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https://doi.org/10.5109/7183408

出版情報：Evergreen. 11 (2), pp.1081-1088, 2024-06. 九州大学グリーンテクノロジー研究教育センター
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Evaluating Environmental Impacts of Green Logistics Initiatives in Batam Indonesia

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(Received December 22, 2023; Revised February 23, 2023; Accepted March 10, 2024).

Abstract: Green Logistics has become a crucial solution in city logistics systems for solving environmental issues. This research aims to measure the effectiveness of Green Logistics initiatives in Batam City as a pilot project for the National Logistics Ecosystems of Indonesia using vehicle emissions and noise level analysis and a simulation-based approach. The result indicated that the Joint Delivery Systems with Urban Consolidation Center (JDS-UCC) is better at reducing pollution compared to the Limited Emissions Zone and the Limited Traffic Zone as it can reduce the number of trucks and fuel consumption. However, in the severe level of pollution, the JDS-UCC needs to be combined with planting *Trembesi* (*Albizia Saman*) trees to effectively reduce the emissions and absorb the noise pollution.

Keywords: city logistics, environmental emissions, freight transport, green logistics initiatives.

1. Introduction

Urbanization has transferred the population density from rural to city. About 70% of the world's population will live in the cities by 2050[1]. As an impact, it would increase the city logistics activities to meet the customers' needs due to a close relationship between economic development and logistics consumption[2]. Moreover, E-commerce is one of the rapidly growing sectors in Indonesia[3]. The urban area will rely on freight transportation systems to collect and distribute goods needed by manufacturers, construction companies, industries, and households. Therefore, freight transportation as the main part of city logistics is essential to support a city's and a country's economic development.

Freight transportation in Indonesia resulted in 11.63 Mtons of CO_2 emissions, or around 8.1% of the total CO_2 emissions from the transportation sector[4]. To reduce the negative environmental impacts of freight delivery, numerous city logistics policies have been proposed and implemented in several cities, including the Green Logistics Initiatives[5]. It is a concept of logistics activities that aims to reduce environmental pollution and resource consumption by using modern logistics technology, transportation planning, storage, packaging, processing, and distribution methods that are environmentally friendly[6,7]

The Joint Delivery Systems with Urban Consolidation Center (JDS-UCC), The Limited Traffic Zone (LTZ)[8,9], and The Limited Emissions Zone (LEZ)[10] are the forceful actions that can optimally reduce the negative impacts of emissions from freight transport. As a combination, Planting Programs such as planting trees, named "Trembesi" in the Indonesian language(*Albizia Saman*) also be solutions to absorb the noise pollution generated by freight transport[11]. Previous works used Data Envelopment Analysis (DEA)[12], experimental investigations method[13], optimization techniques[14], and machine learning[15], to measure efficiency and effectiveness in logistics activity.

The concept of green logistics is being seriously implemented in Batam City, to support the Batam Logistic Ecosystem (BLE) program, which is part of the pilot project National Logistic Ecosystem (NLE) of Indonesia. One of the main ports in Batam is Batu Ampar Port, which attracts and generates huge movement of freight transport. The high volume of freight transport causes congestion, air pollution, and noise pollution on Yos Sudarso Street as the primary arterial road and also the only main road to access Batu Ampar Port. These negative impacts are possibly even worse due to the variety and density of land uses along Yos Sudarso Street such as settlements, offices, schools, industrial, and business districts.

The effectiveness measurement of each solution in The Green Logistics Initiatives is an important process before it can be optimally implemented due to their implications for stakeholders[8]. It is even more challenging due to the different characteristics of activities, infrastructure, land uses, and freight transport systems. This study, therefore, aims to measure the effectiveness of each possible green logistics initiative to reduce emissions and noise by freight transport in Batam City, Indonesia, as a case study using Emissions Analysis and simulation approaches. The optimal and effective Green Logistics Initiatives measured in this research contribute to a better decision-making process to accommodate local needs and problems of the logistics environment.

2. Theoretical review

2.1 Green Logistics

The term "green logistics" is defined as supply chain management practices and strategies that reduce the environmental and energy footprint of freight distribution, which focuses on material handling, waste management, packaging, and transport[16]. Green logistics activities include measuring the environmental impact of different distribution strategies, reducing the energy usage in logistics activities, reducing waste, and managing its treatment[17]. The Green Logistics initiatives should accommodate, motivate, and guide the researchers and practitioners to plan, implement, and evaluate the green logistics measures to make cities liveable and sustainable.

In Indonesia, the emissions from goods transportation are expected to increase by 80% in 2030[18], thus, green logistics is urgently needed in urban and transportation planning due to the social, economic, and environmental impacts related to it. Many green logistics policies have been issued by the policy-maker or city government to reduce the negative environmental impacts of logistics activity, including JDS-UCC, LEZ, LTZ, and planting trees as explained in the following.

2.2 JDS-UCC

A UCC is explained as a logistics facility that is located relatively near to the urban area that it serves such as a city center, a regional, or a specific land use (e.g. a shopping center, airport, terminal, or industrial site)[19]. UCC needs to be established before implementing the JDS measure. JDS is an option for collecting and delivering goods to and from customers promoted by the UCC, instead of distributing the goods directly to their customers. The commitment and cooperation of freight carriers and other stakeholders in JDS are vital to the success of JDS-UCC measures.

The policy of JDS-UCC has been implemented in several countries, including Japan[8], the UK[20], the Netherlands[21], and France[22]. The previous research also has described the benefits of using JDS-UCC to the environment. JDS-UCC further diminishes pollution by providing the uses of environmentally friendly vehicles such as electric and gas-powered trucks, and electrically-assisted tricycles instead of using diesel trucks, and resulted in the reduction of working hours of employees at peak times, since the goods are delivered by UCC[23].

The goal of JDS-UCC is to enhance the effectiveness and efficiency of goods delivery as well as to reduce the negative environmental impacts, alleviate congestion, and improve safety, and security in urban areas by avoiding the need for many freight vehicles to deliver products entering in the congested or dense urban areas.

Figure 1 describes the procedures of JDS-UCC which has been implemented in Motomachi Shopping Street, Yokohama, Japan. An UCC, which is located in or near a city, acts as a central hub for receiving, sorting, and consolidating goods from multiple suppliers before delivering them to their final destinations within the urban area. UCCs receive shipments from various suppliers, including manufacturers, wholesalers, and distributors. Goods are sorted based on their final destination and combined onto fewer, larger vehicles for final delivery. This reduces the number of individual delivery trucks entering the city, leading to several benefits. The consolidated shipments are then delivered to their final destinations within the city by smaller, more efficient vehicles, such as cargo bikes, electric vans, and shared low emissions vehicles such as Compressed Natural Gas (CNG) trucks. Therefore, the concept of JDS-UCC has positive impacts to the environment by consolidating deliveries, UCCs can significantly reduce the number of delivery trucks on the road, leading to less traffic congestion and improved air quality. Fewer trucks mean fewer emissions, which is beneficial for both the environment and public health.

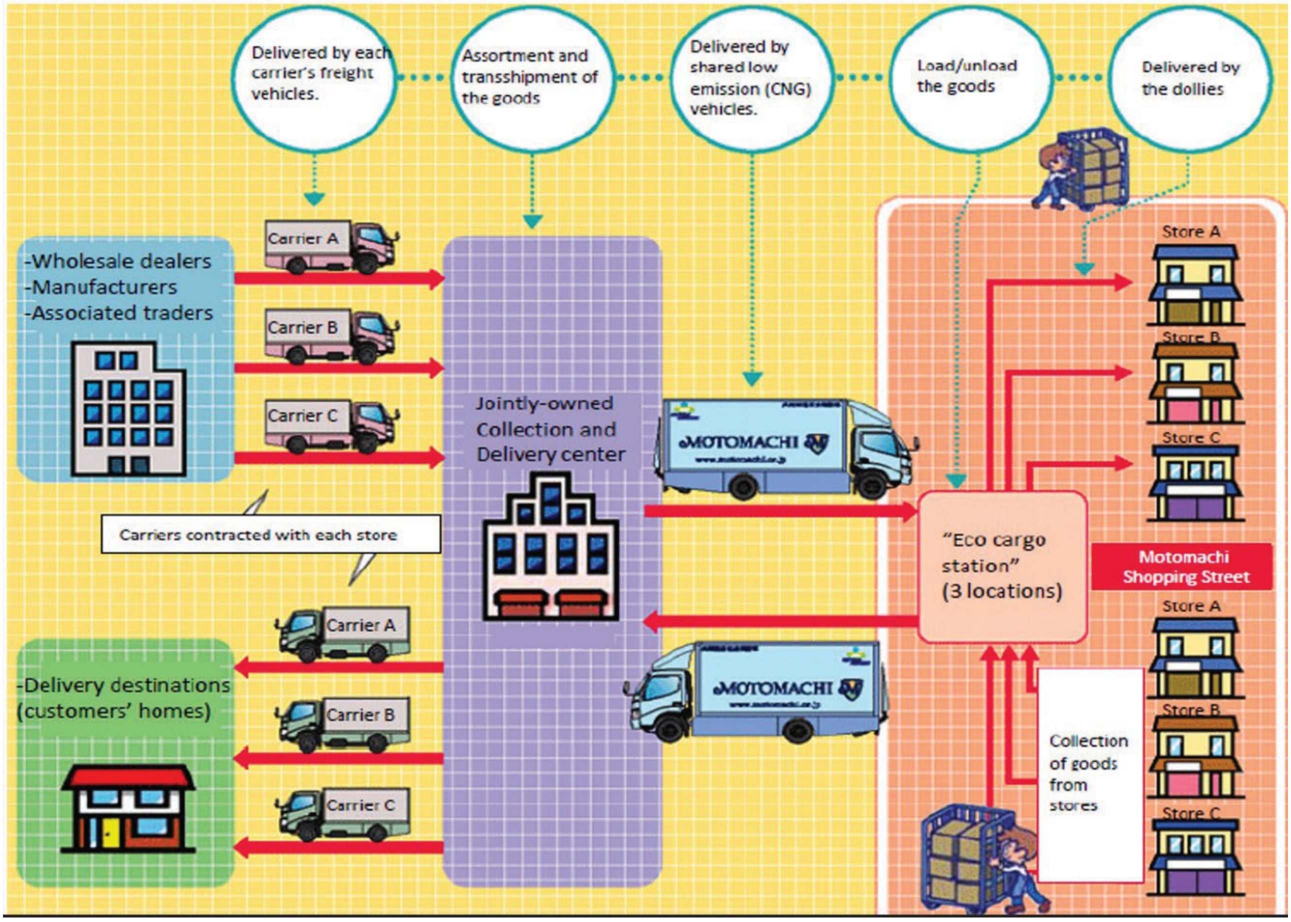

Fig. 1: The concept of joint delivery systems in Motomachi, Yokohama, Japan (Motomachi shopping street association)[24].

However, some UCCs failed to survive due to the low participation and the low commitment of city logistics stakeholders[25]. Supportive regulation, policy, and subsidies are required for the successful and sustainable implementation of JDS-UCC. However, JDS-UCC has not been implemented in Indonesia yet. Therefore, this research used a simulation method to measure the effectiveness of JDS-UCC in reducing environmental impacts by freight transport in Indonesia.

2.3 LEZ

LEZ is one of the solutions in city logistics management to improve the quality of the environment by controlling the emissions in designated areas[10]. Usually, the LEZ controls emissions by implementing restrictions on the movement of freight transport within targeted areas, as it produces the highest pollution to the environment. The designated areas for LEZ scope are usually decided on the pollution level[10]. The higher pollution levels are the highest priority for LEZ implementation. LEZ has been successfully implemented in several cities in Europe, such as Stockholm, Gothenburg, Malmo, and Lund[26].

2.4 LTZ

LTZ is a form of green logistics concept that aims to limit vehicle movement or access to certain areas to reduce emissions. The restrictions imposed may include time, cost, and emission. The implementation of LTZ also has another positive impact in the form of minimizing road damage due to the presence of goods transport which usually has an excess load from the existing capacity[9]. LTZ's main goal is reducing congestion, air pollution, and noise[27].

2.5 Tree planting

Planting vegetation or trees on the side of the road is a form of control over the environment, especially on roads that have high vehicle volumes and heavy traffic[11]. The presence of vegetation or plants can help reduce vehicle emissions, especially the CO[28]. Moreover, vegetation that has a dense leaf mass and a thick appearance or title such as the *Trembesi* tree can absorb emissions, sound, and wind optimally[11].

2.6 Best practices on the effectiveness of green logistics initiatives

The effectiveness measurement of green logistics initiatives has been measured and reported in many countries as shown in Table 1. In this research, the effectiveness percentage for each green logistics initiatives are assumed based on the results of many best practices described in Table 1.

Table 1. Best practices on the effectiveness of green logistics initiatives

Initiatives	Effectiveness Results
JDS-UCC	Location: Costa Cabral Street[29] • Increasing average speed by 49% • Reducing travel time by 55%
	Location: Antwerp, Belgium[30] • Reducing fuel consumption by 36,4%
	Location: Gothenburg, Swedia (Stadsleveransen UCC)[31] • Reducing noise level by 3 dB(A)
	Location: Tokyo[32] • Reducing truck volume by 50 vehicles/day
	Location: London (London Borough Consolidation Centre)[32] • Reducing NOx emissions by 51% • Reducing SPM emissions by 61% • Reducing the number of vehicle trips by 46% • Reducing distance travelled by 45%
	Location: Bandung, Indonesia[18] • Reducing emissions of CO, NOx, and SPM by 21,92% per year
LEZ	Location: Costa Cabral Street[29] • Increasing average speed by 10% • Reducing travel time by 12%
	Location: London[33] • Reducing noise level by less than 0,5 dB(A)
	Location: London[33] • Reducing emissions NOx by 36% • Reducing emissions SPM by 2,46% - 3,07% • Reducing congestion level from 3% to 9%
	Location: Madrid[34] • Reducing air pollution by 40%
	Location: Paris[34] • Reducing emissions NOx by 15% • Reducing emissions SPM by 11%
LTZ	Location: Roma[34] • Reducing congestion level by13% • Reducing freight vehicle volume up to 13.000 – 10.000 per day
	Location: New York[34] • Reducing emissions NOx by 50-60%
	Location: Turin (Italia)[35] • Increasing average speed by 20%
	Location: Naples, Italia[33] • Reducing noise level by 3 dB(A)
Tree Planting	Taiwan Beauty tree can absorb NOx by 65,2%[11]
	Iriansis plant can absorb CO emissions by 88,61%[11]
	10 years old Trembesi (*Albizia Saman*) tree can absorb CO emissions by 28.448,39 kg/tree/year[36]
	Pringgodani Bamboo can absorb noise levels by 0,0786 dB(A)[37]
	Location: Gorontalo, Indonesia Trembesi (*Albizia Saman*) tree can absorb noise by 7,3 dB(A) – 16 dB(A)[38]

3. Research methods

3.1 Data collection and variables.

The research is quantitative research using Vehicle Emissions Analysis and Noise Level Analysis to evaluate changes in environmental quality caused by the movement of goods transportation. Table 2 described the variables used in this research.

Table 2. Research variables

No	Variable
1.	Fuel consumption[39]
2.	Emission factor[39]
3.	Fuel density[39]
4.	Fuel economy[39]
5.	Length of the road[40]
6.	Speed of the vehicle[40]
7.	Noice frequency[41]

Variables related to the calculation of emissions and noise include CO, HC (hydrocarbon), NOx (nitrogen oxide), and SPM (Suspended Particular Matter). Those variables are calculated from the data length of the road, vehicle speed, truck volume and types, emissions factors, and fuels used by freight transport in Yos Sudarso Street during peak hours.

3.1. Emissions and Noise Analysis

The CO and HC parameters are calculated using the IPCC Tier 1 method[39] as equations (1) and (2) below;

$$CO = DAxFEx\rho \quad (1)$$

$$HC = DAxFExEBB \quad (2)$$

Where; CO is the total CO emissions (g/km), HC is the total HC emissions (g/km), DA is the fuel consumption (l/km), FE is the emission factor (g/kg), ρ is the density of fuel (kg/l), and EBB is the fuel economy (km/l). The International standard of CO emissions factor is 0.18023617 g/km and the emission factor for HC is 0.29 g/mile for diesel fuel[42].

The NILIM-based equation[40] used to calculate the NOx and SPM is expressed in equations (3) and (4) below;

$$NO_x = l_{ij}(1.06116 + 0.000213v_{ij}^2 - 0.0246v_{ij} + \frac{16.258}{v_{ij}} \quad (3)$$

$$SPM = l_{ij}(0.03442 + 0.000039391v_{ij}^2 - 0.0036777v_{ij} + \frac{1.2754}{v_{ij}} \quad (4)$$

where l_{ij} is the length of the road between nodes i and j in kilometers and v_{ij} is the speed of the vehicle traveling on the road between nodes i and j in kilometers per hour.

A sound level meter is used to measure the noise intensity between 30 to 130 dBA from a frequency of 20 to 20,000 Hz during 24 hours of measurement[42]. The average noise level (L_{eq}) for 1 minute is calculated using equation (5)[41] below;

$$L_{eq}\ (1\ \text{min}) = 10\ \log\frac{1}{60}\ [(10^{0,1\ L1}) + (10^{0,1\ L2}) + \cdots + (10^{0,1\ L12})5] \quad (5)$$

Calculation of L_{eq} (1 min) is carried out 10 times until the 10th minute and continued by calculating the average noise level for the day (07.00 a.m. to 08.00 p.m.) and the night (11.00 p.m. to 04.00 a.m.) using equations (6) and (7).

$$L_{eq}\ (\text{day}(16\ \text{hours})) = 10\ \log\frac{1}{16}\ [(Ta10^{0,1\ La}) + \cdots + (Td10^{0,1\ Ld})]\ dB(A) \quad (6)$$

$$L_{eq}\ (\text{night}(8\ \text{hours})) = 10\ \log\frac{1}{8}\ [(Te10^{0,1\ Le}) + \cdots + (Tg10^{0,1\ L})]\ dB(A) \quad (7)$$

As the results, the L_{eq} for 24 hours is collected using equation (8) and it will be compared or evaluated using Indonesian noise quality standard[41].

$$L_{eq}\ (24\ \text{hours}) = 10\ \log\frac{1}{24}\ [(16x10^{0,1\ Ls}) + \cdots + (8x10^{0,1\ LM})]\ dB(A) \quad (8)$$

4. Research results and discussion

4.1 Emissions and noise level

The calculation results showed that the total average of CO, HC, NOx, and SPM emissions produced by freight vehicles on Yos Sudarso Street has exceeded the standard level as Table 3 below;

Table 3. The total emissions produced by freight transport

Emissions level (gr/km)		Standard (gr/km)
CO	1.714643733	0.74
HC	0.209434684	0.07
NOx	1.056670175	0.39
SPM	0.151826105	0.06

The results indicated that Yos Sudarso Street is very polluted by the freight transport emissions.

Moreover, the noise analysis also shows that the noise level for the 24-hour average exceeds the standard value, even after being tolerated by +3 dB(A). The highest average 24-hour noise level is captured in the business and trade area along Yos Sudarso Street which reaches 83.40 dB(A), whereas the standard is only 70 dB(A).

These two results indicated that Yos Sudarso Street has a very serious problem of environmental pollution, either emissions or noise by freight transport. Therefore, the implementation of green logistics initiatives is urgently needed in Yos Sudarso Street to improve the quality of the environment.

4.2 Simulation results

In order to measure the effectiveness of green logistics initiatives, this research undertook simulation using four green logistics implementation scenarios; (1) JDS-UCC; (2) LEZ; (3) LTZ; (4) Planting *Trembesi* tree. The simulation's assumptions and parameter were compared and selected from the best practices results as shown in Table 1 in the literature review section.

The reduction of CO, HC, NOx, SPM emissions and noise level in Yos Sudarso Street were explained in Table 4 to Table 8.

Table 4. Simulation results of CO Emissions in Yos Sudarso Street

	JDS-UCC	LEZ	LTZ	Planting *Trembesi* tree
CO level	1.09 gr/ km	1.44 gr/ km	No experiences	7.793,97 g/tree/day
Standard	0.74 gr/ km	0.74 gr/ km	0.74 gr/ km	0.74 gr/ km
Results	Not effective	Not effective	-	Effective

Table 5. Simulation results of HC Emissions in Yos Sudarso Street

	JDS-UCC	LEZ	LTZ	Planting *Trembesi* (*Albizia Saman*) tree
HC level	0.139 gr/ km	0.176 gr/ km	No experiences	7.793,97 g/tree/day
Standard	0.07 gr/ km	0.07 gr/ km	0.07 gr/ km	0.07 gr/ km
Results	Not effective	Not effective	-	Effective

Table 6. Simulation results of NOx Emissions in Yos Sudarso Street

	JDS-UCC	LEZ	LTZ	Planting *Trembesi* (*Albizia Saman*) tree
NOx level	0.756 gr/ km	0.977 gr/ km	0.9083 gr/ km	7.793,97 g/tree/day
Standard	0.39 gr/ km	0.39 gr/ km	0.39 gr/ km	0.39 gr/ km
Results	Not effective	Not effective	Not effective	Effective

Table 7. Simulation results of SPM Emissions in Yos Sudarso Street

	JDS-UCC	LEZ	LTZ	Planting *Trembesi* (*Albizia Saman*) tree
SPM level	0.1476 gr/ km	0.1516 gr/ km	0.1511 gr/ km	7.793,97 g/tree/day
Standard	0.06 gr/ km	0.06 gr/ km	0.06 gr/ km	0.06 gr/ km
Results	Not effective	Not effective	Not effective	Effective

Table 8. Simulation results of noise level in Yos Sudarso Street

	JDS-UCC	LEZ	LTZ	Planting *Trembesi* (*Albizia Saman*) tree
Noise level	80.4 dB(A)	80.4 dB(A)	80.4 dB(A)	67.4 dB(A)
Standard	70 dB(A)	70 dB(A)	70 dB(A)	70 dB(A)
Results	Effective	Not effective	Not effective	Effective

The simulation's results in Table 4 to 8 indicated that the most effective solution for reducing CO, HC, NOx, and SPM from the movement of freight transport is planting a special tree named *Trembesi* (*Albizia Saman*) tree as it can absorb emissions and noise pollution significantly. However, planting 1 *Trembesi* (*Albizia Saman*) tree takes at least 10 years to be fully functional. It needs to be combined with other green logistics initiatives.

However, Table 4 to 8 also also figured out that the implementation of JDS-UCC is better for reducing the emissions and noise levels compared to LEZ and LTZ. Therefore, in the case of Yos Sudarso Street, where the pollution level is high, the JDS-UCC must be combined with planting *Trembesi* (*Albizia Saman*) trees in order to effectively reduce the environmental impacts of freight transport. This research demonstrated that the implementation of green logistics initiatives contributes to mitigate the climate change.

5. Conclusions

The emissions and noise analysis using IPCC method indicated severe pollution levels in Yos Sudarso Street, Batam City, Indonesia, which mainly caused by the very intense activities of freight transport. The simulation results indicated that The JDS-UCC is effective at reducing environmental emissions and noises compared to LEZ and LTZ as it can reduce the number of trucks and fuel consumption. However, in the severe level of pollution, the JDS-UCC needs to be combined with planting *Trembesi* (*Albizia Saman* trees to effectively reduce the emissions and absorb the noise pollution.

We acknowledge a limitation of our study in that it only measures JDS-UCC, LTZ, LEZ and planting trees. Future research could aim to evaluate more green logistics initiatives related to environmental issues.

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