Transport network planning for freight transport based on environmental approach

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Abstract. Economic development in an area depends on the supply of commodities that are available continuously. Therefore, to move goods in large quantities requires vehicles and infrastructure that support the goods transporting process. This condition affects the urban development. The regulation of freight transportation system impacted the accessibility and mobility of the community in carrying out daily activities, so that the freight transport network planning should be planned by considering many aspects, among others are characteristics of the movement of freight transportation, traffic performance, land used, road classification, and air pollution. Balikpapan is a city located in East Kalimantan Province. It has the largest economy in Kalimantan, with total GDP reaching Rp 79.65 trillion in 2016. This city is consistently ranked as one of the most livable cities in Indonesia. As a business and industrial center currently, there is no regulation of the freight transportation route, which causes the roads to be passed by freight transport having low road Level of Service (LOS). The aims of this research are to propose a freight transportation network based on an environmental approach. The research provides a comprehensive analysis of freight transport network planning by considering characteristics of the movement of freight transportation, traffic performance, land used, road classification, and gas emissions. By using AHP (Analytical Hierarchy Process) method, these characteristics are used as assessment criteria in the determination of freight transport networks. The results of the priority vector assessment are obtained freight transportation network with the travel time 21 hours 9 minutes, travel distance 902.6 km, average speed of 35.62 kph. Based on the land use of selected freight transportation routes, it can be seen that the percentage of land use in industrial area 35%, residential area 60%, commercial and service area 5%. The analysis of gas emission obtained value of CO, NOx, and S (smoke level).
Key Words: freight transport, green network, sustainable urban development.

Introduction. Freight transport in urban areas includes all commodity movements produced by the economic needs of regional businesses, that is, all shipment and collection of stock, materials, parts, consumables, mail and refuse that businesses require to implement (Dablanc 2011). Freight transport is a crucial component for the generation of well-being. It facilitates the commodity movements along a supply chain, and it is required for the supply of the commodity and directly influences the efficiency of the economy (Behrends 2011). Economic development in an area depends on the supply of commodities that are available continuously. Therefore, to move goods in large quantities requires vehicles and infrastructure that support the goods transporting process (Behrends 2016; Engstrom 2016). This condition affects in urban development.

Balikpapan is a city located in East Kalimantan Province. It has the largest economy in Kalimantan, with total GDP reaching Rp79.65 trillion in 2016. This city is consistently ranked as one of the most livable cities in Indonesia. As a business and industrial center, the population growth in the city of Balikpapan by 2% per year, resulting in increased economic activity. Based on the data in 2019, the proportion of freight transport movement from internal to an external zone is 60%, and the proportion of freight transport movement from external to internal zone is 34% of the total vehicle movement (Hanif et al 2021).

The regulation of freight transportation system impacted the accessibility and mobility of the community in carrying out daily activities, so that the freight transport network planning should be planned by considering many aspects, among others are

characteristics of the movement of freight transportation, traffic performance, land used, road classification, and air pollution. The aims of this research are to propose the freight transportation network based on an environment approach. Balikpapan has the largest economy in Kalimantan. As a business and industrial center currently, there is no regulation of the freight transportation route, which causes the roads to be passed by freight transport having low road Level of Service (LOS). This freight transport movement impact the environment, mainly resulting in air pollution. The limitations of this research are focused on freight transport network planning by using Analysis Hierarchy Process (AHP) method. The criteria used in this analysis are road performance, land used, and air pollution. Determination of alternative routes for freight transport networks are based on origin-destination of freight transport and road classification (PM 60 of 2019).

Literature review

Freight transport network. Urban logistics is a significant part of the economic power of capital. Further, the characteristic of capital as an area of manufacture also implicates important freight activity related to their role and function in global supply chains. In capital presents as a center for national and international commerce, urban freight is essential for wholesaling, distribution, logistics, and intermodal operations (Newman & Kenworthy 1999). The industry, such as clients and the community are very dependent on effective and efficient road freight transportation. Land transportation is not only part of a large part of the chain of transport, but is also the dominant mode as much of the product is transported only by truck (Hanif et al 2021). Roads are classified according to administrative authority and function. Administrative classes are related to the authority responsible for construction and maintenance: federal, state, country, or city. Functional classes are based on the use and design standards of each type of roadway (Kaiser et al 1995).

Urban freight transport sustainability. Transport activity influences urban development and affect on accessibility and connectivity (Sari & Hidayat 2020). The city sustainability criteria are unique at quite a number of tiers and are not measurable in equal condition. Some of the matters beneath the investigation of sustainable improvement are at once related to cities. These problems include sustainable development through land use planning, reconstruction of the city, sustainable buildings, city structure and energy, sustainable transportation, urban structure and pollution, density function in attaining sustainability, vitality, and meaning (Larijani 2016). Land use developments are contributing to city freight problems. There are two fundamental trends: decentralization and consolidation. Logistics activities are decentralizing (i.e., transferring away from the central city) in section due to rising land values as metropolitan areas grow. Freight amenities are additionally consolidating, in section due to growing scale economies that require large warehouse and distribution services (NCFRP 2013).

The quantity of pollutants concentration produced using of vehicular exhaust emissions generally depends on the degree of pollutant in each vehicle, traffic volume, and time. Optimizing the traffic and transport system is one measure that should be used to manage air pollution ensuing from vehicle exhaust emissions. Through this scheme, we should at least decrease traffic congestion on the road network, which will subsequently decrease pollutant concentration (Hils 1994). Most efforts to control truck traffic are supposed to minimize environmental effects in somehow, along with decreasing congestion and accomplishing different objectives. For example, an expansion in truckload (NCFRP 2013).

Material and Method. The data collection was conducted from October 2019 to December 2019 in Balikpapan City, Kalimantan Island, Indonesia.

Data collection. This study gathered information from several sources. Primary records are collected by traffic survey, roadside interview, freight transport interview, and field

observations. The traffic survey was carried out along the road corridors in the city of Balikpapan.

This record consists of traffic volume, traffic flow, road density, road inventory, and origin-destination freight transport movement. Secondary records were collected using the literature review and Indonesian government regulations. The records consist of road classification and road network map.

Method of analysis. The analysis used an ecological approach with the Analysis Hierarchy Process (AHP) method, which aims to determine the priority of the assessment to find out how important a factor from the criteria is compared to other criteria to be given a relative assessment of each factor. Some of the criteria used in this method are road performance, land used, and air pollution. The hierarchy of each criterion was obtained from interviews with transportation experts and several respondents from logistics companies.

Data analysis. As shown in Figure 1, the Balikpapan City area is divided into 36 zones, of which 34 internal zones and 2 external zones. The industrial areas have the potential to attract and generate freight transport, that are located in Kariangau area (zone 26), Graha Indah area (zone 27), Manggar Area (zone 31) and Prapatan area (zone 7). In these zones there are companies, warehouses and markets. Sustainability design needs two primary approaches: integrated planning and neighborhood participation (Newman & Kenworthy 1999). As shown in Figure 2, determination of alternative routes is based on the integration of the road network in Balikpapan.

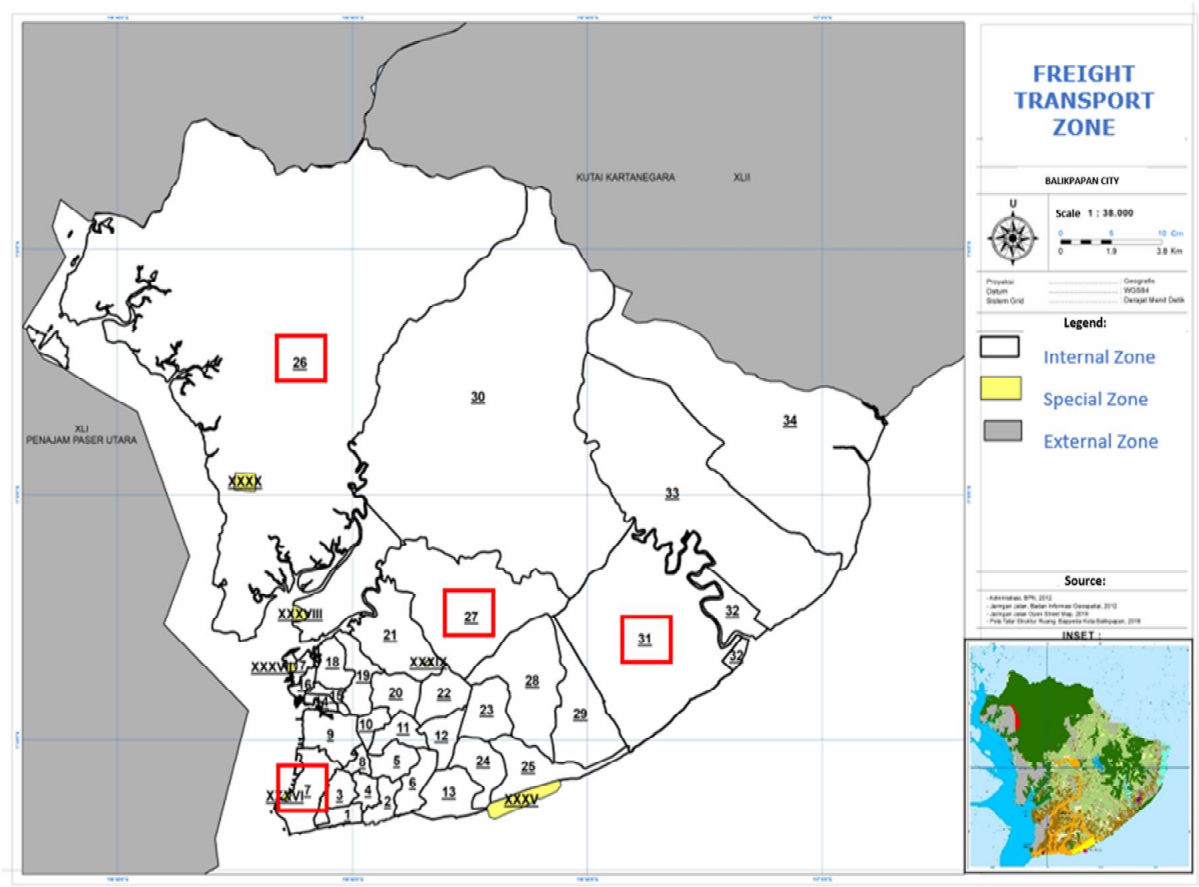

Figure 1. The zone of generation and attraction of freight transport.

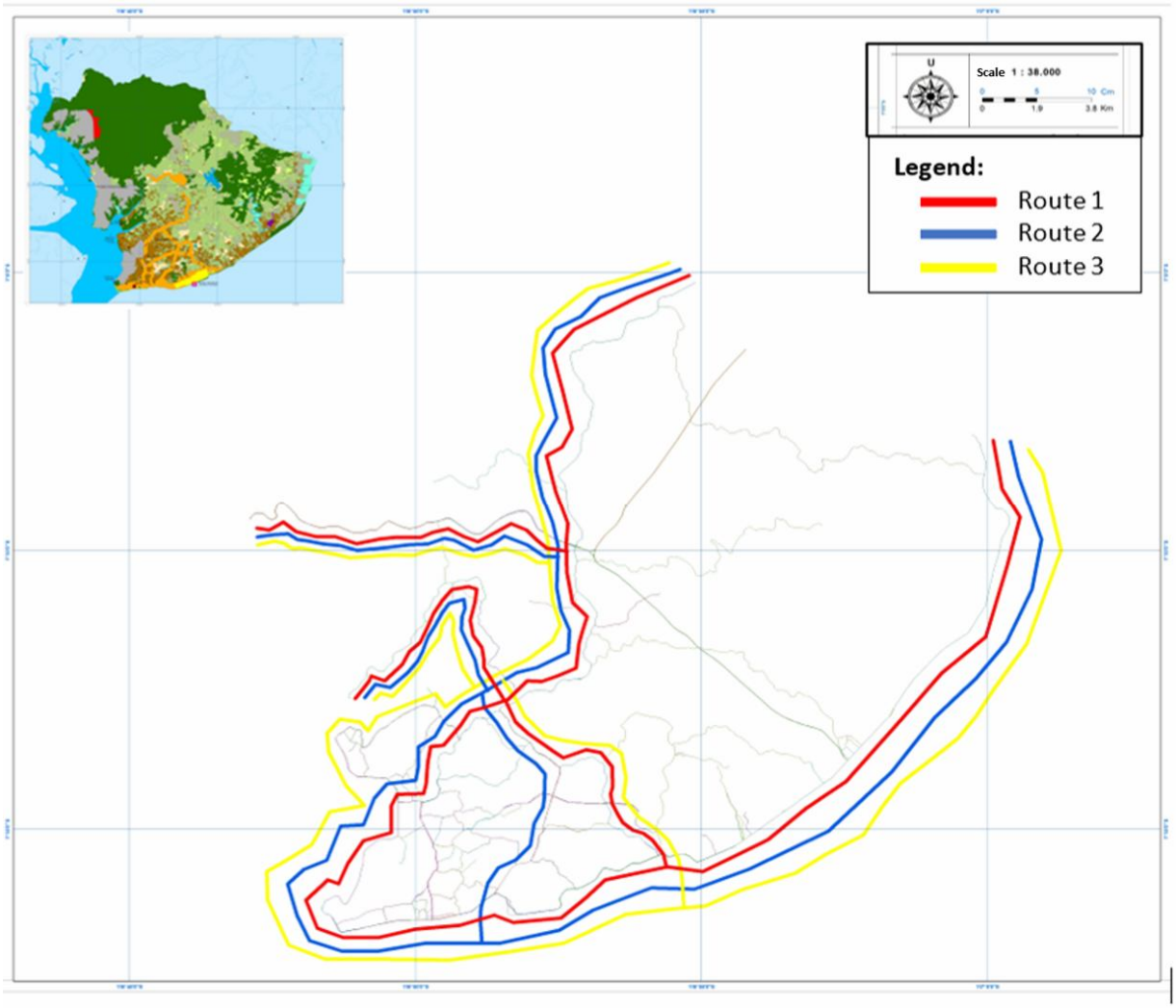

Figure 2. The alternative freight transport network.

Based on origin and destination of freight transport data, it is obtained that the trip generation and trip attraction of freight transport shows the movement pattern of freight transportation from several zones. Based on data of origin and destination of freight transport, it is found that the trip generation and trip attraction of freight transport show the freight transport movement pattern from internal zone to external zone (the highest trips is in zone 26 towards zone 42 of 451 vehicles/day), from external zone to internal zone (the highest trips in zone 42 towards zone 26 of 288 vehicles/day), from external zone to external zone (the highest trips in zone 42 toward zone 41 of 147 vehicles/day) and from internal zone to internal zone (the highest trips in zone 12 toward zone 29 of 11vehicles/day). Based on the freight transport movement pattern we obtained three alternative routes (Figure 2).

The result of the inventory survey, based on Indonesian Government Regulation about road classification, freight transport network is defined by road geometric conditions. The geometric condition consists of the road function, road type, road lane width, maximum vehicle dimensions, and Heaviest Axle Load (Indonesian Regulation No. 22 of 2009). The data from the traffic survey results are processed using VISUM software to obtain existing road network performance in Balikpapan city, where the travel time is 23 hours 31 minutes, travel distance 1019.8 SMP-km, and the average network speeds is 34.62 km/hours.

Results and Discussion

Analysis hierarchy process (AHP). The factors that influence the determination of freight transport routes are used as criteria and sub-criteria. By using AHP method (Saaty 1994) determination of freight transport networt is planned by using several criteria, which are road performance, land use, and air Pollution. Each criterion has 3 sub criteria.

Road performance. Road performance is the ability of the road segment to serve traffic flows that occur on that road. Road performance is determined by capacity, degree of saturation (DS), average speed and travel time (Hanif et al 2021; Sari & Hidayat 2020). In determining the freight transport network, road performance parameters are Volume per capacity (V/C) ratio, travel distance, travel time, and average speeds (MKJI 1997). Data analysis for road network performance on each route is sh own in Table 1.

Table 1

Road network performance

Alternative	*V/C Ratio*	*Travel distance (km)*	*Travel time (hours)*	*Average speed (kph)*
Route 1	0.61	873.14	19:22	41.18
Route 2	0.63	871.53	19:18	41.15
Route 3	0.56	714.49	16:39	40.89

Land use. With the gradual concentration of manufacturing in massive units, urban residents unexpectedly increased at the rate of that in rural areas, and the suitable movement of employees and commodity became a necessary urban feature (Laterrasse 2019). The movement pattern of freight transport is analyzed based on the number of trips based on the zone passed, the trip generation of freight transport, and the attraction of freight transport. Data analysis for road network performance on each route is shown in Table 2. Based on existing land use, the freight transport network gets through an industrial area, residential area, and commercial and service area (Table 3).

Table 2

The movement pattern of freight transport base on land use

Alternative	*Total trips (vehicle/day)*	*Trip generation (vehicle/day)*	*Trip attraction (vehicle/day)*	*Number of zones traversed*
Route 1	2,860	1,496	1,363	20
Route 2	2,923	1,517	1,405	21
Route 3	3,636	2,027	1,609	25

Table 3

Land use activities that are passed by freight transport

Alternative	*Industrial area (%)*	*Residential area (%)*	*Education area (%)*
Route 1	65	30	5
Route 2	40	35	25
Route 3	35	60	5

Air pollution. Environmental aspects that are considered in determining the freight transport network are air pollution caused by freight transport, which consists of the value of CO, NOx, and S (smoke level) (NCFRP 2013). Distribution of goods in Balikpapan city, the proportion of vehicles used is 48% pick-up, 1% small trucks, 28% medium trucks, 19% cargo trucks, and 4% trailers. This type of vehicle affects the levels of each pollutant that causes air pollution (Krzyzanowski et al 2005). In correlation between CO and vehicle speed the slope of the vertical alignment of the road affects CO levels, where

the increase in vehicle speed will be increase the CO level contents that produced from fuel and air exhausted (Sari et al 2018).

The pairwise comparisons matrix. Each criterion in the hierarchy must be known by its weight relative to each other, so it is needed a scale of numbers that show how many times greater necessary or dominant one aspect is over any other aspect related to the criteria or property related to which they are compared. The fundamental scale of the absolute numbers used is obtained from the Pairwise Comparisons Matrix desk by Saaty (1994).

The Pairwise Comparisons Matrix for the criterion related to the purpose is shown in Table 4, and for the sub-criteria, is shown in Table 5, Table 6, and Table 7. The Consistency Ratio (CR) value is used to check the consistency of the hierarchy, if the value is more than 10% then the assessment of the data must be corrected. However, if CR < 0.1 the calculation results can be declared correct.

Table 4

Pairwise Comparisons Matrix of the major criterion related to the purpose

Criterion	*Road performance*	*Land used*	*Air pollution*	*TPV*	*CR*
Road performance	1.00	3.00	0.14	0.37	-0.01
Land used	0.33	1.00	1.00	0.27	-0.01
Air pollution	1.00	1.00	1.00	0.37	-0.01

According to the Pairwise Comparisons Matrix of the major criterion related to the purpose obtained total priority vector (TPV) for road performance 37%, land use 27% and air pollution 37%. It means that the criterion for road performance and air pollution are considered more important than land use.

Table 5

Pairwise Comparison Matrix for the sub-criterion related to road performance

Road performance	*Travel distance*	*Travel time*	*Average speeds*	*TPV*	*CR*
Travel distance	1	0.20	3	0.19	0.10
Travel time	5	1	7	0.72	0.10
Average speed	0.33	0.14	1	0.08	0.10

As shown in Table 5, it can be interpreted that travel time more important than other sub-criteria related to road performance. In Table 6, the determination of TPV of the industrial area of 69%, it means the industrial area more important related to land use.

Table 6

Pairwise Comparison Matrix for the sub-criterion related to land use

Land use	*Industrial*	*Residential*	*Commercial and service*	*TPV*	*CR*
Industrial	1	9	3	0.69	0
Residential	0.11	1	0.33	0.08	0
Commercial and service	0.33	3	1	0.23	0

Pairwise Comparison Matrix for the sub-criterion related to air pollution in Table 7, TPV of CO is 66%, which means the impact of CO is considered the most dangerous compared to other pollutants.

Table 7

Pairwise Comparison Matrix for the sub-criterion related to air pollution

Air pollution	*CO*	*NOx*	*S*	*TPV*	*CR*
CO	1	5	3	0.66	0.04
NOx	0.20	1	1	0.16	0.04
S	0.33	1	1	0.19	0.04

Consistency Random Index for n value, where n is three, then Random Index (RI) is 0.58. The consistency ratio of the criteria matrix value is below 0.1, which indicating that the consistency is right or acceptable. The Pairwise Comparison Matrix is considered consistent if the value of the Consistency Ratio (CR) is below or equal to 0.1.

Determine the eigenvectors to get the final priority of the criteria, each ranking is based on the priority of the criteria or sub-criteria and adds the resulting weight (Table 8).

Table 8

Determination of eigen vector for each criterion and sub-criteria

Criterion	*Road performance*			*Land use*			*Air pollution*		
Weight	*0.37*			*0.27*			*0.37*		
Sub-criteria	*Travel distance*	*Travel time*	*Average speeds*	*Industrial*	*Residential*	*Commercial & Service*	*Co*	*NOx*	*S*
Weights	0.19	0.72	0.08	0.69	0.08	0.23	0.66	0.16	0.19
Route 1	0.02	0.02	0.02	0.25	0.25	0.08	0.24	0.07	0.24
Route 2	0.07	0.26	0.07	0.08	0.08	0.02	0.04	0.04	0.04
Route 3	0.26	0.07	0.26	0.02	0.02	0.25	0.07	0.24	0.07

Eigenvector calculation determines the ranking of the alternative choices for each criterion, as shown in Table 9.

Table 9

Total Score and Priority Ranking of Alternative Routes

Alternative	*TPV*	*Ranking*
Route 1	0.40	2
Route 2	0.20	3
Route 3	0.42	1

The result of AHP method selected Route 3 as a route for the freight transport network in Balikpapan, the analysis results of road network performance are travel time 21 hours 9 minutes, travel distance 902.6 km, and average speed 35.22 km/hours.

Conclusions. The results of the priority vector assessment are obtained from the selected freight transport network get through Soekarno-Hatta Street, Syarifudin Yoes Street, MT. Haryono Street, Mulawarman Street, Marsma R. Iswahyudi Street, Jendral Sudirman Street, Yos Sudarso Street, Woltemongononsidi Street, Baru Street, A.W Syahrani KM 5,5 Kariangau Street, and Pendekat KM 13 Pulau Balang Street. The travel time increased 2%, travel distance decreased 11.5%, and average speeds increased 8.5% compared to road network performance in Balikpapan city. Based on the land use of selected freight transportation routes, it can be seen that the percentage of land use in industrial area 35%, residential area 60%, and education area 5%. The analysis of gas emission obtained value of CO, NOx, and S (smoke level).

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