Hub and Spoke allocation to minimize the distance and frequency of transportation with Lower Noise Consideration

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Abstract. City logistics is a concept that has developed lately. One method that can be applied is the application of Hub and Spoke in the Urban Logistics system. Hubs and spoke are commonly used for logistics systems in general. However, for hub and spoke in urban logistics systems certainly have different considerations. Using the system methodology, this paper proposes a mathematical model of the application of hub and spoke in urban logistics systems by considering several constraints, one of which is the minimization of noise caused by the transportation process.

1. Introduction
Transportation system is built with the hope that the transportation process will work efficiently and effectively. The transportation process supports the flow of the economy. Goods that were bought by people can be enjoyed if the goods are sent by producers and received by consumers. The development of information technology makes it easier for people to order goods and fulfill their needs. To buy something, people only need to access it from the communication media. Then the goods will be delivered. This change in behavior also changes the process of delivering goods. Initially, the movement of goods was carried out directly by the buyer because the buyer was present at the store. Now, the buyer is not present at the store. Through long-distance communication, the goods will be sent without having to be done by the consumer.

Changes in the way of purchase cause the volume of goods shipped to be smaller, but greater frequency. This causes the transportation system to become increasingly complex as the entities involved become more and more detailed. If this process occurs in urban areas, it risks disturbing the comfort of the community. Urban logistics science needs to play a role to anticipate this problem [1, 2].

One solution that can be used is the application of Hub and Spoke. So that the transportation process does not occur too complex involving all individuals, a hub can be built as a center for receiving and sending goods. Each entity does not need to deliver goods directly to the receiving entity. The goods can be sent to the hub and then sent together with other goods collectively to the same destination.

There are several studies that have examined the application of hub and spoke. For example, a research examines the application of Hub and Spoke for Parcel Delivery [3], air transportation [4][5], railway [6], and others. There is also research that examines the development of hub and spoke, for example using congestion [7], linear hub and spoke [8], back up hubs [9], and even for forms of organizational design [10]. There is also research that applies hub and spoke for city systems,
especially for city buses [11]. However, we have not found any research that examines the application of hub and spoke in the context of city logistics, especially considering the noise variable.

From the review of several existing papers, we try to propose a calculation method for selecting the best hub. In the urban logistical context, the method we propose not only considers the distance variable, but also the noise variable that results from the transportation process. From an optimization model point of view, the model we designed optimizes the distance and noise generated by a hub selection decision. In addition, it also considers the volume of goods shipped.

2. Method and Algorithm
This study uses a mathematical model approach and a systems approach. At the initial stage, the system is studied by considering several variables. The system hierarchy is defined in order to keep the complexity of the model manageable. The approximation is done in stages.

At the initial stage, an experiment was carried out that the only variable concerned was distance. The next stage is built a model that considers distance and noise variables. The next stage is to build a more complex model, taking into account the distance and the number of commodities shipped. In the final stage, a model is built that takes into account all variables, namely distance, commodity, and noise.

3. Result and Discussion
Within a region, between entities within the region, shipping activity can occur. The process of sending goods can use an online taxi service. Online taxis can use cars or motorbikes. In Figure 1 it can be seen that the destinations, which are symbolized by a circle icon, have a certain distance. Between these destinations can make each other shipments indicated by lines. There are no constraints made to prohibit between destinations from making deliveries.

![Figure 1. Rich picture of integrated system.](image)

All these delivery possibilities can be seen in Figure 2. It can be seen that there is a complex transmission network. Each destination can be connected to all destinations. If, for example, there are 10 destinations, then each destination can be connected to 9 other destinations. Then in total there are approximately 45 connections from 10 destinations. If for example there are 1000 destinations, the number of connections formed is 499500. The number of connections is growing exponentially as illustrated in Figure 3. The calculation of the number of connections can be seen in equation 1.

\[
Connection = \frac{(n)(n - 1)}{2}
\]
Figure 2. Integrated causal effect diagram.

As seen in Figure 2, one solution to simplify this complexity is to create a hub, the center of goods transactions. Hubs are positioned between the regions of each node. There is a connection between the node and the hub. The number of connections formed becomes less; only as many nodes.

Figure 3. Number of connection based on node.

The number of connections is increasing exponentially. In one city, if there are 3 million people, the number of connections formed will be very large. Although each connection has its own characteristics. The condition of urban logistics is not conducive if there are too many complicated delivery networks like that.

When we are going to create a hub, the next question is how to determine the best location for the hub. As can be seen in Figure 4, it is illustrated that there are three alternative hubs that can be selected. One simple consideration that can be made is determining which location gives the minimum distance
Table 1 lists the coordinates of each node and each hub. Then it can be calculated how much distance between each destination node and the hub. For each hub, the distance between the number of hubs and each node is obtained. So it can be evaluated which hub gives the minimum total distance. One hub may produce a minimum distance to one node, but it can be very far to another node. So the amount of distance is one way to decide which hub is best.

Apart from the distance that is considered, another variable that can be taken into consideration is the noise generated in each transportation process that passes a certain route between hubs and nodes. As hubs and nodes have a distance, between hubs and nodes also have the noise value that is generated when there is a transportation process between the hub and node. The same calculation process can be done with the distance calculation process. Each hub has an implication for the distance value and the resulting noise value. The two values can be accumulated into one score, then evaluated which hub produces the best score.

**Table 1.** Distance and noise evaluation of each hub.

| Sender | x  | y  | Hub 1 | Hub 2 | Hub 3 |
|--------|----|----|-------|-------|-------|
| a      | 12 | 11 | 3.162 | 3.162 | 2.828 |
| b      | 18 | 17 | 11.4  | 11.4  | 11.31 |
| c      | 1  | 5  | 10.44 | 9.434 | 9.849 |
| d      | 19 | 2  | 10    | 12.81 | 11.4  |
| e      | 6  | 16 | 9.434 | 6.708 | 8.062 |
| f      | 13 | 17 | 9.22  | 8.062 | 8.544 |
| g      | 0  | 13 | 12.08 | 9.487 | 10.77 |
| h      | 19 | 4  | 8.944 | 11.66 | 10.3  |
| i      | 12 | 2  | 6.083 | 8.544 | 7.28  |
| j      | 13 | 1  | 7.28  | 9.849 | 8.544 |
| Total  | 88.05 | 91.12 | 88.89 |       |       |

Apart from distance and noise, another variable that can be considered is the amount of goods sent between nodes when passing through one of the hubs. The number of items is then multiplied by the distance between the origin node and the hub and the hub and the destination node. For example, it can be seen in Table 2, figure 26.2 shows the distance and noise score between node A and the hub plus
the hub with node B. Table 2 lists the distance and noise scores between nodes, assuming it passes through the hub first. The dot product between the matrix and the number of commodities matrix gives rise to a score for each hub. Based on this evaluation, it was concluded that Hub 2 was the best decision. This indicates that changes in decision-making criteria can lead to different decision conclusions.

Table 2. Load and distance calculation.

|   | a   | b   | c   | d   | e   | f   | g   | h   | i   | j   |
|---|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| a | 22.3| 26.6| 21.6| 24.2| 32.6| 31.4| 35.2| 24.1| 25.2| 26.4|
| b | 26.6| 30.8| 25.8| 28.4| 36.8| 35.6| 39.5| 28.3| 29.5| 30.7|
| c | 21.6| 25.8| 20.9| 23.4| 31.9| 30.7| 34.5| 23.4| 24.5| 25.7|
| d | 24.2| 28.4| 23.4| 26.0| 34.4| 33.2| 37.1| 25.9| 27.1| 28.3|
| e | 32.6| 36.8| 31.9| 34.4| 42.9| 41.7| 45.5| 34.4| 35.5| 36.7|
| f | 31.4| 35.6| 30.7| 33.2| 41.7| 40.4| 44.3| 33.2| 34.3| 35.5|
| g | 35.2| 39.5| 34.5| 37.1| 45.5| 44.3| 48.2| 37.0| 38.2| 39.4|
| h | 24.1| 28.3| 23.4| 25.9| 34.4| 33.2| 37.0| 25.9| 27.0| 28.2|
| i | 25.2| 29.5| 24.5| 27.1| 35.5| 34.3| 38.2| 27.0| 28.2| 29.4|
| j | 26.4| 30.7| 25.7| 28.3| 36.7| 35.5| 39.4| 28.2| 29.4| 30.6|

4. Conclusion

Hub and spoke is a concept that is commonly used in logistics systems. When Hub and Spoke is going to be applied in the context of Urban Logistics, it will require different considerations. The stakeholders involved in urban logistics are different from the stakeholders in the logistics system in general. Apart from distance, it is necessary to consider the impacts on the population and on the environment. One of the impacts is noise resulting from the transportation process. Through this paper we try to describe how to modify the hub and spoke system by considering noise calculations.

Some research can be done to develop this research. One of them is developing a method of calculating noise caused by the volume of goods shipped. In this research, the noise generated is linearly proportional to the number of goods. However, in reality this did not happen. Shipments of goods are often not in single units. Shipments are made in batches. So that the increase in noise occurs following a certain multiple of the number of goods sent.

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