International Journal of Electrical and Computer Engineering (IJECE)
Vol. 13, No. 3, June 2023, pp. 2899~2907
ISSN: 2088-8708, DOI: 10.11591/ijece.v13i3.pp2899-2907

A transportation scheduling management system using decision tree and iterated local search techniques

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Article Info

Article history:

Received May 19, 2022
Revised Sep 17, 2022
Accepted Oct 1, 2022

Keywords:

Decision tree
First-in-first-out
Iterated local search
Scheduling management
Transportation

ABSTRACT

This paper aimed to develop a delivery truck scheduling management system using a decision tree to support decision-making in selecting a delivery truck. First-in-first-out (FIFO) and decision tree techniques were applied to prioritize loading doors for delivery trucks with the use of iterated local search (ILS) in recommending the route for the transport of goods. Besides, an arrangement of loading doors can be assigned to the door that meets the specified conditions. The experimental results showed that the system was able to assign the job to a delivery truck under the specified conditions that were close to the actual operation at a similarity of 0.80. In addition, the application of ILS suggested the route of the food delivery truck in planning the most effective transportation route with the best total distance.

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1. INTRODUCTION

Currently, logistics systems have been growing in high popularity and competitiveness. Modern technology has been applied to businesses that use logistics systems to enhance their efficiency using systems, robots, and artificial intelligence (AI). One of the reasons for the growth of logistics is due to changes in consumer behavior, the growth of e-commerce businesses as well as the evolution of technological innovation [1], [2]. Transportation is a key factor for almost all kinds of business. The organization focuses on transportation management, affecting the management of various parts of the organization. Good logistics management is essential to efficiency and reducing logistics costs. In addition, the management of quality transportation operations, on-time delivery, and complete delivery without any loss allows the service provided to the customers to become better [3]. Lack of information technology systems in logistics management may cause the following effects: i) it is unable to reduce the amount of paper to be on par with developed countries such as recording of work data that still needs to be written in a notebook; ii) it lacks data links, resulting in inefficient communication and the exchange of information within the organization; iii) it lacks planning for transportation of goods, causing the cost of transportation to be higher whether the cost of labor and cost of transportation; and iv) it lacks performance measurement to assess potential and performance. The use of information technology helps reduce logistics costs and increase the efficiency of transportation, to achieve the goal of the logistics business, which is the fastest and most cost-effective. Therefore, choosing an information technology system for logistics must consider the ability to reduce costs, travel time, and safety which is the main consideration that must also be given to linking the data to other relevant systems to ensure the accuracy of the results and their practicality [4].

Current research reveals that a decision support system has been analyzed and designed to assist timber transport businesses in managing trucks and increasing operational efficiency by scheduling trucks to reduce turnover times. Rotkanok [5] found that the model in the truck scheduling can reduce the time of transportation of wood chips. Limwattanakul [6] used a circular roulette metaheuristic approach to route management in conjunction with Google Maps. The results show that it can reduce the risk of loss of income and trade opportunities if the specialist is unable to work. The lowest total distance can be found and the transportation is optimally managed. Jia *et al*. [7] proposed ant colony optimization (ACO) as a solution to routing problems. Multi-point delivery with time frame conditions and time constraints was found to test the program's best ability to find answers. The data was tested on four client samples of 24 possible answers, with the two best answers out of five tests. Sriwichai [8] presented the development of transportation management systems by applying risk management techniques in conjunction with Tabu Search and Google Maps to find the shortest route. Rolko and Friedrich [9] presented a new freight transport generation model using the locations of logistics service providers (LSP). This database contains manufacturers, retailers, wholesalers, the locations of German LSPs, and transport infrastructure nodes. Pečený *et al.* [10] proposed the optimization of transport and logistics processes. This work was based on Vogel's method of the nearest neighbor and approximation. The nearest neighbor method simplifies the calculations used to optimize a single route. The experimental results showed that Vogel's estimation method is more efficient than the nearest neighbor method as 3 of the 5 distribution paths are resolved. Kauf [11] proposed a study on smart logistics for smart city development. The effective management of the infrastructure, the monitoring of environmental pollution, and the management of the lightning traffic can achieve cost and pollution reductions. In critical situations, it enables rapid response by utilizing automated analysis and incident observation, and intelligent alerts.

Stopka *et al.* [12] focused on the specified transport network as a city logistics scale. This paper aims to find the shortest path during customer delivery activities. The relevant (receiving and delivery) data can be displayed in graphs using graph theory. A finite set of vertices and edges represent the roads' infrastructure in the specific transport network. The results showed a comprehensive optimization in the transport network, including addressing distributed jobs mathematically above all operational research methods. Ardakani *et al.* [13] proposed a multi-door cross-docking system based on truck-to-door sequencing. The results showed that the heuristic algorithm with SC1 and SC4 compared to the other storage cost (SC) provided better solutions. The metaheuristic method [14] is a reliable method of obtaining effective and good-quality answers to be used in various planning in dealing with logistics problems. Metaheuristic methods are therefore used to solve problems. One of the problems that are often encountered is the problem of routing transportation routes. Many methods of metaheuristics can be applied in problem-solving such as the roulette wheel selection method [15], local search method [16], a preliminary answer with constructive heuristics [17], [18], simulated annealing (SA) [19], and iterated local search (ILS) [20]. The implementation of each method depends on the nature of the desired answer, aptitude, or user preference.

Therefore, we proposed the development of a transportation scheduling management system to increase the efficiency of transportation management by enhancing the truck daily scheduling by using the decision tree technique to support decision-making on how to assign delivery trucks. The first-in-first-out (FIFO) technique [21] is applied in conjunction with the decision tree to prioritize the loading doors and delivery trucks after the job has been assigned. In this work, ILS technique is used to suggest routes for goods transportation and prepare daily reports via the system for users. Efficient truck scheduling management can help increase the efficiency of goods transportation and will lead to better business development.

2. METHOD

In this section, we introduce the procedure of our proposed method. The implementation of the scheduling management system development is shown in Figure 1. The details of operations are described as follows.

2.1. Master data

The data structure in the transportation truck scheduling management system can be divided into two parts, including internal and external data. The internal data includes data on loading doors, transportation trucks, and truck drivers and assistants. The external data, namely transport management system (TMS) [22], receives data from TMS to be processed in the system such as a list of items to be delivered.

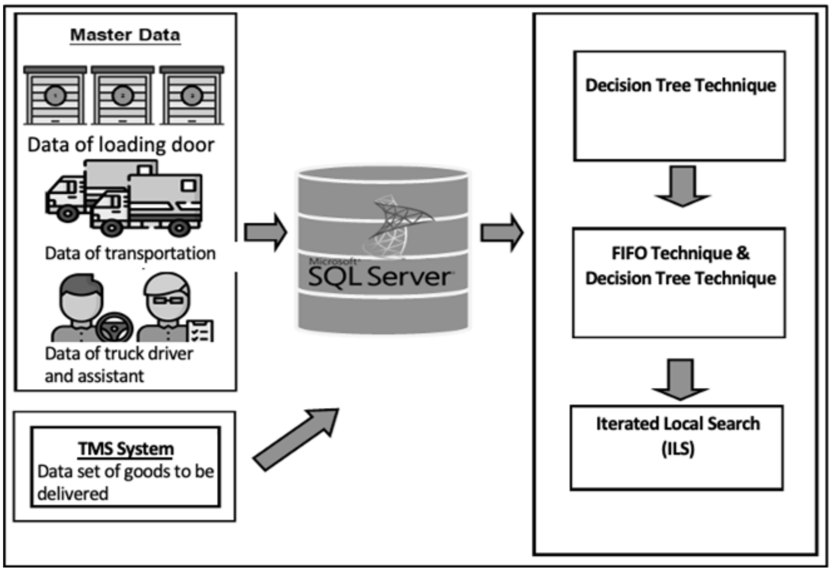


Figure 1. System conceptual framework

2.2. Decision tree

The decision tree technique [23] is applied to determine the criteria for assigning the list of goods to be delivered to the delivery truck, which are shown in Table 1. The selection criteria for the truck assignment are based on the company's actual work and a case study related to data of the delivery truck (status of availability, loading capacity, and transport line). This process includes driver information (performance evaluation rating) and a data set of goods to be delivered (number, weight, and transport lines). The procedure is ranked; i) a transport truck is ready for transportation from check-in through the system; ii) the loading capacity of the truck is sufficient for the weight of the goods to be delivered; iii) the delivery truck is in a line of transport that corresponds to the line of the goods to be delivered; iv) the employee with the highest rating will receive the job of delivering the goods first.

Table 1. Good assignments for delivery truck using decision tree technique

Delivery Truck	Event: List of goods to be delivered, Transport Line: A1, Weight: 250 kg			
	Status	Loading	Transport Line A1	Rating (5 is the highest)
Mr. A	Available	<=300 KG	Yes	4.75
Mr. B	Available	<=100 KG	Yes	5.00
Mr. C	Not Available	<=500 KG	No	4.85
Mr. D	Available	<=300 KG	Yes	4.69
Mr. E	Available	<=500 KG	No	4.52

2.3. FIFO with decision tree for prioritizing the loading door for the transport truck

When a job is assigned to any delivery truck, the next step is to assign a delivery truck to wait for the goods to be loaded at the loading door. The FIFO in conjunction with the decision tree technique is applied in this procedure as shown in Figure 2. In this process, the consignment set is assigned to the driver. It will be queued at the loading door as per the time assigned to such a driver. The organizer has set the criteria for queuing from the data of loading doors (door status, the number of door queues, and the quantity of work on each door) and the data set of goods to be delivered (delivery truck and the amount of work). These can be divided into two cases: i) the delivery truck has no queue at the loading door and ii) there is a queue at the loading door. In the first case, the delivery truck has no queue at the loading door. This means that there is only one set of goods to be delivered. The procedure of the criteria for selecting the loading door for the delivery truck is listed as: i) there is an available loading door, ii) the queue of the delivery truck must not be found at any previous loading door, and iii) the loading door with the lowest queue must be found and selected for the loading queue. In the second case, the delivery trunk has a queue at the loading door. It means that there is more than one set of goods to be delivered. The procedure of the criteria for selecting the loading door for the delivery truck is listed as i) there is an available loading door and ii) the loading door with a queue of a delivery truck will be searched. This door will be selected to wait for the loading queue.

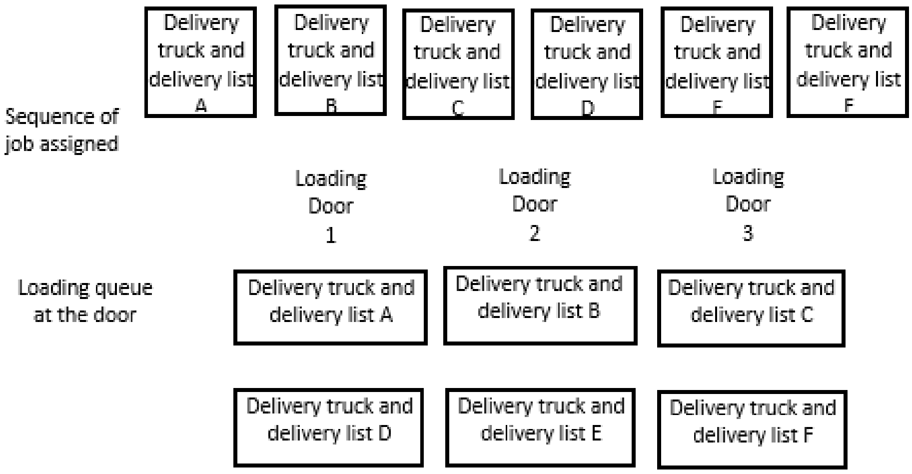


Figure 2. FIFO framework

2.4. ILS for delivery route planning

The system assists in delivery route planning for each delivery truck. It suggests the routing sequence of the trucks by applying the ILS technique. We assume that there are five stores on one particular route. The process of ILS for assisting the delivery route planning is described as: i) Google Maps is used as a tool to measure the distance between each delivery point. In this case, we measure the distance for all five stores. The distance from one store to another store can be varied as shown in Table 2; ii) To find the shortest distance, the ILS method is used as shown in a pseudocode in Figure 3. We assume that the initial answer is $S = sequence$ of the store for goods delivery sequence, $Z(S) = total\ distance$. Therefore, the initial answer is $S^* = 1-3-4-2-5-1$ $Z(S^*) = 83$, which is the shortest total distance; iii) We interfere with the answer S^* for the 1st time with random positions 1 and 2, alternatingly, as shown in Table 3; iv) When the shortest total distance is obtained, interfere with the answer S^* for a second time with random positions 1 and 3 and alternate the positions as shown in Table 4; v) When the shortest total distance is obtained, interfere with the answer S^* for a third time with random positions 2 and 4 and alternate positions as shown in Table 5. Finally, we observe that the shortest total distance is 83. Thus, the route {3-1-2-5-4-3} represents the best answer.

Table 2. Distance from one store to another store

Store	1	2	3	4	5
1	0	17	16	19	20
2	17	0	20	15	17
3	15	97	0	18	19
4	16	15	19	0	16
5	17	17	18	15	0

```
Iterated Local Search
    input: starting solution, S0
    input: Local Search procedure, LS
    current = LS (S0)
    while stopping criterion not met do
        S = perturbation of current based on search history
        S* = LS (S)
        if S* is accepted as the new current solution then
            current = S*
        end if
    end while
```

Figure 3. ILS pseudocode

Table 3. Example of distance measurement (1)

The 1st finding of N(S) by alternating stores with a total of 6 routes			
Alternating position	Alternating store	Route	Total distance
(2,3)	(3,4)	1-4-3-2-5-1	83
(2,4)	(3,2)	1-2-4-3-5-1	87
(2,5)	(3,5)	1-5-4-2-3-1	85
(3,4)	(4,2)	1-3-2-4-5-1	161
(3,5)	(4,5)	1-2-5-2-4-1	83
(4,5)	(2,5)	1-3-4-5-2-1	84

Table 4. Example of distance measurement (2)

Alternating position	Alternating store	Route	Total distance
(1,2)	(1,3)	3-1-5-2-4-3	86
The 2nd finding of N(S) by alternating the position of 3-1-5-2-4-3			
Alternating position	Alternating store	Route	Total distance
(2,3)	(1,5)	3-5-1-2-4-3	87
(2,4)	(1,2)	3-2-5-1-4-3	169
(2,5)	(1,4)	3-4-5-2-1-3	84
(3,4)	(5,2)	3-1-2-5-4-3	83
(3,5)	(5,4)	3-1-4-2-5-3	84
(4,5)	(2,4)	3-1-5-4-2-3	85

Table 5. Example of distance measurement (3)

Alternating position	Alternating store	Route	Total distance
(2,4)	(1,5)	3-5-2-1-4-3	96
The 3rd finding of N(S) by alternating the position of 3-1-5-2-4-3			
Alternating position	Alternating store	Route	Total distance
(2,3)	(5,2)	3-2-5-1-4-3	169
(2,4)	(5,1)	3-1-2-5-4-3	83
(2,5)	(5,4)	3-4-2-1-5-3	88
(3,4)	(2,1)	3-5-1-2-4-3	87
(3,5)	(2,4)	3-5-4-1-2-3	87
(4,5)	(1,4)	3-5-2-4-1-3	83

3. RESULTS AND DISCUSSION

I this section, we present the results and discussion of our proposed method in this section. We show the decision for the job assigned to the delivery trunk, the sequence of loading doors assigned to the delivery truck, route planning, delivery goods, and driver assessment. The detail of each procedure is described below.

3.1. Decision for job assigned to the delivery truck

In this task, the decision tree technique is applied to determine the criteria for assigning the list of goods to be delivered to the delivery truck. The detail of the job assignment to drivers is shown in Table 6. The table shows that the system was able to assign the job to the delivery truck according to the specified conditions based on a random ten sets of the goods delivery. Compared to the results obtained by the transport operators, it is close to the actual work with a similarity of 0.80. Differently, it comes from the fact that the system can assign the job more correctly according to the conditions than the staff who arrange the transport themselves. The table shows that the driver with a high rating receives a job assignment before the driver with a lower rating. Besides, there is no job assigned in a jumping manner from one job number to another. The driver with a lower rating received a job assignment whose frequency is random.

3.2. The sequence of loading doors assigned to the delivery truck

The FIFO technique in conjunction with the decision tree technique can assign the delivery trucks to wait at the loading door. The queue of delivery trucks at the loading door is shown in Table 7. The system selects the door according to the specified conditions. For example, in the case of a DC in Bangkok, there were three sets of goods to be delivered. We found that all sets were queued to load the goods at the same door rather than loading at others, making it more convenient and faster.

Table 6. Job assignment to drivers

Goods delivery No.	Route Zone	Total weight of goods	Results from the system			Result from employee			Similarity
			Driver's name	Rating	Truck's Plate No.	Driver's name	Rating	Truck's Plate No.	
0000329372	B13	398.14	Nikhom	5	Bor.Phor-2171	Nikhom	5	Bor.Phor-2171	1
0000329374	B15	302.30	Nikhom	5	Bor.Phor-2171	Phraphan	4.75	Bor.Bor-6082	0
0000329376	B11	16.28	Chansit	5	Bor.Bor-6175	Nikhom	5	Bor.Phor-2171	0
0000371294	DC5	4,356.38	DC5 Songkhla	5	DC5 Songkhla	DC5 Songkhla	5	DC5 Songkhla	1
0000371324	DC1	1,537.48	DC1 Chaing Mai	5	DC1 Chaing Mai	DC1 Chaing Mai	5	DC1 Chaing Mai	1
0000371325	DC2	374.17	DC2 Phitsanulok	5	DC2 Phitsanulok	DC2 Phitsanulok	5	DC2 Phitsanulok	1
0000371327	DC4	603.07	DC4 Surat	5	DC4 Surat	DC4 Surat	5	DC4 Surat	1
0000370935	B01	69.66	Thawihiat	5	Bor.Bor.-6075	Thawihiat	5	Bor.Bor.-6075	1
0000370938	B04	5.27	Somsak	5	Bor.Bor.-6076	Somsak	5	Bor.Bor.-6076	1
0000371126	B04	0.50	Somsak	5	Bor.Bor.-6076	Somsak	5	Bor.Bor.-6076	1
									0.80

Table 7. Queue of delivery trucks at the loading door

No.	Goods delivery No.	Number of Invoices	Driver	Plate No.	Door	Door Queue No.
1	0000370998	17	DC Bangkok	DC Bangkok	Door 1	1
2	0000370999	13	DC Bangkok	DC Bangkok	Door 1	2
3	0000371000	24	DC Bangkok	DC Bangkok	Door 1	3
4	0000371294	48	DC1 Songkhla	DC1 Songkhla	Door 3	1
5	0000371324	9	DC1 Chaing Mai	DC1 Chaing Mai	Door 2	1
6	0000371325	9	DC2 Phitsanulok	DC2 Phitsanulok	Door 3	2
7	0000371327	8	DC4 Surat	DC4 Surat	Door 2	2

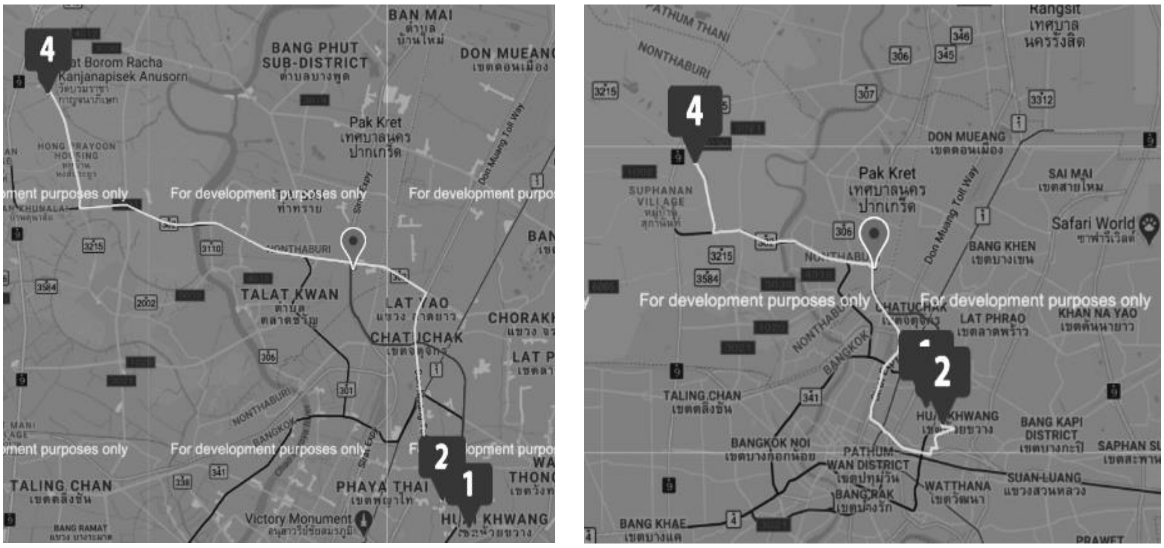
3.3. Route planning for delivery goods

To deliver goods, the ILS technique was applied to suggest the route. The route search results using ILS for specific answers are shown in Table 8. The best result was Route 1 which had a total distance of 46.7 kilometers, including W101 Warehouse → 1. Prachan Phesat → 2. Phisan Osot → 3. Kledthong Osot → 4. Sirichai Phesat. The results were displayed by pinning them on Google Maps, as shown in Figure 4(a). The next route search is route 2 with a total distance of 49.1 kilometers, consisting of W101Warehouse → 1. Kledthong Osot → 2. Sirichai Phesat → 3. Phisan Osot → 4. Prachan Phesat. It was displayed by pinning it on Google Maps, as shown in Figure 4(b). Therefore, the management system for scheduling of freight vehicles based on the ILS technique can help the driver plan a trip conveniently using the shortest total distance.

Table 8. Route search results by using iterated local search (ILS)

Store	Distance from each point (KM)				
	W101	Kledthong Osot	Sirichai Phesat	Phisan Osot	Prachan Phesat
W101	0	16.3	16.3	13.3	**14.3**
Kledthong Osot	19.5	0	0	30.2	31.2
Sirichai Phesat	19.5	0	**0**	30.2	31.2
Phisan Osot	11.9	**27.6**	27.6	0	2.6
Prachan Phesat	16.8	34.9	34.9	**4.8**	0

1.W101 → Prachan Phesat → Phisan Osot → Kledthong Osot → Sirichai Phesat
14.3 KM → 4.8 KM → 27.6 KM → 0 KM
Total distance 46.7 KM
2.W101 → Kledthong Osot → Sirichai Phesat → Phisan Osot → Prachan Phesat
16.3 KM → 0 KM → 30.2 KM → 2.6 KM
Total distance 49.1 KM



(a) (b)

Figure 4. Pinning on Google Maps (a) route 1 with the total distance of 46.7 km and (b) route 2 with a total distance of 49.1 km

3.4. Planning the delivery

The system can select the door for the arrangement of transport vehicles due to the conditions set in the system. Besides, for planning the delivery, the delivery route was suggested using a recursive local search technique [24], [25] in combination with the use of the Google Maps API service [26]. From the experiment, we found that the total distance of manual routing from the staff was 3,161 kilometers, while the total distance of manual routing from the system was 2,451.4 kilometers. The percentage of total mileage was 22.45% shorter than before. The actual trip has a fuel consumption rate of 203.02 liters, and the estimated fuel cost for delivery is 4,457.55 baht. The total distance traveled from the system has a fuel consumption rate of 157.44 liters and estimated fuel costs for delivery at 3,456.51 baht. This can be seen that the total distance traveled from the system has a lower fuel consumption rate than the driver planning trip at 45.58 liters and saves about 1,001.04 baht in fuel costs, as shown in Tables 9 and 10.

Table 9. Summary of total distances of manual and system routing

Shipping summary for the period 5/1/2021-28/01/2021	Total distance (km)		Difference (km)
	Manual routing from staff	Routing from the system	
Total distance	3,161.00	2,451.4	709.7

Table 10. Summary of fuel consumption rates and fuel estimation of manual and system route arrangements

Shipping Summary During the 5/1/2021-28/01/202	Manual routing			Routing from the system			Difference	
	Total distance (km)	Fuel consumption (liters) 15.57 km/liter	Estimated delivery cost (baht)	Total distance (km)	Fuel consumption (liters) 15.57 km/liter	Estimated delivery cost (baht)	Fuel consumption (liters)	Estimated delivery cost (baht)
Total	3,161.00	203.02	4,457.55	2,451.4	157.44	3,456.51	45.58	1,001.04

3.5. Driver assessment

The system has a record of the driver's assessment in case of a shipping error. The scores were recorded from the assessment. This score is taken as part of the terms of the delivery of the truck.

4. CONCLUSION

This paper introduced the development of a transportation scheduling management system to increase the efficiency of transportation management by enhancing the truck’s daily scheduling using the decision tree with FIFO to prioritize the loading doors and delivery trucks. It can suggest routes for goods transportation and prepare daily reports via the system for users efficiently using ILS. Efficient truck scheduling management can help increase the efficiency of goods transportation and will lead to better business development. This paper is beneficial in the case study for the companies to optimize the performance to be more accurate in the decision-making process. It starts by assigning the work to trucks following the specified conditions to make the deliveries more efficient and then arranging the loading door for the delivery truck so that the work process is systematic for both the employee and the driver. This work can be adjusted in the workflow to use for a shorter time. It also recommends the shortest travel distance to help drivers plan transportation routes.

ACKNOWLEDGEMENTS

This research was funded by National Science, Research and Innovation Fund (NSRF), King Mongkut's University of Technology North Bangkok with Contract no. KMUTNB-FF-66-43, and Department of Mathematics, King Mongkut's University of Technology Thonburi.

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