ATLANTIS PRESS

Advances in Intelligent Systems Research, volume 173

1st International Conference on Engineering and Management in Industrial System (ICOEMIS 2019)

Cargo Bikes in Transit Oriented Development: Concept and Route Clustering

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Keywords: Cargo bikes, Transit Oriented Development, Center of Gravity, Sweep Algorithm

Abstract. The increasing growth of the e-commerce market makes the savings of the last mile shipping compete with each other to provide third-party logistics services with the type of shipping and competitive prices. The existence of Cargo bikes in Jakarta city has been popular since 2013 pioneered by the West Bike Messenger Service (WMS) community which provides bicycle shipping services in several areas in Jakarta. Integration of rail transportation modes combined with cargo bikes can provide opportunities for this system to develop from a local scale or a regional scale to a city scale. This study will provide the concept of urban logistics in the TOD areas with bikes. The use of sweep algorithm combined with Center of Gravity (COG), produce cluster delivery routes in three TODs with different characteristics. TOD with the character U1 (Fatmawati) has 9 clusters, U2 (Cipete) has 6 clusters, and 7 clusters are owned by TOD with character R (Blok M).

Introduction

Prediction of e-commerce sales growth in Indonesia according to Statista institution reached Rp 219 trillion in 2022 which rose 133.5% from 2017. Comparison of e-commerce sales to retail in Indonesia which reached 1.25% making Indonesia the first place in ASEAN in research conducted by the Nomura Research Institute. This phenomenon certainly has a big influence on the development of last-mile delivery especially in big cities in Indonesia including Jakarta.

Last-mile delivery is considered to be the most expensive part of the supply chain, 13% to 75% of the total supply chain costs depend on several characteristics. Faced with the problem of the last-mile, Parcel Delivery service providers must adapt their logistics organizations in cities to be more economically and environmentally efficient and to fulfil more complex customer desires. [1] About a quarter of urban traffic is related to goods transportation. When compared with rural shipping, the process of shipping goods in the city is influenced by a significantly higher number of parameters. [2] Urban logistics causes more pollution than long-distance shipments because of the short travel frequency and many stop points which make fuel consumption sharply increase. Every 10 km per stop, fuel consumption increases by 140%. [3]

Responding to the issue, urban logistics that grew rapidly along with the growth of e-commerce contributed to the sustainability of a city. Previous research and implementation of sustainable urban logistics has linked many environmentally friendly logistics with the selection of rail and bicycle-based logistics modes of transportation. Bicycle couriers pick up and deliver goods by bicycle. This type of urban logistics is most often found in the central business district of the metropolitan area. [4]

The presence of Cargo bikes in the city of Jakarta has been popular since 2013 spearheaded by the West Bike Messenger Service (WMS) community. In 2016, JNE as a large logistic company in collaboration with WMS to provide innovative cargo bikes programs as a city-scale logistics option that is environmentally friendly, the program was called 'JNE Eco Courier'. Research that has been carried out suggests that logistics companies do not feel that bicycle couriers can have a relationship

with global networks, but allow for more local and regional coverage as a good option for e-commerce related same-day delivery. [4]

The development of mass transportation-based areas or often called Transit Oriented Development (TOD) is increasing in large cities in Indonesia, especially Jakarta. The development of the TOD area in Jakarta currently focuses on the points of the MRT (Mass Rapid Train) station. Based on the description of the background in terms of urban logistics, cargo bikes, and the TOD area, this study will provide modeling that produces new ideas on the feasibility of applying cargo bikes in the TOD area by simulating a cluster at each station point, from the time and capacity needed by cargo bikes to obtain serving all points of demand in the TOD area that have certain characteristics.

Literature Review

Mumbai Dabbawalas is a lunch box delivery service system that uses informal bicycles but has the capability to implement an appropriate, reliable and affordable urban logistics system for middle-class people in Mumbai. After being awarded the Six Sigma title as a best practice in urban logistics in India, since then, it has been quoted as a best practice of urban logistics in the Indian context. [5] In the study found the facts that urban landscape, public policy, and infrastructure offer a good match between supply and demand, so that the management principles used can be applied in the management of other urban logistics.

In 2012, Maes & Vanelslander wrote a research journal relating to the use of bicycle couriers in a modern logistics. The choice of using bicycle couriers in small volumes has proven to be the right choice for dense urban areas. This study analyzes how bicycle couriers can economically balance the transportation system using fossil fuels by comparing simulations of shipping schemes from these two transports. The results showed that bicycle couriers can offer the same price as conventional transportation, considering that logistics companies do not have warehouses in the city. Providing professional services, bicycle couriers need large volumes so that a close relationship is needed between the logistics company and that capacity. [4]

Bike cycle trial projects have been carried out in several companies, although in commercial implementation and implementation recommendations are still lacking. This will only work, however, if this mode of delivery is given greater consideration in city and transport planning. City policymakers, a network of settings, infrastructure adjustments, appropriate city planning strategies, pilot programs, collaboration with the private sector are the key to achieving integration between large logistics companies such as DHL, Hermes, and TNT with bicycle cargoes in their supply chains. [6–9]

In 2017, there is a study focuses on evaluating the operating performance of bicycle cargoes compared to shipments using motorized vehicles. Consider the characteristics of traffic operations related to travel speed, travel delays, delivery time and travel distance, and are associated with parking locations, CO2, and emissions savings. The end result of this study shows the load of bicycles as a city-scale shipping alternative that provides the benefits of a competitive environment and long-distance shipping options in crowded cities such as NYC. [10]

Constraints on package delivery are not only related to congestion and shipping costs, but also because of the difficulty of delivering faster but the right delivery in an unreliable and dynamic environment. The article made by Zhang et al in 2018, intends to answer the question of how people perceive by changing the distribution of the last mileage by bicycle or using pickup points. Taking an example in Berlin, the simulation model represents the structure of the city (network, difference in space) and the character of temporal traffic jams. This study resulted in the possibility of refilling 28% and emissions of 22% with the use of bicycle cargo options. [11]

Table 1. Cargo Bikes State of Art.

Year	Author	City	Study Case	Concept	Recommendation	Simulation
2012	Baindur, et al.	Mumbai	•		•	
2012	Maes, et al.	Mumbai		•	•	
2015	Schliwa, et al.	London			•	
2017	Rudolph, et al.	London	•		•	
2017	Conway, et al.	New York	•		•	
2018	Zhang, et al.	Berlin				•
2019	Syam, Aziz	Jakarta		•		•

The description of previous research on urban logistics with bicycle transportation modes has provided many possibilities in applications and recommendations for implementation in large cities with high density. As summarized in table 1 from the previous research, there is a research gap for making urban logistical modeling simulations using bicycle transportation modes that are carried out within the scope of densely populated urban development.

The potential of Jakarta as a metropolitan city that is developing transit-based areas commonly called TOD, makes this study able to provide a concept and simulations for regional development that does not only accommodate human movement in a city but also the movement of logistics with environmentally friendly and sustainable solutions.

Research Methodology

As seen in figure 1, the research method begins by identifying problems that occur at the macro scale of the urban logistics and combined with the opportunity to implement cargo bikes in Jakarta. Followed by a literature study of research related to cargo bikes that have operated and researched in several countries so as to produce potential concepts that are in accordance with the conditions of regional development in several points of Jakarta, especially in MRT Phase 1.

Data collection in this study focuses on the demand and coordinate of all demand points which are three TOD areas with different spatial characteristics of the area. Data processing will use the Center of Gravity (COG) approach to simplify the demand points in an area and Capacitated Vehicle Routing Problem (CVRP) with a sweep algorithm to clustering travel routes with limits to the capacity of bicycles used.

The desired result is to get the general cargo bikes concept in the TOD area and find out how many clusters are created for cargo bikes to serve all requests in a TOD area with three different spatial characteristics.

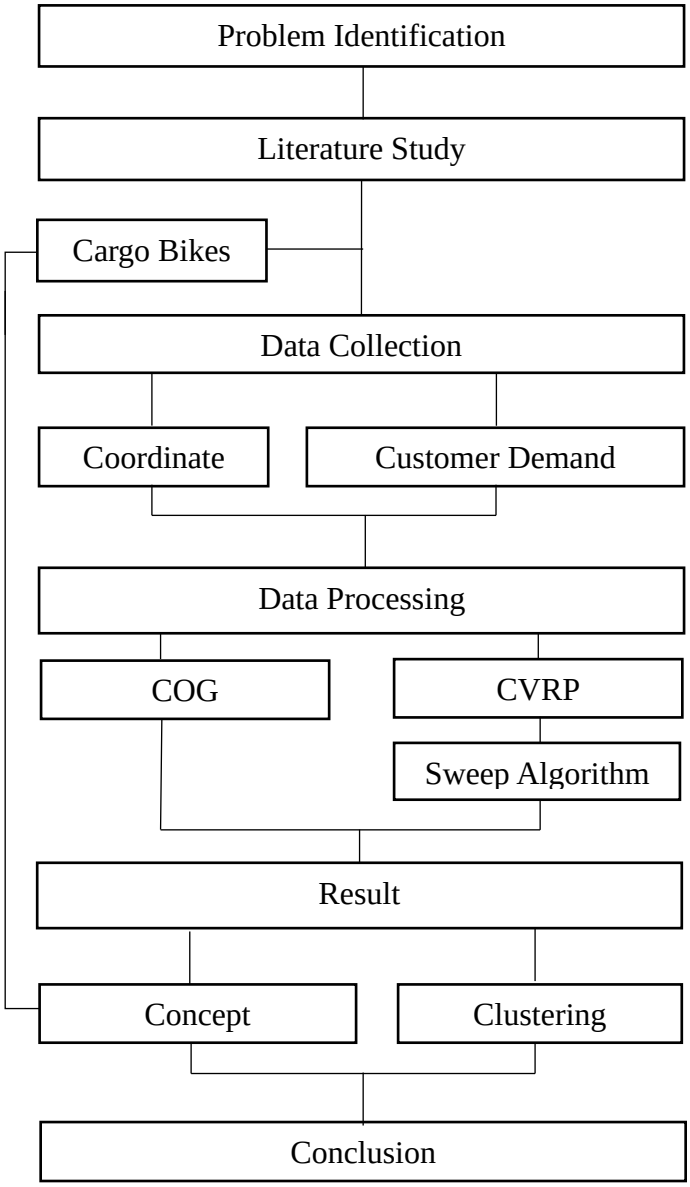

Figure 1. Research Flow.

Data Collection

Data collection in this study focuses on the coordinates and demand of each building and plot of blocks that are in the TOD range in an area of no more than 700m from the Jakarta Phase 1 MRT stop station. Analysis of TOD selection used in this study is based on the TOD area character determined by the study of the provincial government of DKI Jakarta. [12]

TOD Selection

Jakarta MRT Phase 1, which is scheduled to be operational in mid-2019, has 13 station points that stretch from the South Jakarta area to Central Jakarta. Having a regional radius around the station point as far as 700 m, there are seven stations that will be developed into transit-based areas or commonly called Transit Oriented Development (TOD), the stations are Fatmawati, Cipete, Haji Nawi, Blok A, Blok M, Sisingamangaraja, and Dukuh Atas.

Table 2. TOD Characteristic.

Station	Character	Composition of Function (commercial : residential)	Density
Fatmawati	U1	60 : 40	High
Cipete	U2	40 : 60	High - Medium
Haji Nawi	U2	40 : 60	High - Medium
Blok A	U2	40 : 60	High - Medium
Blok M	R	70 : 30	Highest
Sisingamangaraja	U2	40 : 60	High - Medium
Dukung Atas	R	70 : 30	Highest

As attached to table 2 the TOD area developed at seven Jakarta MRT stations in the first phase has a character that is closely related to the conditions of land use planned by the Jakarta MRT in collaboration with the regional government. Using a comparison between composition of function and density, there are three characteristics of the development of TOD namely Regional with commercial and residential versus 70: 30 with very high mixed-use, U-1 with a ratio of 60: 40 with high diversity, and U2 with a ratio of 40: 60 with high-medium diversity.

The selection of three of the seven TODs planned will be developed based on the proximity of a station to other stations, with the aim of obtaining more bound zones and minimal delivery times in future developments, cargo bikes from one TOD to another TOD can be connected. Based on these considerations, the Blok M TOD is chosen which represents the characteristics of the R, Cipete TOD represents the U2 characteristics and Fatmawati TOD represents U1.

Coordinates

The coordinate points of the customers in the pilot model simulation of cargo bikes in the TOD area are carried out by placing points on each building plot with land function zoning and similar height limits from the TOD area which is limited to a radius of 700 m. Figure. 2 shows the customer points placed on the map with clear X and Y coordinates from three different TOD areas. As seen in figure 2, Fatmawati TOD has a total of 109 points, Cipete has 101 points, and Blok M with the R characteristic has 110 points.

Figure 2. Customers coordinates points.

Demand
The use of data such as spatial-oriented data can provide relevant information about urban logistics. [13] Demand data obtained from the number of floors category consisting of four categories according to the spatial design of TOD area, namely category A with a height of 32, category B has a height of 24 floors, C has a height of 16 floors and buildings that only have a maximum height of 4 floors are categorized as building groups D. Buildings A, B, and C on average have office and trade functions, while category D functions more as a residence. The straight comparison is finally used as a guide to demand obtained at each customer point and translated in units of kilograms, see table 3.

TOD	Demand				Total
	A	B	C	D	
Fatmawati	1	3	11	94	109
Cipete		1		100	101
Blok M			8	102	110

Table 3. Demand data.

Fatmawati TOD has a total of 109 points, with 11 points type C, 1 point type A, 3 points type B, and the remaining coordinates are zones of buildings with a height of 4 floors. Cipete TOD with U2 characteristic, has a total of 101 points, with mostly type D buildings and one point of type B. TOD with characteristic R, Blok M has 8 points type C with the rest points are type D of 102.

Data Processing

Simplification with COG
Data processing starts from simplifying using the Center of Gravity (COG) method, the entire service points in the indicated map are still in one block that not too far with a 200m distance limit. In addition to consideration of distance, the service points must also have a similar demand category. Figure 3 illustrates the transformation of service points from each TOD studied. Fatmawati TOD which previously had 109 points, became 46 points, Cipete TOD which previously had 101 points, simplified to 43 points, and Blok M TOD now has 48 points where there were 110 points previously.

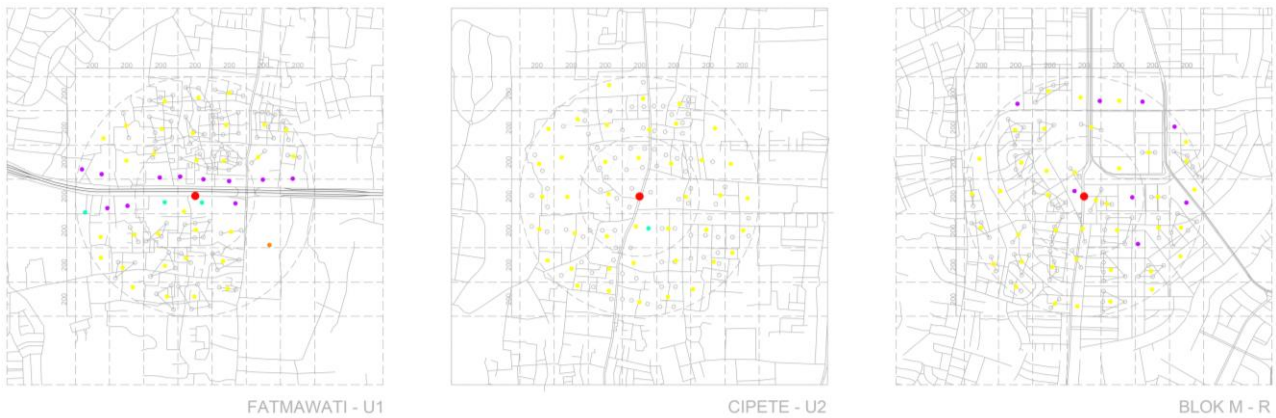

Figure 3. Simplification of service points using Center of Gravity (COG)

Clustering
After the customer points are simplified using the COG method, data processing will be served by bicycle couriers who have an 8kg capacity limit according to the restrictions of Westbike Messenger. These limits will provide clusters of delivery routes for each TOD studied. Using the theory of sweep algorithm, the customer's point is swept clockwise with a capacity limit of 8kg. It can be simulated if

the cargo bikes meet the specified capacity limit, then the bicycle must return to the hub before traveling to the next cluster.

Result

Concept

The relationship between bicycles and public transportation nodes provides a combination of the speed of the train and the flexibility of the bicycle, which is a synergy of mutualism on TOD. [14,15] The big concept of last-mile delivery using bicycles in this TOD area in figure 4, is the integration of each TOD served by the MRT, so that each hub in a station can be served with rail-based cargo that has the right and fast scheduling. This research on non-road modes of urban logistics has also been carried out to provide an option for a delivery system in densely populated urban areas that is more sustainable and supports greener cities.

Research focuses on cargo bikes in the TOD area. Supporting adequate facilities in Transit Oriented Development (TOD) for bike and pedestrian users will add value to the efficiency of a last-mile delivery that adapts the area's infrastructure. The main concept that can be simulated is that each MRT station studied is a logistics hub of the area served by the type of last-mile delivery using cargo bicycles.

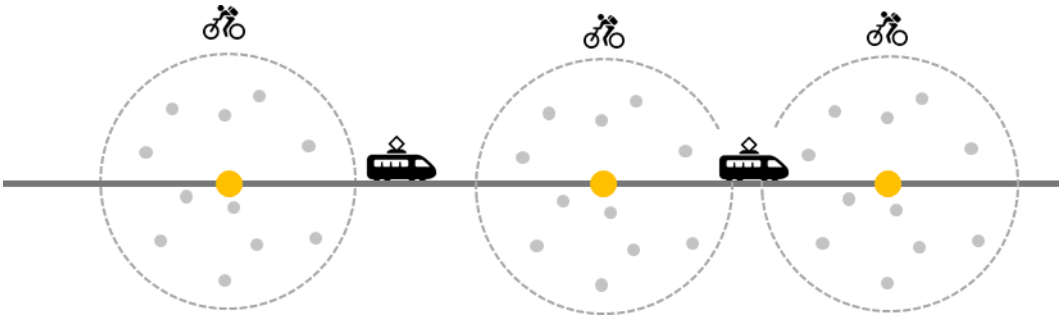

Figure 4. Cargo Bikes in Transit Oriented Development Concept

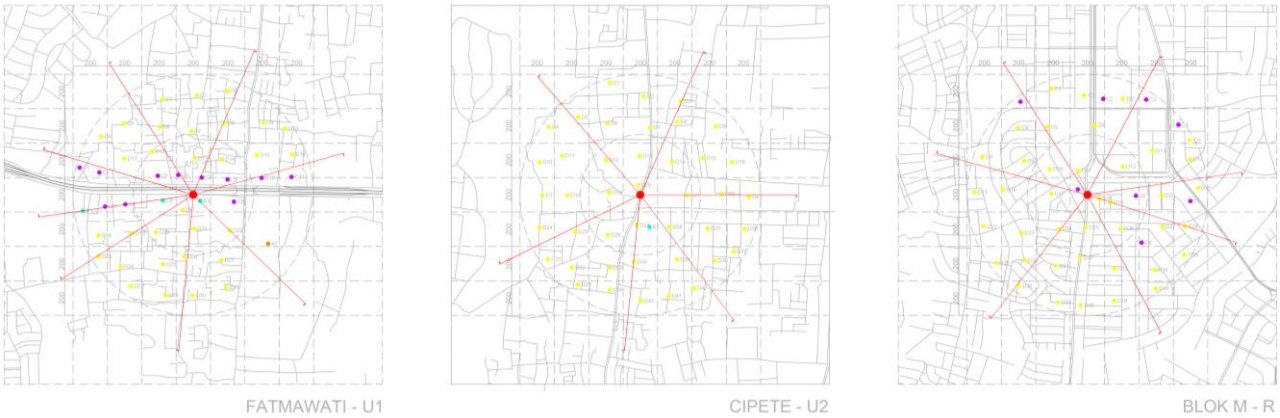

Figure 5. Delivery route clusters for cargo bikes in TOD

Cluster

Figure 5 shows the results of clustering using the cartesian diagram and sweep algorithm method, obtained Fatmawati TOD has 9 clusters, Cipete TOD has fewer clusters, as many as 6 clusters and the last Blok M TOD has 7 clusters. These clusters can be used as a reference for pick-up and delivery routes in simulating cargo bikes operations

Conclusions

This study presents the concept of integrated city logistics between bicycles and rail systems in the MRT Jakarta phase1. The incorporation of urban spatial in the form of Transit Oriented Development (TOD) with an urban logistics system with regional scale using bicycles is expected to be able to provide answers to the option of an energy-efficient and environmentally friendly logistics system. The COG and sweep algorithm method produces a cluster of delivery cargo routes for three TODs with different characteristics. TOD with characteristics of U1 has the most clusters with 9 clusters, followed by TOD with characteristics of R of 7 clusters, and U2 has 6 clusters.

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