The Effectiveness of Home Delivery for Grocery based on External Cost

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Abstract. e-Grocery is one of the e-commerce sectors whose growth has increased significantly. This condition indicates the transition from conventional to online shopping and impacts the rate of home delivery services. Consequently, it may cause home delivery trips to produce the same or even greater externalities compared to conventional shopping trips. This study is aimed to analyze the effectiveness of home delivery based on the external cost aspect. Home delivery trips are analyzed using travel diary data of a grocery delivery service provider, whereas the conventional shopping trips are analyzed using the data taken from the consumers of conventional shopping. Compared to conventional shopping trips which are dominated by cars, home delivery using motorcycles produce an external cost of 23%-57% lower. In order to increase the effectiveness of home delivery, consumers are required to choose more than one-time window. This will provide a greater opportunity to do more efficient delivery routing.

1. Introduction
In 2018, the e-commerce growth in Indonesia reached 78%. This makes Indonesia the country with the fastest growing e-commerce in the world [1]. e-Grocery is one of the e-commerce sectors that has increased sharply, up to three times. People can easily buy groceries without the need to go to the market or supermarket [2]. According to the survey [3], currently more consumers buy goods through e-commerce than through physical stores. This has caused several supermarkets in Indonesia to close and begin to change their business models. However, conventional shopping cannot be completely replaced by e-commerce since the customers still need to face the goods directly [4].

The shift from conventional to online shopping causes changes in the pattern of freight movement. In conventional shopping, the movement of goods in the last mile segment is done by consumers using their vehicles. Meanwhile, in e-commerce, it is carried out by courier. The most common delivery service is home delivery (HD) [5]. As the increase of e-commerce, the HD will increase as well [6]. On the other side, the freight sector is responsible for 30\% of CO\(_2\) emissions from the transportation sector or 7\% of CO\(_2\) emissions globally. Compared to 2010, it is estimated that the amount of gas emissions will increase 3.9 times in 2050 [7].

Emission from the freight transport sector raises external costs, which are defined as costs incurred when social or economic activities of one group have an impact on the other groups, and the impact is not fully calculated or compensated by the first group [8]. The negative impact could be noise, air pollution, accidents, safety and congestion [9] and the urban areas are the most sensitive to these impacts [10]. In Jakarta, transportation contributes to 12\% of total CO\(_2\) emissions nationally, and 90\% of air pollution of CO, HC, NOx, SOx, PM, O\(_3\) substances comes from road transportation [11]. This paper aims to analyze the effectiveness of HD based on the external cost. Practically, the external cost can be
internalized, and it will have an effect on the decision-making process of transport users [12]. This can be done by providing appropriate incentive for transport users using market-based instruments (e.g. taxes, duties, emissions trading, etc.) [13].

2. Research methods

The effectiveness of HD is represented by the ratio of Vehicle Kilometer Travelled (VKT) per item of goods carried by courier as well as the external costs of HD trips to the one of conventional shopping (CS) trips. HD trips are analyzed using travel diary of the grocery delivery service provider, whereas the CS trips are analyzed using the data taken from the consumers of CS who purchase groceries directly in the supermarket. Travel diary data of HD were taken on one day during the pandemic period, and CS surveys were conducted for one month during the pandemic period. Travel diary of HD consists of 608 data and CS survey consists of 58 data spread in Jakarta, Tangerang, Depok, and Bekasi. The data contains the location of consumers and stores; the number of items carried by a courier; type of vehicles; and type of fuel. From the data, some variables are generated for calculating the carbon emissions.

![Figure 1. Carbon emission calculation method [14]](image.png)

Figure 1 shows that there is levelling on methods for calculating the carbon emissions based on the availability of data [14]. The method is influenced by the specificity of data and the accuracy of the study. The higher the level, the data needed will be more detailed and it is more difficult to conduct. However, the results will be more accurate. In this study, the second level method is applied where the data of activity are used to calculate the emission and the amount of fuel consumed is calculated based on assumptions. Equation (1) and (2) are used to calculate the external costs.

\[
CO_2 \ \text{Emissions per Item} = \frac{VKT}{\text{Number of Items}} \cdot F_{FC} \cdot F_{CO2} \quad (1)
\]

\[
\text{External Costs per Item} = CO_2 \ \text{Emission per item} \cdot \text{Unit Cost of emission} \quad (2)
\]

VKT is the total distance (in kilometres) travelled by a vehicle in a certain time period. The number of items on HD is the number of items carried by a courier in one trip, whereas in CS it is represented by the number of items purchased by consumers in supermarkets. The fuel consumption factor \((F_{FC})\) is represented by the distance that can be travelled (in km) using one litre of fuel (table 1) [15]. \(CO_2\) emission factor \((F_{CO2})\) is the amount of carbon emissions produced by each type of vehicle (table 2) [16].

Unit costs of emission are determined by carbon tax [17]. Fuel and carbon taxes are simple and cost-effective tools to limit climate change [18]. Internationally, the lowest carbon tax is €30 per tonne of \(CO_2\). However, Indonesia sets a carbon tax of only €7.46 per tonne (the exchange rate of the Euro currency as of June 19, 2020 is Rp 15,879.79).
3. Results and discussion

A delivery process of HD begins with the consumer applying an order and determining the delivery time on the application, the order is then forwarded to the shopper located at the consumer's preferred supermarket. The shopper is a partner whose job is to purchase goods that consumers have ordered. After that, groceries are sent by couriers to consumer’s homes using motorcycles. HD allows the courier to deliver to more than one point within one trip. However, from 608 data of the HD trips, 80% of the trips deliver to only one point. Meanwhile, 17% of trips made deliveries for two delivery points and 3% delivered for three delivery points. In CS, from 58 travel data, vehicles are dominated by private cars (91%), whereas motorcycles are only 9%.

3.1. Characteristics of home delivery

HD by motorcycles has an average VKT of 10.82 km and a standard deviation of 4.48 km. The number of items on HD has an average of 26.88 with a standard deviation of 25.03. Based on the Kruskal Wallis test, the number of items per trip on HD is categorized into four groups, i.e. very high (number of items >38), high (30 <number of items <38), moderate (22 <number of items <30), and low (number of items <22). This division occurs due to the spreading of the location of the consumer’s house and the time window chosen by them. Customers who are close to each other and have the same time window will have a greater chance to be delivered on the same trip so that the trip has a greater number of items. Table 3 shows that the distance needed to send one grocery item (VKT per Item) of HD is 0.72 km up to 1.14 km. Meanwhile, external costs per item range from Rp 5.10 to Rp 8.12. This external cost depends on the number of items carried by the courier in one trip. The higher the number of items carried by the courier, the smaller the distance needed to send one item and the lower the external cost.

| Number of Items carried in a single delivery | Average VKT per Item (Km/Item) | Average External Cost per Item (Rp/Item) |
|---------------------------------------------|---------------------------------|----------------------------------------|
| Very High (>38)                            | 0.72                            | 5.10                                   |
| High (30-38)                                | 0.77                            | 5.47                                   |
| Moderate (22-29)                            | 0.94                            | 6.70                                   |
| Low (<22)                                   | 1.14                            | 8.12                                   |
3.2. Characteristics of conventional shopping

Table 4 illustrates the VKT and number of items of CS. A CS using car produces a greater VKT and number of items than CS using motorcycle. However, based on the Mann-Whitney test, the difference in VKT and the number of items of the two vehicle types was not significant (p > 0.05). Similar to the location of consumers, the difference in VKT and number of items was not significant (p > 0.05). This indicates that CS’s consumer behavior is uniform in terms of vehicles and supermarket locations. Table 5 illustrates the VKT per item and external costs per item of CS. The VKT per item of car is 0.47 km and the VKT per item of motorcycle is 0.51 km. External costs of CS are in the range of Rp 3.61 up to Rp 11.98. This range depends on the type of vehicle and fuel used.

Table 4. VKT and number of items of conventional shopping trip.

| Vehicles on Conventional Shopping Trip | VKT (Km) | Number of Items |
|---------------------------------------|----------|----------------|
|                                       | Mean     | Standard Deviation | Mean     | Standard Deviation |
| Car                                   | 7.76     | 6.26            | 20.56    | 11.34             |
| Motorcycle                            | 5.7      | 5.23            | 15.80    | 18.30             |

Table 5. VKT per Item and external cost per item of conventional shopping trip.

| Vehicle Type | Fuel Type  | Average VKT per Item (Km/Item) | Average External Cost per Item (Rp/Item) |
|--------------|------------|--------------------------------|----------------------------------------|
| Car          | Diesel Oil | 0.47                           | 11.11                                  |
|              | Fuel Oil   |                                | 11.98                                  |
| Motorcycle   | Fuel Oil   | 0.51                           | 3.61                                   |

3.3. Effectiveness of home delivery

Table 6 shows that HD by motorcycle has a VKT per item 41% to 145% greater compared to CS. From Mann Whitney test, HD by motorcycles and CS by motorcycles have insignificant differences in VKT per item (p > 0.05). However, as HD by motorcycle is compared to CS by car, the difference in VKT per item is quite significant (p < 0.05). The difference is affected by the difference in VKT and number of items. CS by car have a lower VKT than HD by motorcycle and it is significantly different (p > 0.05). In term of the number of items, CS by car (mean = 20.56; SD = 11.34) have insignificant difference in the number of items of HD by motorcycle (p > 0.05) in group of high number of items (mean = 32.07; SD = 29.27) and moderate (mean = 24.9; SD = 21.63). Thus, it can be concluded that HD by motorcycle with a very high number of items has an insignificant difference in VKT per item (p > 0.05). Dividing the higher VKT to the high number of items will produce an equal VKT per item to CS by car. Unlike the case with HD by motorcycle that has the same number of items or even smaller compared to CS by car, the VKT per item obtained will be greater and significantly different (p < 0.05).

Table 6. Ratio of VKT per item and external cost per item of home delivery to conventional shopping trips.

| Number of Items carried in a single HD trip | Ratio of VKT per Item of HD to CS Trips | The Ratio of External Cost per Item of HD to CS Trips |
|-------------------------------------------|----------------------------------------|------------------------------------------------------|
|                                           | Motorcycle | Car | Motorcycle with Fuel Oil | Car with Fuel Oil | Car with Diesel Oil |
| Very High (>38)                           | 1.41*      | 1.53* | 1.42* | 0.43* | 0.46** |
| High (30-38)                              | 1.51*      | 1.64** | 1.52* | 0.46* | 0.49** |
| Moderate (22-29)                          | 1.86*      | 2.02** | 1.86* | 0.56* | 0.60** |
| Low (<22)                                 | 2.25*      | 2.45** | 2.25* | 0.68* | 0.73** |

* Insignificant Difference (p>0.05)
** Significant Difference (p<0.05)
HD by motorcycle has an external cost per item of 42% to 125% greater compared to CS by motorcycles. However, the difference in external costs per item is not significant (p > 0.05) due to the difference in the VKT per item of the two groups which is also not significant (p > 0.05) and the vehicles used are the same, so the fuel multiplier factor and the emission factor will be the same. As HD by motorcycle is compared to CS by car, HD by motorcycle has an external cost per item 27% to 57% smaller. However, the difference in the external costs per item of HD by motorcycle is not significant (p > 0.05) when compared to the car using fuel oil. Meanwhile, VKT per item in the two populations has significant differences (p < 0.05). This is due to the higher fuel factor of car. As HD by motorcycle is compared to cars using diesel oil, there is a significant difference (p < 0.05) in the external cost per item. Cars with diesel oil in urban areas tend to signify high economic status. Thus, the number of items purchased tend to be the same (SD = 0.19). It is different with cars that use fuel oil (SD = 3.62) and motorcycles (SD = 13.17) in CS where they have more dispersed data due to high variability of vehicle types.

4. Conclusion
The comparison on the external cost of conventional shopping (CS) trips (which are dominated by car trips) and home delivery (HD) trips shows that HD by motorcycles produce an external cost of 27% to 57% lower than CS. Hence, HD by motorcycles can be a solution in reducing the carbon emissions in the transportation sector. In HD operations, it is necessary to make more efficient delivery arrangements, in this case the number of items carried or the number of delivery points needs to be maximized because carbon emissions per item will be smaller as the number of delivery points is increasing. In order to increase the effectiveness of HD, consumers are required to choose more than one-time window. This provides a greater opportunity for HD service providers to carry out more efficient routing. i.e. the more chance to deliver to more than one delivery point within one trip. Considering that HD is better than CS trips in terms of externality, promotion on grocery online shopping should be done more intensively. The aim is to attract conventional shoppers, especially private car users, to use HD service in their grocery shopping. It is expected that the trips of grocery home delivery can be more efficient from the aspects of the externality.

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