Determining the Suitable Placement of Online-Based Public Transportation Shelters by Urban Network Analysis

Case Study: Bundaran HI Transit Development Area

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ABSTRACT

Shelters play a significant role in connecting public transportation providers and users. As online-based public transportation usage is rapidly growing, the urban spaces need to catch up to accommodate those online-based user mobility needs; for instance, by providing pick-up points or drivers' waiting space. Existing urban spaces are not sufficiently prepared to satisfy the current needs of online-based transportation. Hence, specialized shelters must be appropriately planned and designed in suitable places to avoid their disruptive effects on urban space. This paper aims to objectively determine the appropriate placement of online-based transportation shelters using a case study of Bundaran HI, an urban space in Jakarta, Indonesia. The method implemented in this study involved three phases, beginning with the analysis phase, followed by a synthesis phase and simulation phase. A literature review was conducted in the analysis phase, related to urban design theory and transit space. It was supported by observations on the context of the selected case study area. The synthesis phase involved multi-criteria analysis in quantifying the data collected in the analysis phase, resulting in quantitative weighting scores criteria for shelters' placement. In the simulation phase, the weighting score criteria were processed through the Urban Network Analysis and Weighted Overlay Simulation using ArcGIS software. The simulation results indicated areas that should be prioritized and recommended for shelter placement to ensure that the shelters were accessible and practical. Consideration given to the targeted area's various options and constraints helped make the determination process more objective. The method described in this study could be applied to other transit areas and could also be used as a reference for future studies about transit space in an urban context.

Keywords: *Online Public Transport Shelter, Transit Space, Multi-Criteria Analysis, Urban Network Analysis, Weighted Overlay.*

1. INTRODUCTION

Transportation is a fundamental element of livable cities. Its system is often called "the veins of the city" because it provides the essential links between various functions and activities that shape the city. In big cities, public transport and its transit areas play an essential role in the public system; they are inclusively available for most people, not just vehicle owners. An accessible transportation system is defined as the ease with which individuals can reach various services, activities, and destinations.

1.1 Position of Online-Based Transport as Paratransit in Urban Transit System

A transit system in the urban context is composed of a hierarchy of transit areas, as shown in Table 1 [1].

During transit in general, passengers access these four transit sites by walking or cycling, including auto access like Park-and-Ride (Figure 1) [2]. For short-distance trips of 400-500 meters, walking is the most efficient way to access these transit sites; it is more convenient, cheaper, and faster than using a vehicle to cover that short distance [3].

Table 1 Hierarchy of Transit Mode.

Category A	Mass Rapid Transit (MRT), Elevated Light Rapid Transit (LRT)	• Fully separated from other modes and are used only by trains. • Separated Stations • High capacity, reliability, and safety • Increased investment and construction cost	
Category B	Bus Rapid Transit (BRT), tram	• Partially separated from other traffic, typically are transit tracks or lanes, sometimes also serving as the street median. • intersects with other vehicles in traffic • Considerable investment, high performance, attract more passenger than Category C	
Category C	Feeder Bus (Damri, Metromini, Kopaja, Angkutan Kota (Angkot)).	• It consists of streets or roads with mixed traffic • Requires little investment • Travels together with cars	• Has a specific route and operational time • Has a stopping point at any distance or important place • A desirable alternative for commuters that live far from transit stations, especially for those who do not have private vehicles.
	Paratransit: Taxi, Online-Based Transport, Rickshaw		• Provides flexible and easy connectivity • No specific route • Door-to-door services (from the origin to the destination)

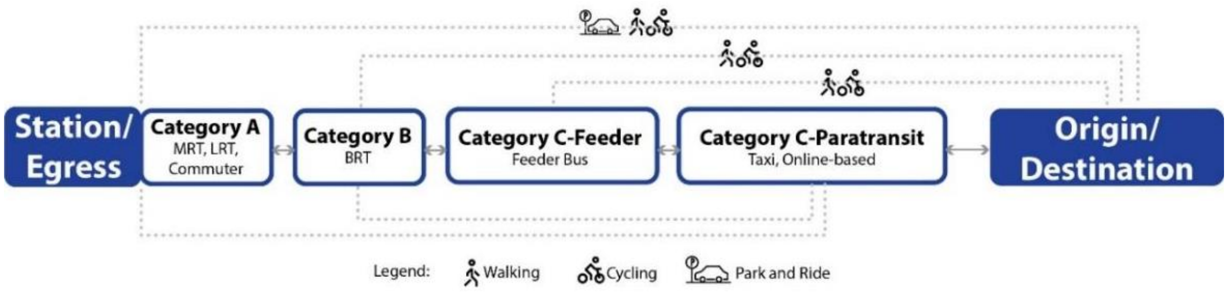

Figure 1 Position of Online-Based Transport in Urban Transit System.

In terms of transportation category, online-based transport can be classified as a paratransit mode of transportation. Ideally, it improves passengers' mobility and accessibility from the point of origin to the mass transit station or the nearest feeder stop. It also helps in integrating the transit system into the city structure itself. Paratransit plays a complementary role in the cars-and-transit system. Paratransit is the most efficient mode in many cities for providing services to the disabled and emergencies [1]. Paratransit fares are typically considerably higher than transit fares, but paratransit offers more personalized services. Therefore, paratransit mode is needed in big cities because it plays a vital role as a supporting system in the transit hierarchy even though it is not as dominant and substantial as Category A and Category B transit, the backbone of the city transport system.

1.2 Actual Condition of online-based transport in Jakarta

The integration of and access to mass transit stations has become a significant issue in many cities in recent years, especially Jakarta. Online-based transportation in Jakarta has changed the order within the hierarchy of urban public transportation systems and pedestrian movement patterns. It has also increased the need for urban public space facilities [4]. Nowadays, online-based transport serves as personal door-to-door services provided through a mobile application, which has not yet to be integrated with urban spatial planning. As a result, activities involving online-based transport, such as pick-up, drop-off, or even waiting for orders, negatively impact public space's visual quality. These impacts include online transport drivers parking their rides on pedestrian walkways while waiting for orders, drivers picking up and dropping off passengers anywhere, disrupting traffic, and drivers using pedestrian space for rest-areas.

As part of the city's transportation system, online-based transport needs facilities or spaces to conduct their activities (picking up and dropping off passengers, parking) in an orderly manner. However, many aspects need to be considered in determining the right location to build such shelters: it does not interfere with the existing urban spatial structure and, instead, can integrate as a whole with the existing city space and transportation system.

1.3 The Importance of Shelter for Online-Based Transport

Building an efficient transit system depends on factors, such as the existing network, land use distribution, and macro and microsystem design. A good feeder network design makes the primary transit system accessible; a low number of stops will reduce its accessibility. Therefore, increasing the number of stops will improve accessibility for larger populations. Paratransit can serve this purpose very well because it is not limited by routes, unlike a feeder system with specific routes that will increase travel time in a cycle of routes [5]. Availability of shelters as passenger pick-up points can make online-based transport run following public space. Shelters for online-based transportation can be placed in private spaces (like an office building, commercial center, et cetera) or public spaces (like public parks, pedestrian way, or transit plaza). This case study focused on online-based transport shelters in public spaces.

2. LOCATION CONTEXT: BUNDARAN HI JAKARTA

The case study for this simulation was conducted in Bundaran HI, Central Jakarta, a part of the Central Business District Area. Based on a pedestrian walking behavior survey, this simulation covered a radius of around 350 meters to 700 meters from the MRT Station center (Figure 2). MRT Station has diverse characteristics: the first layer or main corridor, in M.H. Thamrin Street, has a high-end feature with wide streets and tall buildings; the second layer, in Menteng area and Kebon Kacang Area, displays two different characteristics. Menteng is a historic and preserved area dominated by villas. Kebon Kacang area is an urban village (kampong) with densely populated housings, a busy place due to the nearby MRT Station and the commercial district of Tanah Abang.

Category A transportation mode and facilities have been built in the MRT's primary corridor in terms of the transportation transit system. However, no transport connection is available in a radius of 350 meters to 700 meters, especially the feeder stops. This separation of the transit system with feeders is worsened by the lack of quality in the pedestrian walkway, which causes people to avoid walking even if their houses or flats are in a walkable radius. Consequently, this increases the use of private transportation.

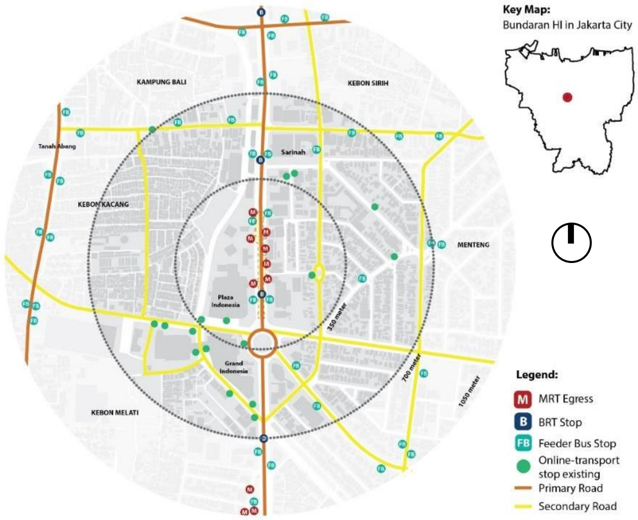

Figure 2 The Location and Context of Bundaran HI.

3. METHOD

There are three phases in determining the placement of an online-based transportation shelter objectively, as illustrated in figure 3.

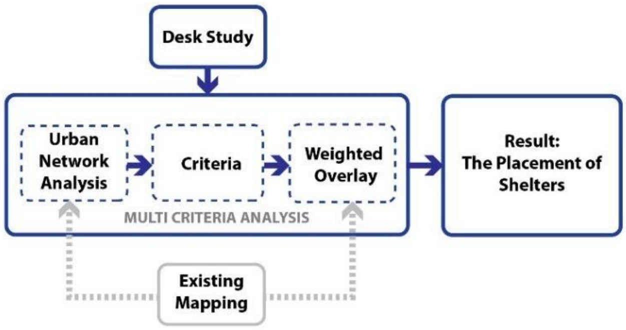

Figure 3 The Method Framework.

3.1 Desk Study

Desk study is an analysis phase involving a literature review on urban design theory, particularly about transit space. This phase is supported by observations on the context of the selected case study site.

3.2 Multi-Criteria Analysis (MCA)

Multi-Criteria Analysis (MCA) is a decision-making tool that identifies a variety of indicators or criteria. In this case study, MCA was used with the ArcGIS application, involving the Weighted Overlay tool as one of the most used overlay analysis approaches to solve multi-criteria problems. The case study followed every general overlay analysis step in implementing the weighted overlay analysis. The Weighted Overlay tool analyzed raster data for every criterion that had value or score. Each measure had to have the same class of value for optimal results. In the case that criteria had different scales, the tool would equalize the value between criteria. The device then overlaid raster images from all criteria with their percentage of influence.

MCA with Weighted Overlay was often used as a tool for decision-making on large areas to determine the most suitable space for development based on specific criteria. For example, the publication by IJEGEO used a weighted overlay to assess a new development area in Kirklareli, Turkey. The criteria used were divided into two groups; Natural Criteria and Artificial Criteria [6].

3.2.1. Understanding Context using Urban Network Analysis Simulation

Urban Network Analysis (UNA) is a toolbox plugin for ArcGIS that offers powerful methods for assessing distances, accessibilities, and encounters between people or places along with spatial networks. This tool incorporates three essential features that make it particularly suited for spatial analysis of urban street networks. First, it can account for both geometry and topology in the input networks, using either metric distance (e.g., Meters) or topological distance (e.g., Turns) as impedance factors in the analysis. Second, unlike previous software tools that operate with two network elements (nodes and edges), UNA includes a third network element: buildings, used as the spatial units of analysis for all measures. Two neighboring buildings on the same street segments can therefore obtain different accessibility results. And third, the UNA tool selectively allows buildings to be weighted according to their particular characteristics [7].

UNA toolbox has Network Centrality Measures and Network Redundancy as its two main analysis methods. Network Centrality Measures are mathematical methods of quantifying the importance of each node in a graph. UNA toolbox can be used to compute five different types of centrality metrics of spatial networks – Reach, Gravity Index, Betweenness, Closeness, and Straightness [7]. In the analysis of online-based transportation shelter placement using Multi-Criteria Analysis (MCA), only Betweenness, Closeness, and Straightness metrics were used.

Another method that works with nodes and edges is Space Syntax. Space Syntax provides a more comprehensive output for forecasting urban movement. The output of Space Syntax is presented in the form of edges and axial lines. In contrast, the UNA Toolbox gives the outcome in the format of points and polygons in ArcMap to provide more comfortable data processing for Weighted Overlay. In this case study, Space Syntax had a significant drawback, in that it was not available for ArcMap used in the case study. Meanwhile, UNA Toolbox could be directly installed to the ArcMap tool in ArcGIS. Considering that the National and Local Government in Indonesia focused on formatting all spatial data into GIS format during this study, UNA Toolbox in ArcGIS was the most practical choice for data processing and decision-making.

Implementation of Urban Network Analysis in this study consisted of two main steps:

a. Data Preparation

Three kinds of primary data were needed to carry out the whole simulation process. The first was building data in polygon format. It contained area shape and building floor data to calculate the Gross Floor Area and building weight. The second was parcel data, which was used as the source of Function and Physical data in MCA. The function aspect added to the layer with the determined score of every land use in every parcel. Parcel data enabled the physical part by providing data on the distance from parking facilities and the nearest stop with determined scores. The third was street data that was used in both UNA and MCA simulation.

b. Running UNA Simulation

UNA simulation required two main data sets. The first was building data with information on building area and the number of floors to calculate the Gross Floor Area of every building to create weight. The second was street data that provided information about the network inside the area. Street data added to the simulation was all street classes, including tertiary and local streets, because UNA calculated all roads that pedestrians could access to reach transportation shelters. UNA simulation provided three outputs of straightness, closeness, and betweenness that then would be added to MCA simulation.

3.2.2 Shelter Placement Criteria

Based on desk study analysis, the site context, and the urban network analysis, it was concluded that online-based transport shelter placement would be determined by three aspects, i.e., physical, function, and urban network aspects. These aspects were divided into sub aspects with weight values and scores to be entered into Weighted Overlay tools in ArcGIS.

Table 2 Criteria of Online Based Transport Placement.

Aspect	Total Weight Value	Sub-aspect	Detail	Score
Physical	45%	Distance from the primary and secondary road (15%)	≤100 m	4
			>100 – ≤200 m	3
			>200 – ≤300 m	2
			>300 m	1
		Distance from Nearest Stop (15%)	>350 m	4
			>200 – ≤350 m	3
			>100 – ≤200 m	2
			≤100	1
		Parking Facilities (15%)	>700 m	4
			>350 – ≤700 m	3
			>100 – ≤350 m	2
			<100 m	1
Function	25%	Land Use	Station/Public Transport Stop and Egress	4
			Commercial	3
			Public Services	2
			Housing	1
Urban Network	30%	Betweenness (10%)	Frequently passed by the people	4
			Moderately passed by the people	3
			Rarely passed by the people	2
			Very rarely passed by the people	1
		Closeness (10%)	Very close to other buildings	4
			Close to other buildings	3
			Quite close to other buildings	2
			Far from other buildings	1
		Straightness (10%)	Have a lot of straight networks	4
			Have many straight networks	3
			Have a few straight networks	2
			Have no straight network	1

Figure 4 Raster Image of Each Sub-Aspects in MCA.

3.2.3 Weighted Overlay

Weighted overlay, a tool from ArcGIS, was used to run MCA simulation in this study. The data of each sub-aspects in figure 4 and table 2 had to be converted to raster data categorized by the determined score values. All raster data were then added to the Weighted Overlay tool, in which every layer was given a predetermined percentage of influence (weight value). The device also provided an option to determine the evaluation range of the result. In this case evaluation range of 1-100 was used to provide a broader range of results.

4. RESULT

Weighting overlay simulation resulted from predetermined criteria indicated that online-based shelters should provide several essential points. Based on the results of this simulation, these points could be grouped into three categories:

a. Value of 70 – 100 (Priority/Highly Recommended Shelter)

Areas with values of 70 – 100 were recommended and prioritized areas for placement of shelters. These shelters should be in reasonably large physical size because the size was directly proportional to the estimated intense pick-up and drop-off activities. Based on the simulation results diagram, priority shelters were scattered within the main corridor and in a public transportation stop point and several main roads in the second layer, especially in intersection areas with high occupancy buildings.

b. Value of 50 – 70 (Recommended)

Areas with values of 50 – 70 would be scattered mostly on the second layer area. In areas with values of 50-70, it was recommended to build shelters of a smaller size than those in priority areas. The shelters could be integrated or separated from feeder shelters.

c. Value <50 (Not Priority)

Areas with values below 50 were areas that did not urgently need a shelter. Hence, building shelters in these areas was not a priority. The majority of these areas were residential areas that tended to be passengers' final destination and the starting point for an online booking. Therefore, it was scattered or not concentrated at one point due to the low occupancy rate of housing.

The simulation results are in line with existing online-based transport concentrations (figure 5). It indicates that the simulation results are in line with the existing context and urban needs. However, there are also areas with high potential for shelters, but they are not yet available.

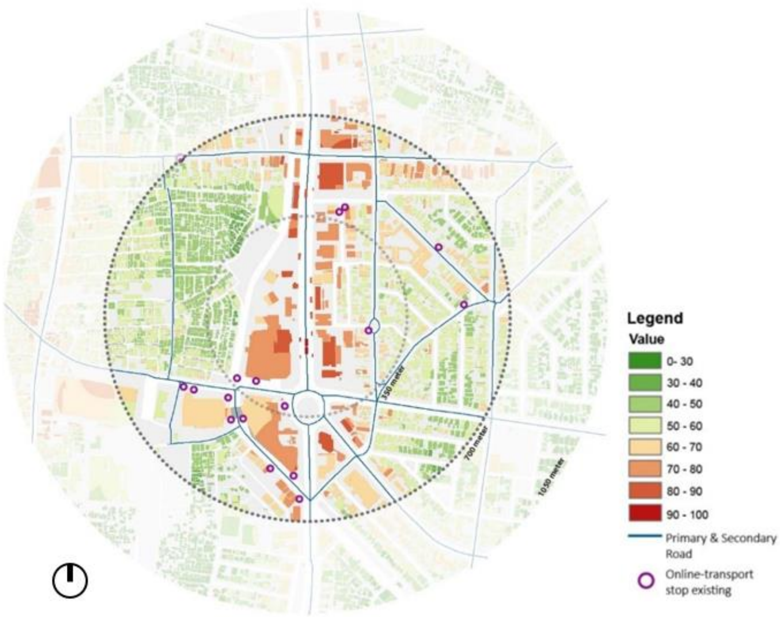

Figure 5 Shelter Placement Area Recommendation

5. DISCUSSION

The placement of online-based transport shelters could be determined by three aspects, i.e., the physical aspect, function or land use, and urban network. For preliminary consideration, Multi-Criteria Analysis, Weighted Overlay, and Urban Network Analysis with ArcGIS were deemed effective to decide on the recommended areas for shelter placement objectively. Shelters in public spaces should be developed in integration with feeder transportation stops. This scheme would facilitate more efficient pedestrian mobility and accessibility, allowing traffic to shift from the main transportation modes (Category A and B) to the feeder or paratransit mode, i.e., online-based transportation. However, the number of shelter points had to be balanced with the quality of pedestrian space. Pedestrian walkway with good quality had a minimal distraction, rich walking experiences, and sufficient space to move and maneuver [3]. Therefore, the pedestrian space leading towards the shelters had to be improved into good quality pedestrian walkways that would be continuous, safe, and have minimal obstacles and many shades.

6. CONCLUSION

This simulation's results were limited by the difficulty to gather the data and the wide area to be covered, resulting in a very general outline of shelter placement. These results can be further improved by considering the shelters' specific locations and their close connection with other elements of urban space. This improvement will ensure that the shelters will not interfere with traffic circulation and visual space. Further studies should be conducted to determine MCA's weight values and scores for a more complete and accurate result. Further studies should also be done on the shelters' typology based on the areas' needs and characteristics.

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