AN APPPLICATION OF THE SAVINGS METHOD TO A VEHICLE ROUTING PROBLEM

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ABSTRACT

This paper presents the authors' research study of the vehicle routing practices of a transport company. This firm provides the delivery of Printed Circuit Board Assembly (PCBA) and electronics components to customers in the Bangkok Metropolitan Region and neighboring provinces in the Central and East regions of Thailand. Currently, traditional truck management is being practiced: this lacks a systematic approach by using only personal experience information.

The inefficient truck management problem in this case study was identified as a Capacitated Vehicle Routing Problem (CVRP). Therefore, the 'Savings Method' designed by Clarke and Wright (1964) was applied to solve the CVRP, using Excel worksheets. The method consists of four procedures. Firstly, identify the distance matrix from the depot to all customers. Secondly, identify the savings matrix. Thirdly, assign customers to the vehicles or routes, in which the highest value is the criteria for selection. Lastly, sequence the customers within these routes.

The research results show that the Savings method reduces the total number of vehicles usage and total distribution distances by 16.46% and 15.70% respectively, and increases truck utilization of truck capacity by 19.70%. These results create significant cost saving for the company.

Keywords: *Vehicle Routing Problem, Capacitated Vehicle Routing Problem, Savings Method,*

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บทคัดย่อ

บทความนี้นำเสนอผลการศึกษาการจัดเส้นทางการขนส่งของบริษัทที่จัดส่งสินค้าประเภทแผงวงจรพิมพ์และชิ้นส่วนอิเล็กทรอนิกส์ให้กับลูกค้าในเขตกรุงเทพมหานครและพื้นที่ใกล้เคียง ซึ่งในปัจจุบันการจัดการเส้นการขนส่งใช้ประสบการณ์ของพนักงานในการจัดเส้นทางและไม่มีแนวทางที่เป็นระบบ ในกรณีศึกษาการจัดเส้นทางการขนส่งที่ไม่มีประสิทธิภาพเป็นปัญหาการจัดเส้นทางการขนส่งแบบ Capacitated Vehicle Routing Problem (CVRP) โดยนำวิธีการแบบประหยัด (Savings Method) ของ Clark และ Wright มาใช้ในการแก้ปัญหาในโปรแกรม Excel ซึ่งประกอบไปด้วย 4 ขั้นตอนดังนี้ ขั้นตอนแรกเป็นการหาระยะทางจากคลังสินค้าไปยังลูกค้าทุกราย ขั้นตอนที่สองเป็นการคำนวณหาตารางความประหยัด หลังจากได้ตารางข้อมูลเรียบร้อยแล้วจะเป็นขั้นตอนการจัดเส้นทางการขนส่งให้ลูกค้าแต่ละรายโดยใช้ค่าความประหยัดสูงสุดเป็นเกณฑ์ในการจัดเส้นทาง และขั้นตอนสุดท้ายคือการจัดลำดับลูกค้าภายในเส้นทางจนครบจำนวนลูกค้าที่ต้องจัดส่งในแต่ละวัน ผลการศึกษาพบว่าวิธีการแบบประหยัดช่วยลดจำนวนการใช้ยานพาหนะลง 16.46% ลดระยะทางการกระจายสินค้าลง 15.70% และเพิ่มอรรถประโยชน์ของการใช้รถบรรทุกได้ถึง 19.70% ซึ่งทำให้บริษัทสามารถประหยัดต้นทุนได้อย่างมีนัยสำคัญ

INTRODUCTION

At present, communication technologies are diversified and have grown rapidly, which lead to increasing business opportunities affecting transportation network expansion and complexity of vehicle routing. The competition becomes more intense, including transportation costs which also have increased accordingly, and thus become an unavoidable cost for the company. However, if the company had a systematic plan for vehicle routing, it would be able to reduce the distance of transportation. Using the optimum number of vehicles, with appropriate truck utilization by using full-load capabilities of vehicles in each delivery, would show a competitive cost of transportation and higher delivery completion capabilities. Therefore, the distribution problem is an important criterion today.

The focal ABC Company (a pseudonym for confidentiality) is a global business creating added value by fully utilizing its experience over 50 years to systematically link the business requirements of various firms. Its main function is a trading and logistics center which provides Printed Circuit Board Assembly (PCBA) and other electronic components. The main activities of this company are purchasing and importing electronic components, entering into intercompany links for the assembly of finished goods (FG). After receiving the finished goods (FG), ABC manages and delivers the shipments to customers. Currently, the company supplies around 39 customers in 20 areas located in Bangkok Metropolitan Region and neighboring provinces in Central and East regions in Thailand.

The products are distributed directly to the customers by four-wheel trucks or pickups. The transport department has seven pickups. The maximum load of each truck is not over 4.45 cubic meters. Since FG are electronic components that are small, light-weight, high value and sensitive to static electricity, they are packed into conductive boxes to prevent static electrification. The truck capacity is calculated in terms of dimension (cubic meter – m^3) not in terms of weight (kilogram – kg).

STATEMENT OF THE PROBLEM

A preliminary study, revealed that the process of the current routing planning is a traditional shipment distribution pattern which lacks a systematic approach. The transport department is assigned to distribute the shipments to customers. The employees allocate the delivery area and the pickup trucks by using their personal experience. Their expertise, gained from working for a long time, has accrued considerable knowledge of the location of each customer, and the location of neighboring customers in the same transport routes, without setting standard routes.

This current routing planning is not effective. If employees who have expertise in the planning team leave or resign, the newly-assigned employees (inexperienced staff) have to spend much time on learning transportation planning, which increases the effect on fleet management. In the future, if the expansion of customers increases, this situation will further reduce the efficiency of delivery routing, whereas it could and should be better.

As the company must improve its delivery efficiency in order to maximize the full capacity of the trucks and minimize the total distances, therefore, the research question formulated in this case study in this research was **"How does vehicle routing affect cost reduction?"**

RESEARCH OBJECTIVES

This study aimed to improve the delivery distribution of sensitive products to customers. The main purpose of this study was to improve the daily vehicle routing and utilize the pickup truck capacities. The present delivery method has not produced the required optimization and efficiency of an effective transportation routing. The Savings method designed by Clarke & Wright (1964), is a system for improving vehicle routes (and has other benefits), and enables the research objectives to be the following:

1. To design a vehicle routing with minimum transportation cost;
2. To minimize the total number of vehicles usage;
3. To optimize the total distribution distances;

4. To utilize the maximum capacity of all trucks.

LITERATURE REVIEW

The Vehicle Routing Problem (VRP) is an important issue in many distribution networks which involve the transportation of raw materials from the manufacturer to the production factory or the transportation of products from the warehouse to the customers. It is necessary for the company to provide efficient transportation and distribution to reduce the operation cost. This would a result in a decrease in the number of vehicles used, maximize the truck capacity efficiency, minimize the distance travelled by all vehicles, and reduce delays in transportation.

The Vehicle Routing Problem (VRP)

The Vehicle Routing Problem (VRP) was first researched and published by Dantzig and Ramser (1959). VRP can be described as the problem of routing a vehicle through a distribution network to find the optimal routes of delivery or pick-up from one or several depots to a number of customers with some constraints. It starts from a base to serve every assigned node or arc of a distribution network and return to the same base with minimal cost (that can be shown by distances, number of vehicles used, or some customized ones). The base points can be represented as an arc or as a node of a distribution network.

VRP can be classified as follows:
The Arc covering problem is divided into three parts: arc partitioning problems, arc augmenting problems, and arc sequencing problems. The objective of solving the Arc covering problem is to travel through all the assigned arcs in a distribution network and to meet the stated goal of optimization. In addition, it can be solved by considering more than one part of a problem at a time. Nevertheless the difficulty and complexity of the problem solving will be increased as more parts of a problem are added (Su & Chang, 1993).

The objective of solving the arc Node covering problem is to serve all the assigned nodes of a distribution network and to meet the stated goal of optimization. It can be classified into many types of VRP, depending on the variants of VRP along with the various constraints

Bodin, Assad and Ball (1981) classified the VRP characteristics in a more detailed list. They focused on the Node Routing Problem. Some of these characteristics are described in the network specification, shown in Table 1, below.

Table 1: Characteristics of a Vehicle Routing Problem

Characteristics	Description
Size of vehicle fleet available	one vehicle
	more than one vehicle
Type of vehicle fleet available	Homogeneous (all vehicles the same)
	Heterogeneous (not all vehicles the same)
Depot / Warehouse	Single
	Multiple
Nature of demands	Deterministic (known demand)
	Stochastic (unknow demand)
	Partial
Location of demands	At nodes (point)
	On arcs (route)
	Mixed
Underlying network	Undirected
	Directed
	Mixed
Vehicle capacity constraints	Uncapacitated
	Capacitated (same for all vehicles)
	Capacitated (different)
Maximum vehicle route times	No
	Single Time Windows
	Multiple Time Windows
	Tight Time Windows (scheduling)
Cost	Variable or routine costs
	Fixed operation or vehicle acquisition costs (Capital costs)
Operations	Delivery / Split Deliveries
	Pick-up / Split Pick-up
	Both
Objective	Minimize routing costs incurred
	Minimize sum of fixed variable costs
	Minimize number of vehicles required

Source: Bodin et al. (1981)

Among the characteristics of VRP, this research has concentrated on the Capacitated Vehicles Routing Problem (CVRP) and its solution methods. CVRP is subject to the following conditions and constraints:
1. the demands of all customers must be met,
2. each customer is served by only one vehicle,
3. the capacity of the vehicles must not exceed the total demand for each route.

Principles of the Savings Method

In 1964, Clarke and Wright proposed the Savings method, a well-known Heuristics algorithm to solve VRP in four steps:
Step 1: Identify the distance matrix from depot to all customers,
Step 2: Identify the saving matrix,

Step 3: Assign customers to the vehicles or routes,
Step 4: Sequence customers within routes.
The vehicles or routes can be combined into a feasible route; however, the total deliveries must not exceed the vehicle's capacity. The advantage of this method is to improve vehicle utilization.

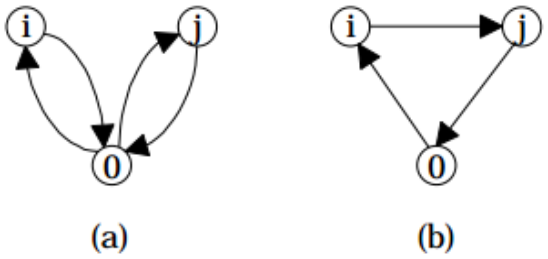
RESEARCH METHODOLOGY

This section explains the details of the case study which consist of the overview of the research methodology and the application of the Savings method in the focal ABC Company. The Savings method was applied to manage the daily vehicle routing to deliver goods to customers by using transport routes in Bangkok Metropolitan Region and neighboring provinces in Central and Eastern regions in Thailand; to maximize the truck capacity, and to minimize the number of vehicle used as well as the total distribution distance. The research methodology is divided into five sections; firstly data collection, which consists of vehicle size, packing, traveling time, routing, and transport distance, which affected vehicle routing management in April, 2016. Secondly there is data analysis, after collecting the data and reviewing the current vehicle routing management. Thirdly is the proposed model and solution, with the new design for the vehicle routing to match the VRP. Fourthly, is an analysis and comparison of the outcomes of both new and current methods, and lastly is a summary.

Proposed Model and Solution

This study proposed the Savings method to create a vehicle route based on the customers' locations. The Savings method calculates the cost savings by joining two routes into one route as shown in Figure 1 below, where point 0 represents the warehouse.

Figure 1: Principle of the Savings Method



Source: Clarke & Wright (1964)

In Figure 1(a), the goods are delivered to customers i and j on separate routes. If these two customers are combined on the same route, the route is shown in Figure 1(b). The transportation cost in Figure 1(a) is $D_a = C_{0i}+C_{i0}+C_{0j}+C_{j0.}$; and

in Figure 1(b), which is a combined route, it is $D_b = C_{0i}+C_{ij}+C_{j0}$. By combining the two routes, savings are gained, S_{ij} is equal to $D_a - D_b = C_{0i}+C_{0j}-C_{ij}$.

Step 1: To compute the savings, the formula is;

$$S_{ij} = C_{i0} + C_{0j} - C_{ji}$$
$$\text{For } i, j = 1,\ldots, n \text{ and } i \neq j$$

The Savings method calculates all the savings (S_{ij}) between customers i and j. Assuming that C_{i0} is the cost of travelling from the warehouse to customer i, and C_{ij} is the cost of travelling from customer i to j, the savings details are shown in Table 2.

Table 2: Savings Table

Saving Algorithm

ID	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
0	0	26	56	39	109	98	79	44	179	91	26	143	56	77	250	50	265	270	28	125	167
1		10	14	11	43	22	22	11	42	43	39	43	22	20	22	14	21	21	38	30	35
2			10	35	19	90	90	39	30	19	14	21	79	96	90	48	89	89	7	51	44
3				10	13	21	22	61	13	13	14	13	19	28	22	60	21	21	3	3	14
4					10	46	43	12	214	154	49	207	33	32	60	15	122	91	54	97	136
5						10	150	17	61	61	28	52	101	125	195	25	195	195	23	144	137
6							10	17	51	48	31	41	101	3	155	26	155	155	25	104	97
7								10	13	13	13	13	21	34	27	81	26	26	3	1	14
8									10	170	50	292	46	44	102	15	163	133	54	134	178
9										10	54	160	37	36	77	20	138	108	58	123	153
10											10	48	29	27	32	17	32	32	38	41	41
11												10	37	35	92	16	154	123	55	124	168
12													10	104	105	29	105	105	22	75	69
13														10	133	41	132	132	24	81	75
14															10	41	475	480	38	222	262
15																10	31	32	4	4	19
16																	10	499	39	237	316
17																		10	27	206	285
18																			10	44	53
19																				10	126
20																					10

Source: Author

Step 2: Create a "Savings list". After calculating the savings, rank the savings list from the largest S_{ij} to smallest S_{ij} , as shown in Table 3:

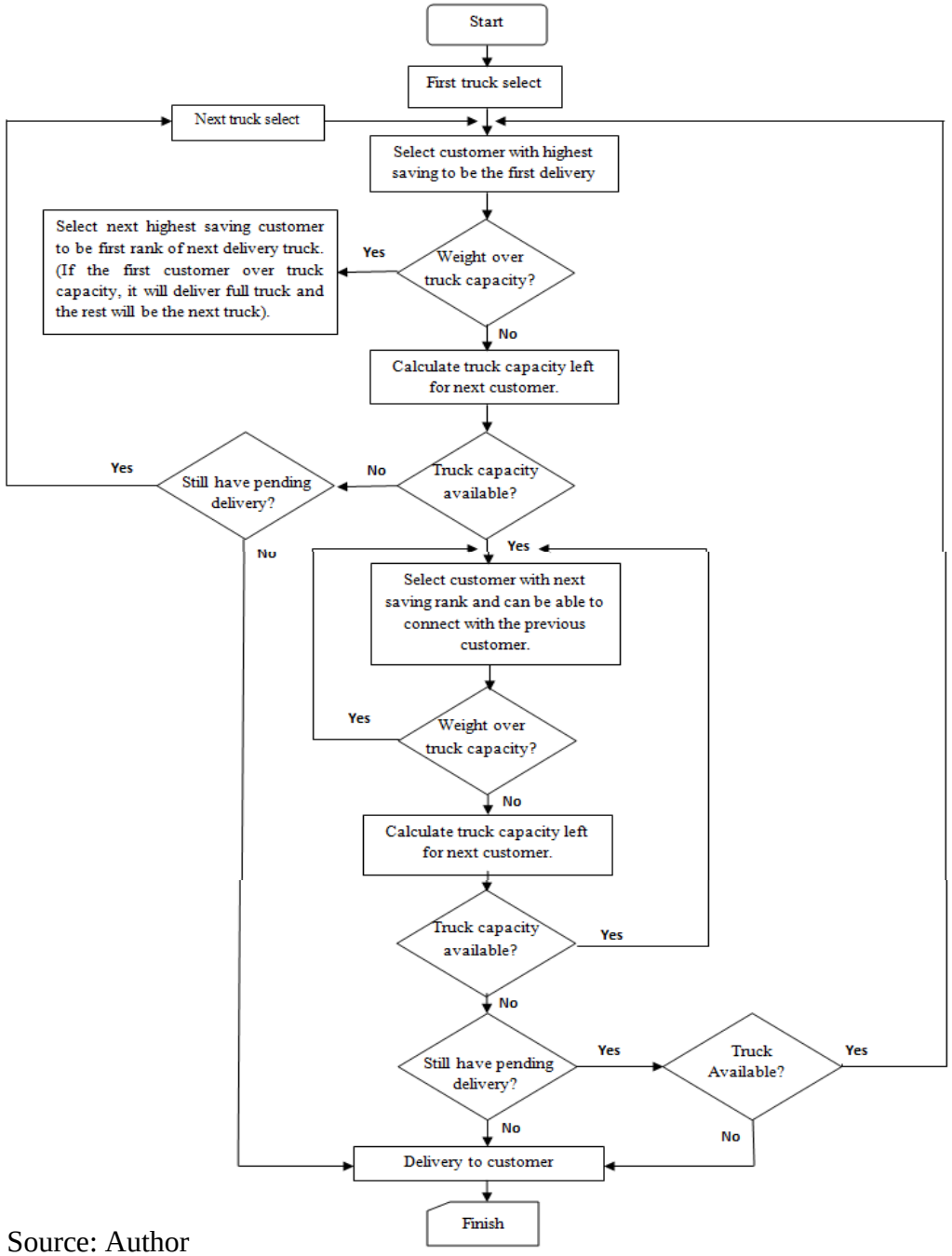
Table 3: Savings List

no.	i	j	kms	no.	i	j	kms	no.	i	j	kms	no.	i	j	kms
1	16	17	499	51	6	12	101	101	10	19	41	151	3	16	21
2	14	17	480	52	4	19	97	102	10	20	41	152	3	17	21
3	14	16	475	53	6	20	97	103	1	10	39	153	7	12	21
4	16	20	316	54	2	13	96	104	2	7	39	154	1	13	20
5	8	11	292	55	11	14	92	105	16	18	39	155	9	15	20
6	17	20	285	56	4	17	91	106	1	18	38	156	2	4	19
7	14	20	262	57	2	5	90	107	10	18	38	157	2	9	19
8	16	19	237	58	2	6	90	108	14	18	38	158	3	12	19
9	14	19	222	59	2	14	90	109	9	12	37	159	15	20	19
10	4	8	214	60	2	16	89	110	11	12	37	160	5	7	17
11	4	11	207	61	2	17	89	111	9	13	36	161	6	7	17
12	17	19	206	62	13	19	81	112	1	20	35	162	10	15	17
13	5	14	195	63	7	15	81	113	2	3	35	163	11	15	16
14	5	16	195	64	2	12	79	114	11	13	35	164	4	15	15
15	5	17	195	65	9	14	77	115	7	13	34	165	8	15	15
16	8	20	178	66	12	19	75	116	4	12	33	166	1	2	14
17	8	9	170	67	13	20	75	117	4	13	32	167	1	15	14
18	11	20	168	68	12	20	69	118	10	14	32	168	2	10	14
19	8	16	163	69	3	7	61	119	10	16	32	169	3	10	14
20	9	11	160	70	5	8	61	120	10	17	32	170	3	20	14
21	6	14	155	71	5	9	61	121	15	17	32	171	7	20	14
22	6	16	155	72	3	15	60	122	6	10	31	172	3	4	13
23	6	17	155	73	4	14	60	123	15	16	31	173	3	8	13
24	4	9	154	74	9	18	58	124	1	19	30	174	3	9	13
25	11	16	154	75	11	18	55	125	2	8	30	175	3	11	13
26	9	20	153	76	4	18	54	126	10	12	29	176	7	8	13
27	5	6	150	77	8	18	54	127	12	15	29	177	7	9	13
28	5	19	144	78	9	10	54	128	3	13	28	178	7	10	13
29	9	16	138	79	18	20	53	129	5	10	28	179	7	11	13
30	5	20	137	80	5	11	52	130	7	14	27	180	4	7	12
31	4	20	136	81	2	19	51	131	10	13	27	181	1	3	11
32	8	19	134	82	6	8	51	132	17	18	27	182	1	7	11
33	8	17	133	83	8	10	50	133	6	15	26	183	2	18	7
34	13	14	133	84	4	10	49	134	7	16	26	184	15	18	4
35	13	16	132	85	2	15	48	135	7	17	26	185	15	19	4
36	13	17	132	86	6	9	48	136	5	15	25	186	3	18	3
37	19	20	126	87	10	11	48	137	6	18	25	187	6	13	3
38	5	13	125	88	4	5	46	138	13	18	24	188	7	18	3
39	11	19	124	89	8	12	45	139	5	18	23	189	7	19	-1
40	9	19	123	90	2	20	44	140	1	5	22	190	3	19	-3
41	11	17	123	91	8	13	44	141	1	6	22				
42	4	16	122	92	18	19	44	142	1	13	22				
43	9	17	108	93	4	6	43	143	1	14	22				
44	12	14	105	94	1	4	43	144	3	6	22				
45	12	16	105	95	1	9	43	145	3	14	22				
46	12	17	105	96	1	11	43	146	12	18	22				
47	6	19	104	97	1	8	42	147	1	16	21				
48	12	13	104	98	6	11	41	148	1	17	21				
49	8	14	102	99	13	15	41	149	2	11	21				
50	5	12	101	100	14	15	41	150	3	5	21				

Source: Author

The next step after producing and considering the savings list is to process a model of the vehicle route by using the Savings method, as a flow chart which is shown in Figure 2 below. Then, the result is analyzed for the next step.

Figure 2: Process of Modeling the Vehicle Route by the Savings Method

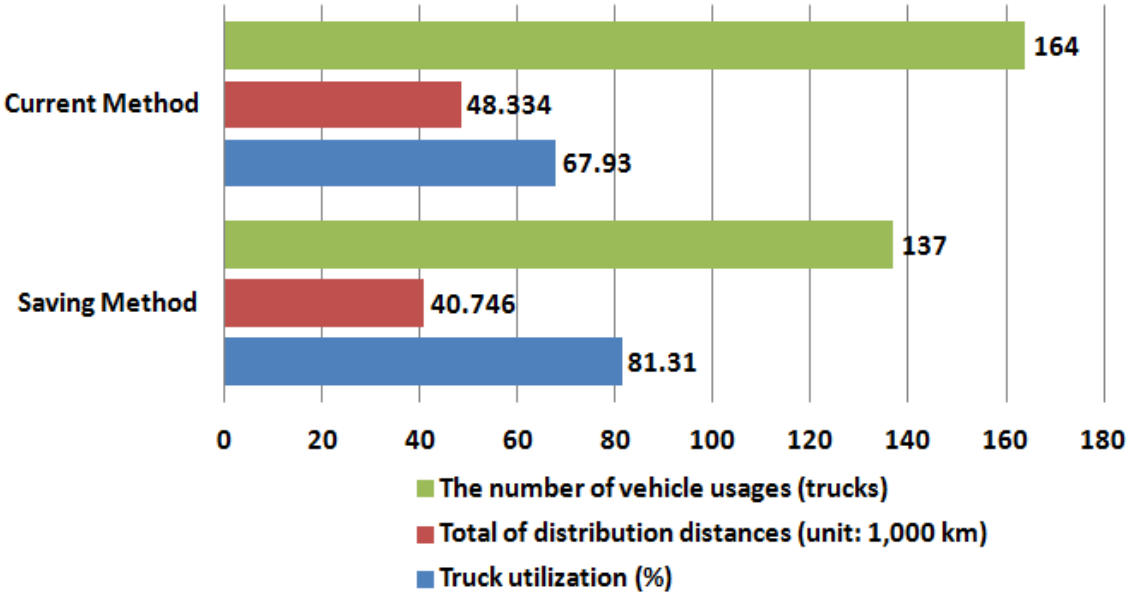


Source: Author

RESULTS AND DISCUSSION

The results of applying the Savings method show that the number of vehicles used is reduced by 27 trucks; the total distribution distance is decreased from 48,334 to 40,746 km; and the truck utilization has increased from 67.93% to 81.31%. The results are shown in Figure 3 below.

Figure 3: Comparison of Current and Savings Method



SUMMARY AND CONCLUSIONS

The Savings method helped to improve the truck management of ABC Company, which reduced the number of vehicles usage and the total distribution distances. Moreover, the truck utilization of truck capacity was improved significantly. The findings show that the Savings method developed truck management into becoming more systematic. The results were analyzed by using Excel worksheets. The summary of the key improvements in this research are as follows:

1. The total number of vehicles usage had significantly decreased by 16.46%.
2. The total distribution distances had reduced by 7,588 km or 15.70%. The company saved a cost of 18,203.61 THB for fuel (calculation is based on diesel price of July 02,2017 at THB 23.99 per liter).
3. The truck capacity was re-arranged with full truck loading. The truck utilization had improved by 19.70%.

According to the results, the proposed model (the Savings method) confirms that the number of vehicles usage, total distribution distances, and truck utilization have all significantly improved. Moreover, the company will save money when applying the new method to its truck management.

Theoretical Implications

In this study, the implementation of the Savings method shows a good result in the improvement of the current truck management when applied to the ABC Company. However, it may not apply to other companies in the same business category because each may have differing constraints and limitations. In other words, the results have low generalizability.

However, the Savings method using the algorithm by Clark and Wright (1964) is likely to produce good result solutions for small-size businesses. In addition, it is easily implemented with few complications and would suit companies faced with a similar situation. However, for large businesses, calculating the large savings values may affect the solution**.**

Managerial Implications

This research is developed for the improvement of the daily operation of truck management of a trading company, ABC. This case study can be a guideline for the company's transport department in managing the daily truck operation. The department may need to take about an hour each day to manage the trucks in this way, but it can save up to THB 18,000 per month or THB 216,000 per year. It is therefore valuable for this firm to apply this method in its transport department.

It has to be said that there was difficulty in collecting the data because the current data method was to collected manually and not systematically. In the future, under the new system, the data will be more accurate and easier to collect. Thus, it is recommended that the company provides a better storage and retrieval system to collect and manage the data.

Limitations and Recommendations for Future Research

The data collection in this study was done manually. The researcher spent much time in collecting the data; thus, this study cannot show a larger number of months within the limitations of research time and resources.

The Savings method helps manage the daily truck operation more systematically. Also, this method is flexible and uncomplicated. It is recommended that future research be applied to SMEs to improve their amount of vehicles usage, total distribution distances, and their truck capacity utilization.

In the future, it is likely that this and other trading business will continue to grow, and supply more customers. Thus, the company should adopt an appropriate method in its operation to cope with the business expansion. It may apply the application program to serve various customers.

For future research, an Enhanced saving method by considering the constraint of frequency of delivery or high volume concentration, etc., may be more usefully applied to match the vehicle routing problem for trading companies or SMEs in their specific practical situation, in order to manage their deliveery operation rather than the Savings method with its capacity constraints.

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