MILK-RUN TRANSPORT COST REDUCTION IN AN AUTOMOTIVE COMPANY IN THAILAND USING INTEGER LINEAR PROGRAMMING

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ABSTRACT

This company case study aims to improve the transportation performance by decreasing the total transportation cost in the focus supplier's milk-run route. During process improvement in 2016, the company case study implemented a Clarke and Wright Saving Algorithm to reduce the total distance between a manufacturer and suppliers. However, this produced transportation distances greater than the original designed route. Thus, this was not an optimal solution to reduce the total distance and transportation cost. Therefore, this research paper tries to find the most appropriate optimization model to solve the cost problem enshrined in the total distance of milk-run routes. The optimization model in this research is performed using an integer linear programming, which is formulated by implementing the Traveling Salesman Problem (TSP) concept. The final result revealed that the transportation distances after using the integer linear programming method produces a greater reduction than implementing the Saving Algorithm, with a reduction of 4.72% or 3,359 THB/month. Therefore, the integer linear programming is a useful method for solving a vehicle routing problem.

Keywords: *Traveling salesman problem, Milk-run transportation, Integer linear programming*

บทคัดย่อ

บริษัทกรณีศึกษาต้องการที่จะปรับปรุงประสิทธิภาพของกระบวนการขนส่งโดยลดต้นทุนที่เกิดขึ้นในเส้นทาง Milk-Run ระหว่างโรงงานผลิตกับผู้จัดหา ทั้งในส่วนของต้นทุนระยะทางและต้นทุนค่าขนส่งที่เกิดขึ้น สำหรับกระบวนการปรับปรุงการขนส่งสินค้า เริ่มแรกในช่วงปี พ.ศ. 2559 ทางบริษัทได้ดำเนินการปรับปรุงระยะทางในการขนส่งสินค้าโดยนำหลักการ “เซฟวิ่ง อัลกอริทึม” มาประยุกต์ใช้ ซึ่งผลลัพธ์ที่ได้คือ สามารถลดระยะทางในการขนส่งสินค้าได้สั้นลง อย่างไรก็ตามหลักการดังกล่าวก็ยังไม่ใช้วิธีที่ดีที่สุด เนื่องจากทางบริษัทประเมินว่ายังสามารถลดระยะทางและต้นทุนในการขนส่งลงได้อีก จากเหตุผลที่ได้กล่าวมานั้น จึงเป็นที่มีของการหาแนวคิดหรืออัลกอริทึมเพิ่มเติมของทางทีมผู้วิจัย เพื่อที่จะนำมาแนวคิดนั้นมาใช้ดำเนินการวิเคราะห์การลดต้นทุนเพิ่มเติมทั้งในส่วนของระยะทางและค่าขนส่ง ซึ่งหนึ่งในแนวคิดที่สามารถนำมาประยุกต์ใช้ได้คือ แนวคิดปัญหาตัวแบบขนส่ง TSP และตัวแบบดังกล่าวสามารถวิเคราะห์ผลลัพธ์ได้โดยใช้วิธีการของ Integer Linear Programming วิเคราะห์หาต้นทุนที่ต่ำที่สุด ซึ่งในกรณีศึกษานี้ คือ ระยะทางระหว่างโรงงานผลิตและผู้จัดหาของบริษัท หลังจากที่มีการนำหลักการของตัวแบบขนส่งมาแก้

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ปัญหา พบว่าระยะทางโดยรวมสั้นลงเมื่อเปรียบเทียบกับการปรับปรุงระยะทางโดยใช้หลักการเซฟวิ่ง อัลกอริทึม ส่งผลให้ค่าใช้จ่ายในการขนส่งลดลงประมาณร้อยละ 4.72 หรือ 3,359 บาทต่อเดือน ดังนั้น ตัวแบบขนส่ง TSP ที่มีการนำมาประยุกต์ใช้กับหลักการของ Integer Linear Programming เหมาะสมกับการแก้ไขปัญหาการจัดเส้นทาง Milk-Run ระหว่างโรงงานผลิตกับผู้จัดหาของบริษัทกรณีศึกษา

INTRODUCTION

Thai industry is experiencing fast and continuous growth, as well as an increasing competition. This prompts a number of companies to improve their performance and reduce their costs as much as possible to handle the ever-changing competition. Transportation cost is a major operating cost (approximately 30-35 percent of total cost). Therefore, transit routes need to be optimally designed to minimize unnecessary costs and create a competitive advantage.

The focus of this company case study is an automotive business, which has a round-trip of road trucks in a Milk-Run network. The loading process in each round is not fully efficient, resulting in high transportation costs. In addition, the firm’s suppliers have a high frequency of transporting supplies to the factory. This causes traffic congestion within the plant and significant delays at the receiving site. Therefore, this case study aimed to reduce the number of round-trips and improve the vehicle routing of transportation by applying the Saving Algorithm created by Clarke and Wright (1964) in order to design the transportation route of the Milk-Run wheel truck and compare the number of round-trips and the distance between the transportation routes of the current Milk-Run shipment. However, even with this Saving Algorithm, the transportation route was still inadequately efficient.

Therefore, the researchers decided to use the Traveling Salesman Problem (TSP), which is a concept for organizing transportation routes and analyzing which route should be have the first pick up and which should be have the next pick up from a range of suppliers. Additionally, the researchers found that the TSP problem can be formulated as an integer linear programming to solve the vehicle routing problem of the Milk Run. The results are compared, between using the Saving Algorithm and the Integer Linear Programming, in generating new route platforms. This paper describes how Integer Linear Programming reduces both transportation distances and transportation costs.

LITERATURE REVIEW

Milk Run

Milk Run, in a logistics aspect, is a round trip that facilitates product distribution and collection for either customer and distributor, or distributor and manufacturer. Moreover, the main concept of Milk Run is to decrease the wastes discovered through the system (Brar & Saini, 2011).

Additionally, there are 6 simplified steps, which display the concept of Milk Run in the automotive industry. To begin with, the first step is “Volume Calculation”: an automotive spare-part company needs to calculate the total volume of each product before distribution to suppliers. Secondly is the next step, “Master Route Planning”: the company should plan its route having regard to the distance, transport period, and product portion of each destination. Thirdly, it is not only planning a number of feasible routes to connect with suppliers, but negotiation also with them to agree the commitment. Then, the company should revise the distance and capacity of master route from the company to suppliers due to their transportation agreement. After that, each dock needs to create the Milk Run schedule matching with suppliers. Finally, the company should be able to implement the master routes with suppliers and transform it to be “Daily Route Planning”.

Due to the Milk Run concept, the researchers try finding the most appropriate Milk Run route to distribute a number of products from the company to the firm’s suppliers by using the concept of Travelling Salesman Problem and formulate an optimization model with Integer Linear Programming.

Travelling Salesman Problem: TSP

The Travelling Salesman Problem (TSP) is a problem in which a salesman travels between many cities and sells his goods in those cities. While travelling, the salesman wants to visit every city in the shortest path and amount of time. The solution to the problem is to find the shortest path covering all cities, which allows visiting every city only once (Horowitz et al., 2007). The traveling salesman problem is ‘NP-complete’, which is Nondeterministic Polynomial, being a problem that can be verified in Polynomial time and displayed as an optimal solution.

Chaiwongsakda et al. (2015) managed the transportation routes of drinking water by dividing the area of service through routing found in TSP, and solved the problem by using Microsoft Excel Solver that reduced the distance by more than the Saving Algorithm; a saving of 4.16%. Patcharalak (2014) studied the routing model for a salesman's travel planning using TSP and Depth First Search that eventually affected the traveling time to meet customers: on-time transportation cost and distances were also reduced. In addition, Thanyaphat et al. (2015) applied TSP for planning the routing of police patrols to increase the efficiency of the route management and to support the reduction of crime in the area of responsibility.

Researchers use the Saving Algorithm to solve routing problems of those companies which have the same need for cost and distance reduction. TSP is one of the solutions to handle shipping route management and may be applied to the transport route of this paper, to find the best solution to reduce transportation cost.

The researchers then compared the transportation costs and the efficiency between The Saving Algorithm routing methods in case studies and TSP, to convey the results of the present study through guideline for the development of effective company transport routes.

Integer Linear Programming

One of the most interesting quantitative analysis methods for an optimization model, is Interger Linear Programming. A number of researchers and business organizations, including automotive chains, implement this method for maximizing profits and minimizing total costs with limited resources. For instance, Kantasa-ard (2016) studied how to optimize the storage area for containing all automotive spare-part pallets by using the concept of interger linear programming. Chaiwongsakda et al. (2015) formulated theTSP concept by using integer linear programming in the Distribution of Drinking Water. Moreover, this case study has demonstrated a set of parameters, objective functions, and all relative constraints to support a minimization model of Milk-Run routes in a company case study of an automotive business.

This chosen method is an excellent tool to manage and optimize transport cost in many business units, and particularly with Milk-Run transport routes in an automotive business. This method consists of three main functions: Objective Function, Relevant Constraints, and Decision Variables.

The Objective function is the main entity to illustrate the relationships between decision variables and relevant parameters to maximize or minimize all operation costs regarding the exact goal of business units.The second attribute consists of all relevant constraints, which define a direction, and is a key factor for the objective function. The reason is that all contraints would be able to influence the optimization model towards being successful.
Finally, the third entity consists of decision variables, which are always positive values.

Table 1: Example of Resource Optimization Matrix Using Linear Programming

Resource no.	Amount of resource Activity/Product				Available resource
	1	2	...	n	
1	a_{11}	a_{12}	…	a_{1n}	b_1
2	a_{21}	a_{22}	…	a_{2n}	b_2
.	.				.
.	.				.
.	.				.
M	a_{m1}	a_{m2}	…	a_{mn}	b_m
Net Value	c_1	c_2	…	c_n	

Source: Dantzig (1998)

Abbreviation

Net Value: this is a fixed value of each product or activity n (j=1,2,..,n)
Available resource: this is a total maximum value of each resource m (i = 1,2,..,m)

Parameter

c_j = the net value of each product/activity

b_i= the amount of available resource i (for i=1,2,…,m)

a_{ij} = the amount of resource ratio from product i to resource j

Decision variable

x_j = the number of resource j (for j = 1,2,3,…,n)

Objective function

$$\boxed{\text{Max } Z = c_1X_1 + c_2X_2 + \ldots + c_nX_n}$$

Constraints

$$\begin{aligned} a_{11}X_1 + a_{12}X_2 + \ldots + a_{1n}X_n &\leq b_1 \\ a_{21}X_1 + a_{22}X_2 + \ldots + a_{2n}X_n &\leq b_2 \\ &. \\ &. \\ a_{m1}X_1 + a_{m2}X_2 + \ldots + a_{mn}X_n &\leq b_m \end{aligned}$$

$$X_1 \geq 0,\ X_2 \geq 0,\ \ldots,\ X_n \geq 0 \text{ or } X_j \geq 0$$

Regarding the information shown in Table 1, the objective function in this case study is to minimize the total distance of the milk-run transport route, which is calculated by the sum of multiplication of the distance between suppliers and the status of each route.There are three main reletive constraints, as follows. The first condition requires that from each city there is a departure to exactly one other city. The second condition requires that each city must be arrived at from one other city. As for the last constraint, there is only a single sub tour, which is a route that covers all suppliers. How to build an optimization model is demonstrated in the research methodology section below. How the total distance and transport cost are mostly reduced is shown later in the research result analysis section.

RESEARCH METHODOLOGY

To tackle the focus firm's existing problem, and with examples from the literature review, there are four main steps to reduce the milk-run transport cost.

1. Defining the problem of the existing ineffective solution;
2. Analyzing and developing a new solution;
3. Illustrating a new model regarding the TSP concept;
4. Using relevant quantitative data from the transportation process in the focus firm.

1. Defining the problem of the existing solution

When the focus company in the automotive business unit thought it had solved a problem of vehicle routing in its Milk-Run by using the Clarke & Wright Saving Heuristic algorithm, the total distances decreased by approximate 28 percent from the current distance. Additionally, the number of total truck rounds considerably decreased by more than 51 percent from the original solution. However, the present research team believes that the company would be able to reduce even further the milk-run cost in order to achieve the optimal transport cost. The research team was able to gather additional information and find some appropriate optimization models to minimize the cost, one of which is the TSP Concept, to decrease the total distances of the route.

2. Analyzing and developing a new solution

Regarding the TSP concept, the research team studied and analyzed a number of relevant algorithms, which will help to solve the problem of milk-run vehicle routing. One of the most popular algorithms that usually solves the problem is the Integer Linear Programming method. The research team demonstrates this solving methodology by explaining its two main steps: (i) collect all relevant data from the existing solution, (ii) setup all relative parameters, as shown below.

First, relevant data from the existing solution consists of the routes designed by the Saving algorithm, the number of truck rounds, and total distances, is condensed into the following Table 2.

Table 2: Original Designed Routes of Company's milk-run, using the Saving Algorithm

Original Designed Route	Round/Day	Distance/Round
RTL > C > B > A > D > E > F > RTL	1	371 Km.
RTL > I > F > RTL	1	335 Km.
RTL > H > G > RTL	1	99 Km.
Total	3	805 Km.

Source: Chaismithkul (2016)

Table 2 shows the relationship among the designed routes, the number of truck rounds, and total distances between each supplier and the focus company. It indicates that the longest distance of the milk-run is the first designed route.

Now, all relative parameters, a decision variable, an objective function, and constraints, have to be considered, as follows:

Main Parameter:

n = the number of company suppliers

D_{ij} = the total distance from supplier i to supplier j

S = the number of company suppliers in a route

Decision variable:
X_{ij} = 1 is the path from supplier i to supplier j, 0 is otherwise

Objective function: the minimum distance of milk-run vehicle routing
Min Z = $\sum_{i=1}^{n}\sum_{j=1}^{n} D_{ij}\, X_{ij}$

Constraints:

1) The first condition requires that from each city is a departure to exactly one other supplier

$$\sum_{j=1}^{n} X_{ij} = 1 \text{ (for i = 1,..,n)}$$

2) The second condition requires that each city must be arrived at from one other supplier

$$\sum_{i=1}^{n} X_{ij} = 1 \text{ (for j = 1,..,n)}$$

3) There is only a single sub tour, which is a route covering all suppliers. It means that one route will consist of at least one supplier and a distribution center and the number of company suppliers in one route should be not greater than the total of suppliers

$$\sum_{i,j}^{n} X_{ij} <= |S|-1 \text{ ; } S \subset n,\ 2 <= |S| <= n$$

3. Illustrating a new model regarding the TSP concept

When an Integer Linear programming model was obtained from the previous step, the model was implemented via an Excel Solver function. The results are shown in Table 4. The minimum distance of milk-run route No. 1 is updated to 334 Km, and milk-run route No. 2 has the same distance as the first route. Additionally, the sequence of vehicle routing in milk-run No.1 and milk-run No.2 are totally different from the original designed route, which was shown in Table 1. Moreover, all integer linear programming equations are based on the information of existing routes and adequate demands, as shown in Table 2, and existing distances which are displayed in Table 3. In this case, the researcher is able to demonstrate the objective function, and relative constraints of vehicle routing in milk-run route no.1 as an example.

Objective function:

Min Z = $134X_{RTL,C} + 132X_{C,RTL} + 121X_{RTL,B} + 124X_{B,RTL} + 127X_{RTL,A} + 130X_{A,RTL} + 104X_{RTL,D} + 99X_{D,RTL} + 89X_{RTL,E} + 94X_{E,RTL} + 83X_{RTL,F} + 92X_{F,RTL} + 15X_{C,B} + 22X_{B,C} + 37X_{C,A} + 37X_{A,C} + 45X_{C,D} + 45X_{D,C} + 53X_{C,E} + 58X_{E,C} + 64X_{C,F} + 63X_{F,C} + 35X_{B,A} + 38X_{A,B} + 28X_{B,D} + 24X_{D,B} + 42X_{B,E} + 42X_{E,B} + 59X_{B,F} + 52X_{F,B} + 46X_{A,D} + 54X_{D,A} + 64X_{A,E} + 61X_{E,A} + 70X_{A,F} + 72X_{F,A} + 25X_{D,E} + 23X_{E,D} + 32X_{D,F} + 33X_{F,D} + 15X_{E,F} + 15X_{F,E}$

Table 3: Transportation Distances from the Focus Company to all Suppliers

จาก ไป	RTL	A	B	C	D	E	F	G	H	I
RTL	0	127	121	134	104	89	83	29	43	146
A	130	0	38	37	46	64	70	115	150	139
B	124	35	0	22	28	42	59	112	127	138
C	132	37	15	0	45	53	64	129	122	123
D	99	54	24	45	0	25	32	96	110	129
E	94	61	42	58	23	0	15	103	97	109
F	92	72	52	63	33	15	0	90	117	105
G	30	113	110	130	100	78	103	0	26	159
H	50	155	127	123	116	94	117	26	0	176
I	146	144	143	123	128	109	97	159	173	0

Source: Chaismithkul (2016)

Constraints:

1) The first condition requires that from each city is a departure to exactly one other city

Starting point: $X_{C,RTL} + X_{B,RTL} + X_{A,RTL} + X_{D,RTL} + X_{E,RTL} + X_{F,RTL} = 1$
Supplier C: $X_{RTL,C} + X_{B,C} + X_{A,C} + X_{D,C} + X_{E,C} + X_{F,C} = 1$
Supplier B: $X_{RTL,B} + X_{C,B} + X_{A,B} + X_{D,B} + X_{E,B} + X_{F,B} = 1$
Supplier A: $X_{RTL,A} + X_{B,A} + X_{C,A} + X_{D,A} + X_{E,A} + X_{F,A} = 1$
Supplier D: $X_{RTL,D} + X_{B,D} + X_{A,D} + X_{C,D} + X_{E,D} + X_{F,D} = 1$
Supplier E: $X_{RTL,E} + X_{B,E} + X_{A,E} + X_{D,E} + X_{C,E} + X_{F,E} = 1$
Supplier F: $X_{RTL,F} + X_{B,F} + X_{A,F} + X_{D,F} + X_{E,F} + X_{C,F} = 1$

2) The second condition requires that each city must be arrived at from one other city

Starting point: $X_{RTL,C} + X_{RTL,B} + X_{RTL,A} + X_{RTL,D} + X_{RTL,E} + X_{RTL,F} = 1$
Supplier C: $X_{C,RTL} + X_{C,B} + X_{C,A} + X_{C,D} + X_{C,E} + X_{C,F} = 1$
Supplier B: $X_{B,RTL} + X_{B,C} + X_{B,A} + X_{B,D} + X_{B,E} + X_{B,F} = 1$
Supplier A: $X_{A,RTL} + X_{A,B} + X_{A,C} + X_{A,D} + X_{A,E} + X_{A,F} = 1$
Supplier D: $X_{D,RTL} + X_{D,B} + X_{D,A} + X_{D,C} + X_{D,E} + X_{D,F} = 1$
Supplier E: $X_{E,RTL} + X_{E,B} + X_{E,A} + X_{E,D} + X_{E,C} + X_{E,F} = 1$
Supplier F: $X_{F,RTL} + X_{F,B} + X_{F,A} + X_{F,D} + X_{F,E} + X_{F,C} = 1$

3) There is only a single sub tour covering all suppliers

$X_{RTL,A} + X_{A,RTL} <= 1$, $X_{RTL,B} + X_{B,RTL} <= 1$, $X_{RTL,C} + X_{C,RTL} <= 1$, $X_{RTL,D} + X_{D,RTL} <= 1$, $X_{RTL,E} + X_{E,RTL} <= 1$, $X_{RTL,F} + X_{F,RTL} <= 1$, $X_{A,B} + X_{B,A} <= 1$, $X_{A,C} + X_{C,A} <= 1$, $X_{A,D} + X_{D,A} <= 1$, $X_{A,E} + X_{E,A} <= 1$, $X_{A,F} + X_{F,A} <= 1$, $X_{B,C} + X_{C,B} <= 1$, $X_{B,D} + X_{D,B} <= 1$, $X_{B,E} + X_{E,B} <= 1$, $X_{B,F} + X_{F,B} <= 1$,

$X_{C,D} + X_{D,C} <= 1$, $X_{C,E} + X_{E,C} <= 1$, $X_{C,F} + X_{F,C} <= 1$, $X_{D,E} + X_{E,D} <= 1$, $X_{D,F} + X_{F,D} <= 1$, $X_{E,F} + X_{F,E} <= 1$, $X_{A,B} + X_{B,C} + X_{C,A} <= 2$, $X_{B,A} + X_{A,C} + X_{C,B} <= 2$, $X_{RTL,E} + X_{E,F} + X_{F,RTL} <= 2$, $X_{E,RTL} + X_{RTL,F} + X_{F,E} <= 2$

Table 4: An Optimization Model After Running via Excel Solver

From/To	RTL	A	B	C	D	E	F
RTL	0	0	0	0	0	0	1
A	1	0	0	0	0	0	0
B	0	0	0	1	0	0	0
C	0	1	0	0	0	0	0
D	0	0	1	0	0	0	0
E	0	0	0	0	1	0	0
F	0	0	0	0	0	1	0

After running an optimization model, a revised version of milk-run No.1 has been shown in Table 4. The result is "RTL > F > E > D > B > C > A > RTL". Moreover, the researcher used a revised version of the vehicle routing model to compare with the existing solution that was already completed with the Saving algorithm. The total distance of the latest route is around 767 Km, which is less than the original route by approximately 38 km. The comparison between the two methods is shown below in Table 5 below.

Table 5: Result of Comparison Between Original Route and Revised Route

Original route with Saving al.	Distance	Revision route with ILP	Distance	Different
RTL > C > B > A > D > E > F > RTL	371	RTL > F > E > D > B > C > A > RTL	334	37
RTL > I > F > RTL	335	RTL > F > I > RTL	334	1
RTL > H > G > RTL	99	RTL > H > G > RTL	99	0
Total distance	805	Total distance	767	38

Source: Author

(Abbreviation: ILP is Integer Linear Programming)

In addition, the milk-run transport cost after revising the sequence of vehicle routing has decreased more than the original route by approximately 3,359 THB/month (based on simulation conditions that are close to real data from the focus company: Oil price is 4.42 THB/Km, Working day is 20 days).

The result above is very similar to another two research projects that formulate the equation by using the integer linear programming (ILP) concept. Chaiwongsakda et.al. (2015) applied this concept in his project, 'A Case Study of a Drinking Water Factory', and found that the total distance had reduced more than the original route by around 4.16 percent. Next, Jaroensuk (2017) implemented this concept in the research project, 'A Study of Truck Fleet Management and Vehicle Routing'. The researcher found that the total cost had reduced by 79% from the existing solution.

Even though these two projects have decreased the total distance, as in this case study, both of them are symmetric distance, whilst the total distance of this case study is asymmetric, which means the two-way directions between starting point and ending point are not the same distance. Therefore, it would be reasonable to conclude that the integer linear programming is compatible to solve a number of vehicle routing problems, both symmetric and asymmetric distances.

CONCLUSION

This research shows the comparative result between the earlier existing solution and the revised solution with integer linear programming based on the Traveling Salesman Problem concept. Moreover, the researcher found that the transportation cost after calculating the new solution has declined by around 3,359 THB/month when compared to the existing solution. The total distance of the new vehicle routing and transport cost are reduced by ~4.72% from the existing solution. Therefore, the integer linear programming model is demonstrated to be the model for distance calculation and transport cost in a wide range of businesses including an automotive firm.

REFERENCES

Brar, G. S., & Saini, G. (2011). Milk run logistics: literature review and directions. *In Proceedings of the world congress on engineering (Vol. 1, pp. 6-8).*

Chaismithkul, C. (2016). *Transport Routing Improvement of Milk-Run Transport project*, Faculty of Logistics, Burapha University, Chonburi.

Chaiwongsakda, N., Ananaue, P., Jeenaboonrueang, N., Winyangkul, S., Sinnarong, K., Jakkaew, T., Jaibal, W., & Srisawang, N. (2015). Vehicle Routing by Using a Saving Algorithm and the Traveling Salesman Problem: A Case Study of a Drinking Water Factory. *Thai Journal of Operations Research, 3*(1), 51-61.

Danzig, George B. (1998). *Linear Programming and Extensions*, 11^{th} ed., Princeton University Press, Princeton, New Jersey.

Dorigo, M., & Gambardella, L. M. (1997). Ant Colony System: A Cooperative Learning Approach to the Traveling Salesman Problem. *IEEE Transactions on Evolutionary Computation, 1*(1).

Horowitz, E., Sahani, S. & Rajasekaran, S. (2007). *Fundamentals of Computer Algorithm*, University Press, New York.

Jaroensuk, K. (2017). *A Study Of Truck Fleet Management And Vehicle Routing: A Case Study Of Liquid Product*, Faculty of Logistics, Burapha University, Chonburi.

Heizer, J., & Render, B. (2008). *Operations Management*, 9th ed., Pearson International Education.

Kantasa-ard, A. (2017). Optimization of the Number of Relocated Automotive Spare-part Pallets using Linear Programming Model. *The 3rd RMUTT Global Business and Economics International Conference (RTBEC). Rajamangala University of Technology Thanyaburi, 2017*, 153-163.

Kantasa-ard, A. (2017). Quality improvement and cost reduction in the management of a warehouse of gasoline-automotive parts. *Journal of Transportation and Logistics, Chulalongkorn University, 1*(10), 91-108.

Muangpan, T., Wonginta, T., & Muangpan, T. (2016). The Conceptual Framework of Motorcycle Patrol Route: The Case Study of Samed Police Station, Chonburi. *Journal of Transportation and Logistics*, *9*(1), 30-42.

Patcharalak.(2014). Route with Local Search for Planning Salesman Travelling. *The 7th National Conference on Technical Education. King Mongkut's University of Technology North Bangkok, 2014,* 185-192.