JURNAL ILMIAH TEKNIK INDUSTRI
ISSN: 1412-6869 (Print), ISSN: 2460-4038 (Online)
Journal homepage: http://journals.ums.ac.id/index.php/jiti/index
doi:10.23917/jiti.v19i2.11908

Consolidation Model Recommendation for Rice Distribution in Indonesian Bureau of Logistics (West Java Regional Division)

Fran Setiawan[1a◆], Loren Pratiwi[1b], Elisa Ferdilia Wigono[1c]

Abstract. *BULOG (Indonesian Bureau of Logistics) Regional Division West Java is a state-owned public company regulating and maintaining a rice supply to meet all Indonesian people's needs. Currently, BULOG is distributing rice from one SubDivre warehouse to another SubDivre warehouse (point-to-point system), so shipping costs are higher because the frequency of transportation used is higher and the total distance traveled is higher. We proposed a consolidation model based on a hub and spoke network topology to reduce distribution costs. Hub and spoke system is done by determining which points become the hubs and which points become the spoke. The problem was determining the location of the hub and spoke is known as the hub location problem. In this problem, a single allocation p-hub median problem is used. We use AMPL to get the solution. A various number of hubs (5,6,7) are tested and evaluated based on total shipping cost. The number of hubs which gives the minimum total shipping cost is 7. The delivery system using the hub and spoke network model can reduce the total cost of distribution by 13,94%.*

Keywords: *consolidation; hub and spoke; hub location problem; p-hub median*

I. INTRODUCTION

According to Chopra and Meindl (2016), the supply chain is an integrated business process and consists of all parts involved, both directly and indirectly, to meet consumer demand. In the supply chain, we need a network used to distribute raw materials from suppliers to consumers. This network is considered very important because, through this network, an item can be processed from raw materials and distributed through each existing network in order to reach the hands of consumers at the right time and in the right amount.

One of the things considered in the supply chain network is the distribution process (Pujawan, 2017). The distribution process is the primary key to profitability and affects the entire supply chain's costs, so distribution costs need to be considered (Chopra & Meindl, 2016). One of the things that can be done to reduce distribution costs is to consolidate the freight. Consolidation is a process of collecting goods from various places that will be packaged into a single unit to be sent to certain places (Chopra & Meindl, 2016). Consolidation is a more efficient method to plan shipments with different origins and destinations when the shipment is made over long distances (Bektas, 2017).

The investment can establish consolidation points or hubs on the network using inter-hub to ship the freight of larger sizes and often faster than services on links between hubs and non-hubs nodes. Hubs can be airports, seaport container terminals, rail yards, truck terminals, and intermodal platforms. Because of scale economy, shipment between hubs is generally more cost-effective than direct shipments between non-hubs points (Bektas, 2017).

In the literature, most of the consolidation systems' configuration is hub and spoke networks (Steadiesifi et al., 2014). The hub is a distribution center, a gathering point for material flow, and a center for delivering goods (Alumur & Kara, 2007). While spoke are the points that become the destination and source of the hub. The concept of hub and spoke lies in centralization. Hubs are used to decrease the number of transportation arcs from origin to destination

[1] Department of Industrial Engineering, Faculty of Industrial Technology, Parahyangan Catholic University, Jl. Ciumbuleuit 94, Bandung, 40141

[a] email: fransetiawan@unpar.ac.id
[b] email: lorenp@unpar.ac.id
[c] email: elisaferdilia20@gmail.com
◆ corresponding author

Submited: 20-08-2020 Revised: 07-12-2020
Accepted: 14-12-2020

nodes (Faharani et al., 2013). Through this hub and spoke system, the efficiency of the distribution of shipping goods can be achieved because it can reduce the frequency of shipments and achieve benefits in the form of economies of scale (Alumur & Kara, 2007). Determining the location of the hub and spoke nodes allocated to the hubs is known as hub location problems (Steadieseifi et al., 2014).

In the Stanimirovic (2010) study, hub and spoke was used to design telecommunications and transportation systems. The solution to the problem used is by using the heuristic method, which is the genetic algorithm. In Rostami and Buchheim's (2017) research, the hub and spoke model was developed to include the vehicle's size to be more realistic by considering the Lagrangian relaxation procedure.

Alumur and Kara (2009) studied a hub location problem for cargo application in Turkey. The single-allocation hub covering model minimized the cost of hubs and hub links. The model is solved using CPLEX optimization solver. Ishfaq and Sox (2010) studied the hub location problem in intermodal logistics in the US that incorporates three different transportation modes (road, rail, and air) using a hub network. The proposed intermodal logistics can reduce transportation costs.

Ghafari-Nasab et al. (2015) studied hub and spoke for third-party logistics service providers. They proposed a mixed-integer non-linear programming model and linearized the model using a step-by-step approach and a numerical approach. The hub and spoke network configuration could reduce substantial cost compared to direct shipment configuration.

Lee and Moon (2014) developed two mathematical models, an integer linear programming for network configuration and vehicle operation and mixed-integer linear programming that considers potential Exchange Center for decision making. This study used modified real data from Korean post. The postal logistics network consists of various functional sites with a hybrid hub and spoke structure. They suggested their model for ease of designing the optimal network for the existing facilities.

In Kartal et al. (2017) research, the single allocation model is applied to a real hub network using a heuristic approach in the form of simulated annealing and ant colony. In Yang's research (2017), the single allocation model was developed with a discount factor as a novel uncertain parameter. A robust optimization approach is used to handle the uncertain parameter and employ an uncertainty interval to describe it to solve it.

In Table 1, rice is the most consumed food by Indonesians. Rice is one of the most important components in the life of the Indonesian Nation. BULOG (Logistics Agency) Regional Division (Divre) of West Java is a state-owned public company regulating and maintaining a supply of rice to meet all Indonesian people's needs. BULOG is currently distributing its rice from one SubDivre warehouse to another SubDivre warehouse (using point to point configuration).

Based on the interviews conducted at the BULOG West Java Regional on a section of Supply and Transportation, it is stated that the problem which occurs is the high frequency of transportation used and the inefficient delivery system where shipping is not done at once. According to the Supply and Transportation section, the total distance will be higher with the current rice delivery system, and the distribution costs will be higher. Distribution costs incurred by the West Java Regional Division of BULOG for the past 3 years amounted to Rp 5.033.288.436. The distribution process without consolidation (point-to-point system) requires a more significant cost because the total distance traveled, and the number of transport vehicles needed is more (Rodrigue, 2020). These problems can be overcome with the consolidation process because rice sent from an area will be sent simultaneously to the same destination to save transportation costs.

Table 1. Food Consumption on Average per Capita per Week

Types of ingredients	Units	Average
Local/glutinous rice	kg	1,6754
Wet corn with skin	kg	0,0222
Corn pocelan / shelled	kg	0,0292
Cassava	kg	0,0960
Sweet potatoes	kg	0,0536
Fresh fish and shrimp	kg	0,2810
Fish and shrimp preserved	ounce	0,4364
Beef/buffalo	kg	0,0073
Broiler/village chicken meat	kg	0,0902
Chicken eggs / village	kg	0,7887
Duck/manila / salted eggs	item	0,0623
Sweetened condensed milk	(397 gr)	0,0673
Baby milk powder	kg	0,0229
Shallot	ons	0,5011
Garlic	ons	0,2961
Red chili	ons	0,2075
Cayenne pepper	ons	0,1849
Tofu	kg	0,1438
Tempe	kg	0,1394
Other coconut / corn / cooking oil	liter	0,2068
Coconut	item	0,1406
Sugar	ons	1,4002
Brown sugar	ons	0,1395

There are some previous studies about rice distribution in BULOG. Nurmalatya and Vanany (2017) optimized the number of trucks and shipping schedule for RASKIN rice (special price for the poor) for solving the tardiness of delivery (total completion time in delivery exceeded the target). They used an integer programming model to optimize the problem. The optimal number of trucks is 11. The optimal number of trucks is less than the number of trucks of current use, which means the frequency of shipping is higher than before. However, this studied still yields the optimal shipping schedule and can reduce the investment cost by about Rp 1.024.800.000-. The data is obtained from the Geographical Information System (GIS).

Another study is done by Nahar et al. (2017). They used Improved Vogel's approximation method to minimize rice distribution cost in the BULOG Medan Sub-divre region. They also solved the problem of distributing RASKIN. The transportation problem model is used in which the objective is to minimize the cost of transporting certain commodities from several sources to several destinations. The proposed algorithm can save the distribution cost of Rp 12.832.034,9.

Previous research studied tactical (Nahar et al., 2017) and operational (Nurmalatya and Vanavy, 2017) levels. They used to point network topology. No previous research on BULOG rice distribution used the consolidation model of distribution or use hub and spoke network topology. In addition, there are no previous researches that tackle the strategic level problem like network design in BULOG distribution. Therefore, this study aims to give the recommendation of a hub and spoke transport network configuration to West Java Regional Division of BULOG as a consolidation system by determining the appropriate selection of locations for hubs as a center of consolidation and assigned node to that hub in the West Java region as the strategic level decision. We use the single allocation p-Hub median problem as the recommendation of the consolidation model to BULOG. The objective is to minimize the overall shipping costs associated with the flows. As we use a single allocation model, the demand node can only be assigned to a single hub, as suggested from the BULOG West Java region. The recommendation of network configuration aims to minimize the costs incurred by BULOG in its distribution process.

II. RESEARCH METHOD

This study aims to find the right selection location for hubs in the West Java region. The cost of distributing rice issued by the West Java Regional Division BULOG becomes smaller. This research was completed using the exact optimization method. According to Winston (2003), optimization is problem-solving by systematically focusing on finding and getting the optimum value. This exact optimization method is the method that produces the most optimum solution compared to other methods. The exact optimization method used is performed by AMPL (A Mathematical Programming Language) software.

In this research, a research methodology is needed to become more systematic and be known step by step to achieve the research objectives. Figure 1 is the methodology of the research conducted.

Literature Review

According to Zapfel and Wasner (2002), the logistics network in the form of a hub and spoke is believed to reduce logistics costs from and to the hub. This shipment has lower prices, expressed by discount factors per load unit, compared to other links (Steadiseifi et al., 2014). This hub and spoke system have a concept that lies in centralization, where the focus is on the hub. This hub system will be the center of shipping goods so that the flow of material is concentrated at the hub.

The logistics network with this system consists of a hub level and also a spoke level. According to Marti et al. (2015), a hub is a facility that functions and acts as a consolidation point, distribution point, collection point, and transfer point. In order to be connected, the hub has several spoke which serve as the origin and destination points. This hub and spoke works because the product will be sent to the existing distribution center, which is the hub, and then will continue shipping from the hub to the destination point. Generally, that fellow hubs will be connected, while the spoke is not connected. Figure 2 below is an overview of the hub and spoke system.

In the hub and spoke network configuration, low-volume demands are first moved from the origins to a hub where the freight is sorted and grouped (consolidated). The consolidated freight is moved between hubs by high frequency and high capacity services (Bektas, 2017). Although a hub and spoke network configuration is likely to

Start

Literature Review

Problem Identification and Formulation

Data Collection

Determine the Location of the Hub

Application of the Hub and Spoke Model in BULOG

Analysis of Research Result

Conclusion

Finish

Figure 1. Flowchart Research

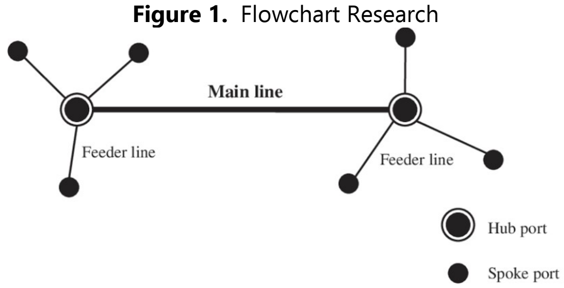

Figure 2. Hub and Spoke

ensure more efficient utilization of resources and lower cost for shippers, it may also result in a higher amount of delays because of the additional operations performed at the hubs (Bektas, 2017).

Hub location problems are related to the hub and spoke system problems, where the location of the exact placement for the hub is unknown, and the allocation of routes from the spoke to the right hub is unknown. In the literature, the hub location problem is commonly modeled as a hub median or hub center problem (SteadiSeifi et al., 2014). In the hub median problem, the main objective is to minimize total transportation cost. If there is a maximum limit on the number of hubs, the problem is called the p-hub median problem. The objective is to minimize the maximum distance between origin and destination pairs in a hub center problem. According to Alumur and Kara (2007), there are two basic types of hub networks, namely as follows:

1. Single allocation model. In this model, all material flows flowing in or out of the spoke from the center of demand are diverted through a single hub, which means only through one hub. Some spoke connected to one hub, then this hub will also be connected with other hubs, and in the end, the hub will send goods according to their respective destinations.
2. Multiple allocation model. In this model, the flow of material entering or exiting the spoke can pass through more than one hub. Multiple spokes can be connected to several hubs, aiming to choose the closest hub and minimize shipping costs. From that hub to be reconnected with other hubs and finally sent to the destination spoke.

For the model used in determining a hub's location for a single allocation network type, first, the point or node is determined, which will be used as a hub. After knowing the location of the hub, then the allocation is made for the existing spoke. This allocation is carried out so that it can find out which spoke node would pass through which hub.

The model used in the single allocation model is based on a formulation made by Skorin-Kapov et al. (1996). The notation and parameters used are as follows:

N = set of n nodes
α = inter-hub discount factor
p = number of hubs needed
W_{ij} = number of flow between node i dan j
C_{ik} = the cost of transportation per unit between nodes i and k
C_{jm} = the cost of transportation per unit between nodes j and m
C_{km} = the cost of transportation per unit between nodes k and m
X_{ijkm} = fraction of flow from node i to j, which is routed through hubs k and m

Decision variable

$$X_{ik} = \begin{cases} 1, & \text{if node } i \text{ is allocated to hub } k \\ 0, & \text{otherwise.} \end{cases}$$

Objective Function:

$$Min \sum_i \sum_j \sum_k \sum_m W_{ij} X_{ijkm} (C_{ik} + C_{mj} + \alpha C_{km}) \quad \text{... (1)}$$

Constraint:

$$\sum_k X_{ik} = 1 \quad \forall i \in N \quad \text{... (2)}$$
$$\sum_k X_{kk} = p \quad \forall k \in N \quad \text{... (3)}$$
$$X_{ik} \le X_{kk} \quad \forall i,j \in N \quad \text{... (4)}$$
$$\sum_m X_{ijkm} = X_{ik} \quad \forall i,j,k \in N \quad \text{... (5)}$$
$$\sum_k X_{ijkm} = X_{jm} \quad \forall i,j,m \in N \quad \text{... (6)}$$
$$X_{ik} \in \{0,1\} \quad \forall i,k \in N \quad \text{... (7)}$$
$$X_{ijkm} \ge 0 \quad \forall i,j,k,m \in N \quad \text{... (8)}$$

Eq. 1 is an objective function of the single allocation model to minimize the cost of shipping goods from the origin to the destination. Eq. 2 through Eq. 8 is a constraint for the single allocation model. Eq. 2 is a constraint that each node will be allocated exactly to one hub. Eq. 3 is a constraint that the number of hubs found is p. Eq. 4 is a constraint that a node can be allocated to another node if the node is selected as a hub. Eq. 5 and Eq. 6 is a constraint that flow must flow through a location that is a hub. Eq. 7 is a constraint for allocating non-hub nodes to hub nodes, and their values are only binary. Eq. 8 is a constraint for the flow fraction, where the fraction's value must not be negative and must be greater than zero.

Data

The data needed in this study includes data on the number of warehouses owned by BULOG, data on the flow of rice delivery between warehouses, distance data between warehouses, and data on shipping costs between warehouses.

BULOG West Java Regional Division has 7 SubDivre, and each SubDivre has several warehouses. The seven Regional Subdivisions are located in Bandung, Cianjur, Cirebon, Indramayu, Karawang, Subang, and Ciamis. The number of warehouses owned by SubDivre is different from one another. Table 2 contains the name of the warehouse owned by each SubDivre, the SubDivre code, and the code used by each warehouse. The code will be used in all data processing carried out during this research.

To calculate the cost of shipping from warehouse to warehouse, data on the distance between warehouses, truck capacity, diesel demand, and the price of diesel per liter are needed. Shipping costs for one ton of rice from a warehouse to a warehouse use the following formula.

$$\text{Shipping Cost} = \frac{\frac{\text{Distance between warehouse}}{\text{diesel Demand}} x \text{ Diesel Price}}{\text{Truck Capacity}} \quad ...(9)$$

The distance between warehouses is obtained through Google Maps. The rice delivery truck used by BULOG has a capacity of 30 tons with diesel fuel. The need for diesel trucks is one liter of diesel fuel used to cover 1.5 kilometers. Based on data from Pertamina, the price of one liter of diesel fuel in the West Java area is Rp 9,400.-.

III. RESULT AND DISCUSSION

This section will discuss the results obtained from the results of calculations using the exact optimization method, that is, branch and bound,

Table 2. Warehouses in BULOG West Java Regional Division

Sub-divre	Warehouses	Warehouse code	Sub-divre	Warehouses	Warehouse code
Bandung	Cisantren	1		Singakerta I	24
	Utama 1	2		Singakerta II	25
	Utama II	3		Losarang	26
	Citereup	4		Pekandangan	27
	Paseh	5	Karawang	Adiarsa	28
Cianjur	Bojong Herang	6		Pangulah	29
	Bojong	7		Palumbon	30
	Pasir Halang	8		Tegalwaru	31
	Dramaga	9		Jatiragas	32
Cirebon	Tuk	10		Purwasari I	33
	Pegambiran	11		Purwasari II	34
	Larangan	12		Amansari	35
	Ciperna	13		Cikangkung	36
	Junjang	14		W. Bongkok	37
	Gintung	15	Subang	Karanganyar	38
	Sidaraja	16		Rancaudik	39
	Bandorasa	17		Binong	40
	Kasokandel	18		Tanjungrasa	41
	Merta	19		Ciwangi	42
Indramayu	Leuwi Gede	20	Ciamis	Pamalayan	43
	Tegalgirang	21		Banjar	44
	Candang	22		Lingga Jaya	45
	Kedung	23		Sukagalih	46

using AMPL. Based on the existing single allocation model theory, the mathematical model is converted into AMPL software to produce optimal solutions.

A parameter is a constant that has a value and will be used in processing data. A variable is a constant whose value is unknown, and that value will be sought in processing this data (acting as a decision variable).

After knowing the parameters and variables needed in making the single allocation hub location problem model, then Eq. 1 through Eq. 6, which is an objective and constraint function, will be translated into the AMPL software. The translation of the model to AMPL is shown in Figure 3.

```
param N;
param p;
param a;
param W {1..N,1..N};
param C {1..N,1..N};


var x {1..N,1..N,1..N,1..N} >=0;
var y {1..N,1..N} binary;


minimize totalcost:
    sum {i in 1..N, j in 1..N, k in 1..N, m in 1..N : i<>j}
        W[i,j]*x[i,j,k,m]*(C[i,k]+C[m,j]+a*C[k,m]);


subject to constraint0 {i in 1..N}:
    sum {k in 1..N} y[i,k] = 1;

subject to constraint1:
    sum {k in 1..N} y[k,k] = p;

subject to constraint2 {i in 1..N, k in 1..N}:
    y[i,k] <= y[k,k];

subject to constraint3 {i in 1..N, j in 1..N, k in 1..N : i<>j}:
    sum {m in 1..N} x[i,j,k,m] = y[i,k];

subject to constraint4 {i in 1..N, j in 1..N, m in 1..N : i<>j}:
    sum {k in 1..N} x[i,j,k,m] = y[j,m];
```

Figure 3. Model Writing in AMPL

The parameter "N" is a set of all warehouses owned by BULOG. This warehouse is the point where the shipment originates and also the destination point of the shipment. Thus, the value of this parameter is 46, according to the number of warehouses owned by BULOG. The parameter "p" is the number of hubs that you want to build or establish. The hub is the point that becomes the center of delivery and receiving center of BULOG rice and will be selected from the existing warehouse. There will be 7 hubs to be built. The number of hubs built is based on the provisions desired by the West Java Regional Division BULOG as many as 5 to 7 hubs. However, the fewer hubs made, the distribution costs increase so that the "p" value is 7.

The parameter "α" is the value of the hub-to-hub transportation cost discount factor. This discount factor has a value between the range of 0 to 1. According to Correia et al. (2010), this parameter's value is assumed to be 0.75. According to Ernst and Krishnamoorthy (1996), in their journal on uncapacitated single allocation, a value of α of 0.75 was used, taking into account the economies of delivery scale. Shipments that have an α value that is too small impact other things that cause cost overruns in different ways so that the value of α is 0.75. The parameter "W" is the amount of flow sent from warehouse to warehouse. This flow amount includes the amount of rice shipped from the sending warehouse to the receiving warehouse. The parameter "C" is the cost of delivering rice, both shipping from the warehouse to the hub or delivery between hubs.

The variable "x" represents the fraction of the flow from the sending warehouse to the receiving warehouse through the selected hubs (flow from node i to node j through hub k and hub m). The value of this variable cannot be negative and must be greater than zero. In the single allocation model, the variable "x" is symbolized by Xijkm. At the same time, the variable "y" will show the results of the selected hub. This variable will be worth 1 if a warehouse is selected as a hub and value 0 if a warehouse is not selected as a hub. In the single allocation model, the variable "y" is symbolized by Xik. But to make it easier to work and read in the AMPL software, the Xik variable is symbolized by the letter "y".

```
reset;
model hubandspoke.mod;
data hubandspoke.dat;
option solver cplex;
solve;
display y;
```

Figure 4. Display File.run in AMPL

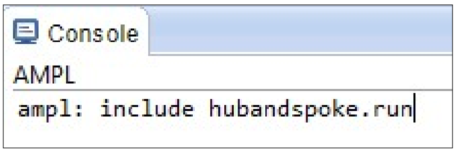

Figure 5. Commands in Running AMPL

After the model file has been completed, a data file (.dat) is then created. The data file contains the data needed in this study: data that explains the value of the parameters made in the model file. The data file contains the values of the parameters discussed: the number of warehouses, the number of hubs to be built, the value of alpha, the data flow of rice delivery, and the data of shipping costs. After finishing working on the file containing the model and also the file containing the data, the next step is to create a file to run this AMPL (file.run). Writing file.run can be seen in Figure 4.

From Figure 4, it can be seen that writing this file aims to run the entire AMPL program that has been created. Without one of the file types, file.mod, file.dat, or file.run, the AMPL program cannot run. This file.run contains commands to call the model file and also the data file that was created earlier, then includes the solver used, and also the command to display the decision variables that have been set.

After creating the three file types that are file.mod, file.dat, and file.run, then to run this program, use the command, as shown in Figure 5. Writing this command is based on the name file.run that was created earlier. After this command is entered, the results have been designed based on the mathematical model.

Optimization Results

We use a NEOS server (https://neos-server.org/neos/) to solve the problem based on the AMPL code. NEOS server is an unpaid service provider to solve optimization problems made by the Wisconsin Institute for Discovery, University of Wisconsin-Madison. We examine several numbers of a hub in our single allocation p-Hub median problem that is 5,6,7. This number of hubs is determined based on the interview with The Transportation Warehousing Supply Section,

Table 3. Allocation of Warehouse to Hub

Hub	Warehouse allocated to a hub (Spoke)	Hub	Warehouse allocated to a hub (Spoke)	Hub	Warehouse allocated to a hub (Spoke)
1	1	9	9	31	23
	2		10		26
	3		11		28
	4		12		29
	46		13		30
7	6		14		31
	7		15		32
	8		16		33
21	5		17		34
	20		18		35
	21		19		36
	22		24		37
	27		25		38
		45	43		39
			44		40
			45		41
					42

BULOG West Java Regional Division. The minimum total transportation cost is on 7 hubs. The comparison of total transportation cost on several numbers of hubs is shown in Table 3.

Based on parameters that have been set that the desired number of hubs as many as 7 pieces, it can be concluded that the warehouse that acts as a hub is warehouse 1, warehouse 7, warehouse 9, warehouse 12, warehouse 21, warehouse 31, and warehouse 45. From the hub that has been this was chosen, then the allocation of rice shipments centered on the seven hubs. Each warehouse that wants to send rice to another warehouse must pass through one hub that has been assigned. In facilitating the reading of AMPL results for allocation from warehouses to hubs, it can be seen in Table 3.

An example is reading the results of the table is as follows: if warehouse 14 wants to send rice to warehouse 3, then rice from warehouse 14 will be allocated to hub 12, and after rice from various warehouses has been collected, then rice from hub 12 will be sent to hub 1, from hub 1, rice will be sent to warehouse 3. To make it easier to read, the allocation of warehouses to the hub can be seen in Figure 6.

Cost Comparison Between Current Policy and Proposed Policy

After knowing the chosen hub, a cost comparison is made between the real situation in the current West Java Regional Bureau of Logistics and the proposal using a consolidated model in the form of a hub. To get the cost of shipping rice carried out by BULOG now is to multiply the amount of flow for 3 years with shipping per ton of rice.

The total shipping costs have also been known based on the design of a single allocation model using AMPL. Therefore, you can compare costs between the current delivery system and the proposed delivery system. The cost comparison can be seen in Table 4.

Table 4. Comparison of Current Shipping Costs with The Consolidation Model

Current Transportation Cost	Rp 5,033,288,436
Consolidation Transportation Cost	Rp 4,331,686,254
Cost Reduction in Rupiah	Rp 701,602,182
Cost Reduction in Percentage	13.94%

Based on Table 4, it can be seen that the current delivery conditions are more significant than the proposal in the form of building a hub as a consolidation center. The difference in shipping costs is Rp. 701.602.182, which means that BULOG can make cost savings of 13,94% of the initial total cost of shipping rice.

Discussion

The location of the hub has been obtained by completing systematic steps using AMPL and NEOS Server. The warehouses selected as hubs are warehouse 1, warehouse 7, warehouse 9, warehouse 12, warehouse 21, warehouse 31, and warehouse 45. These warehouses are selected to minimize the total distribution cost of BULOG West Java Regional.

We use cases where hubs can be located at any node in the network because all the warehouses (node) in BULOG West Java Regional can act as the hub. The flow of rice distribution is from warehouses with an excess supply of rice to any warehouses that are short in supply of rice. There is no certainty which sender warehouse and which is the recipient. It depends on the availability of supply from their local farmer.

Hub in node number 9 does not have any spoke to it because of some reasons. First, node 9 is far from the other hub. Node 6, 7, and 8 are far from node 9. If node 9 is allocated to another hub, then the distribution cost will be higher. Another reason is node 9 has the most significant inflow in the West Java Regional warehouses. Warehouse or node 9 is the warehouse that receives the most shipments of rice from other warehouses. Therefore hub 9 does not speak to any hubs because of the enormous amount of inflow and the far distance.

In this study, we do not consider the warehouse's capacity since The Transportation Warehousing Supply Section, BULOG West Java Regional Division, states that each warehouses' current capacity is still enough to cover hub and spoke consolidation systems that we propose.

The current delivery system using a point-to-point system has the policy that rice is shipped directly from the source of supply to the demand point without the use of any intermediate facilities. For example, if rice will be delivered from node 10 to node 36. The distribution will be performed directly from hub 10 to hub 36 without any intermediate facilities.

In order to maximize the utilization of vehicles (achieving economies of scale in distribution), consolidation systems can be used instead of a point-to-point system. A consolidation-based transportation system can also be structured as a hub and spoke network, where shipments for several origin-destination points may be transferred via intermediate consolidation facilities or hubs.

The principle of consolidation is collecting goods first from various places and then packaged and sent to the destination location. One of the consolidation principles used as a proposal for the problem of sending the West Java Division of the Bureau of Logistics is the hub and spoke system. Using this system, the shipping process becomes more organized, and the costs are less. The hub and spoke system's process is to send goods from the origin points to a point called a hub, then the hub will send goods to another hub and finally sent to the destination point. For example, if we want to deliver the rice from node 10 to node 36. The rice from node 10 is ship to hub 12 and be consolidated with another node in hub 12's spoke. Then all consolidated rice from hub 12 will be delivered to hub 31, and finally, from hub 31, the rice will be delivered to node 36, as shown in Figure 6.

Looking at the delivery path, it does look a bit more complicated than a point-to-point system. This hub and spoke system requires a little longer time because it has to consolidate the goods at specific points used as a hub. The time needed is longer because the delivery can only be done when all goods have been collected together in a hub's distribution center. After that, then new shipments can be made to their destination. Although the time required takes a little longer, but with this hub and spoke system makes shipping costs smaller due to the centralization of shipments made to achieve economies of scale. With the achievement of economies of scale, the

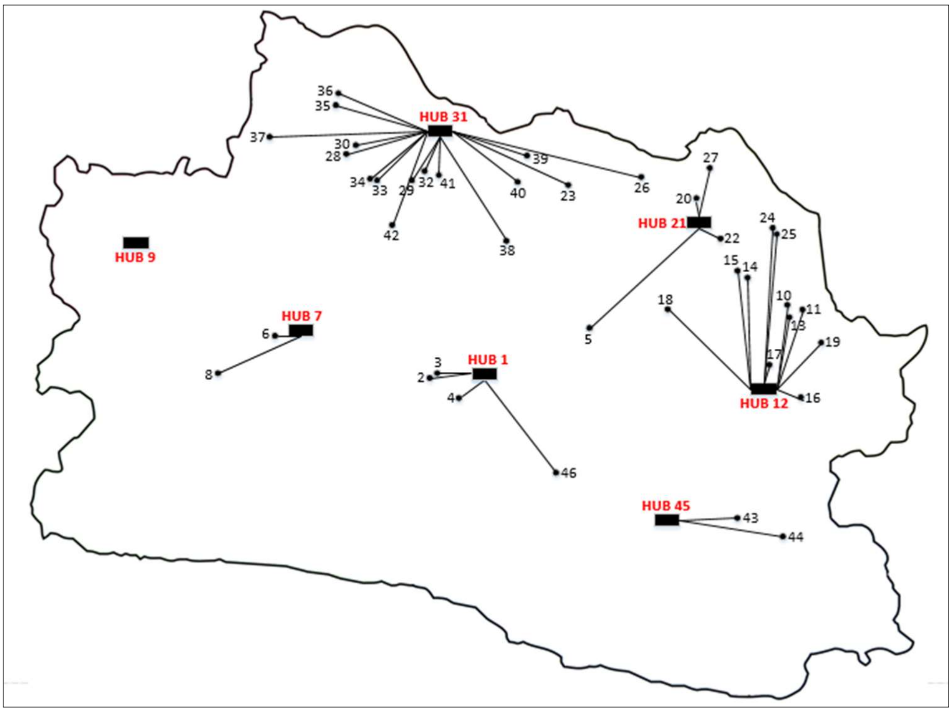

Figure 6. Map Allocation Hub in West Java

Table 5. Comparison of Current Systems and Proposed Systems

	The current system (point-to-point)	Proposed System (hub and spoke)
Scope	Each route serves 1 destination.	Optimal when connecting regions with multiple destinations
Connectivity	No connection provided (directly to destination)	Each point of origin is connected to the hub to proceed to the destination.
Dependency	The route operates independently, not influenced by requests from other routes.	Each route is interdependent on other routes to connect the origin and destination.
Cost	Costs are higher due to the high frequency of shipments.	Lower costs due to achieving economies of scale
Time	Faster delivery time	Delivery times are slower because they have to consolidate goods at the hub.

means of transportation used will be less because of merging shipments. A comparison of the current delivery system with the proposed delivery system can be seen in Table 5.

IV. CONCLUSION

Based on the research results that have been done, it can be concluded that the research objectives. The hub's exact selection location as a center of consolidation in the West Java region is spread over 7 regions. The locations are in Cisaranten Kidul (Bandung), Karang Tengah (Cianjur), Dramaga (Bogor), Larangan (Cirebon), Tegalgirang (Indramayu), Tegalwaru (Karawang), and also in Linggajaya (Tasikmalaya). Each hub has its spokes. Using a hub and spoke configuration, the delivery from one point of delivery to another delivery point must be performed through intermediate facilities or hub. The cost of distributing rice using the current configuration in the West Java region was Rp. 5.033.288.436. However, after using the consolidation by a hub and spoke configuration, the distribution costs amounted to Rp. 4.331.686.254. Thus, savings in rice shipping costs of Rp. 701.602.182 or as many as 13,94%. Further research recommendation is to study the use of other network configurations.

REFERENCES

Alumur, S., Kara, B.Y. (2007). "Network Hub Location Problems: The State of The Art." *European Journal of Operational Research, 190* (1), 1-21. doi: 10.1016/j.ejor.2007.06.008

Badan Pusat Statistik. (2019). *Rata-Rata Konsumsi per Kapita Seminggu Beberapa Macam Bahan Makanan Penting, 2007-2018*. Jakarta: BPS.

Bektas, T. (2017). *Freight Transport and Distribution: Concepts and Optimisation Models*. Florida: CRC Press, Taylor and Francis Group.

Chopra, S., Meindl, P. (2016). *Supply Chain Management: Strategy, Planning, and Operation 6th Ed*. New Jersey: Pearson Education, Inc.

Correia, I., Nickel, S., Saldanha-da-Gama, F. (2010). "The Capacitated Single-Allocation Hub Location Problem Revisited: A Note on A Classical Formulation." *European Journal of Operational Research, 207*(1), 92-96. doi: 10.1016/j.ejor.2010.04.015

Ernst, A. T., Krishnamoorthy, M. (1996). "Efficient Algorithms for The Uncapacitated Single Allocation P-Hub Median Problem." *Location Science, 4*(3), 139-154. doi: 10.1016/S0966-8349(96)00011-3

Faharani, R.Z., Hekmatfar, M., Arabani, A.B., Nikbakhsh, E. (2013). "Hub Location Problem: A Review of Models, Classification, Solution Techniques, and Applications." *Computers & Industrial Engineering*, 64, 1096-1109.

Fernandez, S.A., Ferone, D., Juan, A.A., Silva, D.G., Armas, J. (2017). "A 2-Stage Biased-Randomized Iterated Local Search for the Uncapacitated Single Allocation p-Hub Median Problem." *Transactions on Emerging Telecommunications Technologies 28*.

Ghaffari-Nasab, N., Ghazanfari, M., Teimoury, E. (2015). "Hub-and-spoke logistics network design for third-party logistics service providers." *International Journal of Management Science and Engineering Management*.

Ishfaq, R. Sox, C.R. (2010). "Intermodal Logistics: The Interplay of Financial, Operational and Service Issues." *Transportation Research Part E, 46*, 926-949.

Kartal, Z., Hasgul, S., Ernst, A.T. (2017). "Single Allocation p-Hub Median Location and Routing Problem with Simultaneous Pick-up and Delivery." *Transportation Research Part E: Logistics and Transportation Review 108*, 141-159. doi: 10.1016/j.tre.2017.10.004.

Lee, J.-H., Moon, I. (2014). "A Hybrid Hub-and-Spoke Postal Logistics Network with Realistic Restrictions: A Case Study of Korea Post." *Expert Systems with Applications*, 41, 5509-5519.

Marti, R., Corberan, A., Peiro, J. (2015). "Scatter Search for An Uncapacitated P-Hub Median Problem." *Computers & Operations Research*, 58, 53-66.

Nahar, J., Rusyaman, E., Putri, S. (2018). "*Application of improved Vogel's approximation method in minimization of rice distribution costs of Perum BULOG.*" IOP Conference Series: Materials Science and Engineering, 332 012027.

Narasimhan, S.L., McLeavey, D.W., Billington, P.J. (1995). *Production Planning and Inventory Control*. New Jersey: Prentice-Hall.

Nurmalatya, N., Vanany, I. (2017). "Optimasi Penentuan Jumlah Truk dan Penjadwalan Pengiriman Beras Raskin dengan Data Penunjang dari Sistem Informasi Geografis (SIG) Pada Perum Bulog Sub Divre Surabaya Utara." *Undergraduate Thesis*. Institut Teknologi Sepuluh November.

PT. Pertamina. (2020). Daftar Harga BBK Tmt 01 Februari 2020. PT Pertamina Announcement. (https://www.pertamina.com/id/news-room/announcement/daftar-harga-bbk-tmt-01-februari-2020).

Pujawan, I. N. (2017). *Supply Chain Management, 3rd edition*. Yogyakarta: Penerbit Andi.

Rodrigue, J. P. (2020). *The Geography of Transport Systems 5th Ed.* New York: Routledge.

Rostami, B., Buchheim, C. (2017). The Uncapacitated Single Allocation p-Hub Median Problem with Stepwise Cost Function. *Optimization Online: An Eprint Site for The Optimization Community*, Mathematical Optimization Society.

Skorin-Kapov, D., Skorin-Kapov, J., O'Kelly, M. (1996). "Tight Linear Programming Relaxations of Uncapacitated P-Hub Median Problems." *European Journal of Operational Research 94*(3), 582-593. doi: 10.1016/0377-2217(95)00100-X

Stanimirovic, Z. (2010). "A Genetic Algorithm Approach for The Capacitated Single Allocation P-Hub Median Problem." *Computing and Informatics 29* (1), 117-132.

Steadiseifi, M., Dellaert, N.P., Nutijen, W., van Woensel, T., Raoufi, R. (2014). "Multimodal Freight Transportation Planning: A Literature Review." *European Journal of Operational Research*, 233 (1), 1-15.

Winston, W.L. (2003). *Operations Research Applications and Algorithms 3rd Edition.* California: Duxbury Press.

Yang, M., Yang, G. (2017). "Robust Optimization for The Single Allocation p-hub Median Problem under Discount Factor Uncertainty." *Journal of Uncertain Systems 11* (3), 230-240.

Zapfel, G., Wasner, M. (2002). "Planning and Optimization of Hub-and-Spoke Transportation Networks of Cooperative Third Party Logistics Provider." *International Journal of Production Economics*, 78 (2), 207-220.