DEVELOPMENT OF EVALUATION INDICATORS FOR LOGISTIC TRANSPORTATION SYSTEM WITH TRIPLE BOTTOM LINE APPROACH: JAKARTA STUDY CASE

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Abstract

Jakarta has significant problems related to logistics transportation, including congestion, environmental pollution, and the negative impact of operating overloaded trucks. To overcome these externalities, it is necessary to have an urban logistics system and planning cycle that considers the concept of sustainability. This study aims to propose an arrangement of indicators as a tool for evaluating the urban logistics transportation system. The research was carried out through a literature study process, identification of the long list of indicators and selection criteria, independent selection, surveys and interviews, ranking with the VIKOR Method, and validation with expert considerations. A final set of indicators was produced, namely ten indicators, divided into economic, social, and environmental aspects, for evaluating the sustainability of the city's logistics transportation system. This research is helpful as input in developing a set of indicators for evaluating the logistics transportation system in urban areas, especially in Jakarta Capital Special Region.

Keywords: City Logistics, Urban Freight Transportation, Evaluation, Indicators

Abstrak

Jakarta memiliki permasalahan signifikan terkait transportasi logistik, antara lain kemacetan, pencemaran lingkungan, dan dampak negatif pengoperasian truk dengan muatan berlebih. Untuk mengatasi eksternalitas tersebut, diperlukan sistem logistik perkotaan dan siklus perencanaan yang mempertimbangkan konsep keberlanjutan. Penelitian ini bertujuan untuk mengusulkan suatu susunan indikator sebagai alat bantu evaluasi sistem transportasi logistik perkotaan. Penelitian dilakukan melalui proses studi literatur, identifikasi *Long-list* indikator dan kriteria seleksi, seleksi mandiri, survei dan wawancara, pemeringkatan dengan Metode VIKOR, dan validasi dengan pertimbangan para ahli. Dihasilkan seperangkat indikator akhir, yaitu sepuluh indikator yang terbagi dalam aspek ekonomi, sosial, dan lingkungan untuk menilai keberlanjutan sistem transportasi logistik kota. Penelitian ini bermanfaat sebagai masukan dalam mengembangkan seperangkat indikator untuk mengevaluasi sistem transportasi logistik di perkotaan, khususnya di Daerah Khusus Ibukota Jakarta.

Kata Kunci: Logistik Kota, Transportasi Logistik Kota, Evaluasi, Indikator

INTRODUCTION

Logistics transportation is a basic need for urban communities because it represents economic conditions, transportation, and quality of life. This is related to high traffic movements in densely populated areas such as urban areas (OECD, 2003). Jakarta, with the densest population density compared to other big cities on the island of Java (Badan Pusat Statistik Provinsi DKI Jakarta, 2021), the need for logistics transportation will multiply (Cherrett et al., 2012). A good planning process by various stakeholders in urban areas is needed to maintain and improve economic conditions, transportation, and the quality of life of people in urban areas (Amaya et al., 2021).

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Logistics transportation in urban areas such as Jakarta is dominated by land transportation modes which have various negative impacts such as traffic jams, environmental pollution, and negative effects of the operation of overloaded trucks (Pramtama, 2022). These externalities can be caused by an imbalance in resource consumption in the operation, which is caused by an insufficiency of planning for the city's logistics transportation system and its operational sustainability (Cassiano et al., 2021).

Urban logistics planning includes various stages such as planning, preparation, implementation, and evaluation (Kaszubowski, 2016), which can be used as an aid in making decisions related to a problem (Pathak et al., 2019). Sustainable planning, which purpose is to carry out planning that can meet the needs of the present without compromising the ability of future generations to meet their needs (WCED (World Commission on Environment and Development), 1987), can be applied by considering the balance of economic, social, and environmental aspects, which is commonly referred to as the triple bottom line approach (Elkington, 1997; Morella et al., 2022). Therefore, one solution that can be applied regarding the mentioned needs and externalities is to sustainably evaluate the logistics transportation system as a part of sustainable planning. The evaluation stage has the goal of conducting an assessment related to planning performance, impact, and competence of the logistics transportation system (Kaszubowski, 2019). This performance assessment can be assisted by a series of indicators as a fundamental tool to keep sustainable ideas measurable (Gudmundsson et al., 2016)

The purpose of this study is to develop and propose a set of indicators to evaluate the urban logistics transportation system, with the scope of study namely in the Jakarta Capital Special Region (CSR).

METHODOLOGY

Identification of a Long List of Indicators for Evaluation of Logistics Transportation System

Initially, a literature review was conducted based on various keywords such as "Transport Logistics", "Urban Logistics", "Urban Logistics Transport", "Evaluation", and "Indicators". A review is carried out based on the abstracts of the articles displayed for each keyword, and 22 literatures were marked which were in accordance with the research intent. Based on these literatures, a further review was carried out by observing the content of each literature, and as many as 9 literatures were retrieved that were in accordance with the research intent (Buldeo Rai et al., 2018; Fulzele & Shankar, 2023; Gonzalez-Feliu, 2018; González-Feliu, 2018; Kaszubowski, 2019; Melo & Costa, 2011; Morana & Gonzalez-Feliu, 2015; Morella et al., 2022; Ørving & Jensen, 2021). The 9 literatures propose evaluation indicators in the context of the city's logistics transportation system with various case studies in their respective review areas. From the 9 literatures, it was obtained a total of 94 indicators as potential indicators for the evaluation of the logistics transportation system.

Formation of a Set of Selection Criteria

This process begins with conducting a literature study, using the same literature as in the previous stage but considering the literature that proposes selection criteria for selecting the evaluation indicators that are ultimately proposed (Buldeo Rai et al., 2018; Melo & Costa, 2011). A total of 16 selection criteria were obtained, along with their descriptions. These selection criteria will also go through a screening process to obtain a series of selection criteria that are relevant to the scope of the discussion and are not repeated based on the description of the criteria. Through this process, 6 selection criteria were obtained as parameters for selecting indicators for evaluating a sustainable logistics transportation system in the Jakarta CSR. The selected selection criteria are presented below.

Table 1. Selection Criteria

No	Selection Criteria	Description
1	Dynamic	The indicator has the characteristic that it is sensitive to changes which can be in the form of changes in conditions or improvements to the city's logistics transportation system.
2	Communicative	Indicators have characteristics that can be communicated clearly to the general public to fulfil the objectives of the indicators.
3	Comprehensive	Indicators have the characteristics of being able to cover and represent aspects discussed in the logistics transportation system.
4	Feasible	Indicators have characteristics that are feasible and can be applied practically.
5	Scientifically Valid	Indicators have the characteristics of being able to provide scientifically valid information and can describe cause-and-effect relationships in the system.
6	Measurable	Indicators have the characteristics of being able to obtain measurable data and having small uncertainties.

Selection of The Long List into a Shortlist Draft Based on The Selection Criteria

The researchers carry out the selection process for the initial long list of indicators based on the 6 selection criteria points by assessing each criterion for each indicator with a Likert scale of 1 to 4 according to the characteristics of the study case area. The assessment weight is 1 not suitable, value 2 is not quite suitable, value 3 is quite appropriate, and value 4 is appropriate. Then the assessment for each criterion is averaged to obtain an average value for each indicator. This independent selection is based on the average value, with indicators that have an average value of more than 3.75 will pass, and simplification, based on the description of indicators that are the same and similar to one another.

The selection of indicators is based on the current condition and characteristics of the logistics transportation system in Jakarta CSR. To identify the evaluation indicators for another city, it is necessary to consider several things such as the complexity of the logistics transportation system, the advancement of infrastructure and technology implementation, and key problems that occur in the target city.

Based on this process, it was obtained a total of 24 indicators as the short list draft of indicators for the evaluation of the logistics transportation system, which is presented in the table below.

Table 2. Short List Draft of Evaluation Indicators

Aspect	Category	Scope	No	Indicator	Description	Unit of measurement
Economy	Efficiency and Effectiveness	Transportation Accessibility	1	Area Accessibility	The ability of the accessibility of transport goods to various regions	-
		Supply and Demand of Transportation Services	2	O/D Matrix	O/D matrix as data that represents the movement of vehicles from an area of origin and towards a destination area	Number of vehicles
	Finances and Costs	Cost and Investment	3	Operating Costs	Costs that are borne from the delivery process (in and out), packaging, and application of technology	Monetary unit (Rupiah)
	Operational	Delivery	4	Delivery Mileage	Delivery mileage per day	Length Unit (km)
			5	Delivery Time	Delivery duration per day	Unit of time (minutes or hours)
			6	Number Of Shipments	The number of deliveries made per day	Delivery per day
			7	Number Of Freight Vehicles	Number of goods transported per day per type of vehicle	vehicle/day/vehicle type
	Infrastructure	Soft Infrastructure	8	Road Network Coverage	Coverage of the road network for various modes of logistics transportation in urban areas	Length Unit (km)
		Parking Facility	9	Loading Area Ratio	The ratio of Loading and Unloading Area to	%

Aspect	Category	Scope	No	Indicator	Description	Unit of measurement
					Commercial Area	
		Traffic Conditions	10	Traffic Congestion Intensity	Travel time and length of traffic jams that occur, so that it can affect the required operational costs	km, km/hour
			11	The Intensity of The Flow of Goods Transport	The level of movement and load capacity of the freight vehicle fleet in road use	km.smp, ton.km, %
			12	Disruption of Traffic Flow	Disruption of traffic flow due to loading and unloading activities	Veh.hour
Social	Safety	Risk	13	Traffic Risk Level	Num. of traffic-related accidents, deaths, and injuries	Amount or %
		Traffic Safety Rules	14	Level Of Compliance with Traffic Safety Rules	Comparison of the number of violators against the total number measured against various traffic safety rules such as vehicle speed limits, consumption of hazardous substances, and vehicle condition standards	%
	Mobility	Traffic	15	Travel Time	The travel time taken by the freight fleet per day	hours or minutes
			16	Travel Distance	The distance travelled by the freight fleet per day	km

Aspect	Category	Scope	No	Indicator	Description	Unit of measurement
			17	Traffic Congestion Intensity	Traffic flow conditions are based on basic traffic flow descriptors such as speed, density, and traffic volume	km/hour, vehicle/hour, vehicle/km
			18	Proportion And Use of Load Capacity on The Road	Proportion and use of load capacity on roads by freight transport	% and tons
	Noise	Noise Exposure	19	Perceived Noise Level	Exposure to noise felt by the community around the logistics transportation activity area	Index
Environment	Energy Consumption	Fleet of Goods Transport Vehicles	20	Fuel Consumption	Average fuel consumption per 100 km (MJ per 100 km)	MJ eq.
	Pollution	Air	21	Air Pollutant Emission Levels	Total air pollutants such as Particulate Matter (PM), NOx, greenhouse gases, SOx, VOC, CO, and photochemical oxidants	$\mu g/m^3$ and kg eq.
		Voice	22	Noise Level	Noise intensity generated by logistics transportation activities	dB(A)
	Efforts to Reduce Environmental Impact	Modes and Routes	23	Route Optimization	Optimizing the distribution network to minimize costs and emissions	Amount or %
	Policy and	Monitoring	24	Environmenta	Periodic	Amount or %

Aspect	Category	Scope	No	Indicator	Description	Unit of measurement
	Monitoring			l Aspects Inspection	inspections to carry out monitoring related to environmental protocols and obtain certification	

Interview and Survey to Assess the Shortlist Draft Based on The Selection Criteria

The assessment process through surveys and interviews with experts is carried out directly by filling out questionnaires and elaborating the results of the assessment provided by experts. The interview and survey process are conducted to capture the suitability assessment of the short list draft of evaluation indicators according to the current characteristics and condition of the logistics transportation system in Jakarta CSR based on the selection criteria. A questionnaire assists the assessment survey as a medium, which contains an assessment of the shortlist draft of selected indicators based on selection criteria, with a Likert scale of 1 to 4. Respondents to this assessment survey were experts with academic and government backgrounds.

Ranking Using the VIKOR Method

Based on the results of the assessment, a ranking can then be carried out using the VIKOR method (Chang & Hsu, 2011; Suwardika & Suniantara, 2018; Tong et al., 2007; Tumanggor et al., 2018; Yazdani & Graeml, 2014).

1. Determination of the decision matrix
   The average value that has been obtained through the assessment process can be expressed in the decision matrix in equation (1), with variable I is the indicator being reviewed, while variable C is the selection criterion as the basis for the assessment.

$$D_{24\times6} = \begin{array}{c} \\ I_1 \\ I_2 \\ I_3 \\ \vdots \\ I_{24} \end{array} \begin{array}{c} \begin{array}{cccccc} C_1 & C_2 & C_3 & \dots & C_6 \end{array} \\ \begin{bmatrix} 3.3 & 3.5 & 3.4 & \dots & 3.6 \\ 3.2 & 3 & 2.9 & \dots & 3.2 \\ 3.7 & 3.4 & 3.3 & \dots & 3.6 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 3.8 & 3.8 & 3.7 & \dots & 3.8 \end{bmatrix} \end{array} \quad (1)$$

2. Calculation of maximum and minimum values
   Calculation of the maximum and minimum values for the 6 criteria is based on equations (2) and (3) as follows.

$$x_1^+ = \{max(x_{ij})|j = 1,2,\dots,n\} = \{3.9,3.8,3.9,3.7,3.8,3.9\} \quad (2)$$
$$x_1^- = \{min(x_{ij})|j = 1,2,\dots,n\} = \{2.8,3,2.9,3.1,3.2,3.2\} \quad (3)$$

   The maximum and minimum values represent positive and negative ideal solution for the assessment based on each criterion, which is presented in the following table.

Table 3. Maximum and Minimum Values

X+	X+1	X+2	X+3	X+4	X+5	X+6
	3.9	3.8	3.9	3.7	3.8	3.9
X-	X-1	X-2	X-3	X-4	X-5	X-6
	2.8	3	2.9	3.1	3.2	3.2

3. Calculation of normalized value from the decision matrix
This calculation is carried out to obtain a normalized value based on the maximum and minimum values scale. The example of the calculation for indicator number 1 with criterion number 2 is presented in equation (4).

$$N_{12} = \frac{x_2^+ - x_{12}}{x_2^+ - x_2^-} = \frac{3.8-3.5}{3.8-3} = 0.375 \quad (4)$$

4. Weighting calculation from the decision matrix
This calculation is carried out to obtain a weighted value based on the weight of each criterion. However, in processing this data, the same weight is used for each criterion, hence all normalized values can be multiplied by the same weight, namely $w_j = \frac{1}{n}$, with n is the number of criteria. The following equation (5) is an example of the calculation for indicator number 1 with criterion number 2.

$$F_{12} = N_{12} \times w_2 = 0.375 \times \frac{1}{6} = 0.063 \quad (5)$$

5. Calculation of the utility measure (S) and regret measure (R)
Calculation of the Utility (S) and Regret Measure (R) are carried out based on equations (6) and (7) as examples of calculations for utility and regret measures for indicator 1.

$$S_1 = \sum_{j=1}^{n} F_{1j} = 0.091 + 0.063 + 0.083 + 0.083 + 0.111 + 0.071 = 0.503 \quad (6)$$

$$R_i = \max(0.091, 0.063, \ldots, 0.071) = 0.111 \quad (7)$$

In addition to calculating the utility and regret measures, it is also necessary to determine the maximum and minimum values of the utility and regret measures.

Table 4. Maximum and Minimum Values of Utility and Regret Measures

S+	S-	R+	R-
0.939	0.100	0.167	0.033

6. Calculation of the VIKOR index (Q)
Based on the above calculations, the VIKOR index can then be obtained based on equation (8) as example of calculating the VIKOR index for indicator 1.

$$Q_1 = \left[v \times \frac{S_1 - S^-}{S^+ - S^-}\right] + \left[(1-v) \times \frac{R_1 - R^-}{R^+ - R^-}\right] = \left[0.5 \times \frac{0.503-0.1}{0.939-0.1}\right] + \left[(1-0.5) \times \frac{0.111-0.033}{0.167-0.033}\right] = 0.532 \quad (8)$$

Table 5. VIKOR Index for Each Indicator

Indicator	Q	Rank	Indicator	Q	Rank	Indicator	Q	Rank	Indicator	Q	Rank
1	0.532	17	7	0.719	21	13	0.637	20	19	0.341	12
2	1.000	24	8	0.906	23	14	0.183	6	20	0.031	2
3	0.410	14	9	0.868	22	15	0.288	9	21	0.124	3
4	0.326	11	10	0.134	5	16	0.462	15	22	0.255	7
5	0.401	13	11	0.614	19	17	0.269	8	23	0.131	4
6	0.318	10	12	0.595	18	18	0.528	16	24	0.000	1

Validation of The Short List of Indicators for Evaluation of Logistics Transportation Systems

The validation process is carried out using the same method as in the survey and interview stages, but the assessment is given for the overall result of the ranking and the top 10 rankings of indicators. Validation was carried out on four experts, all of whom had government backgrounds, to validate the top 10 rankings of indicators according to the current characteristics and condition of the logistics transportation system in Jakarta CSR. The top 10 indicators rankings are compiled as the short list of indicators for evaluating the logistics transportation systems.

Table 6. Short List of Evaluation Indicators

Aspect	Category	Scope	Indicator	Description	Unit of measurement
Economy	Operational	Delivery	Number of Shipments	The number of deliveries made per day	Delivery per day
	Infrastructure	Traffic Conditions	Traffic Congestion Intensity	Travel time and length of traffic jams that occur, so that it can affect the required operational costs	km, km/hour
Social	Safety	Traffic Safety Rules	Level of Compliance with Traffic Safety Rules	Comparison of the number of violators against the total number measured against various traffic safety rules such as vehicle speed limits, consumption of hazardous substances, and vehicle condition standards	%
	Mobility	Traffic	Travel Time	The travel time taken by the freight fleet per day	hours or minutes
			Traffic Congestion	Traffic flow conditions are	km/hour, vehicle/hour,

Aspect	Category	Scope	Indicator	Description	Unit of measurement
			Intensity	based on basic traffic flow descriptors such as speed, density, and traffic volume	vehicle/km
Environment	Energy Consumption	Fleet of Goods Transport Vehicles	Fuel Consumption	Average fuel consumption per 100 km (MJ per 100 km)	MJ eq.
	Pollution	Air	Air Pollutant Emission Levels	Total air pollutants such as Particulate Matter (PM), NOx, greenhouse gases, SOx, VOC, CO, and photochemical oxidants	μg/m³ and kg eq.
		Voice	Noise Level	Noise intensity generated by logistics transportation activities	dB(A)
	Efforts to Reduce Environmental Impact	Modes and Routes	Route Optimization	Optimizing the distribution network to minimize costs and emissions	%
	Policy and Monitoring	Monitoring	Environmental Aspects Inspection	Periodic inspections to carry out monitoring related to environmental protocols and obtain certification	%

RESULTS AND DISCUSSION

Externalities in the Jakarta CSR have triggered the need to improve the city's logistics transportation system. The externalities currently being discussed are related to traffic jams, the negative impacts of environmental pollution, and the negative impacts of operational overloaded vehicles.

Based on the literature study, 94 indicators were obtained as potential indicators for evaluating the logistics transportation system in the Jakarta CSR. However, these indicators are normative, considering that these potential indicators are a combination of various case studies in various parts of the world. Therefore, it is necessary to carry out further selection to determine a set of indicators that are appropriate to the context of the Jakarta CSR. To assist the selection process, 6 points of selection criteria were selected,

based on literature study, as a basis for assessing and selecting the evaluation indicators to suit the regional context of the Jakarta CSR.

Various stages, such as independent selection, surveys and interviews, ranking using the VIKOR method, and validation, resulted in a short list of indicators for evaluating logistics transportation system sustainability in the Jakarta CSR. In general, the experts consider the short list of indicators appropriate to be used as a tool for evaluating logistics transportation system sustainability in the study case area. However, the short list of indicators is more oriented towards the environmental aspect because half of the indicator set concerns the environmental aspect. Despite that, the final set of indicators represents the externalities that arise in the Jakarta CSR context. The externality of traffic congestion is represented by the Traffic Congestion Intensity indicator on the Economic and Social aspects, Travel Time, Fuel Consumption, Noise Level, and Route Optimization. Indicators of Fuel Consumption, Air Pollutant Emission Levels, Route Optimization, and Environmental Aspect Inspection represent environmental pollution externalities. The operational externalities of cargo transport vehicles with excess loads are represented by the indicators of the Number of Shipments, Level of Compliance with Traffic Safety Regulations, Fuel Consumption, and Environmental Aspects Inspection. Thus, the indicators on the short list of indicators can provide a representation of the existing conditions and can become a tool for evaluating the current condition of the logistics transportation system in the Jakarta CSR so that improvements can then be implemented according to the stages of the planning cycle.

The proposed short list of indicators is based on the current condition and characteristics of the logistics transportation system in Jakarta CSR. If the methods and indicators presented are to be used for case studies in other cities, there will be differences based on the characteristics of the target city.

CONCLUSION

Based on the research that has been done, a final set of indicators has been obtained in the form of a short list of indicators for evaluating the logistics transportation system with case study in the Jakarta CSR, through various stages such as literature study process, identification of the long list of indicators, identification of selection criteria, independent selection, surveys and interviews, ranking with the VIKOR Method, and validation with expert considerations.

The set of indicators that has been developed can provide a good representation of the existing conditions in the Jakarta CSR so that they can answer problems in the form of externalities that arise in the case study area. Thus, the series of stages carried out in this research can help the local government to develop an evaluation tool for the city's logistics transportation system in the form of a set of indicators.

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