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Location routing problem solving: A case study Thailand Royal Project

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Abstract

This study presents a mathematical model for resolving the location routing problem of agricultural product transportation in royal projects in Thailand. This work aims to minimize the distance between pickup subcenter point locations and transport route links in each area. The difference in product amount in each area affects the product's capacity in the subcenter and its transport to the royal project's main center under the conditions of weight score classification depot, depot capacity, delivery demand, truck capacity, and transport distance. Due to the similar performance of each royal project, selecting a suitable subcenter is difficult. As a result, the mathematical model is created to solve the decision-making problem of selecting the subcenter for pickup and transportation. The mathematical model assumption is tested by the Lingo V16 program, which uses an exact method to find the appropriate subcenter point selection on the five instants in each size of the problem. The testing revealed that the mathematical model could choose an appropriate subcenter point in a small-scale problem effectively and quickly. However, it is not suitable for problem-solving in a medium or large-scale problem. The increasing number of data points influences solution generation speed and quality. The exact method of problem-solving with the Lingo program is unsuitable for problem-solving when the problem is complex and has several parameters that change depending on the current situation. In order to achieve faster algorithms, the best solution-finding method will be improved in the future with a meta-heuristics approach to algorithm design.

Keywords: Location routing problem, Royal project, Transportation, Agriculture product

1. Introduction

Nowadays, agriculture product demand increases consistently in consumption around the world of people. Transportation is essential for product distribution to the retail chain thoroughly. Thus, the goods transportation business grows continuously, leading to high market competition in service and increasing the profit of each organization [1, 2]. The several strategies of transportive operation for product distribution are determined within the resources and facilities of the organization. Transportive business adapted strategy plans from each trader to the direct retail chain, resulting in the design and network generation of the product distribution center and logistical route to the consumer in order to reduce the blasted product and transport cost. [3]. The suitable location and routing selection of the product distribution center is based on the low cost of operation, transport, and opening the distribution center, which is essential to the expense-decreasing organization and logistic system [4]. The goods distribution center open selection is a difficult decision within several conditions such as transport distance, product quantity demand, time window, environment, and fuel cost [5, 6], which is an ambiguous problem to determine the best location and transport route. The recent location routing problem is studied for various problems to be solved, such as warehouse [7], pickup and delivery [8], transportation [9], and inventory [10]. This problem is a combination of the facility location problem (FLP) and the vehicle routing problem (VRP) [11-13]. Then, the problem simulation is determined to be convenient for solving and saving resources. The mathematical model generation of the location routing problem could operate expeditiously and adjust easier the problem condition. Previously, much research focused on solving the location and route selection on different problems with the mathematical model. Leng et al. [14] presented solving the location-routing problem with multiple constraints by mathematical model generation and a heuristic method that could select the location and network route for planning and product distribution at the lowest cost and increase transport effectiveness. Asef et al. [15] used a mathematical model and a heuristic method for the location-routing problem-solving of solid waste management that could reduce the total costs to 20-22%. In 2020 Wang et al. [16] generated a mathematical model for solving the green logistics two-echelon location routing problem and the pickup and delivery problem within a time window constraint to minimize total transport cost. The result is a suitable location routing network design based on the shortest path of pickup and delivery. In 2022 Karakostas et al. [17] mentioned the mathematical

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model and variable neighborhood search algorithm to solve the problem of pollution location inventory routing, which led to a highly effective solution and reduced the total cost of operation. Moreover, several approaches are used for solving LRP, Chen et al. [18] created a mathematical model of the problem and used a method with a hybrid approach between NSGA-II and Tabu Search (TS) for solving full truck loads. The routing of trucks is part of the network design of a low-carbon supply chain to minimize total cost and environmental effects. The LRP solution with entire truck loads reduced total costs and environmental effects. Yu et al. [19] used a simulation annealing (SA) approach to solve the capacitated location routing problem so that it could be effectively solved. In 2021, Yu et al. [20] presented an approach using the mixed-integer nonlinear programming (MINLP) and SA algorithm in problem-solving LRP with the time-dependent demands of customers. The LRP's problems are minimizing costs and choosing a suitable location, which can reduce costs and increase profits for the organization in the face of market competition. The literature reviews show that the mathematical model and heuristic method could solve several location routing problems (LRP) under different constraints. Moreover, the mathematical model and heuristic approaches are used to generate the linking and allocating of location and routing for total cost optimization of logistic systems, such as the adaptive extensive neighborhood search (ALNS) algorithm for location and routing planning of electric vehicles in agriculture [21] and allocation of the marketplace location and tourism routing [22] and the variable neighborhood strategy adaptive search (VaNSAS) algorithm for optimization of the location and routing in agricultural logistics [23]. These approaches generate the optimal solution under different conditions effectively.

The Royal Project of Thailand is an agricultural extension organization with more than 100 locations throughout Thailand. The product of the Royal Project consists of vegetables and fruit transported to the Royal Project centers in each zone in Thailand. Each royal project has an average daily production of 30 tons, which is transported by truck to the royal project center. However, the royal project transported products by truck, which has a capacity of 10-30 tons. Each zone of the royal project has a location for collecting products. Some royal projects transport the products to the royal project center over a long distance with a significant difference in the area, affecting waste products and increasing costs. The agricultural goods of Thailand's royal project must be transported quickly. Because many agricultural products can't be kept for a long time, they may be blasted from transportation to the determinative point of product collection before transport to the main royal project center. Transportation distance reduction is critical for maintaining freshness and reducing costs in agricultural product transformation. The selection of a suitable collection position in the received product means that agriculture is increasingly influential in transporting and reducing the cost of the blasted product. This problem is a location routing problem (LRP) within the time limit, and there was no correction in the royal project. Therefore, the research objective presents a mathematical model of the problem of location-allocation and network routing for the transportation and integration of products. The mathematical model is tested with an exact method by the lingo program V16, which is an exactness test of the mathematical model. The product of each royal project is transported to a suitable collection point before moving from the collection point location transport to the royal project center for each route. The proper location-allocation and transport route network generation consider the constraints of weight score classification depot, depot capacity, delivery demand, truck capacity, and transport distance to minimize the total distance within a day of transportation. The contribution of this research study is the optimal location-allocation of collection and product transport network planning with the shortest distance for reducing the transport cost within the constraints of the different weight scores of performance for a royal project feature, depot capacity, delivery demand, truck capacity, and transport distance. The mathematical model is defined from a real-life case study in Thailand.

This paper is constructed as follows: the LRP literature is reviewed and displayed in Chapter 2. The mathematical model design is shown in Chapter 3. The results of the mathematical model test by Lingo V16 are exhibited in Chapter 4 and in Chapter 5, which displays a conclusion and recommendation.

2. Literature review

Location routing problems are NP-hard to solve with the primary method. Many studies exhibit the different problem-solving methods of LRP for product transportation and proper location. In 2014, Salazar et al. [9] presented a metaheuristic algorithm for transportation location and routing problem-solving with truck capacity. The solution to this problem is reducing distribution costs and balancing workloads for transport in the routing stage. And ref. [24] presented an exact solution method and a variable neighborhood search for solving the warehouse location routing problem in disaster relief, which is a well-organized problem-solving exhibition with an effective result. According to this, the exact method is used to plan the subway's operation strategy within the constraints of inequitable passenger desire and the costs of operation. The mathematical model of integrated mixed-integer non-linear generation optimizes the operational process for service quality and operating costs. The exact method using speed-up techniques could be solved to procreate an optimal solution [25] rapidly. Prasanti et al. [26] presented a local search algorithm using a periodic location routing problem (PLRP) to solve power plant cases, a case of an electricity company in Indonesia. Ten instances of algorithm testing revealed short computing times of less than two hours and a low standard deviation of solutions. Furthermore, Asef et al. [15] mentioned the hybrid algorithm between variable neighborhood search (VNS) and simulated annealing algorithm (SA) for location routing problem-solving in integrated solid waste management at the lowest total cost. The solution accuracy of hybrid algorithms shows a gap of less than 4%, which gives a total cost reduction of 20-22%. In addition, the generation of an LRP network is necessary for linking locations and routing transportation. It is a logistics network. A suitable logistic network could reduce the cost, time, and traffic congestion associated with city freight transportation [27]. Furthermore, the COVID-19 pandemic has significantly impacted the logistic system costs and the people and business sectors of many countries, such as public transportation vehicle routing [28] and food supply chain transportation [29, 30]. Therefore, network linking and planning the logistic system is vital to quality and cost because they affect growth generation, the logistic system's sustainability, the country's income, and the business sector's robustness [31, 32]. From the literature review of logistics, the location and allocation of suitable transportation could be location and allocation on the route of suitable transportation that increases effectiveness in the operation of the organization [33].

The literature review shows several problem-solving on different constraints, as shown in table 1 that the solution finding of LRP initiated the mathematical model creation and exact problem-solving method. Minimizing the total cost is the main objective of several studies. To minimize the total distance, exhibit a few research findings. Furthermore, the various LRP constraints, such as depot capacity, vehicle capacity, travel time, etc., are investigated; these constraints are the root cause of the problem. The difference between problems and limitations indicated different mathematical models of each problem, which is solution finding within using the low resource. The research surveying found that the constraint of weight score classification of the depot is not considered a study in LRP for location allocation and route linking.

Therefore, this work presents a mathematical model of the problem within five constraints for optimal solution finding, which will be presented in this article.

Table 1 Problem solving on different constraints of location-allocation and network routing in LRP.

Authors	**Objectives**	**Method**	**Constrains**							
			Depot capacity	**Vehicles capacity**	**Number of vehicles**	**Delivery demand**	**Demand rate**	**Travel time**	**Weight score classification of depot**	**Distance**
Saif-Eddine et al. (2019) [34]	Minimize total supply chain cost	IGA	✓	✓	✓					
Nataraj et al. (2019) [27]	Minimize the total cost	BR and ILS			✓	✓				
Theeraviriya et al. (2020) [23]	Minimized fuel cost	VaNSAS	✓	✓						✓
Theeraviriya et al. (2020) [21]	Minimized total cost	ALNS		✓						✓
Yu et al. (2021) [20]	Minimized the total distance	MINLP and SA		✓			✓	✓		
Yu et al. (2022) [35]	Minimized the total costs	Hybrid GA and SA	✓	✓						
This work	Minimized the total distance	ExM	✓	✓		✓			✓	✓

Note; IGA = Improved genetic algorithm, BR = Biased Randomization, ILS = Iterated Local Search, VaNSAS = Variable neighborhood strategy adaptive search, ALNS = Adaptive large neighborhood search, MINLP = Mixed-integer nonlinear programming, SA = Simulated annealing, GA = genetic algorithm. ExM = Exact method

3. State of problem

This section is a formal statement of the problem and states the mathematical model assumptions. This research aims to find a suitable location for the product collection center and a transport route for the Royal Project of Thailand. The royal projects comprised 136 sub-branch royal projects, and each royal project produced the product in different amounts. These sub-branches royal project brings their products to the major royal project by truck each day, which various royal projects are far away. Therefore, their royal projects have to increase costs for transportation and blasting products. The allocation of locations and route planning is essential in the logistic system of Thailand's royal projects, which expect to reduce the cost of goods transported.

The objectives of this research are the generation of suitable location allocation for the product collection sector and transport routes network in product receiving of the sub-branch royal project before transport to the royal project center. The target of the solved problem is to minimize the total distance, which separates into two parts: The transport distance between the royal project central to the collective location point and the distance transporting the product to the collection point. The mustering position allocation and routing network generation reduce total transport cost and product damage from sub-branch royal project far away, which is the main problem in solving. Therefore, the conceptual framework is converting the directed goods transport from transport to the branch royal project to the center point, generating the location-allocation and routing network for product collection before transportation to the royal project center shown in Figure 1. The product transport from mustering position allocation on generated routing network influences total cost and marketing. The constraint determines to weight score classification depot, depot capacity, delivery demand, truck capacity, and transport distance. These constraints are the determination of position allocation on generated routing network.

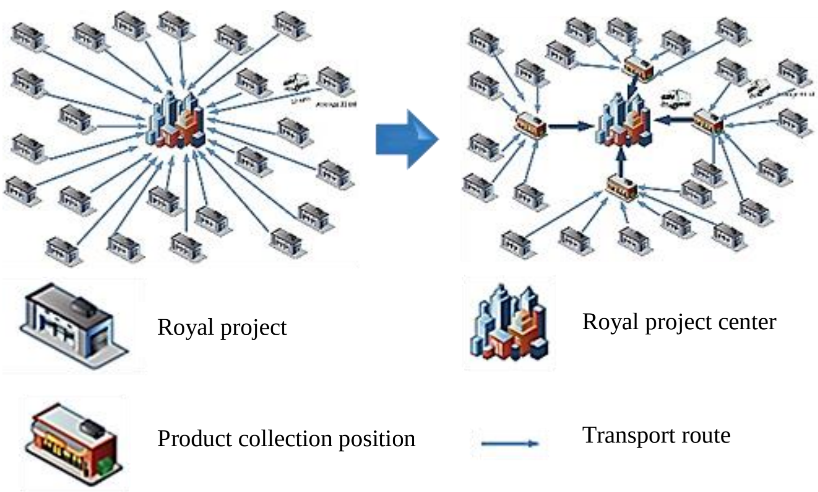

Figure 1 Conceptional framework of location routing problem solving.

3.1 Mathematic equations for problem solving

The LRP solution for royal project transportation provides the fewest number of transportation paths and a suitable location of the product collection center within differences in the weight score classification of the depot, depot capacity, delivery demand, truck capacity, and transport distance for each royal project. The weight score classification of the depot is considered with depot capacity and truck capacity together. The high capacity of depot and truck scrutinizes the high weight score value of depots whose weight scores range from 1-5 scores. The mathematical models can be created as follows:

Indices

i,j are the royal project location for product collection and royal project center (i=1) and i,j values in the set I = 1, 2, …, I

k is truck and k value in the set K = 1, 2, …, K

f is the sub royal project which support the product to collective location point and f is in the set F= 1, 2, …, F

Parameters

Q_i = Weight classification points that give royal project importance i

D^1_{ij} = Distance from royal project location for product collection i go to royal project location for product collection j (kilometer)

D^2_{fj} = Distance from sub royal project f go to royal project location for product collection j (kilometer)

V_k = Capacity of truck k

C_j = Capacity of production collection j

Decision variables

$x_{ijk} = \begin{cases} 1 & \text{When have product transportation from the royal project location } i \text{ go to } j \text{ by vehicle} \\ 0 & \text{Otherwise} \end{cases}$

$y_{fj} = \begin{cases} 1 & \text{When have a delivery from the sub royal project } f \text{ go to royal project location of product collection } j \\ 0 & \text{Otherwise} \end{cases}$

Support variables

u_{ik} = the total weight for truck k at royal project location i

$z_j = \begin{cases} 1 & \text{When have open of product collection at royal project } j \\ 0 & \text{Otherwise} \end{cases}$

$o_j = \begin{cases} 1 & \text{royal project location i is assigned at the starting points } j \\ 0 & \text{Otherwise} \end{cases}$

Objective function

$$MIN = \sum_{i=1}^{I}\sum_{j=1}^{I}\sum_{k=1}^{K} D^1_{ij} x_{ijk} + \sum_{f=1}^{F}\sum_{j=1}^{I} D^2_{fj} y_{fj} \quad (1)$$

Subject to

$$\sum_{j=1}^{J} y_{fj} = 1 \quad \forall f \in F \quad (2)$$

$$y_{fj} \le z_j \quad \forall f \in F, \forall j \in I \quad (3)$$

$$\sum_{f=1}^{F} Q_f y_{fj} \le C_j \quad \forall j \in I \quad (4)$$

$$\sum_{i=2}^{I}\sum_{k=1}^{k} x_{ijk} = z_j - o_j \quad \forall j \in I \quad (5)$$

$$\sum_{i=1}^{I}\sum_{k=1}^{k} x_{jik} = z_j \quad \forall j \in I, j \ne 1 \quad (6)$$

$$\sum_{i=2}^{I}\sum_{k=1}^{k} x_{ijk} = \sum_{i=1}^{I}\sum_{k=1}^{k} x_{jik} - o_j \quad \forall j \in I, j \ne 1 \quad (7)$$

$$\sum_{i=1}^{I}\sum_{j=1}^{I} Q_i x_{ijk} \le V_k \quad \forall k \in K \quad (8)$$

$$u_{jk} - u_{ik} \le Q_j + V_k(1 - x_{jik}) \quad \forall j \in I, \forall i \in I, \forall k \in K \quad (9)$$

$$0 \le u_{ik} \le V_k - Q_i \quad \forall i \in I, \forall k \in K \quad (10)$$

$$x_{jik}, y_{fj}, o_j, z_j \in \{0, 1\} \quad \forall j \in I, \forall f \in F\ \forall i \in I, \forall k \in K \quad (11)$$

The objective of this model is as follow. Equation (1) is an objective equation for the distance of product transported route minimization. In Equation (2), each royal project must send the product to locational collection. In Equation (3), the royal projects are opened suitable locations for product collection point. Equation (4) ensure that total weight of royal projects does not exceed the capacity of production collection. Equation (5-7) guarantee the continuity of the traveling truck. In Equation (8), each of the transport routes are transported to the central royal project not exceeding the capacity of the truck. Equations (9) and (10) are collective weights to eliminate sub tours. Binary variables are defined in Equation (11).

4. The results of mathematic functions

The mathematical model tests the problem-solving of the location-allocation and network routing finding with an exact method for product transport that uses the program Lingo V16. The problem is divided into three sizes small problem size, medium problem size, and extensive problem size that each size consists of 5 instants for mathematical model testing. Each problem size was scored by the importance of the royal project level according to the quantity of product. There are minor problems with 10-30 royal projects in each. The medium-sized problems consist of 31-60 royal projects, and the enormous problems have more than 60 royal projects. The results are shown in Table 2. Such as, the optimal solution of small problem one shows two transport routes, and the goods collection point opening is position number 7 in the first and 10 in the second routes. The optimal total distance in truck transportation on routes 1 and 2 is 205.4 and 210.5 kilometers, respectively. The processing time of routing planning is 4.43 minutes. The result displays the optimal solution of allocating the goods collection point and the shortest total distance in each route network, which shows the difference between the number of route networks and the processing time of all sized problems. The augmenting of the data set exhibits influence on route network increment and analyzed time, including total route network distance. Moreover, the resulting quality may be reduced when used to short processing time, such as the medium and large problems. Thus, the data set variation significantly affects the data analysis and processing time for optimal solution finding.

The example of case study solved testing could be generative the position allocation in product receiving and transport routing with 33 positions and logistic linking of routing and allocation in opening the received center from each sub-royal project that the case study result show in table 3. The routing network of product transportation exhibit linking the five routes and position allocation for collection subcenter opening before product transport to the center point are the position of the royal project at 30, 5, 8, 23, and 6, respectively. For position 19, allocate directive transport to the center point due to the transport distance near the center point. The distance solution of each route consists of 50.4 kilometers for the first route, 175.3 kilometers for the second route, 245.5 kilometers for the third route, 468.5 kilometers for the fourth route, and 387.2 kilometers for the fifth route. That total distance of transport is 1,532.6 kilometers. This result is minimized the total distance of the logistic system. The network route linking of the example case study is shown in Figure 2.

Table 2 Test results for mathematical models.

Problem size	Parameters		Distance Results (kilometer)	Time of test results (hour)	Status
	Route	Product collection point			
Small problem 1	1-4-7-5-3	7	205.4	00:04:43	Global
	2-6-8-10-9	10	210.5		
Small problem 2	1-4-7-5-3	7	205.4	00:04:48	Global
	2-6-8-10-9	10	210.5		
	13-15-12-11-14	15	320.1		
Small problem 3	1-4-7-5-3	7	205.4	00:06:25	Global
	2-6-8-10-9	10	210.5		
	13-15-12-11-14	15	320.1		
	18-16-17-19-20	19	280.7		
Small problem 4	1-4-7-5-3-6	7	207.6	00:06:54	Global
	2-11-8-10-9-12	10	225.3		
	13-15-18-14-17-21	18	231.4		
	16-19-20-22-24-23-25	20	352.1		
Small problem 5	1-4-7-5-3-6	7	207.6	00:07:15	Global
	2-11-8-10-9-12	10	225.3		
	13-15-18-14-17-21	18	231.4		
	16-19-20-22-24-23	20	348.1		
	26-28-30-25-29-27	25	361.2		
Medium Problem 1	1-3-2-5-6-4-7	5	276.2	20:39:26	Global
	9-10-8-11-13-12	11	246.8		
	14-15-13-16-17-18-20	16	302.3		
	24-21-23-25-22-26	22	250.2		
	28-27-29-30	29	238.7		
Medium problem 2	1-3-2-5-6-4-7	5	272.3	29:38:36	Global
	9-10-8-11-13-12	11	245.5		
	14-15-13-16-17-18-20	17	305.9		
	24-21-23-25-22-26	23	268.7		
	28-27-29-30-32-33	29	287.1		
	31-34-36-35-38	36	370.6		
	37-39-40	40	250.4		
Medium problem 3	1-3-2-5-6-4-7	6	272.3	32:56:03	Global
	9-10-8-11-13-12	11	245.5		
	14-15-13-16-17-18-20	16	305.9		
	24-21-23-25-22-26	25	268.7		
	28-27-29-30-32-33	30	287.1		
	31-34-36-35-38	36	370.8		
	37-39-40-45-42-41	45	350.7		
	43-44-46-48	46	343.6		
	47-49-50	49	367.2		
Medium problem 4	1-3-2-5-6-4-7	6	272.3	54:15:22	Global
	9-10-8-11-13-12	11	245.5		
	14-15-13-16-17-18-20	16	305.9		
	24-21-23-25-22-26	25	268.7		
	28-27-29-30-32-33	30	287.1		
	31-34-36-35-38	36	370.8		
	37-39-40-45-42-41	45	350.7		
	43-44-46-48-47-49	46	390.1		
	52-51-55-50-54-53	50	385.2		

Table 2 (continued) Test results for mathematical models.

Problem size	Parameters		Distance Results (kilometer)	Time of test results (hour)	Status
	Route	Product collection point			
Medium problem 5	1-3-2-5-6-4-7	6	272.3	70:27:14	Global
	9-10-8-11-13-12	11	245.5		
	14-15-13-16-17-18-20	16	305.9		
	24-21-23-25-22-26	25	268.7		
	28-27-29-30-32-33	30	287.1		
	31-34-37-36-35-38	36	380.2		
	42-39-40-45-44-41	40	366.4		
	43-51-46-48-47-49	48	391.2		
	55-50-54-53-57-52	57	395.1		
	56-59-58-60	59	256.3		
Large problem 1	1-3-2-5-6-4-7	6	272.3	>75	Feasible
	9-10-8-11-13-12	11	245.5		
	14-15-13-16-17-18-20	17	305.9		
	24-21-23-25-22-26	25	268.7		
	28-27-29-30-32-33	29	287.1		
	31-34-36-35-38	36	370.8		
	37-39-40-45-42-41	40	350.7		
	43-44-46-48	46	343.6		
	47-49-50-52	50	378.7		
	51-54-53-56-55	53	278.8		
	57-59-58-60-61	58	290.6		
Large problem 2	1-3-2-5-6-4-7	4	272.3	>75	Feasible
	9-10-8-11-13-12	13	245.5		
	14-15-16-19-17-18-20	19	305.9		
	24-21-23-25-22-26	21	268.7		
	28-27-29-30-32-33	29	287.1		
	31-34-36-35-38	36	370.8		
	37-39-40-45-42-41	40	350.7		
	43-44-46-48	46	343.6		
	47-49-50-52	50	378.7		
	51-54-53-56-55	53	278.8		
	57-59-58-60-61	58	378.6		
	63-63-62-65	62	367.9		
Large problem 3	1-3-2-5-6-4-7	5	272.3	>75	Feasible
	9-10-8-11-13-12	8	245.5		
	14-15-16-19-17-18-20	19	305.9		
	24-21-23-25-22-26	25	268.7		
	28-27-29-30-32-33	27	287.1		
	31-34-36-35-38	34	370.8		
	37-39-40-45-42-41	45	350.7		
	43-44-46-48	46	343.6		
	47-49-50-52	49	378.7		
	51-54-53-56-55	56	278.8		
	57-59-58-60-61	60	378.6		
	63-63-62-65-67	62	367.9		
	66-68-70-69	70	389.6		
Large problem 4	1-3-2-5-6-4-7	5	272.3	>75	Feasible
	9-10-8-11-13-12	8	245.5		
	14-15-16-19-17-18-20	19	305.9		
	24-21-23-25-22-26	25	268.7		
	28-27-29-30-32-33	27	287.1		
	31-34-36-35-38	34	370.8		
	37-39-40-45-42-41	45	350.7		
	43-44-46-48	46	343.6		
	47-49-50-52	49	378.7		
	51-54-53-56-55	56	278.8		
	57-59-58-60-61-63	58	385.7		
	64-62-65-67-68-66-70	67	401.7		
	71-69-73-72-74-75	70	382.4		
Large problem 5	1-3-2-5-6-4-7	5	272.3	>75	Feasible
	9-10-8-11-13-12	8	245.5		
	14-15-16-19-17-18-20	19	305.9		
	24-21-23-25-22-26	25	268.7		
	28-27-29-30-32-33	27	287.1		
	31-34-36-35-38	34	370.8		
	37-39-40-45-42-41	45	350.7		
	43-44-46-48	46	343.6		
	47-49-50-52	49	378.7		
	51-54-53-56-55	56	278.8		
	57-59-58-60-61-63	58	385.7		
	64-62-65-67-68-66-70	67	401.7		
	71-69-73-72-74-75-77	72	416.5		
	76-79-80-78	80	326.5		

Table 3 Example case study results of solution finding

Testing	Parameters			Distance results (kilometer)	Process time of result finding (hour)	Status
	Routes	Collection point allocations	Center point			
Case study	19	-	1	50.4	19:34:53	Global
	17-15-34	30		175.3		
	31-22-35-12	5		245.5		
	33-32-21	8		205.7		
	14-29-18-4-13-26-10-3-9-11	23		468.5		
	28-25-7-2-16-24-27-20	6		387.2		
			Total distance	1,532.6		

The red point is the main royal project center, which is the position of product collection from product transportation from the subcenter collection to this position. The subcenter royal projects are the blue positions used for position allocation for goods collection before transport to the main royal project center. Green points are general royal project positions that determine the transport of the product to the sub-center point within location-allocation and linking routing generation. However, the processing time for solution finding is lengthy for an optimal solution. Moreover, the solution on the exact method based on the analysis by the Lingo V16 program compared with the other methods reduced result effectiveness and added processing time when increased data set shown in Table 4.

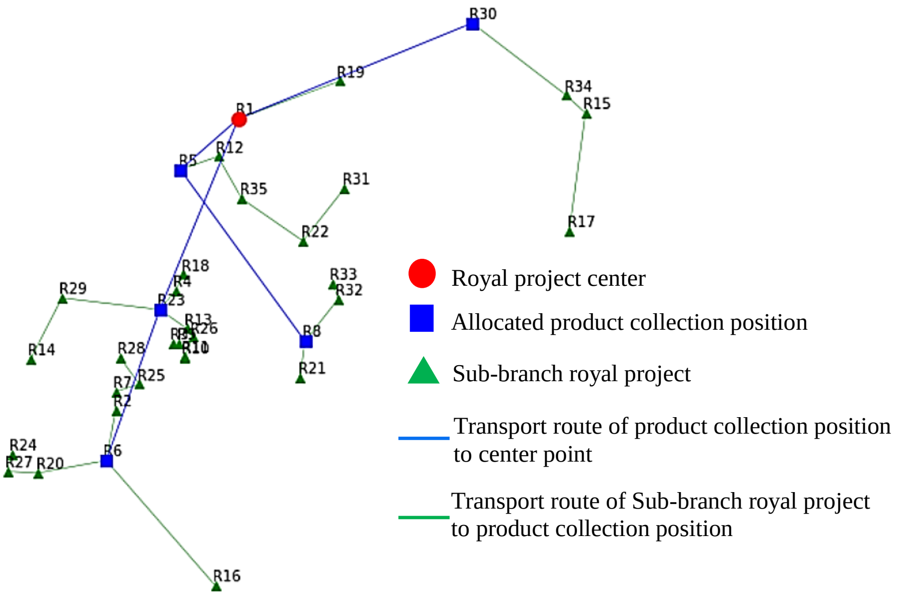

Figure 2 Example allocation and routing of medium problem.

The exact method displays the practical solution and processing time as well as the genetic algorithm (GA) and tabu search algorithm (Tabu) for a small-sized problem. The medium-sized problems give optimal solutions because the transport distance is slightly lower than GA and Tabu methods. However, the exact method uses more than the average processing time of 34.06 hours. For the large problem, the GA and Tabu methods show the effective optimal solution and the fast time of 74.52 hours for the exact method in the analyzed process. The adequate difference of the solution-finding approach could be calculated by equation (12).

$$\%difference = \frac{result_{other\ method} - result_{exact\ method}}{result_{exact\ method}} \times 100 \quad (12)$$

Table 4 Effectiveness comparison of solution finding.

Problem sizes	Number of position test	Exact method			GA [36]			Tabu [36]		
		Status	Total distance (Km)	Time of test results (hour)	Status	Total distance (Km)	Time of test results (hour)	Status	Total distance (Km)	Time of test results (hour)
SP 1	10	Optimal	415.9	00:04:43	Optimal	415.9	00:04:42	Optimal	415.9	00:04:42
SP 2	15	Optimal	736	00:04:48	Optimal	736	00:04:45	Optimal	736	00:04:45
SP 3	20	Optimal	1016.7	00:06:25	Optimal	1016.7	00:06:25	Optimal	1016.7	00:06:20
SP 4	25	Optimal	1016.4	00:06:54	Optimal	1016.4	00:06:18	Optimal	1016.4	00:06:18
		Average	**796.25**	**00:05:42**	**Average**	**796.25**	**00:05:32**	**Average**	**796.25**	**00:05:31**
MP 1	30	Optimal	1314.2	20:39:26	Optimal	1316.3	00:06:40	Optimal	1316.3	00:06:30
MP 2	40	Optimal	2000.5	29:38:36	Optimal	2010.4	00:06:55	Optimal	2011.5	00:06:57
MP 3	50	Optimal	2811.8	32:56:03	Optimal	2816.7	00:07:51	Optimal	2816.7	00:07:51
MP 4	55	Optimal	2876.3	54:15:22	Optimal	2878.5	00:08:45	Optimal	2878.3	00:08:40
		Average	**2250.70**	**34:13:45**	**Average**	**2255.40**	**00:07:22**	**Average**	**2255.70**	**00:07:19**
LP 1	61	Feasible	3392.7	>75	Optimal	3312.4	00:08:24	Optimal	3313.4	00:08:53
LP 2	65	Feasible	3848.6	>75	Optimal	3806.6	00:08:35	Optimal	3805.4	00:08:57
LP 3	70	Feasible	4238.2	>75	Optimal	4208.1	00:08:42	Optimal	4206.3	00:08:55
LP 4	75	Feasible	4271.9	>75	Optimal	4225.2	00:08:53	Optimal	4226.1	00:08:58
		Average	**3937.85**	**75**	**Average**	**3888.07**	**00:08:38**	**Average**	**3887.80**	**00:08:55**

The % difference in solution finding approach is shown in table 5. The comparison of result effectiveness found that the small-sized problem shows no difference in optimal results from the three methods. However, the processing time of the exact method displays more time than the approach of GA to 1.84 % and 2.02 % of Tabu. In the medium-sized problem, the exact method exhibits obvious the optimal solution on the different comparison of the result of GA and Tabu approach merely 0.2%. Thus, three solution-finding methods indicate a nearby effective solution, but the exact method uses a higher processing time than GA and Tabu at 99.65%. Large scale problems, the GA and Tabu approaches show higher result effectiveness than an exact method at 1.26% and 1.27 %, respectively, including the processing time, which is faster than 99.82%. This result shows that increasing the amount of data affects the optimal result finding on long processing time. This problem affects the generation of logistic-linked system planning when variable parameters are expanded.

Table 5 Comparison of % difference the methods effectiveness.

Problems	% Difference			
	Result of Exact method Vs GA	**Result of Exact method Vs Tabu**	**Processing time of Exact method Vs GA**	**Processing time of Exact method Vs GA**
Small problem	0	0	-1.84	-2.02
Medium problem	0.20	0.20	-99.65	-99.65
Large problem	-1.26	-1.27	-99.82	-99.82

Then, the exact method based on the analysis by the Lingo program is not suitable for complex data analysis. Therefore, the heuristic algorithm will be considered to improve the problem-solving for this research next time, showing high performance; the optimal solution finding follows as ref. [37, 38].

5. Conclusion and suggestion

The product transport network routing and suitable location allocation for the product collection for Thailand's royal projects are solved on the mathematical model under an exact method in the Lingo program. The optimal solution appears in small and medium-sized problems but differs from that in large ones. The increased data set display influence on solving a long time and reduced effects of finding the solution. Wherefore, the parameter increasing of number and value displays expand the processing time although it gives the optimal solution. Moreover, the large-scale data could not analyze to optimal solutions within the expanded processing time, exceptionally with local search method solving, which uses more than 75 hours. Ref [21-23] mention the local search method for the optimal solution of LRP problem solving, which is the lower effects of solution finding than the heuristic approach when the data set and long processing time increases. Therefore, the big data set exhibited increased complex analysis that difficult to optimal solution investigation led to low performance the solution that the Lingo program gave the high error solution of 7.24% [21]. The exact method of solving with the Lingo program is unsuitable for problem-solving when the problem shows complexity and several parameters. Therefore, the determination of the problem-solving method is essential for high-performance solutions and reduced processing time for large-scale data. The belated planning of product transportation impacts cost, goods damage, and market competition. Problem-solving expeditiously within complex and changed variables is imperative to the current business situation.
In the future, the meta-heuristic will be applied to the design of problem-solving algorithms in this case study.

6. References

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