Hub Location Problem Model to Determine the Location of Facilities by Considering Capacity and Routes

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Abstract

This study used the Hub Location Problem (HLP) model to determine the location of the freight hub facilities in the railway station to carry out the loading and unloading of goods. On this HLP model, freight is carried from the origin office to the destination office using a railway. The objective of this study is to develop a model optimization to minimize the total cost of the establishment of an office at the selected railway stop station and the total cost of transportation needed to deliver the goods to the inter-office through the rail network. The model developed in this study takes into account the limitations of carriage capacity and railway routes. The decision variables including the optimal location of the hub station and the allocation of freight sent. The model was processed for one of the railway routes used. The resulting hub networks was observed using computational analysis. By using this model, decision-makers can evaluate the location selection of station facilities which can provide a minimum hub opening cost and transportation cost.

Keywords
Hub Location Problem, Facility Location, Capacity, Route, Cost Minimization.

1. Introduction
Hub Location Problem (HLP) is a new research topic that is popular and flourishes in location theory (Farahani et al., 2013). A hub facility is defined as a place where all activities related to logistics, transportation, and distribution of goods for national or international transit are operated by several operators (Alam, 2013). Hubs can be truck terminals, rail yards, seaport container terminals, airports, and intermodal platforms. HLP is concerned with selecting the hub establishment location as well as allocating request nodes to the hub, so as to effectively route traffic between origin-destination points (Serper and Alumur, 2016). Determining the exact location of the hub can minimize the cost of transportation of goods because the position of the hub will affect the cost of transportation from the point of origin to the point of destination.

Literature studies on the problem of the hub location was conducted to gather general knowledge based on research from Alumur and Kara (2008), Hekmatfar and Pishvaee (2009), Contreras (2015), Farahani et al. (2013), and Campbell and O'Kelly (2012). Several studies on the problem of hub locations in logistics and supply chain management been done by several researchers. Sender and Clausen (2013) developed a capacitated multiple allocation hub location problem for the delivery of goods by train. Correia et al. (2013) developed a capacitated single allocation hub location problem model for shipping goods via land transportation. The solution to the problem used is by using mixed-integer programming. Wang et al. (2013) developed an uncapacitated single allocation p-median hub location problem.

Another study also developed a model HLP is Yang et al. (2014) who developed an uncapacitated single allocation p-hub center location problem using mixed-integer programming. Sadeghi et al. (2015) developed a capacitated single allocation p-covering hub location problem. The model is solved using a genetic algorithm and Differential Evolution (DE) algorithm. Rothenbacher et al. (2016) developed a capacitated multiple allocation p-median hub location problems to deliver goods using rail-road multimodal transportation by considering time constraints in delivery. In this study, a branch-and-bound-and-cut algorithm was used to solve the problem. Peiro et al. (2017) developed an uncapacitated multiple allocation p-center hub location problems by considering Greedy Randomized Adaptive Search Procedure (GRASP). Then Taherkhani and Alumur (2018) proposed a mixed-integer linear programming model for a capacitated multiple allocation p-covering hub location problems. Another study on the allocation model was also conducted by Hisjam et al. (2012). They develop a raw material allocation in the supply chain.

In previous research, Saputri et al. (2019) conducted a preliminary study related to the problem of location allocation. This study aims to develop a hub location problem model that can minimize total costs by allocating non-hub nodes to hub nodes. Total cost includes cost of establishing new hub, transportation costs from origin to destination, and carbon emission costs. Then, Saputri et al. (2019) also conducted research to resolve logistical issues related to the selection of optimal hub facility locations for delivery of goods by train that minimizes transportation costs. However, this model is still possible to be able to select a location based on the direction of the return delivery.

Furthermore, this new study aims to develop a capacitated multiple allocation median hub location model for shipping goods using rail transportation. The development of this model is an improvement from the previous model Saputri et al. (2019). The limitations on the development of this model have been adjusted to the conditions in the real system. The trains that are processed in this study only consist of one train and a one-way route. Thus, in this model, it is not possible to transfer goods between trains. The objective is to minimize the overall transportation costs associated with the flows. The result can recommend solving logistical problems related to choosing the optimal location of the hub facility.

2. Research Method

2.1 Initial Identification

One of the freight forwarders that provides delivery by rail is PT Kereta Api Logistik (PT KALOG). KALOG is one of the subsidiaries of PT Kereta Api Indonesia (Persero) or KAI that provides logistics distribution services using trains. Creating added value along the value chain of logistics distribution services, transportation of goods and warehousing is the function and role of KALOG. This focus and strengthening of the important role of KALOG are manifested in the pre-service and post-service stages of the services provided by KAI.

The locations of KALOG's integrated logistics services are spread across Java, Sumatra, and Bali. Courier and cargo services are one of the services available at KALOG that send various types of goods such as packages, documents, and motorbikes. The number of BHP freight for KALOG couriers in 2017 increased by 22.8% from 2016, namely from 23,929 tonnes to 29,384 tonnes of BHP courier cargoes (KAI, 2017). This shows that there is a possibility that consumers of goods delivery services by train at the KALOG company will continue to experience an increase every year.

Currently, KALOG has 67 KALOG Express outlets, namely 63 offices on the island of Java and 4 offices on the island of Bali. Along with the increasing demand for goods delivery services via train, KALOG can increase the coverage of its service area, namely by adding new offices, especially in big cities on the island of Java, by considering the selection of station locations for loading-unloading goods. This is also supported by the existence of several 78 train stations through which 10 trains were rented by KALOG to deliver goods on the island of Java.

Selection of the location of loading-unloading station for such goods would have to consider the main aspects of the shipping of goods, that is the cost of clearing goods storage facilities and transportation costs. In its application, the delivery of goods by train as a mode of land transportation must be supported by other lands transportation modes such as cars or trucks, as feeders for pick-up from the sending office and delivery to the receiving office, because trains are only capable of transporting from station to station. One of the ways to minimize the costs of opening the goods storage facilities and transportation costs is to determine the appropriate location of the facilities.

2.2 Model Development

This stage describes the components of the model, the model development process, as well as verification and validation of the model. The description of the system and model components used in the model is illustrated in Figure 1. This research focuses on the process of KALOG sending goods from the origin KALOG office to the destination KALOG office by using the train. Each carriage included in the series of trains have limited capacity. The flow of material entering or exiting the spoke can pass through more than one hub, aiming to choose the closest hub and minimize shipping costs. The main objective is to minimize total transportation cost, which consists of collection cost, transfer cost, and distribution cost. So, the model developed in this research is capacitated multiple allocation median hub location model.

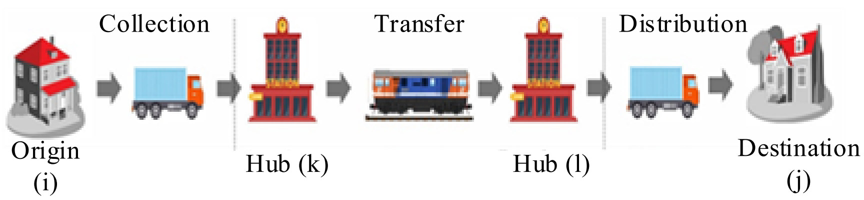

Figure 1. The system used in model development

The formulation of the model in this study was compiled by developing an existing model, namely the initial reference model of Ernst and Krishnamoorthy (1999). Then another model that is also used as a reference is the model of Ebery et al. (2000) and Rothenbacher et al. (2016). The development of mathematical formulas is modified based on the operation of the real system on the delivery of goods via rail transportation.

Then, verification and validation of the model that has been developed are carried out. Verification is done by checking the unit consists of all mathematical equations in the model. The validations used in this study are validation based on model assumptions and model behavior. Validation based on model assumptions is done by testing the basic assumptions used in the model. Validation based on the behavior of the model is carried out by conducting tests that evaluate the provisions between the model and the existing system by confirming to KALOG.

2.3 Coding and Analysis

At this stage, IBM ILOG CPLEX Optimization Studio software was used for model coding. This software is commonly used to solve optimization problems for linear and integer programming. The model that has been made is transformed into codes in the ILOG CPLEX software. The result of the calculation can be known after complete the coding process and running the model. The steps used in processing data on ILOG CPLEX are shown in Figure 2.

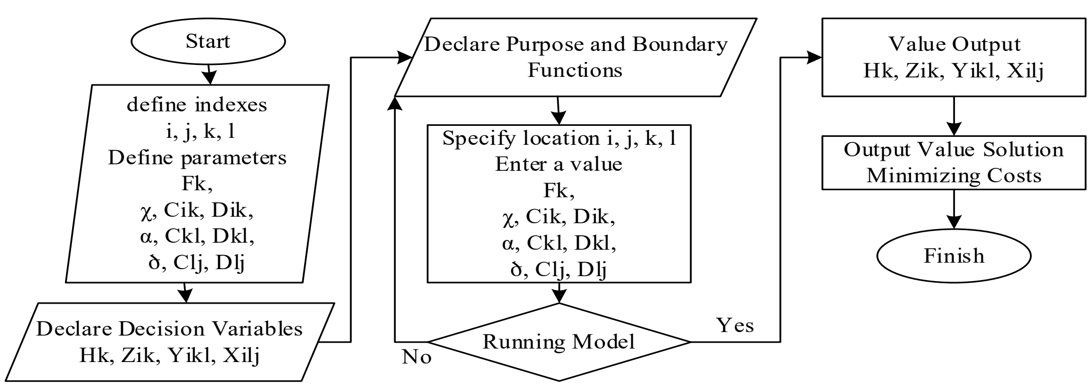

Figure 2. Flowchart of Data Processing at ILOG CPLEX

3. Model Formulation

Formulation of the model in this study will be described from mathematical notation and mathematical models used the whole model. The mathematical notation of the model developed in this study is shown in Table 1, Table 2, and Table 3. Table 1 shows the index of the model. Table 2 shows the parameter used in this study. Table 3 shows the decision variable.

Table 1. Index of the Model

Notation	Explanation
i	Origin
j	Destination
k	First hub
l	Second hub

Table 2. Parameter of the Model

Notation	Explanation
χ	Collection coefficients
α	Transfer coefficients
δ	Distribution coefficients
W_{ij}	Amount of flow from origin *i* to destination *j*
C_{ij}	Unit cost from *i* to *j*
D_{ij}	Distance from origin *i* to destination *j*
F_k	Setup cost of establishing a hub at *k*
Γ_k	Capacity of a hub located at *k*

Table 3. Decision Variables of the Model

Notation	Explanation
H_k	1 if a hub is located at *k* 0 otherwise
X_{lj}^{i}	Flow from origin *i* to destination *j* via hub *l*
Y_{kl}^{i}	Flow from origin *i* via hubs *k* and *l*
Z_{ik}	Flow from origin *i* to hub *k*

Based on the development model that has been done, then the mathematical model is obtained as follows:

Objective Function

$$\min M = \sum_{k\epsilon N} F_k H_k + \sum_{i\epsilon N, i\neq k}\left(\chi \sum_{k\epsilon N} C_{ik} D_{ik} Z_{ik} + \alpha \sum_{k\epsilon N}\sum_{l\epsilon N, k\neq l} C_{kl} D_{kl} Y_{kl}^{i} + \delta \sum_{l\epsilon N}\sum_{j\epsilon N, j\neq l} C_{lj} D_{lj} X_{lj}^{i}\right) \quad (1)$$

Constraint

$$\sum_{k\in N, i\neq k} Z_{ik} = \sum_{j\in N, j\neq i} W_{ij} \qquad \forall i \in N \qquad (2)$$

$$\sum_{l\in N, i\neq l\neq j} X_{lj}^{i} = W_{ij} \qquad \forall i, j \in N \qquad (3)$$

$$\sum_{l\in N, i\neq k\neq l} Y_{kl}^{i} = Z_{ik} \qquad \forall i, k \in N \qquad (4)$$

$$\sum_{i\in N, i\neq k} Z_{ik} \leq \Gamma_k H_k \qquad \forall k \in N \qquad (5)$$

$$\sum_{k\in N, i\neq k\neq l} Y_{kl}^{i} \leq \Gamma_l H_l \qquad \forall i, l \in N \qquad (6)$$

$$Z_{ik} \leq \sum_{j\in N, i\neq k\neq j} W_{ij} H_k \qquad \forall i, k \in N \qquad (7)$$

$$\sum_{i\in N, i\neq l\neq j} X_{lj}^{i} \leq \sum_{i\in N, i\neq l\neq j} W_{ij} H_l \qquad \forall l, j \in N \qquad (8)$$

$$X_{lj}^{i}, Y_{kl}^{i}, Z_{ik} \geq 0 \qquad \forall i \neq j \neq k \neq l \in N \qquad (9)$$

$$H_k \in \{0,1\} \qquad \forall k \in N \qquad (10)$$

The objective function of this research is (1) to minimize the total cost which consists of the cost of opening hubs and transportation costs. The transportation costs consist of costs from the origin i to the hub k (collection costs), inter-hub costs (k-l) (transfer costs), and costs from hub l to destination j (distribution costs). Constraint (2) shows that the flow of origin i is equal to the amount of flow at destination j. Constraint (3) indicates that the load from origin i to destination j through all open hubs can meet the existing demand. Constraint (4) shows the load from origin i through hubs k and l is equal to the load from origin i to hub k. Constraint (5) shows the limits of the hub k. Constraint (6) shows the limits of the hub l. Constraint (7) indicates the opening of the hub when the node receives or sends goods. Constraint (8) indicates the opening of the hub when the node receives or sends goods. Constraint (9) shows a charge must be greater than zero. The limiter (10) indicates the opening of the hub with a binary number.

4. Result and Discussion

4.1 Case Study

This section will discuss the results obtained from the results of calculations using the exact optimization method, that is branch-and-cut using ILOG CPLEX. The data processing in this study took a case study of KALOG in delivering goods using the Senja Utama Solo train. The route used is from Solo Balapan station with the final destination at Pasar Senen station. So the stations that are passed include Solo Balapan, Klaten, Yogyakarta, Kutoarjo, Purwokerto, Cirebon, and Jatinegara. In processing this data, it is assumed that the values of χ= 1, $\boldsymbol{\delta}$= 1, $\boldsymbol{\alpha}$= 0.75, $\boldsymbol{C_{ik}}$ = Rp. 1,000, $\boldsymbol{C_{kl}}$= Rp. 13,298, and $\boldsymbol{C_{lj}}$= Rp. 1,000. After the mathematical model and data is converted into ILOG CPLEX software, then the optimal solution can be found.

The results of selecting the optimal hub location are shown in Table 4. The results in Table 4 show a value of 1 if the station is selected as a hub and a value of 0 if otherwise. The stations selected as hubs are Yogyakarta, Kutoarjo, Purwokerto, Cirebon, and Jatinegara stations.

Table 4. Hub Location Selection Results

Hub Station	Value
Solo Balapan	0
Klaten	0
Yogyakarta	1
Kutoarjo	1
Purwokerto	1
Cirebon	1
Jatinegara	1

Other decision variables are the load allocated from the initial KALOG office to the hub station, the load allocated from the initial KALOG office to the hub station and final station, and the load allocated from the initial KALOG office to the destination KALOG office through the final station. The results are presented respectively in Table 5, Table 6, and Table 7.

Table 5. Loads Allocated from the KALOG Office of Origin to the Hub Station

Origin	Load Allocation at Hub Station (Kg)				
	Yogyakarta	Kutoarjo	Purwokerto	Cirebon	Jatinegara
Solo	1,260	0	0	0	0
Sragen	0	1,400	0	0	0
Paron	0	589	0	0	0
Tegalsepur Klaten	709	0	451	0	0
Kebon Dalem Kidul	0	700	0	0	0
Pasar Kembang	0	1,695	0	0	0
Wates Kulonprogo	0	900	0	0	0
Gunung Kidul	0	576	79	0	0
Kutoarjo	0	0	990	0	0
Cilacap Tengah	0	0	930	0	0
Bajing	0	0	720	0	0
Sidamulya	0	0	830	0	0
Purwokerto	0	140	0	850	110
Kesenden	0	0	0	655	0
Junjang	0	0	0	0	500
Bekasi	0	0	0	0	390
Jatinegara	0	0	0	495	0
Total Each Hub	**1,969**	**6,000**	**4,000**	**2,000**	**1,000**
Total	**14,969**				

Table 6. Loads Allocated from the Origin KALOG Office to the Hub Station and Final Station

Origin	Hub Station	Load at Final Station (Kg)
Solo	Yogyakarta	1,260
Tegalsepur Klaten		709
Sragen	Kutoarjo	1,400
Paron		589
Kebon Dalem Kidul		700
Purwokerto		140
Pasar Kembang		1,695
Wates Kulonprogo		900
Gunung Kidul		576

Origin	Hub Station	Load at Final Station (Kg)
Tegalsepur Klaten	Purwokerto	451
Gunung Kidul		79
Kutoarjo		990
Cilacap Tengah		930
Bajing		720
Sidamulya		830
Kesenden	Cirebon	655
Purwokerto		850
Jatinegara		495
Purwokerto	Jatinegara	110
Junjang		500
Bekasi		390

Table 7. Loads Allocated from the Origin KALOG Office to the Destination KALOG Office via the Final Station

Origin	Final Station	Destination	Loads (Kg)
Solo	Pasar Senen	Jakarta Gudang	360
		Jakarta Kota	250
		Manggarai	100
		Bogor Tengah	200
		Bogor Utara	100
		Tangerang	150
		Gondangdia	100
Sragen	Pasar Senen	Jakarta Gudang	100
		Jakarta Kota	300
		Manggarai	200
		Bogor Tengah	150
		Bogor Utara	150
		Tangerang	200
		Gondangdia	300
Paron	Pasar Senen	Jakarta Gudang	75
		Jakarta Kota	100
		Manggarai	80
		Bogor Tengah	70
		Bogor Utara	74
		Tangerang	90
		Gondangdia	100
Tegalsepur Klaten	Pasar Senen	Jakarta Gudang	200
		Jakarta Kota	150
		Manggarai	100
		Bogor Tengah	100
		Bogor Utara	110
		Tangerang	200
		Gondangdia	300

Origin	Final Station	Destination	Loads (Kg)
Cilacap Tengah	Pasar Senen	Jakarta Gudang	100
		Jakarta Kota	250
		Manggarai	180
		Bogor Tengah	100
		Bogor Utara	150
		Tangerang	50
		Gondangdia	100
Bajing	Pasar Senen	Jakarta Gudang	150
		Jakarta Kota	100
		Manggarai	100
		Bogor Tengah	150
		Bogor Utara	70
		Tangerang	60
		Gondangdia	90
Sidamulya	Pasar Senen	Jakarta Gudang	200
		Jakarta Kota	100
		Manggarai	100
		Bogor Tengah	150
		Bogor Utara	80
		Tangerang	100
		Gondangdia	100
Purwokerto	Pasar Senen	Jakarta Gudang	210
		Jakarta Kota	200
		Manggarai	200
		Bogor Tengah	90
		Bogor Utara	100
		Tangerang	150
		Gondangdia	150

Table 7. Loads Allocated from the Origin KALOG Office to the Destination KALOG Office via the Final Station (Cont.)

Origin	Final Station	Destination	Loads (Kg)
Kebon Dalem Kidul	Pasar Senen	Jakarta Gudang	100
		Jakarta Kota	100
		Manggarai	150
		Bogor Tengah	80
		Bogor Utara	100
		Tangerang	70
		Gondangdia	100
Pasar Kembang	Pasar Senen	Jakarta Gudang	240
		Jakarta Kota	275
		Manggarai	300
		Bogor Tengah	230
		Bogor Utara	200
		Tangerang	100
		Gondangdia	350
Wates Kulonprogo	Pasar Senen	Jakarta Gudang	150
		Jakarta Kota	100
		Manggarai	200
		Bogor Tengah	100
		Bogor Utara	150
		Tangerang	100
		Gondangdia	100
Gunung Kidul	Pasar Senen	Jakarta Gudang	75
		Jakarta Kota	100
		Manggarai	150
		Bogor Tengah	70
		Bogor Utara	100
		Tangerang	70
		Gondangdia	90
Kutoarjo	Pasar Senen	Jakarta Gudang	200
		Jakarta Kota	150
		Manggarai	120
		Bogor Tengah	200
		Bogor Utara	150
		Tangerang	100
		Gondangdia	70

Origin	Final Station	Destination	Loads (Kg)
Kesenden	Pasar Senen	Jakarta Gudang	100
		Jakarta Kota	100
		Manggarai	100
		Bogor Tengah	100
		Bogor Utara	75
		Tangerang	80
		Gondangdia	100
Junjang	Pasar Senen	Jakarta Gudang	100
		Jakarta Kota	70
		Manggarai	100
		Bogor Tengah	70
		Bogor Utara	60
		Tangerang	30
		Gondangdia	70
Bekasi	Pasar Senen	Jakarta Gudang	70
		Jakarta Kota	100
		Manggarai	50
		Bogor Tengah	30
		Bogor Utara	40
		Tangerang	50
		Gondangdia	50
Jatinegara	Pasar Senen	Jakarta Gudang	70
		Jakarta Kota	100
		Manggarai	75
		Bogor Tengah	50
		Bogor Utara	50
		Tangerang	70
		Gondangdia	80

Table 5 presents the results of the allocation of cargo to be sent from the original KALOG office to the selected hub station location. The allocation of this load is adjusted to the remaining carriage capacity of each hub station. In this study, it is assumed that the initial station has a full capacity of 15 tons, then there is a reduction in carriage capacity for each station that has been passed. So that the allocation of cargo to be sent adjusts to the remaining capacity. Table 6 presents the results of the allocation of cargo sent from the original KALOG office to the hub station and final station. Because in this study it is assumed that there is no decrease or movement of goods at each station, all cargo that has been sent from the hub station will be transported to the final destination station.

Then, Table 7 presents the results of the allocation of cargo from the KALOG office of origin to the destination KALOG office through the final station. The total load of goods sent is 14,969 kg, where this total load does not exceed the total gate capacity on the Senja Utama Solo train, so that the entire load can be sent from the original KALOG office to the destination KALOG office through the final station at Pasar Senen. After knowing the selected hub station, the amount of cargo sent, and the distance traveled to deliver the goods, the total cost needed to open the hub facility can then be calculated. By using ILOG CPLEX, it can be seen directly that the total cost required is IDR 53,392,963,341.57,-

4.2 Model Analysis

This research has developed a Hub Location Problem model for logistics transportation via rail. This model takes into account the limitations of the cargo-carrying capacity and the train routes used. The model developed is in the form of minimizing the total cost of opening a new hub which consists of setup costs for opening selected hubs and transportation costs for collection, transfer, and distribution of goods. The input parameters in this model include setup costs for opening a hub, collection coefficients, transfer coefficients, distribution coefficients, collection costs, transfer costs, distribution costs, collection distances, transfer distances, distribution distances, and the total load to be sent.

To find out the suitability of the developed model, therefore, several analyzes of the model were carried out. The analysis was carried out by testing the coefficients with several value scenarios. The analysis used in the process of model testing with the following scenarios:

Analysis of the effect of changes in coefficient parameters χ, α, ẟ on the model

This section explains how changes in the parameter values of the collection coefficient (χ), transfer coefficient (α), and distribution coefficient (ẟ) affect the model solution. The collection coefficient is related to the delivery of goods from the original KALOG office to the hub station. The transfer coefficient is related to the delivery of goods between stations. Then the distribution coefficient is related to the delivery of goods from the final station to the destination KALOG office. These coefficients describe how capable the selected location is to deliver goods from the point of origin to the point of destination. The value of the coefficient ranges from 0 to 1. The greater the ability of a location to be able to deliver goods, the value will also be large, which is close to 1 or worth 1. The analysis are presented in Table 8 and Figure 3.

Table 8. Scenario of Change in Coefficient Value χ, α, ẟ

Scenario	Coefficient Values χ, α, ẟ			
	0	0.5	0.75	1
Selected Hub Stations	Solo Balapan	Yogyakarta Kutoarjo Purwokerto Cirebon Jatinegara	Yogyakarta Kutoarjo Purwokerto Cirebon Jatinegara	Yogyakarta Kutoarjo Purwokerto Cirebon Jatinegara
Total Cost (IDR)	4,109,589.00	35,295,492,208.38	52,937,073,929.07	70,578,655,649.76

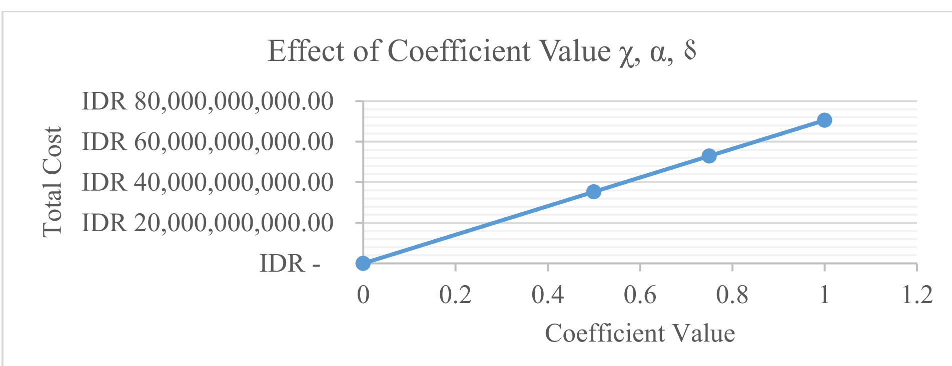

Figure 3. Graph of Effect of Changes in Coefficient Values χ, α, ẟ on Model Solutions

Based on these results from Table 8 and Figure 3, it can be seen that the greater the coefficient of collection, transfer, and distribution, the greater the total cost. This is because the coefficient will have a direct effect on the increase in collection, transfer, and distribution costs, so that the total cost of shipping goods will also increase. If the value of each coefficient is 0, then the train will automatically depart from the initial station, namely Solo Balapan, to Pasar Senen station without sending goods. Meanwhile, if the coefficient value is greater than 0, several stations will be selected as hubs. This is because there are several alternative coefficients of collection, transfer, and distribution in the delivery of goods that affect the total load that can be sent.

Analysis of the effect of changes in coefficient parameters α on the model
This section explains how changes in the transfer coefficient (α) parameter value to the model solution if the collection coefficient (χ) and distribution coefficient (ẟ) are equal to 1. A value of 1 in the collection and distribution coefficient indicates that the first KALOG office is considered to be able to send goods to the initial station and the final station can send goods to the destination KALOG office. Scenarios of variation in value changes for parameters and their results are presented in Table 9 and Figure 4.

Table 9. Scenario of Change in Coefficient Value α

Scenario	Coefficient Value α			
χ, ẟ = 1	0	0.5	0.75	1
Selected Hub Stations	Solo Balapan Klaten Yogyakarta Kutoarjo Purwokerto Cirebon Jatinegara	Yogyakarta Kutoarjo Purwokerto Cirebon Jatinegara	Yogyakarta Kutoarjo Purwokerto Cirebon Jatinegara	Yogyakarta Kutoarjo Purwokerto Cirebon Jatinegara
Total Cost (IDR)	977,763,432.00	36,207,271,033.38	53,392,963,341.57	70,578,655,649.76

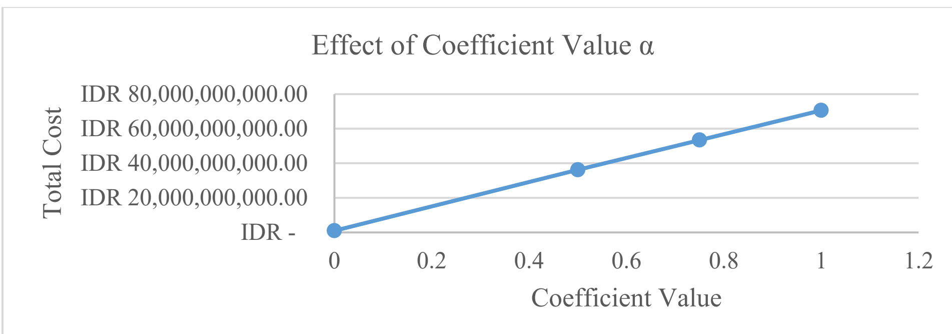

Figure 4. Graph of Effect of Changes in Coefficient Value α on Model Solutions

The greater the value of the transfer coefficient, the greater the total cost. This is because the coefficient will have a direct effect on the increase in transfer costs for sending goods from one station to another, so that the total transportation costs for shipping goods are also getting bigger. Then when the transfer coefficient is 0, it is known that all stations are selected as hubs. This is because the initial KALOG office will directly send goods to the nearest station from their location, so that each station can be opened as a hub for shipping goods.

Analysis of the effect of changes in total carriage capacity parameters to the model
In this study, it has been determined that the total capacity of the carriages used in one train series is 15 tons, which is in accordance with the current state of KALOG. However, this analysis aims to determine whether the capacity limits set on the model can be used or not. Therefore, a trial was carried out by changing the value of the total capacity of the carriage.

Based on the test results of the scenario in Table 10, it can be seen that if the capacity of the carriage is 0, then no results can be displayed in the search for solutions. Then if the capacity value is less than or more than 15 tons, then there are results that come out in the search for solutions. This proves that the capacity constraints in the model can be used to locate hubs where there are limited capacity.

Table 10. Effect of Changes in Carriage Capacity on Model

Total Capacity of the Carriages (Tons)	Result
0	No Solution
10	Solution
15	Solution
20	Solution

Analysis of the effect of changes in the parameters of the load sent on the model
This analysis aims to determine if there is an overload of goods sent in one carriage whether there are results or not on the model. From these trials, it was found that if the load sent is less than the capacity limit of the carriage, a value will appear in the search for solutions. Meanwhile, if the amount of cargo sent is greater than the capacity of the carriage, no results will appear in the software. This proves that the model can be used according to existing constraints. The analysis is presented in Table 11.

Table 11. Effect of Changes in Delivered Load on Model

The Load Sent	**Result**
W < 15 tons	Solution
W > 15 tons	No Solution

The model development has been successfully carried out, where the model produces outputs in the form of the selected hub location, collection load allocation, transfer load allocation, and distribution load allocation of goods sent. This model can be used as a decision-making system for companies in making decisions related to determining the location of the hub. Not only for the Senja Utama Solo train for the Solo Balapan-Pasar Senen route but this model can also be applied to 9 other trains used by KALOG, namely by filling in data according to the trains that will be used in the model.

This model can also assist decision-makers in analyzing the possibility of a new hub location that can be built. Through the simulation results on the model, it can be used by companies to make decisions. The input parameters used for the simulation are the same as the input parameters in the mathematical model, namely setup costs for opening a hub, collection costs and distance from the origin office to the hub station, transfer costs, and distance from the hub station to the destination station, distribution costs and distance from the destination station to the destination station. the destination office, as well as the amount of cargo to be sent from the origin office to the destination office.

5. Conclusion

This study focuses on services as a transporter, namely a service where KALOG sends goods from the original KALOG office to the destination KALOG office with the main mode of a train. The model developed in this study can be used to determine the location of the hub as delivery of goods with minimal costs by considering the capacity and route of the train used. The variable components used in the model are KALOG office points of origin, destination KALOG office points, starting stations as hubs, destination stations, collection coefficients, distribution coefficients, transfer coefficients, setup costs for opening hubs, hub capacity, total carriage capacity, shipping costs for collection, shipping costs for transfers, shipping costs for distribution, cargo sent, the distance between the origin KALOG office and the hub station, the distance between stations, and the distance between the last stop station and the destination KALOG office.

The decision variables used in the model developed in this study include the selected hub station, the load allocated from the origin KALOG office to the hub station, the load allocated from the origin KALOG office to the hub station and final station, and the load allocated from the origin KALOG office. to the destination KALOG office via the final station. In this study the delivery of goods using the KA Senja Utama Solo. The route used is from Solo Balapan station with the final destination at Pasar Senen station. The stations selected as hubs are Yogyakarta, Kutoarjo, Purwokerto, Cirebon, and Jatinegara stations with a total cost of IDR 53,392,963,341.57,-

This model can also assist decision-makers in analyzing the possibility of a new hub location that can be built. Through the simulation results on the model, it can be used by companies to make decisions. The input parameters used for the simulation are the same as the input parameters in the mathematical model, namely setup costs for opening a hub, collection costs and distance from the origin office to the hub station, transfer costs, and distance from the hub station to the destination station, distribution costs and distance from the destination station to the destination station. the destination office, as well as the amount of cargo to be sent from the origin office to the destination office.

The limitation of this research is that the model can only be used to determine the location of the hub on one type of train and one train line. This is because each train has its route. In addition, the route to and from the train concerned is also different. So it has not yet arrived at the development of a model that can accommodate the synchronization of the system for the entire train. In the future, it is hoped that further research can be carried out that can consider the existence of more than one route and consider the transfer of goods between trains.

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