Freight shipper's mode choice preference for sustainable inland transportation

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Abstract. Modelling of transport mode choice preference has been currently regarded essential to identify the preference of transport agents towards a transport policy. This research proposes a model of the freight mode choice preference by using Stated Preference Methods for the data collection from industrial freight shippers in Gresik, Indonesia. This research examines how truck as an existing mode and rail as a sustainable mode alternative compete for goods movement. As the common feature of discrete choice models, the Binary Logit was utilized to analyze the data. The sensitivity of mode preferences was investigated by changing the shipping cost and hauling time. The results indicated that the respondents were sensitive to haul time and shipping cost. When the shipping cost and hauling time was similar, the probability of choosing a truck was 77%. However, the industrial freight shippers changed the preference when the truck's shipping cost and haul time was higher than that in the train. The train had a 65% choosing probability when the cost difference was IDR 500,000 lower and the hauling time difference was two days faster than the truck. This study assisted the policymakers to correctly design the variables of shipping cost and hauling time for the future sustainable inland transportation based on freight shipper's preferences.

1. Introduction

The urban area has relied on freight transportation systems to collect and distribute goods necessitated by the industries, manufacturers, construction companies, and households. Therefore, sustainability and Industry 4.0 have presented a prevalent issue in the literature due to their close social, economic, and environmental aspects. Further, sustainable Industry 4.0 is included in the Sustainable Development Goals for 2030, proposed by the United Nations, supporting all the sustainable policies related to minimizing the impacts of industrial processes, such as promoting sustainable freight transportation. Approximately 90% of freight transportations in Indonesia include road transportation, particularly 70% dominated by trucks [1]. However, the over-usage of trucks has led to issues, such as: congestion, road damage, accidents, and pollutions, due to the everyday use of over-dimension and overload trucks. Moreover, road transportation emissions are 92% from the total transport sector emissions, and 28% are from the road freight transportation [2]. Therefore, the most significant consequence of using roads for freight transport lies in the sustainability [3].

On the other hand, freight transportation by rail offers an alternative model for modifying and minimizing the use of trucks for transporting industrial goods. Rail transportation is considered to be more sustainable than trucks. The external costs of trucking were over three times than those of rail [4]. Efficiency in city logistics delivery refers to the use of few vehicles and resources, proper utilization of
the vehicle's capacity, and minimum usage of fuel or energy, thereby reducing the negative environmental impacts as well as saving time and costs. Comprehensive and integrated transportation infrastructure is linked with lower transportation costs [5]. For this reason, a more sustainable alternative mode of transportation is deemed necessary to create a more environmentally friendly freight transportation.

Modelling of transport mode choice is deemed essential to identify the preference of transport agents towards a transport policy. Therefore, studying freight shipper's mode choice preferences is encouraged to achieve a sustainable inland transportation policy. This research modelled the freight mode choice preference by utilizing Stated Preference Methods to collect the data from industrial freight shippers in Gresik, Indonesia. In addition, this research examines how truck as an existing mode and rail as a sustainable mode alternative could compete for goods movement.

2. Methods
For sustainable transportation, the researcher examined that a more certain logistics mode can be conducted by urban rail freight transportation, which supplements the traditional road-based logistics hierarchy, effectively promoting cities’ sustainable development [6]. This research modelled the freight mode choice preference by using Stated Preference Methods to collect the data from industrial freight shippers and examines how trucks as an existing mode and rail as a sustainable mode alternative could compete for goods movement. As the common feature of discrete choice models, the Binary Logit was applied to analyze the data. The sensitivity of mode choice preferences was investigated by shifting the shipping cost and hauling time. Furthermore, freight transportation by rail is proved to be more sustainable than using a fleet of trucks for shipping.

2.1. A Stated Preference (SP)
Stated Preference technique based on demand estimation in an analysis of responses to hypothetical choices, such as in facilities, are considerably not ready (in the planning), unable to predict the variables, further applied to build the model, required when compiling hypothetical conditions. The survey is conducted based on the behaviour of the market reach, based on existing zones of origin-destination, related to the quantities described on the attributes of each mode of transportation. The survey was conducted based on (hypothesis) the reliable characteristics of the new model variables to construct the model (previously determined when compiling hypothetical conditions). An experiment might present a significant gap in individuals’ actual and preferred choices. SP surveys enable a wide range of situations to be investigated, which may not be measured when observing the actual behaviour [7].

In this research, SP survey utilizes a questionnaire technique by constructing the alternative hypothetical shipping situations as a combination of changes in the service attributes for the truck as an existing mode and rail as a sustainable mode alternative competing for goods movement, further tested on respondents by using interviews or distributing questionnaires to navigate the freight mode choice preference of industrial freight shippers in Gresik Industrial Area.

The obtained data is primary data derived from the survey results; the macro data is resorted to obtain the required data. Firstly, the macro data process is conducted by identifying any attributes that affect the choice of modes. For example, in the literature, cost and time are the most common factors influencing mode choice [8-13]. Therefore, in this research, those two variables were questioned to the respondents to model the preference of mode choice between truck and train.

The SP survey with Respondents' opinions regarding the question of mode selection in industrial freight shippers in Gresik consists of 5 answer scale choices with the following questions:
1) Option 1: Choose to use a truck;
2) Option 2: Maybe choose to use a truck;
3) Choice 3: Balanced choice;
4) Option 4: Maybe choose to use the train; and
5) Option 5: Choose to use the train.
The mode selection model determines the respondents' preferences to choose between truck and rail transportation. The preference is determined by the influence of the haul time difference and the shipping cost difference between truck and rail transportation. Respondents could choose preferences based on a scale of 1-5 options that have been provided. The choice scale or probability scale is then converted into a utility value (quantitative scale).

Table 1: Transforming qualitative to quantitative scale

| Scale | Preference                        | Probability Scale (P) | Utility Ln (p/1-p) |
|-------|----------------------------------|-----------------------|-------------------|
| 1     | Choose to use a truck            | 0.9                   | 2.1972            |
| 2     | Maybe choose to use a truck      | 0.7                   | 0.8473            |
| 3     | Balanced choice                  | 0.5                   | 0.0000            |
| 4     | Maybe choose to use the train    | 0.3                   | -0.8473           |
| 5     | Choose to use the train          | 0.1                   | -2.1972           |

Source: [14]

The scale obtained from the respondents is further utilized to construct the model. In this research, Logistic Regression is accustomed to calculate the probability of a specific categorical event depending on the values of independent variables consisting of the difference in the cost of shipping ($X_1$) and the difference between a truck and train haul times ($X_2$). As the common feature of discrete choice models, the Binary Logit was utilized to analyze the data [15]. The sensitivity of mode choice preferences was investigated by gradually changing the shipping cost and haul time. Freight shipper's mode choice preference model was constructed by using SPSS Software.

The values of the constants and coefficients are applied to construct a utility ($U$) and probability ($P$) of model equation as follows.

$$(U_{\text{truck}} - U_{\text{train}}) = b_0 + b_1(X_1) + b_2(X_2)$$

(1)

in which:

$U_{\text{truck}}$ is the trucking utility value.

$U_{\text{train}}$ is the train utility value.

$b_0$ is model constant,

$b_{1,2,3}$ is variable coefficient.

$X_1$ is defined as the difference in the cost of shipping between trucks and trains in Indonesian Rupiah (IDR)

$X_2$ is the difference between a truck and train haul times (day)

Further, the probability equation of truck and train is formulated as equations (2) and (3);

$$P_{\text{truck}} = \frac{e^{U_{\text{truck}} - U_{\text{train}}}}{1 + e^{U_{\text{truck}} - U_{\text{train}}}}$$

(2)

$$P_{\text{train}} = 1 - P_{\text{truck}}$$

(3)

This utility model is utilized to generate the probability value of model selection with the binary logit. Subsequently, the probability value is multiplied by the difference in the shipping cost of truck and train ($X_1$) and the difference between a truck and train haul times ($X_2$).

3. Results and Discussion

3.1. Freight Shipper's Mode Choice Preference for the Same Shipping Cost and Haul Time. The responses of freight shipper's mode choice preference for the exact shipping cost and haul time between truck and train is illustrated in figure 1.
Figure 1. Freight shipper's mode choice preference for the same shipping cost and haul time
Source: Author's document

About 60% of respondents choose to use a truck if there is no difference in shipping cost and haul time between truck and train. The results proved that truck is a preferred mode of freight transportation as very convenient and easy for loading and unloading goods from door to door.

Further, the data to model the choice preference of freight shippers for the exact shipping cost and haul time is analyzed by using multiple linear regression by SPSS, as illustrated in Table 2.

Table 2. Mode choice model for the exact shipping cost and haul time

| Model                          | B       | Std. Error | Beta | t      | Sig.  |
|--------------------------------|---------|------------|------|--------|-------|
| 1 (Constant)                   | 1,200   | 0,384      |      | 3,783  | 0,000 |
| Cost Difference (X₁)           | 3,276   | 0,360      | 0,394| 4,422  | 0,000 |
| Time Difference (X₂)           | -0,019  | 0,000      | -0,724| -9,605 | 0,000 |

Source: Author's document

The model coefficients and constants from Table 2 are then compiled into a utility (U) and probability (P) model.

\[ U_{truck} - U_{train} = 1,200 + 3,276 (X₁) - 0,019 (X₂). \]

The results of probability simulations using zero difference of shipping cost and hauling time are illustrated as follows.

\[ P_{truck} = \frac{e^{U_{truck} - U_{train}}}{1 + e^{U_{truck} - U_{train}}} = \frac{e^{1.200 + 3.276(0) - 0.019(0)}}{1 + e^{1.200 + 3.276(0) - 0.019(0)}} = 0.7685 = 77\% \]

\[ P_{train} = 1 - P_{truck} = 1 - 0.77 = 0.23 = 23\% \]

The results indicate that the truck has a 77% choosing probability by the freight shippers in Gresik industrial area for shipping goods when the shipping cost and haul time between truck and train are the same.

3.2. Freight Shipper's Mode Choice Preference for the Different Shipping Cost and Haul Time.
The sensitivity of mode choice preferences was investigated by changing (higher and lower) the shipping cost and haul time of truck and train. The responses of freight shipper's mode choice preferences are presented in Table 3.
Table 3. Freight shipper’s mode choice preference when the truck shipping cost is higher, and the hauling time is longer than train

| Shipping Cost Difference | Haul Time difference | Options | | | | |
|--------------------------|----------------------|---------|---------|---------|---------|---------|
|                         | (1) Choose to use a truck. | (2) Maybe choose to use a truck. | (3) Balanced choice | (4) Maybe choose to use a train. | (5) Choose to use a train |
| IDR 500,000,-           | 1 day | 0 | 0 | 20% | 62% | 18% |
|                         | 2 day | 0 | 0 | 0 | 30% | 70% |
| IDR 250,000,-           | 1 day | 5% | 55% | 40% | 0 | 0 |
|                         | 2 day | 0 | 40% | 8% | 52% | 0 |

Source: Author’s document

If the truck shipping cost is IDR 250,000 higher, and the hauling time is one day longer than the train, approximately 55% of respondents might choose to use the truck. However, when the truck shipping cost is IDR 500,000 higher and the hauling time is two days longer than the train, 70% of the respondents might use the train. The next step is conducted for modelling the choice preference of freight shippers using Multiple linear regression, as presented in Table 4.

Table 4. Mode choice model when the truck shipping cost is higher, and the hauling time is longer than the train.

| Model | Unstandardized Coefficients | Standardized Coefficients | t | Sig. |
|-------|-----------------------------|---------------------------|---|------|
|       | B                           | Std. Error                | Beta |      |
| 1     | (Constant)                  | 0,116                     | 0,500 | 5,183 | 0,000 |
|       | Cost difference             | 0,475                     | 0,104 | 0,323 | 14,610 | 0,000 |
|       | Time difference             | -0,170                    | 0,000 | -0,210 | -44,752 | 0,000 |

Source: Author’s document

The model coefficients and constants from Table 4 are then compiled into a utility (U) and probability (P) model.

\[(U_{truck} - U_{train}) = 0,116 + 0,475 (X_1) – 0,170 (X_2)\].

The probability simulations by changing the value of shipping cost difference (IDR 250,000 and IDR 500,000) and the hauling time difference (1 day and two days) to navigate the probability of choosing a truck and train, in which the results are illustrated in Table 5.

Table 5. The probability simulations results

| Cost Difference | Time Difference | P_{truck} | P_{truck} | P_{train} | P_{train} |
|-----------------|-----------------|-----------|-----------|-----------|-----------|
| IDR 500,000,-   | 1 Day           | 0.44      | 0.56      | 0.35      | 0.65      |
|                 | 2 Days           |           |           |           |           |
| IDR 250,000,-   | 0.54            | 0.46      | 0.45      | 0.55      |

Source: Author’s document
The results indicated that the mode truck's probability would decrease as the shipping cost and haul time difference increases of more than IDR 250,000 and the hauling time difference is 1 day longer than the train. The train has a 65% choosing probability when the cost difference is IDR 500,000 and the hauling time difference is two days slower than the truck.

This study is expected to assist the policymakers in designing the variables of shipping cost and hauling time for the future sustainable inland transportation. For example, approximately 65% probability of the freight shippers in Gresik Industrial Area will choose train when the cost difference is IDR 500,000 and the hauling time difference is two days slower than the truck, thereby encouraging the policymaker to create the future train for shipping goods in affordable price and reliable hauling time. The lower shipping cost and the hauling time of the future train will attract more freight shippers, further achieving the sustainable inland transportation program.

4. Conclusion
The results indicated that the respondents were sensitive to haul time and shipping cost. When the shipping cost and hauling time are the same, the probability of choosing a truck was 77%. However, the industrial freight shippers changed the choice when the truck's shipping cost and haul time is higher than the that in the train. For example, the train has a 65% choosing probability when the cost difference is IDR 500,000 lower and the hauling time difference is two days faster than the truck.

In sum, this study is expected to assist the policymakers in designing the variables of shipping cost and hauling time for the future sustainable inland transportation. For example, approximately 65% probability of the freight shippers in Gresik Industrial Area will choose train when the cost difference is IDR 500,000 and the hauling time difference is two days slower than the truck, thereby encouraging the policymaker to create the future train for shipping goods in affordable price and reliable hauling time. The lower shipping cost and the hauling time of the future train will attract more freight shippers, further achieving the sustainable inland transportation program.

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