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TECHNICAL NOTE

INDONESIA ZERO EMISSIONS APPLICATION (EMISI): METHODOLOGY FOR CALCULATING INDIVIDUAL EMISSIONS FROM GOODS DELIVERIES, AND MARINE AND AVIATION TRANSPORT

MUHAMAD RIZKI, JEANLY SYAHPUTRI, NANDA NOOR, PHILLIPE GUNAWAN GAN, RETNO WIHANESTA

1. INTRODUCTION

Society is becoming ever more mobile, globalized, and digitalized, and there has been a significant increase in movements of passengers and goods (Noussan and Tagliapietra 2020). In 2016, transport activities accounted for more than 24 percent of global carbon dioxide (CO_2) emissions; they also contribute to the deterioration of air quality in cities (Wang and Ge 2019; Ritchie 2020; Lindau 2015). The transport sector is a major emitter of greenhouse gases (GHGs), which accelerate climate change (IPCC 2018), as well as increasing public health risks (Amalia et al. 2013). Studies report that the transportation sector accounts for approximately one-quarter of total global CO_2 emissions related to energy (Ritchie 2020; Sims et al. 2015; US EPA 2021). Similarly, the Indonesian Ministry of Energy and Mineral Resources (Ministry of Energy and Mineral Resources Indonesia 2016) reported that in 2015 the transportation sector accounted for 28 percent of national GHG emissions, mostly due to fossil fuel combustion. However, because more than 50 percent (2018) of transport emissions came from aviation, marine, and road-freight transport (Ritchie 2020), more attention should be given to this sector, especially in developing countries such as Indonesia. Though the government has set up initiatives to accelerate the electrification of the transport sector, aviation, marine, and road freight are difficult to decarbonize and electrify and therefore other efforts to reduce or mitigate emissions from these sectors are important.

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WRI Technical Notes document methodology underpinning research publications, interactive applications, and other tools.

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Aviation and marine transport serve critical roles in Indonesia, given the geographical characteristics of this archipelagic country (Leung 2016). The number of passengers in the aviation and marine transport sectors almost doubled between 2009 and 2019, reaching 28.2 million air passengers and 98.5 million marine passengers (Indonesian Bureau of Statistics 2019; 2010). Furthermore, personal logistics services, meaning business-to-customer (B2C) and customer-to-customer (C2C) logistics services (i.e., conventional couriers and couriers based online), have also grown in line with an increase in economic activities. This growth has further accelerated with the digitalization of Indonesia's economy and has been supported by the rise of e-commerce, where revenues increased from US$8.459 billion in 2017 to $30.309 billion in 2020 (Clement 2020). In fact, logistics firms that cater to e-commerce fulfillment and shipping saw up to a 40 percent increase in business in 2020, and their growth continued into the first quarter of 2021 (*Jakarta Post* 2021). This was triggered by the COVID-19 outbreak; with people confined to home, they increased their use of information and communication technology (ICT) to shop and order food and beverages (Abdelrhim and Elsayed 2020).

Although the number of marine and aviation passengers decreased during the pandemic, it is predicted that numbers will increase as the pandemic recedes, and lead to higher emissions. Such an increase is also predicted for personal logistics services. This is first because the Indonesian government has launched a road map for strategic urban, industrial, and tourism development from 2020 to 2024 (Ministry of National Development Planning 2020). The development, which includes infrastructure and tourist attractions, will encourage more people to travel. Second, Indonesia is continuously improving the accessibility and quality of its ICT infrastructure. It aims not only to promote the digital economy, online activities, and tourism, but also to facilitate e-logistics services (i.e., delivery of food and beverages, and e-commerce) (Das et al. 2016; Roberts et al. 2019). Last, the Indonesian government also disburses social and financial incentives to the public, and to small and large businesses as a response to COVID-19 (Bhwana 2020). This policy aims to increase consumption and boost the economy, which in turn leads to increased mobility (Ministry of National Development Planning 2020).

While marine, aviation, and logistics services are expected to increase in the next decades and contribute to climate change, Indonesians, however, still tend to deny that their activities contribute to this issue. In fact, a study by YouGov in 2019 found that 18 percent of Indonesia's population still argue that human activity does not contribute to the climate crisis (Hilman and Harvey 2019). Given the climate emergency, it is important to establish locally relevant and practical platforms that can educate Indonesians about emissions from their aviation and marine transport, and from logistics activities.

The Indonesia Zero Emissions Application (EMISI) has since 2020 enabled Indonesians to learn, measure, track, and act on their climate impacts by helping them to calculate, reduce, and sequestrate their own personal emissions. A previous study (Rizki et al. 2020) provided methodologies for calculating emissions and pollutants for Indonesia's urban transport sector, meaning *car*, *motorcycle*, *train*, *bus*, *paratransit*, for the EMISI app. This technical note describes the methodologies the next iteration of EMISI will use for calculating emissions from *personal aviation* and *marine transport*, and from *logistics*. Personal aviation and marine transport refers to passengers using aviation transport (i.e., airplanes) and marine transport (i.e., ferries, including ro-ro[1]), while personal logistics transport refers to the domestic delivery of personal goods, both B2C and C2C. The B2C delivery refers to the final phase of delivery, when the product is sent directly from seller to end customer, without any individual or organization, such as a supplier or distributor, in between. By including these calculations, EMISI aims to educate people about the impact of their transport behavior and their personal logistics activities (e.g., e-shopping and sending packages) on climate change and provide them with opportunities to mitigate this.

This technical note focuses on calculating methane (CH_4) and CO_2 as GHG emissions, followed by carbon monoxide (CO), nitrogen oxides (NO_x), fine particulate matter ($PM_{2.5}$, meaning particulate matter with diameter less than 2.5 micrometers), sulfur dioxide (SO_2), and non-methane volatile organic compounds (NMVOCs) as air pollutants, considering their substantial implications for climate change and air pollution. Consequently, further adjustments to methodologies of the Intergovernmental Panel on Climate Change (IPCC) are made by adopting Indonesia-specific emission factors, coefficients, and assumptions from best available government data (Ministry of Energy and Mineral Resource Indonesia 2017; Ministry of Environment and Forestry Indonesia 2017; 2010), with complementary international sources (ICAO 2016; Olmer et al. 2017; United Nations 2020).

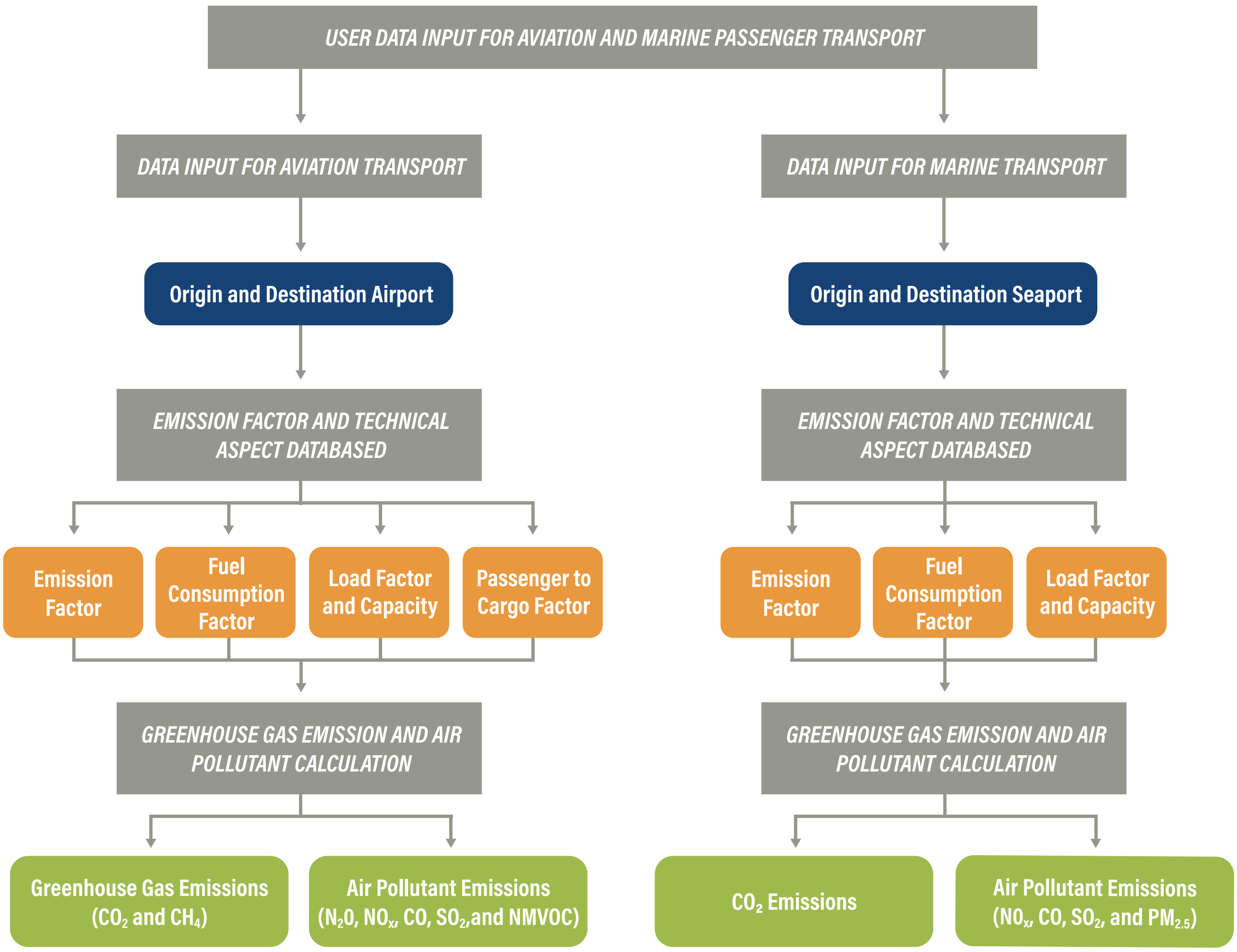
2. EMISSIONS FOR PASSENGER AVIATION AND MARINE TRANSPORT

2.1 Method

The Guidelines for National Greenhouse Gas Inventories (Eggleston et al. 2006) classifies transport activities as emissions from mobile sources. According to the guidelines, GHG and air pollutant emissions can be calculated using a top-down or bottom-up approach. A top-down approach uses aggregate data, such as the total fuel consumed in a country, while the bottom-up approach calculates the emissions or air pollutants from data relating to individual trips. The methodology to calculate aviation and marine transport emissions uses a bottom-up approach; EMISI gathers data on the travel of individuals.

This section describes the methodology for calculating emissions from aviation and marine passenger transport, while the next focuses on aviation and marine logistics transport. Figure 1 displays the calculation framework for aviation and marine passenger transport, where several parameters are needed to calculate emissions and air pollutants. The gray boxes represent the process of calculating, the green boxes represent the calculation output, and the boxes in other colors represent secondary data. As the bottom-up approach requires activity data from individuals, users input their airport or seaport of origin and destination. This is used to generate an individual's travel distance using the Google Maps app, which is included in EMISI.

Figure 1 | **Aviation and Marine Passenger Transport Method Framework**



Note: Blue boxes indicate data input, orange: based on empirical data; and green indicate output.
Sources: WRI Indonesia

The emissions and air pollutants caused by individuals are calculated based on two types of considerations. The first are technical determinants related to an aircraft or ship, such as capacity, load factor, passenger-to-cargo factor, and fuel consumption factor. For aviation transport, EMISI uses data from various publications and reports, mainly from Indonesian airlines (i.e., Garuda Indonesia, Lion, etc.) and the International Civil Aviation Organization (ICAO 2018). For marine transport, the methodology only focuses on ferry or ro-ro services, which are commonly used as passenger vessels (Utami 2020). Technical data is gathered from publications and reports from the Ministry of Transportation (Ministry of Transportation 2014). Second, emission-related factors such as emission factors for CO_2, SO_2, and NO_X pollutants must be considered. The EMISI app uses emission factors from the ICAO (2018), IPCC (2006), and local conversion factors from the Ministry of Energy and Mineral Resource (2017).

2.2 Calculating Aviation Transport Emissions

Method: Calculating Greenhouse Gas and Air Pollutant Emissions

Emissions of GHGs and air pollutants of passenger aviation are calculated according to the ICAO (2018) and Ministry of Energy and Mineral Resources (2017). To simplify the information required from users, the ICAO designed a fuel-based approach using aircraft-type data and factors (i.e., fuel consumption, correction) related to distance, and route data. Under a fuel-based approach, emissions calculations are based on the fuel consumption of every trip per individual. The fuel consumption calculation consists of fuel consumed during the landing and take-off period (LTO), including taxiing, and climb-cruise-descent time (CCD). As mentioned in ICAO (2020), the LTO period specifically refers to activity below 914 m (3,000 feet). To convert from trip-based calculation to individual-based, the formula also considers technical factors such as the capacity and load factor of the aircraft. For the calculation, users are required to enter the route of their trip and the type of aircraft. If journeys are indirect, individuals must calculate the GHG emissions and air pollution for each leg of their journey.

The formula for the fuel-based method to calculate GHG emissions and air pollutants is as follows:

$$\textit{Total aviation emissions per person } (TAEP_{pe})$$

$$= \sum_{i=1}^{N}\left(\left(\left(EF_{CCD\ e/ap}\ x\ Dc_i x Fa_{CCD-j}\right) + EF_{LTO\ e/ap}\right) x \frac{PCF_i}{S_{ij}\ x\ PLF_i}\right) \quad (1)$$

where i (i=1,2,…N) is the number of trips (i^{th}); j is the aircraft type; $EF_{CCD\ e/ap}$ is emission/pollutant (e/ap) factor (kg (GHG/p)/kg fuel) during CCD; Dc_i is the total distance in the i^{th} trip (kilometers; km), which is corrected with a distance correction factor; Fa_{CCD-j} is fuel consumption factor (kg fuel/km) of j- aircraft during cruise time; $EF_{LTO\ e/ap}$ is emission/pollutant (e/ap) factor (kg (e)/LTO cycle) during LTO; PCF_i is passenger-to-cargo factor or the ratio of number of passengers to tonnage of mail and freight for the i^{th} trip; S_{ij} is the total number of seats available based on the aircraft type (j) for the i^{th} trip; and PLF_i is passenger load factor or the ratio of number of passengers transported and the number of available seats for the i^{th} trip. The total emissions and air pollutants per person is the sum of the calculation for every stage of the journey.

Technical Determinant for Calculating Greenhouse Gas and Air Pollutant Emissions

The technical determinants for calculating aviation emissions are aircraft-related characteristics and parameters including fuel consumption, load factor, number of seats, and passenger-to-cargo factor. A correction factor—shown in Table 1—should be added to the trip distance when determining the fuel consumption during CCD (see Table 2). This correction factor represents excess distance including stacking, waiting, and weather-driven correction (ICAO 2018) and is essential to correctly calculate GHG emissions and air pollutants per person.

Table 1 | Distance Correction

Trip Distance (km)	Distance Correction Factor (km)
Less than 550	50
Between 550 km and 5500	100
More than 5500	125

Source: ICAO. 2018. "Airport Air Quality Manual. Doc 9889." www.icao.int/environmental-protection/CarbonOffset/Documents/Methodology%20ICAO%20Carbon%20Calculator_v11-2018.pdf.

The fuel consumption factor during the CCD period is described in Table 2. As the CCD period substantially depends on the distance traveled, the fuel consumption factor will be based on distance, the unit for which is kilograms of fuel per kilometer. The ICAO (2018) assesses fuel consumption based on type of engine and distance, and the resulting number is for the entire flight including LTO and CCD. Therefore, to calculate the CCD fuel consumption according to ICAO 2018, the fuel consumption during LTO has to be subtracted from the total fuel consumption. For both LTO and CCD, the fuel consumption factors employed are for those engines commonly used by Indonesian aircraft. Furthermore, while ICAO (2018) also divides the fuel emission factors based on distance (e.g., 150 nautical miles (nm), 250 nm, 500 nm, 750 nm, 1000 nm, etc.), this technical note limits the distance to 2000 nm for domestic flights and 3500 nm for international flights, considering the capacity of local aircraft. Fuel consumption factors are calculated by dividing fuel consumption by distance. Results can be seen in Table 2.

Table 2 | **Fuel Consumption during Climb-Cruise-Descent Period**

Aircraft Maker	Aircraft	Total Climb-Cruise-Descent Fuel Consumption for Varying Flight Distances (kg fuel/km)								Average (kg fuel/km)
		125 nm	250 nm	500 nm	750 nm	1000 nm	1500 nm	2000 nm	3500 nm	
		~231 km	~463 km	~926 km	~1389 km	~1852 km	~2778 km	~3704 km	~4630 km	
Airbus	A320-200CEO [m]	3.90	5.75	4.12	3.92	3.78	3.60	3.48	3.48	4.00
	A320-200NEO [m]	3.90	5.75	4.12	3.92	3.78	3.60	3.48	3.48	4.00
	A320-200	3.90	5.75	4.12	3.92	3.78	3.60	3.48	3.48	4.00
	A320NEO	3.90	5.75	4.12	3.92	3.78	3.60	3.48	3.48	4.00
	A321NEO	3.08	5.33	3.91	3.78	3.68	3.53	3.43	3.43	3.77
	A330-200 [m]	5.47	10.90	8.37	8.17	8.00	7.75	7.57	7.23	7.93
	A330-300	5.47	10.90	8.37	8.17	8.00	7.75	7.57	7.23	7.93
	A330-300[m]	5.47	10.90	8.37	8.17	8.00	7.75	7.57	7.23	7.93
	A330-900NEO [m]	5.47	10.90	8.37	8.17	8.00	7.75	7.57	7.23	7.93
	A330-900NEO	5.47	10.90	8.37	8.17	8.00	7.75	7.57	7.23	7.93
	Average	4.60	8.28	6.22	6.03	5.88	5.67	5.52	5.35	5.94
	Average [m]	4.60	8.28	6.22	6.03	5.88	5.67	5.52	5.35	5.94
Boeing	737 Max 8	1.88	4.71	3.52	3.45	3.38	3.26	3.16	2.97	3.29
	737 Max 8 [m]	1.88	4.71	3.52	3.45	3.38	3.26	3.16	2.97	3.29
	737-300	3.95	5.74	4.03	3.80	3.64	3.43	3.29	3.04	3.87
	737-300 [m]	3.95	5.74	4.03	3.80	3.64	3.43	3.29	3.04	3.87
	737-500	3.95	5.74	4.03	3.80	3.64	3.43	3.29	3.04	3.87
	737-500 [m]	3.95	5.74	4.03	3.80	3.64	3.43	3.29	3.04	3.87
	737-800	3.52	5.53	3.93	3.72	3.58	3.39	3.26	3.03	3.75
	737-800NG [m]	3.52	5.53	3.93	3.72	3.58	3.39	3.26	3.03	3.75
	737-900ER	3.52	5.53	3.93	3.72	3.58	3.39	3.26	3.03	3.75
	737-900ER [m]	3.52	5.53	3.93	3.72	3.58	3.39	3.26	3.03	3.75
	777-300ER	4.89	11.36	8.98	8.91	8.80	8.62	8.48	8.20	8.53
	777-300ER [m]	4.89	11.36	8.98	8.91	8.80	8.62	8.48	8.20	8.53
	Average	3.62	6.43	4.74	4.57	4.44	4.25	4.12	3.89	4.51
	Average [m]	3.62	6.43	4.74	4.57	4.44	4.25	4.12	3.89	4.51
Other	ATR72-600	0.92	1.39	1.21	1.19	1.18	1.19	1.22	1.22	1.19
	CRJ1000	2.45	3.18	2.23	2.03	1.92	1.79	1.79	1.79	2.15
	Average	1.69	2.29	1.72	1.61	1.55	1.49	1.50	1.50	1.67

Note: 1 nautical mile (nm) = 1.852 kilometers (km); [m] means multiple classes of seating are available.
Source: ICAO. 2018. "Airport Air Quality Manual. Doc 9889." www.icao.int/environmental-protection/CarbonOffset/Documents/Methodology%20ICAO%20Carbon%20Calculator_v11-2018.pdf.

The passenger-to-cargo factor expresses the contribution of passenger mass to total mass. Total mass consists of passengers, seats, freight/cargo, and mail (ICAO 2018). The passenger-to-cargo factor, as shown in Table 3, is divided based on travel route. This technical note compiled the PCF data from ICAO (2017) and CEIC (2020). However, the routes shown are limited to travel within Indonesia and travel with Indonesia as either origin or destination.

Table 3 | **Passenger-to-Cargo Factor**

Route	Passenger-to-Cargo Factor (%)
Africa–Indonesia[a]	83.90
Central Asia and Southwest Asia–Indonesia[a]	80.65
Europe–Indonesia[a]	63.49
Intra Indonesia[b]	62.09
Intra Pacific Southeast Asia–Indonesia[a]	79.99
Middle East–Indonesia[a]	81.26
North America–Indonesia[a]	84.44
North Asia–Indonesia[a]	79.99

Sources: [a] ICAO. 2018. "Airport Air Quality Manual. Doc 9889." www.icao.int/environmental-protection/CarbonOffset/Documents/Methodology%20ICAO%20Carbon%20Calculator_v11-2018.pdf.; [b] CEIC. 2020. Indonesia Airline Production. CEIC. www.ceicdata.com/en/indonesia/airline-production.

Seating capacity/passenger capacity is used to calculate the average number of passengers in the aircraft; seating capacity is multiplied by the passenger load factor. There are many airlines operating in Indonesia; this technical note describes seating capacity for Garuda Indonesia and Lion Air, the largest. Seating capacity, also categorized by aircraft type, is illustrated in Table 4.

Table 4 | **Average Aircraft Seating Capacity**

Aircraft	Code	Average Seating Capacity
Airbus	320-200CEO [m][c]	156
	320-200NEO [m][c]	156
	A320-200[d]	180
	A320NEO[d]	180
	A321NEO[d]	236
	A330-200 [m][a]	222
	A330-300[b]	440
	A330-300[m][a]	251
	A330-900NEO [m][a]	301
	A330-900NEO[d]	365
	Average	280
	Average [m]	217
Boeing	737 Max 8[b]	108
	737 Max 8 [m][a]	170
	737-300[d]	149
	737-300 [m][d]	126
	737-500[d]	138
	737-500[d] [m]	110
	737-800[b]	189
	737-800NG [m][a]	162
	737-900ER[b]	213
	737-900ER [m][c]	190
	777-300ER	396
	777-300ER [m][a]	314
	Average	198
	Average [m]	178
Other	ATR72-600	70
	CRJ1000	96
	Average	83

Note: [m] means multiple classes of seating are available; seating capacity excludes cockpit and cabin crew(s).

Sources: [a] Garuda Indonesia. 2020. "Revitalisasi Armada." 2020. www.garuda-indonesia.com/id/id/garuda-indonesia-experience/fleets/fleet-revitalization; [b] Lion Air. 2020. "Armada Kami." www.lionair.co.id/tentang-kami/armada-kami; [c] Husaini, Azis. 2020. "Batik Air, maskapai pesaing Garuda yang kini telah operasikan 76 pesawat." kontan.co.id. May 9. http://industri.kontan.co.id/news/batik-air-maskapai-pesaing-garuda-yang-kini-telah-operasikan-76-pesawat; [d] Casanova, Albert M., Bert van Leeuwen, Coen Capelle, Simon Finn, and Steven Guo. 2017. "An Overview of Commercial Aircraft 2018–2019." Schipol/London: DVB Bank. www.dvbbank.com/~/media/Files/D/dvbbank-corp/aviation/dvb-overview-of-commercial-aircraft-2018-2019.pdf.

The PLF expresses the average number of passengers in the aircraft divided by its capacity. The PLF of domestic flights on multiple Indonesian airlines is provided by the Ministry of Transportation (2018). For international flights, PLFs are provided by the ICAO (2017) according to the trip route. The domestic and international flight PLFs are summarized in Table 5.

Table 5 | **Passenger Load Factors for Domestic and International Flights**

Domestic Flights	
Airline	**PLF/ Passenger Load Factor**
Air Asia[a]	79
Batik Air[a]	75
Citilink[a]	84
Garuda Indonesia[a]	74
Lion Air[a]	81
Malindo Air[b]	76
Nam Air	79
Sriwijaya Air	82
Wings Air[a]	70
Other[b]	78
International Flights	
Airline	**Passenger Load Factor (%)**
Air Asia[a]	76
Batik Air[a]	61
Citilink[a]	71
Garuda Indonesia[a]	71
Lion Air[a]	81
Nam Air[a]	65
Sriwijaya Air[a]	85
Wings Air[a]	63
Other domestic airlines[a]	74
International airlines (origin/destination: Africa[c])	73
International airlines (origin/destination: Central Asia and Southwest Asia[c])	77
International airlines (origin/destination: Europe[c])	80
International airlines (origin/destination: Intra Pacific Southeast Asia[c])	76
International airlines (origin/destination: Middle East[c])	78
International airlines (origin/destination: North America[c])	78
International airlines (origin/destination: North Asia[c])	78

Sources: [a] Ministry of Transportation. 2018. "Transportation Statistics 2018." http://dephub.go.id/public/files/uploads/posts/ppidposts/postbody/buku-statistik-1-2018-final.pdf; [b] Casanova, Albert M., Bert van Leeuwen, Coen Capelle, Simon Finn, and Steven Guo. 2017. "An Overview of Commercial Aircraft 2018–2019." Schipol/London: DVB Bank. www.dvbbank.com/~/media/Files/D/dvbbank-corp/aviation/dvb-overview-of-commercial-aircraft-2018-2019.pdf; [c] ICAO. 2018. "Airport Air Quality Manual. Doc 9889." www.icao.int/environmental-protection/CarbonOffset/Documents/Methodology%20ICAO%20Carbon%20Calculator_v11-2018.pdf.

Determinants of Emissions of Greenhouse Gases and Air Pollutants

The bottom-up approach uses emission factors to calculate emissions of GHGs – CO_2 and CH_4 – and air pollutants – CO, nitrous oxide (N_2O), NO_X, NMVOCs, and SO_2. These factors express the calculated ratio between the amount of GHG and air pollutant emissions per unit of fuel consumption. The emission factors for CO_2 are based on fossil fuel consumption. As suggested by Indonesia's Ministry of Environment and Forestry (2010), emission factors are adopted from the IPCC's Guidelines for National Greenhouse Gas Inventories (Eggleston et al. 2006), which measured a default emission factor of 70,000 tonnes per terajoule (TJ) released by kerosene and aviation gasoline. In particular, the fossil fuel emission factors resulted from conversions: Indonesian emission factors from the Ministry of Environment and Forestry (2017) and the Ministry of Energy and Mineral Resources (2017) in kilograms of CO_2 per TJ are multiplied by the heating value of the fuel (TJ/liter).

Calculating passenger emissions of air pollutants (CO, N_2O, NO_X, NMVOCs, and SO_2) in kilograms requires emission factors for each air pollutant. The required data is similar to that needed for the GHG emissions calculation. Table 6 and Table 7 present emission factors of LTO and CCD, respectively, sourced from the ICAO (2020) and Eggleston et al. (2006), as suggested by Indonesia's Ministry of Environment (2012). In addition, the emission factors from the IPCC (Eggleston et al. 2006) were initially obtained in tonnes per TJ, and subsequently converted into unitless emission factors with conversion factors suggested by the UN (2020).

Table 6 | Landing-Take-Off: Emission Factors for GHGs and Air Pollutants

Aircraft	Code	Landing-Take-Off Emission Factor (kg/Landing-Take-Off)						
		CO_2 [a]	CH_4 [b]	CO[a]	N_2O [a]	NOx [b]	NMVOC [b]	SO_2 [a]
Airbus	A320-200CEO [m]	2665	0.06	8.14	0.10	9.90	0.51	0.42
	A320-200NEO [m]	1981	0.06	6.95	0.10	5.95	0.51	0.31
	A320-200	2665	0.06	8.14	0.10	9.90	0.51	0.42
	A320NEO	1981	0.06	6.95	0.10	5.95	0.51	0.31
	A321NEO	2373	0.14	6.94	0.10	10.76	1.27	0.38
	A330-200 [m]	7052	0.13	16.20	0.20	35.57	1.15	1..12
	A330-300	7052	0.13	16.20	0.20	35.57	1.15	1..12
	A330-300[m]	7052	0.13	16.20	0.20	35.57	1.15	1..12
	A330-900NEO [m]	7052	0.13	16.20	0.20	35.57	1.15	1..12
	A330-900NEO	7052	0.13	16.20	0.20	35.57	1.15	1..12
	Average	4693	0.10	11.81	0.15	22.03	0.91	0.37
	Average [m]	4693	0.10	11.81	0.15	22.03	0.91	0.37
Boeing	737 Max 8	2784	0.07	7.07	0.10	6.98	0.65	0.44
	737 Max 8 [m]	2784	0.07	7.07	0.10	6.98	0.65	0.44
	737-300	2737	0.08	6.48	0.10	6.98	0.75	0.43
	737-300 [m]	2737	0.08	6.48	0.10	6.98	0.75	0.43
	737-500	2737	0.08	6.48	0.10	6.98	0.75	0.43
	737-500 [m]	2737	0.08	6.48	0.10	6.98	0.75	0.43
	737-800	2784	0.07	7.07	0.10	12.30	0.65	0.44
	737-800NG [m]	2784	0.07	7.07	0.10	12.30	0.65	0.44
	737-900ER	2784	0.07	7.07	0.10	12.30	0.65	0.44
	737-900ER [m]	2784	0.07	7.07	0.10	12.30	0.65	0.44
	777-300ER	7197	0.07	16.60	0.30	37.47	0.59	1.14
	777-300ER [m]	7197	0.07	16.60	0.30	37.47	0.59	1.14
	Average	3520	0.07	8.46	0.13	13.84	0.67	0.55
	Average [m]	3520	0.07	8.46	0.13	13.84	0.67	0.55
Other	ATR72-600	641	0.30	2.35	1.88	10.20	2.60	0.10
	CRJ1000	1517	0.30	4.12	2.27	10.20	2.60	0.24
	Average	849	0.30	3.24	2.08	10.20	2.60	0.17

Note: [m] means multiple classes of seating are available. CO_2 is carbon dioxide, CH_4 is methane, CO is carbon monoxide, N_2O is nitrous oxide, NO_x means nitrogen oxides, NMVOC means non-methane volatile organic compound, and SO_2 is sulfur dioxide.
Sources: [a] ICAO. 2020. "ICAO Carbon Emissions Calculator Methodology." www.icao.int/publications/Documents/9889_cons_en.pdf; [b] Eggleston, Simon, Leandro Buendia, Kyoko Miwa, Todd Ngara, and Kyoto Tanabe. 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories. IPCC. www.ipcc-nggip.iges.or.jp/public/2006gl/.

Table 7 | Climb-Cruise-Descent: Emission Factors for Greenhouse Gas and Air Pollutant Emissions

Flight Type	Climb-Cruise-Descent Emission Factor (kg/kg fuel)						
	CO_2	CH_4	CO	N_2O	NO_x	NMVOC	SO_2
Domestic	3.15	0.02	7.0	0.001	0.011	0.0007	1.0
International	3.15	0.02	5.0	0.001	0.017	0.0027	1.0

Note: Domestic and international aviation emission factors are derived from emission factors of typical aircraft for domestic and international flights as suggested by Eggleston et al. (2006). CO_2 is carbon dioxide, CH_4 is methane, CO is carbon monoxide, N_2O is nitrous oxide, NO_x means nitrogen oxides, NMVOC means non-methane volatile organic compound, and SO_2 is sulfur dioxide.
Source: Eggleston, Simon, Leandro Buendia, Kyoko Miwa, Todd Ngara, and Kyoto Tanabe. 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories. IPCC. www.ipcc-nggip.iges.or.jp/public/2006gl/.

An illustration of calculations for passenger aviation emissions is provided in Table 8. The table presents two routes: Jakarta (CGK) to Makassar (UPG) and Makassar (UPG) to Kendari (KDI). This is a route to Eastern Indonesia with a transit in Makassar, an Indonesian hub airport.

Table 8 | **Sample Calculation for Aviation Passenger Emissions**

CO_2	Flight number	Route (D/I)*	Airline	Aircraft	Emission Factor: CCD (kg CO_2/kg fuel)	Emission Factor: LTO (kg CO_2/LTO)	Distance (km)	Distance correction factor (km)	Climb-cruise-descent fuel consumption rate (kg/km)	Trip total emissions (kgCO_2)	Passenger-to-cargo factor (%)	Seating capacity (pax)	Passenger load factor (%)	Emissions per person (kg CO_2/trip)
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)=((E)*((G)+(H))*(I))+(F)	(K)	(L)	(M)	(N)=(J)*(K)/((L)*(M))
	1	CGK-UPG [D]	Garuda Indonesia	Boeing 737-800NG [m]	3.15	2784	1528	100	3.85	22528	62.09	162	74	117
	2	UPG-KDR [D]	Garuda Indonesia	Boeing 737-800	3.15	2784	376	50	3.56	7561	62.09	189	74	34
	Emissions per person for entire journey (kg CO_2/trip)													150

CH_4	Flight number	Route (D/I)*	Airline	Aircraft	Emission Factor: CCD (kg CH_4/kg fuel)	Emission Factor: LTO (kg CH_4/LTO)	Distance (km)	Distance correction factor (km)	Climb-cruise-descent fuel consumption rate (kg/km)	Trip total emissions (kgCH_4)	Passenger-to-cargo factor (%)	Seating capacity (pax)	Passenger load factor (%)	Emissions per person (kg CH_4/trip)
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)=((E)*((G)+(H))*(I))+(F)	(K)	(L)	(M)	(N)=(J)*(K)/((L)*(M))
	1	CGK-UPG [D]	Garuda Indonesia	Boeing 737-800NG [m]	0.02	0.07	1528	100	3.85	125	62.09	162	74	0.6496
	2	UPG-KDR [D]	Garuda Indonesia	Boeing 737-800	0.02	0.07	376	50	3.56	30	62.09	189	74	0.1350
	Emissions per person for entire journey (kg CH_4/trip)													0.7846

CO	Flight number	Route (D/I)*	Airline	Aircraft	Emission Factor: CCD (kg CO/kg fuel)	Emission Factor: LTO (kg CO/LTO)	Distance (km)	Distance correction factor (km)	Climb-cruise-descent fuel consumption rate (kg/km)	Trip total emissions (kgCO)	Passenger-to-cargo factor (%)	Seating capacity (pax)	Passenger load factor (%)	Emissions per person (kg CO/trip)
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)=((E)*((G)+(H))*(I))+(F)	(K)	(L)	(M)	(N)=(J)*(K)/((L)*(M))
	1	CGK-UPG [D]	Garuda Indonesia	Boeing 737-800NG [m]	7	7.07	1528	100	3.85	43882	62.09	162	74	227.2784
	2	UPG-KDR [D]	Garuda Indonesia	Boeing 737-800	7	7.07	376	50	3.56	10623	62.09	189	74	47.1601
	Emissions per person for entire journey (kg CO/trip)													274.4385

N_2O	Flight number	Route (D/I)*	Airline	Aircraft	Emission Factor: CCD (kg N_2O/kg fuel)	Emission Factor: LTO (kg N_2O/LTO)	Distance (km)	Distance correction factor (km)	Climb-cruise-descent fuel consumption rate (kg/km)	Trip total emissions (kgN_2O)	Passenger-to-cargo factor (%)	Seating capacity (pax)	Passenger load factor (%)	Emissions per person (kg N_2O/trip)
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)=((E)*((G)+(H))*(I))+(F)	(K)	(L)	(M)	(N)=(J)*(K)/((L)*(M))
	1	CGK-UPG [D]	Garuda Indonesia	Boeing 737-800NG [m]	0.001	0.1	1528	100	3.85	6	62.09	162	74	0.0330
	2	UPG-KDR [D]	Garuda Indonesia	Boeing 737-800	0.001	0.1	376	50	3.56	2	62.09	189	74	0.0072
	Emissions per person for entire journey (kg N_2O/trip)													0.0402

NO_x	Flight number	Route (D/I)*	Airline	Aircraft	Emission Factor: CCD (kg NO_x/kg fuel)	Emission Factor: LTO (kg NO_x/LTO)	Distance (km)	Distance correction factor (km)	Climb-cruise-descent fuel consumption rate (kg/km)	Trip total emissions (kgNO_x)	Passenger-to-cargo factor (%)	Seating capacity (pax)	Passenger load factor (%)	Emissions per person (kg NO_x/trip)
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)=((E)*((G)+(H))*(I))+(F)	(K)	(L)	(M)	(N)=(J)*(K)/((L)*(M))
	1	CGK-UPG [D]	Garuda Indonesia	Boeing 737-800NG [m]	0.011	12.3	1528	100	3.85	81	62.09	162	74	0.4208
	2	UPG-KDR [D]	Garuda Indonesia	Boeing 737-800	0.011	12.3	376	50	3.56	29	62.09	189	74	0.1287
	Emissions per person for entire journey (kg NO_x/trip)													0.5495

NMVOC	Flight number	Route (D/I)*	Airline	Aircraft	Emission Factor: CCD (kg NMVOC/kg fuel)	Emission Factor: LTO (kg NMVOC/LTO)	Distance (km)	Distance correction factor (km)	Climb-cruise-descent fuel consumption rate (kg/km)	Trip total emission (kgNMVOC)	Passenger-to-cargo factor (%)	Seating capacity (Pax)	Passenger load factor (%)	Emissions per person (kg NMVOC/trip)
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)=((E)*((G)+(H))*(I))+(F)	(K)	(L)	(M)	(N)=(J)*(K)/((L)*(M))
	1	CGK-UPG [D]	Garuda Indonesia	Boeing 737-800NG [m]	0.0007	0.65	1528	100	3.85	5	62.09	162	74	0.0261
	2	UPG-KDR [D]	Garuda Indonesia	Boeing 737-800	0.0007	0.65	376	50	3.56	2	62.09	189	74	0.0076
	Emissions per person for entire journey (kg NMVOC/trip)													0.0337

SO_2	Flight number	Route (D/I)*	Airline	Aircraft	Emission Factor: CCD (kg SO_2/kg fuel)	Emission Factor: LTO (kg SO_2/LTO)	Distance (km)	Distance correction factor (km)	Climb-cruise-descent fuel consumption rate (kg/km)	Trip total emission (kgSO_2)	Passenger-to-cargo factor (%)	Seating capacity (pax)	Passenger load factor (%)	Emissions per person (kg SO_2/trip)
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)=((E)*((G)+(H))*(I))+(F)	(K)	(L)	(M)	(N)=(J)*(K)/((L)*(M))
	1	CGK-UPG [D]	Garuda Indonesia	Boeing 737-800NG [m]	1	0.44	1528	100	3.85	6268	62.09	162	74	32
	2	UPG-KDR [D]	Garuda Indonesia	Boeing 737-800	1	0.44	376	50	3.56	1517	62.09	189	74	7
	Emissions per person for entire journey (kg SO_2/trip)													39

Note: *D=domestic flight, I=international flight; CCD is climb-cruise-descent; LTO is landing and take-off period. CO_2 is carbon dioxide, CH_4 is methane, CO is carbon monoxide, N_2O is nitrous oxide, NO_x means nitrogen oxides, NMVOC means non-methane volatile organic compound, and SO_2 is sulfur dioxide.
Source: WRI Indonesia calculations.

2.3 Calculating Marine Transport Emissions

Method: Calculating Greenhouse Gas and Air Pollutant Emissions

Calculating GHG emissions and air pollutants for marine passenger transport is carried out according to Sims et al. (2015) and the ADEME (Environment and Energy Management Agency 2012). Similarly with aviation, the ADEME also simplifies the data required from users and gathers various determinants for calculating GHG and air pollutant emissions. A fuel-based approach—an emission calculation based on the fuel consumption on every trip—is used. As users input their travel distance, the fuel consumption is calculated by multiplying travel distance with a fuel consumption factor applicable to the vessel type. Then the fuel consumption is multiplied by the emission factors to calculate the total emissions per trip. To convert this into personal emissions, the total emissions per trip are divided by the capacity of the vessel and the average load factor.

The formula for the fuel-based method of calculating emissions of GHGs and air pollutants is as follows:

$$Total \text{ marine } emissions\ per\ person\ (TSEP_{pe})$$

$$= \sum_{i=1}^{N} \left(EF_{e/ap}\ x D_i x\ Fs_j \left(\frac{PTC_{ij}}{S_{ij}\ x\ ALF_i} + \frac{1 - PTC_{ij}}{PC_i\ x\ VO_i\ x\ VF_i} \right) \right) \quad (2)$$

where i (i=1,2,...N) is the number of trips (i^{th}); j is type of vessel; $EF_{e/ap}$ is emission/pollutant (e/ap) factor (tonne/kg (GHG/p)/ton fuel); D_i is the total distance in the i-trips (km); Fs_j is fuel consumption factor (kg fuel/km) of j- vessel; PTC_{ij} is the passenger-to-cargo factor or the ratio of total weight of passengers to the payload based on the vessel type (j) for the i^{th} trip; S_{ij} is the total number of seats available based on the vessel type (j) for the i^{th} trip; and ALF_i is average PLF or the ratio of average number of passengers transported; the number of available seats in the vessel for the i^{th} trip; PC_i is the car capacity based on the vessel type (j) for the i^{th} trip; VO_i is the vehicle occupancy for people traveling together in a car for the i^{th} trip; and VF_i is the vehicle factor (car=1, motorcycle=6) for the i^{th} trip. The total emissions/air pollutants per person are the sum of the calculations for every leg of the journey.

Technical Determinant for Calculating GHG and Air Pollutant Emissions

Fuel consumption, load factor, and seating capacity are used to calculate the marine transport GHG emissions and air pollutants. To ensure the results are relevant locally, the authors use the load factor and average vessel capacity from the busiest passenger seaport in Indonesia, Merak–Bakauheni. The port serves more than 18 million passengers per year (Ministry of Transportation 2014) and connects Java with Sumatra. It is located near Greater Jakarta, the nation's economic and industrial center.

Fuel consumption factors are generated based on an equation from the European Environment Agency (2019). This calculates fuel consumption (kg fuel/km) based on the total energy consumption of the ship in kilowatts (kW), which is generated by using travel time and power factor (kW hour) divided by trip distance. The data for these calculations are based on data from Indonesia's Ministry of Transportation (2014), which describes route characteristics (i.e., origin and destination, distance, travel time) and type of ship (i.e., weight, etc). Table 9 provides the fuel consumption factor by ship type.

Table 9 | **Marine Transport Fuel Consumption Factors**

Weight of Ship (Gross Tonnage)	Fuel Consumption Factor (kg fuel/km)
<250	15
250–500	21
5000–1000	25
>1000	53

Sources: WRI Indonesia calculations based on European Environment Agency (2019) and Ministry of Transportation (2014): European Environment Agency. 2019. "EMEP/EEA Air Pollutant Emission Inventory Guidebook 2019 — European Environment Agency." Publication. 2019. www.eea.europa.eu/publications/emep-eea-guidebook-2019; Ministry of Transportation. 2014. "Land Transport in Figure." Ministry of Transportation.

The passenger capacity of the vessel is represented by seating capacity. The average number of passengers in the ship is calculated by multiplying seating capacity with the PLF. The seating capacity numbers come from the Ministry of Transportation (2014), which gives average seating capacity for the busiest passenger seaport routes. Seating capacity and load factor are illustrated in Table 10. The highest average capacity is found for Merak to Bakauheni with 919 persons per vessel, while the lowest is Tanjung Api-Api to Tanjung Kelian with 188 persons per vessel.

Table 10 | **Marine Transport Seating Capacity and Load Factors**

Route	Average Load Factor (%)	Average Seating Capacity	Average Gross Tonnage	Passenger-to-Cargo Factor	Vehicle Capacity of Vessel
Bajoe–Kolaka	39.41	345	511	0.51	27
Kayangan–Pototano	28.09	288	329	0.54	20
Ketapang–Gilimanuk	37.91	277	331	0.43	30
Lintas Ujung–Kamal	56.37	250	116	0.80	5
Merak–Bakauheni	33.62	919	2877	0.42	102
Padang Bai–Lembar	34.03	241	513	0.44	25
Tanjung Api-Api–Tanjung Kelian	66.07	188	186	0.45	19
Average	39.36	354	695	0.51	33

Source: Ministry of Transportation. 2014. "Land Transport in Figure." Ministry of Transportation.

The average load factor represents the average number of passengers on a vessel divided by its seating capacity, and is calculated afresh for different routes. Data from the Ministry of Transportation (2014) are used to determine the average load factors. The highest average load factor is found for Tanjung Api-Api to Tanjung Kelian (66.07 percent), while the lowest is Kayangan to Pototano (28.09 percent). The average load factor numbers are also summarized in Table 10. Where route data are unavailable, average values are used.

Determinants of Emissions of Greenhouse Gases and Air Pollutants

As with aviation, emission factors are used to calculate GHG (CO_2) and air pollutant (CH_4, NO_X, $PM_{2.5}$, and SO_2) emissions for marine transport. While the emission factor ratio between GHG and air pollutant emissions and *fuel consumption* are used for the fuel-based approach, the emission factor ratio between GHG and air pollutant emissions and *distance* are used for the distance-based approach calculation. Emission factors for CO_2 and air pollutants are based on fossil fuel consumption. The emission factors for marine transport are calculated based on ship and fuel type using data from the European Environment Agency (2019) and Kristensen (2012), as shown in Table 11.

Table 11 | **Greenhouse Gas and Air Pollutant Emission Factors by Vessel Type**

Vessel Type	Fuel Type	Emission Factors (kg/kg fuel)				
		NO_X [a]	CO[a]	SO_2 [a]	$PM_{2.5}$ [a]	CO_2 [b]
Ship	Marine diesel oil/marine gas oil	0.0785	0.0074	0.0200	0.0014	3.114
	Gasoline	0.0094	0.5739	0.0200	0.0095	2.750
Boat	Diesel	0.0384	0.0198	0.0200	0.0046	3.206
	Gasoline: 2-stroke	0.0033	0.4810	0.0200	0.0126	3.114
	Gasoline: 4-stroke	0.0268	0.8510	0.0200	0.1880	3.151

Note: NO_X means nitrogen oxides, CO is carbon monoxide, SO_2 is sulfur dioxide, $PM_{2.5}$ is fine particulate matter with a diameter less than 2.5 micrometers, and CO_2 is carbon dioxide.
Sources: [a] European Environment Agency. 2019. "EMEP/EEA Air Pollutant Emission Inventory Guidebook 2019 — European Environment Agency." Publication. 2019. www.eea.europa.eu/publications/emep-eea-guidebook-2019; [b] Kristensen, Hans Otto. 2012. "Energy Demand and Exhaust Gas Emissions of Marine Engines." Clean Shipping Currents.

An example of the calculation is shown in Table 12: Merak to Bakauheni route, the busiest passenger route originating in Java.

Table 12 | **Sample Calculation for Marine Passenger Emissions**

	Route	Vehicle (car/ motorcycle/ non)	Vehicle occupancy (person)	Fuel type	Average gross tonnage (GT)	Emission factor (kg CO_2/kg fuel)	Distance (km)	Fuel consumption rate (kg fuel/km)	Passenger-to-cargo factor	Seating capacity (pax)	Average passenger load-factor	Car parking capacity (unit)	Vehicle factor
CO_2	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)
	Merak–Bauheni	Car	2	Marine diesel oil	2877	3.114	27.78	53	0.42	919	33.62	102	1
CO	Route	Vehicle (car/ motorcycle/ non)	Vehicle occupancy (person)	Fuel type	Average gross tonnage (GT)	Emission factor (kg CO/kg fuel)	Distance (km)	Fuel consumption rate (kg fuel/km)	Passenger-to-cargo factor	Seating capacity (pax)	Average passenger load-factor	Car parking capacity (unit)	Vehicle factor
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)
	Merak–Bauheni	Car	2	Marine diesel oil	2877	0.0074	27.78	53	0.42	919	33.62	102	1
SO_2	Route	Vehicle (car/ motorcycle/ non)	Vehicle occupancy (person)	Fuel type	Average gross tonnage (GT)	Emission factor (kg SO_2/kg fuel)	Distance (km)	Fuel consumption rate (kg fuel/km)	Passenger-to-cargo factor	Seating capacity (pax)	Average passenger load-factor	Car parking capacity (unit)	Vehicle factor
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)
	Merak–Bauheni	Car	2	Marine diesel oil	2877	0.02	27.78	53	0.42	919	33.62	102	1
$PM_{2.5}$	Route	Vehicle (car/ motorcycle/ non)	Vehicle occupancy (person)	Fuel type	Average gross tonnage (GT)	Emission factor (kg $PM_{2.5}$/kg fuel)	Distance (km)	Fuel consumption rate (kg fuel/km)	Passenger-to-cargo factor	Seating capacity (pax)	Average passenger load-factor	Car parking capacity (unit)	Vehicle factor
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)
	Merak–Bauheni	Car	2	Marine diesel oil	2877	0.0014	27.78	53	0.42	919	33.62	102	1
NO_x	Route	Vehicle (car/ motorcycle/ non)	Vehicle occupancy (person)	Fuel type	Average gross tonnage (GT)	Emission factor (kg NO_x/kg fuel)	Distance (km)	Fuel consumption rate (kg fuel/km)	Passenger-to-cargo factor	Seat capacity (pax)	Average passenger load-factor	Car parking capacity (unit)	Vehicle factor
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)
	Merak–Bauheni	Car	2	Marine diesel oil	2877	0.0785	27.78	53	0.42	919	33.62	102	1

Note: CO_2 is carbon dioxide, CH_4 is methane, CO is carbon monoxide, N_2O is nitrous oxide, NO_x is nitrogen oxides, NMVOC is non-methane volatile organic compound, SO_2 is sulfur dioxide, and $PM_{2.5}$ is fine particulate matter with a diameter less than 2.5 micrometers.
Source: WRI Indonesia calculations

EMISSIONS FOR PERSONAL LOGISTICS TRANSPORT

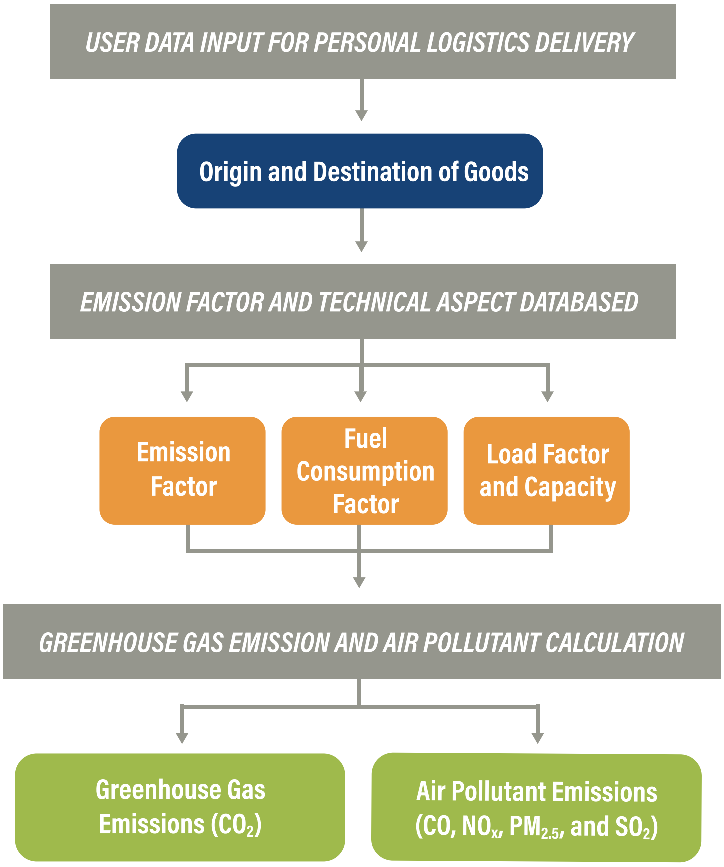
3.1 Method

The *Guidelines for National Greenhouse Gas Inventories* (Eggleston et al. 2006) classifies emissions from transport activities, including from logistics transport, as emissions from mobile sources. While there are top-down and bottom-up approaches for calculating emissions of GHGs and air pollutants generally, the methodology for calculating personal logistics emissions uses a bottom-up approach. If data are available, the bottom-up approach is preferable, as suggested by the IPCC (Eggleston et al. 2006). Therefore, EMISI gathers data on the logistics activities of individuals. In this technical note, the authors define personal logistics transport as courier services, both B2C and C2C, delivering personal goods. This method is specific to e-commerce goods; calculations would be different for transporting heavier goods, such as the bulk transport of coal, cement, or crude oil.

Several parameters are needed to calculate the GHG and air pollutant emissions for personal logistics services. The calculation is illustrated in Figure 2, where the gray boxes represent the process of calculation, the green boxes represent the calculation output, and boxes in other colors represent secondary data. The data needed consist of technical determinants (e.g., mode of transport, capacity of vehicle, distance), data related to the goods to be transported (e.g., type of package, dimensions, and weight), and emission factors. Some data are gathered from users, while others follow parameters from international or Indonesian reports, and others come from interviews with delivery companies (e.g., SiCepat, Ninja Express, Grab). The origin and destination, type of package, dimensions, and weight of the goods are among the data that users input in EMISI.

However, there are complexities in assessing the logistics chain during the journey from origin to destination. The individual has no information about the mode of transport a courier company uses for sending packages, or about the travel distance and mode of transport for each leg. Therefore, this technical note uses a decision tree (see Figure 2) to assess the mode of transport in every leg of a trip.

Figure 2 | **Framework for Personal Logistics Calculation**



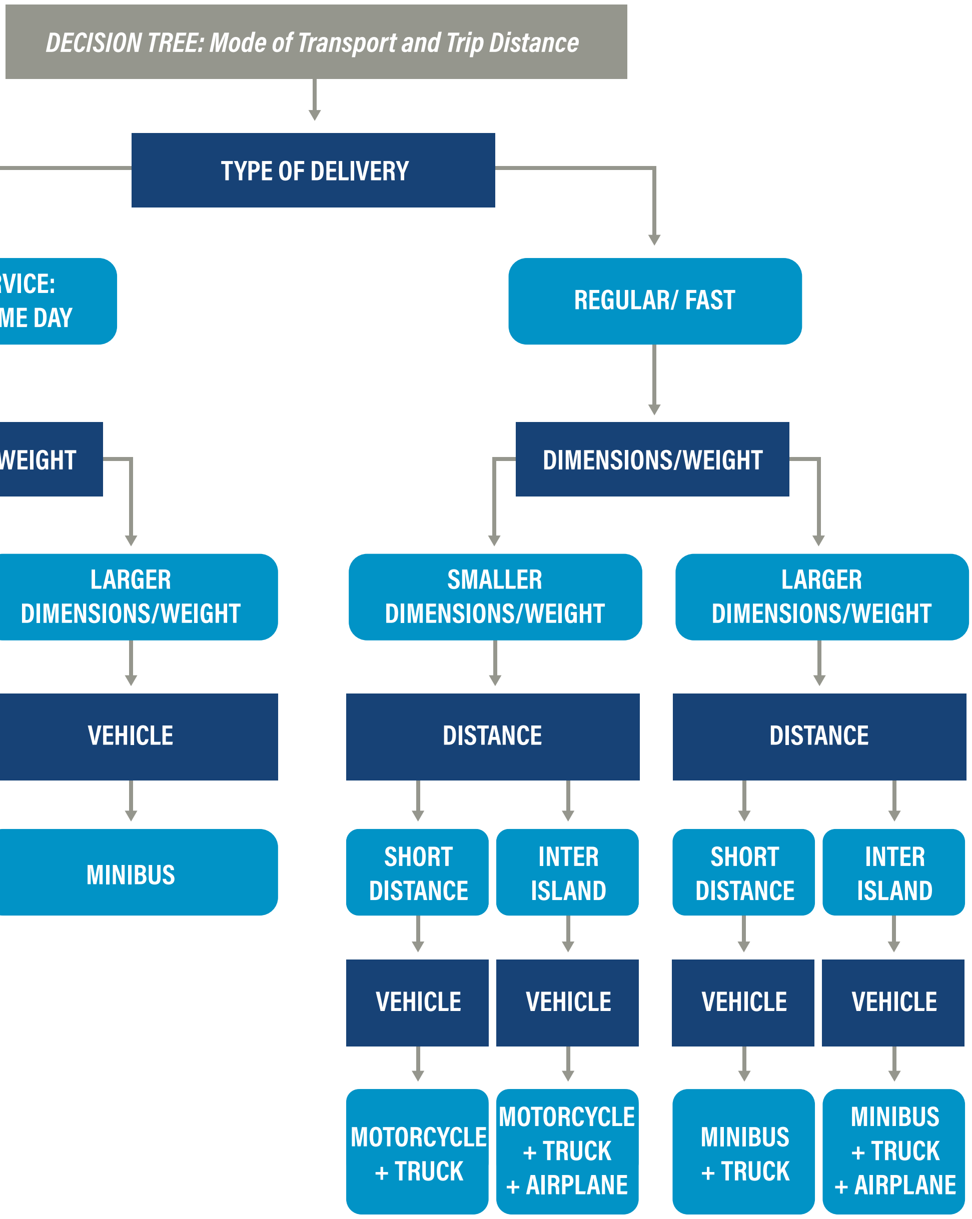
Note: Blue boxes indicate data input, orange are databased and green show output.
Source: WRI Indonesia

3.2 Determination of Logistics Trip Chain Based on Origin and Destination of Goods

The decision tree in Figure 3 was developed following interviews with courier companies in Indonesia (e.g., SiCepat, Grab, Ninja Express). The interviews focused on the behavior of operators in managing each delivery (e.g., the combination of several trips to accomplish one journey [the trip chain], choice of mode of transport). Interestingly, most courier companies stated that they use airplanes instead of marine transport for long-distance (intercity and interisland) delivery. The assessment within EMISI is based on the type of delivery service that users input: first, direct services or, second, regular or fast service. With direct services, the courier picks up the package and takes it directly to the recipient. Direct services are usually found for short to medium-length inner-city trips and do not require multiple modes of transport. In Indonesia, *direct services* are commonly offered by ride-hailing companies such as Grab. Two types of direct service are offered: express/instant, meaning goods ordered by one customer are directly delivered from origin to destination, and *regular/fast* services, which are same-day services, where multiple packages are carried on one trip. Regular/fast services can be characterized as conventional courier services that require multiple modes of transport for package delivery. This is due to a variety of distance or terrain (e.g., interisland, medium/short intercity distance).

Next, the dimensions and weight of a package are assessed; the package is then categorized as either small or large. The weight and dimensions influence the type of transport used. Motorcycles are used for smaller packages and minibuses for larger. In addition, regular/fast services are divided by trip distance, while for direct services, distance is not considered. Courier companies (e.g., SiCepat, Ninja Express, Grab, Tiki, Gojek) state that direct/express services commonly serve inner-city movement (Grab 2021) and have a maximum distance they will cover, as they must be completed on the same day. Fast/regular services generally require multiple modes of transport and are divided into truck-based and airplane-based multimodal trips. A marine transport–based multimodal trip is not used in this technical note because most courier companies in Indonesia use airplanes for interisland services. As with fast services, the modes of transport for the first mile and last mile of the trip in fast/regular services are determined based on the dimension/weight of the packages.

Figure 3 | **Decision Tree for Personal Logistics Trip**

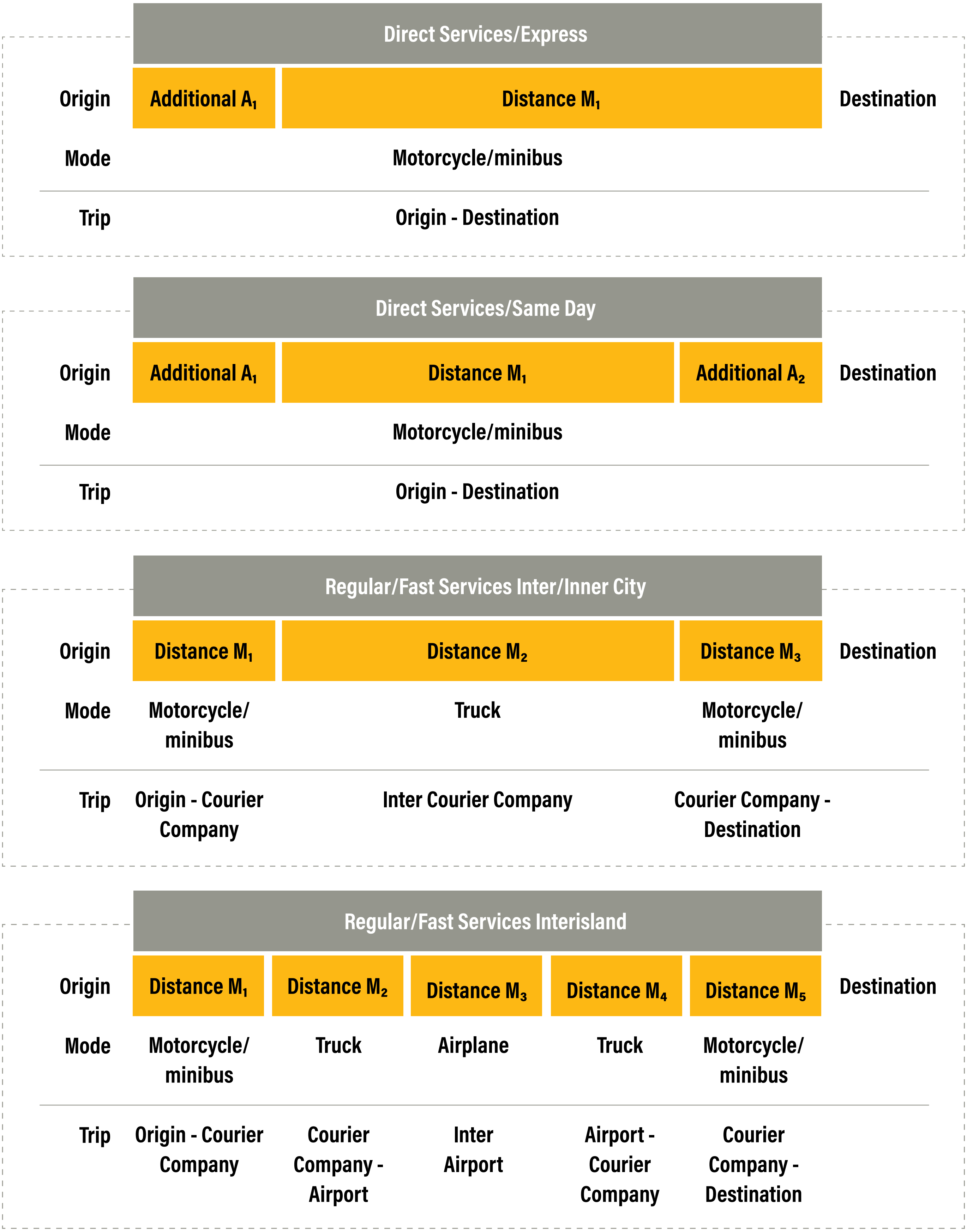


Source: WRI Indonesia, following interviews with delivery companies.

Travel Distance Component

Two types of trip exist in the delivery of personal goods: first, *direct services or express/same day*, with a single mode of transport (e.g., motorcycle or minibus), which is dictated by the dimensions and weight of the package; second, *regular/fast services*, which are commonly served by multiple modes of transport given the trip distance. Bearing in mind those characteristics, the trip distance component was developed. The trip distance for direct services is based on the distance between origin and destination, as assessed by Google Maps. Additional miles must be added for the direct express/same-day and multi-package services, due to the distance a driver must travel to pick up a package (same day) and for extra pickups and drop-offs for other customers (multi-package). Based on interviews with delivery companies, average distance between the driver and the location of each package is 1–2 km. This technical note assumes additional distance (*A*) of 1.5 km multiplied by 2 to account for both pickup and drop-off. The additional distance is also applied for express direct services but only for the pickup phase. On the other hand, for regular/fast services, the travel distance from origin and destination must be disaggregated based on the multiple modes of transport used. The illustration of one trip and its components (e.g., distance, modes, and trips) is shown in Figure 4.

Figure 4 | **Distance, Mode of Transport, and Trip Description**



Note: M1=First Mode, M2=Second Mode, M3=Third Mode, M4=Fourth Mode, M5=Fifth Mode, A=Additional distance.
Source: WRI Indonesia, following interviews with delivery companies.

The total distance of a multimode journey is the sum of the first-mile trip, the trunk trip, and the last-mile trip. The first-mile trip is the distance between the origin point of the parcel to the courier office and the last mile is the distance from the courier office to the destination of the parcel. The trunk trip means the lengthiest leg of the journey, and the modes of transport employed here are usually those with the largest capacity of any on the journey. For an interisland trip, the trunk trip consists of truck and airplane transport, while intercity trips are carried out by truck.

Given that EMISI only collects the distance between origin and destination, the distance of every multimode trip is assumed based on several parameters. Firstly, the first-mile trip from/to home to courier office distance is assumed based on the city. To determine the trip distance the number of courier offices in a city is divided by the area of the city. The outcome represents the area covered by one courier office. The calculation for determining the distance between home and courier office is shown in Table 13. Furthermore, the distance between airports is estimated based on data from Google Maps. The distance between airport and courier company is estimated using total distance between origin and destination, as input by a user, minus the distance between airports and distance between home and courier office.

Table 13 | **Average Distance to Courier Company**

City	Average Distance to Courier Office (km)
Bandar Lampung	0.82
Bandung	0.48
Batam	2.37
Jakarta	0.42
Makassar	0.85
Surabaya	0.86
Manado	2.93
Denpasar	0.72
Tasikmalaya	5.41
Medan	0.77
Padang	1.49
Palembang	1.07
Pekanbaru	1.0
Semarang	1.09
Balikpapan	1.66
Ambon	4.04
Sorong	13.46
Average	2.32

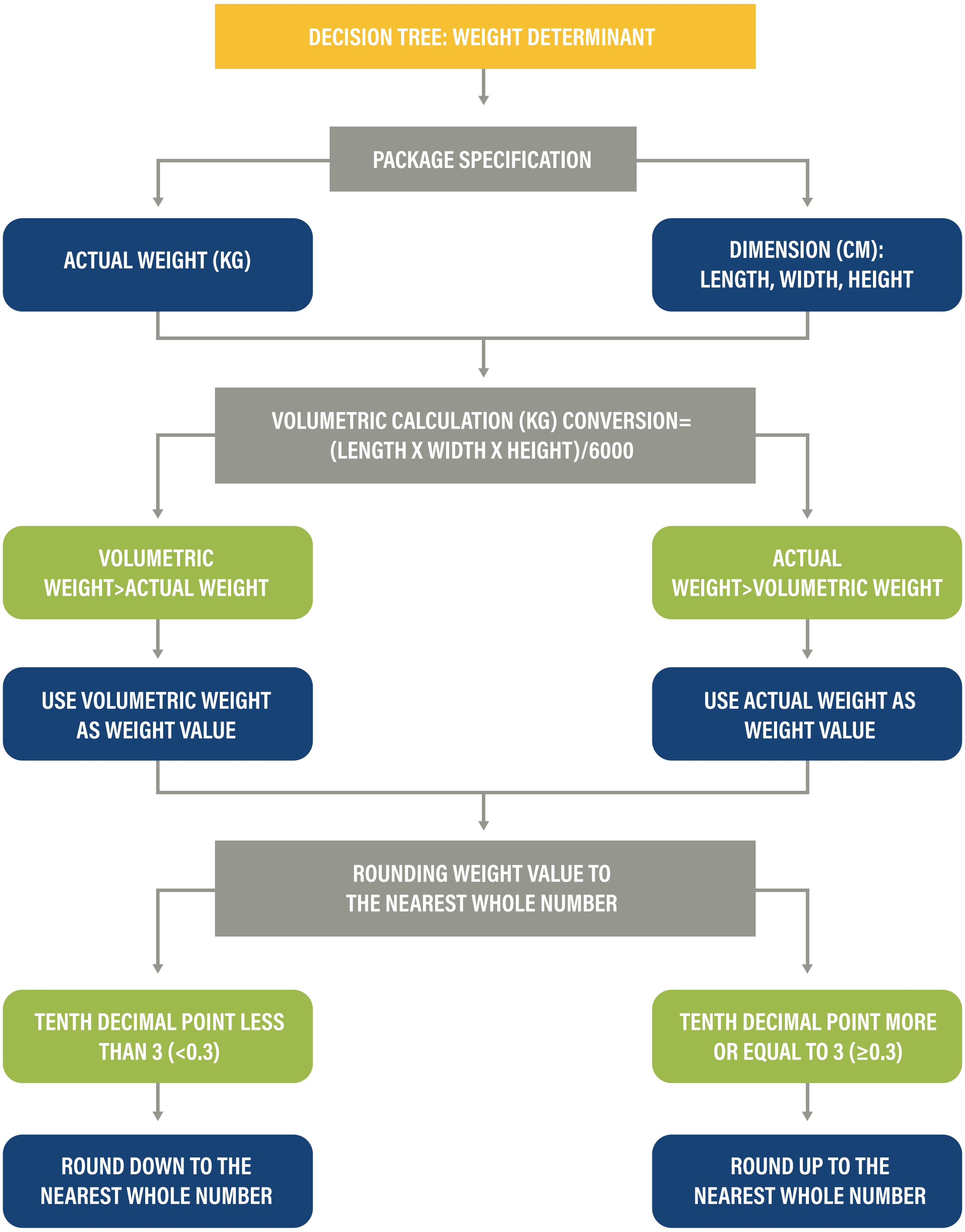
Source: WRI Indonesia calculations based on data from courier Tiki. Tiki.id. 2021. Lokasi Tiki. https://tiki.id/id/location.

Dimension and Weight Classification

Figure 5 shows a decision tree on how goods are quantified in kilograms by local delivery companies, a system used by local e-commerce outlets. The actual weight and the volumetric weight, as calculated according to the dimension of the goods, are compared. As the capacity of a container is defined not only by the total weight it carries, but also by its volume, a package is quantified based on both weight and dimensions.

However, as weight and dimension use different units, volumetric weight is based on a comparable value between volume and weight of a package. Logistic services in Indonesia define volumetric weight as the product of length (*L; cm*), width (*W; cm*), and height (*H; cm*) of the package, divided by 6,000, as a converting factor.

Figure 5 | **Classifying Weight and Dimensions**



Sources: Tokopedia. 2021. Berat dan Ukuran Paket Benar, Kunci Pengiriman Lancar. https://seller.tokopedia.com/edu/cara-menghitung-berat-paket/; WRI Indonesia.

3.3 Calculating Aviation Emissions in Personal Logistics Transport

Method: Calculating Greenhouse Gas and Air Pollutant Emissions

Airplanes are commonly used for delivering packages long distances and emissions per person must be calculated. The calculation of the aviation element also uses the fuel-based method, and considers the CCD and LTO, as explained in Section 2.2, "Calculating Emissions from Aviation."

The formula for calculating GHG and air pollutant emissions from an aviation leg of personal logistics is:

$$Total\ aviation\ logistics\ emissions\ per\ person\ (TALEP_{pe})$$

$$= \sum_{i=1}^{N}\left(\left((EF_{CCD\ e/ap}\ x\ Dc_i x Fa_{CCD}) + EF_{LTO\ e/ap}\right) x \frac{W}{C_{ij}\ x\ LF_i}\right) \quad (3)$$

where i (i = 1, 2,... N) is number of trips (i^{th}) captured; $EF_{CCD\ e/ap}$ is emission/pollutant (*e/ap*) factor (kg (GHG/p)/kg fuel) during CCD; Dc_i is the total distance in the *i*-trips (km) corrected with distance correction factor; Fa_{CCD} is fuel consumption factor (kg fuel/km) during cruise time; $EF_{LTO\ e/ap}$ is emission/pollutant (*e/ap*) factor (kg (GHG/p)/LTO cycle) during LTO; *W* is the weight of transported goods in kilograms based on weight determination; C_{ij} is the capacity of the mode of transport (*j*) for the i^{th} trip in kilograms; and LF is the load factor of the mode of transport (*j*) for the i^{th} trip. The total GHG and air pollutant emissions per person is the sum of the calculations for every leg of the entire journey.

Technical Determinant for Calculating Greenhouse Gas and Air Pollutant Emissions

The technical determinants for calculating aviation emissions are aircraft characteristics, including fuel consumption during the trip. In contrast to the aviation transport calculation for passengers, the load factor and capacity used are based on the cargo weight. These characteristics are essential for calculating GHG and air pollutant emissions per person. Similar with passenger transport, the fuel consumption for CCD is calculated, this time based on the logistics aircraft Boeing 737-300, which is commonly used by Indonesian airlines for logistics. Table 14 summarizes fuel consumption during CCD based on distance.

Table 14 | **Aviation Fuel Consumption during Climb-Cruise-Descent**

Distance	Fuel Consumption Rate (kg fuel/km)
125 nm~231 km	3.95
250 nm~463 km	5.74
500 nm~926 km	4.03
750 nm~1389 km	3.8
1000 nm~1852 km	3.64
1500 nm~2778 km	3.43
2000 nm~3704 km	3.29
Average	3.98

Note: 1 nautical mile (nm) = 1.852 kilometer (km)
Source: ICAO. 2018. "Airport Air Quality Manual. Doc 9889." www.icao.int/environmental-protection/CarbonOffset/Documents/Methodology%20ICAO%20Carbon%20Calculator_v11-2018.pdf.

The cargo load factor expresses the average amount of cargo (by weight and dimensions) carried by an aircraft divided by its capacity. The cargo load factor used is based on the type of aircraft, with information provided by the CEIC (2018). The methodology also uses the cargo capacity, the total cargo in kilograms that can be carried by the aircraft. The capacity is used to calculate the average weight of cargo in the aircraft by multiplying the capacity by the cargo load factor. The cargo capacity numbers use data from the ICAO (2018) for Boeing 737-300 (see Table 15).

Table 15 | **Capacity and Load Factor of Cargo Airplane**

Aircraft	Capacity (kg)	Load Factor (%)
Boeing 737-300	17000[a]	62.11 [b]

Sources: [a] ICAO. 2018. "Airport Air Quality Manual. Doc 9889." www.icao.int/environmental-protection/CarbonOffset/Documents/Methodology%20ICAO%20Carbon%20Calculator_v11-2018.pdf; [b] CEIC. 2018. "Indonesia Airline Production: International: Passenger Load Factor." www.ceicdata.com/en/indonesia/airline-production/airline-production-international-passenger-load-factor.

Determinants of Emissions of Greenhouse Gases and Air Pollutants

As the fuel-based method is used for this calculation, emission factors based on fuel consumption are used to calculate emissions of GHGs (CO_2 and CH_4) and air pollutants (NO_x, SO_2 and NMVOC). These factors express the calculated ratio between GHG and air pollutant emissions and fuel consumption. Emission factors for CO_2 are based on fossil fuel consumption. The emission factors used for aviation logistics (see Table 16) are similar to those used for airline passengers in Section 2.2.

Table 16 | **Aviation Greenhouse Gas and Air Pollutant Emission Factors**

Greenhouse Gas / Air Pollutant	Emission Factor	
	Climb-Cruise-Descent (kg/kg fuel)	Landing-Take-Off (kg/landing-take-off)
CO_2	3.15	2737
CH_4	0.02	0.08
CO	7.0	6.48
N_2O	0.001	0.10
NO_X	0.011	6.98
NMVOC	0.0007	0.76
SO_2	1.0	0.43

Note: CO_2 is carbon dioxide, CH_4 is methane, CO is carbon monoxide, N_2O is nitrous oxide, NO_X means nitrogen oxides, NMVOC is non-methane volatile organic compound, and SO_2 is sulfur dioxide.
Source: Eggleston, Simon, Leandro Buendia, Kyoko Miwa, Todd Ngara, and Kyoto Tanabe. 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. IPCC. www.ipcc-nggip.iges.or.jp/public/2006gl/.

3.4 Calculating Land Transport Emissions in Personal Logistics

Method: Calculating Greenhouse Gas and Air Pollutant Emissions

First, the formula for the *fuel-based method* to calculate GHG emissions for land transport in the fast services and regular services delivery is:

$$Fuel - based\ total\ land\ transport\ delivery\ emissions\ per\ person\ (FTLDEPp)$$
$$= \sum_{i=1}^{N} \left(EF_{e/ap-ij}\ x\ \frac{FCR_{ji}\ x\ D_{ji}\ x\ W}{C_{ij}\ x\ LF_{ij}} \right) \quad (4)$$

where i (i = 1, 2,... N) is number of trips (i^{th}) captured; j is land transport modes (e.g., motorcycle, minibus, or truck); D_{ji} is the distance (km) for the land transport mode (j) for the i^{th} trip; $EF_{e/ap-ij}$ is emission/pollutant (e/ap) factor based on the land transport mode (j) in the unit of (kg (GHG)/liter); FCR_{ji} is the fuel consumption rate (liter per km) for the transport mode (j) for the i^{th} trip; W is the weight of transported goods in the unit of kilograms based on weight determination; C_{ij} is the capacity of the transport mode (j) for the i^{th} trip in the unit of kilograms; and LF_{ij} is the load factor of the transport mode (j) for the i^{th} trip. The total emissions per package is the sum of emissions for each leg of the trip.

The formula for the *distance-based method* to calculate air pollutant emissions for land transport for fast and regular deliveries is:

$$Distance - based\ total\ land\ transport\ delivery\ emissions\ per\ person\ (DTLDEPp)$$
$$= \sum_{i=1}^{N} \left(EF_{e/ap-ij}\ x\ \frac{D_{ij}\ x\ W}{C_{ij}\ x\ LF_{ij}} \right) \quad (5)$$

where i (i = 1, 2,... N) is number of trips (i^{th}) captured; j is land transport modes (e.g., motorcycle, minibus, or truck); D_{ij} is the distance (km) for the land transport mode (j) for the i^{th} trip; $EF_{e/ap-ij}$ is emission/pollutant (e/ap) factor based on the land transport mode (j) for the i^{th} trip in the unit of (kg (pollutant)/distance); W is the weight of transported goods in the unit of kilograms based on weight determination; C_{ij} is the capacity of the transport mode (j) for the i^{th} trip in the unit of kilograms; and LF is the load factor of the transport mode (j) for the i^{th} trip. The total emissions per goods is the sum of the emissions for each leg of the trip.

For direct services, the *fuel-based method* is used to calculate GHG emissions, with motorcycle and minibus the main modes of transport used for deliveries. The method for calculating emissions is different than that used for regular/fast services as direct services are provided exclusively for a limited number of packages; load factor is not used in the calculation, and capacity is based on the number of packages. Direct services are characterized with single modes of transport rather than multiple.

The formula for the *fuel-based method* to calculate *GHG emissions* in direct services, meaning express/instant and same-day is:

$$Fuel - based\ total\ express\ delivery\ emission\ per\ person\ (FTEEP_{pe})$$
$$= EF_{e/ap-j}\ x\ \frac{FCR_j\ x\ (D_j + A_d)}{C_j} \quad (6)$$

where j is land transport modes (e.g., motorcycle or minibus); $EF_{e/ap-j}$ is the emission and pollutant factor based on the transport mode (j) in the unit of (kg (GHG)/liter fuel); FCR_j is the fuel consumption rate (liter per km) for the transport mode (j); and D_j is the total distance (kilometer) for the transport mode (j); A_d is the additional distance due to driver have to pick-off and drop-off multiple packages (1.5 km for instant/express and 3 km for same day); C_j is the maximum number of packages transported in a single trip. The maximum capacity for each mode of transport can be seen in Table 17 and Table 18.

The *distance-based method* is used to calculate *air pollutants* in direct services, meaning express/instant and same day:

$$\text{Distance} - \text{based total express delivery emission per person } (DTEEP_{pe}) = EF_{e/ap-j}\ x\ \frac{(D_j + A_d)}{C_j} \qquad (7)$$

where j is land transport modes (e.g., motorcycle or minibus); $EF_{e/ap-j}$ is the emission and pollutant factor based on the transport mode (j) in the unit of (kg (pollutant)/distance); and D_j is the total distance (kilometer) for the transport mode (j); A_d is the distance added to account for the driver having to pick up and drop off multiple packages (1.5 km for instant/express and 3 km for same day); C_j is the maximum number of items transported in a single trip. The maximum number of items are assumed, as seen in Table 17 and Table 18, based on the type of service chosen by the user.

Technical Determinant for Calculating Greenhouse Gas and Air Pollutant Emissions

The technical determinants for calculating land transport emissions are vehicle related and include the fuel consumption for the trip and the capacity of the vehicle. These characteristics are essential for calculating GHG emissions and air pollutants per person. Fuel consumption and capacity of the vehicle are given in four types of vehicle generally used for land transport logistics services, and fuel consumption and capacity are presented for each in Table 17. Fuel consumption means the fuel consumed by the vehicle during the journey which, in this methodology, is based on a regulation issued by the Ministry of Environment and Forestry (2010). The regulation provides the fuel consumption rate based on the vehicle and the factors described in Table 17. However, the load factor for land transport logistics is assumed at 70 percent due to lack of data availability.

Table 17 | **Fuel Consumption Factors and Vehicle Capacity for Land Transport**

Vehicle	Fuel Consumption Rate (km/l)	Capacity (kg)
Large truck	4.4[a]	4 000[b]
Small truck	4[a]	2 200[b]
Minibus	8[a]	720[b]
Motorcycle	28[a]	50[c]

Sources: [a] Ministry of Environment and Forestry. 2010. "Peraturan Menteri Negara Lingkungan Hidup Nomor 12 Tahun 2010 - Hukumonline.Com." Ministry of Environment and Forestry Indonesia. https://m.hukumonline.com/pusatdata/detail/lt4c283ee4c67c5/node/lt511a13750665b/peraturan-menteri-negara-lingkungan-hidup-no-12-tahun-2010-pelaksanaan-pengendalian-pencemaran-udara-di-daerah; [b] Deliveree. 2021. "Jasa Ekspedisi Kargo Murah Delivery Jakarta (Dimanapun 2021)." www.deliveree.com/id (blog). 2021. www.deliveree.com/id/jasa-ekspedisi-kargo-murah-delivery-jakarta/; [c] Astramotor. 2020. "6 Tips Dan Cara Sederhana Merawat Motor Baru, Sangat Mudah Dilakukan." 2020. www.astramotor.co.id/tips-dan-cara-sederhana-merawat-motor-baru-sangat-mudah-dilakukan/.

For motorcycles, the capacity is commonly determined by the type of service. The fact that there is no specific standard or available publication for the goods capacity of motorcycles, combined with the complexity of motorcycle delivery services, means most delivery companies develop safety procedures to ensure drivers do not overload their motorcycles. (Drivers are paid by the number of packages they deliver, and therefore may try to carry too much, while customers tend to underestimate the size of their packages.) Some of these companies provide drivers with equipment, such as large bags, for carrying the goods to increase the efficiency of deliveries. This equipment is very visible for the regular and fast delivery services as well as same-day direct services. The capacity of motorcycle delivery services is provided in Table 18 and is based on interviews with local delivery companies. The express/instant direct services provided more exclusive delivery services for one package, while for same-day direct services the capacity ranges from four to six packages. The regular/fast services have the highest capacity (30–40 packages) because the companies have a sorting facility.

Table 18 | **Motorcycle Capacity for Deliveries**

Service	Capacity (packages)
Direct (door-to-door) service—express/instant	1
Direct (door-to-door) service—same day	4–6
Regular/fast service	30–40

Sources: WRI Indonesia based on interviews with delivery companies.

Determinants of Emissions of Greenhouse Gases and Air Pollutants

Fuel consumption is calculated by multiplying the fuel consumption factor by distance traveled. The total emissions and air pollutants, consequently, are calculated by multiplying fuel consumption by emission factors. The emission factors are described in Table 19. Like the fuel consumption, emission factors for CO_2 are calculated on a fuel-based method; the unit, therefore, is emissions per liter of fuel consumed. Fossil fuel emission factors are calculated by multiplying Indonesian emission factors from the MoEF (2019) and the Ministry of Energy and Mineral Resources (2019) in kg CO_2/TJ unit by the heating value (TJ/liter) of the fuel.

Table 19 | **CO_2 Emission Factors**

Fuel/Energy	CO_2 Emission Factor (kg CO_2/liter)
Automotive diesel oil	3.26
RON 92 gasoline	3.08
RON 88 gasoline	3.11

Sources: Ministry of Energy and Mineral Resources. 2019. "Updated Emission Factor for Energy Sector." Pusat Data dan Informasi, Ministry of Energy and Forestry.

While the CO_2 calculation uses the fuel-based method, calculating air pollutants (CO, NO_X, $PM_{2.5}$, and SO_2) requires the distance-based method. The required data are similar to those needed for the CO_2 emission calculation, although the emission factors are based on distance traveled and the mode of transport. The emission factors for air pollutants are obtained from studies conducted by the MoEF (2010), as shown in Table 20. The emission factors from electricity are sourced from Hasan et al. (2012), who distinguish air pollutant emission factors based on the type of fuel used in power plants in Indonesia. The emission factors for $PM_{2.5}$ and other air pollutants were compiled from Shrestha et al. (2013), who developed the *Atmospheric Brown Clouds Emission Inventory Manual* for Asian developing countries. Emission factors for vehicles without pollution control devices are adopted for $PM_{2.5}$. Uncontrolled emission factors tend to be higher than the controlled emission factors since they are acquired from vehicles without air pollution control equipment.

Table 20 | **Air Pollutant Emission Factors**

Vehicle Type	Air Pollutant Factor			
	kg CO/km[b]	kg NO_X/km[b]	kg $PM_{2.5}$/km[b]	kg SO_2/km[a]
Truck	0.0045	0.0126	0.0012	0.00093
Minibus (gasoline)	0.039	0.0011	0.00005	0.000026
Minibus (diesel)	0.0069	0.00249	0.0005	0.00044
Motorcycle[c]	0.0694	0.00029	0.00023	0.0001

Note: The heating value for gasoline is 33x10^{-6} TJ/liter, and for diesel is 38x10^{-6} TJ/liter. CO is carbon monoxide; NO_X means nitrogen oxides, $PM_{2.5}$ means fine particulate matter with a diameter less than 2.5 micrometers, and SO_2 is sulfur dioxide. 1 TJ = 0.2778 GWh.
Sources: [a] Ministry of Environment and Forestry. 2010. "Peraturan Menteri Negara Lingkungan Hidup Nomor 12 Tahun 2010 - Hukumonline.Com." Ministry of Environment and Forestry Indonesia. https://m.hukumonline.com/pusatdata/detail/lt4c283ee4c67c5/node/lt511a13750665b/peraturan-menteri-negara-lingkungan-hidup-no-12-tahun-2010-pelaksanaan-pengendalian-pencemaran-udara-di-daerah; [b] Shrestha, R. M., Kim Oanh, N. T., Shrestha, R., Rupakheti, M., Permadi, D. A., Kanabkaew, T., and Salony, R. 2013. *Atmospheric Brown Clouds Emission Inventory Manual.* Nairobi, Kenya: United Nation Environmental Programme; [c] Oanh, N. T. K., Permadi, D. A., Dong, N. P., and Nguyet, D. A. 2018. "Emission of toxic air pollutants and greenhouse gases from crop residue open burning in Southeast Asia." In *Land-Atmospheric Research Applications in South and Southeast Asia,* Springer Remote Sensing/Photogrammetry, edited by Krishna Prasad Vadrevu, Toshimasa Ohara, and Chris Justice, 47-66. Cham: Springer International Publishing.

To show the calculations in action, examples are given in Table 21, Table 22, and Table 23 for direct, inter/inner-city, and interisland journeys, respectively. The sample calculations present three scenarios involving typical personal logistics services (i.e., direct, intercity, and interisland) in Indonesia. The first scenario, described in Table 21, illustrates direct services whereby users send packages expecting delivery within one to two hours, or six to eight hours. Such services are typical of online delivery services attached to the ride-hailing apps (e.g., Grab and Gojek) that emerged in 2015. Table 22 describes the second scenario that illustrates the intercity personal logistics services, while the third scenario illustrates the interisland personal logistics services (Table 23). Both scenarios represent the personal courier services that exist currently in Indonesia (i.e., Tiki, SiCepat, Ninja Express, JNT, etc.)

Table 21 | **Sample Calculation for Direct Service Logistics Transport Emissions**

CO_2	Type of direct service	Distance (km)	Additional distance (km)	Emission factor (kg CO_2/liter)	Fuel consumption rate (km/liter)	Average items delivered per trip	Emissions per person (g CO_2/trip)
	(A)	(B)	(C)	(D)	(E)	(F)	(G)=((D)*((B)+(C)))/((E)*(F))
	Motorcycle (1–2 hours delivery)	20	1.5	2.68	28	1	2058

CO	Type of direct service	Distance (km)	Additional distance (km)	Emission factor (kg CO/km)	Average items delivered per trip	Emissions per person (g CO/trip)
	(A)	(B)	(C)	(D)	(E)	(F)=((D)*((B)+(C)))/(E)
	Motorcycle (1–2 hours delivery)	20	1.5	0.0694	1	1492
NO_x	Type of direct service	Distance (km)	Additional distance (km)	Emission factor (kg NO_x/km)	Average items delivered per trip	Emissions per person (g NO_x/trip)
	(A)	(B)	(C)	(D)	(E)	(F)=((D)*((B)+(C)))/(E)
	Motorcycle (1–2 hours delivery)	20	1.5	0.00029	1	6.24
$PM_{2.5}$	Type of direct service	Distance (km)	Additional distance (km)	Emission factor (kg $PM_{2.5}$/km)	Average items delivered per trip	Emissions per person (g $PM_{2.5}$/trip)
	(A)	(B)	(C)	(D)	(E)	(F)=((D)*((B)+(C)))/(E)
	Motorcycle (1–2 hours delivery)	20	1.5	0.00023	1	4.95
SO_2	Type of direct service	Distance (km)	Additional distance (km)	Emission factor (kg SO_2/km)	Average items delivered per trip	Emissions per person (g SO_2/trip)
	(A)	(B)	(C)	(D)	(E)	(F)=((D)*((B)+(C)))/(E)
	Motorcycle (1–2 hours delivery)	20	1.5	0.0001	1	2.15

Note: CO_2 is carbon dioxide, CH_4 is methane, CO is carbon monoxide, N_2O is nitrous oxide, NO_x means nitrogen oxides, NMVOC means non-methane volatile organic compound, SO_2 is sulfur dioxide, and $PM_{2.5}$ is fine particulate matter with a diameter less than 2.5 micrometers.
Source: WRI Indonesia calculations.

Table 22 | Calculation Sample for Inter/Inner-City Service Logistics Transport Emissions

Calculation of Weight Value

Description			Value	Unit
Input	Length (L)	(A)	50	cm
	Width (W)	(B)	37.5	cm
	Height (H)	(C)	34	cm
	Weight	(D)	7	kg
Dimension to weight conversion		(E)=(A)*(B)*(C)/6000	10.63	kg
Weight value		(F)=max((D),(E))	10.63	kg

Calculation of Distance of Each Trip

Description			Value	Unit
Input	Origin city	(A)	Bogor	
	Destination city	(B)	Bandung	
	Distance	(C)	183	km
First-mile and last-mile trip	Origin	(D)	1	km
	Destination	(E)	0.5	km
Trunk trip distance		(D)=(C)-(D)-(E)	181.5	km

Total Emissions of Inter/Inner-City Service Logistics Transport

	Trip number	Transport mode	Emission factor (kg CO_2/liter)	Distance (km)	Fuel consumption rate (km/liter)	Fuel consumption (liter)	Weight value (kg)	Vehicle capacity (kg)	Load factor (%)	Emissions per person (g CO_2/trip)
CO_2	(A)	(B)	(C)	(D)	(E)	(F)=(D)/(E)	(G)	(H)	(I)	(J)=(C)*(F)*(G)/((H)*(I))
	1	Minibus (diesel)	2.68	4	8	0.5	10.63	720	70	28
	2	Truck	2.68	176	4	44	10.63	4000	70	447
	3	Minibus (diesel)	2.68	3	8	0.375	10.625	720	70	21
	Emissions per goods delivered (kg CO_2/trip)									497

	Trip number	Transport mode	Emission factor (kg CO/km)	Distance (km)	Weight value (kg)	Vehicle capacity (kg)	Load factor (%)	Emissions per person (g CO/trip)
CO	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)=(C)*(D)*(E)/((F)*(G))
	1	Minibus (diesel)	0.0069	4	10.63	720	70	0.5818
	2	Truck	0.0045	176	10.63	4000	70	3.0054
	3	Minibus (diesel)	0.0069	3	10.63	720	70	0.4364
	Emissions per goods delivered (kg CO/trip)							4.0236

	Trip number	Transport mode	Emission factor (kg NO_x/km)	Distance (km)	Weight value (kg)	Vehicle capacity (kg)	Load factor (%)	Emissions per person (g NO_x/trip)
NO_x	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)=((C)*(D)*(E)/((F)*(G))
	1	Minibus (diesel)	0.00249	4	10.63	720	70	0.2100
	2	Truck	0.0126	176	10.63	4000	70	8.4150
	3	Minibus (diesel)	0.00249	3	10.63	720	70	0.1575
	Emissions per goods delivered (kg NO_x/trip)							8.7824

	Trip number	Transport mode	Emission factor (kg $PM_{2.5}$/km)	Distance (km)	Weight value (kg)	Vehicle capacity (kg)	Load factor (%)	Emissions per person (g $PM_{2.5}$/trip)
$PM_{2.5}$	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)=((C)*(D)*(E)/((F)*(G))
	1	Minibus (diesel)	0.0005	4	10.63	720	70	0.0422
	2	Truck	0.0012	176	10.63	4000	70	0.8014
	3	Minibus (diesel)	0.0005	3	10.63	720	70	0.0316
	Emissions per goods delivered (kg $PM_{2.5}$/trip)							0.8752

	Trip number	Transport mode	Emission factor (kg SO_2/km)	Distance (km)	Weight value (kg)	Vehicle capacity (kg)	Load factor (%)	Emissions per person (g SO_2/trip)
SO_2	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)=((C)*(D)*(E)/((F)*(G))
	1	Minibus (diesel)	0.00044	4	10.63	720	70	0.0371
	2	Truck	0.00093	176	10.63	4000	70	0.6211
	3	Minibus (diesel)	0.00044	3	10.63	720	70	0.0278
	Emissions per goods delivered (kg SO_2/trip)							0.6860

Note: CO_2 is carbon dioxide, CH_4 is methane, CO is carbon monoxide, N_2O is nitrous oxide, NO_x means nitrogen oxides, NMVOC means non-methane volatile organic compound, SO_2 is sulfur dioxide, and $PM_{2.5}$ is fine particulate matter with a diameter less than 2.5 micrometers.
Source: WRI Indonesia calculations

Table 23 | **Sample Calculation for Interisland Service Logistics Transport Emissions**

Weight Value Calculation				
Description			**Value**	**Unit**
Input	Length	(A)	20	cm
	Width	(B)	20	cm
	Height	I	20	cm
	Weight	(D)	3	kg
Dimension to weight conversion		(E)=(A)*(B)*(C)/6000	1.33	kg
Weight value		(F)=max((D),(E))	3.00	kg

Calculation of Distance of Each Trip				
Description			**Value**	**Unit**
Input	Origin city	(A)	Bogor	
	Destination city	(B)	Pontianak	
	Distance	(C)	183	km
First mile and last mile	Origin	(D)	1	km
	Destination	(E)	2	km
Intermediate distance		(F)=(C)-(D)-(E)	180	km

Emissions from Land Transport

	Trip order	Transport mode	Emission factor (kg CO_2/liter)	Distance (km)	Fuel consumption rate (km/liter)	Fuel consumption (liter)	Weight value (kg)	Vehicle capacity (kg)	Load factor (%)	Emissions per person (g CO_2/trip)
CO_2	(A)	(B)	(C)	(D)	(E)	(F)=(D)/(E)	(G)	(H)	(I)	(J)=((C)*(F)*(G)/((H)*(I)) *1000
	M1	Motorcycle	2.68	4	28	0.14	3.00	50	70	33
	M2	Large truck	2.68	60	4.4	13.63	3.00	4000	70	39
	M4	Small truck	2.68	20	4	5	3.00	2200	70	26
	M5	Motorcycle	2.68	3	28	0.11	3.00	50	70	25
	Emissions per parcel delivered (kg CO_2/trip)									123

	Trip order	Transport mode	Emission factor (kg CO/km)	Distance (km)	Weight value (kg)	Vehicle capacity (kg)	Load factor (%)	Emissions per person (g CO/trip)
CO	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)=((C)*(D)*(E)/((F)*(G)) *1000
	M1	Motorcycle	0.0694	4	3	50	70	23.7943
	M2	Large truck	0.0045	60	3	4000	70	0.2893
	M4	Small truck	0.0045	20	3	2200	70	0.1753
	M5	Motorcycle	0.0694	3	3	50	70	17.8457
	Emissions per parcel delivered (kg CO/trip)							42.1046

	Trip order	Transport mode	Emission factor (kg NO_x/km)	Distance (km)	Weight value (kg)	Vehicle capacity (kg)	Load factor (%)	Emissions per person (g NO_x/trip)
NO_x	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)=((C)*(D)*(E)/((F)*(G)) *1000
	M1	Motorcycle	0.00029	4	3	50	70	0.0994
	M2	Large truck	0.0126	60	3	4000	70	0.8100
	M4	Small truck	0.0119	20	3	2200	70	0.4636
	M5	Motorcycle	0.00029	3	3	50	70	0.0746
	Emissions per parcel delivered (kg NO_x/trip)							1.4476

	Trip order	Transport mode	Emission factor (kg $PM_{2.5}$/km)	Distance (km)	Weight value (kg)	Vehicle capacity (kg)	Load factor (%)	Emissions per person (g $PM_{2.5}$/trip)
$PM_{2.5}$	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)=((C)*(D)*(E)/((F)*(G)) *1000
	M1	Motorcycle	0.00023	4	3	50	70	0.0789
	M2	Large truck	0.0012	60	3	4000	70	0.0771
	M4	Small truck	0.0012	20	3	2200	70	0.0468
	M5	Motorcycle	0.00023	3	3	50	70	0.0591
	Emissions per parcel delivered (kg $PM_{2.5}$/trip)							0.2619

	Trip order	Transport mode	Emission factor (kg SO_2/km)	Distance (km)	Weight value (kg)	Vehicle capacity (kg)	Load factor (%)	Emissions per person (g SO_2/trip)
SO_2	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)=((C)*(D)*(E)/((F)*(G)) *1000
	M1	Motorcycle	0.0001	4	3	50	70	0.0343
	M2	Large truck	0.00093	60	3	4000	70	0.0598
	M4	Small truck	0.00093	20	3	2200	70	0.0362
	M5	Motorcycle	0.0001	3	3	50	70	0.0257
	Emissions per parcel delivered (kg SO_2/trip)							0.1560

Emissions from Aviation Transport

	Trip order	Route	Emission factor ($kg\ CO_2/kg$ fuel)		Distance (km)	Distance correction factor (km)	Fuel consumption rate (kg/km)	Emission per trip ($kgCO_2$)	Weight value (kg)	Capacity (kg)	Load factor (%)	Emissions per goods delivered ($g\ CO_2$/trip)
CO_2			CCD ($kg\ CO_2/kg$ fuel)	LTO ($kg\ CO_2$/LTO)								
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)=((C)*((E)+(F))*(G))+(D)	(I)	(J)	(K)	(L)= ((H)*(I)/((J)*(K)) *1000
	M3	CGK-PNK	3.15	2737	732	100	3.98	13168	3.00	17000	63	3688
CH_4	Trip order	Route	Emission factor ($kg\ CH_4/kg$ fuel)		Distance (km)	Distance correction factor (km)	Fuel consumption rate (kg/km)	Emission per trip ($kgCH_4$)	Weight value (kg)	Capacity (kg)	Load factor (%)	Emissions per goods delivered ($g\ CH_4$/trip)
			CCD ($kg\ CH_4/kg$ fuel)	LTO ($kg\ CH_4$/LTO)								
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)=((C)*((E)+(F))*(G))+(D)	(I)	(J)	(K)	(L)= ((H)*(I)/((J)*(K)) *1000
	M3	CGK-PNK	0.02	0.08	732	100	3.98	66	3.00	17000	63	18.57
CO	Trip order	Route	Emission factor (kg CO/kg fuel)		Distance (km)	Distance correction factor (km)	Fuel consumption rate (kg/km)	Emission per trip (kgCO)	Weight value (kg)	Capacity (kg)	Load factor (%)	Emissions per goods delivered (g CO/trip)
			CCD (kg CO/kg fuel)	LTO (kg CO/LTO)								
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)=((C)*((E)+(F))*(G))+(D)	(I)	(J)	(K)	(L)= ((H)*(I)/((J)*(K)) *1000
	M3	CGK-PNK	7	6.48	732	100	3.98	23186	3.00	17000	63	6494.68
N_2O	Trip order	Route	Emission factor ($kg\ N_2O/kg$ fuel)		Distance (km)	Distance correction factor (km)	Fuel consumption rate (kg/km)	Emission per trip (kgN_2O)	Weight value (kg)	Capacity (kg)	Load factor (%)	Emissions per goods delivered ($g\ N_2O$/trip)
			CCD ($kg\ N_2O/kg$ fuel)	LTO ($kg\ N_2O$/ LTO)								
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	'(H)=((C)*((E)+(F))*(G))+(D)	(I)	(J)	(K)	(L)= ((H)*(I)/((J)*(K)) *1000
	M3	CGK-PNK	0.001	0.1	732	100	3.98	3	3.00	17000	63	0.9556
NO_x	Trip order	Route	Emission factor ($kg\ NO_x/kg$ fuel)		Distance (km)	Distance correction factor (km)	Fuel consumption rate (kg/km)	Emission per trip ($kgNO_x$)	Weight value (kg)	Capacity (kg)	Load factor (%)	Emissions per goods delivered (g NOx/trip)
			CCD ($kg\ NO_x/kg$ fuel)	LTO ($kg\ NO_x$/ LTO)								
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)=((C)*((E)+(F))*(G))+(D)	(I)	(J)	(K)	(L)= ((H)*(I)/((J)*(K)) *1000
	M3	CGK-PNK	0.011	6.98	732	100	3.98	43	3.00	17000	63	12.16
NMVOC	Trip order	Route	Emission factor (kg NMVOC/kg fuel)		Distance (km)	Distance correction factor (km)	Fuel consumption rate (kg/km)	Emission per trip (kgNMVOC)	Weight value (kg)	Capacity (kg)	Load factor (%)	Emissions per goods delivered (g NMVOC/trip)
			CCD (kg NMVOC/kg fuel)	LTO (kg NMVOC/ LTO)								
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)=((C)*((E)+(F))*(G))+(D)	(I)	(J)	(K)	(L)= ((H)*(I)/((J)*(K)) *1000
	M3	CGK-PNK	0.0007	0.76	732	100	3.98	3	3.00	17000	63	0.8622
SO_2	Trip order	Route	Emission factor ($kg\ SO_2/kg$ fuel)		Distance (km)	Distance correction factor (km)	Fuel consumption rate (kg/km)	Emission per trip ($kgSO_2$)	Weight value (kg)	Capacity (kg)	Load factor (%)	Emissions per goods delivered ($g\ SO_2$/trip)
			CCD ($kg\ SO_2/kg$ fuel)	LTO ($kg\ SO_2$/LTO)								
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)=((C)*((E)+(F))*(G))+(D)	(I)	(J)	(K)	(L)= ((H)*(I)/((J)*(K)) *1000
	M3	CGK-PNK	1	0.43	732	100	3.98	3312	3.00	17000	63	927.6723

Note: CO_2 is carbon dioxide, CH_4 is methane, CO is carbon monoxide, N_2O is nitrous oxide, NO_x means nitrogen oxides, NMVOC means non-methane volatile organic compound, and SO_2 is sulfur dioxide.
Source: WRI Indonesia calculations.

Table 24 | **Summary of Emissions by Transport Type**

Summary									
Trip order	Mode of transport	Emissions (gram)							
		CO_2	CH_4	CO	N_2O	NO_x	NMVOC	$PM_{2.5}$	SO_2
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
1	Motorcycle	33		23.7943		0.0994		0.0789	0.0343
2	Large truck	39		0.2893		0.8100		0.0771	0.0598
3	Airplane	3688	18.57	6494.68	0.96	12.16	0.86		927.67
4	Small truck	26		0.1753		0.4636		0.0468	0.0362
5	Motorcycle	25		17.8457		0.0746		0.0591	0.0257
Total emission (grams)		3811	18.5734	6536.7825	0.9556	13.6059	0.8622	0.2619	927.83

Note: CO_2 is carbon dioxide, CH_4 is methane, CO is carbon monoxide, N_2O is nitrous oxide, NO_x means nitrogen oxides, NMVOC means non-methane volatile organic compound, SO_2 is sulfur dioxide, and $PM_{2.5}$ is fine particulate matter with a diameter less than 2.5 micrometers.

4. LIMITATIONS

The EMISI app uses the best methods and best available data for calculating emissions in the Indonesian context. While there are several methods provided by the IPCC, ranging from simple to advanced calculations, EMISI tries to balance simple data inputs from users and the complexities of methodology. Most of the calculations for personal aviation, marine, and logistics emissions use Indonesia-specific factors, especially for technical determinants (i.e., capacity, load factors, fuel consumption). The methodology focuses on developing the best estimates and, when local data are unavailable, uses data from global contexts to develop next-best estimates. The calculations in this technical note achieve numbers that are relatively consistent with results from other calculators, especially for countries with similar characteristics to Indonesia. For example, when comparing the CO_2 emissions of an airline passenger from Jakarta (CGK) to Makassar (UPG), the difference between the results using the calculations in this technical note and ICAO calculators is insignificant (2.7 percent). The slight difference is due to the fact that emission factors, capacity, and load factors used in this technical note are based on data for Indonesia. However, given the conditions in Indonesia, the methodology is also subject to some limitations as explained in this section. Some prominent literature on calculating aviation air pollution (e.g., Eggleston et al. 2006 and European Environment Agency 2019) presents methods for calculating other significant air pollutants (e.g., $PM_{2.5}$). These, however, require air pollution emission factors from local data, which are unavailable for Indonesia.

Developing locally relevant tools depends substantially on the availability of data and the existing conditions in the country (i.e., technology, materials, behavior). Unfortunately, although the methodology itself is not overly complicated, data availability is the key barrier for the calculation in developing countries, as identified by Song (2017). While some of the factors used in this note have been provided by studies conducted by Indonesian stakeholders (i.e., Ministry of Transport, Ministry of Environment and Forestry, Ministry of Energy and Mineral Resources, airlines, and marine services companies), up-to-date factors are still limited. Recent and upcoming research data on the determinants for calculating emissions in Indonesia-specific cases, such as emission factors and fuel consumption, will improve future calculations. These studies also encourage more detailed and localized data to be produced for the determinants due to demographic, economic, and infrastructure disparities across nations, which affect behavior and thus influence capacity, load factor, fuel consumption factor, and consequently the results of the emissions calculation. Moreover, for direct services of personal logistics, weight and dimensions are not taken into account because the car or motorcycle will carry only one parcel, even though it could carry more.

Specifically for personal logistics calculations, the assumption on the chain of modes of transport used during deliveries relies on characteristics of the courier industry. In this technical note, as the distance input by users is the distance from origin to destination of the goods, disaggregation of distance is achieved using the framework for courier logistics behavior (Figure 4). The assumption of the first and last mile is the distance from the origin to the nearest package drop-off point. This distance is determined based on the radius of the catchment area, which is calculated based on the number of drop-off points for packages in cities in Indonesia. In addition, the chain of modes of transport used during the journey is dependent on company policy, which is sensitive to government policy (i.e., price, tax, etc.) or availability of those modes. Therefore, it is important to have up-to-date numbers for the first and last miles and the decision tree to increase the reliability of the calculation. Moreover, the personal logistic calculation is limited to domestic deliveries, as data on the international delivery logistic chains are unavailable.

The methodology documented in this technical note will form the basis of the next EMISI update. The EMISI app aims to educate individuals about their carbon footprint and empower them to take actions to protect the climate. The methodology can be adopted by various stakeholders in Indonesia, including government, nongovernmental and private organizations, scientific experts, communities, and individuals. Opportunities to integrate the calculator with current transport apps, public campaigns, and crowdfunding platforms are also being explored. Data resulting from calculations derived from this technical note could also help improve Indonesia's emissions inventory knowledge at the individual level, as well as add value to other research and development activities.

ABBREVIATIONS

B2C	business to customer
C2C	customer to customer
CCD	climb-cruise-descent
CO	carbon monoxide
CO_2	carbon dioxide
CH_4	methane
EF	emission factor
EMISI	Indonesia Zero Emissions Application
f	function
FCR	fuel consumption rate
GHG	greenhouse gas
ICAO	International Civil Aviation Organization
ICT	Information and Communication Technology
IPCC	Intergovernmental Panel on Climate Change
LF	load factor
LTO	landing and take-off period
NMVOC	non-methane volatile organic compound
PLF	passenger load factor
$PM_{2.5}$	particulate matter with diameter less than 2.5 micrometers
SO_2	sulfur dioxide

ENDNOTES

1 For the explanation of ro-ro services see: https://www.marineinsight.com/types-of-ships/what-are-ro-ro-ships/.

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ABOUT THE AUTHORS

Muhamad Rizki
Mobility and Transport Specialist, WRI Indonesia
Lecturer, Civil Engineering Department,
Institut Teknologi Nasional Bandung
muhamad.rizki@wri.org

Jeanly Syahputri
Former Transportation Intern, WRI Indonesia
School of Transport Science, Hasselt University
jeanlysyahputri@gmail.com

Nanda A. Noor
Sustainable Landscape & Business Senior Lead, WRI Indonesia
nanda.noor@wri.org

Philipe G. Gan
Former Data Scientist Intern, WRI Indonesia
PhD Candidate, Australian National University
philipe.gunawan@anu.edu.au

Retno Wihanesta
Urban Transport Planner, WRI Indonesia
retno.wihanesta@wri.org

ABOUT WRI

World Resources Institute is a global research organization that turns big ideas into action at the nexus of environment, economic opportunity, and human well-being.

Our Challenge
Natural resources are at the foundation of economic opportunity and human well-being. But today, we are depleting Earth's resources at rates that are not sustainable, endangering economies and people's lives. People depend on clean water, fertile land, healthy forests, and a stable climate. Livable cities and clean energy are essential for a sustainable planet. We must address these urgent, global challenges this decade.

Our Vision
We envision an equitable and prosperous planet driven by the wise management of natural resources. We aspire to create a world where the actions of government, business, and communities combine to eliminate poverty and sustain the natural environment for all people.

Our Approach
COUNT IT
We start with data. We conduct independent research and draw on the latest technology to develop new insights and recommendations. Our rigorous analysis identifies risks, unveils opportunities, and informs smart strategies. We focus our efforts on influential and emerging economies where the future of sustainability will be determined.

CHANGE IT
We use our research to influence government policies, business strategies, and civil society action. We test projects with communities, companies, and government agencies to build a strong evidence base. Then, we work with partners to deliver change on the ground that alleviates poverty and strengthens society. We hold ourselves accountable to ensure our outcomes will be bold and enduring.

SCALE IT
We don't think small. Once tested, we work with partners to adopt and expand our efforts regionally and globally. We engage with decision-makers to carry out our ideas and elevate our impact. We measure success through government and business actions that improve people's lives and sustain a healthy environment.

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