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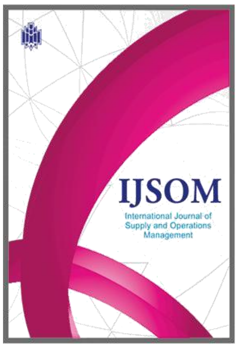

Evaluation of Transportation Distance Optimization Route for Milk Run Logistics System

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Abstract

An efficient logistic system has become more important in today's business process. Milk run system is being introduced to encourage efficient logistic system in manufacturing which has indirectly resulted in a reduction of transportation cost, travelling path, as well as fuel consumption. However, the poor optimal state of the original delivery route and low vehicle loading rate has a huge impact on the production effectiveness. The objective of this study is to evaluate the current milk run route, optimize the transportation volume capacity and propose a transportation route for the milk run logistics system. The milk run concept is introduced to deliver components to the production line from multiple suppliers. This approach is based on the Just-In-Time concept promoted by Toyota Production System where the small batch is delivered to the production line to reduce the side inventory. A high frequency of delivery is required. Therefore, the load for each of the delivery needs to be calculated to achieve maximum load with minimum inventory. The Saving Matrix Method based on Tabu Search model and Ant Colony Optimization model is used to evaluate the current milk run route. The result of the analysis showed an unutilized capacity of 49% that can be reduced to 3% with a distance deviation between 0% for direct milk run route and 2.0% to 6.8% for indirect milk run route. The managerial suggestions that can increase the logistics efficiency of the milk run are provided to benefit the organization by reducing the total logistics cost.

Keywords: Milk Run; Saving Matrix; Heuristic Method; Cross-Border Trucking; Full-Truck-Load; Transportation Efficiency.

1. Introduction

The logistics activity in the just-in-time supply pickup and delivery system supports the logistics operation between a manufacturer and the suppliers. This is done by controlling the sequence, timing and frequency of the delivery and container pickup. It is important for the system to maintain a small inventory in the production line. The just-in-time production line receives components and raw materials regularly, frequently and usually in a small quantity. Frequent delivery in less-than-truck-load (LTL) might cause a high transportation cost. Therefore, to mitigate this problem, most manufacturers consolidate the small delivery into a full truck load (FTL) by scheduling pickup route to several suppliers. Generally, a route consists a few suppliers in the local regions to reduce the transportation cost.

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Specifically, milk run logistics is a term of logistics procurement method that uses routing to consolidate goods collection by the buyer. Using the predefined route, a truck is dispatched on an agreed time for goods collection from various suppliers and delivered to destination or factory (Nemoto, Hayashi, & Hashimoto, 2010). Its method uses small-lot frequent pick up by consolidating the shipment into a fully loaded distribution. Milk run logistics system is widely used in the automotive industries as manufacturers need to control low inventories at the production line side due to space constraint. In addition, milk run system is also practised by suppliers that supply common component or material to several customers. In the case where several customers require the same components to be delivered in a small quantity over several times per day, some suppliers used milk run approach to reduce their transportation cost while meeting customers' requirement. Therefore, it can be concluded that milk run system is also applicable for many situations especially when the main objective is to reduce the cost of transportation.

In the automotive manufacturing industries, a competitive advantage has become a major focus to ensure profitability. Supply chain is designed to meet the competitive advantage by focusing on the transportation management and inventory management. Different distribution strategies provide a different cost advantage to the company. As prevalent in the automotive industries, the logistics cost contributes a signification amount of cost of supply chain. The proposal to use milk run is to support the lean manufacturing system while simultaneously saving the logistics cost. Multiple suppliers can supply the component as requested more frequently while keeping the inventory level low. Understanding the freight is transported from one location to another is very important to determine the company business plan as well as the company's financial strength.

Therefore, milk run delivery has been introduced to optimize and manage transportation and inventory. This system aims to generally support the just-in-time (JIT) system and save the operation cost. However, the threat for this system is the poor optimal state of the original delivery route and the low vehicle loading rate which have a huge impact on the production effectiveness.

In the past literature, the method currently being practised, is reviewed to evaluate the milk run implementation in the current industries. The methods might not be suitable for all the milk run design depending on the systems need. However, it could be used to evaluate the current state of the systems and compare the gap between the current and newly proposed by using the Saving Matrix method, a heuristic method to determine the product distribution routes based on the capacity of the vehicle to obtain the shortest route (Suparjo, 2019). On top of that, the meta heuristic method such as Tabu Search is used to ensure distance of the route sequence calculated is not repeated (Glover & Laguna, 2008) and Elias et al. (2021) and Ant Colony Optimization is used to ensure the shortest route identified. (Maniezzo, Gambardella, & de Luigi, 2004) and Li, Tian, Leung (2009).

In this study, the cross-border milk run operations of an automotive manufacturer company located in Selangor, Malaysia has been evaluated. The study focussed on the company's goods collection and logistics operation situated in four main provinces in Thailand which are Bangkok, Rayong, Chonburi and Ayutthaya using cross-border trucking. There are two types of milk run that are currently practised by the company which are direct milk run and indirect milk run. In the direct milk run, the truck collects the automotive component from multiple suppliers and directly delivers to the production line. The delivery is very time sensitive as the component must be delivered within the allocated time to ensure no disruption to the production line. However, in the indirect milk run system, the truck collects the automotive component from the suppliers and deliver to the warehouse. Then, upon the manufacturer request, the component is delivered to the production line from the warehouse. The indirect delivery is usually being practised for the supplier that is located further from the manufacturer location. In this study, only the routing of the milk run system will be evaluated instead of the whole delivery system to the manufacturer. Considering the long distance from the suppliers and the company, the final location of the study is centred in the Bukit Kayu Hitam (BKH) where all the shipments from Thailand to Malaysia will stop at transit depot for complete documentation verification and custom clearance.

The aim of this study is to optimize the shipment volume based on the milk run system. The study hypothesised that the capacity volume and distance of current direct milk run, and indirect milk run routes can be optimized by using the Saving Matrix approach derived from the Tabu and Ant Colony Method. The logistics cost can be controlled as the supply is consolidated. The vehicle routing is the main element in just-in-time supplier pickup and delivery system. The goal of routing is to provide efficient transportation route between plant and suppliers. There is no established system to determine the most efficient route. However, in the present study, the route is consolidated based on the location of the suppliers and capacity of the lorry. This is very important as by optimizing the distance, the cost can be reduced in the supply chain.

Moreover, the value of the optimized route distance is determined, and the current volume capacity utilization is analysed using the proposed method. This might open the possibility to propose a new route to increase the capacity volume utilization for every trip and at the same time to gain cost benefit by reducing the logistics cost from the increased efficiency (Moryadee et al., 2019). As such, it is assumed that the capacity demand throughout the study is consistent, and the traffic flow congesting factors is ignored. This is because in the actual condition, the fluctuation in demand does impact the capacity of vehicle loading and the trip required. Furthermore, the high flow traffic congestion increases the delivery timing and affects the just-in-time system. Therefore, the constraint will be put on the vehicle loading and the distance only.

The remaining sections of this paper are structured with Literature Review highlighting an evaluation of the study concepts, variables and background of the proposed methods of study. Section 3 then describes the research methodology and this is followed by results and discussion in Section 4. Lastly Section 5 provides the conclusion with the managerial suggestions postulated at the end of the paper.

2. Literature Review

Supply Chain Management and Logistics Management

Council of Supply Chain Management Professionals (CSCMP) defines Supply Chain Management as the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. The activity also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies (CSCMP, 2013). The objective of the supply chain management is to increase the value of the supply chain while reducing the cost by optimizing the chain. (Shukla, Garg, & Agarwal, 2011). SCM objective is also to provide support to related parties in the network such as suppliers, producers, customers, and personnel responsible for transport by supporting the management of an interconnected business network (Ramos, Pettit, Flanigan, Romero, & Huayta, 2020).

The logistics management is a part of supply chain management that plans, implements, and controls the efficient, effective forward and reverses flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements. (CSCMP, 2013). Logistics in Supply Chain Management can be viewed in four different perspectives which are traditionalist, relabeling, unionist and inter-sectionist (Larson & Halldorsson, 2004). In traditionalist, supply chain management is a subset of logistics operation while the unionist sees logistics as a subset of supply chain management. From relabeling perspective, logistics is simply renamed as supply chain management. There's no distinguished distinctive difference between supply chain management and logistics from relabeling perspective. Meanwhile, inter-sectionist views logistics and supply chain management intersect each other in strategic and integrative elements. All the important participants in the supply chain such as suppliers, customers and logistics service providers need to be on board in order to make sure the supply chain management is effectively implemented. Moreover, a common understanding needs to be established between the supply chain participants to ensure adoption of common perspective.

Supply chain management focuses on managing the supply chain asset and product, information and financial flow to increase the supply chain surplus. (Chopra, 2019). A good supply chain management will benefit all the contributing members of the supply chain. The supply chain management is defined as a sound philosophy of management based on coordination and integration of functions. It links the activities and key processes within the company and the entire value system in order to synchronize and optimize product flow management, services and information. Therefore, it can create value for the customer. (Dhiba & Velda, 2017). The main idea of supply chain management is to manage the relationship rather than optimizing the individual component of the systems (Larson & Halldorsson, 2004). While planning for competitive strategy of the firm, it is crucial to evaluate the overall supply chain instead of individual operation or department. Shukla, Garg, & Agarwal (2011) proposed six stages of managing the supply chain. It starts with planning the supply chain followed by analyzing the various factor involved in the supply chain. The third stage is developing a mutual trust, information system and relationship with members of the supply chain. The forth stage is to integrate all the functional field in the supply chain. The fifth is to deliver the product and service and the last stage is to manage the return from the market issue and problem. (Shukla, Garg, & Agarwal, 2011).

The main concern in the supply chain management are transportation and inventory management. While designing a supply chain, these two factors need to be integrated to achieve a competitive advantage. Berman and Wang proposed for milk run strategy to improve the system to tackle this issue. (Berman & Wang, 2006). In the competitive business environment, the customer's expectation for the low cost with high quality product is increasing. The automotive industry is being pressured to keep the cost low and meet customers' expectation. Understanding the complex yet sophisticated supply chain in automotive industries help to manage the supply chain and reduce the cost.

Therefore, using supply chain management and focusing on the logistics aspect of the supply chain, the managers manage to identify the area of improvement and optimization to increase overall supply chain surplus. Milk-run logistics supports the lean manufacturing system in the automotive industries. This method reduces the inventory with high delivery frequency with the combination of several suppliers' delivery.

Just-In-Time Delivery System in Automotive Industries

Just-in-time is defined as producing required unit at the required quantity and the required time. Just-in-time concept is supported by jidoka which means automation. Jidoka is required in just-in-time system to ensure that no defect is carried to the next process. (Monden, 2012). Any irregularities in the process will automatically stop the process and resolve the issue. Therefore, the cost of defect can be reduced as the issue is under control. On top of cost, the other factors that make just-in-time systems unique are product quality, performance, delivery reliability, and availability. Successful just-in-time system in the automotive is heavily dependent on the supplier relationship management. Good collaboration between customers and suppliers will create the value in the supply chain during just-in-time implementation and reduce the risk of failure.

The planning and implementation of the just-in-time concept is surrounded by two basic ideas which are to reduce the cost through eliminating of waste and to optimize the worker's capabilities. (Sugimori et al., 1977). Just-in-time delivery system in automotive industries work around the idea of pull systems. Pull system corresponds with the actual usage of consumption. Using the Kanban card, the just-in-time replenishment can be monitored and coordinated systematically. Kanban is the organized system to manage the inventory since inventory is considered as waste regardless pull or push system. (Liker, 2004). Therefore, just-in-time focuses on producing the parts at the rate of customer's demand by eliminating the waste.

Milk Run

Milk run concept is adopted from the dairy industries. In order to ensure fresh delivery and prevent overstocking, a tanker is sent to several farmers to collect milk and deliver to milk processing firm or farms? Milk run has been widely practised by automotive manufacturer as the efficient and effective system will reduce the production-based price and increase the overall profit (Singh Brar & Saini, 2011). The goal of milk run is to achieve in time delivery while avoiding material shortage and production downtime (Zhang, Zou, & Hu, 2016). The inventory can be reduced by having a high frequency delivery in small batches to the production line. The features are to improve loading rate, to increase transportation reliability, to standardize returnable boxes and container, to optimize resources and to increase coordination in supply chain component (Singh Brar & Saini, 2011). Supply chain cost can be minimized in milk run transportation systems compared to direct delivery system. The cost is reduced by consolidating shipment to multiple location in single truck. The combination of small delivery quantity and close multiple locations make it favourable to combine the delivered quantity per delivery (Chopra, 2019).

This method is widely adapted in the automotive industries to support the just-in-time delivery system. Milk run is considered as an important element to be integrated in the lean logistics strategy. On top of that, milk run optimized transport capacity usage by ensuring continuous production, reduction of production line stoppage and reduce the material handling space in the production (Simic, et al., 2020) The advantages of milk run are increasing efficiency, updating identification, demand-based production and decreasing inventory. The milk run concept is also being introduced in the in-plan supply as the concept of milk run perfectly supports the implementation of pull-system, Kanban system and just-in-time systems. (Macsay & Banyai, 2017). The in-plan milk run system in the in-plant supply improves the process in the Value Stream Map. While there is a proven benefit in 5S and kaizen, the concept also is because it improves and reduces the source of waste. Therefore, the efficient implementation involves a huge amount of information flow.

Various studies have been conducted to access the effectiveness of milk run implementation. Kovac (2009) investigated the storage issue for the warehouse storage investment served by milk run logistics. Using a mathematical model, he proposed for Multiple Individual Picker (MIP) model which is 36-38% improvement compared to Classical Order Index (COI) model in ordering cycle time, average picking effort or the linear combination of both criteria. (Kov´acs, 2009). Lin, Ge and Shi (2010) analyze the relationship between inventory and transportation by combining Vehicle Routing Problem (VRP) model of Inventory Transportation Integration Optimization (ITIO) to solve milk run optimization issue. By using this model, the total of milk run network system is optimized (Lin, Ge, & Shi, 2010).

In the milk run system, several trucks are assigned to respective routes to pick up the components. The truck delivered empty racking and returnable polybox that have to be returned to the suppliers in the route. Kanban ordering instruction is used by the supplier to fill those racking and returnable polybox with the new orders. Upon arrival at the suppliers, the empty racking will be replaced with the full racking based on the earlier Kanban ordering. Then, the truck will proceed to the other suppliers in the same route. The system is designed to maintain certain level of inventories which usually can last for about four hours. Multiple pick-ups increase the pickup frequency while reducing the shipment size. Therefore, each supplier is normally scheduled to be visited several times a day for pickup arrangement and replenishment.

Heuristics and Metaheuristics Approach

The heuristic approach uses experience, intuition, and estimation when solving a problem. Unlike exact methods, heuristic methods do not represent knowledge about the structure and relationships within the model to solve the problem. Some heuristic approaches to solving the problem of routing vehicles are inserting the nearest neighbours, adding the farthest and nearest neighbour, adding the two-pass sweep method, the Clark-Wright method, and the Saving Matrix method. Heuristic methods represent the rule of choice, filtering and rejecting solutions, and also help to reduce the number of possible ways to solve problems. Heuristic algorithms are often based on the construction of routes where the construction and improvement of routes with respect to the target function are performed iteratively (Saračević et al., 2013). Due to this, the Saving Matrix Method based on the Tabu Search model and Ant Colony Optimization model is used to evaluate the current milk run route by integrating heuristic and meta-heuristic methods.

Metaheuristics, in practice, is a set of algorithms used in solving a variety of optimization problems where the algorithm itself is very little changed depending on the problem being solved. Due to the difficulty of solving large-scale optimality instances of vehicle routing problems, a significant research effort has been dedicated to metaheuristics. Metaheuristic techniques are often preferred for large-scale applications with complicating constraints and decision sets. The metaheuristics approach to solving the problem of routing vehicles is usually based on local search-guided processes taken from nature, such as Simulated Annealing, Genetic Algorithm, Ant Colony Optimization, Tabu Search, and Adaptive Large Neighborhood Search (ALNS) (Saračević et al., 2013).

The Saving Matrix Method based on the Tabu Search model and Ant Colony Optimization model is used to evaluate the current milk run route in this study due to the suitability of the methods with the case study company condition.

Saving Matrix Methods

Saving Matrix is one of the heuristic methods used to solve the transportation problems which include determining the transportation scheduling. The method is used to determine the product distribution route by determining route that must be traversed, and the number of vehicles based on the vehicle capacity in order to obtain the shortest route and minimal shipping cost (Iriani & Asmara, 2020). By using saving matrix method, the distance, time, and shipping cost efficiency can be minimized. Although the method can provide a quick and practical solution when dealing with the transportation distribution problem, the results do not guarantee an optimal solution. However, it can provide an ease of modification when solving problem related to vehicle capacity, number of vehicles, delivery time and other constraints. The proposed step flow for saving matrix is as in Figure 1 below (Lukmandono , M Basuki, M J Hidayat, & F B Aji, 2019)

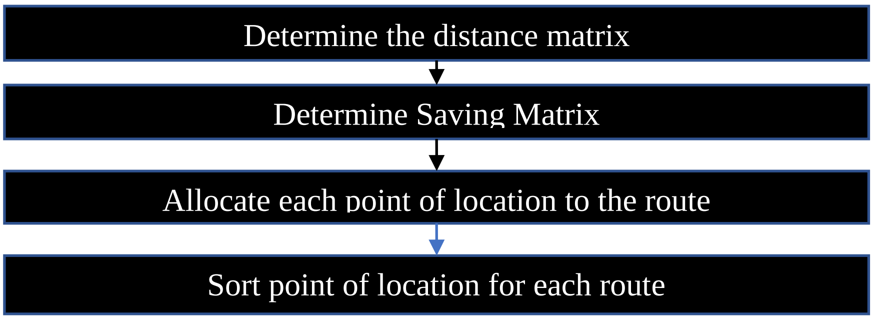

Figure 1. The Step of Saving Matrix Method

First of all, in determining the distance matrix, the distance between each different suppliers and the destination is determined. The distance between two locations can be calculated by using below formula:

$$j_{(1,2)} = \sqrt{(x_1 - x_2) + (y_1 - y_2)}^2$$

$j_{(1,2)}$ = the distance between two location (location 1 and location 2)
x_1 = horizontal coordinate value of location 1
x_2 = horizontal coordinate value of location 2
y_1 = vertical coordinate value of location 1
y_2 = vertical coordinate value of location 2

In the case where the distance between the two location is known, the existing distance should be used instead. (Suparjo, 2019). In this step, the assumption is that each shipment will be delivered directly by using individual route and truck. This distance is also considered as the shortest distance between two locations.

Secondly, the saving matrix is determined by merging several routes that is considered one-way with the other route. The routes that interfere with the merged route will be eliminated from the route calculation. The saving matrix is calculated by using the formula below:

$$S_{(x,y)} = j_{(i,x)} + j_{(i,y)} - j_{(x,y)}$$

Information:
$S_{(x,y)}$ = The distance saving from combining route x with route y.
$j_{(i,x)}$ = The distance from the destination to one supplier.
$j_{(i,y)}$ = The distance from the destination to other customer.
$j_{(x,y)}$ = The distance from one customer to another customer.

Next is to allocate each point of location to the route. In this step, all the suppliers' destination are confirmed to be in the new route determined in the second step by maximizing the savings. It is crucial to confirm that no repeated route and all related destinations are in the new route. At the same time, the total of shipment capacity from each supplier must not exceed the total capacity of the delivery vehicle.

Finally, the location point of each route is sorted according to the visit order. In this step, the objective is to minimize the distance between two locations in the same route. The order is determined by using nearest insert and nearest neighbour sequencing procedure as in Tabu Search Algorithm and Ant Colony Optimization method.

Several studies used Saving Matrix method to evaluate the delivery routes efficiency. The value of saving in transportation system has an effect on the saving total distance (Suparjo, 2019). The impact of the reduced milk run mileage by 15% using saving matrix method has reduced the cost of transportation milk run per trip (Kholil, Hendri, Mangaraja, & Yosan, 2019). In the study of distribution route of fabric product using saving method, there is a cost saving of 32.05% by reducing the transportation mileage by 6.76% (Iriani & Asmara, 2020).

The Savings matrix method is used to determine the PPE distribution route in West Java found that the distance travelled used the shortest distance so that distribution speeds can be achieved and thus reducing the PPE shortages due to timely distribution. Besides, the costs incurred is also lesser than the normal distribution method (Kurnia, Salsabila, Sihombing, Kharisma, & Anwar, 2021)

Tabu Search Algorithm

The Tabu Search is a meta-heuristic method applied in most of the optimization problems. The method is commonly used in network design, financial analysis, telecommunication, production scheduling and many more. The most famous application of Tabu Search is in the Travelling Salesman Problems. In the Travelling Salesman Problem, the salesman is required to travel in several numbers of cities without a particular order. He will visit each of the city only once and end at the starting point while keeping the cost and travelled distance as low as possible. Travelling Salesman Problem represents a lot of problems in logistics and distribution field and used Travelling Salesman Problem model as the model for the solution. (Basu, 2012).

In Tabu Search, the initial solution is being set and called as current solution. Then it will search the neighbourhood for the best solution and set the best solution as the current solution. This process will keep on repeating till the conditions have been met. Usually, conditions are set by the number of iterations, execution time or quality of the solution is met. In Tabu Search, each of the solution is being kept in the list and would not be repeated. Therefore, it is considered as tabu as it bans the repetition of the previous work (Basu, 2012). The unique characteristic of Tabu Search is the adaptive memory, which supported flexible search behaviour.

Alhamdy, Noudehi, & Majdara (2012) did a comparative study of Tabu Search method and Simulated Annealing method to find the most efficient solution using MATLAB. He found out that in small size problem with 10 and 15 cities, both Simulated Annealing and Tabu Search manage to provide a good solution for optimization with 0% gap. However, the optimized result is not consistent with a big gap of 14.93% for large size of problems and required a lot of fine tuning to close the gap. (Adewole et al., 2012).

Tabu Search method is also being used to evaluate milk run to develop better route for the logistics company in the auto industries. The method is selected due to the strong local search ability, having the characteristic of the global search, and the effective and efficient capability for optimization. (Zhang, Zou, & Hu, 2016).

Ant Colony Optimization

Ant Colony Optimization (ACO) is a metaheuristics method to find the optimal reliability design. This method is used to solve the Travelling Salesman Problem (TSP) and also the Vehicle Routing Problem. It is suitable for designing effective combinational optimization problem. The design of ACO method is inspired by real life ant which continuously construct the shortest trail based on the previous information. As a very sociable insect, the survival of the ant is dependent on the survival of the colony rather than the individual. Therefore, ants moved in a colony while foraging for food. Initially all ants will move on the random path to the source of the food. The subsequent ants will follow the path following a higher level of chemical pheromone leaving by the previous ants. Basically, a shorter path leaves a higher concentration of pheromone which will guide more ants to travel the path. If a longer path is taken, the pheromone will evaporate and leave a low level of concentration and lesser ants will travel using the path. Soon enough all the ants will converge into a single most effective path which is the shortest path. The combination of the priori information and posteriori information help to construct a good, optimized solution.

The approach of ACO is based on four basic stages which are constructing the initial solution, evaluating, improving and updating the system. (Kou & Wan, 2007). This stage is iteratively constructed with the combination of several paths till the good solution is found. ACO start with a random set of paths and converge into the most optimized path by imitating the behaviour of the ant.

Way Kou and Ryu Wan (2007) studied and compared several heuristic and metaheuristic methods such as Ant Colony Optimization (ACO) algorithm, Tabu Search (TS), Immune Algorithm (IA), linear approximation method and heuristic method. They found out that all the methods yield high reliability. ACO gave a consistent result with different size and parameter. ACO has been used to evaluate the optimal reliability design and shows a promising general result. However, there’s a concern premature convergent situation due to many unknown parameters (Kou & Wan, 2007).

Nguyen and Dao introduced new method named Hybrid Ant Colony Optimization and Tabu Search to optimize milk run delivery and cost in supply chain. They compared the Tabu Search method, Ant Colony Optimization and Hybrid

Ant Colony Optimization and found that the result Hybrid Ant Colony Optimization outperformed Tabu Search method and Ant Colony method. However, this only applies in a large scale of supply chain. (Nguyen & Dao, 2015). The method for optimization can be summarized as in the table (1).

Table 1. Optimization Method Comparison

Method	Method Types	Details
Saving Matrix Methods	Heuristic	Method used to solve the transportation problems which include determining transportation distribution route and scheduling
Tabu Search Algorithm	Meta-heuristic	Method prohibited the repetition of previous work in the iteration process till the condition is met based on the unique characteristic which is adaptive memory.
Ant Colony Optimization	Meta-heuristics	Method to find the optimal reliability design and suitable for designing effective combinational optimization problem inspired by real life ant behaviour

Methodology

In order to achieve the research project objectives, DMAIC (Define, Measure, Analyse, Improve and Control) method is used along with Saving Matrix method for data analysis. The tool used to analyse the data is Microsoft Excel software and Google Map. The methodologies used in this research includes data collection from current system, data analysis by using the Saving Matrix method and Microsoft Excel software, data comparison and finally proposing the solution for the improvement.

The data collection is obtained from current operation. The distance is determined based on the total distance travelled in the route with reference from Google Map for better accuracy. Considering the same multiple locations for pick up, the sequence of the pickup is changed based on the most optimized distance. Saving Matrix method is used to determine the optimized route considering both distance and capacity of shipment. Figure2 presents the research methodology flow.

DMAIC (Define, Measure, Analyse, Improve, Control) Method

In this research project DMAIC method is used as the framework to approach the overall improvement system. DMAIC is the acronym for Define, Measure, Analyse, Improve and Control. The approach is seen as suitable since it provides a systematic step to tackle the research objectives in an orderly manner. The DMAIC method used to improve the data driven problem is seen as simple yet effective to explore the potential improvement and solution of the research subject.

Define

During the defining stage, the problem statement is being identified. The parameters are being identified based on the literature review of the similar research. In the literature review, the research scope is determined and compared to the case study which is defined to be the distance, the collection sequence, and the shipment capacity. Using that information, the parameter for the case study could be identified whether it will reflect on the expected result of the research.

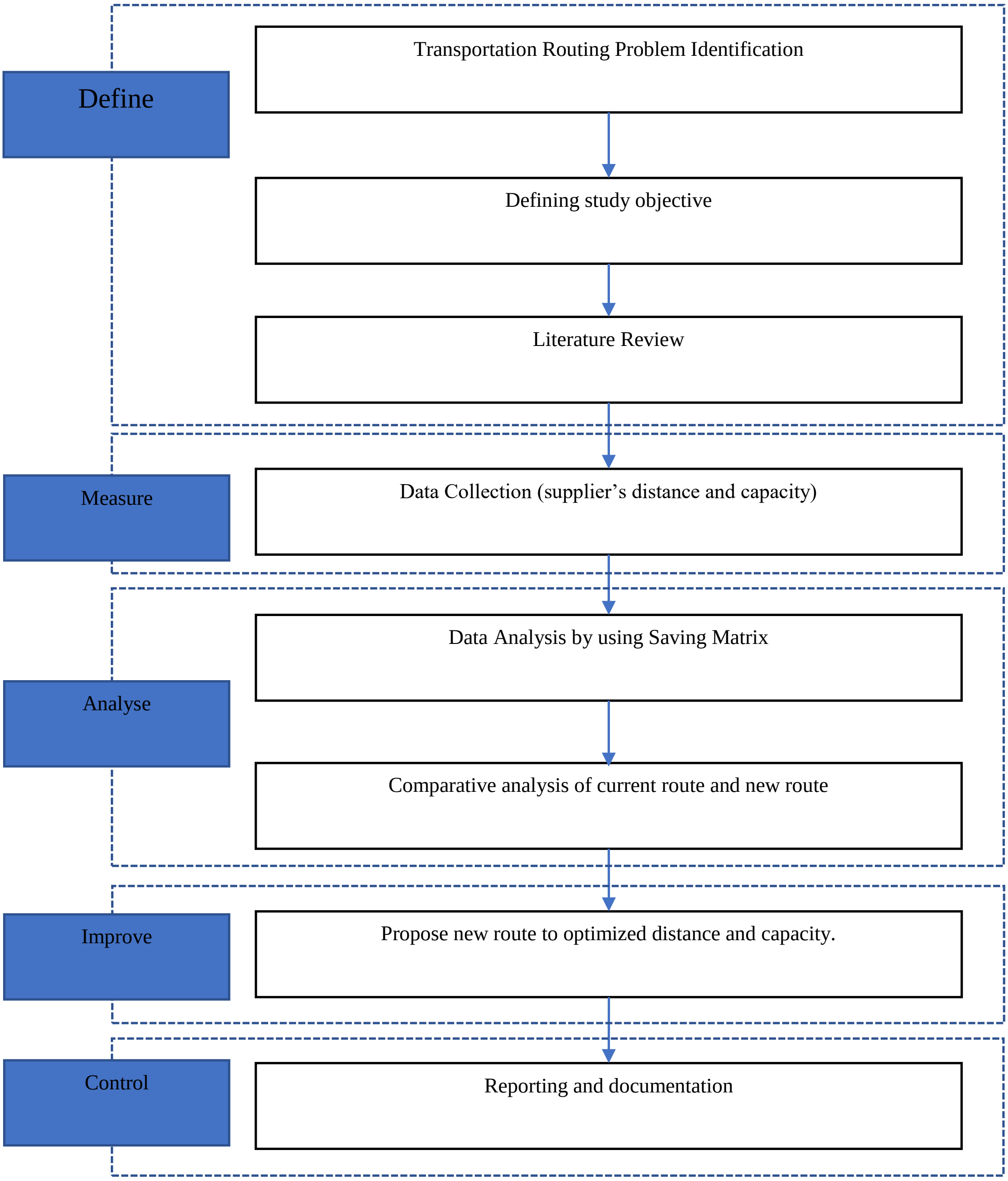

Figure 2. Flowchart of the research methodology using DMAIC approach

On the other hand, any parameter that could not be determined from the case study will be omitted from consideration and being declared as constraint. In this research, the production inventory level and traffic condition are considered as constants. This assumption is made to define the research based on the distance and suppliers' capacity only. In the actual practice, production inventory level and traffic condition may affect the route taken. However, for this research, the parameters are not being considered due to research duration constraints.

Using the guideline from the literature review, the method of analysis is also being identified. Most of the study proposed for Saving Matrix method that it is considered as the simplest method to solve the milk run logistics optimization problem (Suparjo, 2019). Moreover, the Tabu Search Algorithm and Ant Colony Optimization method is also being proposed to increase the optimization accuracy (Jing et al., 2022). These two methods need to be defined and studied in depth to determine the feasibility of the proposed method to the data from the case study. In order to optimize the route, some tools that are used based on the literature review are Microsoft Excel and MATLAB. The tools used are to be decided by the complexity of the data and routing. Small data set can be solved by using Microsoft Excel. However, as the data expands, MATLAB might be a better choice to solve the optimization problem.

Measure

In the measuring stage, the data is collected to establish current baseline as the basis for further improvement in the research. The current baseline is used to compare with the performance at the end of the research to determine whether there is any significant improvement that has been made using the method proposed. In this stage, the data is to be measured and the formula for calculation are determined.

There are two types of parameters collected at this stage which are the distance location of the suppliers and monthly collection capacity. The data collected for the duration of seven months from June 2020 to January 2021. Based on current data, there are ten suppliers that have been identified in the study. The distance between each of the supplier to Bukit Kayu Hitam as well as distance between one supplier to another is measured and recorded for reference. Google Map is used to ensure the accuracy of the distance.

There are two types of capacity data which are actual shipment capacity and actual paid capacity. Actual shipment capacity is based on the volume declared in the packing list document for every shipment. Meanwhile, the actual paid capacity is based on the type of shipment whether full truck load (FTL) or less than truck load (LTL) which is declared for invoicing purposes. The basis for actual paid capacity refers to the volume of container for FTL shipments. Assuming a constant production inventory level, the average capacity of seven months is used for this study for the purpose of calculation and measurement.

At this stage, the first objective of the research project is measured in order to evaluatethe current milk run route and system in the company in term of the capacity efficiency or utilization of the shipment. Based on the current milk run route and system of the company, the percentage of capacity utilization is calculated using the formula below:

$$\text{Volume Utilization} = \frac{V_{actual}}{V_{paid}} \times 100$$

V_{actual} = Actual shipment volume
V_{paid} = Actual paid volume

The volume utilization is used as the baseline for current system for improvement comparison. The unutilized volume is the remaining volume percentage from the volume utilization.

$$\text{Volume Unutilized} = 1 - \frac{V_{actual}}{V_{paid}} \times 100$$

V_{actual} = Actual shipment volume
V_{paid} = Actual paid volume

Any percentage reduction from the baseline is considered as an improvement from the current system.

Analyze

In the analyzing stage, the data is being validated to ensure it is aligned with the research goal. The data is analyzed using Saving Matrix utilising four main steps which are to determine the distance matrix, determine the saving matrix, allocate the location point to the route and sortthe location point for each route (Kholil, Hendri, Mangaraja, & Yosan, 2019). The most optimal route is considered for the shortest distance.

First of all, the distance matrix is established by determining distance from each of the supplier to the destination and to each other. The distance is used to determine the saving matrix. The unit is kilometre (km). The distance between two locations could be calculated using formula or using real distance if the distance is known.

$$j_{(1,2)} = \sqrt{(x_1 - x_2) + (y_1 - y_2)}^2$$

$j_{(1,2)}$ = the distance between two location (location 1 and location 2)
x_1 = horizontal coordinate value of location 1
x_2 = horizontal coordinate value of location 2
y_1 = vertical coordinate value of location 1
y_2 = vertical coordinate value of location 2

Secondly, the saving matrix is determined by using saving matrix formula. Saving matrix represents the saving obtained in term of distance in kilometre once merging two suppliers in one route. The saving matrix formula is as below:

$$S_{(x,y)} = j_{(i,x)} + j_{(i,y)} - j_{(x,y)}$$

Information:
$S_{(x,y)}$ = The distance saving from combining route x with route y.
$j_{(i,x)}$ = The distance from the destination to one supplier.
$j_{(i,y)}$ = The distance from the destination to other customer.
$j_{(x,y)}$ = The distance from one customer to another customer.

The saving matrix is mapped in matrix form and arranged in descending order from the highest saving to the lowest saving.

The third step is to allocate the location point to the route. In this step the objective is to maximize the saving by using iteration procedure which combines the capacity of different suppliers into the same route considering the total capacity does not exceed the capacity of the vehicle. This procedure is repeated till there are no more feasible combination available. In the third step, the capacity for each route is determined. The data is considered as improved using the method proposed if the new data shows a value of less than the current data. However, in case of the data is larger than current data, it is concluded that the current data has been optimized. In this step, the second objective which is to optimize the shipment volume based on milk run system is met. By comparing the capacity of the new routes and the capacity of the current route, the amount of reduction is obtained by using this method.

The final step is to sort the location point for each route. In this step the suppliers' sequence for each route is determined by minimizing the milage travelled for each route. The sequence order has a significant impact on the total milage. Therefore, the Tabu Search is used to find the best sequence in the route. In Tabu Search, the initial route solution is being set and called as current solution. Then it will search the neighbourhood for the best solution and set the best solution as the current solution. This process will keep on repeating till the conditions have been met. Usually, conditions are set by the number of iterations, execution time or quality of the solution is met. In Tabu Search, each of the solution is being kept in the list and would not be repeated. In this step, Ant Colony Optimization method is also used to ensure the shortest route chosen based on the previous iteration process.

Improve

In the improvement stage, the data is being validated to ensure it is aligned with the research goal. The routes identified in the analyzing stage is being examined to ensure the level of improvement obtained compared the current stage. There are two types of improvements which are the capacity and distance.

The capacity improvement is obtained once there is an increase of total utilized capacity based on the new proposed routes. The unutilized capacity is reduced by combining capacity from different suppliers in the same route. Therefore, the capacity is improved.

The distance improvement is obtained by comparing the distance of farthest supplier distance in the route with the total distance route. There will be various gap between one route to another in the combined route as more suppliers in the same route. However, the improvement is considered with the reduction of direct delivery from each supplier to the destination by using the method proposed. Therefore, the third objective which is to propose transportation routes for milk run logistics system is met.

Control

The last stage in the DMAIC step is control. The control stage is to make sure that the change is embedded in the system and system sustainability is met. Control is the most important stage as the system needs to run within the improved structure. All the data and method will be compiled and used as the guideline for future reference in case of new routing is proposed. In this stage, it is important to monitor the delivery routing to identify if there is any obstacle. The initial stage control will guarantee the stability of the logistics system. Mitigation plans need to be put in place; in case the system becomes unstable. In the case of routing, it might need to look at the options in case the optimized route is not feasible after implementation. As the systems become stable, the improvement steps need to be integrated in the standard operation procedure.

Results and Discussion

The research was conducted at one of the automotive manufacturers in Shah Alam, Selangor. The components for the production manufacturing were produced locally and imported from various countries around the world via sea, air, and land. The manufacturer subcontracted a freight forwarder to pick up components at the suppliers in Thailand and Singapore and bring them directly to either the warehouse or production plant depending on the manufacturing requirement.

The method used to transport component via land is by using cross-border trucking. The cross-border trucking is used to move shipment from suppliers located in Singapore and Thailand to the company’s warehouses in Selangor. The movement of the imported component through border boost the trucking business in the ASEAN region. Furthermore, cross-border trucking is faster than sea freight and cheaper than air freight which makes it a more favourable option in moving the shipment to save time and money. The flexibility of routing option and departure allows new transport route to be established and supports door to door delivery services.

In order to ensure a successful cross-border shipment, attention needs to be focussed on the timely planning of the shipment, effective communication between related parties and strong implementation of the shipment planning. A proper planning is crucial to avoid last minute surprise which may affect the shipment and incur additional cost to the company. Moreover, related parties involved need to communicate effectively to align and coordinate the shipment across the border and ensure a strong implementation to deliver in timely manner.

The research focused on the cross-border trucking shipment from Thailand to Malaysia via Bukit Kayu Hitam. There are 10 suppliers to be evaluated for the purpose of this research. The locations of the suppliers are in four main provinces in Thailand which are Rayong, Bangkok, Chonburi and Ayutthaya.

The road infrastructure between the main provinces is well connected and facilitate the industry establishment and economic growth in the area. Many clusters of automotive manufacture and automotive component suppliers are concentrated within these provinces to support Thailand automotive industry as well as the international trade (Warr & Kohpaiboon, 2017).

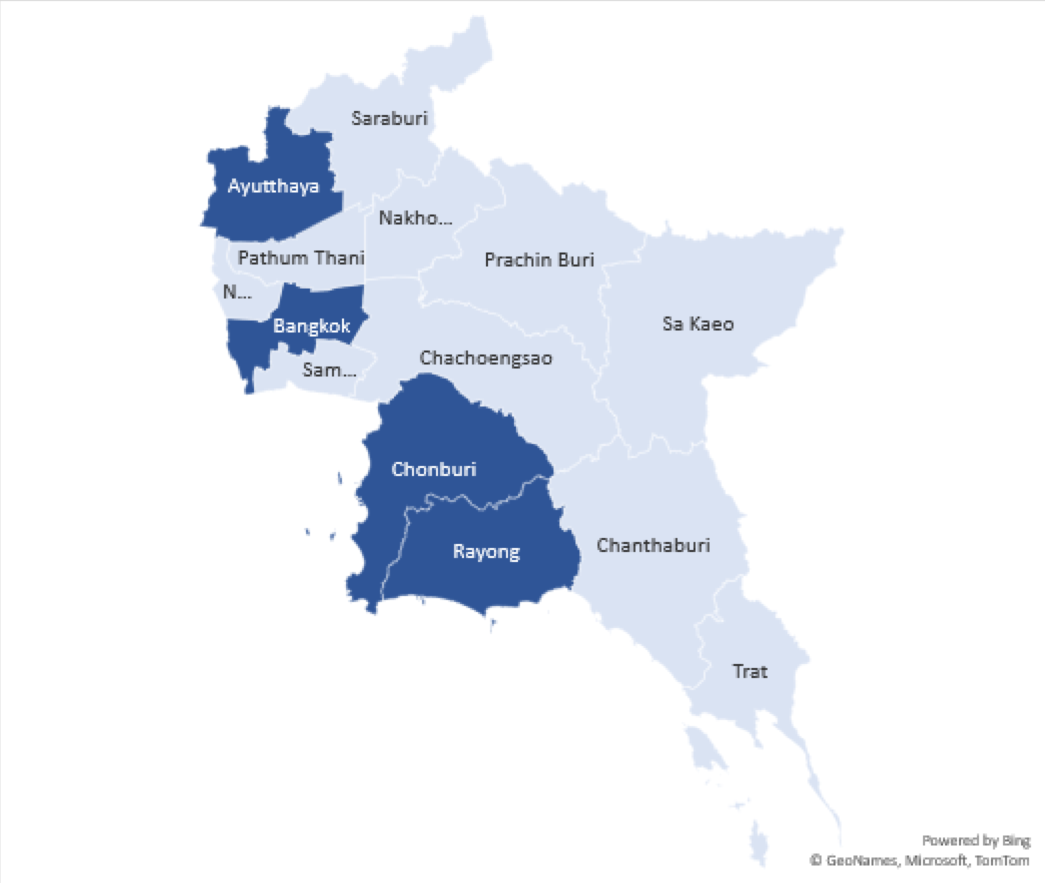

Figure 3. Location of the suppliers in Thailand provinces

The distance of respected suppliers' location to the border in Bukit Kayu Hitam were determined and tabulated by assuming that each supplier's location will be passed by one truck exclusively. The distance is obtained from determining the distance between the supplier to Bukit Kayu Hitam border using Google Maps as follows

Table 2. List of Suppliers and Distance from Bukit Kayu Hitam

Supplier	Location	Distance to Bukit Kayu Hitam (km)
S1	Bangkok	1,018
S2	Chonburi	1,070
S3	Chonburi	1,036
S4	Rayong	1,122
S5	Chonburi	1,065
S6	Chonburi	1,062
S7	Rayong	1,121
S8	Ayutthaya	1,071
S9	Rayong	1,122
S10	Chonburi	1,108

The shipment from each of supplier was delivered directly to Bukit Kayu Hitam regardless of the shipment capacity in Less than truckload (LTL) or Full truckload (FTL). LTL shipment refer to small shipment with volume of up to 5 pallets and weighs from 45 kg to 4,500 kg. The shipment usually shares shipment with other customers and does not fill the entire truck. Note that small quantity shipment is chosen to save the shipment cost as the cost is only charged to the space required in the truck. Meanwhile, FTL shipment is typically used for a bigger shipment with volume up to 12 pallets and weighs up to 20,000 kg. It took the entire truck and might benefit in term of economic of scale.

Moreover, FTL shipment is also easier to handle and significantly lower risk of damage due to minimum handling. There are two types of container size used for the FCL shipment which are 20 ft container and 40 ft container. For 20 ft container, the maximum volume of 33 cbm but shipment capacity to be considered is 26 cbm. Meanwhile, for 40 ft container, the maximum volume is 67 cbm but the shipment capacity to be considered is 54 cbm. The shipment capacity is lower than the actual container volume to consider the space margin required for loading and unloading activity as well as the stacking requirement. Some of this component packaging are not suitable for stacking to avoid packaging damage. Therefore, there are some empty space that is unable to be utilized. For this case study, the margin volume is considered around 20% from the total volume. The dimension and volume of the container used is as below:

Table 3. The dimension and volume of container

Type	**Container Weight**			**Interior Measurement**			
	Gross (kg)	Tare (kg)	Net (kg)	Length (m)	Width (m)	Height (m)	Capacity (m3)
20’ dry container	24,000	2,370	21,630	5,898	2,352	2,394	33.20
40’ dry container	30,480	4,000	26,480	12,031	2,352	2,394	67.74

The route used for individual delivery shipment is determined by the shortest route from the individual supplier to customer via Bukit Kayu Hitam border. Each shipment was delivered directly from supplier to destination upon ordering request. This method reduces the delivery lead time but increases the number of LTL shipments and handling risk due to mixture of shipments from other companies in same truck during a long-distance travel. The current delivery route using the shortest distance between the supplier and destination could be demonstrated as diagram below:

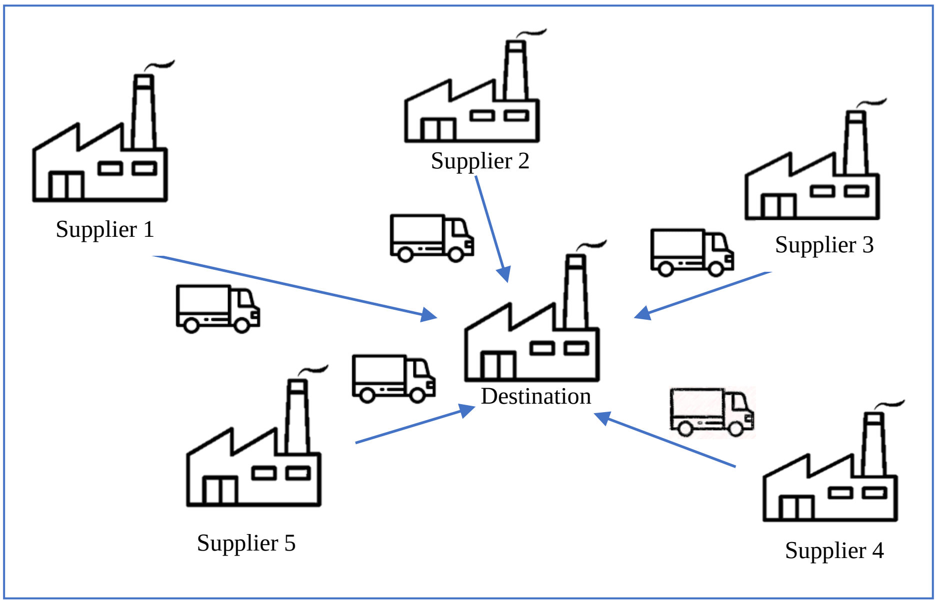

Figure 0. Individual delivery shipment

For this study purpose, there are three objectives that are analyzed which are the evaluation of current milk run route, the optimization volume of the milk run system and to propose the transportation route for a milk run logistics system.

Evaluation of The Current Milk Run Routes

For this study, the capacity data is collected considering the volume capacity of each shipment from June 2020 to Jan 2021. There is slight fluctuation in demand capacity during this period as the impact from Covid-19 pandemic. Therefore, the average capacity is used to minimize the impact of fluctuation to the calculation analysis. The capacity data used in the study are from ten suppliers which are located in four provinces throughout Thailand namely Rayong, Chonburi, Ayutthaya and Bangkok.

There are two main parameters which are taken into consideration while evaluating the current milk run route. The parameters were actual capacity paid and the actual shipment capacity. Actual capacity paid is based on the total shipment capacity used to deliver the shipment via FTL or LTL regardless of the actual size of the shipment's packaging. Meanwhile, the actual capacity is considered based on the actual size of the shipment's packaging. For actual capacity paid, the total capacity depends on the container size for FTL shipment.
In order to have an overview of the current route, the average capacity for each supplier is determined to evaluate the current milk run route using the Saving Matrix method. The monthly capacity volume data for the 10 suppliers is tabulated in Table 4.3 Monthly Shipment Capacity Volume and Actual Paid Capacity.

Table 4. Monthly Shipment Capacity Volume (m^3) and Actual Paid Capacity (m^3)

Vendor Code	**Area**	**Total Volume (m^3)**								
		Jun-20	Jul-20	Aug-20	Sep-20	Oct-20	Nov-20	Dec-20	Jan-21	Average
S1	Bangkok	0.36	0.34	0.33	0.34	0.24	0.22	0.26	0.21	0.29
S2	Chonburi	127.67	132.31	117.22	120.71	136.96	106.78	111.42	70.15	115.40
S3	Chonburi	-	-	-	-	1.87	9.33	-	-	1.40
S4	Rayong	0.93	0.90	0.37	0.01	0.45	0.46	0.48	0.39	0.50
S5	Chonburi	11.15	10.95	10.24	10.73	7.38	6.98	8.47	5.30	8.90
S6	Chonburi	0.50	0.48	0.50	0.44	0.50	0.44	0.39	0.23	0.43
S7	Rayong	8.79	12.41	13.96	13.96	10.34	9.31	7.24	4.14	10.02
S8	Ayutthaya	1.78	1.82	1.73	1.98	2.03	1.66	1.65	1.06	1.71
S9	Rayong	212.58	231.95	193.73	194.17	156.38	124.62	132.65	162.93	176.13
S10	Chonburi	-	0.10	-	336.00	432.00	552.00	600.00	360.00	285.01
Total Shipment Capacity (m^3)		363.76	391.27	338.09	678.34	748.15	811.79	862.56	604.40	599.79
Actual Paid Capacity (m^3)		521.51	625.29	843.07	1400.00	1566.12	1813.42	161.12	1270.13	1225.08
Unutilized capacity (m^3)		157.75	234.02	504.98	721.66	817.97	1,001.63	898.56	665.73	625.29
Utilized Capacity (%)		70%	63%	40%	48%	48%	45%	49%	48%	51%
Unutilized capacity (%)		30%	37%	60%	52%	52%	55%	51%	52%	49%

space available every time the shipment was arranged.

Shipment capacity volume optimization of the milk run system

In optimizing the shipment volume in the milk run system by using saving matrix, the parameter usedis not only the distance but also the capacity of the shipment. This is to ensure the greatest saving value is obtained for the shipment arrangement and to balance out between the distance and capacity. The main objective is to find the common ground in order to shorten travel distance and increase in the load efficiency.

First of all, the distance for each of the suppliers to Bukit Kayu Hitam (BKH) was tabulated in the matrix form to easily identify the distribution distance. The distance in kilometre (km) is determined based on Google Maps;

Table 5. Distance Matrix

	BKH	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
BKH	0.0	1,018.0	1,070.0	1,036.0	1,122.0	1,065.0	1,062.0	1,121.0	1,070.0	1,122.0	1,108.0
S1		0.0	54.7	20.6	104.0	49.3	45.7	45.5	108.0	106.0	92.4
S2			0.0	44.7	60.3	7.5	11.7	54.2	147.0	59.1	63.4
S3				0.0	98.2	31.2	39.8	99.8	115.0	96.5	86.7
S4					0.0	60.7	69.6	7.0	200.0	8.0	14.6
S5						0.0	8.7	57.2	135.0	62.1	64.8
S6							0.0	68.8	141.0	65.5	55.7
S7								0.0	201.0	3.8	15.4
S8									0.0	199.0	18.9
S9										0.0	16.2
S10											0.0

The shortest distance was the round-trip distance from each of the suppliers to Bukit Kayu Hitam. The result of the distance calculation is used to determine the saving matrix.

The saving matrix represents the savings due to the merger of two or more suppliers in a same trip. The saving matrix value is in kilometre (km). Trip was referring to the operational visit sequences by the transportation. For example, trip to S1 starts off from BKH to S1 and returns to BKH. This trip can be merged with another trip when determining the route of a truck when seeking to maximize the saving. While calculating the saving, the capacity constraint is not put into consideration. It is assumed that the capacity of the truck is infinite.

After calculating the distance matrix value from each of the supplier to the origin, the saving value is mapped in saving matrix by calculated the value of saving obtained if the distribution of several suppliers is merged. The saving matrix is tabulated as the table 6.

Table 6. The Saving Matrix

	BKH	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
BKH											
S1		0.0	2,033.3	2,085.4	2,054.0	2,137.7	2,081.3	2,137.5	2,083.0	2,086.0	2,137.6
S2			0.0	2,085.4	2,054.0	2,137.7	2,081.3	2,137.5	2,083.0	2,086.0	2,137.6
S3				0.0	2,059.8	2,155.8	2,087.2	2,083.2	2,076.0	2,095.5	2,143.3
S4					0.0	2,126.3	2,057.4	2,176.0	1,991.0	2,184.0	2,215.4
S5						0.0	2,118.3	2,125.8	2,056.0	2,129.9	2,165.2
S6							0.0	2,114.2	2,050.0	2,126.5	2,174.3
S7								0.0	1,990.0	2,188.2	2,214.6
S8									0.0	1,993.0	2,211.1
S9										0.0	2,213.8
S10											0.0

The distance of the saving matrix was ranked from the largest value to the lowest value:

Table 7. Matrix for Saving Based On Value in Descending Order

Rank	Route	Value	Rank	Route	Value	Rank	Route	Value
1	S4-S10	2,215.4	**16**	S1-S7	2,137.5	**31**	S1-S8	2,083.0
2	S7-S10	2,214.6	**17**	S2-S7	2,137.5	**32**	S2-S8	2,083.0
3	S9-S10	2,213.8	**18**	S5-S9	2,129.9	**33**	S1-S6	2,081.3
4	S8-S10	2,211.1	**19**	S6-S9	2,126.5	**34**	S2-S6	2,081.3
5	S7-S9	2,188.2	**20**	S4-S5	2,126.3	**35**	S3-S8	2,076.0
6	S4-S9	2,184.0	**21**	S5-S7	2,125.8	**36**	S3-S4	2,059.8
7	S4-S7	2,176.0	**22**	S5-S6	2,118.3	**37**	S4-S6	2,057.4
8	S6-S10	2,174.3	**23**	S6-S7	2,114.2	**38**	S5-S8	2,056.0
9	S5-S10	2,165.2	**24**	S3-S9	2,095.5	**39**	S1-S4	2,054.0
10	S3-S5	2,155.8	**25**	S3-S6	2,087.2	**40**	S2-S4	2,054.0
11	S3-S10	2,143.3	**26**	S1-S9	2,086.0	**41**	S6-S8	2,050.0
12	S1-S5	2,137.7	**27**	S2-S9	2,086.0	**42**	S1-S2	2,033.3
13	S2-S5	2,137.7	**28**	S1-S3	2,085.4	**43**	S8-S9	1,993.0
14	S1-S10	2,137.6	**29**	S2-S3	2,085.4	**44**	S4-S8	1,991.0
15	S2-S10	2,137.6	**30**	S3-S7	2,083.2	**45**	S7-S8	1,990.0

By referring to the saving matrix table, the supplier's allocation processes can be carried out. The iteration process to determine to combine route with highest saving in the same trip with consideration that the total capacity did not exceed the capacity of delivery truck in the same trip. The process started with the highest saving in descending ranking order.

The capacity at each supplier is determined by the average capacity from Jun 2020 to Jan 2021. Assigning the suppliers to the vehicle is only feasible if the total capacity from each supplier in the same route did not exceed the truck delivery capacity. In the research case, the truck delivery capacity was set 26 cbm for 20ft container and 54 cbm for 40ft container.

Table 8. Total Actual Capacity Based on New Routes

Supplier Code	Area	Actual Volume Capacity (m^3)	Route 1	Route 2	Route 3	Route 4	Route 5
S1	Bangkok	0.29		0.29			
S2-1	Chonburi	108.00					108.00
S2-2	Chonburi	7.40		7.40			
S3	Chonburi	1.40		1.40			
S5	Chonburi	8.90		8.90			
S6	Chonburi	0.43	0.43				
S10-1	Chonburi	270.00			270.00		
S10-2	Chonburi	15.01	15.01				
S4	Rayong	0.50	0.50				
S7	Rayong	10.02	10.02				
S9-1	Rayong	162.00				162.00	
S9-2	Rayong	14.13	14.13				
S8	Ayutthaya	1.71		1.71			
Total Actual Capacity (m^3)		**599.79**	**40.09**	**19.70**	**270.00**	**162.00**	**108.00**

There were five routes identified using saving matrix where the capacity had been assigned for each of the route according to the total actual capacity. Supplier S1, S9 and S10 have quite big capacity. Therefore, the shipment capacity was broken into two quantities in order to maximize the shipment according to container size. In this case, there will be two routes assigned to these suppliers. The first route will carry full containers of shipment from the supplier only and the second route is the merged shipment with other supplier to fulfil the remaining capacity.

Each of the route is assigned containers as the table below to carry the shipment. All shipments are merged to fulfil a full truck load (FTL) and eliminate any less-than-truck-load (LCL). The container size assigned based on the closest actual capacity to reduce the number of unutilized spaces:

Table 9. Route Capacity based on Saving Matrix

Container Size	**Volume (m^3)**	**No. of container**					**Total**
		Route 1	Route 2	Route 3	Route 4	Route 5	
20ft	**26**	0	1	0	0	0	**1**
40ft	**54**	1	0	5	3	2	**11**
Capacity based on saving matrix (m^3)		54	26	270	162	108	**620**

Based on saving matrix, the total route capacity of the shipment is 620 m^3 while the actual capacity is 599.79 m^3. The difference between actual capacity and route capacity is 20.21 m^3 or 3%. The initial value prior to saving matrix analysis is 625.29 m^3 or 49%. Therefore, by using saving matrix the volume is optimized and there is a significant reduction in unutilized volume from 49% to 3% of the total shipment.

Transportation routes proposal for milk run logistics system

Based on the result of analysing the route from the average capacity data, there are five routes identified for the component collection route as in the table below:

Table 10. Proposed Component Collection Routes

Route	**Delivery Schedule**	**Total Distance (km)**	**Total Volume (m3)**
ROUTE 1	BKH→S4→S10→S7→S9-2→S6→BKH	2,288	40.09
ROUTE 2	BKH→S3→S2→S5→S8→S1→BKH	2,285	19.70
ROUTE 3	BKH→S10-1→BKH	2,216	270.00
ROUTE 4	BKH→S9-1→BKH	2,244	162.00
ROUTE 5	BKH→S2-1→BKH	2,140	108.00

The route is grouped according to the data result from the Saving Matrix method. All the routes started and ended at Bukit Kayu Hitam (BKH). Route 1 and Route 2 were groups of five supplier locations. Meanwhile, Route 3, Route 4 and Route 5 only consisted of one supplier location. The route decision was made based on the capacity of the shipment. For Route 1 and Route 2, the capacity of each supplier was quite low. Therefore, the capacity was merged to reduce the trip and optimized each trip capacity using one 40ft container and one 20ft container for Route 1 and Route 2 respectively.

The sequence of suppliers' location for Route 1 and Route 2 were evaluated based on the farthest location of the supplier in each route from Bukit Kayu Hitam (BKH). Tabu Method and Ant Colony method are used on evaluate the location sequence to ensure the shortest distance is determined to be the final routes. The process involved numbers of iteration till the shortest distance is met. In order to ensure the location distance accuracy, Google Map was used to identify the location and assist with the evaluation.

For Route 1, the suppliers located around Rayong and Chonburi provinces only. However, for Route 2, the suppliers' location covered a larger area which are Bangkok, Chonburi and Ayutthaya.

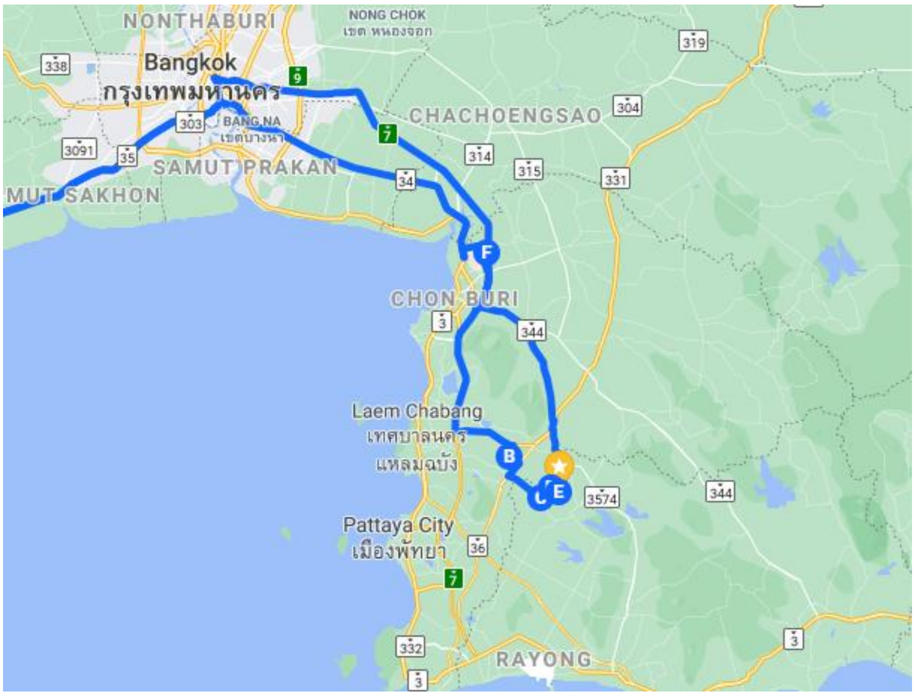

Figure 5. Route 1

Route 1 consisted of five supplier locations with the farthest was S9-2 with the total distance round trip from BKH of 2,244 km. After merging the Route 1, the total route distance was 2,288 km. The different was only 44 km or 2.0% increase from the farthest distance.

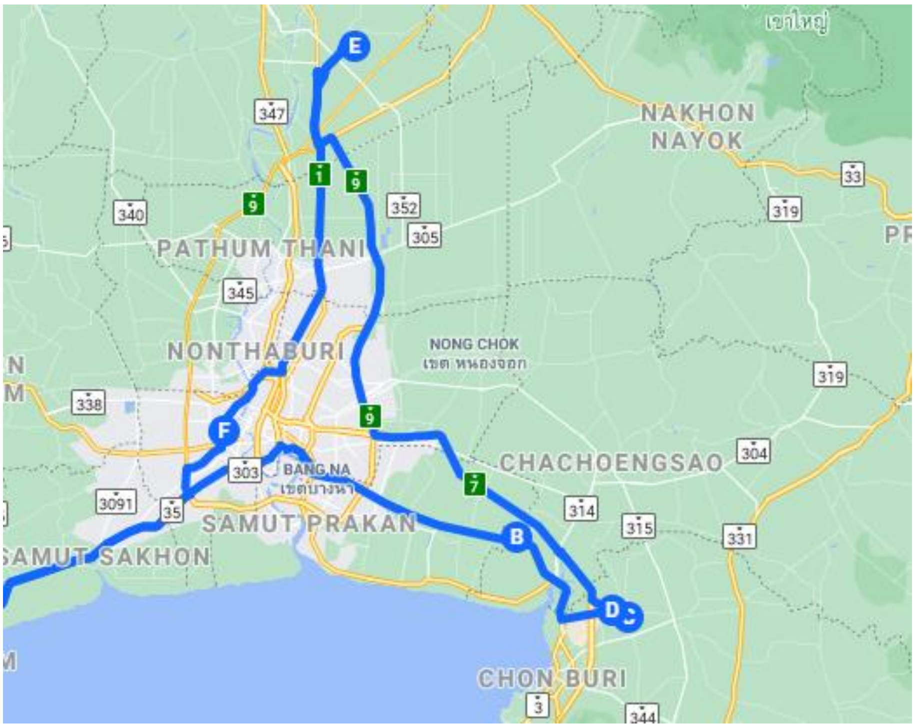

Figure 6. Route 2

Route 2 also consisted of five supplier locations with the farthest was S2 with the total distance round trip from BKH of 2,140 km. After merging the Route 2, the total route distance was 2,285 km. The different was 145 km or 6.8% increase from the farthest distance.

Table 11 Result comparison of the maximum distance and optimal distance

Route	Delivery Schedule	Farthest Location	Max distance (km)	Optimum distance (km)	Different (%)
ROUTE 1	BKH→S4→S10→S7→S9-2→S6→BKH	S9-2	2,244	2,288	2.0%
ROUTE 2	BKH→S3→S2→S5→S8→S1→BKH	S2	2,140	2,285	6.8%
ROUTE 3	BKH→S10-1→BKH	S10-1	2,216	2,216	0.0%
ROUTE 4	BKH→S9-1→BKH	S9-1	2,244	2,244	0.0%
ROUTE 5	BKH→S2-1→BKH	S2-1	2,140	2,140	0.0%

There are significant differences in total distance difference between the farthest location in the group with the total distance between Route 1 and Route 2 of 2.0% and 6.8%. This is due to the location of concentration of location between Route 1 and Route 2. Route 1 supplier's locations are more concentrated in Rayong and Chonburi area. Since the distance between each supplier is closer, the difference between the farthest location and total location is smaller. However, in Route 2, the supplier's location is less concentrated. Suppliers in Route 2 consisted of suppliers from Chonburi, Ayutthaya and Bangkok province. Therefore, there was a bigger different value from the farthest location with the total route distance. Based on the analysis, it could be concluded that the distance of 2,288 km and 2,285 km for Route 1 and Route 2 respectively ae the shortest distance.

Route 3, Route 4 and Route 5 consisted of only one supplier location. The capacity of each supplier is big enough to cater a direct trip from the suppliers' location to the destination without the need to merge the shipment. As the trip is considered as direct milk run trip, there was no difference between the farthest location and total location distance. Therefore, the shortest distance was decided based on the direct distance from the supplier to the destination.
The shortest distance for each route were identified based on the individual route analysis with deviation from the farthest distance of 2.0% and 6.8% difference for merging routes of indirect milk run and 0% for direct milk run route.

Table 12. Summary of the Report

Objective	Findings	Conclusion
To evaluate the current milk run route and system in the company	Current unutilized capacity volume is 49%.	Current routes are less efficient due to high unutilized capacity volume.
To optimize the shipment volume based on the milk run system	The total unutilized capacity has been reduced from 49% to 3% by analysing using saving matrix method.	The new proposed routes have a higher volume efficiency compared to the current route.
To propose a transportation route for milk run logistics system.	1. Five new routes are identified. 2. 0% deviation for direct milk run (3 routes) 3. 2.0% and 6.8% deviation for indirect milk run (2 routes)	The proposed milk run routes have higher distance efficiency in managing multiple locations within proximity between each other.

The saving matrix method of the distribution route can reduce three U-shape Ready Mix Concrete routes and two O-shape routes in a company that engages in manufacturing building materials. The cost-saving for the transportation cost to distribute U-shape Ready Mix Concrete with savings of IDR 628.817per month and for O-shape with IDR 922.250 per month by contributing to the transportation cost reduction of 36.15% for U-shape products and 53.02% for O-shape products (Rizkya et al., 2019).

Conclusion

Logistics and transportation management activity has a vital role in connecting the interest between the suppliers and the customers. Therefore, it needs to be managed efficiently in order to eliminate the waste and maintain the benefit to all related parties especially if it involves a long-distance shipment by land. The saving matrix method is used to minimize the distance, time, and cost to produce efficient shipping routes. By determining the delivery route, the transportation problem can be solved for multiple suppliers by merging the capacity of each supplier. A feasible route for merging is decided if the total combined capacity is smaller than the capacity of the transportation. Thus, the efficiency can be achieved as the capacity volume and distance are optimized. With that idea in mind, the objective of this report is to evaluate the current milk run route, to optimize the transportation volume capacity and to propose a transportation route for milk run logistics system.

The evaluation of current milk-run system for cross-border shipment for an automotive manufacturer in Shah Alam, Selangor showed that there is a lack of efficiency. The average unutilized capacity volume is 49% from the total volume paid to the forwarders. A very high unutilized volume is contributed by the direct delivery method from each of suppliers to the destination based on the demand. This delivery method is fast and effective in terms of communication and time delivery as less coordination is required to manage the delivery. However, in case of small shipment volume demand, the empty space in the shipment will not be filled and may cause waste as the customer still need to pay for the unutilized space. Therefore, the current milk run route and system in the company is concluded as less efficient due to high unutilized capacity volume. Improvement in term of communication and coordination will ensure a successful implementation of the merging shipment.

The current shipment volume had to be optimized to reduce the capacity volume waste. There are five new routes identified by evaluating and analysing using the saving matrix method. The capacity for each route is maximized and optimized based on the total transportation capacity. After the optimization, the total unutilized capacity has been reduced from 49% to 3%. As the result, the new proposed routes have a higher efficiency compared to the current route.

The proposed milk run transportation routes managed to reduce the distance travelled as less trip required to meet the reduced capacity volume. On top of that, the routes distance also showed a deviation between 2.0% to 6.8% of from the farthest supplier distance in the merger shipments for indirect milk run routes. The deviation percentage is high when the distance between the supplier is farther, and the deviation percentage is lower when the distance between the suppliers is closer. Therefore, it can be concluded that the proposed milk run transportation routes system have higher efficiency in managing multiple locations within proximity between each other.

Based on the results, Saving Matrix is proven able to solve transportation routing problem and scheduling while paying attention on the maximum capacity of the truck by combining several delivery points. The shipment capacity can be optimized while the shortest route of the shipment identified. As the result, the land shipping mileage can be reduced which in turn will increase the efficiency of the logistics operation and give significant cost reduction to the company. In order to increase the efficiency and effectiveness of the transportation and logistics system, there are high opportunity to further explore in term of evaluation on the cost structure, improvement on the management and coordination, further analysis on the benefit of volume and distance optimization to the organization and evaluation of computerized method for better optimization result.

For the purpose of evaluating the cost for the combined shipment, it is recommended to understand the cost structure differences between the direct delivery and combined delivery. For combined delivery, the multiple stops for the pick-up collection have the impact on the cost due to longer time required to make the stop despite the shortest route distance used for the trips. In real operation, there are many factors that influence the delivery time such as traffic density, road condition, vehicle maintenance status and driving behaviour. A deeper study and research on the cost impact on the time factor for combined collection route may be explored to provide a concrete support on the effectiveness of the merged route.

Furthermore, to ensure a successful combined collection route operation, it is recommended for the demand to be properly managed and coordinated. A properly managed demand will help to maximize the delivery volume for each trip by reducing unutilized space. Lower or higher volume than the plan impacted the delivery efficiency and effectiveness as the optimization cannot be met. On top of that, the communication between the related internal and external parties needs to be smooth to avoid miscommunication which may cause chaos in operation.

Based on the study, it is also recommended to implement milk-run to for the collection activity for suppliers that are located within proximity due to shorter distance from each other. However, in order to decide on the implementation, a proper comparison between the benefit of volume optimization versus distance optimization must be properly tabled out to avoid misleading the decision makers. The company's uniqueness operational objective must be considered to suit the logistics model proposed to implement. In some cases, the benefits of volume optimization outweigh the benefits of shorter distance especially when the low transportation rate situation. Therefore, an overview of the system to meet the company's objective must be put in place. Future study is suggested to focus on both scenarios with consideration of the different operational objectives to further evaluate the effectiveness of the milk-run implementation from Thailand to Malaysia. In this context, a contingency theory can be used to understand the operational differences and uniqueness based on the environment that the company is dealing with (Aunyawong et al., 2021)

Saving matrix method is more suitable to calculate and evaluate the route manually. The optimization method can be improved using appropriate computer software especially while dealing a large set and complicated data. Different method and tool may present a different outcome. The effectiveness of different method can be done by comparing the result from different method using manual or computer software. Based on a comparison study between Saving Matrix method and Cross Entropy to solve vehicle routing problem, it was found that Cross Entropy method is better to be used (Lukmandono et al., 2019). Saving Matrix is processed manually while Cross Entropy Method is calculated using Matric Laboratory software. It is crucial to understand the complexity of the routing prior deciding the suitable method for optimization. In conclusion, the saving method can help to optimize capacity volume and distance of milk run systems for cross-border shipment arrangement. The findings from the study showed that there is still room for improvement to increase the overall efficiency of current system.

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