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A Comparative Analysis of Carbon Emissions from Transportation and Logistics of the Consumer Goods Industry in Southeast Asia

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Abstract. This research continues previous work that developed a framework for calculating carbon dioxide (CO_2) emissions specifically for countries in Southeast Asia. The purpose of the present research is to comparatively analyze carbon emissions produced by the transportation and logistics activities of a consumer goods company with factories in Indonesia, Vietnam, Thailand, and the Philippines to better understand the factors driving CO_2 emissions generated by the factories. Several steps were conducted for this research: calculating the carbon emissions from the factories in each country, comparing the results, and analyzing the impacts of several factors on the carbon emissions. The factors are the production numbers of each operating factory, the source of emissions related to the distance traveled, and the ratio of road and sea transportation used by the company. This research used three scenarios: data from (1) 2015 and (2) 2018 and (3) the optimal scenario considering the optimal distribution network.

Keywords: CO_2 emissions; Consumer goods industry; Green logistics in Southeast Asia; Transportation and logistics; Supply chain management

1. Introduction

The issue of greenhouse gas (GHG) emissions is increasingly the concern of political leaders, business executives, and environmentalists alike, as they contribute to the GHG effect by increasing the heat in the atmosphere, ultimately leading to global warming (United Nations Evironment Program [UNEP], 2003). The initiative to reduce GHG emissions has also become an integral part of the sustainable development goals as global warming and GHG emissions are significant challenges faced by all countries. Rising levels of GHG emissions is a major driver of harmful climate change. Reducing such emissions while preserving economic growth and social welfare is a challenge all countries face (Berawi, 2016).

Transport and logistics, as parts of the operational activities of companies, can have significant impacts not only on their competitive advantages but also on their environmental sustainability. One activity that requires close attention is how companies manage their consumptions of fuel to reduce carbon dioxide (CO_2) emissions from their transport and logistic activities. Handling emissions wisely can improve their environmental impacts.

The Intergovernmental Panel on Climate Change (IPCC) (Sims et al., 2014) explained that transport is a primary source of emissions, contributing around 23% of global CO_2.

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Of all forms of transportation, road transportation makes the largest contribution to these emissions. The World Economic Forum (2009) also released data regarding the number of global carbon emissions created by logistics and transportation, showing that 5.5% of global carbon emissions are generated solely from logistics and transportation. In 2015, the IPCC stated that road transportation was a dominant contributor to freight transport emissions, releasing more than 1,700 million tons of CO_2 emissions.

Southeast Asia, where economic growth has been increasing at an average rate of 5% per year (Diaconu, as cited in Maxim, 2014), will continue to become an attractive place due to its competitive advantages. Southeast Asia has more than 600 million people under the age of 30, indicating the region's passion for new technology and the new industrial revolution (The ASEAN, 2019). Indeed, Southeast Asia is an exciting region for global manufacturing companies (Rao, 2004). From the perspective of transportation and logistics, the challenges for a company in this region are its geography, uneven population distribution, and excessive CO_2 emissions.

Many studies have researched sustainable supply chains and logistics. Building on this literature, this study aims to understand the initiative of a company in Southeast Asia to adopt sustainable supply chain and logistics as their strategy, which faces two great challenges. The first is the problem of measuring CO_2 emissions as the basis for a sustainable supply chain and logistics strategy. Several researchers have attempted to calculate CO_2 emissions in this region, including Mubarak and Zainal (2018), who developed a framework to calculate CO_2 emissions specifically in Southeast Asia. The second is that the region is dominated by the sea despite many companies still using road transportation as the main mode for distributing products (Tham and Siew, 2018).

Only a few studies, however, have tried to calculate CO_2 emissions in Southeast Asia. If companies want to calculate their own CO_2 emissions, they are forced to refer to methodology developed for the other countries with different characteristics than those in Southeast Asia. Thus, this research implements the framework developed by previous research for factories in Indonesia, Vietnam, Thailand, and the Philippines.

To study the drivers of carbon emissions of operating factories throughout Southeast Asia, this research examines factory production numbers, distance traveled, and the ratio of road and sea transportation used by companies in daily business operations. This calculation and comparison of CO_2 emissions should help companies in Southeast Asia calculate their CO_2 emissions and better understand the emissions of each of their factories. These calculations may form bases for companies to generate further environmental initiatives based on the characteristics of the countries in which they operate.

2. Literature Review

Southeast Asia has become an important, attractive region due to its competitive advantages (Diaconu, as cited in Maxim, 2014). Because the region plays such a vital role, many companies select Southeast Asia for their production locations. Rao (2004) mentioned that many companies to move their factories to Southeast Asia due to cheaper manufacturing costs. The region is also attractive due to having the highest level of Internet usage in the world, people spending around 3.6 hours online every day (World Bank Group, 2019). Southeast Asia has also embraced the concept of sustainable supply chain and logistics in business activities (Rao and Holt, 2005), emphasizing their economic, ecological, and social aspects (Rao, 2002; Svensson, 2007).

Bacallan (2000) has mentioned several reasons companies adopt sustainable supply chains and logistics in Southeast Asia: increasing competitiveness by complying with environmental regulations, resolving customer concerns with environmental issues, and mitigating the harmful impacts of production and service activities. Mariano et al. (2017) discussed some ways to reduce CO_2 emissions, such as reducing transport intensity by using local sourcing, decentralizing distribution, and enacting CO_2 emissions taxation. Many companies in Southeast Asia, in fact, have started such sustainability initiatives.

Measuring the number of CO_2 emissions of logistics activities is an important prerequisite to determining appropriate public policies to reduce emissions. Though little research has examined CO_2 emissions in Southeast Asia to understand the factors that differentiate each country in the region, the following are notable exceptions. In Vietnam, Binh and Tuan (2016) predicted the CO_2 emissions of freight transport logistics specifically in the rice industry. Padfield et al. (2012) approximated the CO_2 emissions from consumption and production in the Malaysian food sector. Previous research by Mubarak and Zainal (2018) developed a framework for calculating CO_2 emissions in transport and logistics in Southeast Asia. Like this latter work, the present research focuses on calculating CO_2 emissions in specific locations to approach a better understanding of the transportation and logistics emissions of each country in Southeast Asia. Toward this end, this research comparatively analyzes the factors influencing the emissions of the transport and logistics of a company with operating factories in several Southeast Asian countries.

3. Methodology

Several methods to measure CO_2 emissions exist, such as the GHG protocol, the Global Logistics Emissions Council (GLEC), and the Bilancarbone framework, which attempt to calculate CO_2 emissions from human activities. Based on a recent review of the methodology to assess CO_2 emissions, however, this paper adopts a method developed in previous research by Mubarak and Zainal (2018) to calculate carbon emissions. Several steps were conducted for this research: calculating the carbon emissions from the factories in Vietnam, Thailand, and the Philippines, comparing the results, and analyzing the impacts of several factors on carbon emissions. Table 1 below explains the input and output data for the calculation of CO_2 emissions.

Table 1 Input and output data

	Road transportation	Sea transportation	Transshipment center
Input data	Total distance traveled	Total distance traveled	Electricity consumption
	Total weight of shipment	Total weight of cargo	
	Type of truck	Type of ship and cargo	
	Route profile	Consumption factor	
	Type of truck and route profile	Allocation of weight	
	Allocation of weight cargo	Type of fuel	
	Type of fuel		
	Emission factor		
Output data	Energy consumption CO_2 emissions		

3.1. Data Collection

The data used for this research come from the multinational company which owns several factories in Southeast Asia. The company produces consumer products, such as infant nutrition, dairy-based beverages, cheese, and desserts. The case study of this research comprises transportation and logistics operations in Vietnam, Thailand, and the

Philippines, as the calculation for the company's factory in Indonesia was done in previous research. Currently, the company only uses two types of transportation: road and sea. The outputs of the calculations are the carbon emissions of each factory.

3.2. *Calculation of CO_2 Emissions*

Using the CO_2 emissions calculation method developed in the aforementioned research (Mubarak and Zainal, 2018), the following formulas are used to calculate the CO_2 emissions of each of the company's operating factories in Southeast Asia.

Emission of road transportation ($kgCO_2$) = emission due to refrigerant ($kgCO_2$) + energy consumption (liter) × emission factors ($kgCO_2$/liter)

Emission of sea transportation ($kgCO_2$) = emission due to refrigerant ($kgCO_2$) + energy consumption (liter) × emission factors ($kgCO_2$/liter)

Emission of transshipment centers ($kgCO_2$) = emission due to fuel consumption ($kgCO_2$) + emission due to electricity consumption ($kgCO_2$) + emission due to packaging material and waste ($kgCO_2$) + emission due to refrigerant ($kgCO_2$)

4. Results and Discussion

4.1. *Calculation of Carbon Emissions*

The calculation of CO_2 emissions involves three factories in three different locations in Southeast Asia. Tables 2, 3, and 4 present the data. For factories in Vietnam and the Philippines, PT. XYZ uses road and sea transportation. Their factory in Thailand uses only road transportation to ensure products arrive in a timely manner.

The calculation of carbon emissions produced by the company uses three scenarios: the emission generated by the distribution network in 2015; emissions generated by the distribution network in 2018 and demand in 2015; and the optimal scenario using the distribution network in 2018 and demand in 2018. In the optimal scenario, the distribution network generates the optimal profit with cost as the main consideration. The output of carbon emissions for each country is compared with the CO_2 emissions produced by the factory in Indonesia.

Table 2 Input data for Vietnam

	Baseline 2015	Baseline 2018	Optimal scenario
Road transportation			
Total distance traveled (km)	7,242,057.92	7,493,998.38	7,679,544.68
Total weight of cargo (ton)	795.963	813.091	829
Emission factor (kg CO_2/liter)	5.49	5.49	5.49
Route profile	Flat	Flat	Flat
Consumption factor (liter/ton/km)	0.03	0.03	0.03
Sea transportation			
Total distance traveled (km)	315,546.6	356,407.113	403,082.6
Average weight of cargo (ton)	40.99	40.63	40.99
Consumption factor (liter/ton/km)	0.0014	0.0014	0.0014
Emission factor (kg CO_2/liter)	3.92	3.92	3.92
Transshipment center			
Total electricity consumption per year (MWh)	184.944	184.944	184.944
Emission factor for electricity (ton CO_2/MWh)	0.57	0.57	0.57

Table 3 Input data for the Philippines

	Baseline 2015	Baseline 2018	Optimal scenario
Road transportation			
Total distance traveled (km)	4,924,945.97	5,528,547.52	6,048,035.95
Average weight of cargo (ton)	41.87	42	42
Emission factor (kg CO_2/liter)	5.49	5.49	5.49
Route profile	Flat	Flat	Flat
Consumption factor (liter/ton/km)	0.02	0.02	0.02
Sea transportation			
Total distance traveled (km)	5,810,135	7,207,546.52	7,588,913.61
Average weight of cargo (ton)	37.4	38	38
Consumption factor (liter/ton/km)	0.0014	0.0014	0.0014
Emission factor (kg CO_2/liter)	3.92	3.92	3.92
Transshipment center			
Total electricity consumption per year (MWh)	257.08	184.944	184.944
Emission factor for electricity (ton CO_2/MWh)	0.57	0.57	0.57

Table 4 Input data for Thailand

	Baseline 2015	Baseline 2018	Optimal scenario
Road transportation			
Total distance traveled (km)	6,297,454	7,778,519	11,860,786
Weight of cargo (ton)	309,124	291,511.1401	290,437.103
Emission factor (kg CO_2/liter)	5.49	5.49	5.49
Route profile	Flat	Flat	Flat
Consumption factor (liter/ton/km)	0.03	0.03	0.03
Sea transportation			
Total distance traveled (km)	0	0	0
Average weight of cargo (ton)	0	0	0
Consumption factor (liter/ton/km)	0	0	0
Emission factor (kg CO_2/liter)	0	0	0
Transshipment center			
Total electricity consumption per year (Mwh)	6900	6900	6900
Emission factor for electricity (ton CO_2/Mwh)	0.57	0.57	0.57

Input data for transportation and logistics activity in Vietnam, Philippines, and Thailand are divided based on the mode of transportation (road and sea) and transshipment center. This research does not consider air and train transportation because most companies in Southeast Asia do not use them. Based on total distance traveled, road transportation is the most frequently used transportation mode.

Regarding the calculation of carbon emissions by road transportation, there are two possible conditions related to data availability. First, the data can provide detailed information for each trip. This is ideal. Another option is using the total distance traveled and total load, information with which the calculation can be done using the combination method: average distance traveled and total weight of cargo or distance traveled and average weight of cargo.

Regarding assumptions and limitations, this research used an emissions factor 40% higher than in Europe because of the low qualities of vehicles in the region (Binh and Tuan, 2016). For the calculation of CO_2 emissions of transshipment centers, the number of warehouses is assumed to be the same in each scenario.

4.2. Comparative Analysis of Transport and Logistics in Different Countries

This research compares the following aspects of the carbon emissions produced by three operating factories in Vietnam, Thailand, and the Philippines: production number, sources of emissions related to distance traveled and the ratio of road and sea transportation, and three scenarios (the years 2015 and 2018 and the optimal scenario). Based on the observed data, these three countries share similar transportation modes used for transport and logistics. Only in Thailand does the company solely depend on road transportation.

Generally, carbon emissions rise in all three scenarios. Indonesia and the Philippines, countries with thousands of islands, still depend on road transportation. Indeed, more than 80% of transport and logistics still depend on roads rather than sea transportation, possibly due to less infrastructure to facilitate sea transportation than for road. By shifting to sea transportation, CO_2 emission levels may fall. Binh and Tuan (2016) certainly think so, as they developed an optimal scenario of CO_2 emissions by reducing 10% of road transportation in the Vietnam rice industry.

Of the four countries, the operating factory in Thailand produces the most CO_2 emissions. Its superlatively high production may explain this difference. In this region, PT. XYZ sold around 521,122 tons of products in 2015, 744,710 in 2018, and 824,767 in the optimal scenario. The factories in Vietnam and the Philippines produce less and generate fewer CO_2 emissions than the others, and the carbon emissions positively, linearly correlate with factory and production size. Increasing company competitiveness by enlarging factories, then, increases CO_2 emissions (Mariano et al., 2017).

Table 5 CO_2 emissions for each operating country

	Total road transportation emission (ton)	Total sea transportation emissions (ton)	Total transshipment center emissions (ton)	Total emission	CO_2 per ton sold
			Vietnam		
Baseline 2015	10,190.88	38.16	105.42	10,334.45	0.0378
Baseline 2018	12,126.88	43.61	105.42	12,275.91	0.0334
Optimal	12,257.53	51.31	105.42	12,414.26	0.0346
			The Philippines		
Baseline 2015	8,795.78	596.27	135.58	9,527.63	0.0312
Baseline 2018	9,685.96	751.55	135.58	10,573.09	0.0301
Optimal	10,620.66	791.31	135.58	11,547.55	0.0300
			Thailand		
Baseline 2015	36,356.48	0.00	3,933.00	40,289.48	0.0773
Baseline 2018	42,348.32	0.00	3,933.00	46,281.32	0.0621
Optimal	64,335.35	0.00	3,933.00	68,268.35	0.0828
			Indonesia		
Baseline 2015	37,262.33	1,187.58	51.47	38,501.38	0.1007
Baseline 2018	63,434.66	1,733.56	51.47	65,219.69	0.1202
Optimal	59,887.50	2,204.07	51.47	62,143.04	0.1137

In the optimal scenario, in which each operating factory has a perfect distribution network and product demand, only the operating factory in Indonesia decreased its carbon emissions; in the other three countries, carbon emissions still increased from the previous year (Figure 1). This finding implies little impact on CO_2 emissions by only focusing on optimal distribution without significantly reducing demand.

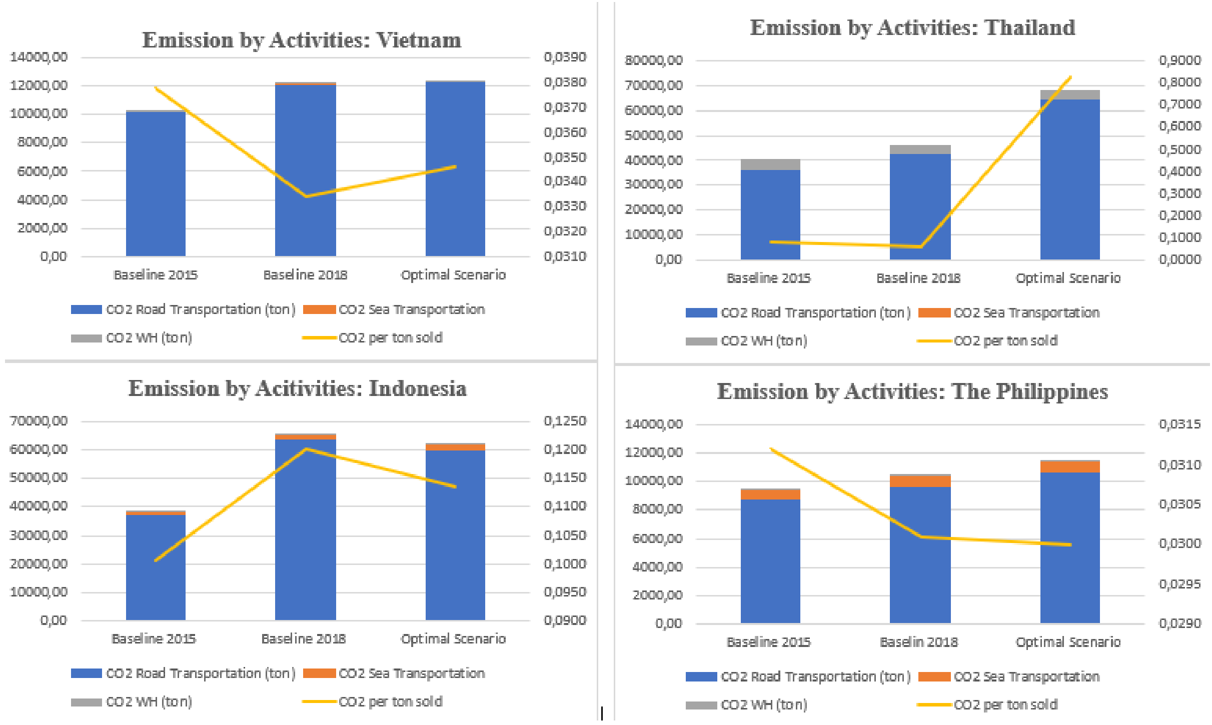

Figure 1 Emission profiles of four members of the Association of Southeast Asian Nations (ASEAN) by activities, primary y-axis is number of CO_2 emissions (ton), secondary y-axis is CO_2 per ton sold

When measuring CO_2 emissions per ton sold, the operating factory in Indonesia had the highest: around 0.1007 in 2015, 0.1202 in 2018, and 0.1137 in the optimal scenario. Although Thailand led in production, Indonesia emitted more CO_2 per ton sold. By this indicator, the operating factory in Indonesia is the worst carbon emitter, generating 0.1007 CO_2 emissions per ton sold.

Regarding the sources of emissions, road transportation clearly contributes to carbon emissions the most. The distance traveled by road is much greater than sea transportation. The size of the transshipment centers are also highly related to the number of products sold by the company: The contribution of transshipment center to carbon emissions is positively, linearly correlates with the number of products sold. Table 5 shows that the transshipment center in the operating factory in Thailand generates more carbon emissions than the others, which is caused by the many products sold there. The higher the number of products sold, the higher the energy consumption by the operating factory.

The operating factory in Indonesia used sea transportation more than the others, though the distance traveled by sea is a fraction of road transportation. Increasing sea transportation is one way to reduce carbon emissions in transport and logistics.

5. Conclusions

This research builds on previous work on a framework to calculate the carbon emissions of transportation and logistics activity in Southeast Asia. The last study discussed the ideal framework to calculate CO_2 emissions specifically for this region because most of the methods developed by researchers in the United States and Europe do not apply there. In this research, the focus is implementing this framework to calculate the CO_2 emissions of the company PT. XYZ to compare the CO_2 emissions produced by its operating factories in Indonesia, Vietnam, Thailand, and the Philippines. The comparative analysis, which considered production numbers, distance traveled, ratio of road and sea transportation, and transshipment centers in three scenarios, deepens our understanding of CO_2 emissions by revealing several differences and similarities between operating factories. The differences are mostly related to facility size, which positively correlates with carbon emissions produced: The greater the production, the more distance traveled by the company to distribute their products due to greater energy consumption. Regarding similarity, the operating factories all mainly depend on road transportation despite being surrounded by thousands of islands that can be connected by sea transportation.

This research can be built upon by analyzing the impact of shifting road transportation to sea transportation on CO_2 emissions. Integrating these findings with financial aspects would also be an interesting next step, as companies need to understand how their sustainable supply chain and logistics strategies impact on their financial situations.

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