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DEVELOPMENT OF A FRAMEWORK FOR THE CALCULATION OF CO_2 EMISSIONS IN TRANSPORT AND LOGISTICS IN SOUTHEAST ASIA

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ABSTRACT

Southeast Asia, as the world fastest growing market, has become the destination for multinational companies to operate their businesses. The increasing number of companies in the region will result in raised levels of CO_2 emissions because of their transport and logistics activity. This paper aims to develop a CO_2 emissions framework by considering the actual conditions of the region, and by calculating the level of emissions with a case study of Indonesia. Several steps were involved in the design of the framework. First, research was conducted on available frameworks which estimate CO_2 emissions in logistics. Second, the model for CO_2 emissions calculation was built by breaking down all the factors influencing calculations. Third, the model was applied using distribution network data of companies in Indonesia. The output of the research is a framework which helps companies to calculate CO_2 emissions, and which gauges the level of such emissions generated by companies operating in Indonesia. In addition, the impact of the different distribution network scenarios on the amount of CO_2 emissions produced is assessed.

Keywords: CO_2 emissions calculation model; Greenhouse gas emissions; Logistics in Southeast Asia; Sustainable logistics; Transport and logistics

1. INTRODUCTION

In 2009, The World Economic Forum calculated that the transport and logistics sector was responsible for 5.5% of total emissions from human activity, at around 2,800 mega-tonnes annually (World Economic Forum, 2009). In addition, Hao et al. (2015) found that the freight transport sector was responsible for 788 mega-tonnes of emissions, which represented around 8% of national Greenhouse Gas (GHG) emissions in China in 2013. The release of GHG emissions into the atmosphere increases heat, which ultimately leads to global warming (UNEP, 2003). Additionally, Abbasi and Nilsson (2016) discuss several negative impacts of logistics activities, such as visual pollution, congestion, intimidation, vibration, injuries and accidents.

As a fast-growing market with low-cost operations, many businesses have decided to move their production plants to Southeast Asia (SEA). Rao (2002) states that the region is an exciting location for most global manufacturing companies. The main driver of this movement is the cheaper production process. By increasing the number of companies that operate in SEA, this factor also increases the level of CO_2 emissions from transport and logistics activities. As Southeast Asia has become a good option for production plants, environmental issues need to

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be addressed to avoid severe problems in the future (Hart, 1997).

The effort to calculate CO_2 emissions from companies in transport and logistics, known as a green logistics activity (Sbihi & Eglese, 2007), is a useful consideration for companies before developing the right policy for CO_2 emissions reduction. Currently, frameworks, calculation tools, methodologies and reporting formats which can be used to calculate CO_2 emissions can be easily accessed. The problem with these tools is the absence of a global method specific to logistics operations (Greene & Lewis, 2016).

Measuring CO_2 emissions more accurately, with consideration of the actual conditions in Southeast Asia, has been one of the challenges faced by companies in the region. A holistic approach is needed in terms of CO_2 emissions reduction in the logistics sector, supported by different measurements (Nilsson et al., 2013). There are several standards for CO_2 emissions calculation, but none is specifically aimed at companies in Southeast Asia. Moreover, little research has been conducted on CO_2 emissions calculation in transport and logistics specifically for companies in Southeast Asia, one of the few examples being recent research developed in SEA by Binh & Tuan (2016). In the other area, Padfield et al. (2011) conducted research to measure CO_2 emissions for consumption and production of food in Southeast Asia specifically for the Malaysian food sector. The development of a calculation model for CO_2 emissions in Southeast Asia will help local companies to achieve more accurate measurement of their impact and will represent the actual conditions found in the region. Companies can use the results of the CO_2 emissions calculation when developing initiatives as part of sustainability efforts in their business operations.

2. METHODOLOGY

The study consisted of three steps. First, research on the available frameworks for CO_2 emissions in logistics was conducted. Second, the model for CO_2 emissions calculation in logistics was developed. The output of this step was a chart that explains in detail the factors that influence the calculation of the emissions, specifically in SEA. Third, the model was applied to a company in Indonesia; this step started with the collection of data on the distribution network. Using these data and different scenarios, the output of this process was the calculation of the amount of CO_2 emissions.

2.1. Research on Available Frameworks for CO_2 Emissions in Logistics

2.1.1. Review of available frameworks

Several initiatives have been developed to answer the need for companies to increase their awareness of sustainability. One of these is the measurement of CO_2 emissions and the use of this as a basis for reducing companies' environmental impact. Nowadays, there are many frameworks, methodologies and tools whose goal is to calculate emissions and to report the formats used by different countries, customers and programs. However, Green and Lewis (2016) argue that there is still an absence of a global method which focuses on the calculation of CO_2 emissions from the logistics aspect. Miodrag et al. (2016) also discuss the challenges for logistics service providers with regard to CO_2 emissions assessment due to the high costs and length of time involved.

One of the most comprehensive studies in the field of methodology for calculating emissions is that of Straube and Doch (2011). They evaluated five methods that focus on logistical aspects. Another relevant research which reviewed existing methods, calculation tools and databases was the Carbon Footprint of Freight Transport (COFRET) project (COFRET, 2011), which was funded by the European Commission and aimed to establish and test a method for CO_2 emissions in transport and logistics.

The COFRET project evaluated 102 frameworks and listed nine top priorities based on these criteria: transport modes; vehicles and equipment; logistics operations and the supply chain element; the phases of the life cycle; emission compounds; methodological ambition; referenced methods and data; the relevant calculation context; the geographical context; and publicity and availability. Another framework is Global Logistics Emissions Council (GLEC). Short explanations are shown below.

Table 1 List of frameworks

No	Framework	Description
1	Bilancarbone	Bilancarbone measures direct and indirect emissions.
2	Department for Environment, Food and Rural Affairs (DEFRA)	DEFRA focuses on the calculation of GHG emissions for freight transport activity.
3	Deutsche Speditions- und Logistikverband e.V (DSLV)	DSLV uses the draft for EN 16258:2011 as a primary method.
4	Greenhouse Gas (GHG) Protocol	The objective of this method is to develop gas standards and programs in different sectors, such as transport and logistics.
5	Intergovernmental Panel on Climate Change (IPCC)	This guidance was developed for the National Greenhouse Gas Inventories.
6	Network for Transport Measures (NTM)	The purpose of this guideline is to measure emissions for all transport modes.
7	ZichtopCO_2	This guideline focuses on making detailed calculations of emissions, specifically for the logistics sector.
8	Gronn godstransport	Gronn godstransport has the objective of measuring the environmental aspect of freight transport companies.
9	European Norm (EN) 16258	This methodology calculates and publishes GHG emissions, as well as the energy consumption of transport services.
10	GLEC	GLEC has the purpose of measuring CO_2 emissions from the logistics sector and aims to develop a single framework which can be used in different sectors.

2.2. Development of a Model for CO_2 Emissions Calculation in Logistics

After reviewing the available frameworks, the next step was to identify the factors influencing the calculation of CO_2 emissions, specifically in SEA. Based on the frameworks, the factors influencing the calculation were generated. For example, GLEC lists the basic methods which are useful in thoroughly understanding the components which affect the calculation of CO_2 emissions in air transportation. Then, using the results of the review process of the current frameworks, the most important factors, included the step that considers the actual condition of Southeast Asia, were developed. According to the World Economic Forum (WEF), road transportation contributes 57% of total GHG emissions, ocean freight 17%, and logistics 14% (World Economic Forum, 2009). These three sources of CO_2 emissions therefore represent 88% of the total contribution of GHG emissions.

3. RESULTS AND DISCUSSION

Based on the steps taken in developing the model for CO_2 emissions calculation, the charts shown in Figures 1, 2 and 3 only consider road transportation, sea transportation and transhipment centres. These charts provide guidance to users for easier understanding of the calculation of CO_2 emissions.

3.1. Model for CO_2 Emissions Calculation in Logistics

The calculation of CO_2 emissions is the sum of the total emissions of road transportation, transhipment centres and sea transportation. The charts explain the detailed calculation of each part and are presented below.

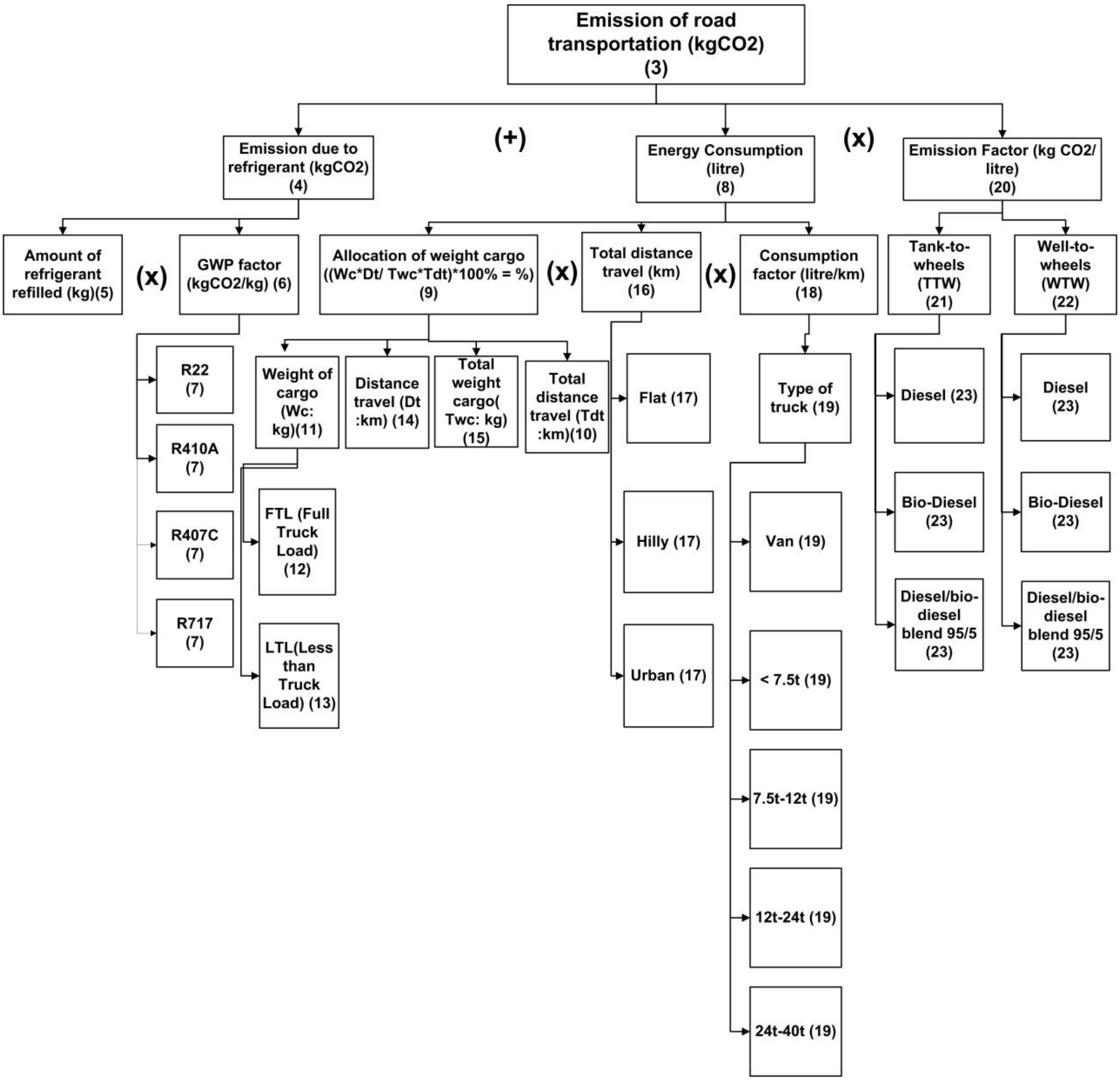

Figure 1 Road transportation emissions

Emissions of road transportation (kgCO_2) = Emissions due to refrigerant (kgCO_2) + Energy consumption (litre) × Emission factors (kgCO_2/litre)

Emissions due to refrigerant (kgCO_2) = Amount of refrigerant refilled (kg) × GWP factor (kgCO_2/kg)

Energy consumption (litre) = Allocation of weight cargo (%) × Total distance travelled (km) × Consumption factor (litre/km)

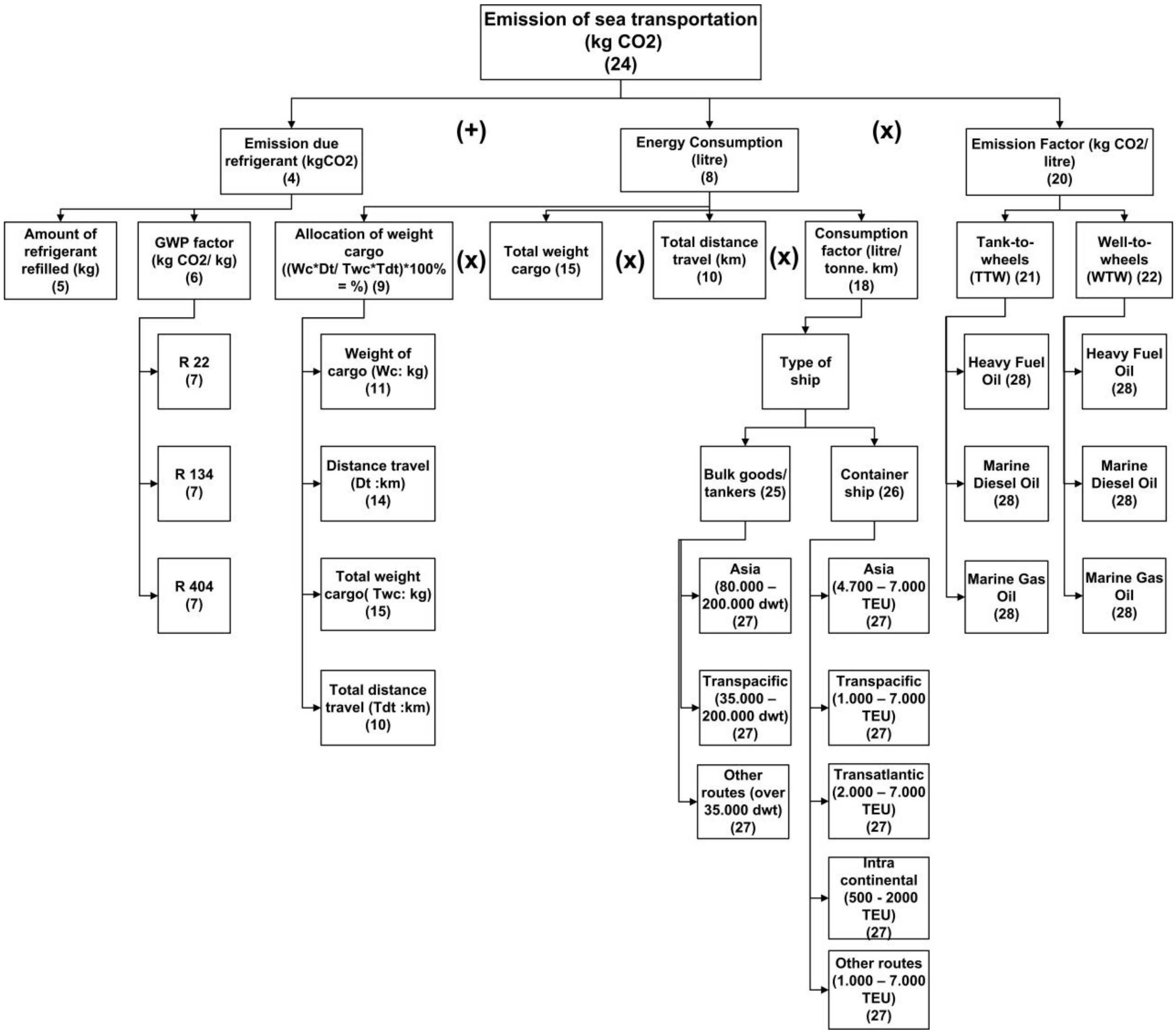

Figure 2 Sea transportation emissions

Emissions of Sea transportation ($kgCO_2$) = Emissions due to refrigerant ($kgCO_2$) + Energy consumption (litre) × Emission factors ($kgCO_2$/litre)

Emissions due to refrigerant ($kgCO_2$) = Amount of refrigerant refilled (kg) × GWP factor ($kgCO_2$/kg)

Energy consumption (litre) = Allocation of weight cargo (%) × Total weight cargo (tonne) × Total distance travel (km) × Consumption factor (litre/tonne.km)

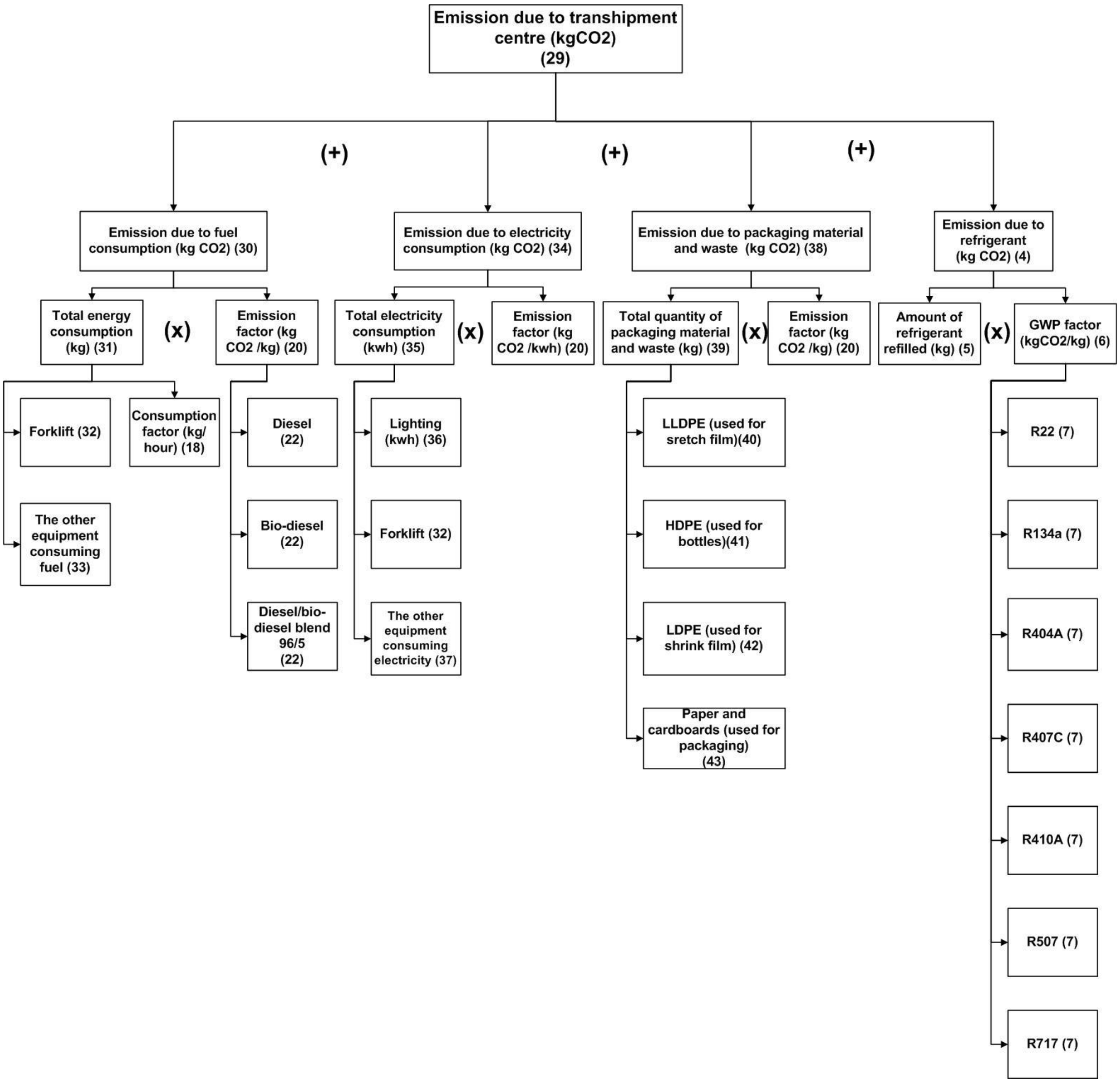

Figure 3 Transshipment centre emissions

Transshipment centre emissions ($kgCO_2$) = Emissions due to fuel consumption ($kgCO_2$) + Emissions due to electricity consumption ($kgCO_2$) + Emissions due to packaging material and waste ($kgCO_2$) + Emissions due to refrigerant ($kgCO_2$)

Emissions due to fuel consumption ($kgCO_2$) = Total energy consumption (kg) × Emission factor ($kgCO_2$ /kg)

Emissions due to electricity consumption ($kgCO_2$) = Total electricity consumption (kwh) × Emission factor ($kgCO_2$/kwh)

Emissions due to packaging material and waste = Total quantity of packaging material and waste (kg) × Emission factor ($kgCO_2$/kg)

Emissions due to refrigerant = Amount of refrigerant refilled (kg) × GWP factor ($kgCO_2$/kg)

An explanation of the factors influencing the CO_2 emissions calculation is given below. The model description is based on the information in Figures 1, 2 and 3.

3.2. Model Application for Calculating CO_2 Emissions

The objective was to apply the model represented by the charts to the case study. The charts were exported to Microsoft Excel to make the calculation easier.

3.2.1. Data collection

The data used in the application of the model for calculating CO_2 emissions were taken from the distribution network of PT. XYZ, which operates in Indonesia. The company focuses on the production of consumer products such as dairy-based beverages, infant nutrition, cheese and desserts. The output of the calculation of the model is the level of emissions produced by the distribution network in 2015; prediction of the emissions in 2018 with the scenario of demand in 2018 and the distribution network in 2015; and the level of emissions in the optimal scenario, which means using demand in 2018 and the distribution network in 2018. Another output of this calculation is comparison of emissions based on activity, meaning a comparison of the emissions emitted by road and sea transportation, and transhipment centres.

3.2.2. Assumptions and limitations

For the calculation of CO_2 emissions, the follows assumptions were made:

a) The emission factor, which represents the value to convert fuel consumption into emissions, is adjusted with comparison to the value applied in Europe, due to the low quality of vehicles and infrastructure in Southeast Asia (Binh & Tuan, 2016). Therefore, the emission factor of this region is 40% higher than that in Europe.
b) The number of warehouses in 2018 is considered to be the same.
c) The packaging material and refrigerant factors in the transportation modes are excluded, since these data were not provided by the company.

3.2.3. Calculation of CO_2 emissions

After the calculation of CO_2 emissions using the data from the operating company in Indonesia, there are three types of results, based on the scenario used: first, the scenario using the distribution network and demand in 2015; second, the baseline 2018 scenario with the future distribution network in 2018, using the distribution network in 2015 and demand in 2018; and third, the optimal scenario, the distribution network in 2018 and demand in 2018. Using these scenarios, the impact of increasing demand in the future and the distribution network will be calculated.

Table 2 CO_2 emissions of the operating company in Indonesia

	Baseline 2015	Baseline 2018	Optimal Scenario
Road Transportation			
Average distance travelled (km)	265	280	296
Total weight of cargo (ton)	753,583	1,214,159	1,084,305
Emission factor (kg CO_2/litre)	5.49	5.49	5.49
Route profile	Flat	Flat	Flat
Consumption factor (litre/ton.km)	0.03	0.03	0.03
Sea Transportation			
Average distance travelled (km)	2,094	2,140	2,402
Total weight of cargo (ton)	103,341	147,608	167,201
Consumption factor (kg/ton.km)	0.00140	0.00140	0.00140
Emission factor	3.92	3.92	3.92
Transhipment Centre			
Total electricity consumption per year (Mwh)		63.54	
Emission factor for electricity (ton CO_2/Mwh)		0.81	

Table 3 shows the level of CO_2 emissions produced by the company. The trend shows that using the baseline scenario of 2015 and 2018 results in an increasing level of CO_2 emissions in 2018 compared to 2015. It is indicated that increasing the level of demand in the future can increase the level of CO_2 emissions emitted by the company. Mariano et al. (2017) discuss this situation. Increasing company competitiveness can increase CO_2 emissions. Furthermore, the optimal scenario shows a decreasing level of CO_2 emissions compared to the baseline scenario in 2018. Table 3 also shows total CO_2 emissions produced per ton sold; that is, a comparison between total CO_2 emissions and tons sold. For instance, 1 ton sold by the company produces 0.1007-ton CO_2 emissions.

Table 3 Total CO_2 emissions produced

	Total CO_2 emissions in tons	Total CO_2 emissions per tons sold
Baseline 2015	38,501	0.1007
Baseline 2018	65,219	0.1202
Optimal Scenario	62,143	0.1137

Regarding the composition of CO_2 emissions of the company in Indonesia, those from road transportation still contribute the highest level. Table 4 shows the level of CO_2 emissions produced by sea transportation is low. However, Indonesia consists of many islands. The infrastructure to support sea transportation can the reason why the company still uses trucks as the main mode of transportation to distribute products to the end customers.

Table 4 Composition of CO_2 emissions

	Total Road Transportation Emissions (ton)	Total Sea Transportation Emissions (ton)	Total Transshipment Centre Emissions (ton)
Baseline 2015	37,262.33	1,187.58	51.47
Baseline 2018	63,434.66	1,733.56	51.47
Optimal Scenario	59,887.50	2,204,07	51.47

Figure 4 Emission by activities

The model for calculation of CO_2 emissions shown in Figure 4 will help companies to identify the causes of CO_2 emissions based on the type of activity. Through understanding these causes, they will be able to determine the right initiatives to reduce CO_2 emissions.

4. CONCLUSION

In comparison to the current models of CO_2 emissions calculation, the model developed in this study represents the actual conditions of the transport and logistics activity of companies in Southeast Asia by implementing a standard input adjusted to the conditions of the region. Therefore, the level of CO_2 emissions generated by the model is better than in the other models. Another advantage of this model is that it can be used without high investment.

The results of the calculations indicate an increase in CO_2 emissions in 2018, even though the scenario uses the same distribution network. Increasing demand will increase the number of transportation modes used, leading to higher energy consumption. Another interesting finding is the contribution of trucks to CO_2 emissions. Road transportation produced more than 50% of CO_2 emissions in 2018. Moreover, Indonesia consists of 13,466 islands, which shows that sea transportation plays an important role in connecting these (Central Intelligence Agency, 2017). However, the results show that sea transportation is not used optimally. Changing the use of trucks to sea transportation could be one alternative to reduce CO_2 emissions.

With regard to future research, this study was developed without considering the financial aspect, especially how initiatives in CO_2 emissions reduction could have a positive impact on this. Therefore, the model would be more effective if it identified the relationship between the financial aspect, distribution networks and the level of CO_2 emissions generated.

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