และค่าเช่าศูนย์กระจายสินค้า เพื่อลดค่าใช้จ่ายด้านขนส่ง เมื่อเปรียบเทียบกับกลยุทธ์การจัดส่งในปัจจุบันของบริษัท การลงทุนในที่ตั้งศูนย์กระจายสินค้าที่ถูกต้องจะส่งผลเชิงบวกต่อความสามารถในการทำกำไรของบริษัท และช่วยประหยัดต้นทุน อีกทั้งปรับปรุงประสิทธิภาพทางการแข่งขันในตลาด

วิธีการแก้ปัญหาแบ่งออกเป็นสองส่วน ส่วนแรกคือการแบ่งกลุ่มลูกค้า วิธีนี้จะช่วยลดขนาดข้อมูลโดยการจัดกลุ่มลูกค้าตามที่ตั้งทางภูมิศาสตร์ผ่านวิธีการจัดกลุ่มแบบ k-mean ผ่านแพลตฟอร์ม GIS จากนั้น ผลลัพธ์ที่ได้รับจากกระบวนการจัดกลุ่มนี้จะถูกป้อนเข้าสู่ส่วนที่สอง ซึ่งก็คือการเพิ่มประสิทธิภาพการเดินรถด้วยวิธี CVRP วิธีการนี้ใช้เพื่อค้นหาตำแหน่งที่เหมาะสมที่สุดสำหรับศูนย์กระจายสินค้าและเส้นทางที่เหมาะสมที่สุดจากศูนย์กระจายสินค้านั้นไปยังลูกค้าทั้งหมดในแต่ละกลุ่มลูกค้า

การวิจัยครั้งนี้จัดกลุ่มลูกค้าออกเป็นสี่และห้ากลุ่มเพื่อกำหนดแหล่งลงทุนของศูนย์กระจายสินค้า จากการคำนวณพบว่าสี่กลุ่มลูกค้าจะทำให้บริษัทได้รับประโยชน์จากการประหยัดต้นทุนมากที่สุด ซึ่งจังหวัดที่ถูกคัดเลือกจาก CVRP นั้น ได้แก่ พิษณุโลก ปทุมธานี (สำนักงานใหญ่) นครราชสีมา และชุมพร ซึ่งจะทำให้บริษัทมีค่าใช้จ่ายลดลง 40%

สาขาวิชา	วิศวกรรมอุตสาหการ	ลายมือชื่อนิสิต	....
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This research aims to determine suitable locations to build distribution centers for a specific company that distributes traffic safety products to highway offices across every province in Thailand using strategic methods. In this problem set, the predetermined location of customers and each corresponding demand were given. With customer locations spreading widely across Thailand, this research aims to find locations of distribution centers, which will result in the lowest cost to travel from the company's headquarter to the distribution centers and the cost of travelling to and from customers from those distribution centers by considering the transportation cost, vehicle cost and distribution centre rental cost. The research aims to provide the company with a comprehensive decision-making solution in location to invest in distribution centers to minimise the company's logistic expenses. Compared to the company's current delivery strategy, investing in correct distribution center locations shall positively impact the company's profitability through cost savings and improve its competitiveness in the marketplace.

The solution methodology was decomposed into two parts. The first part is clustering. This minimises the data size by grouping customers based on their geographical location through the k-mean clustering method via a GIS platform. The result obtained from this clustering process is then fed into the second part, CVRP optimisation. This optimisation method is used to find the optimal location for the distribution center and the optimal routes from that distribution center to all customers in each cluster.

This research grouped customers into four and five clusters to determine the best investment location. It was calculated that four clusters would give the company a higher cost-saving benefit. The provinces with the lowest CVRP objective cost for four clusters are Phitsanulok, Pathumthani (the headquarter), Nakhon Ratchasrima, and Chumphon. This method will decrease the company's transportation cost by 40%.

Field of Study:	Industrial Engineering	Student's Signature ....
Academic Year:	2023	Advisor's Signature ....

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Pakaporn Bunwit

TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

Page

CHAPTER 1 - INTRODUCTION

Logistics cost is considered the main expense in many companies, and it contributes significantly to the company's total expenses, significantly impacting the company's profitability. This excess expense in logistics is often due to poor logistic network planning of the company. Due to this reason, many companies are striving to enhance the efficiency of their logistics network planning to alleviate costs. An efficient logistics network also allows the company to improve its use of logistic resources to its highest capability. Therefore, having a well-planned logistics network is essential to reducing costs and increasing the company's profitability[1]. The farther apart the customer locations are, the more significant the logistic cost becomes as the distance needed to be covered to reach each customer increases.

Delivering hub, such as distribution centre, cross-dock facility or warehouse, is one of the possible solutions used to improve the delivery of products to customers, with destinations being far apart in terms of timing and cost in the long term [2-5]. This thesis will be focusing on the use of distribution centre. A distribution centre is the median stage where products from the supplier or retailer are distributed to customers similar to a cross-dock or a warehouse. What differentiates a distribution centre from a warehouse is its minimal handling time. The products are unloaded from an incoming truck, screened, sorted, stored, and reloaded onto an outgoing truck when needed. Distribution centre has many benefits besides redefining efficiency and cost saving, such as increasing flexibility, promoting competitiveness, and scalability. By utilising distribution centres, the company can react smoothly to market changes and fluctuations in demand; this is also true for seasonal variations. Distribution centre also promotes a fuller load for each trip, which reduces costs. Additionally, an efficient logistics network through distribution centre can improve customer satisfaction levels by enabling the company to respond faster to customer demand, promoting the company to become more competitive in the market. In the retailing industry, speed and efficiency are critical factors in achieving customer loyalty.

Given that distribution centres require an investment in land rental, potential initial infrastructure construction, and maintenance costs, the location to implement the distribution centre is an important investment decision the company has to make. Therefore, a thorough investigation into the optimal location from a timing and value-for-money perspective is required to use the funds best. This research looks at the concept of enhancing delivery using the method of distribution centres as median stage or delivery hubs. This research aims to find the optimal location for these distribution centres to be built, determine the corresponding number of outgoing trucks needed at each distribution centre to cover demand and plan their delivery routes. The optimisation process involving the routing of outgoing trucks is commonly known as the Vehicle Routing Problem (VRP), which will form the core of this research. Specifically, having capacity as part of the constraints in routing, the problem is called a Capacitated Vehicle Routing Problem (CVRP), a subset of VRP [6-7]. More details on CVRP will be mentioned in Chapter 2.

1.1. COMPANY BACKGROUND

The company in focus for this study is based in Thailand. The company manufactures and retails an extensive range of traffic safety products and delivers them to highway districts across every province in Thailand. Highway districts are monitored by the Department of Highways (DOH), a government agency with critical roles in developing, maintaining and managing the Thai national highway network. DOH ensures the safety of road users and is responsible for implementing road safety measures, which require the installation of traffic safety products, which are the category of goods the company specialises in. Customers mentioned in this research are referring to the highway districts.

There is a total of 104 highway districts throughout 76 provinces of Thailand. In significant provinces such as Chiangmai, there is more than one highway district because more roads within the province need to be looked after. Each office within the same province is distinguished using a number following the province name; for example, there are three highway districts in Chiangmai, which are Chiangmai 1, Chiangmai 2 and Chiangmai 3. The geographical distribution of highway districts is shown in Figure 1.1. The company's headquarter is located in Pathumthani, Thailand, as denoted by a square in Figure 1.1. This is where the finished product is stored; therefore, it is the centre of the company logistic network where the products are distributed. The company currently does direct deliveries from the headquarter to end customers across 76 provinces throughout Thailand.

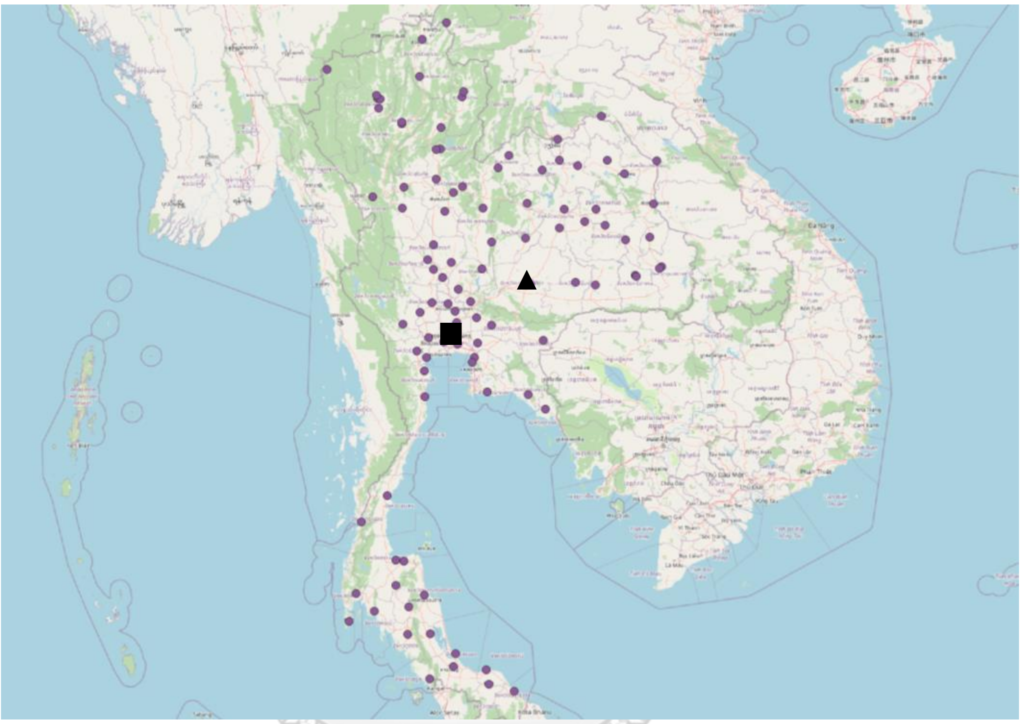

Figure 1.1 – Location of 104 highway district offices

The leading product being delivered by the company is Traffic cones. A traffic cone is a conical-shaped traffic safety product; it has a wide square base with a point top and is made of flexible materials such as plastic. Traffic cones are used for various applications such as construction warnings, hazard warnings, at events, or safety barriers to promote safety to users. Traffic cones are available in many sizes, but the typical size used in Thailand is 80 cm high. Traffic cones are temporary traffic safety controls as they are portable. It is an essential tool for managing traffic and ensuring safety. It is considered a piece of emergency equipment used by all highway district offices to control traffic conditions and, in some cases, for emergency response and disaster management. Therefore, traffic cones must be available at hand at the earliest possible time, so they are often ordered in large quantities with short notice and require fast delivery.

When fast delivery is crucial, the company attempts to deliver its products as soon as an order is placed. Even though Pathumthani is a prime location as it is located in the centre of the country, the distance needed to travel across the country is high due to Thailand's geographical shape, which results in high transportation costs. With long travel distances, the company suffers huge expenses from transporting traffic cones over Thailand. The use of third-party services is also not ideal because of high quantity orders and also because of the bulky size of traffic cones. To reduce this excess logistic cost, the company proposed renting distribution centres in main cities to act as logistic hubs and reduce transportation costs from long-distance travel.

This research investigates the company's proposed idea of investing in distribution centres as delivery hubs. The decision was based on the number of distribution centres that gave the company the highest reduction in cost. As these distribution centres will be in charge of delivering products to nearby cities instead of from the headquarter, it requires the decision of the best location of where it should be based and the number of vehicles required to accommodate nearby demand. The research was approached through clustering and vehicle routing optimisation. The initial number of distribution centres was determined through clustering, and the location was later determined through vehicle routing optimisation. The logistic cost currently accounts for 22% of the gross margin. This research aims to reduce that to a figure below 20%.

Figure 1.2 shows a comparison of the company's current logistic network model and the proposed logistic network model. In the current logistic network model on the left, the company operates from one centralised warehouse, which is the headquarter. The headquarter directly serves all customers across the country. The proposed logistic network model on the right considers distribution centres in multiple provinces as a midpoint between the headquarter and customers. The products will first be transported from the headquarters to the distribution centres in this proposed logistic network model. The remaining distance to the customer will be done from these distribution centres. The company purchased one distribution centre located in Nakhon Ratchasima a few months back to examine the proposed model and would like to determine other locations to invest in other parts of Thailand. However, for other distribution centres, rentals are preferred to lessen the weight of the investment.

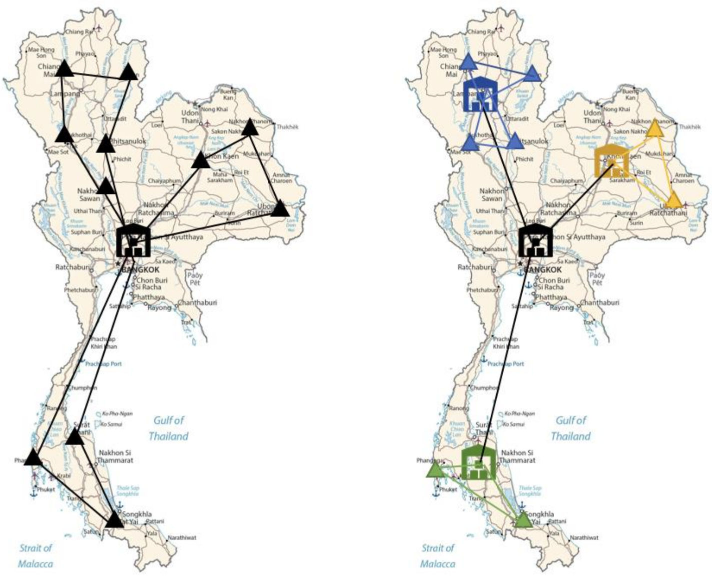

Figure 1.2 – Left: Current model, Right: Proposed model

1.2. OBJECTIVE

To determine the number and the location of distribution centres along with the corresponding number of vehicles at each distribution centre that gives the company the lowest investment cost, which includes transportation cost, vehicle maintenance cost and rental cost.

1.3. SCOPE

1.3.1. Actual monthly demand data for each customer and the monthly frequency of customer delivery were given by the company from fiscal year 2021 to 2023.

1.3.2. Limitation in daily demand data because it was calculated from the monthly demand and frequency.

1.3.3. The use of actual distance data taken from Google Maps based on the geographical location of customers.

1.3.4. The location of the headquarter in Pathumthani and the existing distribution centre in Nakhon Ratchasrima, and therefore, the cluster containing each of the two provinces was not examined.

1.3.5. Vehicles are company-owned vehicles. The company owns 12 vehicles which are 6-wheeled trucks of the same size and capacity, and it was assumed that all have the same maintenance cost.

1.4. METHODS

1.4.1. Investigate the demand trends and distribution

1.4.2. Understanding the problem the company is facing

1.4.3. Defining the objective and scope

1.4.4. Gathering all necessary data, such as distance data and related costs

1.4.5. Literature review to determine the methodology that was proven to give satisfying results for location-allocation

1.4.6. Defining the mathematical model for the problem

1.4.7. Preparing the thesis proposal

1.4.8. Presenting the thesis proposal

1.4.9. Forming Python script to utilise the mathematical model

1.4.10. Use the Python script to find the most appropriate solution to the problem

1.4.11. Calculating the cost-saving of each solution

1.4.12. Comparing the cost-benefit analysis for the optimal solution

1.4.13. Concluding research results

1.4.14. Preparing the final thesis

1.4.15. Presenting the final thesis

1.5. OUTPUT

The output from this research is the optimal number and locations for distribution centres and their corresponding number of vehicles to aid the company's investment decision. The optimal locations shall result in the lowest transportation and distribution centre rental costs.

1.6. BENEFIT

1.6.1. The conclusion from this research will be a guideline for the company to decide on the number of distribution centres and the corresponding locations to invest in. The mathematical model used in the research can also be modified for other uses by alternating the constraints.

1.6.2. Other companies facing similar problems of high logistic costs could also use this model to alleviate costs and increase delivery efficiency. Effective logistic planning would also promote additional cash flows to the company through the benefit of a decrease in working hours of the company employees, which reduces the company's expenses on overtime expenditure.

CHAPTER 2 - LITERATURE REVIEW

This research aims to identify the most strategic locations for potential investments in distribution centres. The correct selection of distribution centre locations allows the company to use its resources more efficiently by serving more customers within predefined timeframes. Efficient use of resources can significantly impact the company's competitiveness from improvement in customer satisfaction, and therefore, a method in finding the correct location is pivotal. This research will find the location of distribution centres using mathematic modelling optimisation.

2.1. MATHEMATICAL MODEL

Mathematical modelling is a process that uses mathematical functions to represent real-world scenarios. Given a scenario, it is transformed into a mathematical function of symbols representing that of the real-world [8-9]. Optimisation is a study to find the best possible solution to a given problem by maximising or minimising a mathematical function, known as the objective function. The objective function determines the goal of that optimisation problem; this could be to maximise profit, minimise cost, optimise resource allocation by minimising distance, and many more. Within the objective function, there will be a term commonly denoted as x. This is called the decision variable. The decision variable is an adjustable variable that will influence the output value of the objective function. An optimisation model aims to find the best value of the decision variable that will give the best possible value according to that objective function's goal, whether to find the largest or the smallest value possible. However, real-world problems are bound to limits, and therefore, within the optimisation models, there need to be constraints and limitations representing the problem's boundaries and restrictions. Examples of constraints could be budget constraints, resource availability, or capacity. The mathematical functions for constraints define what solution is feasible. In other words, the decision variable value should optimise the objective function while staying within these constraints' boundaries. Given the objective function and constraints, the mathematical model will iteratively find the correct decision variable value that will result in the optimal solution to the problem. Optimisation is employed in many industries to solve complex real-world problems such as manufacturing, finance, and logistics.

2.2. VEHICLE ROUTING PROBLEM (VRP)

In this research, a logistics optimisation technique known as VRP was studied. VRP is an optimisation model that finds the most efficient vehicle delivery routes to end customers [10-12]. Given a central depot node and customer node with corresponding demand, a VRP will calculate a route to each customer where every customer must be visited precisely only once and the best route is given based on the distance travelled. While VRP only solves for the most efficient routes to serve customers, CVRP also considers the vehicle's capacity limit by adding in a capacity constraint to ensure the capacity limit of the vehicle is not exceeded during the routing process.

A typical CVRP mathematical model would consist of [13]:

1. Objective function: To find the optimum route by either minimise transportation costs or travel distance
2. Decision variables: Binary variables that indicate whether a route or a vehicle is chosen, which will influence the value of the objective function solution
3. Parameters: Constant values that are part of the calculation to get a solution for the objective function, for example, the cost of fuel
4. Depot node and customer nodes: A depot node marks the start and end position for the vehicle, and customer nodes mark the set of customers with corresponding demands that must be fulfilled
5. Constraints: Boundaries must be set in a world where nothing is infinite. For example, a vehicle would have a finite capacity. Therefore, this constraint will limit the number of goods a vehicle can carry for each run to ensure that the total demand in one route does not exceed the vehicle capacity. Other constraints needed for a VRP model are the connectivity, degree, and sub-tour elimination constraints

A solution to a CVRP problem is a set of vehicle routes that gives minimum travel costs. Each route will start and end at the depot such that each customer is visited only once and by one vehicle, and as stated in the name, the capacities of vehicles must not be exceeded. CVRP can be solved using many approaches and applied in many industries. As a result, CVRP is an active area of research with many promising techniques being explored.

In a local context, Vanichchinchai and Apirakkhit [14] applied CVRP in a similar data set to this research. The delivery of grocery goods to different provinces throughout Thailand was studied using population data from individual provinces and distance data between provinces. Provinces with the lowest total transportation cost for shipping to end customers were identified by calculating intra-transportation distances within provinces using land area data, radius calculations, and distance data. The study also adopts freight rates for trucks at specific fuel prices and travel speeds, assuming that every route uses the same type of vehicles and the same product is being delivered. It was also pointed out by Typaldos et al. [15] that the travel cost of a vehicle is strongly related to fuel consumption and that it is crucial to have it as a parameter in the objective. The study identified that vehicles' driving and acceleration behaviour results in different fuel consumption. Considering the fluctuating customer demand and the importance of flexibility in delivery time, Stauss et al. studied VRP with the limitation of having flexible time slots for delivery to consider customer behaviour in the VRP formulation [16]. The method used in the study was the dynamic pricing model, which combines the tractable linear programming formulation, demand management decisions and routing cost implications together. The VRP model used a fixed number of same-sized trucks, each with a fixed capacity. It was concluded from the study that routing can be done on dynamic demand, which aids the idea of flexibility in delivery slots, which comes along with significant improvement in customer satisfaction and profitability.

Another VRP study by Borcinova demonstrated integer linear programming to solve two methods of CVRP and eliminate sub-tour constraints to prevent the result from forming a separate route not connected to the depot [17]. The first method of CVRP is the “Flow-Based Formulation” method, which uses a binary variable to indicate if a vehicle travels on an arc by giving it a value of 1 if it does. The aim is to minimise the total travel cost with constraints to ensure that each customer is visited exactly once, the capacity of vehicles is not exceeded, and sub-tours are eliminated. However, this CVRP method has many sub-tour elimination constraints; therefore, solving them all requires high computational power. The second CVRP method is the “Modified Assignment Formulation” method. This method also used binary variables to determine the used arc, but instead of minimising the total cost, it maximises the total travel savings. This results in fewer sub-tour elimination constraints and is more efficient and suitable for large data sets.

One of the main challenges faced when solving VRP is the complexity that comes with a large problem size. When the scale of the VRP problem is large, there are many customer nodes to consider, making the problem become out of hand. Along with the capacity constraint of the vehicle used in CVRP, the computational complexity of the optimisation model increased substantially. In optimisation like CVRP, where many variables and constraints are being considered, the problem complexity grows with the data size because more possible combinations and interactions between variables and constraints must be considered. As a result, the time required to find the optimal solution becomes very long, and this relation between problem size and time is not linear but exponential; this is called a combinatorial explosion [18-20]. A combinatorial explosion occurs when the number of possible solutions or combinations in an optimisation problem grows exponentially with the problem size because it has to explore all possible combinations of decision variables to find the optimal solution. Adding one more variable means all combination and permutation with the new variable included has to be considered.

Due to the problem of combinatorial explosions, it is extremely hard to obtain a global minimum from optimisation problems like VRP or Traveling Salesman (TSP). A simple approach used to reduce the workload of CVRP is to reduce the data set size before applying CVRP to it. Data size reduction can be done with clustering, which groups customers with similarities into distinct groups.

2.3. CLUSTERING

Clustering is the process of grouping unlabelled objects based on certain similarities. The technique of clustering used in this study was k-mean clustering. K-means is a commonly used clustering method because it has the advantage of simplicity, flexibility, and ease of implementation [21-23]. Additionally, it is easy to visualise k-means clustering groups. K-mean clustering groups data points by minimising the squared error sum between the cluster's empirical mean value and all points within that cluster. This also minimises the sum of that error for all clusters. The equation form of k-mean clustering is referred to in (1), where ∂_a is a set of sample points within a data set to be put into cluster B where B=1, …, b [24].

$$minimize \sum_{b \in B} \sum_{\partial_a \epsilon \rho_b} \| \partial_a - \mu_b \|^2 \quad (1)$$

2.4. VRP WITH CLUSTERING

By reducing the size of the information used in the optimisation process through clustering, the optimisation model can find the optimal solution faster. However, even with the help of other techniques in combination with CVRP, the difficulty in finding the true optimal solution remains. The optimisation algorithms are sometimes compelled to provide a near-optimal solution because achieving global optimal is not guaranteed [25].

Many past researches show that data clustering can effectively simplify the complexity of having a large problem set. Abdillah and Suyanto [26] proposed an effective solution to the complex CVRP by clustering nodes into groups using a hybrid evolutionary firefly algorithm (HEFA), a combination of Firefly Algorithm (FA) and Differential Evolution (DE). HEFA was used to find the optimal clusters to give the total value per cluster while staying within the vehicle capacity limit. In the clustering stage, vehicles were grouped into dense clusters for analysis, and these clusters were used as the initial population for CVRP analysis. Following the cluster stage, CVRP was used to search for routes with minimum cost from the depot within each cluster. To align with the capacity limits of CVRP, if a vehicle's capacity is exceeded, then selected locations are redistributed. The result from the simulations demonstrates that the clustered model through HEFA outperforms the original CVRP model as it reduces the problem size, which improves the optimisation result.

Similarly, Casazza et al. [27] used a branch-and-price algorithm to optimise the route for clustered data. The study focused on the relationship between the pickup and delivery VRP, where several vehicles are used at each node. The VRP optimisation aims to find vehicle routes, the order of customer visits, and the number of goods to be loaded and unloaded at each node while giving the lowest travel cost. The approach of generating clusters as the first step before applying CVRP was used to allow a simpler set of routes. It was found from the study that the smaller the number of nodes in a cluster, the more effective the algorithm performs, with the optimal number of nodes of ten to twenty. By decomposing vehicle routes into a sequence of clusters, it avoids the feasible solution not being reached from a combinatorial explosion. The method was shown to give promising results in optimising logistics networks.

Another approach to solving CVRP with the use of cross-dock facilities was proposed by Lo and Chuang [28]. Lo and Chuang aim to reduce operational costs and increase logistic management efficiency through cross-docking to promote faster response to customers' demands. To improve the relationship between the suppliers and the retailers, the study combines cross-docking operations and the optimal vehicle routing schedule into one. The planning of the logistic network used in this study was based on an artificial immune system with a combination of sweep methods. The research tackled the problem using a two-phase algorithm to solve VRP by first clustering to satisfy the capacity constraints of the vehicles, followed by routing using a mathematical programming model to find an optimal solution with the fewest vehicles used. In the objective function, two types of costs, transportation and operational costs, were considered.

A similar two-phase algorithm was used by Pan et al. [29]. The study used k-mean clustering to reduce the problem size and ant colony optimisation (ACO) to solve the CVRP problem with extra constraints of random change in demand. The study aimed to minimise the energy consumption due to transportation and simultaneously consider the effect of the variation in vehicle load and the fluctuation of customer demand, which is considered a random parameter. It was found that using a k-mean clustering algorithm improved the optimisation performance of the algorithm because the large-scale problem was decomposed into smaller-scale subproblems, which can be optimised more efficiently with VRP with a feedback algorithm, such as an ant colony algorithm.

Using a large data set, Alesiani et al. [30] used a constrained clustering CVRP approach to reduce the computational complexity that came with the original CVRP. The data set used in the study was a large-scale CVRP used in communication networks; therefore, a data scale reduction method was required. The k-mean clustering method was used to divide data into subgroups, and the constraints of the original CVRP problem were included by transforming the capacity constraints into one that can be used during the clustering process instead of during CVRP routing.

Given that the CVRP is classified under NP-hard problems, the performance of CVRP would be better when it is applied to smaller-size dataset problems. Therefore, the integration of clustering is beneficial for CVRP.

CHAPTER 3 - METHODOLOGY

The method used in this research is overviewed in Figure 3.1. The first stage was clustering. The customer locations are grouped based on their geographical location, where customer locations within the same area were grouped into smaller clusters using k-means clustering. The second stage is vehicle routing optimisation through the CVRP mathematical model, where the dock locations were determined from vehicle routing, resulting in the lowest cost.

For clustering, a GIS platform software called QGIS was used. QGIS is a Geographic Information System (GIS) software. It is a tool for solving geography-related problems such as location-based clustering. GIS also aids in the visualisation of those clustered points on a map. By putting the latitude and longitude of all customer locations into the software, k-mean clustering can be performed on those locations. Each group was labelled with a cluster ID number from 1 to N. Working on one cluster ID at a time reduces the number of locations that need to be considered in a single optimisation. This allows the optimisation algorithm to focus on optimising routes for small groups of customers rather than a large group of customers, which can significantly reduce the complexity and make the problem more manageable.

The results obtained from the clustering stage were then individually fed into IBM CPLEX to solve for the optimal distribution centre from potential distribution centre locations for each cluster ID by calculating each corresponding vehicle travelling cost through vehicle routing in the CVRP model. The objective function of this CVRP model contains the total vehicle travelling cost, including the cost to and from the headquarter, using the mathematical model in Section 2 of this Chapter.

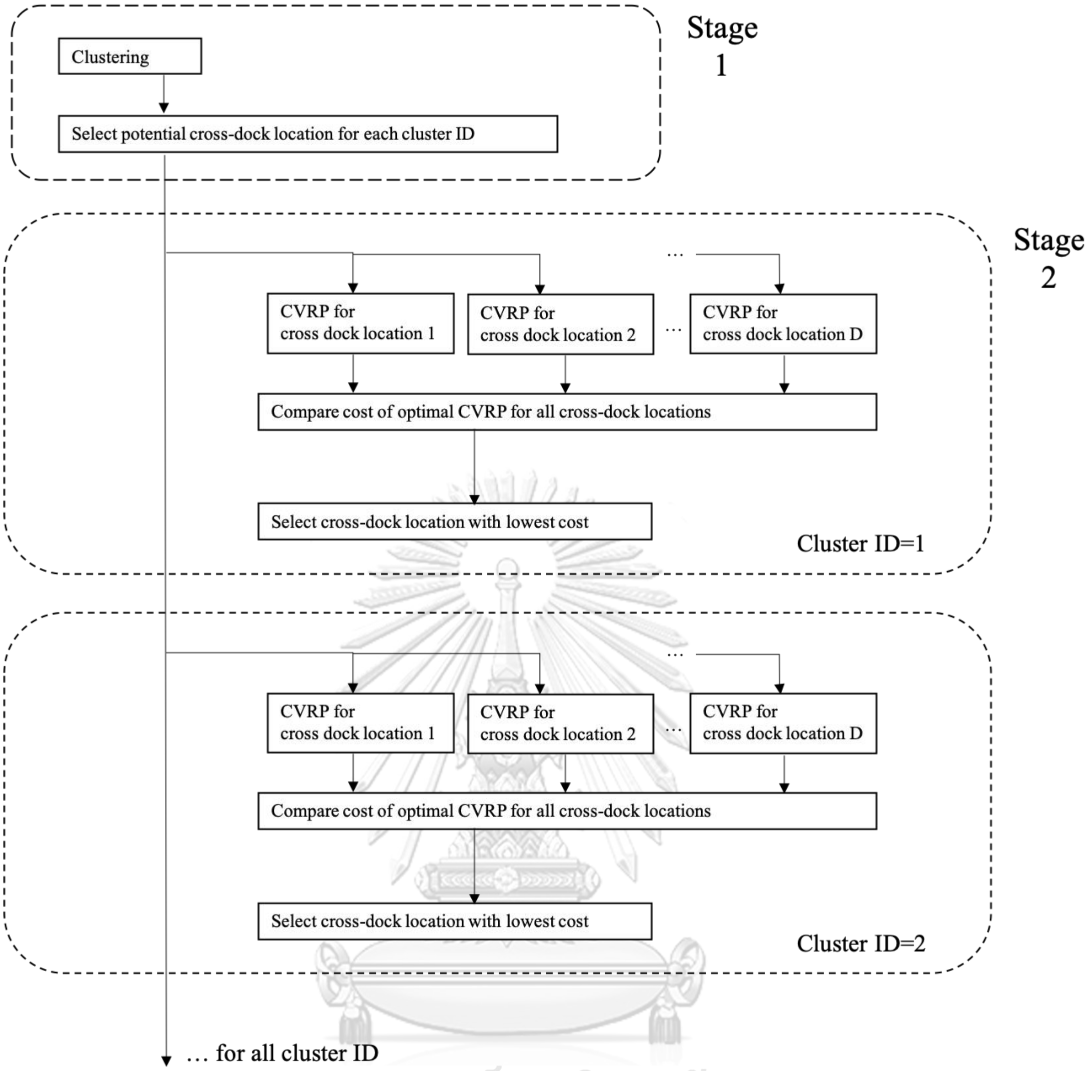

Figure 3.1 – Flowchart of the overall process

3.1. DATA ANALYSIS

The company provided data on customer demand and other data, such as distance between customers and fuel cost, used in this research are real-world data obtained from the web [31-34] to provide a solution that is as close to the real-world to aid the company with investment decision-making as much as possible.

3.1.1. DEMAND DATA

The data given by the company for this evaluation is traffic cone demand, which is the sales data for the fiscal year 2021 to 2023. The Thai government fiscal year starts in October of the previous year to September of the current year. An example of the demand data for a cluster group is shown in Table 3.1. In the data table, the province name of each customer was replaced with its abbreviation [35]. A table for the full province name and its corresponding abbreviation can be found in the Appendix.

Table 3.1 – Example of demand for a cluster example

Customer	Average monthly demand of traffic cone (piece)
CMI1	2,014
CMI2	1,006
CMI3	241
LPN	488
LPG1	755
LGP2	665
MSN	564
PRE	198
CRI1	659
CRI2	929
PYO	636
NAN1	520
NAN2	764
TAK1	671
TAK2	300
KPT	1,203
STI	551

PLK1	569
PLK2	1,241
PCK	499
UTT1	103
UTT2	627
PNB1	1,457
LEI1	264
LEI2	399

The sales of traffic cones for each highway district were recorded monthly. The demand in every province follows the same seasonal trend where the high demand seasons are wrapped around Thai national holidays, which are December-January for New Year and April for Songkran. Another high demand season is during the fiscal year-end time in August-September. The rest are considered low demand seasons, as shown in Figure 3.2. Demand data were used for CVRP analysis, but the numbers used in this report are modified for confidential purposes; however, the relative scale between the values remains the same.

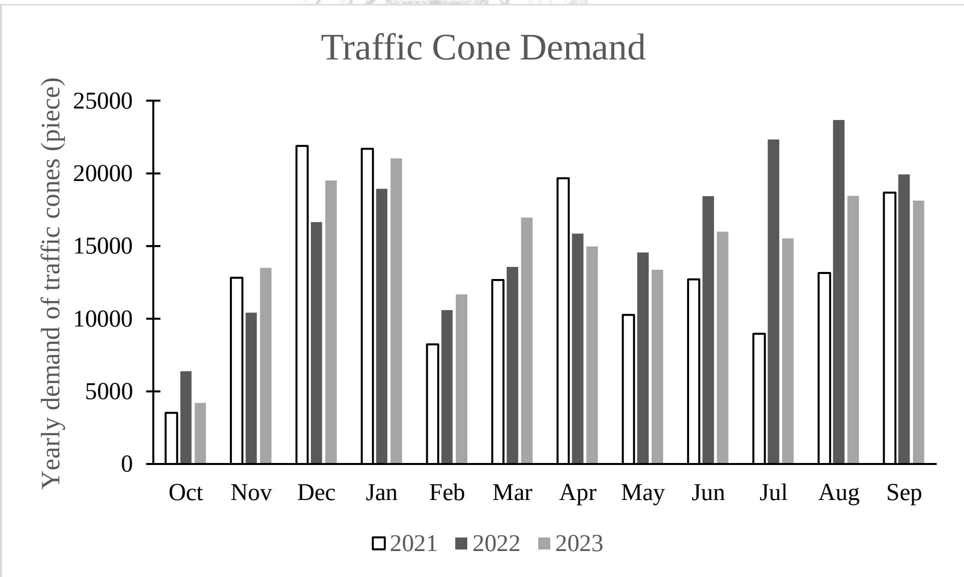

Figure 3.2 – Demand for Traffic cones in each month from 2021 to 2023

3.1.2. DELIVERY DATA

The frequency of delivery to each customer differs every month, and there are no distinct patterns apart from the higher number of deliveries during the high demand season and the lower number of deliveries during the low demand season. The number of deliveries to each customer for each month in 2021 is shown in Table 3.2. The frequency of delivery to each customer in a month range from 0 to 10. The average amount of deliveries per year for each customer was calculated to be 12, and the average amount of deliveries per month for each customer was 1.01. However, the data shows that different region has different frequency of delivery. Therefore, the demand frequency shall be calculated for each cluster individually.

Table 3.2 – Number of deliveries to each customer in Fiscal year 2021

Customers	Oct -20	Nov -20	Dec -20	Jan -21	Feb -21	Mar -21	Apr -21	May -21	Jun -21	Jul -21	Aug -21	Sep -21	Total
CMI1	0	0	1	3	0	0	0	2	1	4	1	5	17
CMI2	0	0	1	1	0	0	0	0	1	0	1	0	4
CMI3	1	0	0	1	2	0	1	1	1	1	0	0	8
LPN	0	1	1	1	0	2	3	2	2	1	2	0	15
LPG1	0	1	0	0	1	1	2	1	3	0	4	3	16
LGP2	0	0	1	0	1	0	2	1	1	4	0	2	12
MSN	0	0	0	0	1	1	2	0	2	1	0	3	10
PRE	0	0	0	1	0	0	0	0	0	1	0	0	2
CRI1	0	0	1	1	0	1	1	1	4	1	0	0	10
CRI2	0	0	1	3	1	1	2	1	0	2	0	1	12
PYO	0	1	1	2	1	1	1	2	0	1	0	1	11
NAN1	1	0	1	0	1	2	1	1	2	1	1	4	15
NAN2	0	1	0	0	0	1	1	0	1	2	3	1	10
SNK1	1	5	6	4	3	2	5	2	0	1	0	1	30
SNK2	0	0	0	0	1	0	1	0	1	1	1	0	5
NPM	0	2	0	4	1	3	0	2	1	2	2	0	17
NKI	0	0	1	4	4	1	3	2	0	0	2	1	18
BKN	1	5	5	2	4	3	3	4	5	4	3	2	41
MDH	0	1	1	1	0	0	1	1	1	1	0	0	7
TAK1	1	2	3	1	2	2	2	3	1	5	2	1	25
TAK2	2	2	3	2	3	1	1	0	0	2	4	4	24
KPT	0	1	2	1	1	1	1	3	5	4	3	2	24
STI	0	2	2	2	3	1	2	2	2	2	2	2	22
PLK1	0	0	3	4	1	2	2	5	1	3	1	4	26

PLK2	0	0	1	4	1	1	2	1	1	1	3	3	18
PCK	0	0	0	1	0	1	0	0	0	0	0	0	2
UTT1	0	0	0	1	0	1	1	0	2	1	2	1	9
UTT2	0	0	1	1	1	0	0	0	1	0	0	2	6
PNB1	0	1	1	4	0	3	0	1	4	1	2	2	19
PNB2	0	0	0	0	0	0	0	0	0	0	0	0	0
LEI1	0	0	2	2	0	0	0	0	0	1	0	1	6
LEI2	0	0	0	0	1	0	0	1	4	2	0	1	9
NBP	0	1	0	0	1	1	0	0	0	0	0	0	3
KKN1	0	0	0	1	1	1	1	1	0	2	0	3	10
KKN2	0	0	0	1	0	0	1	0	2	0	0	1	5
KKN3	0	0	0	0	0	1	1	1	0	0	0	0	3
UDN1	0	3	4	3	1	1	1	0	1	0	2	3	19
UDN2	0	0	0	0	0	0	0	0	0	0	0	0	0
CPM	0	0	0	0	2	1	1	3	1	1	0	1	10
MKM	0	0	0	1	0	0	1	0	0	1	0	0	3
YST	0	2	2	2	1	3	3	3	2	1	0	1	20
KSN	0	1	3	1	1	3	1	2	2	1	0	1	16
RET	1	0	2	2	1	2	3	0	2	1	2	1	17
UBN1	0	2	2	2	1	1	0	2	2	2	1	2	17
UBN2	1	0	0	0	1	1	2	0	0	2	1	0	8
SSK1	0	1	4	2	1	2	0	0	0	1	0	2	13
SSK2	0	0	0	0	0	0	0	0	0	0	0	0	0
SRN	0	0	0	0	0	0	0	0	0	0	0	0	0
ACR	1	2	1	1	1	0	4	1	1	2	3	0	17
NMA1	1	4	2	2	0	2	2	2	3	2	3	2	25
NMA2	2	1	7	6	3	3	2	3	7	4	2	1	41
NMA3	0	3	4	3	4	3	2	4	2	3	3	4	35
BRM	0	0	0	0	0	0	0	0	1	0	0	1	2
PRI	0	0	2	2	3	4	3	1	1	4	3	4	27
SKW	0	0	0	0	2	0	0	1	1	2	1	2	9
LRI1	0	1	3	6	2	5	4	4	4	4	4	2	39
LRI2	0	2	3	3	0	1	2	1	1	0	0	0	13
NSN1	0	1	3	0	0	1	0	1	1	0	0	1	8
NSN2	0	0	4	1	2	2	2	1	0	1	0	0	13
SRI	0	4	3	4	2	1	1	2	5	2	1	1	26
SBR	0	6	5	7	3	8	4	3	3	3	3	5	50
SPB1	1	2	2	1	1	2	2	2	2	1	2	2	20
SPB2	0	1	4	2	2	2	0	0	1	0	0	0	12
KRI	0	1	1	3	1	3	2	3	1	1	5	2	23
CNT	0	1	1	0	0	0	1	2	1	0	0	1	7
UTI	1	1	1	2	3	2	0	1	3	1	2	5	22
ATG	0	0	1	0	0	0	2	3	2	1	2	1	12

BKK	0	0	0	0	1	1	0	1	0	1	3	3	10
SKN	3	2	4	1	2	6	3	3	5	4	2	5	40
AYA	0	1	2	5	1	3	0	0	3	1	1	1	18
PTE	2	3	2	1	1	1	2	2	4	3	2	2	25
SPK	0	0	0	0	0	0	0	1	1	0	2	1	5
NBI	2	0	2	5	3	4	2	6	6	7	5	10	52
TNB	0	1	1	0	1	1	0	0	1	0	1	1	7
NYK	0	0	1	0	0	0	0	0	0	0	0	0	1
CBI1	0	0	0	0	1	2	1	1	1	1	1	2	10
CBI2	0	1	2	0	1	1	1	1	1	1	0	0	9
CCO	0	1	0	1	1	1	1	0	0	0	0	0	5
CTI	0	0	0	0	0	1	0	1	2	0	0	3	7
TRT	0	0	0	0	0	0	0	2	0	0	2	2	6
RYG	0	0	0	0	0	1	1	2	0	0	1	1	6
PKN	0	0	0	0	0	0	0	1	1	1	0	0	3
NPT	0	0	0	0	0	0	0	0	0	1	0	0	1
CPN	0	0	0	0	0	0	0	0	0	0	0	0	0
RBR	0	0	0	0	0	0	0	0	0	0	0	0	0
SKM	0	0	0	0	0	0	0	1	0	2	0	1	4
PBI	0	0	0	0	0	2	1	0	0	1	0	1	5
NRT1	0	2	1	2	0	0	1	0	0	0	0	0	6
NRT2	0	0	0	0	0	0	1	0	0	0	0	0	1
SNI1	0	0	0	0	0	0	0	0	0	0	0	0	0
SNI2	0	0	0	0	0	0	0	0	0	1	0	1	2
SNI3	0	0	0	0	0	0	0	0	0	0	1	0	1
KBI	0	0	0	0	0	0	0	0	3	0	3	0	6
PKT	0	1	1	0	3	1	1	0	0	1	1	0	9
RNG	0	0	0	0	0	1	1	1	0	1	3	0	7
TRG	0	0	0	0	0	0	0	0	0	0	0	0	0
PNA	0	0	0	0	0	0	0	0	1	1	0	1	3
PLG	0	0	0	0	0	0	0	0	0	0	0	0	0
SKA1	0	0	0	0	0	0	0	0	0	0	0	1	1
SKA2	0	0	0	0	0	0	0	0	0	4	2	1	7
YLA	0	0	0	0	0	1	1	0	0	1	2	2	7
PTN	0	0	0	0	0	0	0	1	0	0	0	1	2
NWT	0	0	0	0	0	0	0	0	0	1	0	0	1
STN	0	0	0	0	0	0	0	1	0	0	0	0	1

3.1.3. VEHICLE DATA

The cost calculation unit used in this mathematical model is in Thai Baht (THB), while the distance unit is in kilometres (km). The historical fuel price data shows that the fuel price in 2023 fluctuates around 30 THB. To consider inflation in fuel prices, the highest fuel price in the past few years was rounded up to the nearest ten THB, which is 40 THB. The average fuel cost is calculated to be 4 THB per km, assuming that vehicle fuel usage is 10 km per litre, and the fuel price is 40 THB per litre.

A typical truck can transport 1,500 units of traffic cones. To account for the transportation of other traffic safety products in each delivery, the number used for the capacity of a vehicle will be 2/3 of the total or 1,000 units of traffic cones. The company currently owns 12 trucks. Since no new vehicle must be purchased, the cost of the vehicle considered in the calculation is the hidden cost of owning a car. This includes maintenance, insurance, and oil transfer costs, which total approximately 3,500 THB.

For the analysis, the following assumptions and dependencies were made:

1. The infrastructure of the road and the difficulty of travelling between each city were not considered
2. All vehicles travel at the same constant speed of 80 km per hour, which is the maximum speed for trucks travelling across provinces as stated by the law
3. The cost of expressways, tolls or motorways was not considered
4. There is only one bidirectional route between each city, which is the shortest route, and no alternative route is available
5. The company's customers are government offices, and therefore, it is assumed that the government budget was not affected by COVID-19
6. All vehicle is of the same size with the same capacity.
7. The company owns all vehicles used, and therefore, only hidden cost for vehicle was considered

3.1.4. LOCATION DATA

The customer locations used were the latitude and longitude of each customer location taken from Google Maps. The distance between all locations was also retrieved from Google Maps by choosing the value of the shortest route available. An example of the distance data recorded between locations is shown in Table 3.3. Since land location could not be obtained for all provinces as land rent differs from owner to owner, unbiasedly, Amphur Muang of each province was used as the location of distribution centres. The distances between location i and location j used were the distance from location i to j; it is assumed that the distance is the same from i to j and from j to i.

Table 3.3 – Example of distance between nodes, in km

	DC	CMI1	CMI2	CMI3	LPN	LPG1	LGP2	MSN	PRE	CRI1	CRI2	PYO	NAN1	NAN2
DC		6	19	9	40	105	106	240	211	192	283	161	322	341
CMI1	6		13	10	36	102	102	241	208	188	279	158	318	337
CMI2	19	13		18	28	93	94	247	199	188	278	157	309	298
CMI3	9	10	18		41	106	107	232	212	191	281	160	322	301
LPN	40	36	28	41		74	75	262	179	212	302	181	290	309
LPG1	105	102	93	106	74		5	331	111	231	290	140	221	240
LGP2	106	102	94	107	75	5		330	108	231	290	140	219	238
MSN	240	241	247	232	262	331	330		441	418	509	387	552	567
PRE	211	208	199	212	179	111	108	441		231	289	140	111	130
CRI1	192	188	188	191	212	231	231	418	231		102	94	224	227
CRI2	283	279	278	281	302	290	290	509	289	102		157	264	243
PYO	161	158	157	160	181	140	140	387	140	94	157		154	157
NAN1	322	318	309	322	290	221	219	552	111	224	264	154		20
NAN2	341	337	298	301	309	240	238	567	130	227	243	157	20	

3.2. MATHEMATICAL MODEL

Using the data table containing distances between nodes, the best location for distribution centre was determined by finding the route with the lowest cost to aid the company in its decision-making regarding where to invest through CVRP. The following is the CVRP mathematical model modified from [36].

Notations:

J The set of customers, j = 1, 2, …, n

N The set of nodes, i = 0, 1, 2, …, n

(node 0 = distribution centre, node 1 - n = customers)

K The set of vehicles k = 1, 2, …p

Parameters:

Q The capacity of a vehicle, in piece

F Fuel price, in THB per km

q_j Demand at customer node j, in pieces per cycle

C_{ij} Distance from customer i to customer j, in km

M Fixed cost of using a vehicle, in THB

Decision Variables:

x_{ijk} 1 if vehicle k is used to travel from i to j, 0 otherwise

y_k 1 if that vehicle k is in use, 0 otherwise

u_j a variable that increments in demand at every node j it visits

Objective Function:

$$minimize\ Z = \sum_{i\in N}\sum_{j\in N}\sum_{k\in K} C_{ij}x_{ijk}F + \sum_{k\in K} y_k \mathrm{M} \quad (2)$$

Subjects to:

Degree constraints

$$\sum_{i\in N}\sum_{k\in K} x_{ijk} = 1 \qquad \forall j \in J \quad (3)$$

$$x_{iik} = 0 \qquad \forall \mathrm{k} \in \mathrm{K}, i \in N \quad (4)$$

$$\sum_{j\in J} x_{0jk} = y_k \qquad \forall k \in K \quad (5)$$

Connectivity constraints

$$\sum_{i \in N} x_{ijk} = \sum_{i \in N} x_{jik} \qquad \forall\, j \in N, k \in K \quad (6)$$

Capacity constraints

$$\sum_{i \in N} \sum_{j \in J} q_j x_{ijk} \leq Q y_k \qquad \forall k \in K \quad (7)$$

Subtour elimination constraints

$$u_j - u_i \geq q_j - Q\left(1 - x_{ijk}\right) \quad \forall k \in K, i \in N, j \in J, i \neq j \quad (8)$$

$$q_j \leq u_j \leq Q \qquad \forall j \in N \quad (9)$$

Where

$$x_{ij} \in \{0,1\}$$
$$y_k \in \{0,1\}$$
$$u_0 = 0$$

This mathematical model aims to determine the optimal routing from a given potential distribution centre location. The objective function (2) aims to find the optimum set of routes resulting in the shortest total travelling distance while using the lowest number of vehicles to serve all customers within a cluster. This also results in optimal location allocation for the distribution centre. The objective function value is based on the cost of travelling to each customer, calculated by multiplying the total distance travelled by F, the average fuel cost, the cost of travelling from the headquarters to the province where the distribution centre is located, and the cost of vehicles where M is the monthly cost of a vehicle.

The decision variable $\boldsymbol{x_{ijk}}$ determines whether a route is decided from one node to another. If that route was used, that arc value is set to 1. On the other hand, if there is no route between the two nodes, that arc value is set to 0. The variable $\boldsymbol{u_j}$ is an extra variable from the Miller-Tucker-Zemlin formulation [38], which eliminates potential subtours resulting from CVRP formulations.

Equations (3) to (5) are the degree constraints. The constraints referred to in (3) set the sum of the decision variable $\boldsymbol{x_{ijk}}$ to 1 for all customer nodes to ensure that all customer is reached by the vehicle to be marked as a complete routing and that all customers must be visited only once. Similarly, the constraints in (4) ensure that once a customer is visited by a vehicle, the vehicle departs from that node and does not return to the customer node it has already visited. The constraints in (5) are for vehicles to be utilised. If vehicle k leaves the depot, $\boldsymbol{y_k}$ is assigned to 1. Equations in (6) are the connectivity constraint. These constraints ensure that the inflow and the outflow to a node are from the same vehicle by setting both the left and right side of the equation to the decision variable $\boldsymbol{x}$ with different subscription orders of nodes. Equations in (7) are the capacity constraint key to a CVRP optimisation model. The constraints referred to in (7) ensure that the sum of the demand of all customers in a route does not exceed the capacity limit of the vehicle serving that route.

Lastly, the constraints referred to in (8) are subtour elimination constraint. The value of the decision variable $\boldsymbol{u_j}$ is an incrementable demand which increments in value every time it visits a customer node. It takes the value of that customer node and adds that to its current value, and therefore, its value increases, making it greater than the previous node it visits to ensure that it does not drive in a circle. Constraint referred to in (9) supports constraint (8) by ensuring the highest possible value of $\boldsymbol{u_j}$ is Q, the vehicle capacity limit, and the lowest possible value is $\boldsymbol{q_j}$ to allow each side to be 0.

Even with data clustering, the number of combinations needed for this problem set is still significant. Therefore, a stop condition is set to prevent computing optimisation for a prolonged time. Several ways to use force to stop the never-ending search are reducing tolerance, setting a limit to the number of nodes and setting a time limit. A time limit was chosen to obtain an answer as close to the optimal solution as possible in a reasonable time window to allow the optimisation model to discover all the small changes and reduce the chance of the optimisation model returning a suboptimal solution. The time limit was set to one hour. After an hour of computing, the model will return the best solution it has so far. This time was chosen from trial and error. When ten random sample was chosen to run CVRP on for time from an hour to two hours with an increment of fifteen minutes, there was no change in the optimising result. Furthermore, location-allocation optimisation is not a time-dependent problem; it does not require an answer to be provided quickly, and therefore, the timing was set only to allow all the required values to be obtained for analytic purposes. In practice, more time can be given to find the true optimal.

Within a cluster ID, one at a time, each province was set as the depot node to obtain the objective cost of having a distribution centre in that province. The optimisation model is repeated for all possible provinces within a cluster by replacing the location of the depot location, which changes the respecting distance in each run. The result obtained from this change does not affect one another. After obtaining the optimal result of each potential distribution centre location, the objective value was put together and compared, and the one with the minimum cost was chosen.

CHAPTER 4 - RESULTS

4.1. CLUSTERING

The number of cluster IDs examined for this research was four, five and six; the three cluster results are shown in Figures 4.1, 4.2 and 4.3. The circle represents customer location, the square represents the headquarter, and the triangle represents the distribution centre in Nakhon Ratchasima. The number of customer nodes for each cluster set is shown in Table 4.1.

The number of clusters of four, five and six were chosen based on the geographic shape of Thailand. Since there is already a headquarter in Pathumthani and a distribution centre at Nakhon Ratchasrima to cover the remaining region, at least two more distribution centres will be required, one in the northern part and one in the southern part. Therefore, four was the lowest possible number of clusters. Three clusters were not examined because the result groups the headquarters in Pathumthani and the existing distribution centre in Nakhon Ratchasima together in a cluster, which is not ideal. When customers were clustered into six clusters instead of five, the southern customers were split into two groups. This is not ideal since the demand in the south is much lower compared to other regions of Thailand, and therefore, the number of clusters to be considered in this study is four and five.

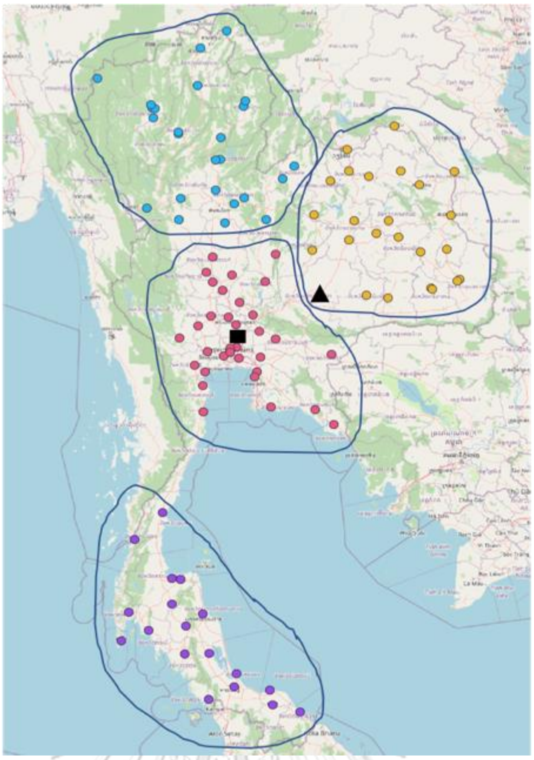

Figure 4.1 – Clustering of customer locations for four clusters

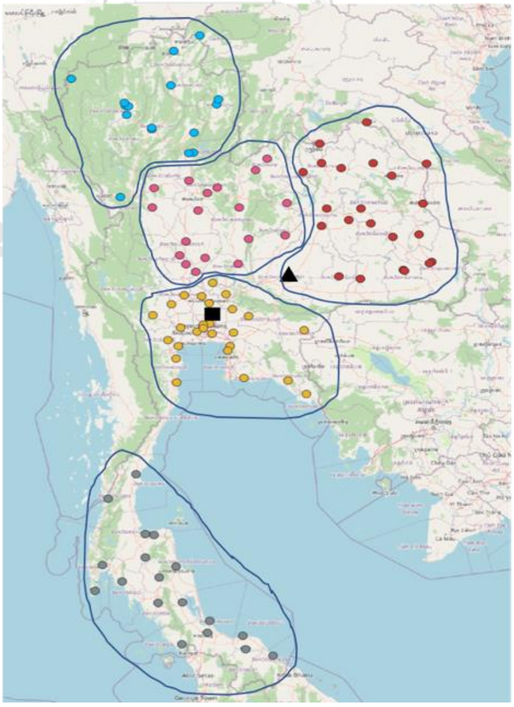

Figure 4.2 – Clustering of customer locations for five clusters

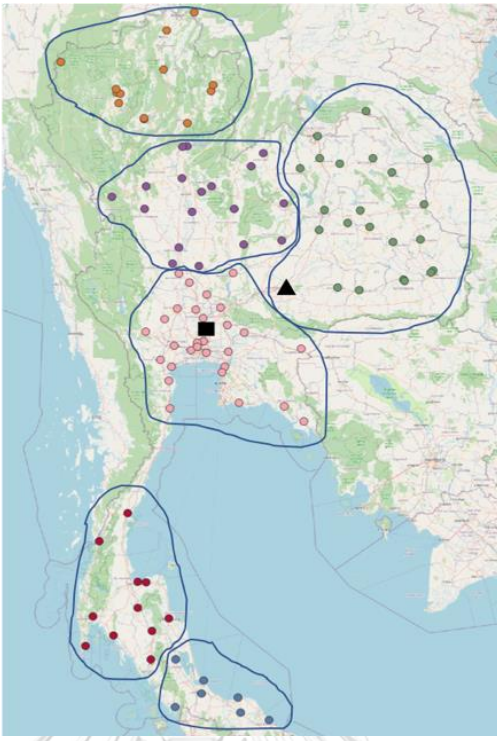

Figure 4.3 – Clustering of customer locations for six clusters

Table 4.1 – Number of customer nodes within each cluster

	Size of a cluster ID					
Number of clusters	ID = 1	ID = 2	ID = 3	ID = 4	ID = 5	ID = 6
4	25	27	34	18		
5	13	25	30	18	18	
6	13	25	30	18	11	7

Tables 4.2, 4.3 and 4.4 shows the clustering result for all clusters. The "Cluster ID" column indicates which of the five distinct clusters each customer location belongs to, and the "Cluster Size" column displays the number of customers in each cluster ID. Grouping customer locations into distinct clusters provided a better understanding of the geographic customer distribution across Thailand, and these clustered groups are the size-reduced dataset to be fed into CVRP optimisation in the next stage.

Table 4.2 – k -mean clustering output of customers for four clusters

Cluster ID	Customers	Cluster Size	Demand (Piece)
1	CMG1, CMG2, CMG 3, LPN, LPG1, LPG2, MSN, PRE, CRI1, CRI2, PYO, NAN1, NAN2, TAK1, TAK2, KPT, STI, PLK1, PLK2, PCK, UTT1, UTT2, PNB1, LEI1, LEI2	25	17,323
2	NMA1, NMA 2, NMA3, SNK1, SNK2, NPM, NKI, BKN, MDH, NBP, KKN1, KKN2, KKN3, UDN1, UDN2, MKM, YST, KSN, RET, UBN1, CPM, UBN2, SSK1, SSK2, SRN, ACR, BRM	27	17,022
3	PRI, SKW, LRI1, LRI2, SRI, SBR, SPB1, SPB2, KRI, CNT, ATG, BKK, SKN, AYA, PTE, SPK, NBI, TNB, NYK, CBI1, CBI2, CCO, CTI, TRT, RYG, PKN, NPT, RBR, SKM, PBI, PNB2, NSN1, NSN2, UTI	34	26,354
4	CPN, NRT1, NRT2, SNI1, SNI 2, SNI 3, KBI, PKT, RNG, TRG, PNA, PLG, SKA1, SKA2, YLA, PTN, NWT, STN	18	7,401

Table 4.3 – k -mean clustering output of customers for five clusters

Cluster ID	Customers	Cluster Size	Demand (Piece)
1	CMG1, CMG2, CMG 3, LPN, LPG1, LPG2, MSN, PRE, CRI1, CRI2, PYO, NAN1, NAN2	13	9,439
2	NMA1, NMA 2, NMA3, SNK1, SNK2, NPM, NKI, BKN, MDH, NBP, KKN1, KKN3, UDN1, UDN2, MKM, YST, KSN, RET, UBN1, UBN2, SSK1, SSK2, SRN, ACR, BRM	25	15,190
3	PRI, SKW, LRI1, LRI2, SRI, SBR, SPB1, SPB2, KRI, CNT, ATG, BKK, SKN, AYA, PTE, SPK, NBI, TNB, NYK, CBI1, CBI2, CCO, CTI, TRT, RYG, PKN, NPT, RBR, SKM, PBI	30	22,485
4	TAK1, TAK2, KPT, STI, PLK1, PLK2, PCK, UTT1, UTT2, PNB1, LEI1, LEI2, KKN2, PNB1, PNB2, NSN1, NSN2, UTI	18	13,585
5	CPN, NRT1, NRT2, SNI1, SNI 2, SNI 3, KBI, PKT, RNG, TRG, PNA, PLG, SKA1, SKA2, YLA, PTN, NWT, STN	18	7,401

Table 4.4 – k -mean clustering output of customers for six clusters

Cluster ID	Customers	Cluster Size	Demand (Piece)
1	CMG1, CMG2, CMG 3, LPN, LPG1, LPG2, MSN, PRE, CRI1, CRI2, PYO, NAN1, NAN2	13	9,439
2	NMA1, NMA 2, NMA3, SNK1, SNK2, NPM, NKI, BKN, MDH, NBP, KKN1, KKN3, UDN1, UDN2, MKM, YST, KSN, RET, UBN1, UBN2, SSK1, SSK2, SRN, ACR, BRM	25	15,190
3	PRI, SKW, LRI1, LRI2, SRI, SBR, SPB1, SPB2, KRI, CNT, ATG, BKK, SKN, AYA, PTE, SPK, NBI, TNB, NYK, CBI1, CBI2, CCO, CTI, TRT, RYG, PKN, NPT, RBR, SKM, PBI	30	22,485
4	TAK1, TAK2, KPT, STI, PLK1, PLK2, PCK, UTT1, UTT2, PNB1, LEI1, LEI2, KKN2, PNB1, PNB2, NSN1, NSN2, UTI	18	13,585
5	CPN, NRT1, NRT2, SNI1, SNI 2, SNI 3, KBI, PKT, RNG, TRG, PNA	11	4,673
6	PLG, SKA1, SKA2, YLA, PTN, NWT, STN	7	2,728

Using the delivery data from Table 3.2, the average monthly deliveries for four and five clusters were calculated as shown in Table 4.5. The headquarter of the company is located in Pathumthani, which was grouped in cluster ID=3 and the existing distribution centre in Nakhon Ratchasima was grouped in cluster ID=2 since the two clusters already have a hub where the products will be distributed to customers; no analysis was done for cluster ID=2 and 3.

The demands used in the CVRP stage were demand per cycle which was calculated by dividing the total monthly demand by the average delivery frequencies for each cluster to give the approximate daily demand. For example, for the four clusters, the average number of deliveries to cluster ID=1 is fourteen; therefore, the monthly demand is divided by fourteen. Demand per cycle was used for the CVRP analysis because of the inconsistency in the customers' ordering patterns. To ensure that demand is met for each delivery, the CVRP was analysed to give a route covering the demand per order of each customer in the cluster for the worst-case scenario where all customers order simultaneously.

Table 4.5 – Average number of deliveries to each cluster ID per month

Four clusters		Five clusters	
Cluster ID	The average frequency of delivery per month	Cluster ID	The average frequency of delivery per month
1	14	1	9
2	16	2	16
3	17	3	16
4	5	4	13
		5	5

4.2. VEHICLE ROUTING

CVRP optimisation was done through the IBM CPLEX algorithm through Python to determine the optimum routes from each distribution centre to all customers within each cluster. Using the mathematical model in Section 3, the variable J is the number of customers within the cluster ID, and variable N is J+1 as it includes the distribution centre location to the 0^{th} node. The variable K is set to 12, which is the number of vehicles the company owns. The parameter Q representing the capacity vehicle was set to 1,000 to occupy 2/3 of the total capacity. The parameter F, representing the fuel price per km, was set to 4. The parameter q is the demand for each customer, which is the monthly demand divided by the average frequency of delivery per month of each cluster ID. Lastly, distance parameter C is a matrix of distance between each node. Tables containing all values for q and C can be found in the Appendix.

The solution to a CVRP problem will be a set of routes, where each route is dedicated to one vehicle, which will serve all customers on that tour. The objective value for each potential distribution centres location was found by inputting a data table of the distance between each location and routing the vehicle for the route with the lowest cost by multiplying the distance with the fuel cost. When all value of the arc is set, the objective value or the cost of having a particular distribution centre at that province and the cost of travelling to and from the headquarter to that distribution centre location was calculated for all possible distribution centre locations within that cluster.

After calculating the objective cost for each possible distribution centre location within the cluster, the one with the minimum objective cost was chosen. HQ stands for the headquarter in Pathumthani. The chosen distribution centre location resulting in the lowest cost is marked in bold text. Since the headquarter of the company is located in Pathumthani, cluster ID=3 was set to be served by the headquarter. The existing distribution centre in Nakhon Ratchasima will serve the customers cluster ID=2, and therefore, the distribution centre location was also manually set to be Nakhon Ratchasima. The CVRP was done on cluster ID=1 and 4 for four clusters and cluster ID=1,4 and 5 for five clusters since no investment decision is required for cluster ID=2 and 3 for both four and five clusters. The CVRP objective costs are shown in Table 4.6 and Table 4.7.

Table 4.6 – Objective values for potential distribution centre facilities for four clusters

Cluster ID=1	
Distribution centre Location	Objective Solution (THB)
Chiangmai	22,548
Lamphun	22,252
Lampang	22,368
Mae Hong Sorn	25,604
Phrae	22,140
Chiangrai	24,284
Phayao	23,080
Nan	23,196
Tak	20,684
Kamphaeng Phet	20,312
Sukothai	20,704
Phitsanulok	**19,972**
Phichit	20,052
Uttaradit	21,624
Phetchabun	21,008
Loei	22,824
Cluster ID=2	
Distribution centre Location	Objective Solution (THB)
Nakorn Ratchasrima	N/A
Cluster ID=3	
Distribution centre Location	Objective Solution (THB)
Pathumthani	N/A
Cluster ID=4	
Distribution centre Location	Objective Solution (THB)
Chumphon	**20,948**

Nakhon Si Thammarat	22,060
Surat Thani	21,108
Krabi	22,096
Phuket	23,620
Ranong	22,112
Trang	22,180
Pangnga	22,160
Phattalung	22,400
Songkla	23,192
Yala	24,784
Pattani	24,576
Narathiwat	26,120
Satun	23,680

Note: No CVRP analysis were done for cluster ID=2 and 3 because there is already a hub and therefore was denoted as N/A

Table 4.7 – Objective values for potential distribution centres for five clusters

Cluster ID=1	
Distribution centre Location	Objective Solution (THB)
Chiangmai	14,476
Lamphun	14,188
Lampang	**14,068**
Mae Hong Sorn	16,036
Phrae	14,084
Chiangrai	15,332
Phayao	14,512
Nan	15,040
Cluster ID=2	
Distribution centre Location	Objective Solution (THB)
Nakorn Ratchasrima	N/A
Cluster ID=3	
Distribution centre Location	Objective Solution (THB)
Pathumthani	N/A
Cluster ID=4	
Distribution centre Location	Objective Solution (THB)
Tak	13,152
Kamphaeng Phet	12,644
Sukothai	13,708
Phitsanulok	13,012
Phichit	12,640
Uttaradit	14,104
Phetchabun	12,792
Loei	14,700

Khon Kaen	13,836
Chaiyaphum	12,528
Nakhon Sawan	**11,852**
Uthai Thani	11,916
Cluster ID=5	
Distribution centre Location	Objective Solution (THB)
Chumphon	**20,948**
Nakhon Si Thammarat	22,060
Surat Thani	21,108
Krabi	22,096
Phuket	23,620
Ranong	22,112
Trang	22,180
Pangnga	22,160
Phattalung	22,400
Songkla	23,192
Yala	24,784
Pattani	24,576
Narathiwat	26,120
Satun	23,680

Note: No CVRP analysis were done for cluster ID=2 and 3 because there is already a hub and therefore was denoted as N/A

The output of the CVRP analysis was plotted on a graph for each cluster. Plotting of results allowed a more comprehensive and intuitive representation of the most efficient and cost-effective route to delivering goods to all customers within a cluster. The routing for each distribution centre is shown in Figures 4.4 to 4.8. The figures display the customer locations as circular points, the distribution centre location as a red triangular point, and the x and y axes represent the longitude and latitude, respectively. The location of customers and potential dock used actual latitude and longitude coordinates.

Note: Eventhough the real distance between provinces was used for route calculations, a straight-line was drawn on the plot for a more straightforward presentation of the routes.

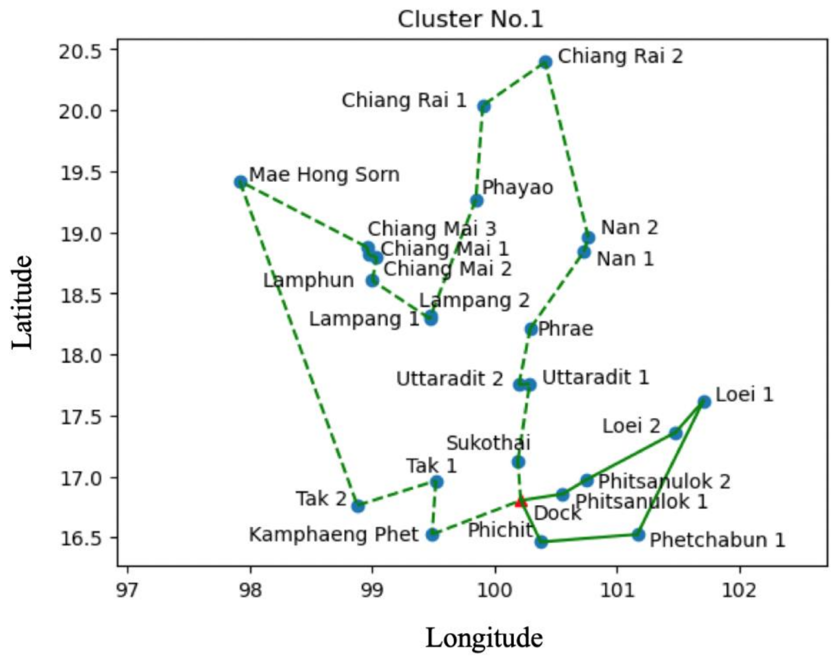

Figure 4.4 – Routing of Cluster ID=1 in four clusters

Phitsanulok is the province with the lowest objective for cluster ID=1 in four clusters. Figure 4.4 shows the optimised route of the cluster. The corresponding number of vehicles required to serve the demand with the distribution centre located in Phitsanulok is two, and the route for each vehicle is as follows:

Phitsanulok distribution centre → Sukothai →Uttaradit 1 → Uttaradit 2 → Phrae → Nan 1 → Nan 2 → Chiangrai 2→ Chiangrai 1 → Phayao → Lampang 2 → Lampang 1 → Lamphun → Chiangmai 2 → Chiangmai 1 → Chiangmai 3 → Mae Hong Sorn → Tak 2 → Tak 1 → Kampaeng Phet → Phitsanulok distribution centre

Phitsanulok distribution centre → Phitsanulok 1 → Phitsanulok 2 → Loei 2 → Loei 1 → Phetchabun 1 → Phichit → Phitsanulok distribution centre

Note: Eventhough the real distance between provinces was used for route calculations, a straight-line was drawn on the plot for a more straightforward presentation of the routes.

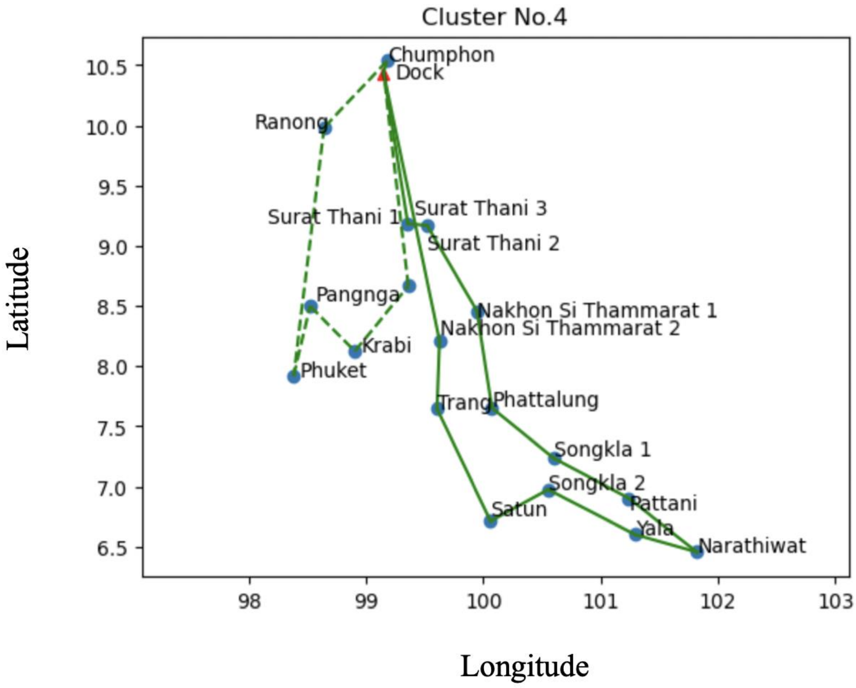

Figure 4.5 – Routing of Cluster ID=4 in four clusters

Chumphon is the province with the lowest objective for cluster ID=4 in four clusters. Figure 4.5 shows the optimised route of the cluster. The corresponding number of vehicles required to serve the demand with the distribution centre facility located in Chumphon is two, and the route for each vehicle is as follows:

Chumphon distribution centre → Nakhon Si Thammarat 2 → Trang → Satun → Songkla 1 → Pattani → Narathiwat → Yala → Songkla 2 → Phattalung → Nakhon Si Thammarat 1 → Surat Thani 2 → Surat Thani 1 → Chumphon distribution centre

Chumphon distribution centre → Surat Thani 3 → Krabi → Pangnga → Phuket → Ranong → Chumphon → Chumphon distribution centre

Note: Eventhough the real distance between provinces was used for route calculations, a straight-line was drawn on the plot for a more straightforward presentation of the routes.

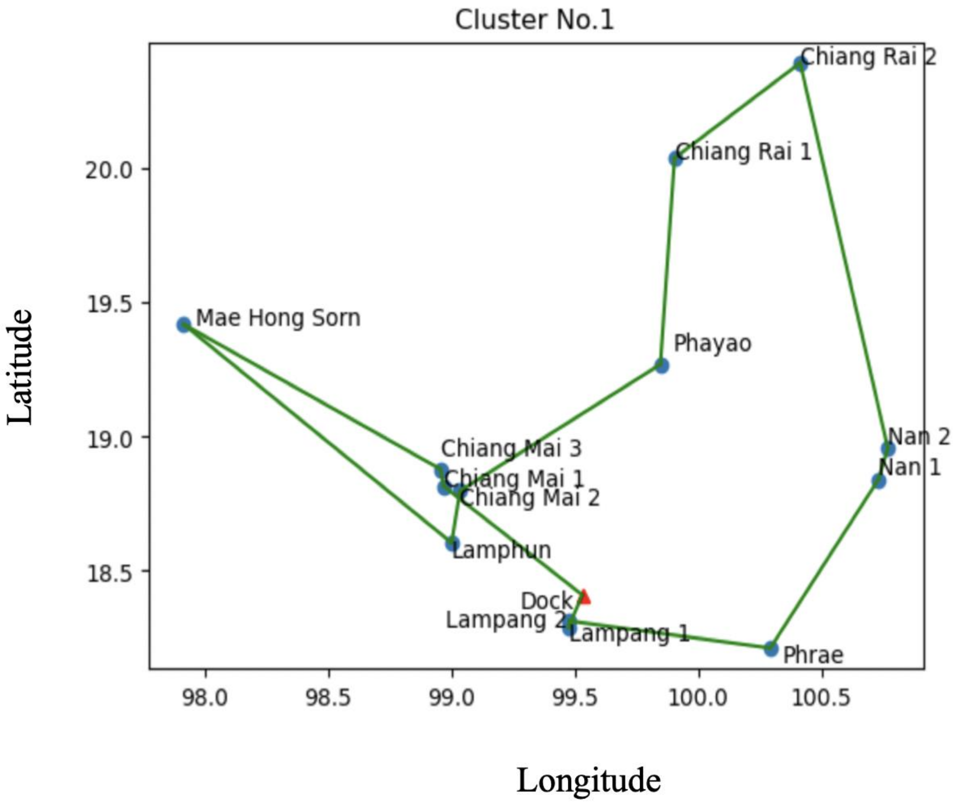

Figure 4.6 – Routing of Cluster ID=1 in five clusters

Lampang is the province with the lowest objective for cluster ID=1 in five clusters. Figure 4.6 shows the optimised route of the cluster. The corresponding number of vehicles required to serve the demand with the distribution centre facility located in Lampang is one, and the route for the vehicle is as follows:

Lampang distribution centre → Lampang 1 → Lampang 2 → Phrae → Nan 1 → Nan 2 →Chiangrai 2 → Chiangrai 1 →Phayao → Chiangmai 2 → Lamphun → Mae Hong Sorn →Chiangmai 3 → Chiangmai 1 → Lampang distribution centre

Note: Eventhough the real distance between provinces was used for route calculations, a straight-line was drawn on the plot for a more straightforward presentation of the routes.

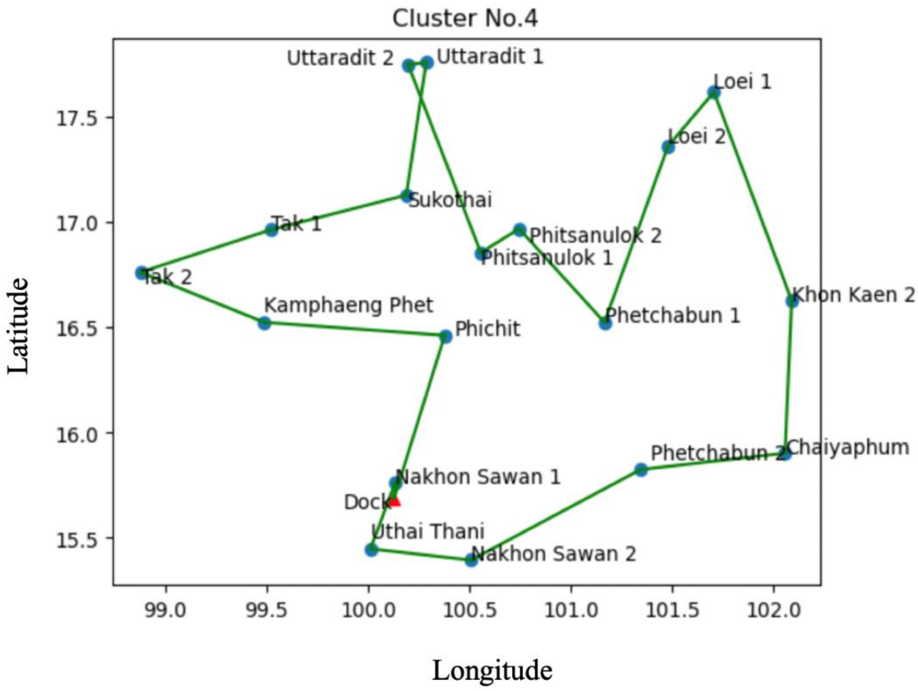

Figure 4.7 – Routing of Cluster ID=4 in five clusters

Nakhon Sawan is the province with the lowest objective for cluster ID=4 in five clusters. Figure 4.7 shows the optimised route of the cluster. The corresponding number of vehicles required to serve the demand with the distribution centre located in Nakhon Sawan is one, and the route for the vehicle is as follows:

Nakhon Sawan distribution centre → Phichit → Kampaeng Phet → Tak 2 → Tak 1 → Sukothai → Uttaradit 1 → Uttaradit 2 → Phitsanulok 1 → Phitsanulok 2 →Phetchabun 1 → Loei 2 → Loei 1 → Khon Kaen 2 → Chaiyaphum → Phetchabun 2 →Nakhon Sawan 2 → Uthai Thani → Nakhon Sawan 1 → Nakhon Sawan distribution centre

Note: Eventhough the real distance between provinces was used for route calculations, a straight-line was drawn on the plot for a more straightforward presentation of the routes.

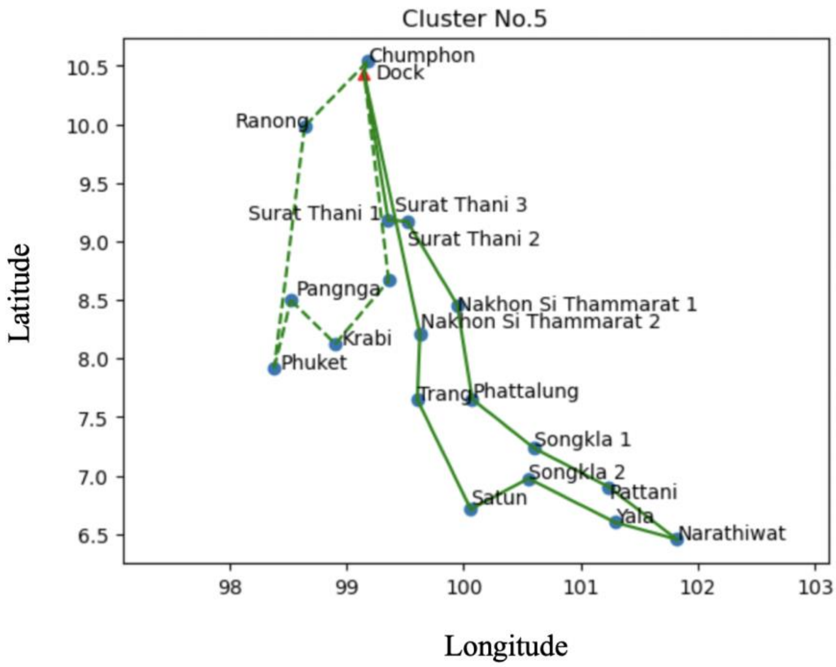

Figure 4.8 – Routing of Cluster ID=5 in five clusters

Chumphon is the province with the lowest objective for cluster ID=5 in five clusters. This is the same as cluster ID=4 in four clusters. Figure 4.8 shows the optimised route of the cluster. The corresponding number of vehicles required to serve the demand with the distribution centre located in Chumphon is two, and the route for each vehicle is as follows:

Chumphon distribution centre → Nakhon Si Thammarat 2 → Trang → Satun → Songkla 1 → Pattani → Narathiwat → Yala → Songkla 2 → Phattalung → Nakhon Si Thammarat 1 → Surat Thani 2 → Surat Thani 1→ Chumphon distribution centre

Chumphon distribution centre → Surat Thani 3 → Krabi → Pangnga → Phuket → Ranong → Chumphon → Chumphon distribution centre

4.3. OVERALL RESULTS AND DISCUSSION

The CVRP optimisation model shows that the optimal locations for distribution centres the company should consider investing in are Lampang, Nakhon Sawan and Chumphon for four clusters and Phitsanulok and Chumphon for five clusters. Apart from the transportation cost, another important factor that needs to be considered is the rental cost of distribution centres in each province. Using rental prices collected from thaihometown.com, the monthly rental cost for commercial buildings of approximately 100 m^2 in size in selected Amphur Muang are shown in Table 4.8.

Table 4.8– Rental cost for the distribution centre in each province

Four clusters		Five clusters	
Distribution centre location	Rental cost per month (THB)	Distribution centre location	Rental cost per month (THB)
Phitsanulok	9,000	Lampang	4,500
Chumphon	7,500	Nakhon Sawan	8,000
		Chumphon	7,500

The expected monthly cost for exploiting each distribution centre is shown in Table 4.9 for four clusters and Table 4.10 for five clusters. The transportation cost was calculated by multiplying the objective solution by the average frequency of monthly delivery. Comparing the cost from four clusters and five clusters, the final investment cost is lower in four clusters than in five clusters. Therefore, it could be concluded that four clusters would result in a better cost-saving plan than five clusters.

Table 4.9 – Expected monthly cost for each distribution centre for four clusters

Distribution centre location	Monthly cost (THB)	
Phitsanulok	Transportation	181,608
	Vehicle Maintenance	7,000
	Rent	9,000
Chumphon	Transportation	69,740
	Vehicle Maintenance	7,000
	Rent	7,500
	Total	281,848 THB

Table 4.10 – Expected monthly cost for each distribution centre for five clusters

Distribution centre location	Monthly cost (THB)	
Lampang	Transportation	95,112
	Vehicle Maintenance	3,500
	Rent	4,500
Nakhon Sawan	Transportation	108,576
	Vehicle Maintenance	3,500
	Rent	8,000
Chumphon	Transportation	69,740
	Vehicle Maintenance	7,000
	Rent	7,500
	Total	307,428 THB

One of the significant advantages of distribution centres would be the reduction of distance between the headquarter and the distribution centres. In other words, instead of having to travel every time from the headquarter to customers, the distance between the headquarter and the distribution centre, which accounts for the majority of the distance between headquarter and customers, only has to be travelled at a certain number of times as illustrated in Figure 4.9. For clarification, using cluster ID=1 from five clusters as an example, instead of having to travel to the customer in that cluster nine times a month from the headquarter, if the distribution centre is filled up, for example, once a month, then the distance between headquarter and the distribution centre will only have to be carried out once.

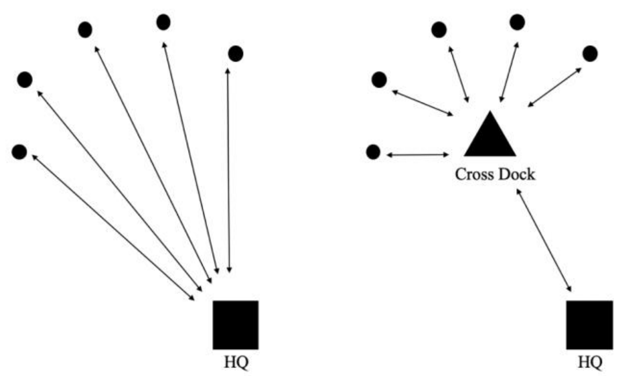

Figure 4.9 – Illustration of the saving of transportation distance

To compare the current and the proposed model, the current transportation cost where all products are being shipped from the headquarter was compared to the transportation cost where products are being shipped from the distribution centre within each cluster. This was calculated based on the product being shipped without routing, or in other words, each trip of the vehicle only contains one customer. The vehicle travels from its starting hub to the customer, then back to the hub. This calculation was done to fairly compare the transportation cost with the current model since in the current model there was no vehicle routing involved. The result is shown in Table 4.11. It compares the cost where every customer is being visited once. For the current model, the cost consists of the sum of all distance from the customer to the headquarter multiplied by two for back-and-forth travel and by four, which is the chosen fuel price for the analysis. For the proposed model, the costs were separated into clusters. In each cluster, the sum of all distances from the customer to the distribution centre is added with the distance between the distribution centre and the headquarter multiplied again by two and four. The vehicle maintenance cost was not included in the comparison because it is the same for both cases.

Table 4.11 – Transportation cost comparison between the current and the proposed model

Current Model			Proposed Model		
Delivering from	Transportation Cost (THB)	Rental Cost (THB)	Delivering from	Transportation Cost (THB)	Rental Cost (THB)
Pathumthani (HQ)	360,680	-	Phitsanulok	49,936	9,000
			Nakorn Ratchasrima	60,024	-
			Pathumthani (HQ)	35,016	-
			Chumpon	55,128	7,500
Total	360,680 THB		Total	216,604 THB	

From Table 4.11, when the current model is used, the transportation cost to serve all customers is 360,680 THB, while when the proposed model is used, the transportation cost is reduced significantly to 216,604 THB. This was realised from the reduction in the total transportation distance to reach all customers. Using a distribution centre would allow the company to save approximately 40% on its transportation costs. The company could profit even more from planning the number of trips products from the headquarter would have to fill up the distribution centre to fulfil the surrounding demand. The lower the number of times the distribution centre must be filled up, the more the company would save on transportation costs.

CHAPTER 5 - CONCLUSION

5.1. CONCLUSION

The company in focus of this research have been facing extensive logistic cost due to long-distance travel to deliver products from the headquarter to its customers located all over Thailand. The company proposed an idea of the usage of distribution centres to act as a midpoint of the delivery to alleviate the logistic cost. The objective of this thesis was to determine the number and the location of those midpoints, or so-called distribution centres, along with the corresponding number of vehicles at each distribution centre that gives the company the lowest investment cost. The problem was decomposed into two parts. The first part was clustering to group customer locations based on their geographic characteristic using k-mean clustering. The second was routing vehicles through CVRP optimisation. Each clustered group was analysed through the CVRP model using customer demand data and actual distance data to determine the optimal routes corresponding to distribution centre locations with the lowest travelling cost. As a result of the analysis, the distribution centres that result in the lowest investment cost determined by the CVRP are Phitsanulok, Pathumthani, Nakhon Ratchasrima and Chumphon for four clusters and Lampang, Pathumthani, Nakhon Ratchasrima, Nakhon Sawan and Chumphon for five clusters. By comparing the transportation cost of utilising distribution centres and the amount of money the company could save, it was concluded that investing in four clusters provides a higher beneficial response than investing in five clusters. Investment in the four clusters model means the company to alleviate the company's operational costs in the long run will include having two additional distribution centres in Phitsanulok and Chumphon, with two vehicles fixate at each.

5.2. RECOMMENDATION

The investment in two new distribution centres in Phitsanulok and Chumphon, which were chosen to have the lowest transportation cost to surrounding customers, is recommended because it could significantly save the company's transportation costs and allow for a faster response to customer demand. Phitsanulok is located roughly in the centre of northern Thailand, enabling further expansion. Similarly, Chumphon is located roughly in the middle between the headquarter and the dense group of customers in southern Thailand. Investing in Chumphon can, in the future, connect to the potential investment in a distribution centre in the more southern part of Thailand. Therefore, this thesis recommends that the company follow the four clusters model, which contains the headquarter in Pathumthani, the existing distribution centre in Nakhon Ratchasrima and two new distribution centres in Phitsanulok and Chumphon.

5.3. LIMITATION

The routing was carried out based on the total demand in a month divided by the average frequency of delivery per month; this does not reflect the actual scenario when an order is placed and when it is preferred for the product to be delivered as soon as possible. Some of the customer locations have 0 demand but were also considered in the routing and were forced to visit by the vehicle for future potential market gain. In addition, using daily data for analysis would mean the data set will become much more extensive. A more sophisticated method would be required to solve larger data sets with dynamic demand; those methodologies shall be explored in future research. The trade-off between the ease of visiting a province and the rental price, how large the province is, and the difference in land price between a more developed province was not considered in this thesis. Since the travel cost dominates the land rental cost in the analysis, the possibility of the land price potentially changing the optimisation solution was assumed to be low.

Though it was calculated that the proposed model could save up to 40% in the transportation cost, when put into practice, there would be other costs that need to be taken into consideration, such as the operating cost of having a distribution centre and the labour cost of requiring someone to locate at the distribution centre. Also, fixing vehicles at distribution centres could lead to a shortage of vehicles at the headquarter. These limitations shall be put into consideration for actual implementation because it could add up on top of the initial investment.

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APPENDIX

Appendix A – Latitude and longitude of customers and English Abbreviation

Customer Office Name	Latitude	Longitude	Abbreviation
Chiang Mai 1	18.8152237	98.96924355	CMI1
Chiang Mai 2	18.7972984	99.03479204	CMI2
Chiang Mai 3	18.87863634	98.95613386	CMI3
Lamphun	18.60413604	99.00128948	LPN
Lampang 1	18.28932993	99.4750226	LPG1
Lampang 2	18.31279023	99.47726898	LGP2
Mae Hong Sorn	19.41933174	97.91568153	MSN
Phrae	18.21133557	100.29165	PRE
Chiang Rai 1	20.03918902	99.90389674	CRI1
Chiang Rai 2	20.39457652	100.4128212	CRI2
Phayao	19.26997139	99.84690968	PYO
Nan 1	18.84005202	100.729453	NAN1
Nan 2	18.95667228	100.7677077	NAN2
Sakon Nakhon 1	17.24271524	104.1203304	SNK1
Sakon Nakhon 2	17.52093698	103.7586111	SNK2
Nakhon Phanom	17.51064003	104.7843822	NPM
Nong Khai	17.95801359	102.7220422	NKI
Bueng Kan	18.44523424	103.6344388	BKN
Mukdahan	16.6126033	104.7195967	MDH
Tak 1	16.96407357	99.52055639	TAK1
Tak 2	16.76257454	98.87809972	TAK2
Kamphaeng Phet	16.52463456	99.48816367	KPT
Sukothai	17.12924492	100.190007	STI

Phitsanulok 1	16.85560078	100.5571251	PLK1
Phitsanulok 2	16.96923738	100.746083	PLK2
Phichit	16.46251484	100.3789649	PCK
Uttaradit 1	17.75854061	100.2873995	UTT1
Uttaradit 2	17.75044447	100.1981387	UTT2
Phetchabun 1	16.52463456	101.1671891	PNB1
Phetchabun 2	15.82465174	101.3453494	PNB2
Loei 1	17.61872885	101.7070686	LEI1
Loei 2	17.36126879	101.4803192	LEI2
Nong Bua Lamphu	17.32004144	102.3981144	NBP
Khon Kaen 1	16.50393021	102.8570121	KKN1
Khon Kaen 2	16.62812301	102.0903831	KKN2
Khon Kaen 3	16.11012899	102.7598339	KKN3
Udon Thani 1	17.52093699	102.7652325	UDN1
Udon Thani 2	17.41278991	103.1431484	UDN2
Chaiyaphum	15.90254948	102.0579905	CPM
Maha Sarakham	16.24959622	103.2875624	MKM
Yasothon	15.87002975	104.1420133	YST
Kalasin	16.49875377	103.5264628	KSN
Roi et	16.16961194	103.706727	RET
Ubon Ratchathani 1	15.30668741	104.8914602	UBN1
Ubon Ratchathani 2	15.27078723	104.8491678	UBN2
Si Sa Ket 1	15.12712522	104.3399671	SSK1
Si Sa Ket 2	15.09772778	104.3568841	SSK2
Surin	14.9212579	103.5076523	SRN
Amnat Charoen	15.91654607	104.6471604	ACR
Nakhon Ratchasima 1	14.98440934	102.1105952	NMA1
Nakhon Ratchasima 2	14.98440934	102.1119042	NMA2
Nakhon Ratchasima 3	14.94169457	102.1568292	NMA3

Buriram	14.97682894	103.1016451	BRM
Prachin Buri	14.08689472	101.3502693	PRI
Sa Kaeo	13.7713343	102.4223635	SKW
Lop Buri 1	14.83915399	100.6568691	LRI1
Lop Buri 2	15.26010551	101.1423071	LRI2
Nakhon Sawan 1	15.76286272	100.1351058	NSN1
Nakhon Sawan 2	15.39386904	100.5082656	NSN2
Saraburi	14.57723905	100.9144485	SRI
Sing Buri	15.07524443	100.3299414	SBR
Suphan Buri 1	14.55486593	100.1020828	SPB1
Suphan Buri 2	14.35660547	99.86431723	SPB2
Kanchanaburi	14.10052613	99.50436658	KRI
Chai Nat	15.24736166	100.1351058	CNT
Uthai Thani	15.44798701	100.0129207	UTI
Ang Thong	14.53568718	100.4455219	ATG
Bangkok	13.91437865	100.5932148	BKK
Samut Sakhon	13.73662322	100.3567439	SKN
Ayutthaya	14.37276385	100.5880281	AYA
Pathum Thani	14.13553675	100.6161247	PTE
Samut Prakan	13.68633114	100.6470531	SPK
Nonthaburi	13.89102796	100.4763744	NBI
Thonburi	13.80983821	100.4740834	TNB
Nakhon Nayok	14.23500397	101.0399358	NYK
Chonburi 1	13.41683934	100.9895561	CBI1
Chonburi 2	13.3087346	100.9414453	CBI2
Chachoengsao	13.71304089	101.0605768	CCO
Chanthaburi	12.63792835	102.1065622	CTI
Trat	12.33960303	102.4707286	TRT
Rayong	12.69933746	101.2576019	RYG

Prachuap Khiri Khan	12.59201777	99.96338616	PKN
Nakhon Pathom	13.82839068	100.0422537	NPT
Chumphon	10.53612535	99.17743886	CPN
Ratchaburi	13.54869588	99.78880041	RBR
Samut Songkhram	13.41446959	99.99148402	SKM
Phetchaburi	13.13419696	99.94565963	PBI
Nakhon Si Thammarat 1	8.456617346	99.94503312	NRT1
Nakhon Si Thammarat 2	8.212336401	99.62525363	NRT2
Surat Thani 1	9.184047524	99.35559378	SNI1
Surat Thani 2	9.167747317	99.52070875	SNI2
Surat Thani 3	8.66587801	99.35955449	SNI3
Krabi	8.123892665	98.90339845	KBI
Phuket	7.91667221	98.38140545	PKT
Ranong	9.983706299	98.64174188	RNG
Trang	7.646431001	99.60409178	TRG
Pangnga	8.498478656	98.52248464	PNA
Phattalung	7.65342218	100.0720044	PLG
Songkla 1	7.23608482	100.5963488	SKA1
Songkla 2	6.974759673	100.5516737	SKA2
Yala	6.601186257	101.2899882	YLA
Pattani	6.902402582	101.2382591	PTN
Narathiwat	6.45401346	101.8190351	NWT
Satun	6.710953416	100.0602479	STN

Appendix B – Distance for customer in 4 clusters, Cluster ID=1, Dock=Chiangmai

	DC CMI	CMI1	CMI2	CMI3	LPN	LPG1	LGP2	MSN	PRE	CRI1	CRI2	PYO	NAN1	NAN2	TAK1	TAK2	KPT	STI	PLK1	PLK2	PCK	UTT1	UTT2	PNB1	LEI1	LEI2
DC CMI		6	19	9	40	105	106	240	211	192	283	161	322	341	283	364	354	314	349	356	412	246	238	491	483	402
CMI1	6		13	10	36	102	102	241	208	188	279	158	318	337	279	361	350	310	345	352	408	242	235	487	480	398
CMI2	19	13		18	28	93	94	247	199	188	278	157	309	298	270	352	342	301	336	344	399	233	226	478	471	389
CMI3	9	10	18		41	106	107	232	212	191	281	160	322	301	283	365	355	315	349	357	412	246	239	492	484	403
LPN	40	36	28	41		74	75	262	179	212	302	181	290	309	251	332	322	282	317	324	380	214	207	459	452	370
LPG1	105	102	93	106	74		5	331	111	231	290	140	221	240	180	262	251	211	248	255	311	145	138	390	383	301
LGP2	106	102	94	107	75	5		330	108	231	290	140	219	238	184	265	255	215	246	253	309	143	136	388	381	299
MSN	240	241	247	232	262	331	330		441	418	509	387	552	567	468	391	529	486	541	586	630	476	469	699	714	632
PRE	211	208	199	212	179	111	108	441		231	289	140	111	130	230	312	254	168	181	189	245	79	72	324	316	235
CRI1	192	188	188	191	212	231	231	418	231		102	94	224	227	413	494	484	404	418	425	481	315	308	560	553	471
CRI2	283	279	278	281	302	290	290	509	289	102		157	264	243	471	552	542	462	476	483	539	373	366	618	611	529
PYO	161	158	157	160	181	140	140	387	140	94	157		154	157	320	401	391	311	325	332	388	222	215	467	460	378
NAN1	322	318	309	322	290	221	219	552	111	224	264	154		20	342	423	368	277	291	298	354	188	181	433	426	344
NAN2	341	337	298	301	309	240	238	567	130	227	243	157	20		360	442	381	295	309	317	372	206	199	451	444	362
TAK1	283	279	270	283	251	180	184	468	230	413	471	320	342	360		83	73	88	146	169	174	164	174	303	368	286
TAK2	364	361	352	365	332	262	265	391	312	494	552	401	423	442	83		143	169	227	250	244	245	255	363	449	368
KPT	354	350	342	355	322	251	255	529	254	484	542	391	368	381	73	143		93	115	140	107	175	185	226	339	258
STI	314	310	301	315	282	211	215	486	168	404	462	311	277	295	88	169	93		59	82	126	93	101	216	280	199
PLK1	349	345	336	349	317	248	246	541	181	418	476	325	291	309	146	227	115	59		27	82	110	113	161	225	144
PLK2	356	352	344	357	324	255	253	586	189	425	483	332	298	317	169	250	140	82	27		72	118	121	135	199	117
PCK	412	408	399	412	380	311	309	630	245	481	539	388	354	372	174	244	107	126	82	72		173	177	120	270	189
UTT1	246	242	233	246	214	145	143	476	79	315	373	222	188	206	164	245	175	93	110	118	173		11	252	245	163
UTT2	238	235	226	239	207	138	136	469	72	308	366	215	181	199	174	255	185	101	113	121	177	11		256	248	167
PNB1	491	487	478	492	459	390	388	699	324	560	618	467	433	451	303	363	226	216	161	135	120	252	256		189	111
LEI1	483	480	471	484	452	383	381	714	316	553	611	460	426	444	368	449	339	280	225	199	270	245	248	189		85
LEI2	402	398	389	403	370	301	299	632	235	471	529	378	344	362	286	368	258	199	144	117	189	163	167	111	85	

Appendix C – Distance for customer in 4 clusters, Cluster ID=1, Dock=Lamphun

	DC LPN	CMI1	CMI2	CMI3	LPN	LPG1	LGP2	MSN	PRE	CRI1	CRI2	PYO	NAN1	NAN2	TAK1	TAK2	KPT	STI	PLK1	PLK2	PCK	UTT1	UTT2	PNB1	LEI1	LEI2
DC LPN		35	29	41	8	67	68	271	173	213	303	182	283	302	244	326	316	276	310	318	373	207	200	453	445	364
CMI1	35		13	10	36	102	102	241	208	188	279	158	318	337	279	361	350	310	345	352	408	242	235	487	480	398
CMI2	29	13		18	28	93	94	247	199	188	278	157	309	298	270	352	342	301	336	344	399	233	226	478	471	389
CMI3	41	10	18		41	106	107	232	212	191	281	160	322	301	283	365	355	315	349	357	412	246	239	492	484	403
LPN	8	36	28	41		74	75	262	179	212	302	181	290	309	251	332	322	282	317	324	380	214	207	459	452	370
LPG1	67	102	93	106	74		5	331	111	231	290	140	221	240	180	262	251	211	248	255	311	145	138	390	383	301
LGP2	68	102	94	107	75	5		330	108	231	290	140	219	238	184	265	255	215	246	253	309	143	136	388	381	299
MSN	271	241	247	232	262	331	330		441	418	509	387	552	567	468	391	529	486	541	586	630	476	469	699	714	632
PRE	173	208	199	212	179	111	108	441		231	289	140	111	130	230	312	254	168	181	189	245	79	72	324	316	235
CRI1	213	188	188	191	212	231	231	418	231		102	94	224	227	413	494	484	404	418	425	481	315	308	560	553	471
CRI2	303	279	278	281	302	290	290	509	289	102		157	264	243	471	552	542	462	476	483	539	373	366	618	611	529
PYO	182	158	157	160	181	140	140	387	140	94	157		154	157	320	401	391	311	325	332	388	222	215	467	460	378
NAN1	283	318	309	322	290	221	219	552	111	224	264	154		20	342	423	368	277	291	298	354	188	181	433	426	344
NAN2	302	337	298	301	309	240	238	567	130	227	243	157	20		360	442	381	295	309	317	372	206	199	451	444	362
TAK1	244	279	270	283	251	180	184	468	230	413	471	320	342	360		83	73	88	146	169	174	164	174	303	368	286
TAK2	326	361	352	365	332	262	265	391	312	494	552	401	423	442	83		143	169	227	250	244	245	255	363	449	368
KPT	316	350	342	355	322	251	255	529	254	484	542	391	368	381	73	143		93	115	140	107	175	185	226	339	258
STI	276	310	301	315	282	211	215	486	168	404	462	311	277	295	88	169	93		59	82	126	93	101	216	280	199
PLK1	310	345	336	349	317	248	246	541	181	418	476	325	291	309	146	227	115	59		27	82	110	113	161	225	144
PLK2	318	352	344	357	324	255	253	586	189	425	483	332	298	317	169	250	140	82	27		72	118	121	135	199	117
PCK	373	408	399	412	380	311	309	630	245	481	539	388	354	372	174	244	107	126	82	72		173	177	120	270	189
UTT1	207	242	233	246	214	145	143	476	79	315	373	222	188	206	164	245	175	93	110	118	173		11	252	245	163
UTT2	200	235	226	239	207	138	136	469	72	308	366	215	181	199	174	255	185	101	113	121	177	11		256	248	167
PNB1	453	487	478	492	459	390	388	699	324	560	618	467	433	451	303	363	226	216	161	135	120	252	256		189	111
LEI1	445	480	471	484	452	383	381	714	316	553	611	460	426	444	368	449	339	280	225	199	270	245	248	189		85
LEI2	364	398	389	403	370	301	299	632	235	471	529	378	344	362	286	368	258	199	144	117	189	163	167	111	85	

Appendix D – Distance for customer in 4 clusters, Cluster ID=1, Dock=Lampang

	DC LPG	CMI1	CMI2	CMI3	LPN	LPG1	LGP2	MSN	PRE	CRI1	CRI2	PYO	NAN1	NAN2	TAK1	TAK2	KPT	STI	PLK1	PLK2	PCK	UTT1	UTT2	PNB1	LEI1	LEI2
DC LPG		101	95	107	75	1	3	332	111	232	291	141	221	240	202	284	273	236	264	272	328	162	154	407	399	318
CMI1	101		13	10	36	102	102	241	208	188	279	158	318	337	279	361	350	310	345	352	408	242	235	487	480	398
CMI2	95	13		18	28	93	94	247	199	188	278	157	309	298	270	352	342	301	336	344	399	233	226	478	471	389
CMI3	107	10	18		41	106	107	232	212	191	281	160	322	301	283	365	355	315	349	357	412	246	239	492	484	403
LPN	75	36	28	41		74	75	262	179	212	302	181	290	309	251	332	322	282	317	324	380	214	207	459	452	370
LPG1	1	102	93	106	74		5	331	111	231	290	140	221	240	180	262	251	211	248	255	311	145	138	390	383	301
LGP2	3	102	94	107	75	5		330	108	231	290	140	219	238	184	265	255	215	246	253	309	143	136	388	381	299
MSN	332	241	247	232	262	331	330		441	418	509	387	552	567	468	391	529	486	541	586	630	476	469	699	714	632
PRE	111	208	199	212	179	111	108	441		231	289	140	111	130	230	312	254	168	181	189	245	79	72	324	316	235
CRI1	232	188	188	191	212	231	231	418	231		102	94	224	227	413	494	484	404	418	425	481	315	308	560	553	471
CRI2	291	279	278	281	302	290	290	509	289	102		157	264	243	471	552	542	462	476	483	539	373	366	618	611	529
PYO	141	158	157	160	181	140	140	387	140	94	157		154	157	320	401	391	311	325	332	388	222	215	467	460	378
NAN1	221	318	309	322	290	221	219	552	111	224	264	154		20	342	423	368	277	291	298	354	188	181	433	426	344
NAN2	240	337	298	301	309	240	238	567	130	227	243	157	20		360	442	381	295	309	317	372	206	199	451	444	362
TAK1	202	279	270	283	251	180	184	468	230	413	471	320	342	360		83	73	88	146	169	174	164	174	303	368	286
TAK2	284	361	352	365	332	262	265	391	312	494	552	401	423	442	83		143	169	227	250	244	245	255	363	449	368
KPT	273	350	342	355	322	251	255	529	254	484	542	391	368	381	73	143		93	115	140	107	175	185	226	339	258
STI	236	310	301	315	282	211	215	486	168	404	462	311	277	295	88	169	93		59	82	126	93	101	216	280	199
PLK1	264	345	336	349	317	248	246	541	181	418	476	325	291	309	146	227	115	59		27	82	110	113	161	225	144
PLK2	272	352	344	357	324	255	253	586	189	425	483	332	298	317	169	250	140	82	27		72	118	121	135	199	117
PCK	328	408	399	412	380	311	309	630	245	481	539	388	354	372	174	244	107	126	82	72		173	177	120	270	189
UTT1	162	242	233	246	214	145	143	476	79	315	373	222	188	206	164	245	175	93	110	118	173		11	252	245	163
UTT2	154	235	226	239	207	138	136	469	72	308	366	215	181	199	174	255	185	101	113	121	177	11		256	248	167
PNB1	407	487	478	492	459	390	388	699	324	560	618	467	433	451	303	363	226	216	161	135	120	252	256		189	111
LEI1	399	480	471	484	452	383	381	714	316	553	611	460	426	444	368	449	339	280	225	199	270	245	248	189		85
LEI2	318	398	389	403	370	301	299	632	235	471	529	378	344	362	286	368	258	199	144	117	189	163	167	111	85	

Appendix E – Distance for customer in 4 clusters, Cluster ID=1, Dock=Mae Hong Sorn

	DC MSN	CMI1	CMI2	CMI3	LPN	LPG1	LGP2	MSN	PRE	CRI1	CRI2	PYO	NAN1	NAN2	TAK1	TAK2	KPT	STI	PLK1	PLK2	PCK	UTT1	UTT2	PNB1	LEI1	LEI2
DC MSN		267	271	272	247	322	323	41	428	457	548	427	538	557	453	376	514	471	526	573	615	462	455	707	700	613
CMI1	267		13	10	36	102	102	241	208	188	279	158	318	337	279	361	350	310	345	352	408	242	235	487	480	398
CMI2	271	13		18	28	93	94	247	199	188	278	157	309	298	270	352	342	301	336	344	399	233	226	478	471	389
CMI3	272	10	18		41	106	107	232	212	191	281	160	322	301	283	365	355	315	349	357	412	246	239	492	484	403
LPN	247	36	28	41		74	75	262	179	212	302	181	290	309	251	332	322	282	317	324	380	214	207	459	452	370
LPG1	322	102	93	106	74		5	331	111	231	290	140	221	240	180	262	251	211	248	255	311	145	138	390	383	301
LGP2	323	102	94	107	75	5		330	108	231	290	140	219	238	184	265	255	215	246	253	309	143	136	388	381	299
MSN	41	241	247	232	262	331	330		441	418	509	387	552	567	468	391	529	486	541	586	630	476	469	699	714	632
PRE	428	208	199	212	179	111	108	441		231	289	140	111	130	230	312	254	168	181	189	245	79	72	324	316	235
CRI1	457	188	188	191	212	231	231	418	231		102	94	224	227	413	494	484	404	418	425	481	315	308	560	553	471
CRI2	548	279	278	281	302	290	290	509	289	102		157	264	243	471	552	542	462	476	483	539	373	366	618	611	529
PYO	427	158	157	160	181	140	140	387	140	94	157		154	157	320	401	391	311	325	332	388	222	215	467	460	378
NAN1	538	318	309	322	290	221	219	552	111	224	264	154		20	342	423	368	277	291	298	354	188	181	433	426	344
NAN2	557	337	298	301	309	240	238	567	130	227	243	157	20		360	442	381	295	309	317	372	206	199	451	444	362
TAK1	453	279	270	283	251	180	184	468	230	413	471	320	342	360		83	73	88	146	169	174	164	174	303	368	286
TAK2	376	361	352	365	332	262	265	391	312	494	552	401	423	442	83		143	169	227	250	244	245	255	363	449	368
KPT	514	350	342	355	322	251	255	529	254	484	542	391	368	381	73	143		93	115	140	107	175	185	226	339	258
STI	471	310	301	315	282	211	215	486	168	404	462	311	277	295	88	169	93		59	82	126	93	101	216	280	199
PLK1	526	345	336	349	317	248	246	541	181	418	476	325	291	309	146	227	115	59		27	82	110	113	161	225	144
PLK2	573	352	344	357	324	255	253	586	189	425	483	332	298	317	169	250	140	82	27		72	118	121	135	199	117
PCK	615	408	399	412	380	311	309	630	245	481	539	388	354	372	174	244	107	126	82	72		173	177	120	270	189
UTT1	462	242	233	246	214	145	143	476	79	315	373	222	188	206	164	245	175	93	110	118	173		11	252	245	163
UTT2	455	235	226	239	207	138	136	469	72	308	366	215	181	199	174	255	185	101	113	121	177	11		256	248	167
PNB1	707	487	478	492	459	390	388	699	324	560	618	467	433	451	303	363	226	216	161	135	120	252	256		189	111
LEI1	700	480	471	484	452	383	381	714	316	553	611	460	426	444	368	449	339	280	225	199	270	245	248	189		85
LEI2	613	398	389	403	370	301	299	632	235	471	529	378	344	362	286	368	258	199	144	117	189	163	167	111	85	

Appendix F – Distance for customer in 4 clusters, Cluster ID=1, Dock=Phrae

	DC PRE	CMI1	CMI2	CMI3	LPN	LPG1	LGP2	MSN	PRE	CRI1	CRI2	PYO	NAN1	NAN2	TAK1	TAK2	KPT	STI	PLK1	PLK2	PCK	UTT1	UTT2	PNB1	LEI1	LEI2
DC PRE		234	231	244	208	139	137	470	27	260	312	169	133	152	258	340	272	186	199	207	263	97	90	342	334	253
CMI1	234		13	10	36	102	102	241	208	188	279	158	318	337	279	361	350	310	345	352	408	242	235	487	480	398
CMI2	231	13		18	28	93	94	247	199	188	278	157	309	298	270	352	342	301	336	344	399	233	226	478	471	389
CMI3	244	10	18		41	106	107	232	212	191	281	160	322	301	283	365	355	315	349	357	412	246	239	492	484	403
LPN	208	36	28	41		74	75	262	179	212	302	181	290	309	251	332	322	282	317	324	380	214	207	459	452	370
LPG1	139	102	93	106	74		5	331	111	231	290	140	221	240	180	262	251	211	248	255	311	145	138	390	383	301
LGP2	137	102	94	107	75	5		330	108	231	290	140	219	238	184	265	255	215	246	253	309	143	136	388	381	299
MSN	470	241	247	232	262	331	330		441	418	509	387	552	567	468	391	529	486	541	586	630	476	469	699	714	632
PRE	27	208	199	212	179	111	108	441		231	289	140	111	130	230	312	254	168	181	189	245	79	72	324	316	235
CRI1	260	188	188	191	212	231	231	418	231		102	94	224	227	413	494	484	404	418	425	481	315	308	560	553	471
CRI2	312	279	278	281	302	290	290	509	289	102		157	264	243	471	552	542	462	476	483	539	373	366	618	611	529
PYO	169	158	157	160	181	140	140	387	140	94	157		154	157	320	401	391	311	325	332	388	222	215	467	460	378
NAN1	133	318	309	322	290	221	219	552	111	224	264	154		20	342	423	368	277	291	298	354	188	181	433	426	344
NAN2	152	337	298	301	309	240	238	567	130	227	243	157	20		360	442	381	295	309	317	372	206	199	451	444	362
TAK1	258	279	270	283	251	180	184	468	230	413	471	320	342	360		83	73	88	146	169	174	164	174	303	368	286
TAK2	340	361	352	365	332	262	265	391	312	494	552	401	423	442	83		143	169	227	250	244	245	255	363	449	368
KPT	272	350	342	355	322	251	255	529	254	484	542	391	368	381	73	143		93	115	140	107	175	185	226	339	258
STI	186	310	301	315	282	211	215	486	168	404	462	311	277	295	88	169	93		59	82	126	93	101	216	280	199
PLK1	199	345	336	349	317	248	246	541	181	418	476	325	291	309	146	227	115	59		27	82	110	113	161	225	144
PLK2	207	352	344	357	324	255	253	586	189	425	483	332	298	317	169	250	140	82	27		72	118	121	135	199	117
PCK	263	408	399	412	380	311	309	630	245	481	539	388	354	372	174	244	107	126	82	72		173	177	120	270	189
UTT1	97	242	233	246	214	145	143	476	79	315	373	222	188	206	164	245	175	93	110	118	173		11	252	245	163
UTT2	90	235	226	239	207	138	136	469	72	308	366	215	181	199	174	255	185	101	113	121	177	11		256	248	167
PNB1	342	487	478	492	459	390	388	699	324	560	618	467	433	451	303	363	226	216	161	135	120	252	256		189	111
LEI1	334	480	471	484	452	383	381	714	316	553	611	460	426	444	368	449	339	280	225	199	270	245	248	189		85
LEI2	253	398	389	403	370	301	299	632	235	471	529	378	344	362	286	368	258	199	144	117	189	163	167	111	85	

Appendix G – Distance for customer in 4 clusters, Cluster ID=1, Dock=Chiangrai

	DC CRI	CMI1	CMI2	CMI3	LPN	LPG1	LGP2	MSN	PRE	CRI1	CRI2	PYO	NAN1	NAN2	TAK1	TAK2	KPT	STI	PLK1	PLK2	PCK	UTT1	UTT2	PNB1	LEI1	LEI2
DC CRI		191	188	191	212	232	231	419	231	14	111	93	231	234	411	493	483	403	416	424	480	314	306	559	551	470
CMI1	191		13	10	36	102	102	241	208	188	279	158	318	337	279	361	350	310	345	352	408	242	235	487	480	398
CMI2	188	13		18	28	93	94	247	199	188	278	157	309	298	270	352	342	301	336	344	399	233	226	478	471	389
CMI3	191	10	18		41	106	107	232	212	191	281	160	322	301	283	365	355	315	349	357	412	246	239	492	484	403
LPN	212	36	28	41		74	75	262	179	212	302	181	290	309	251	332	322	282	317	324	380	214	207	459	452	370
LPG1	232	102	93	106	74		5	331	111	231	290	140	221	240	180	262	251	211	248	255	311	145	138	390	383	301
LGP2	231	102	94	107	75	5		330	108	231	290	140	219	238	184	265	255	215	246	253	309	143	136	388	381	299
MSN	419	241	247	232	262	331	330		441	418	509	387	552	567	468	391	529	486	541	586	630	476	469	699	714	632
PRE	231	208	199	212	179	111	108	441		231	289	140	111	130	230	312	254	168	181	189	245	79	72	324	316	235
CRI1	14	188	188	191	212	231	231	418	231		102	94	224	227	413	494	484	404	418	425	481	315	308	560	553	471
CRI2	111	279	278	281	302	290	290	509	289	102		157	264	243	471	552	542	462	476	483	539	373	366	618	611	529
PYO	93	158	157	160	181	140	140	387	140	94	157		154	157	320	401	391	311	325	332	388	222	215	467	460	378
NAN1	231	318	309	322	290	221	219	552	111	224	264	154		20	342	423	368	277	291	298	354	188	181	433	426	344
NAN2	234	337	298	301	309	240	238	567	130	227	243	157	20		360	442	381	295	309	317	372	206	199	451	444	362
TAK1	411	279	270	283	251	180	184	468	230	413	471	320	342	360		83	73	88	146	169	174	164	174	303	368	286
TAK2	493	361	352	365	332	262	265	391	312	494	552	401	423	442	83		143	169	227	250	244	245	255	363	449	368
KPT	483	350	342	355	322	251	255	529	254	484	542	391	368	381	73	143		93	115	140	107	175	185	226	339	258
STI	403	310	301	315	282	211	215	486	168	404	462	311	277	295	88	169	93		59	82	126	93	101	216	280	199
PLK1	416	345	336	349	317	248	246	541	181	418	476	325	291	309	146	227	115	59		27	82	110	113	161	225	144
PLK2	424	352	344	357	324	255	253	586	189	425	483	332	298	317	169	250	140	82	27		72	118	121	135	199	117
PCK	480	408	399	412	380	311	309	630	245	481	539	388	354	372	174	244	107	126	82	72		173	177	120	270	189
UTT1	314	242	233	246	214	145	143	476	79	315	373	222	188	206	164	245	175	93	110	118	173		11	252	245	163
UTT2	306	235	226	239	207	138	136	469	72	308	366	215	181	199	174	255	185	101	113	121	177	11		256	248	167
PNB1	559	487	478	492	459	390	388	699	324	560	618	467	433	451	303	363	226	216	161	135	120	252	256		189	111
LEI1	551	480	471	484	452	383	381	714	316	553	611	460	426	444	368	449	339	280	225	199	270	245	248	189		85
LEI2	470	398	389	403	370	301	299	632	235	471	529	378	344	362	286	368	258	199	144	117	189	163	167	111	85	

Appendix H – Distance for customer in 4 clusters, Cluster ID=1, Dock=Phayao

	DC PYO	CMI1	CMI2	CMI3	LPN	LPG1	LGP2	MSN	PRE	CRI1	CRI2	PYO	NAN1	NAN2	TAK1	TAK2	KPT	STI	PLK1	PLK2	PCK	UTT1	UTT2	PNB1	LEI1	LEI2
DC PYO		146	243	146	167	142	141	374	142	100	168	13	156	159	321	403	393	313	327	334	390	224	217	469	462	380
CMI1	146		13	10	36	102	102	241	208	188	279	158	318	337	279	361	350	310	345	352	408	242	235	487	480	398
CMI2	243	13		18	28	93	94	247	199	188	278	157	309	298	270	352	342	301	336	344	399	233	226	478	471	389
CMI3	146	10	18		41	106	107	232	212	191	281	160	322	301	283	365	355	315	349	357	412	246	239	492	484	403
LPN	167	36	28	41		74	75	262	179	212	302	181	290	309	251	332	322	282	317	324	380	214	207	459	452	370
LPG1	142	102	93	106	74		5	331	111	231	290	140	221	240	180	262	251	211	248	255	311	145	138	390	383	301
LGP2	141	102	94	107	75	5		330	108	231	290	140	219	238	184	265	255	215	246	253	309	143	136	388	381	299
MSN	374	241	247	232	262	331	330		441	418	509	387	552	567	468	391	529	486	541	586	630	476	469	699	714	632
PRE	142	208	199	212	179	111	108	441		231	289	140	111	130	230	312	254	168	181	189	245	79	72	324	316	235
CRI1	100	188	188	191	212	231	231	418	231		102	94	224	227	413	494	484	404	418	425	481	315	308	560	553	471
CRI2	168	279	278	281	302	290	290	509	289	102		157	264	243	471	552	542	462	476	483	539	373	366	618	611	529
PYO	13	158	157	160	181	140	140	387	140	94	157		154	157	320	401	391	311	325	332	388	222	215	467	460	378
NAN1	156	318	309	322	290	221	219	552	111	224	264	154		20	342	423	368	277	291	298	354	188	181	433	426	344
NAN2	159	337	298	301	309	240	238	567	130	227	243	157	20		360	442	381	295	309	317	372	206	199	451	444	362
TAK1	321	279	270	283	251	180	184	468	230	413	471	320	342	360		83	73	88	146	169	174	164	174	303	368	286
TAK2	403	361	352	365	332	262	265	391	312	494	552	401	423	442	83		143	169	227	250	244	245	255	363	449	368
KPT	393	350	342	355	322	251	255	529	254	484	542	391	368	381	73	143		93	115	140	107	175	185	226	339	258
STI	313	310	301	315	282	211	215	486	168	404	462	311	277	295	88	169	93		59	82	126	93	101	216	280	199
PLK1	327	345	336	349	317	248	246	541	181	418	476	325	291	309	146	227	115	59		27	82	110	113	161	225	144
PLK2	334	352	344	357	324	255	253	586	189	425	483	332	298	317	169	250	140	82	27		72	118	121	135	199	117
PCK	390	408	399	412	380	311	309	630	245	481	539	388	354	372	174	244	107	126	82	72		173	177	120	270	189
UTT1	224	242	233	246	214	145	143	476	79	315	373	222	188	206	164	245	175	93	110	118	173		11	252	245	163
UTT2	217	235	226	239	207	138	136	469	72	308	366	215	181	199	174	255	185	101	113	121	177	11		256	248	167
PNB1	469	487	478	492	459	390	388	699	324	560	618	467	433	451	303	363	226	216	161	135	120	252	256		189	111
LEI1	462	480	471	484	452	383	381	714	316	553	611	460	426	444	368	449	339	280	225	199	270	245	248	189		85
LEI2	380	398	389	403	370	301	299	632	235	471	529	378	344	362	286	368	258	199	144	117	189	163	167	111	85	

Appendix I – Distance for customer in 4 clusters, Cluster ID=1, Dock=Nan

	DC NAN	CMI1	CMI2	CMI3	LPN	LPG1	LGP2	MSN	PRE	CRI1	CRI2	PYO	NAN1	NAN2	TAK1	TAK2	KPT	STI	PLK1	PLK2	PCK	UTT1	UTT2	PNB1	LEI1	LEI2
DC NAN		269	266	269	302	221	220	497	128	205	246	137	18	22	358	440	384	293	307	315	370	204	197	450	380	308
CMI1	269		13	10	36	102	102	241	208	188	279	158	318	337	279	361	350	310	345	352	408	242	235	487	480	398
CMI2	266	13		18	28	93	94	247	199	188	278	157	309	298	270	352	342	301	336	344	399	233	226	478	471	389
CMI3	269	10	18		41	106	107	232	212	191	281	160	322	301	283	365	355	315	349	357	412	246	239	492	484	403
LPN	302	36	28	41		74	75	262	179	212	302	181	290	309	251	332	322	282	317	324	380	214	207	459	452	370
LPG1	221	102	93	106	74		5	331	111	231	290	140	221	240	180	262	251	211	248	255	311	145	138	390	383	301
LGP2	220	102	94	107	75	5		330	108	231	290	140	219	238	184	265	255	215	246	253	309	143	136	388	381	299
MSN	497	241	247	232	262	331	330		441	418	509	387	552	567	468	391	529	486	541	586	630	476	469	699	714	632
PRE	128	208	199	212	179	111	108	441		231	289	140	111	130	230	312	254	168	181	189	245	79	72	324	316	235
CRI1	205	188	188	191	212	231	231	418	231		102	94	224	227	413	494	484	404	418	425	481	315	308	560	553	471
CRI2	246	279	278	281	302	290	290	509	289	102		157	264	243	471	552	542	462	476	483	539	373	366	618	611	529
PYO	137	158	157	160	181	140	140	387	140	94	157		154	157	320	401	391	311	325	332	388	222	215	467	460	378
NAN1	18	318	309	322	290	221	219	552	111	224	264	154		20	342	423	368	277	291	298	354	188	181	433	426	344
NAN2	22	337	298	301	309	240	238	567	130	227	243	157	20		360	442	381	295	309	317	372	206	199	451	444	362
TAK1	358	279	270	283	251	180	184	468	230	413	471	320	342	360		83	73	88	146	169	174	164	174	303	368	286
TAK2	440	361	352	365	332	262	265	391	312	494	552	401	423	442	83		143	169	227	250	244	245	255	363	449	368
KPT	384	350	342	355	322	251	255	529	254	484	542	391	368	381	73	143		93	115	140	107	175	185	226	339	258
STI	293	310	301	315	282	211	215	486	168	404	462	311	277	295	88	169	93		59	82	126	93	101	216	280	199
PLK1	307	345	336	349	317	248	246	541	181	418	476	325	291	309	146	227	115	59		27	82	110	113	161	225	144
PLK2	315	352	344	357	324	255	253	586	189	425	483	332	298	317	169	250	140	82	27		72	118	121	135	199	117
PCK	370	408	399	412	380	311	309	630	245	481	539	388	354	372	174	244	107	126	82	72		173	177	120	270	189
UTT1	204	242	233	246	214	145	143	476	79	315	373	222	188	206	164	245	175	93	110	118	173		11	252	245	163
UTT2	197	235	226	239	207	138	136	469	72	308	366	215	181	199	174	255	185	101	113	121	177	11		256	248	167
PNB1	450	487	478	492	459	390	388	699	324	560	618	467	433	451	303	363	226	216	161	135	120	252	256		189	111
LEI1	380	480	471	484	452	383	381	714	316	553	611	460	426	444	368	449	339	280	225	199	270	245	248	189		85
LEI2	308	398	389	403	370	301	299	632	235	471	529	378	344	362	286	368	258	199	144	117	189	163	167	111	85	

Appendix J – Distance for customer in 4 clusters, Cluster ID=1, Dock=Tak

	DC TAK	CMI1	CMI2	CMI3	LPN	LPG1	LGP2	MSN	PRE	CRI1	CRI2	PYO	NAN1	NAN2	TAK1	TAK2	KPT	STI	PLK1	PLK2	PCK	UTT1	UTT2	PNB1	LEI1	LEI2
DC TAK		272	266	278	246	183	186	457	233	414	473	323	343	363	8	82	72	94	148	171	173	167	176	306	370	289
CMI1	272		13	10	36	102	102	241	208	188	279	158	318	337	279	361	350	310	345	352	408	242	235	487	480	398
CMI2	266	13		18	28	93	94	247	199	188	278	157	309	298	270	352	342	301	336	344	399	233	226	478	471	389
CMI3	278	10	18		41	106	107	232	212	191	281	160	322	301	283	365	355	315	349	357	412	246	239	492	484	403
LPN	246	36	28	41		74	75	262	179	212	302	181	290	309	251	332	322	282	317	324	380	214	207	459	452	370
LPG1	183	102	93	106	74		5	331	111	231	290	140	221	240	180	262	251	211	248	255	311	145	138	390	383	301
LGP2	186	102	94	107	75	5		330	108	231	290	140	219	238	184	265	255	215	246	253	309	143	136	388	381	299
MSN	457	241	247	232	262	331	330		441	418	509	387	552	567	468	391	529	486	541	586	630	476	469	699	714	632
PRE	233	208	199	212	179	111	108	441		231	289	140	111	130	230	312	254	168	181	189	245	79	72	324	316	235
CRI1	414	188	188	191	212	231	231	418	231		102	94	224	227	413	494	484	404	418	425	481	315	308	560	553	471
CRI2	473	279	278	281	302	290	290	509	289	102		157	264	243	471	552	542	462	476	483	539	373	366	618	611	529
PYO	323	158	157	160	181	140	140	387	140	94	157		154	157	320	401	391	311	325	332	388	222	215	467	460	378
NAN1	343	318	309	322	290	221	219	552	111	224	264	154		20	342	423	368	277	291	298	354	188	181	433	426	344
NAN2	363	337	298	301	309	240	238	567	130	227	243	157	20		360	442	381	295	309	317	372	206	199	451	444	362
TAK1	8	279	270	283	251	180	184	468	230	413	471	320	342	360		83	73	88	146	169	174	164	174	303	368	286
TAK2	82	361	352	365	332	262	265	391	312	494	552	401	423	442	83		143	169	227	250	244	245	255	363	449	368
KPT	72	350	342	355	322	251	255	529	254	484	542	391	368	381	73	143		93	115	140	107	175	185	226	339	258
STI	94	310	301	315	282	211	215	486	168	404	462	311	277	295	88	169	93		59	82	126	93	101	216	280	199
PLK1	148	345	336	349	317	248	246	541	181	418	476	325	291	309	146	227	115	59		27	82	110	113	161	225	144
PLK2	171	352	344	357	324	255	253	586	189	425	483	332	298	317	169	250	140	82	27		72	118	121	135	199	117
PCK	173	408	399	412	380	311	309	630	245	481	539	388	354	372	174	244	107	126	82	72		173	177	120	270	189
UTT1	167	242	233	246	214	145	143	476	79	315	373	222	188	206	164	245	175	93	110	118	173		11	252	245	163
UTT2	176	235	226	239	207	138	136	469	72	308	366	215	181	199	174	255	185	101	113	121	177	11		256	248	167
PNB1	306	487	478	492	459	390	388	699	324	560	618	467	433	451	303	363	226	216	161	135	120	252	256		189	111
LEI1	370	480	471	484	452	383	381	714	316	553	611	460	426	444	368	449	339	280	225	199	270	245	248	189		85
LEI2	289	398	389	403	370	301	299	632	235	471	529	378	344	362	286	368	258	199	144	117	189	163	167	111	85	

Appendix K – Distance for customer in 4 clusters, Cluster ID=1, Dock=Kampaeng Phet

	DC KPT	CMI1	CMI2	CMI3	LPN	LPG1	LGP2	MSN	PRE	CRI1	CRI2	PYO	NAN1	NAN2	TAK1	TAK2	KPT	STI	PLK1	PLK2	PCK	UTT1	UTT2	PNB1	LEI1	LEI2
DC KPT		341	335	347	314	251	255	530	249	482	542	391	358	378	72	142	5	94	116	141	108	174	183	227	340	259
CMI1	341		13	10	36	102	102	241	208	188	279	158	318	337	279	361	350	310	345	352	408	242	235	487	480	398
CMI2	335	13		18	28	93	94	247	199	188	278	157	309	298	270	352	342	301	336	344	399	233	226	478	471	389
CMI3	347	10	18		41	106	107	232	212	191	281	160	322	301	283	365	355	315	349	357	412	246	239	492	484	403
LPN	314	36	28	41		74	75	262	179	212	302	181	290	309	251	332	322	282	317	324	380	214	207	459	452	370
LPG1	251	102	93	106	74		5	331	111	231	290	140	221	240	180	262	251	211	248	255	311	145	138	390	383	301
LGP2	255	102	94	107	75	5		330	108	231	290	140	219	238	184	265	255	215	246	253	309	143	136	388	381	299
MSN	530	241	247	232	262	331	330		441	418	509	387	552	567	468	391	529	486	541	586	630	476	469	699	714	632
PRE	249	208	199	212	179	111	108	441		231	289	140	111	130	230	312	254	168	181	189	245	79	72	324	316	235
CRI1	482	188	188	191	212	231	231	418	231		102	94	224	227	413	494	484	404	418	425	481	315	308	560	553	471
CRI2	542	279	278	281	302	290	290	509	289	102		157	264	243	471	552	542	462	476	483	539	373	366	618	611	529
PYO	391	158	157	160	181	140	140	387	140	94	157		154	157	320	401	391	311	325	332	388	222	215	467	460	378
NAN1	358	318	309	322	290	221	219	552	111	224	264	154		20	342	423	368	277	291	298	354	188	181	433	426	344
NAN2	378	337	298	301	309	240	238	567	130	227	243	157	20		360	442	381	295	309	317	372	206	199	451	444	362
TAK1	72	279	270	283	251	180	184	468	230	413	471	320	342	360		83	73	88	146	169	174	164	174	303	368	286
TAK2	142	361	352	365	332	262	265	391	312	494	552	401	423	442	83		143	169	227	250	244	245	255	363	449	368
KPT	5	350	342	355	322	251	255	529	254	484	542	391	368	381	73	143		93	115	140	107	175	185	226	339	258
STI	94	310	301	315	282	211	215	486	168	404	462	311	277	295	88	169	93		59	82	126	93	101	216	280	199
PLK1	116	345	336	349	317	248	246	541	181	418	476	325	291	309	146	227	115	59		27	82	110	113	161	225	144
PLK2	141	352	344	357	324	255	253	586	189	425	483	332	298	317	169	250	140	82	27		72	118	121	135	199	117
PCK	108	408	399	412	380	311	309	630	245	481	539	388	354	372	174	244	107	126	82	72		173	177	120	270	189
UTT1	174	242	233	246	214	145	143	476	79	315	373	222	188	206	164	245	175	93	110	118	173		11	252	245	163
UTT2	183	235	226	239	207	138	136	469	72	308	366	215	181	199	174	255	185	101	113	121	177	11		256	248	167
PNB1	227	487	478	492	459	390	388	699	324	560	618	467	433	451	303	363	226	216	161	135	120	252	256		189	111
LEI1	340	480	471	484	452	383	381	714	316	553	611	460	426	444	368	449	339	280	225	199	270	245	248	189		85
LEI2	259	398	389	403	370	301	299	632	235	471	529	378	344	362	286	368	258	199	144	117	189	163	167	111	85	

Appendix L – Distance for customer in 4 clusters, Cluster ID=1, Dock=Sukothai

	DC STI	CMI1	CMI2	CMI3	LPN	LPG1	LGP2	MSN	PRE	CRI1	CRI2	PYO	NAN1	NAN2	TAK1	TAK2	KPT	STI	PLK1	PLK2	PCK	UTT1	UTT2	PNB1	LEI1	LEI2
DC STI		293	287	299	266	203	207	478	174	403	462	312	283	302	83	162	91	11	68	91	135	96	104	225	289	207
CMI1	293		13	10	36	102	102	241	208	188	279	158	318	337	279	361	350	310	345	352	408	242	235	487	480	398
CMI2	287	13		18	28	93	94	247	199	188	278	157	309	298	270	352	342	301	336	344	399	233	226	478	471	389
CMI3	299	10	18		41	106	107	232	212	191	281	160	322	301	283	365	355	315	349	357	412	246	239	492	484	403
LPN	266	36	28	41		74	75	262	179	212	302	181	290	309	251	332	322	282	317	324	380	214	207	459	452	370
LPG1	203	102	93	106	74		5	331	111	231	290	140	221	240	180	262	251	211	248	255	311	145	138	390	383	301
LGP2	207	102	94	107	75	5		330	108	231	290	140	219	238	184	265	255	215	246	253	309	143	136	388	381	299
MSN	478	241	247	232	262	331	330		441	418	509	387	552	567	468	391	529	486	541	586	630	476	469	699	714	632
PRE	174	208	199	212	179	111	108	441		231	289	140	111	130	230	312	254	168	181	189	245	79	72	324	316	235
CRI1	403	188	188	191	212	231	231	418	231		102	94	224	227	413	494	484	404	418	425	481	315	308	560	553	471
CRI2	462	279	278	281	302	290	290	509	289	102		157	264	243	471	552	542	462	476	483	539	373	366	618	611	529
PYO	312	158	157	160	181	140	140	387	140	94	157		154	157	320	401	391	311	325	332	388	222	215	467	460	378
NAN1	283	318	309	322	290	221	219	552	111	224	264	154		20	342	423	368	277	291	298	354	188	181	433	426	344
NAN2	302	337	298	301	309	240	238	567	130	227	243	157	20		360	442	381	295	309	317	372	206	199	451	444	362
TAK1	83	279	270	283	251	180	184	468	230	413	471	320	342	360		83	73	88	146	169	174	164	174	303	368	286
TAK2	162	361	352	365	332	262	265	391	312	494	552	401	423	442	83		143	169	227	250	244	245	255	363	449	368
KPT	91	350	342	355	322	251	255	529	254	484	542	391	368	381	73	143		93	115	140	107	175	185	226	339	258
STI	11	310	301	315	282	211	215	486	168	404	462	311	277	295	88	169	93		59	82	126	93	101	216	280	199
PLK1	68	345	336	349	317	248	246	541	181	418	476	325	291	309	146	227	115	59		27	82	110	113	161	225	144
PLK2	91	352	344	357	324	255	253	586	189	425	483	332	298	317	169	250	140	82	27		72	118	121	135	199	117
PCK	135	408	399	412	380	311	309	630	245	481	539	388	354	372	174	244	107	126	82	72		173	177	120	270	189
UTT1	96	242	233	246	214	145	143	476	79	315	373	222	188	206	164	245	175	93	110	118	173		11	252	245	163
UTT2	104	235	226	239	207	138	136	469	72	308	366	215	181	199	174	255	185	101	113	121	177	11		256	248	167
PNB1	225	487	478	492	459	390	388	699	324	560	618	467	433	451	303	363	226	216	161	135	120	252	256		189	111
LEI1	289	480	471	484	452	383	381	714	316	553	611	460	426	444	368	449	339	280	225	199	270	245	248	189		85
LEI2	207	398	389	403	370	301	299	632	235	471	529	378	344	362	286	368	258	199	144	117	189	163	167	111	85	

Appendix M – Distance for customer in 4 clusters, Cluster ID=1, Dock=Phitsanulok

	DC PLK	CMI1	CMI2	CMI3	LPN	LPG1	LGP2	MSN	PRE	CRI1	CRI2	PYO	NAN1	NAN2	TAK1	TAK2	KPT	STI	PLK1	PLK2	PCK	UTT1	UTT2	PNB1	LEI1	LEI2
DC PLK		350	344	357	324	252	253	540	188	417	476	326	297	317	145	225	106	57	9	42	70	117	121	176	240	159
CMI1	350		13	10	36	102	102	241	208	188	279	158	318	337	279	361	350	310	345	352	408	242	235	487	480	398
CMI2	344	13		18	28	93	94	247	199	188	278	157	309	298	270	352	342	301	336	344	399	233	226	478	471	389
CMI3	357	10	18		41	106	107	232	212	191	281	160	322	301	283	365	355	315	349	357	412	246	239	492	484	403
LPN	324	36	28	41		74	75	262	179	212	302	181	290	309	251	332	322	282	317	324	380	214	207	459	452	370
LPG1	252	102	93	106	74		5	331	111	231	290	140	221	240	180	262	251	211	248	255	311	145	138	390	383	301
LGP2	253	102	94	107	75	5		330	108	231	290	140	219	238	184	265	255	215	246	253	309	143	136	388	381	299
MSN	540	241	247	232	262	331	330		441	418	509	387	552	567	468	391	529	486	541	586	630	476	469	699	714	632
PRE	188	208	199	212	179	111	108	441		231	289	140	111	130	230	312	254	168	181	189	245	79	72	324	316	235
CRI1	417	188	188	191	212	231	231	418	231		102	94	224	227	413	494	484	404	418	425	481	315	308	560	553	471
CRI2	476	279	278	281	302	290	290	509	289	102		157	264	243	471	552	542	462	476	483	539	373	366	618	611	529
PYO	326	158	157	160	181	140	140	387	140	94	157		154	157	320	401	391	311	325	332	388	222	215	467	460	378
NAN1	297	318	309	322	290	221	219	552	111	224	264	154		20	342	423	368	277	291	298	354	188	181	433	426	344
NAN2	317	337	298	301	309	240	238	567	130	227	243	157	20		360	442	381	295	309	317	372	206	199	451	444	362
TAK1	145	279	270	283	251	180	184	468	230	413	471	320	342	360		83	73	88	146	169	174	164	174	303	368	286
TAK2	225	361	352	365	332	262	265	391	312	494	552	401	423	442	83		143	169	227	250	244	245	255	363	449	368
KPT	106	350	342	355	322	251	255	529	254	484	542	391	368	381	73	143		93	115	140	107	175	185	226	339	258
STI	57	310	301	315	282	211	215	486	168	404	462	311	277	295	88	169	93		59	82	126	93	101	216	280	199
PLK1	9	345	336	349	317	248	246	541	181	418	476	325	291	309	146	227	115	59		27	82	110	113	161	225	144
PLK2	42	352	344	357	324	255	253	586	189	425	483	332	298	317	169	250	140	82	27		72	118	121	135	199	117
PCK	70	408	399	412	380	311	309	630	245	481	539	388	354	372	174	244	107	126	82	72		173	177	120	270	189
UTT1	117	242	233	246	214	145	143	476	79	315	373	222	188	206	164	245	175	93	110	118	173		11	252	245	163
UTT2	121	235	226	239	207	138	136	469	72	308	366	215	181	199	174	255	185	101	113	121	177	11		256	248	167
PNB1	176	487	478	492	459	390	388	699	324	560	618	467	433	451	303	363	226	216	161	135	120	252	256		189	111
LEI1	240	480	471	484	452	383	381	714	316	553	611	460	426	444	368	449	339	280	225	199	270	245	248	189		85
LEI2	159	398	389	403	370	301	299	632	235	471	529	378	344	362	286	368	258	199	144	117	189	163	167	111	85	

Appendix N – Distance for customer in 4 clusters, Cluster ID=1, Dock=Phichit

	DC PCK	CMI1	CMI2	CMI3	LPN	LPG1	LGP2	MSN	PRE	CRI1	CRI2	PYO	NAN1	NAN2	TAK1	TAK2	KPT	STI	PLK1	PLK2	PCK	UTT1	UTT2	PNB1	LEI1	LEI2
DC PCK		401	395	407	375	303	304	632	239	468	527	377	348	367	170	240	102	120	77	67	7	168	172	126	265	184
CMI1	401		13	10	36	102	102	241	208	188	279	158	318	337	279	361	350	310	345	352	408	242	235	487	480	398
CMI2	395	13		18	28	93	94	247	199	188	278	157	309	298	270	352	342	301	336	344	399	233	226	478	471	389
CMI3	407	10	18		41	106	107	232	212	191	281	160	322	301	283	365	355	315	349	357	412	246	239	492	484	403
LPN	375	36	28	41		74	75	262	179	212	302	181	290	309	251	332	322	282	317	324	380	214	207	459	452	370
LPG1	303	102	93	106	74		5	331	111	231	290	140	221	240	180	262	251	211	248	255	311	145	138	390	383	301
LGP2	304	102	94	107	75	5		330	108	231	290	140	219	238	184	265	255	215	246	253	309	143	136	388	381	299
MSN	632	241	247	232	262	331	330		441	418	509	387	552	567	468	391	529	486	541	586	630	476	469	699	714	632
PRE	239	208	199	212	179	111	108	441		231	289	140	111	130	230	312	254	168	181	189	245	79	72	324	316	235
CRI1	468	188	188	191	212	231	231	418	231		102	94	224	227	413	494	484	404	418	425	481	315	308	560	553	471
CRI2	527	279	278	281	302	290	290	509	289	102		157	264	243	471	552	542	462	476	483	539	373	366	618	611	529
PYO	377	158	157	160	181	140	140	387	140	94	157		154	157	320	401	391	311	325	332	388	222	215	467	460	378
NAN1	348	318	309	322	290	221	219	552	111	224	264	154		20	342	423	368	277	291	298	354	188	181	433	426	344
NAN2	367	337	298	301	309	240	238	567	130	227	243	157	20		360	442	381	295	309	317	372	206	199	451	444	362
TAK1	170	279	270	283	251	180	184	468	230	413	471	320	342	360		83	73	88	146	169	174	164	174	303	368	286
TAK2	240	361	352	365	332	262	265	391	312	494	552	401	423	442	83		143	169	227	250	244	245	255	363	449	368
KPT	102	350	342	355	322	251	255	529	254	484	542	391	368	381	73	143		93	115	140	107	175	185	226	339	258
STI	120	310	301	315	282	211	215	486	168	404	462	311	277	295	88	169	93		59	82	126	93	101	216	280	199
PLK1	77	345	336	349	317	248	246	541	181	418	476	325	291	309	146	227	115	59		27	82	110	113	161	225	144
PLK2	67	352	344	357	324	255	253	586	189	425	483	332	298	317	169	250	140	82	27		72	118	121	135	199	117
PCK	7	408	399	412	380	311	309	630	245	481	539	388	354	372	174	244	107	126	82	72		173	177	120	270	189
UTT1	168	242	233	246	214	145	143	476	79	315	373	222	188	206	164	245	175	93	110	118	173		11	252	245	163
UTT2	172	235	226	239	207	138	136	469	72	308	366	215	181	199	174	255	185	101	113	121	177	11		256	248	167
PNB1	126	487	478	492	459	390	388	699	324	560	618	467	433	451	303	363	226	216	161	135	120	252	256		189	111
LEI1	265	480	471	484	452	383	381	714	316	553	611	460	426	444	368	449	339	280	225	199	270	245	248	189		85
LEI2	184	398	389	403	370	301	299	632	235	471	529	378	344	362	286	368	258	199	144	117	189	163	167	111	85	

Appendix O – Distance for customer in 4 clusters, Cluster ID=1, Dock=Uttaradit

	DC UTT	CMI1	CMI2	CMI3	LPN	LPG1	LGP2	MSN	PRE	CRI1	CRI2	PYO	NAN1	NAN2	TAK1	TAK2	KPT	STI	PLK1	PLK2	PCK	UTT1	UTT2	PNB1	LEI1	LEI2
DC UTT		247	241	254	221	150	150	483	86	314	373	223	194	214	189	269	200	114	128	135	191	25	15	270	263	181
CMI1	247		13	10	36	102	102	241	208	188	279	158	318	337	279	361	350	310	345	352	408	242	235	487	480	398
CMI2	241	13		18	28	93	94	247	199	188	278	157	309	298	270	352	342	301	336	344	399	233	226	478	471	389
CMI3	254	10	18		41	106	107	232	212	191	281	160	322	301	283	365	355	315	349	357	412	246	239	492	484	403
LPN	221	36	28	41		74	75	262	179	212	302	181	290	309	251	332	322	282	317	324	380	214	207	459	452	370
LPG1	150	102	93	106	74		5	331	111	231	290	140	221	240	180	262	251	211	248	255	311	145	138	390	383	301
LGP2	150	102	94	107	75	5		330	108	231	290	140	219	238	184	265	255	215	246	253	309	143	136	388	381	299
MSN	483	241	247	232	262	331	330		441	418	509	387	552	567	468	391	529	486	541	586	630	476	469	699	714	632
PRE	86	208	199	212	179	111	108	441		231	289	140	111	130	230	312	254	168	181	189	245	79	72	324	316	235
CRI1	314	188	188	191	212	231	231	418	231		102	94	224	227	413	494	484	404	418	425	481	315	308	560	553	471
CRI2	373	279	278	281	302	290	290	509	289	102		157	264	243	471	552	542	462	476	483	539	373	366	618	611	529
PYO	223	158	157	160	181	140	140	387	140	94	157		154	157	320	401	391	311	325	332	388	222	215	467	460	378
NAN1	194	318	309	322	290	221	219	552	111	224	264	154		20	342	423	368	277	291	298	354	188	181	433	426	344
NAN2	214	337	298	301	309	240	238	567	130	227	243	157	20		360	442	381	295	309	317	372	206	199	451	444	362
TAK1	189	279	270	283	251	180	184	468	230	413	471	320	342	360		83	73	88	146	169	174	164	174	303	368	286
TAK2	269	361	352	365	332	262	265	391	312	494	552	401	423	442	83		143	169	227	250	244	245	255	363	449	368
KPT	200	350	342	355	322	251	255	529	254	484	542	391	368	381	73	143		93	115	140	107	175	185	226	339	258
STI	114	310	301	315	282	211	215	486	168	404	462	311	277	295	88	169	93		59	82	126	93	101	216	280	199
PLK1	128	345	336	349	317	248	246	541	181	418	476	325	291	309	146	227	115	59		27	82	110	113	161	225	144
PLK2	135	352	344	357	324	255	253	586	189	425	483	332	298	317	169	250	140	82	27		72	118	121	135	199	117
PCK	191	408	399	412	380	311	309	630	245	481	539	388	354	372	174	244	107	126	82	72		173	177	120	270	189
UTT1	25	242	233	246	214	145	143	476	79	315	373	222	188	206	164	245	175	93	110	118	173		11	252	245	163
UTT2	15	235	226	239	207	138	136	469	72	308	366	215	181	199	174	255	185	101	113	121	177	11		256	248	167
PNB1	270	487	478	492	459	390	388	699	324	560	618	467	433	451	303	363	226	216	161	135	120	252	256		189	111
LEI1	263	480	471	484	452	383	381	714	316	553	611	460	426	444	368	449	339	280	225	199	270	245	248	189		85
LEI2	181	398	389	403	370	301	299	632	235	471	529	378	344	362	286	368	258	199	144	117	189	163	167	111	85	

Appendix P – Distance for customer in 4 clusters, Cluster ID=1, Dock=Phetchabun

	DC PNB	CMI1	CMI2	CMI3	LPN	LPG1	LGP2	MSN	PRE	CRI1	CRI2	PYO	NAN1	NAN2	TAK1	TAK2	KPT	STI	PLK1	PLK2	PCK	UTT1	UTT2	PNB1	LEI1	LEI2
DC PNB		507	501	513	480	409	410	738	345	574	633	484	454	473	304	375	236	236	183	162	130	274	277	23	210	133
CMI1	507		13	10	36	102	102	241	208	188	279	158	318	337	279	361	350	310	345	352	408	242	235	487	480	398
CMI2	501	13		18	28	93	94	247	199	188	278	157	309	298	270	352	342	301	336	344	399	233	226	478	471	389
CMI3	513	10	18		41	106	107	232	212	191	281	160	322	301	283	365	355	315	349	357	412	246	239	492	484	403
LPN	480	36	28	41		74	75	262	179	212	302	181	290	309	251	332	322	282	317	324	380	214	207	459	452	370
LPG1	409	102	93	106	74		5	331	111	231	290	140	221	240	180	262	251	211	248	255	311	145	138	390	383	301
LGP2	410	102	94	107	75	5		330	108	231	290	140	219	238	184	265	255	215	246	253	309	143	136	388	381	299
MSN	738	241	247	232	262	331	330		441	418	509	387	552	567	468	391	529	486	541	586	630	476	469	699	714	632
PRE	345	208	199	212	179	111	108	441		231	289	140	111	130	230	312	254	168	181	189	245	79	72	324	316	235
CRI1	574	188	188	191	212	231	231	418	231		102	94	224	227	413	494	484	404	418	425	481	315	308	560	553	471
CRI2	633	279	278	281	302	290	290	509	289	102		157	264	243	471	552	542	462	476	483	539	373	366	618	611	529
PYO	484	158	157	160	181	140	140	387	140	94	157		154	157	320	401	391	311	325	332	388	222	215	467	460	378
NAN1	454	318	309	322	290	221	219	552	111	224	264	154		20	342	423	368	277	291	298	354	188	181	433	426	344
NAN2	473	337	298	301	309	240	238	567	130	227	243	157	20		360	442	381	295	309	317	372	206	199	451	444	362
TAK1	304	279	270	283	251	180	184	468	230	413	471	320	342	360		83	73	88	146	169	174	164	174	303	368	286
TAK2	375	361	352	365	332	262	265	391	312	494	552	401	423	442	83		143	169	227	250	244	245	255	363	449	368
KPT	236	350	342	355	322	251	255	529	254	484	542	391	368	381	73	143		93	115	140	107	175	185	226	339	258
STI	236	310	301	315	282	211	215	486	168	404	462	311	277	295	88	169	93		59	82	126	93	101	216	280	199
PLK1	183	345	336	349	317	248	246	541	181	418	476	325	291	309	146	227	115	59		27	82	110	113	161	225	144
PLK2	162	352	344	357	324	255	253	586	189	425	483	332	298	317	169	250	140	82	27		72	118	121	135	199	117
PCK	130	408	399	412	380	311	309	630	245	481	539	388	354	372	174	244	107	126	82	72		173	177	120	270	189
UTT1	274	242	233	246	214	145	143	476	79	315	373	222	188	206	164	245	175	93	110	118	173		11	252	245	163
UTT2	277	235	226	239	207	138	136	469	72	308	366	215	181	199	174	255	185	101	113	121	177	11		256	248	167
PNB1	23	487	478	492	459	390	388	699	324	560	618	467	433	451	303	363	226	216	161	135	120	252	256		189	111
LEI1	210	480	471	484	452	383	381	714	316	553	611	460	426	444	368	449	339	280	225	199	270	245	248	189		85
LEI2	133	398	389	403	370	301	299	632	235	471	529	378	344	362	286	368	258	199	144	117	189	163	167	111	85	

Appendix Q – Distance for customer in 4 clusters, Cluster ID=1, Dock=Loei

	DC LEI	CMI1	CMI2	CMI3	LPN	LPG1	LGP2	MSN	PRE	CRI1	CRI2	PYO	NAN1	NAN2	TAK1	TAK2	KPT	STI	PLK1	PLK2	PCK	UTT1	UTT2	PNB1	LEI1	LEI2
DC LEI		487	481	494	461	389	390	718	325	554	613	464	366	385	377	457	349	288	235	214	280	254	258	202	11	94
CMI1	487		13	10	36	102	102	241	208	188	279	158	318	337	279	361	350	310	345	352	408	242	235	487	480	398
CMI2	481	13		18	28	93	94	247	199	188	278	157	309	298	270	352	342	301	336	344	399	233	226	478	471	389
CMI3	494	10	18		41	106	107	232	212	191	281	160	322	301	283	365	355	315	349	357	412	246	239	492	484	403
LPN	461	36	28	41		74	75	262	179	212	302	181	290	309	251	332	322	282	317	324	380	214	207	459	452	370
LPG1	389	102	93	106	74		5	331	111	231	290	140	221	240	180	262	251	211	248	255	311	145	138	390	383	301
LGP2	390	102	94	107	75	5		330	108	231	290	140	219	238	184	265	255	215	246	253	309	143	136	388	381	299
MSN	718	241	247	232	262	331	330		441	418	509	387	552	567	468	391	529	486	541	586	630	476	469	699	714	632
PRE	325	208	199	212	179	111	108	441		231	289	140	111	130	230	312	254	168	181	189	245	79	72	324	316	235
CRI1	554	188	188	191	212	231	231	418	231		102	94	224	227	413	494	484	404	418	425	481	315	308	560	553	471
CRI2	613	279	278	281	302	290	290	509	289	102		157	264	243	471	552	542	462	476	483	539	373	366	618	611	529
PYO	464	158	157	160	181	140	140	387	140	94	157		154	157	320	401	391	311	325	332	388	222	215	467	460	378
NAN1	366	318	309	322	290	221	219	552	111	224	264	154		20	342	423	368	277	291	298	354	188	181	433	426	344
NAN2	385	337	298	301	309	240	238	567	130	227	243	157	20		360	442	381	295	309	317	372	206	199	451	444	362
TAK1	377	279	270	283	251	180	184	468	230	413	471	320	342	360		83	73	88	146	169	174	164	174	303	368	286
TAK2	457	361	352	365	332	262	265	391	312	494	552	401	423	442	83		143	169	227	250	244	245	255	363	449	368
KPT	349	350	342	355	322	251	255	529	254	484	542	391	368	381	73	143		93	115	140	107	175	185	226	339	258
STI	288	310	301	315	282	211	215	486	168	404	462	311	277	295	88	169	93		59	82	126	93	101	216	280	199
PLK1	235	345	336	349	317	248	246	541	181	418	476	325	291	309	146	227	115	59		27	82	110	113	161	225	144
PLK2	214	352	344	357	324	255	253	586	189	425	483	332	298	317	169	250	140	82	27		72	118	121	135	199	117
PCK	280	408	399	412	380	311	309	630	245	481	539	388	354	372	174	244	107	126	82	72		173	177	120	270	189
UTT1	254	242	233	246	214	145	143	476	79	315	373	222	188	206	164	245	175	93	110	118	173		11	252	245	163
UTT2	258	235	226	239	207	138	136	469	72	308	366	215	181	199	174	255	185	101	113	121	177	11		256	248	167
PNB1	202	487	478	492	459	390	388	699	324	560	618	467	433	451	303	363	226	216	161	135	120	252	256		189	111
LEI1	11	480	471	484	452	383	381	714	316	553	611	460	426	444	368	449	339	280	225	199	270	245	248	189		85
LEI2	94	398	389	403	370	301	299	632	235	471	529	378	344	362	286	368	258	199	144	117	189	163	167	111	85	

Appendix R – Distance for customer in 4 clusters, Cluster ID=4, Dock=Chumphon

(Distance for customer in 5 clusters, Cluster ID=5, Dock=Chumphon)

	DC CPN	CPN	NRT1	NRT2	SNI1	SNI2	SNI3	KBI	PKT	RNG	TRG	PNA	PLG	SKA1	SKA2	YLA	PTN	NWT	STN
DC CPN		10	313	288	178	195	223	314	374	122	362	292	381	501	483	603	575	669	501
CPN	10		322	296	186	203	231	322	382	121	370	300	389	509	491	611	583	677	510
NRT1	313	322		65	134	119	108	154	304	363	126	221	108	191	207	309	281	375	229
NRT2	288	296	65		134	141	66	110	254	320	75	172	94	214	196	315	288	382	214
SNI1	178	186	134	134		19	71	161	245	210	210	162	228	322	330	440	412	507	349
SNI2	195	203	119	141	19		75	165	249	227	213	167	232	304	335	422	394	488	353
SNI3	223	231	108	66	71	75		102	207	255	141	125	159	280	262	382	354	448	280
KBI	314	322	154	110	161	165	102		163	304	122	81	185	306	287	407	379	474	261
PKT	374	382	304	254	245	249	207	163		301	280	90	344	464	446	566	538	632	420
RNG	122	121	363	320	210	227	255	304	301		399	228	418	539	521	640	613	707	539
TRG	362	370	126	75	210	213	141	122	280	399		193	64	183	165	285	257	351	140
PNA	292	300	221	172	162	167	125	81	90	228	193		262	382	364	484	456	550	338
PLG	381	389	108	94	228	232	159	185	344	418	64	262		124	106	226	198	292	124
SKA1	501	509	191	214	322	304	280	306	464	539	183	382	124		35	132	104	198	119
SKA2	483	491	207	196	330	335	262	287	446	521	165	364	106	35		122	95	189	101
YLA	603	611	309	315	440	422	382	407	566	640	285	484	226	132	122		44	73	222
PTN	575	583	281	288	412	394	354	379	538	613	257	456	198	104	95	44		94	194
NWT	669	677	375	382	507	488	448	474	632	707	351	550	292	198	189	73	94		288
STN	501	510	229	214	349	353	280	261	420	539	140	338	124	119	101	222	194	288	

Appendix S – Distance for customer in 4 clusters, Cluster ID=4, Dock=Nakhon Si

(Distance for customer in 5 clusters, Cluster ID=5, Dock=Nakhon Si)

	DC NRT	CPN	NRT1	NRT2	SNI1	SNI2	SNI3	KBI	PKT	RNG	TRG	PNA	PLG	SKA1	SKA2	YLA	PTN	NWT	STN
DC NRT		319	4	63	136	118	112	158	307	344	124	225	107	183	199	301	273	368	228
CPN	319		322	296	186	203	231	322	382	121	370	300	389	509	491	611	583	677	510
NRT1	4	322		65	134	119	108	154	304	363	126	221	108	191	207	309	281	375	229
NRT2	63	296	65		134	141	66	110	254	320	75	172	94	214	196	315	288	382	214
SNI1	136	186	134	134		19	71	161	245	210	210	162	228	322	330	440	412	507	349
SNI2	118	203	119	141	19		75	165	249	227	213	167	232	304	335	422	394	488	353
SNI3	112	231	108	66	71	75		102	207	255	141	125	159	280	262	382	354	448	280
KBI	158	322	154	110	161	165	102		163	304	122	81	185	306	287	407	379	474	261
PKT	307	382	304	254	245	249	207	163		301	280	90	344	464	446	566	538	632	420
RNG	344	121	363	320	210	227	255	304	301		399	228	418	539	521	640	613	707	539
TRG	124	370	126	75	210	213	141	122	280	399		193	64	183	165	285	257	351	140
PNA	225	300	221	172	162	167	125	81	90	228	193		262	382	364	484	456	550	338
PLG	107	389	108	94	228	232	159	185	344	418	64	262		124	106	226	198	292	124
SKA1	183	509	191	214	322	304	280	306	464	539	183	382	124		35	132	104	198	119
SKA2	199	491	207	196	330	335	262	287	446	521	165	364	106	35		122	95	189	101
YLA	301	611	309	315	440	422	382	407	566	640	285	484	226	132	122		44	73	222
PTN	273	583	281	288	412	394	354	379	538	613	257	456	198	104	95	44		94	194
NWT	368	677	375	382	507	488	448	474	632	707	351	550	292	198	189	73	94		288
STN	228	510	229	214	349	353	280	261	420	539	140	338	124	119	101	222	194	288	

Appendix T – Distance for customer in 4 clusters, Cluster ID=4, Dock=Surat Thani

(Distance for customer in 5 clusters, Cluster ID=5, Dock=Surat Thani)

	DC SNI	CPN	NRT1	NRT2	SNI1	SNI2	SNI3	KBI	PKT	RNG	TRG	PNA	PLG	SKA1	SKA2	YLA	PTN	NWT	STN
DC SNI		192	146	126	10	28	62	152	236	217	201	154	219	340	322	442	414	508	340
CPN	192		322	296	186	203	231	322	382	121	370	300	389	509	491	611	583	677	510
NRT1	146	322		65	134	119	108	154	304	363	126	221	108	191	207	309	281	375	229
NRT2	126	296	65		134	141	66	110	254	320	75	172	94	214	196	315	288	382	214
SNI1	10	186	134	134		19	71	161	245	210	210	162	228	322	330	440	412	507	349
SNI2	28	203	119	141	19		75	165	249	227	213	167	232	304	335	422	394	488	353
SNI3	62	231	108	66	71	75		102	207	255	141	125	159	280	262	382	354	448	280
KBI	152	322	154	110	161	165	102		163	304	122	81	185	306	287	407	379	474	261
PKT	236	382	304	254	245	249	207	163		301	280	90	344	464	446	566	538	632	420
RNG	217	121	363	320	210	227	255	304	301		399	228	418	539	521	640	613	707	539
TRG	201	370	126	75	210	213	141	122	280	399		193	64	183	165	285	257	351	140
PNA	154	300	221	172	162	167	125	81	90	228	193		262	382	364	484	456	550	338
PLG	219	389	108	94	228	232	159	185	344	418	64	262		124	106	226	198	292	124
SKA1	340	509	191	214	322	304	280	306	464	539	183	382	124		35	132	104	198	119
SKA2	322	491	207	196	330	335	262	287	446	521	165	364	106	35		122	95	189	101
YLA	442	611	309	315	440	422	382	407	566	640	285	484	226	132	122		44	73	222
PTN	414	583	281	288	412	394	354	379	538	613	257	456	198	104	95	44		94	194
NWT	508	677	375	382	507	488	448	474	632	707	351	550	292	198	189	73	94		288
STN	340	510	229	214	349	353	280	261	420	539	140	338	124	119	101	222	194	288	

Appendix U – Distance for customer in 4 clusters, Cluster ID=4, Dock=Krabi

(Distance for customer in 5 clusters, Cluster ID=5, Dock=Krabi)

	DC KBI	CPN	NRT1	NRT2	SNI1	SNI2	SNI3	KBI	PKT	RNG	TRG	PNA	PLG	SKA1	SKA2	YLA	PTN	NWT	STN
DC KBI		317	156	113	155	162	121	12	158	298	126	76	190	310	292	411	384	478	265
CPN	317		322	296	186	203	231	322	382	121	370	300	389	509	491	611	583	677	510
NRT1	156	322		65	134	119	108	154	304	363	126	221	108	191	207	309	281	375	229
NRT2	113	296	65		134	141	66	110	254	320	75	172	94	214	196	315	288	382	214
SNI1	155	186	134	134		19	71	161	245	210	210	162	228	322	330	440	412	507	349
SNI2	162	203	119	141	19		75	165	249	227	213	167	232	304	335	422	394	488	353
SNI3	121	231	108	66	71	75		102	207	255	141	125	159	280	262	382	354	448	280
KBI	12	322	154	110	161	165	102		163	304	122	81	185	306	287	407	379	474	261
PKT	158	382	304	254	245	249	207	163		301	280	90	344	464	446	566	538	632	420
RNG	298	121	363	320	210	227	255	304	301		399	228	418	539	521	640	613	707	539
TRG	126	370	126	75	210	213	141	122	280	399		193	64	183	165	285	257	351	140
PNA	76	300	221	172	162	167	125	81	90	228	193		262	382	364	484	456	550	338
PLG	190	389	108	94	228	232	159	185	344	418	64	262		124	106	226	198	292	124
SKA1	310	509	191	214	322	304	280	306	464	539	183	382	124		35	132	104	198	119
SKA2	292	491	207	196	330	335	262	287	446	521	165	364	106	35		122	95	189	101
YLA	411	611	309	315	440	422	382	407	566	640	285	484	226	132	122		44	73	222
PTN	384	583	281	288	412	394	354	379	538	613	257	456	198	104	95	44		94	194
NWT	478	677	375	382	507	488	448	474	632	707	351	550	292	198	189	73	94		288
STN	265	510	229	214	349	353	280	261	420	539	140	338	124	119	101	222	194	288	

Appendix V – Distance for customer in 4 clusters, Cluster ID=4, Dock=Phuket

(Distance for customer in 5 clusters, Cluster ID=5, Dock=Phuket)

	DC PKT	CPN	NRT1	NRT2	SNI1	SNI2	SNI3	KBI	PKT	RNG	TRG	PNA	PLG	SKA1	SKA2	YLA	PTN	NWT	STN
DC PKT		390	308	266	246	252	211	169	6	305	285	94	348	468	450	569	542	636	425
CPN	390		322	296	186	203	231	322	382	121	370	300	389	509	491	611	583	677	510
NRT1	308	322		65	134	119	108	154	304	363	126	221	108	191	207	309	281	375	229
NRT2	266	296	65		134	141	66	110	254	320	75	172	94	214	196	315	288	382	214
SNI1	246	186	134	134		19	71	161	245	210	210	162	228	322	330	440	412	507	349
SNI2	252	203	119	141	19		75	165	249	227	213	167	232	304	335	422	394	488	353
SNI3	211	231	108	66	71	75		102	207	255	141	125	159	280	262	382	354	448	280
KBI	169	322	154	110	161	165	102		163	304	122	81	185	306	287	407	379	474	261
PKT	6	382	304	254	245	249	207	163		301	280	90	344	464	446	566	538	632	420
RNG	305	121	363	320	210	227	255	304	301		399	228	418	539	521	640	613	707	539
TRG	285	370	126	75	210	213	141	122	280	399		193	64	183	165	285	257	351	140
PNA	94	300	221	172	162	167	125	81	90	228	193		262	382	364	484	456	550	338
PLG	348	389	108	94	228	232	159	185	344	418	64	262		124	106	226	198	292	124
SKA1	468	509	191	214	322	304	280	306	464	539	183	382	124		35	132	104	198	119
SKA2	450	491	207	196	330	335	262	287	446	521	165	364	106	35		122	95	189	101
YLA	569	611	309	315	440	422	382	407	566	640	285	484	226	132	122		44	73	222
PTN	542	583	281	288	412	394	354	379	538	613	257	456	198	104	95	44		94	194
NWT	636	677	375	382	507	488	448	474	632	707	351	550	292	198	189	73	94		288
STN	425	510	229	214	349	353	280	261	420	539	140	338	124	119	101	222	194	288	

Appendix W – Distance for customer in 4 clusters, Cluster ID=4, Dock=Ranong

(Distance for customer in 5 clusters, Cluster ID=5, Dock=Ranong)

	DC RYG	CPN	NRT1	NRT2	SNI1	SNI2	SNI3	KBI	PKT	RNG	TRG	PNA	PLG	SKA1	SKA2	YLA	PTN	NWT	STN
DC RYG		136	340	314	204	222	249	292	288	16	388	217	407	527	509	629	601	696	528
CPN	136		322	296	186	203	231	322	382	121	370	300	389	509	491	611	583	677	510
NRT1	340	322		65	134	119	108	154	304	363	126	221	108	191	207	309	281	375	229
NRT2	314	296	65		134	141	66	110	254	320	75	172	94	214	196	315	288	382	214
SNI1	204	186	134	134		19	71	161	245	210	210	162	228	322	330	440	412	507	349
SNI2	222	203	119	141	19		75	165	249	227	213	167	232	304	335	422	394	488	353
SNI3	249	231	108	66	71	75		102	207	255	141	125	159	280	262	382	354	448	280
KBI	292	322	154	110	161	165	102		163	304	122	81	185	306	287	407	379	474	261
PKT	288	382	304	254	245	249	207	163		301	280	90	344	464	446	566	538	632	420
RNG	16	121	363	320	210	227	255	304	301		399	228	418	539	521	640	613	707	539
TRG	388	370	126	75	210	213	141	122	280	399		193	64	183	165	285	257	351	140
PNA	217	300	221	172	162	167	125	81	90	228	193		262	382	364	484	456	550	338
PLG	407	389	108	94	228	232	159	185	344	418	64	262		124	106	226	198	292	124
SKA1	527	509	191	214	322	304	280	306	464	539	183	382	124		35	132	104	198	119
SKA2	509	491	207	196	330	335	262	287	446	521	165	364	106	35		122	95	189	101
YLA	629	611	309	315	440	422	382	407	566	640	285	484	226	132	122		44	73	222
PTN	601	583	281	288	412	394	354	379	538	613	257	456	198	104	95	44		94	194
NWT	696	677	375	382	507	488	448	474	632	707	351	550	292	198	189	73	94		288
STN	528	510	229	214	349	353	280	261	420	539	140	338	124	119	101	222	194	288	

Appendix X – Distance for customer in 4 clusters, Cluster ID=4, Dock=Trang

(Distance for customer in 5 clusters, Cluster ID=5, Dock=Trang)

	DC TRG	CPN	NRT1	NRT2	SNI1	SNI2	SNI3	KBI	PKT	RNG	TRG	PNA	PLG	SKA1	SKA2	YLA	PTN	NWT	STN
DC TRG		370	124	75	209	215	140	118	276	394	4	193	62	181	163	283	255	349	146
CPN	370		322	296	186	203	231	322	382	121	370	300	389	509	491	611	583	677	510
NRT1	124	322		65	134	119	108	154	304	363	126	221	108	191	207	309	281	375	229
NRT2	75	296	65		134	141	66	110	254	320	75	172	94	214	196	315	288	382	214
SNI1	209	186	134	134		19	71	161	245	210	210	162	228	322	330	440	412	507	349
SNI2	215	203	119	141	19		75	165	249	227	213	167	232	304	335	422	394	488	353
SNI3	140	231	108	66	71	75		102	207	255	141	125	159	280	262	382	354	448	280
KBI	118	322	154	110	161	165	102		163	304	122	81	185	306	287	407	379	474	261
PKT	276	382	304	254	245	249	207	163		301	280	90	344	464	446	566	538	632	420
RNG	394	121	363	320	210	227	255	304	301		399	228	418	539	521	640	613	707	539
TRG	4	370	126	75	210	213	141	122	280	399		193	64	183	165	285	257	351	140
PNA	193	300	221	172	162	167	125	81	90	228	193		262	382	364	484	456	550	338
PLG	62	389	108	94	228	232	159	185	344	418	64	262		124	106	226	198	292	124
SKA1	181	509	191	214	322	304	280	306	464	539	183	382	124		35	132	104	198	119
SKA2	163	491	207	196	330	335	262	287	446	521	165	364	106	35		122	95	189	101
YLA	283	611	309	315	440	422	382	407	566	640	285	484	226	132	122		44	73	222
PTN	255	583	281	288	412	394	354	379	538	613	257	456	198	104	95	44		94	194
NWT	349	677	375	382	507	488	448	474	632	707	351	550	292	198	189	73	94		288
STN	146	510	229	214	349	353	280	261	420	539	140	338	124	119	101	222	194	288	

Appendix Y – Distance for customer in 4 clusters, Cluster ID=4, Dock=Pangnga

(Distance for customer in 5 clusters, Cluster ID=5, Dock=Pangnga)

	DC PNA	CPN	NRT1	NRT2	SNI1	SNI2	SNI3	KBI	PKT	RNG	TRG	PNA	PLG	SKA1	SKA2	YLA	PTN	NWT	STN
DC PNA		298	217	176	155	162	121	79	87	232	194	4	258	378	360	480	452	546	334
CPN	298		322	296	186	203	231	322	382	121	370	300	389	509	491	611	583	677	510
NRT1	217	322		65	134	119	108	154	304	363	126	221	108	191	207	309	281	375	229
NRT2	176	296	65		134	141	66	110	254	320	75	172	94	214	196	315	288	382	214
SNI1	155	186	134	134		19	71	161	245	210	210	162	228	322	330	440	412	507	349
SNI2	162	203	119	141	19		75	165	249	227	213	167	232	304	335	422	394	488	353
SNI3	121	231	108	66	71	75		102	207	255	141	125	159	280	262	382	354	448	280
KBI	79	322	154	110	161	165	102		163	304	122	81	185	306	287	407	379	474	261
PKT	87	382	304	254	245	249	207	163		301	280	90	344	464	446	566	538	632	420
RNG	232	121	363	320	210	227	255	304	301		399	228	418	539	521	640	613	707	539
TRG	194	370	126	75	210	213	141	122	280	399		193	64	183	165	285	257	351	140
PNA	4	300	221	172	162	167	125	81	90	228	193		262	382	364	484	456	550	338
PLG	258	389	108	94	228	232	159	185	344	418	64	262		124	106	226	198	292	124
SKA1	378	509	191	214	322	304	280	306	464	539	183	382	124		35	132	104	198	119
SKA2	360	491	207	196	330	335	262	287	446	521	165	364	106	35		122	95	189	101
YLA	480	611	309	315	440	422	382	407	566	640	285	484	226	132	122		44	73	222
PTN	452	583	281	288	412	394	354	379	538	613	257	456	198	104	95	44		94	194
NWT	546	677	375	382	507	488	448	474	632	707	351	550	292	198	189	73	94		288
STN	334	510	229	214	349	353	280	261	420	539	140	338	124	119	101	222	194	288	

Appendix Z – Distance for customer in 4 clusters, Cluster ID=4, Dock=Phattalung

(Distance for customer in 5 clusters, Cluster ID=5, Dock=Phattalung)

	DC PLG	CPN	NRT1	NRT2	SNI1	SNI2	SNI3	KBI	PKT	RNG	TRG	PNA	PLG	SKA1	SKA2	YLA	PTN	NWT	STN
DC PLG		396	115	100	234	241	166	189	346	420	70	264	7	128	113	232	205	299	131
CPN	396		322	296	186	203	231	322	382	121	370	300	389	509	491	611	583	677	510
NRT1	115	322		65	134	119	108	154	304	363	126	221	108	191	207	309	281	375	229
NRT2	100	296	65		134	141	66	110	254	320	75	172	94	214	196	315	288	382	214
SNI1	234	186	134	134		19	71	161	245	210	210	162	228	322	330	440	412	507	349
SNI2	241	203	119	141	19		75	165	249	227	213	167	232	304	335	422	394	488	353
SNI3	166	231	108	66	71	75		102	207	255	141	125	159	280	262	382	354	448	280
KBI	189	322	154	110	161	165	102		163	304	122	81	185	306	287	407	379	474	261
PKT	346	382	304	254	245	249	207	163		301	280	90	344	464	446	566	538	632	420
RNG	420	121	363	320	210	227	255	304	301		399	228	418	539	521	640	613	707	539
TRG	70	370	126	75	210	213	141	122	280	399		193	64	183	165	285	257	351	140
PNA	264	300	221	172	162	167	125	81	90	228	193		262	382	364	484	456	550	338
PLG	7	389	108	94	228	232	159	185	344	418	64	262		124	106	226	198	292	124
SKA1	128	509	191	214	322	304	280	306	464	539	183	382	124		35	132	104	198	119
SKA2	113	491	207	196	330	335	262	287	446	521	165	364	106	35		122	95	189	101
YLA	232	611	309	315	440	422	382	407	566	640	285	484	226	132	122		44	73	222
PTN	205	583	281	288	412	394	354	379	538	613	257	456	198	104	95	44		94	194
NWT	299	677	375	382	507	488	448	474	632	707	351	550	292	198	189	73	94		288
STN	131	510	229	214	349	353	280	261	420	539	140	338	124	119	101	222	194	288	

Appendix AA – Distance for customer in 4 clusters, Cluster ID=4, Dock=Songkla

(Distance for customer in 5 clusters, Cluster ID=5, Dock=Songkla)

	DC SKA	CPN	NRT1	NRT2	SNI1	SNI2	SNI3	KBI	PKT	RNG	TRG	PNA	PLG	SKA1	SKA2	YLA	PTN	NWT	STN
DC SKA		503	186	208	314	296	274	292	449	527	173	367	118	16	28	128	100	194	113
CPN	503		322	296	186	203	231	322	382	121	370	300	389	509	491	611	583	677	510
NRT1	186	322		65	134	119	108	154	304	363	126	221	108	191	207	309	281	375	229
NRT2	208	296	65		134	141	66	110	254	320	75	172	94	214	196	315	288	382	214
SNI1	314	186	134	134		19	71	161	245	210	210	162	228	322	330	440	412	507	349
SNI2	296	203	119	141	19		75	165	249	227	213	167	232	304	335	422	394	488	353
SNI3	274	231	108	66	71	75		102	207	255	141	125	159	280	262	382	354	448	280
KBI	292	322	154	110	161	165	102		163	304	122	81	185	306	287	407	379	474	261
PKT	449	382	304	254	245	249	207	163		301	280	90	344	464	446	566	538	632	420
RNG	527	121	363	320	210	227	255	304	301		399	228	418	539	521	640	613	707	539
TRG	173	370	126	75	210	213	141	122	280	399		193	64	183	165	285	257	351	140
PNA	367	300	221	172	162	167	125	81	90	228	193		262	382	364	484	456	550	338
PLG	118	389	108	94	228	232	159	185	344	418	64	262		124	106	226	198	292	124
SKA1	16	509	191	214	322	304	280	306	464	539	183	382	124		35	132	104	198	119
SKA2	28	491	207	196	330	335	262	287	446	521	165	364	106	35		122	95	189	101
YLA	128	611	309	315	440	422	382	407	566	640	285	484	226	132	122		44	73	222
PTN	100	583	281	288	412	394	354	379	538	613	257	456	198	104	95	44		94	194
NWT	194	677	375	382	507	488	448	474	632	707	351	550	292	198	189	73	94		288
STN	113	510	229	214	349	353	280	261	420	539	140	338	124	119	101	222	194	288	

Appendix AB – Distance for customer in 4 clusters, Cluster ID=4, Dock=Yala

(Distance for customer in 5 clusters, Cluster ID=5, Dock=Yala)

	DC YLA	CPN	NRT1	NRT2	SNI1	SNI2	SNI3	KBI	PKT	RNG	TRG	PNA	PLG	SKA1	SKA2	YLA	PTN	NWT	STN
DC YLA		601	300	306	428	410	371	391	548	626	272	466	217	123	111	9	44	80	212
CPN	601		322	296	186	203	231	322	382	121	370	300	389	509	491	611	583	677	510
NRT1	300	322		65	134	119	108	154	304	363	126	221	108	191	207	309	281	375	229
NRT2	306	296	65		134	141	66	110	254	320	75	172	94	214	196	315	288	382	214
SNI1	428	186	134	134		19	71	161	245	210	210	162	228	322	330	440	412	507	349
SNI2	410	203	119	141	19		75	165	249	227	213	167	232	304	335	422	394	488	353
SNI3	371	231	108	66	71	75		102	207	255	141	125	159	280	262	382	354	448	280
KBI	391	322	154	110	161	165	102		163	304	122	81	185	306	287	407	379	474	261
PKT	548	382	304	254	245	249	207	163		301	280	90	344	464	446	566	538	632	420
RNG	626	121	363	320	210	227	255	304	301		399	228	418	539	521	640	613	707	539
TRG	272	370	126	75	210	213	141	122	280	399		193	64	183	165	285	257	351	140
PNA	466	300	221	172	162	167	125	81	90	228	193		262	382	364	484	456	550	338
PLG	217	389	108	94	228	232	159	185	344	418	64	262		124	106	226	198	292	124
SKA1	123	509	191	214	322	304	280	306	464	539	183	382	124		35	132	104	198	119
SKA2	111	491	207	196	330	335	262	287	446	521	165	364	106	35		122	95	189	101
YLA	9	611	309	315	440	422	382	407	566	640	285	484	226	132	122		44	73	222
PTN	44	583	281	288	412	394	354	379	538	613	257	456	198	104	95	44		94	194
NWT	80	677	375	382	507	488	448	474	632	707	351	550	292	198	189	73	94		288
STN	212	510	229	214	349	353	280	261	420	539	140	338	124	119	101	222	194	288	

Appendix AC – Distance for customer in 4 clusters, Cluster ID=4, Dock=Pattani

(Distance for customer in 5 clusters, Cluster ID=5, Dock=Pattani)

	DC PTN	CPN	NRT1	NRT2	SNI1	SNI2	SNI3	KBI	PKT	RNG	TRG	PNA	PLG	SKA1	SKA2	YLA	PTN	NWT	STN
DC PTN		586	284	291	413	395	356	375	533	610	256	450	201	108	97	48	4	93	197
CPN	586		322	296	186	203	231	322	382	121	370	300	389	509	491	611	583	677	510
NRT1	284	322		65	134	119	108	154	304	363	126	221	108	191	207	309	281	375	229
NRT2	291	296	65		134	141	66	110	254	320	75	172	94	214	196	315	288	382	214
SNI1	413	186	134	134		19	71	161	245	210	210	162	228	322	330	440	412	507	349
SNI2	395	203	119	141	19		75	165	249	227	213	167	232	304	335	422	394	488	353
SNI3	356	231	108	66	71	75		102	207	255	141	125	159	280	262	382	354	448	280
KBI	375	322	154	110	161	165	102		163	304	122	81	185	306	287	407	379	474	261
PKT	533	382	304	254	245	249	207	163		301	280	90	344	464	446	566	538	632	420
RNG	610	121	363	320	210	227	255	304	301		399	228	418	539	521	640	613	707	539
TRG	256	370	126	75	210	213	141	122	280	399		193	64	183	165	285	257	351	140
PNA	450	300	221	172	162	167	125	81	90	228	193		262	382	364	484	456	550	338
PLG	201	389	108	94	228	232	159	185	344	418	64	262		124	106	226	198	292	124
SKA1	108	509	191	214	322	304	280	306	464	539	183	382	124		35	132	104	198	119
SKA2	97	491	207	196	330	335	262	287	446	521	165	364	106	35		122	95	189	101
YLA	48	611	309	315	440	422	382	407	566	640	285	484	226	132	122		44	73	222
PTN	4	583	281	288	412	394	354	379	538	613	257	456	198	104	95	44		94	194
NWT	93	677	375	382	507	488	448	474	632	707	351	550	292	198	189	73	94		288
STN	197	510	229	214	349	353	280	261	420	539	140	338	124	119	101	222	194	288	

Appendix AD – Distance for customer in 4 clusters, Cluster ID=4, Dock=Narathiwat

(Distance for customer in 5 clusters, Cluster ID=5, Dock=Narathiwat)

	DC NWT	CPN	NRT1	NRT2	SNI1	SNI2	SNI3	KBI	PKT	RNG	TRG	PNA	PLG	SKA1	SKA2	YLA	PTN	NWT	STN
DC NWT		681	380	386	508	490	452	477	634	706	352	552	297	204	192	77	100	12	292
CPN	681		322	296	186	203	231	322	382	121	370	300	389	509	491	611	583	677	510
NRT1	380	322		65	134	119	108	154	304	363	126	221	108	191	207	309	281	375	229
NRT2	386	296	65		134	141	66	110	254	320	75	172	94	214	196	315	288	382	214
SNI1	508	186	134	134		19	71	161	245	210	210	162	228	322	330	440	412	507	349
SNI2	490	203	119	141	19		75	165	249	227	213	167	232	304	335	422	394	488	353
SNI3	452	231	108	66	71	75		102	207	255	141	125	159	280	262	382	354	448	280
KBI	477	322	154	110	161	165	102		163	304	122	81	185	306	287	407	379	474	261
PKT	634	382	304	254	245	249	207	163		301	280	90	344	464	446	566	538	632	420
RNG	706	121	363	320	210	227	255	304	301		399	228	418	539	521	640	613	707	539
TRG	352	370	126	75	210	213	141	122	280	399		193	64	183	165	285	257	351	140
PNA	552	300	221	172	162	167	125	81	90	228	193		262	382	364	484	456	550	338
PLG	297	389	108	94	228	232	159	185	344	418	64	262		124	106	226	198	292	124
SKA1	204	509	191	214	322	304	280	306	464	539	183	382	124		35	132	104	198	119
SKA2	192	491	207	196	330	335	262	287	446	521	165	364	106	35		122	95	189	101
YLA	77	611	309	315	440	422	382	407	566	640	285	484	226	132	122		44	73	222
PTN	100	583	281	288	412	394	354	379	538	613	257	456	198	104	95	44		94	194
NWT	12	677	375	382	507	488	448	474	632	707	351	550	292	198	189	73	94		288
STN	292	510	229	214	349	353	280	261	420	539	140	338	124	119	101	222	194	288	

Appendix AE – Distance for customer in 4 clusters, Cluster ID=4, Dock=Satun

(Distance for customer in 5 clusters, Cluster ID=5, Dock=Satun)

	DC STN	CPN	NRT1	NRT2	SNI1	SNI2	SNI3	KBI	PKT	RNG	TRG	PNA	PLG	SKA1	SKA2	YLA	PTN	NWT	STN
DC STN		519	238	224	358	349	289	261	419	544	142	336	135	135	114	234	206	300	17
CPN	519		322	296	186	203	231	322	382	121	370	300	389	509	491	611	583	677	510
NRT1	238	322		65	134	119	108	154	304	363	126	221	108	191	207	309	281	375	229
NRT2	224	296	65		134	141	66	110	254	320	75	172	94	214	196	315	288	382	214
SNI1	358	186	134	134		19	71	161	245	210	210	162	228	322	330	440	412	507	349
SNI2	349	203	119	141	19		75	165	249	227	213	167	232	304	335	422	394	488	353
SNI3	289	231	108	66	71	75		102	207	255	141	125	159	280	262	382	354	448	280
KBI	261	322	154	110	161	165	102		163	304	122	81	185	306	287	407	379	474	261
PKT	419	382	304	254	245	249	207	163		301	280	90	344	464	446	566	538	632	420
RNG	544	121	363	320	210	227	255	304	301		399	228	418	539	521	640	613	707	539
TRG	142	370	126	75	210	213	141	122	280	399		193	64	183	165	285	257	351	140
PNA	336	300	221	172	162	167	125	81	90	228	193		262	382	364	484	456	550	338
PLG	135	389	108	94	228	232	159	185	344	418	64	262		124	106	226	198	292	124
SKA1	135	509	191	214	322	304	280	306	464	539	183	382	124		35	132	104	198	119
SKA2	114	491	207	196	330	335	262	287	446	521	165	364	106	35		122	95	189	101
YLA	234	611	309	315	440	422	382	407	566	640	285	484	226	132	122		44	73	222
PTN	206	583	281	288	412	394	354	379	538	613	257	456	198	104	95	44		94	194
NWT	300	677	375	382	507	488	448	474	632	707	351	550	292	198	189	73	94		288
STN	17	510	229	214	349	353	280	261	420	539	140	338	124	119	101	222	194	288	

Appendix AF – Distance for customer in 5 clusters, Cluster ID=1, Dock=Chiangmai

	DC CMI	CMI1	CMI2	CMI3	LPN	LPG1	LGP2	MSN	PRE	CRI1	CRI2	PYO	NAN1	NAN2
DC CMI		6	19	9	40	105	106	240	211	192	283	161	322	341
CMI1	6		13	10	36	102	102	241	208	188	279	158	318	337
CMI2	19	13		18	28	93	94	247	199	188	278	157	309	298
CMI3	9	10	18		41	106	107	232	212	191	281	160	322	301
LPN	40	36	28	41		74	75	262	179	212	302	181	290	309
LPG1	105	102	93	106	74		5	331	111	231	290	140	221	240
LGP2	106	102	94	107	75	5		330	108	231	290	140	219	238
MSN	240	241	247	232	262	331	330		441	418	509	387	552	567
PRE	211	208	199	212	179	111	108	441		231	289	140	111	130
CRI1	192	188	188	191	212	231	231	418	231		102	94	224	227
CRI2	283	279	278	281	302	290	290	509	289	102		157	264	243
PYO	161	158	157	160	181	140	140	387	140	94	157		154	157
NAN1	322	318	309	322	290	221	219	552	111	224	264	154		20
NAN2	341	337	298	301	309	240	238	567	130	227	243	157	20	

Appendix AG – Distance for customer in 5 clusters, Cluster ID=1, Dock=Lamphun

	DC LPN	CMI1	CMI2	CMI3	LPN	LPG1	LGP2	MSN	PRE	CRI1	CRI2	PYO	NAN1	NAN2
DC LPN		35	29	41	8	67	68	271	173	213	303	182	283	302
CMI1	35		13	10	36	102	102	241	208	188	279	158	318	337
CMI2	29	13		18	28	93	94	247	199	188	278	157	309	298
CMI3	41	10	18		41	106	107	232	212	191	281	160	322	301
LPN	8	36	28	41		74	75	262	179	212	302	181	290	309
LPG1	67	102	93	106	74		5	331	111	231	290	140	221	240
LGP2	68	102	94	107	75	5		330	108	231	290	140	219	238
MSN	271	241	247	232	262	331	330		441	418	509	387	552	567
PRE	173	208	199	212	179	111	108	441		231	289	140	111	130
CRI1	213	188	188	191	212	231	231	418	231		102	94	224	227
CRI2	303	279	278	281	302	290	290	509	289	102		157	264	243
PYO	182	158	157	160	181	140	140	387	140	94	157		154	157
NAN1	283	318	309	322	290	221	219	552	111	224	264	154		20
NAN2	302	337	298	301	309	240	238	567	130	227	243	157	20	

Appendix AH – Distance for customer in 5 clusters, Cluster ID=1, Dock=Lampang

	DC LPG	CMI1	CMI2	CMI3	LPN	LPG1	LGP2	MSN	PRE	CRI1	CRI2	PYO	NAN1	NAN2
DC LPG		101	95	107	75	1	3	332	111	232	291	141	221	240
CMI1	101		13	10	36	102	102	241	208	188	279	158	318	337
CMI2	95	13		18	28	93	94	247	199	188	278	157	309	298
CMI3	107	10	18		41	106	107	232	212	191	281	160	322	301
LPN	75	36	28	41		74	75	262	179	212	302	181	290	309
LPG1	1	102	93	106	74		5	331	111	231	290	140	221	240
LGP2	3	102	94	107	75	5		330	108	231	290	140	219	238
MSN	332	241	247	232	262	331	330		441	418	509	387	552	567
PRE	111	208	199	212	179	111	108	441		231	289	140	111	130
CRI1	232	188	188	191	212	231	231	418	231		102	94	224	227
CRI2	291	279	278	281	302	290	290	509	289	102		157	264	243
PYO	141	158	157	160	181	140	140	387	140	94	157		154	157
NAN1	221	318	309	322	290	221	219	552	111	224	264	154		20
NAN2	240	337	298	301	309	240	238	567	130	227	243	157	20	

Appendix AI – Distance for customer in 5 clusters, Cluster ID=1, Dock=Mae Hong Sorn

	DC MSN	CMI1	CMI2	CMI3	LPN	LPG1	LGP2	MSN	PRE	CRI1	CRI2	PYO	NAN1	NAN2
DC MSN		267	271	272	247	322	323	41	428	457	548	427	538	557
CMI1	267		13	10	36	102	102	241	208	188	279	158	318	337
CMI2	271	13		18	28	93	94	247	199	188	278	157	309	298
CMI3	272	10	18		41	106	107	232	212	191	281	160	322	301
LPN	247	36	28	41		74	75	262	179	212	302	181	290	309
LPG1	322	102	93	106	74		5	331	111	231	290	140	221	240
LGP2	323	102	94	107	75	5		330	108	231	290	140	219	238
MSN	41	241	247	232	262	331	330		441	418	509	387	552	567
PRE	428	208	199	212	179	111	108	441		231	289	140	111	130
CRI1	457	188	188	191	212	231	231	418	231		102	94	224	227
CRI2	548	279	278	281	302	290	290	509	289	102		157	264	243
PYO	427	158	157	160	181	140	140	387	140	94	157		154	157
NAN1	538	318	309	322	290	221	219	552	111	224	264	154		20
NAN2	557	337	298	301	309	240	238	567	130	227	243	157	20	

Appendix AJ – Distance for customer in 5 clusters, Cluster ID=1, Dock=Phrae

	DC PRE	CMI1	CMI2	CMI3	LPN	LPG1	LGP2	MSN	PRE	CRI1	CRI2	PYO	NAN1	NAN2
DC PRE		234	231	244	208	139	137	470	27	260	312	169	133	152
CMI1	234		13	10	36	102	102	241	208	188	279	158	318	337
CMI2	231	13		18	28	93	94	247	199	188	278	157	309	298
CMI3	244	10	18		41	106	107	232	212	191	281	160	322	301
LPN	208	36	28	41		74	75	262	179	212	302	181	290	309
LPG1	139	102	93	106	74		5	331	111	231	290	140	221	240
LGP2	137	102	94	107	75	5		330	108	231	290	140	219	238
MSN	470	241	247	232	262	331	330		441	418	509	387	552	567
PRE	27	208	199	212	179	111	108	441		231	289	140	111	130
CRI1	260	188	188	191	212	231	231	418	231		102	94	224	227
CRI2	312	279	278	281	302	290	290	509	289	102		157	264	243
PYO	169	158	157	160	181	140	140	387	140	94	157		154	157
NAN1	133	318	309	322	290	221	219	552	111	224	264	154		20
NAN2	152	337	298	301	309	240	238	567	130	227	243	157	20	

Appendix AJ – Distance for customer in 5 clusters, Cluster ID=1, Dock=Chiangrai

	DC CRI	CMI1	CMI2	CMI3	LPN	LPG1	LGP2	MSN	PRE	CRI1	CRI2	PYO	NAN1	NAN2
DC CRI		191	188	191	212	232	231	419	231	14	111	93	231	234
CMI1	191		13	10	36	102	102	241	208	188	279	158	318	337
CMI2	188	13		18	28	93	94	247	199	188	278	157	309	298
CMI3	191	10	18		41	106	107	232	212	191	281	160	322	301
LPN	212	36	28	41		74	75	262	179	212	302	181	290	309
LPG1	232	102	93	106	74		5	331	111	231	290	140	221	240
LGP2	231	102	94	107	75	5		330	108	231	290	140	219	238
MSN	419	241	247	232	262	331	330		441	418	509	387	552	567
PRE	231	208	199	212	179	111	108	441		231	289	140	111	130
CRI1	14	188	188	191	212	231	231	418	231		102	94	224	227
CRI2	111	279	278	281	302	290	290	509	289	102		157	264	243
PYO	93	158	157	160	181	140	140	387	140	94	157		154	157
NAN1	231	318	309	322	290	221	219	552	111	224	264	154		20
NAN2	234	337	298	301	309	240	238	567	130	227	243	157	20	

Appendix AK – Distance for customer in 5 clusters, Cluster ID=1, Dock=Phayao

	DC PYO	CMI1	CMI2	CMI3	LPN	LPG1	LGP2	MSN	PRE	CRI1	CRI2	PYO	NAN1	NAN2
DC PYO		146	243	146	167	142	141	374	142	100	168	13	156	159
CMI1	146		13	10	36	102	102	241	208	188	279	158	318	337
CMI2	243	13		18	28	93	94	247	199	188	278	157	309	298
CMI3	146	10	18		41	106	107	232	212	191	281	160	322	301
LPN	167	36	28	41		74	75	262	179	212	302	181	290	309
LPG1	142	102	93	106	74		5	331	111	231	290	140	221	240
LGP2	141	102	94	107	75	5		330	108	231	290	140	219	238
MSN	374	241	247	232	262	331	330		441	418	509	387	552	567
PRE	142	208	199	212	179	111	108	441		231	289	140	111	130
CRI1	100	188	188	191	212	231	231	418	231		102	94	224	227
CRI2	168	279	278	281	302	290	290	509	289	102		157	264	243
PYO	13	158	157	160	181	140	140	387	140	94	157		154	157
NAN1	156	318	309	322	290	221	219	552	111	224	264	154		20
NAN2	159	337	298	301	309	240	238	567	130	227	243	157	20	

Appendix AL – Distance for customer in 5 clusters, Cluster ID=1, Dock=Nan

	DC NAN	CMI1	CMI2	CMI3	LPN	LPG1	LGP2	MSN	PRE	CRI1	CRI2	PYO	NAN1	NAN2
DC NAN		269	266	269	302	221	220	497	128	205	246	137	18	22
CMI1	269		13	10	36	102	102	241	208	188	279	158	318	337
CMI2	266	13		18	28	93	94	247	199	188	278	157	309	298
CMI3	269	10	18		41	106	107	232	212	191	281	160	322	301
LPN	302	36	28	41		74	75	262	179	212	302	181	290	309
LPG1	221	102	93	106	74		5	331	111	231	290	140	221	240
LGP2	220	102	94	107	75	5		330	108	231	290	140	219	238
MSN	497	241	247	232	262	331	330		441	418	509	387	552	567
PRE	128	208	199	212	179	111	108	441		231	289	140	111	130
CRI1	205	188	188	191	212	231	231	418	231		102	94	224	227
CRI2	246	279	278	281	302	290	290	509	289	102		157	264	243
PYO	137	158	157	160	181	140	140	387	140	94	157		154	157
NAN1	18	318	309	322	290	221	219	552	111	224	264	154		20
NAN2	22	337	298	301	309	240	238	567	130	227	243	157	20	

Appendix AM – Distance for customer in 5 clusters, Cluster ID=4, Dock=Tak

	DC TAK	TAK1	TAK2	KPT	STI	PLK1	PLK2	PCK	UTT1	UTT2	PNB1	PNB2	LEI1	LEI2	KKN2	CPM	NSN1	NSN2	UTI
DC TAK		8	82	72	94	148	171	173	167	176	306	300	370	289	383	419	185	257	217
TAK1	8		83	73	88	146	169	174	164	174	303	301	368	286	381	420	186	258	218
TAK2	82	83		143	169	227	250	244	245	255	363	371	449	368	462	490	256	328	288
KPT	72	73	143		93	115	140	107	175	185	226	232	339	258	352	378	116	188	149
STI	94	88	169	93		59	82	126	93	101	216	228	280	199	293	364	182	255	225
PLK1	148	146	227	115	59		27	82	110	113	161	173	225	144	238	338	136	192	179
PLK2	171	169	250	140	82	27		72	118	121	135	162	199	117	212	312	161	182	203
PCK	173	174	244	107	126	82	72		173	177	120	115	270	189	283	251	98	134	140
UTT1	167	164	245	175	93	110	118	173		11	252	264	245	163	329	400	244	283	286
UTT2	176	174	255	185	101	113	121	177	11		256	268	248	167	333	404	248	287	290
PNB1	306	303	363	226	216	161	135	120	252	256		86	189	111	153	221	189	174	222
PNB2	300	301	371	232	228	173	162	115	264	268	86		275	197	239	149	120	90	138
LEI1	370	368	449	339	280	225	199	270	245	248	189	275		85	126	226	360	364	402
LEI2	289	286	368	258	199	144	117	189	163	167	111	197	85		183	283	279	285	321
KKN2	383	381	462	352	293	238	212	283	329	333	153	239	126	183		100	344	328	377
CPM	419	420	490	378	364	338	312	251	400	404	221	149	226	283	100		262	235	291
NSN1	185	186	256	116	182	136	161	98	244	248	189	120	360	279	344	262		78	42
NSN2	257	258	328	188	255	192	182	134	283	287	174	90	364	285	328	235	78		79
UTI	217	218	288	149	225	179	203	140	286	290	222	138	402	321	377	291	42	79	

Appendix AN – Distance for customer in 5 clusters, Cluster ID=4, Dock=Kamphaeng Phet

	DC KPT	TAK1	TAK2	KPT	STI	PLK1	PLK2	PCK	UTT1	UTT2	PNB1	PNB2	LEI1	LEI2	KKN2	CPM	NSN1	NSN2	UTI
DC KPT		72	142	5	94	116	141	108	174	183	227	233	340	259	353	376	117	189	150
TAK1	72		83	73	88	146	169	174	164	174	303	301	368	286	381	420	186	258	218
TAK2	142	83		143	169	227	250	244	245	255	363	371	449	368	462	490	256	328	288
KPT	5	73	143		93	115	140	107	175	185	226	232	339	258	352	378	116	188	149
STI	94	88	169	93		59	82	126	93	101	216	228	280	199	293	364	182	255	225
PLK1	116	146	227	115	59		27	82	110	113	161	173	225	144	238	338	136	192	179
PLK2	141	169	250	140	82	27		72	118	121	135	162	199	117	212	312	161	182	203
PCK	108	174	244	107	126	82	72		173	177	120	115	270	189	283	251	98	134	140
UTT1	174	164	245	175	93	110	118	173		11	252	264	245	163	329	400	244	283	286
UTT2	183	174	255	185	101	113	121	177	11		256	268	248	167	333	404	248	287	290
PNB1	227	303	363	226	216	161	135	120	252	256		86	189	111	153	221	189	174	222
PNB2	233	301	371	232	228	173	162	115	264	268	86		275	197	239	149	120	90	138
LEI1	340	368	449	339	280	225	199	270	245	248	189	275		85	126	226	360	364	402
LEI2	259	286	368	258	199	144	117	189	163	167	111	197	85		183	283	279	285	321
KKN2	353	381	462	352	293	238	212	283	329	333	153	239	126	183		100	344	328	377
CPM	376	420	490	378	364	338	312	251	400	404	221	149	226	283	100		262	235	291
NSN1	117	186	256	116	182	136	161	98	244	248	189	120	360	279	344	262		78	42
NSN2	189	258	328	188	255	192	182	134	283	287	174	90	364	285	328	235	78		79
UTI	150	218	288	149	225	179	203	140	286	290	222	138	402	321	377	291	42	79	

Appendix AO – Distance for customer in 5 clusters, Cluster ID=4, Dock=Sukothai

	DC STI	TAK1	TAK2	KPT	STI	PLK1	PLK2	PCK	UTT1	UTT2	PNB1	PNB2	LEI1	LEI2	KKN2	CPM	NSN1	NSN2	UTI
DC STI		83	162	91	11	68	91	135	96	104	225	238	289	207	302	402	191	264	233
TAK1	83		83	73	88	146	169	174	164	174	303	301	368	286	381	420	186	258	218
TAK2	162	83		143	169	227	250	244	245	255	363	371	449	368	462	490	256	328	288
KPT	91	73	143		93	115	140	107	175	185	226	232	339	258	352	378	116	188	149
STI	11	88	169	93		59	82	126	93	101	216	228	280	199	293	364	182	255	225
PLK1	68	146	227	115	59		27	82	110	113	161	173	225	144	238	338	136	192	179
PLK2	91	169	250	140	82	27		72	118	121	135	162	199	117	212	312	161	182	203
PCK	135	174	244	107	126	82	72		173	177	120	115	270	189	283	251	98	134	140
UTT1	96	164	245	175	93	110	118	173		11	252	264	245	163	329	400	244	283	286
UTT2	104	174	255	185	101	113	121	177	11		256	268	248	167	333	404	248	287	290
PNB1	225	303	363	226	216	161	135	120	252	256		86	189	111	153	221	189	174	222
PNB2	238	301	371	232	228	173	162	115	264	268	86		275	197	239	149	120	90	138
LEI1	289	368	449	339	280	225	199	270	245	248	189	275		85	126	226	360	364	402
LEI2	207	286	368	258	199	144	117	189	163	167	111	197	85		183	283	279	285	321
KKN2	302	381	462	352	293	238	212	283	329	333	153	239	126	183		100	344	328	377
CPM	402	420	490	378	364	338	312	251	400	404	221	149	226	283	100		262	235	291
NSN1	191	186	256	116	182	136	161	98	244	248	189	120	360	279	344	262		78	42
NSN2	264	258	328	188	255	192	182	134	283	287	174	90	364	285	328	235	78		79
UTI	233	218	288	149	225	179	203	140	286	290	222	138	402	321	377	291	42	79	

Appendix AP – Distance for customer in 5 clusters, Cluster ID=4, Dock=Phitsanulok

	DC PLK	TAK1	TAK2	KPT	STI	PLK1	PLK2	PCK	UTT1	UTT2	PNB1	PNB2	LEI1	LEI2	KKN2	CPM	NSN1	NSN2	UTI
DC PLK		145	225	106	57	9	42	70	117	121	176	185	240	159	253	320	126	199	168
TAK1	145		83	73	88	146	169	174	164	174	303	301	368	286	381	420	186	258	218
TAK2	225	83		143	169	227	250	244	245	255	363	371	449	368	462	490	256	328	288
KPT	106	73	143		93	115	140	107	175	185	226	232	339	258	352	378	116	188	149
STI	57	88	169	93		59	82	126	93	101	216	228	280	199	293	364	182	255	225
PLK1	9	146	227	115	59		27	82	110	113	161	173	225	144	238	338	136	192	179
PLK2	42	169	250	140	82	27		72	118	121	135	162	199	117	212	312	161	182	203
PCK	70	174	244	107	126	82	72		173	177	120	115	270	189	283	251	98	134	140
UTT1	117	164	245	175	93	110	118	173		11	252	264	245	163	329	400	244	283	286
UTT2	121	174	255	185	101	113	121	177	11		256	268	248	167	333	404	248	287	290
PNB1	176	303	363	226	216	161	135	120	252	256		86	189	111	153	221	189	174	222
PNB2	185	301	371	232	228	173	162	115	264	268	86		275	197	239	149	120	90	138
LEI1	240	368	449	339	280	225	199	270	245	248	189	275		85	126	226	360	364	402
LEI2	159	286	368	258	199	144	117	189	163	167	111	197	85		183	283	279	285	321
KKN2	253	381	462	352	293	238	212	283	329	333	153	239	126	183		100	344	328	377
CPM	320	420	490	378	364	338	312	251	400	404	221	149	226	283	100		262	235	291
NSN1	126	186	256	116	182	136	161	98	244	248	189	120	360	279	344	262		78	42
NSN2	199	258	328	188	255	192	182	134	283	287	174	90	364	285	328	235	78		79
UTI	168	218	288	149	225	179	203	140	286	290	222	138	402	321	377	291	42	79	

Appendix AQ – Distance for customer in 5 clusters, Cluster ID=4, Dock=Phichit

	DC PCK	TAK1	TAK2	KPT	STI	PLK1	PLK2	PCK	UTT1	UTT2	PNB1	PNB2	LEI1	LEI2	KKN2	CPM	NSN1	NSN2	UTI
DC PCK		170	240	102	120	77	67	7	168	172	126	122	265	184	278	257	104	141	146
TAK1	170		83	73	88	146	169	174	164	174	303	301	368	286	381	420	186	258	218
TAK2	240	83		143	169	227	250	244	245	255	363	371	449	368	462	490	256	328	288
KPT	102	73	143		93	115	140	107	175	185	226	232	339	258	352	378	116	188	149
STI	120	88	169	93		59	82	126	93	101	216	228	280	199	293	364	182	255	225
PLK1	77	146	227	115	59		27	82	110	113	161	173	225	144	238	338	136	192	179
PLK2	67	169	250	140	82	27		72	118	121	135	162	199	117	212	312	161	182	203
PCK	7	174	244	107	126	82	72		173	177	120	115	270	189	283	251	98	134	140
UTT1	168	164	245	175	93	110	118	173		11	252	264	245	163	329	400	244	283	286
UTT2	172	174	255	185	101	113	121	177	11		256	268	248	167	333	404	248	287	290
PNB1	126	303	363	226	216	161	135	120	252	256		86	189	111	153	221	189	174	222
PNB2	122	301	371	232	228	173	162	115	264	268	86		275	197	239	149	120	90	138
LEI1	265	368	449	339	280	225	199	270	245	248	189	275		85	126	226	360	364	402
LEI2	184	286	368	258	199	144	117	189	163	167	111	197	85		183	283	279	285	321
KKN2	278	381	462	352	293	238	212	283	329	333	153	239	126	183		100	344	328	377
CPM	257	420	490	378	364	338	312	251	400	404	221	149	226	283	100		262	235	291
NSN1	104	186	256	116	182	136	161	98	244	248	189	120	360	279	344	262		78	42
NSN2	141	258	328	188	255	192	182	134	283	287	174	90	364	285	328	235	78		79
UTI	146	218	288	149	225	179	203	140	286	290	222	138	402	321	377	291	42	79	

Appendix AR – Distance for customer in 5 clusters, Cluster ID=4, Dock=Uttaradit

	DC UTT	TAK1	TAK2	KPT	STI	PLK1	PLK2	PCK	UTT1	UTT2	PNB1	PNB2	LEI1	LEI2	KKN2	CPM	NSN1	NSN2	UTI
DC UTT		189	269	200	114	128	135	191	25	15	270	283	263	181	347	447	262	301	304
TAK1	189		83	73	88	146	169	174	164	174	303	301	368	286	381	420	186	258	218
TAK2	269	83		143	169	227	250	244	245	255	363	371	449	368	462	490	256	328	288
KPT	200	73	143		93	115	140	107	175	185	226	232	339	258	352	378	116	188	149
STI	114	88	169	93		59	82	126	93	101	216	228	280	199	293	364	182	255	225
PLK1	128	146	227	115	59		27	82	110	113	161	173	225	144	238	338	136	192	179
PLK2	135	169	250	140	82	27		72	118	121	135	162	199	117	212	312	161	182	203
PCK	191	174	244	107	126	82	72		173	177	120	115	270	189	283	251	98	134	140
UTT1	25	164	245	175	93	110	118	173		11	252	264	245	163	329	400	244	283	286
UTT2	15	174	255	185	101	113	121	177	11		256	268	248	167	333	404	248	287	290
PNB1	270	303	363	226	216	161	135	120	252	256		86	189	111	153	221	189	174	222
PNB2	283	301	371	232	228	173	162	115	264	268	86		275	197	239	149	120	90	138
LEI1	263	368	449	339	280	225	199	270	245	248	189	275		85	126	226	360	364	402
LEI2	181	286	368	258	199	144	117	189	163	167	111	197	85		183	283	279	285	321
KKN2	347	381	462	352	293	238	212	283	329	333	153	239	126	183		100	344	328	377
CPM	447	420	490	378	364	338	312	251	400	404	221	149	226	283	100		262	235	291
NSN1	262	186	256	116	182	136	161	98	244	248	189	120	360	279	344	262		78	42
NSN2	301	258	328	188	255	192	182	134	283	287	174	90	364	285	328	235	78		79
UTI	304	218	288	149	225	179	203	140	286	290	222	138	402	321	377	291	42	79	

Appendix AS – Distance for customer in 5 clusters, Cluster ID=4, Dock=Phetchabun

	DC PNB	TAK1	TAK2	KPT	STI	PLK1	PLK2	PCK	UTT1	UTT2	PNB1	PNB2	LEI1	LEI2	KKN2	CPM	NSN1	NSN2	UTI
DC PNB		304	375	236	236	183	162	130	274	277	23	88	210	133	160	199	195	176	224
TAK1	304		83	73	88	146	169	174	164	174	303	301	368	286	381	420	186	258	218
TAK2	375	83		143	169	227	250	244	245	255	363	371	449	368	462	490	256	328	288
KPT	236	73	143		93	115	140	107	175	185	226	232	339	258	352	378	116	188	149
STI	236	88	169	93		59	82	126	93	101	216	228	280	199	293	364	182	255	225
PLK1	183	146	227	115	59		27	82	110	113	161	173	225	144	238	338	136	192	179
PLK2	162	169	250	140	82	27		72	118	121	135	162	199	117	212	312	161	182	203
PCK	130	174	244	107	126	82	72		173	177	120	115	270	189	283	251	98	134	140
UTT1	274	164	245	175	93	110	118	173		11	252	264	245	163	329	400	244	283	286
UTT2	277	174	255	185	101	113	121	177	11		256	268	248	167	333	404	248	287	290
PNB1	23	303	363	226	216	161	135	120	252	256		86	189	111	153	221	189	174	222
PNB2	88	301	371	232	228	173	162	115	264	268	86		275	197	239	149	120	90	138
LEI1	210	368	449	339	280	225	199	270	245	248	189	275		85	126	226	360	364	402
LEI2	133	286	368	258	199	144	117	189	163	167	111	197	85		183	283	279	285	321
KKN2	160	381	462	352	293	238	212	283	329	333	153	239	126	183		100	344	328	377
CPM	199	420	490	378	364	338	312	251	400	404	221	149	226	283	100		262	235	291
NSN1	195	186	256	116	182	136	161	98	244	248	189	120	360	279	344	262		78	42
NSN2	176	258	328	188	255	192	182	134	283	287	174	90	364	285	328	235	78		79
UTI	224	218	288	149	225	179	203	140	286	290	222	138	402	321	377	291	42	79	

Appendix AT – Distance for customer in 5 clusters, Cluster ID=4, Dock=Loei

	DC LEI	TAK1	TAK2	KPT	STI	PLK1	PLK2	PCK	UTT1	UTT2	PNB1	PNB2	LEI1	LEI2	KKN2	CPM	NSN1	NSN2	UTI
DC LEI		377	457	349	288	235	214	280	254	258	202	287	11	94	135	235	369	376	412
TAK1	377		83	73	88	146	169	174	164	174	303	301	368	286	381	420	186	258	218
TAK2	457	83		143	169	227	250	244	245	255	363	371	449	368	462	490	256	328	288
KPT	349	73	143		93	115	140	107	175	185	226	232	339	258	352	378	116	188	149
STI	288	88	169	93		59	82	126	93	101	216	228	280	199	293	364	182	255	225
PLK1	235	146	227	115	59		27	82	110	113	161	173	225	144	238	338	136	192	179
PLK2	214	169	250	140	82	27		72	118	121	135	162	199	117	212	312	161	182	203
PCK	280	174	244	107	126	82	72		173	177	120	115	270	189	283	251	98	134	140
UTT1	254	164	245	175	93	110	118	173		11	252	264	245	163	329	400	244	283	286
UTT2	258	174	255	185	101	113	121	177	11		256	268	248	167	333	404	248	287	290
PNB1	202	303	363	226	216	161	135	120	252	256		86	189	111	153	221	189	174	222
PNB2	287	301	371	232	228	173	162	115	264	268	86		275	197	239	149	120	90	138
LEI1	11	368	449	339	280	225	199	270	245	248	189	275		85	126	226	360	364	402
LEI2	94	286	368	258	199	144	117	189	163	167	111	197	85		183	283	279	285	321
KKN2	135	381	462	352	293	238	212	283	329	333	153	239	126	183		100	344	328	377
CPM	235	420	490	378	364	338	312	251	400	404	221	149	226	283	100		262	235	291
NSN1	369	186	256	116	182	136	161	98	244	248	189	120	360	279	344	262		78	42
NSN2	376	258	328	188	255	192	182	134	283	287	174	90	364	285	328	235	78		79
UTI	412	218	288	149	225	179	203	140	286	290	222	138	402	321	377	291	42	79	

Appendix AU – Distance for customer in 5 clusters, Cluster ID=4, Dock=Khon Kaen

	DC KKN	TAK1	TAK2	KPT	STI	PLK1	PLK2	PCK	UTT1	UTT2	PNB1	PNB2	LEI1	LEI2	KKN2	CPM	NSN1	NSN2	UTI
DC KKN		459	539	431	371	317	297	362	408	412	232	268	205	262	80	122	380	354	407
TAK1	459		83	73	88	146	169	174	164	174	303	301	368	286	381	420	186	258	218
TAK2	539	83		143	169	227	250	244	245	255	363	371	449	368	462	490	256	328	288
KPT	431	73	143		93	115	140	107	175	185	226	232	339	258	352	378	116	188	149
STI	371	88	169	93		59	82	126	93	101	216	228	280	199	293	364	182	255	225
PLK1	317	146	227	115	59		27	82	110	113	161	173	225	144	238	338	136	192	179
PLK2	297	169	250	140	82	27		72	118	121	135	162	199	117	212	312	161	182	203
PCK	362	174	244	107	126	82	72		173	177	120	115	270	189	283	251	98	134	140
UTT1	408	164	245	175	93	110	118	173		11	252	264	245	163	329	400	244	283	286
UTT2	412	174	255	185	101	113	121	177	11		256	268	248	167	333	404	248	287	290
PNB1	232	303	363	226	216	161	135	120	252	256		86	189	111	153	221	189	174	222
PNB2	268	301	371	232	228	173	162	115	264	268	86		275	197	239	149	120	90	138
LEI1	205	368	449	339	280	225	199	270	245	248	189	275		85	126	226	360	364	402
LEI2	262	286	368	258	199	144	117	189	163	167	111	197	85		183	283	279	285	321
KKN2	80	381	462	352	293	238	212	283	329	333	153	239	126	183		100	344	328	377
CPM	122	420	490	378	364	338	312	251	400	404	221	149	226	283	100		262	235	291
NSN1	380	186	256	116	182	136	161	98	244	248	189	120	360	279	344	262		78	42
NSN2	354	258	328	188	255	192	182	134	283	287	174	90	364	285	328	235	78		79
UTI	407	218	288	149	225	179	203	140	286	290	222	138	402	321	377	291	42	79	

Appendix AV – Distance for customer in 5 clusters, Cluster ID=4, Dock=Chaiyaphum

	DC CPM	TAK1	TAK2	KPT	STI	PLK1	PLK2	PCK	UTT1	UTT2	PNB1	PNB2	LEI1	LEI2	KKN2	CPM	NSN1	NSN2	UTI
DC CPM		439	510	381	383	330	309	264	421	424	208	152	228	274	102	9	256	237	288
TAK1	439		83	73	88	146	169	174	164	174	303	301	368	286	381	420	186	258	218
TAK2	510	83		143	169	227	250	244	245	255	363	371	449	368	462	490	256	328	288
KPT	381	73	143		93	115	140	107	175	185	226	232	339	258	352	378	116	188	149
STI	383	88	169	93		59	82	126	93	101	216	228	280	199	293	364	182	255	225
PLK1	330	146	227	115	59		27	82	110	113	161	173	225	144	238	338	136	192	179
PLK2	309	169	250	140	82	27		72	118	121	135	162	199	117	212	312	161	182	203
PCK	264	174	244	107	126	82	72		173	177	120	115	270	189	283	251	98	134	140
UTT1	421	164	245	175	93	110	118	173		11	252	264	245	163	329	400	244	283	286
UTT2	424	174	255	185	101	113	121	177	11		256	268	248	167	333	404	248	287	290
PNB1	208	303	363	226	216	161	135	120	252	256		86	189	111	153	221	189	174	222
PNB2	152	301	371	232	228	173	162	115	264	268	86		275	197	239	149	120	90	138
LEI1	228	368	449	339	280	225	199	270	245	248	189	275		85	126	226	360	364	402
LEI2	274	286	368	258	199	144	117	189	163	167	111	197	85		183	283	279	285	321
KKN2	102	381	462	352	293	238	212	283	329	333	153	239	126	183		100	344	328	377
CPM	9	420	490	378	364	338	312	251	400	404	221	149	226	283	100		262	235	291
NSN1	256	186	256	116	182	136	161	98	244	248	189	120	360	279	344	262		78	42
NSN2	237	258	328	188	255	192	182	134	283	287	174	90	364	285	328	235	78		79
UTI	288	218	288	149	225	179	203	140	286	290	222	138	402	321	377	291	42	79	

Appendix AX – Distance for customer in 5 clusters, Cluster ID=4, Dock=Nakhon Sawan

	DC NSN	TAK1	TAK2	KPT	STI	PLK1	PLK2	PCK	UTT1	UTT2	PNB1	PNB2	LEI1	LEI2	KKN2	CPM	NSN1	NSN2	UTI
DC NSN		191	262	121	169	122	149	87	232	236	184	120	348	267	311	255	15	88	57
TAK1	191		83	73	88	146	169	174	164	174	303	301	368	286	381	420	186	258	218
TAK2	262	83		143	169	227	250	244	245	255	363	371	449	368	462	490	256	328	288
KPT	121	73	143		93	115	140	107	175	185	226	232	339	258	352	378	116	188	149
STI	169	88	169	93		59	82	126	93	101	216	228	280	199	293	364	182	255	225
PLK1	122	146	227	115	59		27	82	110	113	161	173	225	144	238	338	136	192	179
PLK2	149	169	250	140	82	27		72	118	121	135	162	199	117	212	312	161	182	203
PCK	87	174	244	107	126	82	72		173	177	120	115	270	189	283	251	98	134	140
UTT1	232	164	245	175	93	110	118	173		11	252	264	245	163	329	400	244	283	286
UTT2	236	174	255	185	101	113	121	177	11		256	268	248	167	333	404	248	287	290
PNB1	184	303	363	226	216	161	135	120	252	256		86	189	111	153	221	189	174	222
PNB2	120	301	371	232	228	173	162	115	264	268	86		275	197	239	149	120	90	138
LEI1	348	368	449	339	280	225	199	270	245	248	189	275		85	126	226	360	364	402
LEI2	267	286	368	258	199	144	117	189	163	167	111	197	85		183	283	279	285	321
KKN2	311	381	462	352	293	238	212	283	329	333	153	239	126	183		100	344	328	377
CPM	255	420	490	378	364	338	312	251	400	404	221	149	226	283	100		262	235	291
NSN1	15	186	256	116	182	136	161	98	244	248	189	120	360	279	344	262		78	42
NSN2	88	258	328	188	255	192	182	134	283	287	174	90	364	285	328	235	78		79
UTI	57	218	288	149	225	179	203	140	286	290	222	138	402	321	377	291	42	79	

Appendix AY – Distance for customer in 5 clusters, Cluster ID=4, Dock=Uthai Thani

	DC UTI	TAK1	TAK2	KPT	STI	PLK1	PLK2	PCK	UTT1	UTT2	PNB1	PNB2	LEI1	LEI2	KKN2	CPM	NSN1	NSN2	UTI
DC UTI		215	286	146	222	174	202	140	285	289	220	138	401	319	340	285	41	81	5
TAK1	215		83	73	88	146	169	174	164	174	303	301	368	286	381	420	186	258	218
TAK2	286	83		143	169	227	250	244	245	255	363	371	449	368	462	490	256	328	288
KPT	146	73	143		93	115	140	107	175	185	226	232	339	258	352	378	116	188	149
STI	222	88	169	93		59	82	126	93	101	216	228	280	199	293	364	182	255	225
PLK1	174	146	227	115	59		27	82	110	113	161	173	225	144	238	338	136	192	179
PLK2	202	169	250	140	82	27		72	118	121	135	162	199	117	212	312	161	182	203
PCK	140	174	244	107	126	82	72		173	177	120	115	270	189	283	251	98	134	140
UTT1	285	164	245	175	93	110	118	173		11	252	264	245	163	329	400	244	283	286
UTT2	289	174	255	185	101	113	121	177	11		256	268	248	167	333	404	248	287	290
PNB1	220	303	363	226	216	161	135	120	252	256		86	189	111	153	221	189	174	222
PNB2	138	301	371	232	228	173	162	115	264	268	86		275	197	239	149	120	90	138
LEI1	401	368	449	339	280	225	199	270	245	248	189	275		85	126	226	360	364	402
LEI2	319	286	368	258	199	144	117	189	163	167	111	197	85		183	283	279	285	321
KKN2	340	381	462	352	293	238	212	283	329	333	153	239	126	183		100	344	328	377
CPM	285	420	490	378	364	338	312	251	400	404	221	149	226	283	100		262	235	291
NSN1	41	186	256	116	182	136	161	98	244	248	189	120	360	279	344	262		78	42
NSN2	81	258	328	188	255	192	182	134	283	287	174	90	364	285	328	235	78		79
UTI	5	218	288	149	225	179	203	140	286	290	222	138	402	321	377	291	42	79	

Appendix AZ – Demand for customer in 4 clusters, Cluster ID=1

Office	Demand
Chiang Mai 1	2014
Chiang Mai 2	1006
Chiang Mai 3	241
Lamphun	488
Lampang 1	755
Lampang 2	665
Mae Hong Som	564
Phrae	198
Chiang Rai 1	659
Chiang Rai 2	929
Phayao	636
Nan 1	520
Nan 2	764
Tak 1	671
Tak 2	300
Kamphaeng Phet	1203
Sukothai	551
Phitsanulok 1	569
Phitsanulok 2	1241
Phichit	499
Uttaradit 1	103
Uttaradit 2	627
Phetchabun 1	1457
Loei 1	264
Loei 2	399

Appendix BA – Demand for customer in 4 clusters, Cluster ID=4

(Demand for customer in 5 clusters, Cluster ID=5)

Office	Demand
Chumphon	61
Nakhon Si Thammarat 1	615
Nakhon Si Thammarat 2	175
Surat Thani 1	490
Surat Thani 2	148
Surat Thani 3	434
Krabi	970
Phuket	528
Ranong	320
Trang	456
Pangnga	476
Phattalung	245
Songkla 1	336
Songkla 2	327
Yala	955
Pattani	290
Narathiwat	274
Satun	301

Appendix BB – Demand for customer in 5 clusters, Cluster ID=1

Office	Demand
Chiang Mai 1	2014
Chiang Mai 2	1006
Chiang Mai 3	241
Lamphun	488
Lampang 1	755
Lampang 2	665
Mae Hong Som	564
Phrae	198
Chiang Rai 1	659
Chiang Rai 2	929
Phayao	636
Nan 1	520
Nan 2	764

Appendix BC – Demand for customer in 5 clusters, Cluster ID=4

Office	Demand
Tak 1	671
Tak 2	300
Kamphaeng Phet	1203
Sukothai	551
Phitsanulok 1	569
Phitsanulok 2	1241
Phichit	499
Uttaradit 1	103
Uttaradit 2	627
Phetchabun 1	1457
Phetchabun 2	151
Loei 1	264
Loei 2	399
Khon Kaen 2	488
Chaiyaphum	1344
Nakhon Sawan 1	1803
Nakhon Sawan 2	656
Uthai Thani	1259

Appendix BD – Latitude and longitude of docks and its distance from HQ

Dock	Latitude	Longitude	Distance from HQ
HQ	14.02520095	100.6222634	0
Chiangmai	18.79829	98.94704	656
Lamphun	18.54416	99.0577	618
Lampang	18.40979	99.53008	584
Mae Hong Sorn	19.09344	98.0622	818
Phrae	18.10525	100.30738	541
Chiangrai	19.91536	99.78075	751
Phayao	10.14903	99.86217	660
Nan	18.82342	100.6627	649
Nakorn Ratchasima	14.93604	102.11233	228
Tak	16.84985	99.1442	377
Kamphaeng Phet	16.45545	99.50631	317
Sukothai	17.03416	99.79194	406
Phitsanulok	16.80254	100.21438	334
Phichit	16.40008	100.38454	312
Uttaradit	17.73767	100.21856	469
Phetchabun	16.32234	101.26004	315
Loei	17.53724	101.72412	505
Khon Kaen	16.47167	102.7593	417
Chaiyaphum	15.86553	102.03299	299
Nakhon Sawan	15.68822	100.12983	202
Uthai Thani	15.43597	100.01235	190
Chumphon	10.43827	99.14935	507
Nakhon Si Thammarat	8.42275	99.99572	816
Surat Thani	9.09273	99.36022	685
Krabi	8.16574	98.88473	811
Phuket	7.85945	98.37806	881
Ranong	9.85322	98.59388	626
Trang	7.60604	99.62244	866
Pangnga	8.43088	98.53663	794
Phattalung	7.62399	100.12727	893
Songkla	7.08262	100.62232	999
Yala	6.55037	101.247	1097
Pattani	6.85042	101.26988	1084
Narathiwat	6.35603	101.84105	1175
Satun	6.70639	99.97396	1008

Appendix BE – Python code

```
import numpy as np
import matplotlib.pyplot as plt
import pandas as pd
from docplex.mp.model import Model
import math
```

```
df=pd.read_csv(r'DOHDensity_6Cluster1.csv') ##importvalues
df=np.asmatrix(df)
##cluster1=13
##cluster2=25
##cluster3=30
##cluster4=18
##cluster5=18
```

```
n=13 #no of customer
Q=1000 ##vehicle cap
N=[i for i in range(1,n+1)] ##node f customer from 1 to n+1
V=[0]+N #set of vertices with V = {0} U N
K=[i for i in range(1,10)]#number of available vehicle
fuelprice=4

DOH=df[0:n,0:1]
location=df[0:n,1:3]
#high demand
demand=df[0:n,3:4]
#low demand
#demand=df[0:n,4:5]
demand=np.ravel(demand)

q={i:math.ceil(demand[i-1]/9) for i in N} #amount to be deliver to customer

location_x=np.zeros((n,1))
location_y=np.zeros((n,1))

E=[i for i in range(0,n)]
for i in E:
    location_x[i]=location[i,1]#logitude
    location_y[i]=location[i,0]#latitude

DOH=np.insert(DOH,0,'Dock')
DOH=np.ravel(DOH)
location_x=np.insert(location_x,0,0)
location_y=np.insert(location_y,0,0)
print(demand)
print(K)
```

```
#realdistance

dfdistance = pd.read_csv(r'Cluster1Distance_lampang.csv')
dfdistance=np.matrix(dfdistance)

distance_matrix=np.matrix(dfdistance[1:n+3,2:n+3])

#print(type(distance_matrix))
```

```
#crossdock location
dfdock = pd.read_csv(r'LocationofDock.csv')
dfdock=np.matrix(dfdock)

#name = 'Mae Hong Sorn'
name=dfdistance[1,1]
print(name)

index = np.where(dfdock[:, 0] == name)[0][0]
print(name)
print(index)
distancefromHQ=dfdock[index,3]
print(distancefromHQ)
```

```
def optimisingmodel(distance_matrix):
    mdl = Model('CVRP')

    num_locations = len(distance_matrix)
    V = range(num_locations)
    N = range(1, num_locations)

    A = [(i, j) for i in V for j in V if i != j]
    c = {(i, j): float(distance_matrix[i, j]) for i, j in A}

    x = mdl.binary_var_dict(A, name='x')
    y = mdl.binary_var_dict(K, name='y')
    u = mdl.continuous_var_dict(N, ub=Q, name='u')


    # Objective function components
    cost_per_route = mdl.sum(c[i, j] * x[i, j] * fuelprice for i, j in A)
    fuel_cost_from_HQ = int(distancefromHQ) * fuelprice * 2
    #cost_of_vehicle= mdl.sum(x[i,j]*10000 for i=0 for j in A)
    #vehicle_cost = mdl.sum(y[k] for k in K)

    cost_of_vehicle = mdl.sum(x[i, j] * 3500 if i == 0 else 0 for i, j in A)

    # Combine the components to form the objective
    mdl.minimize(cost_per_route + fuel_cost_from_HQ+cost_of_vehicle)

    mdl.add_constraints(mdl.sum(x[i, j] for j in V if j != i) == 1 for i in N)
    mdl.add_constraints(mdl.sum(x[i, j] for i in V if i != j) == 1 for j in N)
    mdl.add_indicator_constraints(mdl.indicator_constraint(x[i, j], u[i] + q[i] == u[j]) for i, j in A if i != 0 and j != 0)
    mdl.add_constraints(u[i] >= q[i] for i in N)


    mdl.parameters.timelimit = 3600


    solution = mdl.solve(log_output=False)
    objective = mdl.objective_value
    return objective,solution,A,x,c
```

```
result,solution,A,x,_=optimisingmodel(distance_matrix)
print(name,':',result)
```

```
location_x[0]=dfdock[index,2]
location_y[0]=dfdock[index,1]

active_arcs = [a for a in A if x[a].solution_value>0.9] #is active arc if value is 1
print(solution)
```

VITA

NAME Pakaporn Bunwit

DATE OF BIRTH 1 September 1997

PLACE OF BIRTH Bangkok