Resilience Development Initiative

GREENPEACE

JAKARTA TRANSPORTATION TRANSFORMATION:

Reassessing Net Zero Emission Target of Transportation Sector for 2050

Reassessing Net Zero Emission Target
of Transportation Sector for 2050

JAKARTA TRANSPORTATION TRANSFORMATION:

Reassessing Net Zero Emission Target of Transportation Sector for 2050

RESEARCH TEAM:

Resilience Development Initiative

Elisabeth Rianawati - Husnul Alberdi - Aisha Hanifa Salsabilla - Maya Larasati - Nadiya Pranindita

Greenpeace Indonesia

Muharram Atha Rasyadi - Bondan Andriyanu - Arsi Agnitasari - Jane Francisca Latuheru - Rizkiana Sidqiyatul Hamdani

REPORT WRITER:

Elisabeth Rianawati - Husnul Alberdi - Aisha Hanifa Salsabilla - Maya Larasati - Nadiya Pranindita - Rizkiana Sidqiyatul Hamdani

DESIGN & LAYOUT:

Syahrul Firmansyah

CITATION RECOMMENDATION:

Rianawati, Elisabeth, Husnul Alberdi, Aisha Sallsabilla, Maya Larasati, Nadiya Pranindita, Rizkiana S Hamdani. 2022. Jakarta Transportation Transformation: Reassessing Net Zero Emission Target of the Transportation Sector for 2050. Jakarta: Greenpeace Indonesia and Resilience Development Initiative

The Indonesian version of this report was published in June 2022
The English version of this report was published in December 2023
under the responsibility of
Greenpeace Indonesia
Jl. HOS. Cokroaminoto No. 19 RT 1/RW 2
Gondangdia, Menteng District
Central Jakarta, 10350

https://www.greenpeace.or.id

Table of Contents

List of Figures

List of Tables

List of Terms and Acronyms

BAU	Business as Usual
CO	Carbon Monoxide
CO_2e	Carbon dioxide equivalent
BRT	Bus Rapid Transit
DLH	Environment Office/Dinas Lingkungan Hidup
EMU	Electric multiple unit
EV	Electric Vehicles (Vehicles powered by electricity, partially or fully)
Gg CO_2-e	Giga carbon dioxide equivalent
GHG	Greenhouse Gas/Gas Rumah Kaca
GOS	Green Open Space
GPC	Global Protocol for Community-Scale Greenhouse Gas Emission Inventories
IPPU	Industrial Processes and Product Use
LEZ	Low Emissions Zone
LRT	Light Rail Transit
MRT	Mass Rapid Transit
MTOE	Million Tonnes of Oil Equivalent
NMT	Non-motorized transport
NZE	Net Zero Emissions
PKM	Passenger-kilometer
PLN	State Electricity Company/Perusahaan Listrik Negara
PLTU	Steam Power Plant/Pembangkit Listrik Tenaga Uap
PLTGU	Steam-Gas Power Plant/Pembangkit Listrik Tenaga Gas dan Uap
RE	Renewable Energy
RUPTL	Electricity Supply Business Plan/Rencana Usaha Penyediaan Tenaga Listrik
SPKLU	Public Electric Vehicle Charging Stations/Stasiun Pengisian Kendaraan Listrik Umum
SRUT	Vehicle Type Test Certification
TOD	Transit-Oriented Development

Preface

The ability to breathe clean and fresh air in DKI Jakarta is presently considered very challenging. This is because emissions obtained from various urban activities contaminate the air and pose significant health risks to the city residents. The proliferation of greenhouse gasses acquired from emissions also places Jakarta in a precarious position. This focuses on heightened susceptibility to a tangible climate crisis, such as increased temperature and more unpredictable extreme weather intensity. Since transportation sector is one of the biggest problem contributors, the exploration of various near to-zero emissions transportation scenarios is considered a step in mitigating its negative effect on the city environment. This research is aiming to contribute to that niche of knowledge, preparing the pathway to a near-zero emission transportation from various scenarios.

The research outcomes will subsequently lack significance when appropriate is not conducted into coordinated efforts for the transformation of transportation prioritizing various stakeholders. Furthermore, the responsibility for reducing emissions is not only limited to the government and service providers, with people (citizens) requiring the through the adoption of lower-emissions transportation modes. In this case, the research team supports the immediate actualization of clean air, the right of all citizens.

Signed,

Research team

DISCLAIMER:

The content of this report is the analytical outputs conducted by the Research Team and not the opinions of RDI or Greenpeace Indonesia as an organization. The contents are also academically informative and not established for commercial purposes.

© Nugroho Adi Putera / Greenpeace

A million bicycle action commemorating World Cycling Day carrying a banner with the message "THIS MACHINE FIGHTS CLIMATE CHANGE" in Jakarta 5 June 2022

EXECUTIVE SUMMARY

Air emissions in DKI Jakarta are in an alarming condition, with vehicular emissions being the main problem. The transportation sector specifically causes health problems in children and pregnant women by producing NOx, CO, PM10, and PM2.5 emissions, accounting for 72.4%, 92.36%, 57.99%, and 67.03%, respectively. Besides health effects, the emissions also intensify the existing climate crisis, such as the annual average temperature rise of around 1.6°C over the last century in Jakarta. In this context, the temperature increase is considered higher than the global average rise of 0.85°C. Additionally, the intensity of rain due to extreme weather is predicted to continuously increase, reaching 377 mm per day in 2020. This condition is observed because of the increased carbon emissions in the atmosphere, which has the potential to worsen the flooding risk.

The increasing number of vehicles in DKI Jakarta also intensifies emission levels, with the vehicle ownership growth rate in motorcycles and cars reaching 4.9% and 7.01%, respectively, exceeding the population growth rate of 0.92%. This indicates that private vehicles have presently outnumbered the residents at 20.2 million units, comprising 3.3 and 16.1 million cars and motorcycles, respectively. The COVID-19 pandemic in 2020 and 2021 is also responsible for reduced use of public transportation to avoid crowded conditions as to prevent the spread of airborne disease. In this context, the urgency of solving that problematic condition is the background of the DKI Jakarta government's target to achieve NZE by 2050, specifically in the transportation sector. This government program includes the development of pedestrian and bicycle lanes, integration of multi-modal public transportation, as well as electrifying 50% and 100% of the Transjakarta buses by 2025 and 2030, respectively. Therefore, this research aimed to predict the achievement level of the NZE target set by the DKI Jakarta government by 2050. These predictions were carried out using two scenarios, namely (i) calculation of emissions according to the present situation, and (ii) emissions estimations from the implementation of government programs and changes in people behavior. Two additional scenarios were also proposed in this research regarding the recommended actions for more progressive emissions reduction.

A mixed approach of both qualitative and quantitative techniques was used for this research. In this context, the quantitative approach was conducted through emissions calculations focusing on available statistical data and an online survey to determine mobility behavior. The survey obtained 3,097 respondents with 2,097 valid data. These instruments were filled out by residents who have been actively working/studying in the DKI Jakarta area for over 18 years. The qualitative approach was carried out by formulating strategies and action recommendations through interviews with key informants, two Focus Group Discussion (FGD) engaging various actors, and a review of relevant literature. In this case, FGD was conducted twice to obtain input on the developed strategies and recommendations.

To assess the feasibility of the NZE target in DKI Jakarta, the following scenarios were developed in this research, they are: (1) Business as usual, (2) Government Program and Policy Intervention, (3) Electrification and Renewable Energy Use, and (4) Net Zero Emissions (NZE) 2050. The Business as Usual Scenario was developed based on existing trends with no relevant changes. The Government Program and Policy Intervention scenario considers prioritized policies and targets set by both the provincial and national governments. The Electrification and Renewable Energy Use scenario implemented more ambitious assumptions concerning the targets set by international institutions. Lastly, the NZE 2050 Scenario used more ambitious and progressive assumptions to reduce emissions to a very minimum level or nearly to achieve zero emissions.

Based on the emissions estimation results, the NZE target from the transportation sector could only be achieved when all commutation actors in DKI Jakarta used low-carbon modes. According to the DLH report (2018), this sector contributed 13.2 million tons of CO_2, leading to the need for massive behavioral changes to achieve NZE. The analysis related to the behavior and perceptions of DKI Jakarta people was subsequently conducted to understand the people's potential and readiness to change shown as follows;

1. **Most participants were commuters that used multi-modes transportation and selected online motorcycle taxis and walked for their first and last mile, expressing the following points;**

    - Most informants changed transportation modes two (40%) to three times (27%).
    - The most widely used first-mile mode was online motorcycle taxis (23%), followed by walking (32%) or public transportation (39%) in the second mile. The online motorcycle taxis were widely used for the last mile transport modes (50%).
    - The main transportation modes used by respondents were public transportation (40.18%) and private motorcycles (39.51%), whose selections were due to cost (27%), reliability (32%), and route availability (17%).
    - Public transportation was highly preferred for long-distance trips with an average duration of 62 minutes, followed by private cars and motorcycles at 44 and 34 minutes, respectively. Based on walking and cycling, the average participant walked or cycled for 15 or 22 minutes to work/school, respectively.

2. **Pedestrian facilities obtained the lowest evaluation score compared to other transportation infrastructure, as described below,**

    - A significant proportion of participants walked up to 15 minutes daily.
    - The lowest evaluation scores were specifically acquired in terms of safety from vehicles and air pollution.

3. **Almost all respondents were willing to shift to low-emissions transportation, despite facing challenges related to the reliability of commutation modes and the accessibility of facilities, as described below,**

    - The respondents showed a desire to shift transportation modes from motorcycle users to public transportation and cycling.
    - The respondents also showed a high aspiration (97%) regarding the private and public use of environmentally friendly and low-emissions transportation.
    - People still expect continuous improvement from public transportation services, specifically waiting time, ease of access, and travel distance to the closest bus stop/station.
    - Respondents were willing to pay an additional fee of around IDR10,000 for an electric-powered public transportation ticket.

According to the mobility behavior of people, the estimation of DKI Jakarta present emissions conditions and future conditions to achieve NZE in 2050 were estimated and analyzed, leading to the following outputs,

1. **Emissions in 2020 were predicted to reach 22.8 million tons of CO_2e, with private fossil fuel vehicles being the largest contributors and public transportation smallest contributors, as presented below,**
   - Estimated emissions in 2020 were 22,815,356 tons of CO_2e.
   - The largest contribution originated from car and motorcycle users, reaching around 15.84 million tons of CO_2e. According to the vehicle types, the highest contributor was the motorcycles (9,833,690 tons). This number was equivalent to 16.12% of the total national transportation sector emissions in 2019.
   - From the energy source, fossil fuel gasoline was the highest contributor in the transportation sector (16,566,857 tons CO_2e).
   - Compared to other vehicles, public transportation was the smallest contributor at 0.90% (200,360 tons CO_2e).

2. **The NZE targets were very difficult to achieve when limiting only on the implementation of the government programs. This result shows the urge for more ambitious and comprehensive targets and programs. This result is comprehensively detailed as follows,**
   - Based on the Business as Usual Scenario, the emissions reached up to 46 million tons of CO_2e or doubled the 2020 emissions. The largest contributors are cars and motorcycles at 36% and 47%, respectively.
   - The Intervention of Government Policy Programs and Changes in people behaviors scenario was estimated to reduce emissions by 4.5 million tons CO_2e compared to emissions in 2020. This reduction occurred due to technological improvements and transformations in various individuals' mobility behavior toward intensifying the use of public transportation and the use of walking or bicycles for shorter travel distances. Emissions reduction was also achieved through the transition to renewable energy using electric vehicles appropriate to the Indonesian government's energy mix target in 2030.
   - The Electrification and Renewable Energy Use scenario was considered a higher emissions reduction strategy than the Central and DKI Jakarta and Indonesian government programs. In this scenario, emissions were reduced by 10 million tons of CO_2e compared to the 2020 simulation. This was achieved by increasing the number of private and public vehicles with daily discharge reductions of 1.8 and 2 million, respectively, maintaining an energy mix of 31%. Therefore, vehicle electrification was expected to be at or close to 100% by 2050, due to its present prevalence in DKI Jakarta.
   - The near-to zero emissions (NZE) Scenario showed 2.6 million tons of CO_2e, the smallest of all the estimated scenarios. These emissions originated from electricity generation for vehicle operation. This scenario predicted an urge for a significant shift in public behavior, including the reduction of cars (2.5 million units) and motorcycles (12.5 million units) in 2050. The role of the 100% deployment of renewable energy is a significant role in emissions reduction from electricity generation.

Call to Action

The present research shows that the DKI Jakarta 2050 goal for zero-emissions transportation is hardly achievable with existing policies and programs. This is specifically due to the sole emphasis on operational emissions from transportation within the city, without including the emissions generated during the establishment and development of transportation modes and infrastructure. The maximum achievable emissions reduction by 2050 is expected to be approximately 88.5%, equivalent to a reduction of 20.2 million tons of CO_2e compared to the present discharges. Therefore, comprehensive multi-stakeholder actions are needed to achieve the reduction scenario closest to NZE by 2050, such as the following:

1. Increased collective, synergy, complementary, and integrated actions are needed from various stakeholders, including the governments, PLN, public transportation service providers, vehicle manufacturers, and the community. This collective effort aims to instigate a shift in habits while also driving behavior towards a more low-carbon approach.

2. The reduction of private vehicles and transformation to shift into public transportation is needed. This is supported by the expansion of the network and integration of mass transit, which represents the lowest-emissions transportation mode.

3. Public transportation service providers should also expand coverage for people to reach their destination without shifting modes using motorcycle taxis. The maximum distance from the last transportation mode point to the final destination should not exceed a 15-minute walk, enabling the ability of various individuals to use non-motorized transport such as walking or cycling.

4. Walking, as the most common last mile mode, needs to be encouraged by providing and improving the quality of the pedestrian infrastructure. This suggests the necessity to incorporate green infrastructure for cycling and walking to continually absorb emissions. Pedestrian facilities should also be separated from other activities, such as street vendors, on-street parking, and public meetings.

5. High-carbon emission power plants, specifically the coal power plant around DKI Jakarta, need to be retired and transitioned to be powered by renewable energy sources in 2030 and 2036, aligning with the road map designed by the central government.

1

The empty streets of DKI Jakarta show the dominance of lanes for private motorized vehicles compared to public transportation, pedestrians and the absence of bicycle lanes.

INTRODUCTION

Urgency of Emissions reduction

A large intake of oxygen is required by humans daily, at about 550 liters of pure O_2. Meanwhile, emissions polluting the air can reduce the oxygen content entering the body. In this context, emissions include the carbon monoxide (CO) produced by burning vehicle fuel, whose high and severe inhalation commonly causes O_2 deprivation and death. This condition is observed due to the binding of gas to hemoglobin, which is prevented from effectively attaching to the required oxygen in the body. The annual death toll obtained from air pollution discharges is more than 95,000 cases[1] and the number of losses due to air pollution reached IDR 38.5 trillion in 2010 (KLHK, 2010).

City residents who are receiving respiratory assistance
© Jurnasyanto Sukarno / Greenpeace

According to various reports (World Research Institute, 1999; WHO, 2005; Haryanto, 2007), children were more vulnerable to emissions than adults. This was due to their ongoing growth and development, specifically in important organs including the lungs. In this context, the incomplete metabolism and immature defense systems led to the high susceptibility to higher emissions reaching their lungs. Furthermore, pregnant women represented the second most vulnerable group to diseases associated with air-polluting emissions issues (Stock & Clemens, 2017). This was because the impact on pregnancy complications and childhood illnesses was extensively documented, including effects on fetal growth (Clemens et al., 2017), premature birth (Langrish et al., 2012), miscarriage (DeFranco et al., 2016), and respiratory infections leading to fetal morbidity (Green et al., 2015). Since harmful emissions in the atmosphere were often not observable to the naked eye, the measures and regulations to prevent air pollution remained inadequately enforced.

Emissions also subsequently influence the existing climate crisis. According to the recent IPCC report (2022), a 1.5°C increase in weather was likely under the lowest GHG emissions scenario. This condition often led to increased flooding in Asia, accompanied by ocean acidification and warming, biodiversity loss, extreme weather, famine, and economic instability (IPCC, 2022). A concrete example was Jakarta annual average temperature rise of about 1.6°C over the last century, higher than global average temperature increase. Rainfall intensity due to extreme weather was also predicted to continuously increase, reaching 377 mm per day in 2020, a 7-fold increase from the average daily rainfall in 2018 (BPS, 2018), with increasing acidity due to the air-polluting discharges (Singh and Agrawal, 2007). Another effect of climate change was sea level rise due to the mass loss of glaciers and ice sheets. This condition affected land subsidence to 1-15 cm per year in Jakarta and was higher than the global sea level rise of about 1.6-1.9 mm per year.[3]

---

1 2016 data from WHO 2018 Climate Transparency Report 2020.

2 IPCC (2013) in Siswanto et al. 2015. Changes in temperature, extreme precipitation, and diurnal precipitation in
3 urbanized Jakarta over the past 130 years. International Journal of Climatology.

Explained by Abidin et al. (2011) in the Greenpeace Report (2021) entitled The Projected Economic Impact of Extreme Sea-Level Rise in Seven Asian Cities in 2030.

Jakarta Transportation Problems

The main source of air pollution in Jakarta is vehicle emissions, with the total discharge load for NOx, and CO being approximately 52.9 and 143.9 kton in 2015, respectively. In this context, the largest contributor to the pollutants originated from the road transportation sector, contributing 57% and 93% to NOx and CO, respectively. In the same year, total emissions for PM2.5 in Jakarta were also around 4.6 kton, mostly from the road transportation sector at 2.1 kton (46%) (Cochrane, 2015, DLH Jakarta Province, 2019, Lestari et al., 2020). Moreover, emissions generated from vehicle fuel in daily use provided 27% of annual CO_2 discharges (IESR, 2020)[4]. Gasoline and diesel vehicle fumes were also estimated to provide 32%-57% of the total air pollution in Jakarta (Vital Strategies and ITB, 2020).

The GHG emissions from the transportation sector in DKI Jakarta subsequently increased from 2010-2018 (Figure 1). This showed that the level of direct GHG emissions in the transportation sub-sector in 2018 was calculated to reach 13 million (Gg CO_2e)[5]. Meanwhile, the indirect emissions increased from 33,394 to 120,589 tons of CO_2e between 2010 to 2018. The GHG emissions generated by DKI Jakarta were also equivalent to those generated by all cities in West Java (Bappenas, 2014). **This proved that reducing emissions from the transportation sector is one of the main solutions to decrease the air pollution levels in Jakarta.**

---

[4] This data is presented in the annual report entitled "Climate Transparency Report" year 2020.

[5] This figure includes indirect emissions from electric passenger land transportation in Jakarta. From the electrically-fueled land transportation, only electricity use forCommuter Line is included in the calculation, while electric cars are not included due to their low use and unavailable electricity consumption data.

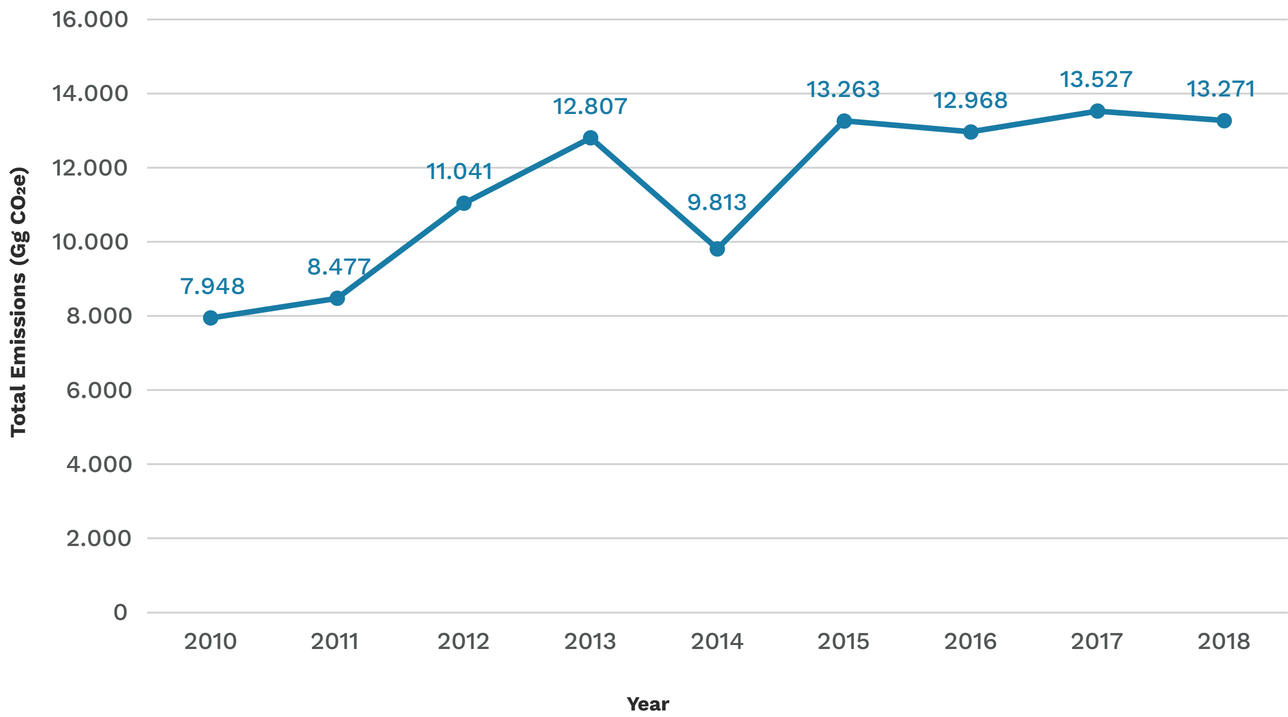


Figure 1. GHG Inventory of Transportation Sector in DKI Jakarta 2010-2018[6]
Source: DLH DKI Jakarta Province, 2019

One of the causes of the high contribution of emissions from the transportation sector is the high number of private vehicles ownership within DKI Jakarta, the second-highest urban agglomeration in the world with a 10 million population in 2020 (Martinez & Masron, 2020). Consequently, many travel and movement needs for people as well as goods are frequently internally and externally observed in the city (United Nations, 2019). The private vehicle ownership reaching twice the population at 20.2 million units, with 3.3 and 16.1 million cars and motorcycles expressed, respectively[7] (BPS, 2020). Therefore, the ratio prioritizing the number of motorcycles and cars to the total population is 1,500 and 380 per 1,000. This is higher than Indonesia's vehicle ownership ratio of only 445 and 62 per 1,000. The high preference to possess private automobiles ownership/utilization is also reflected in the increase rate within motorcycles (4.9%) and cars (7.01%)[8]. This percentage was higher than the population growth rate of Jakarta (0.92%) (BPS, 2020) or the addition of roads (0.01% per year) (Wismadi et al., 2013).

The above descriptions lead to traffic congestion and lengthy travel times, causing significant consequences, including fuel wastage, air pollution, increased stress, and deteriorating public health. The World Bank (2019) estimated that congestion in Jakarta caused annual losses amounting to IDR 37 trillion. However, the addition of more roads for

[6] Activity data used to calculate GHG emissions in the transportation sector are sales or realization data of fuel distribution issued by BPH Migas, PT Pertamina from the previous year's GHG emissions inventory report data and railway electricity data from PT PLN. This calculation is called a direct emissions calculation that calculates emissions from fuel combustion. Meanwhile, indirect GHG are emissions from the use of electricity in certain activities.

[7] Other types of transportation are buses (35,266 units), trucks (679,708 units), not including freight.

[8] Delivered by Ir. Driejana, M.SCE, PhD from the Faculty of Civil Engineering, Bandung Institute of Technology (2021) in Public Consultation: Grand Design of Air Pollution Control, DKI Jakarta Province.

private vehicles was not a relevant solution. According to the well-known induced demand concept (Downs, 2000, Duranton & Turner, 2011, Andani et al., 2019), the expansion of road infrastructure encouraged drivers to adopt the new capacity, leading to congestion levels similar to those before the amenity expansion. For instance, the widening of road sections on Teuku Umar Street in Bandar Lampung did not significantly reduce congestion (Putra et al., 2012). Another analysis on the effectiveness of an underpass was also considered ineffective in enhancing route performance on a particular road (Alam et al., 2017). Similar reports were also observed in urban areas of the UK and Amsterdam, where the addition of road sections was reported to increase traffic volumes by 5%-27% within a year (Nugmanova et al., 2019).

According to the TUMI Initiative (2019), the dependency on private vehicles was supported by other factors, such as incentives to purchase, fuel subsidies, additional road infrastructure, and limited access to public transportation (Figure 2). In Indonesia, fuel subsidies also reached up to 210 trillion rupiahs in 2013 (Biro Analisa Anggaran dan Pelaksanaan APBN DPR RI, 2014), causing an increase in vehicle ownership, congestion, air pollution, and CO_2 emissions.

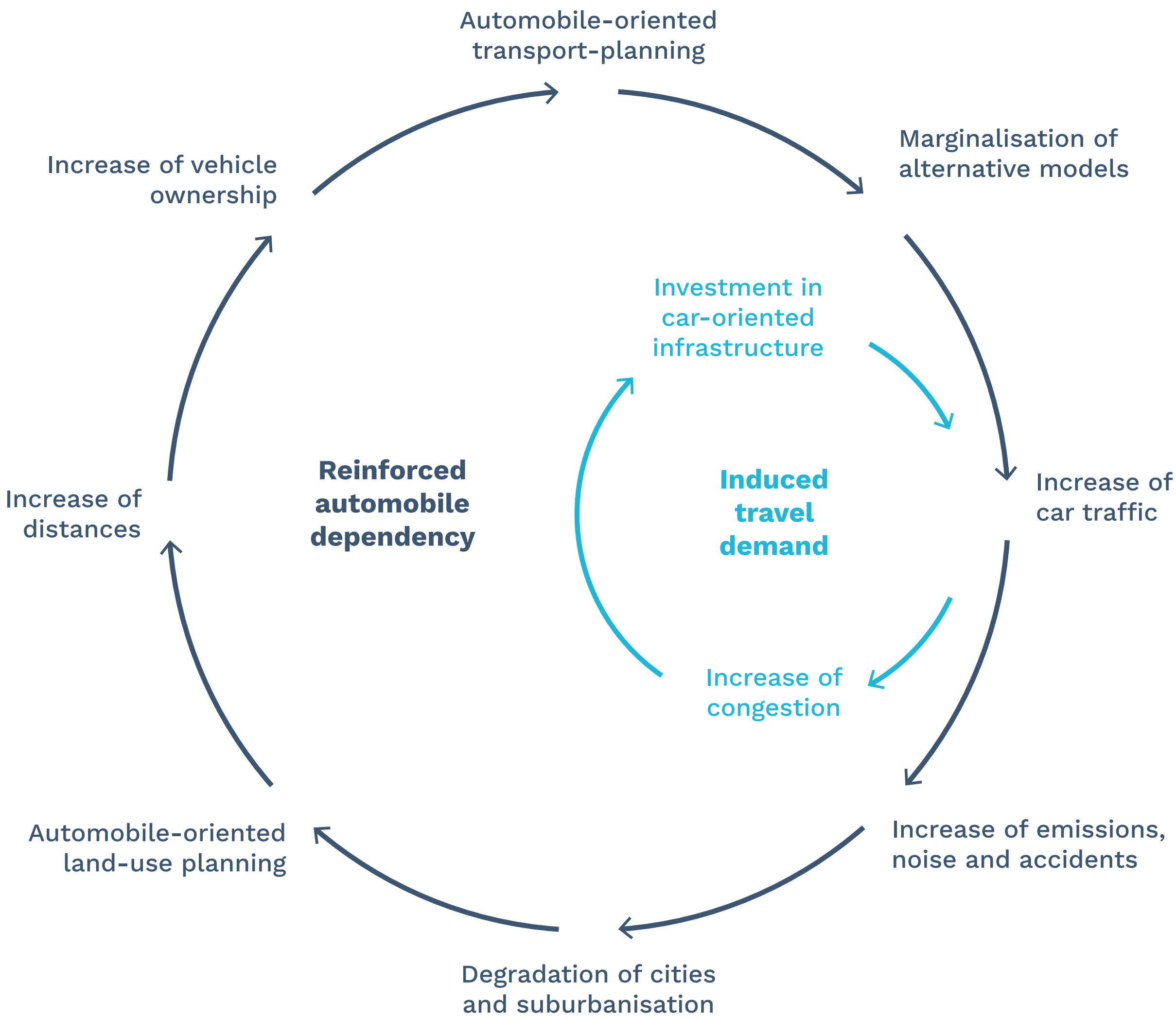


Figure 2. Cycle of dependence on motorized vehicles
Source: TUMInitiative (2019)

Jakarta is also facing the challenge of increasingly limited land availability (Harahap et al., 2017). On the other hand, there is an urge to prioritize and better accommodate urban land availability for green open space (GOS), sidewalks, cycling, and other public facilities. The latest report stated that green open spaces in DKI Jakarta is only about 9.2% of Jakarta City is presently achieved (Prakoso and Herdiansyah, 2019). In contrast, the convenience in facilities and public spaces is subsequently believed to double the number of users, such as cyclists and pedestrians (Linton et al., 2022). It can also provide a positive experience for public transport users, causing the realization of behavioral changes toward reducing dependence on private vehicles and shifting to public transport (Tsavachidis & Le Petit, 2022).

Based on the above data and phenomena, intervention in emissions sources is needed to achieve NZE Jakarta. The emissions from the transportation sector should be reduced to the lowest point or even zero. The DKI Jakarta government is also responsible for launching the Net Zero Emissions (NZE) target to address this issue by 2050. The NZE is defined as a condition when the discharges released were equal to those potentially absorbed. This condition is progressively achieved, with the first stage targeting a reduction of 30-50% in emissions by 2030. Besides the NZE plan, the DKI Jakarta government had been started to reduce transportation sector emissions since 2012[9]. This includes the use of low-emissions energy sources to install solar panels on the roofs of executive and private buildings, as well as various public facilities comprising schools, health services, hospitals, and sports. The DKI Jakarta government also plans to increase public transportation services to 90% by 2022. This is accompanied by integrating services with other modes of transportation, regenerating 346 km of sidewalks and 103.5 km of bicycle lanes (Ramadhan, 2022). In addition, there is also a target to use 50% electric energy for TransJakarta buses by 2025 is prioritized, with 30 relevant buses already prevalent. Another program includes a 30% expansion of Green Open Space (GOS) by 2030. The DKI Jakarta government has also implemented a Low Emissions Zone (LEZ) in the Kota Tua area, to restrict private vehicles and enhance air quality. These efforts caused a reduction of 1.5 million tons of CO_2e in 2018, equivalent to 11% of total emissions from the transportation sector.

Assuming the growth rate of vehicles at the same rate, scenario calculations are needed to assess the achievement level of the NZE target by DKI Jakarta in 2050. Currently,emissions from the transportation sector were estimated at 15.9 and predicted to increase up to 47.56 million CO_2eq in 2020 and 2030 (RAD GRK Jakarta, 2021). With that being said, the annual emission reduction goal requires at least 2.97 million CO_2eq. Therefore, this research aims to measure carbon emissions scenarios until 2050 with several scenarios, to achieve an appropriate reduction target. These scenarios include (i) calculation appropriate to the present situation, and (ii) estimation with the implementation of government programs and changes in people behavior. Two additional scenarios are also designed to serve as recommendations and illustrations for achieving the zero-carbon emissions target in Jakarta.

[9] Jakarta Environment Agency and Vital Strategies. 2020. *Menuju Udara Bersih Jakarta.*

Transportation Emissions reduction Concepts & Theory

Net Zero Emissions (NZE)

The concept of NZE is considered an activity to prevent emissions into the atmosphere or to balance emissions with absorption (Davis et al., 2018; Rogelj et al., 2021). Besides the reduction of emissions, the achievement of NZE is also responsible for implementation optimization, ensuring the remainder of the total emissions at zero. Several countries also have globally set targets for emissions reduction, toward the predicted achievement of NZE by 2050. According to the International Energy Agency (IEA, 2021), a roadmap or scenario was developed to achieve the 2050 targets by implementing various strategies through the following three pillars. Firstly, the use/uptake of all emissions-reducing technologies, considering costs, technology maturity, policy trends, potential trade-offs, broader societal objectives, market dynamics, and country-specific conditions. Secondly, all countries need to work together to effectively, mutually, and beneficially achieve global NZE, ensuring a suitable transition and considering different economic developments across nations and regions. Thirdly, an orderly transition across the energy sector, specifically in ensuring the security of fuel and electricity supply, minimizing stranded assets, and avoiding volatile energy markets.

Low Carbon Mobility

Low-carbon mobility is defined as the movement significantly emitting less CO_2 than high-emitting transportation, such as fossil fuel vehicles (Givoni and Banister, 2013). This shows that mobility achievement requires a systematic shift, specifically demanding a radical transition to break present habits (Givoni, 2013). From this context, the transition process is often carried out for years or even decades (Schwanen, 2013; Banister, 2013). Based on Givoni and Banister (2013), the journey toward low-carbon mobility was conducted with changes in societal norms, economic models, and transportation approaches.

a. Norm change:
   i. Fossil to renewable fuels.
   ii. Car-based development toward TOD (transit-oriented development).
   iii. Commuting to remote working.

b. Transformation in the economic model:
   i. "Growth is better" to "The closer the better".
   ii. A fuel-based economy to a digital industry.
   iii. Globalization to glocalization.

c. Change in transportation mode:
   i. Motorized to non-motorized transport, such as cycling and walking.
   ii. Private vehicles to public transportation.
   iii. Internal combustion engine to electric-powered vehicles.

Avoid-Shift-Improve (ASI) Framework

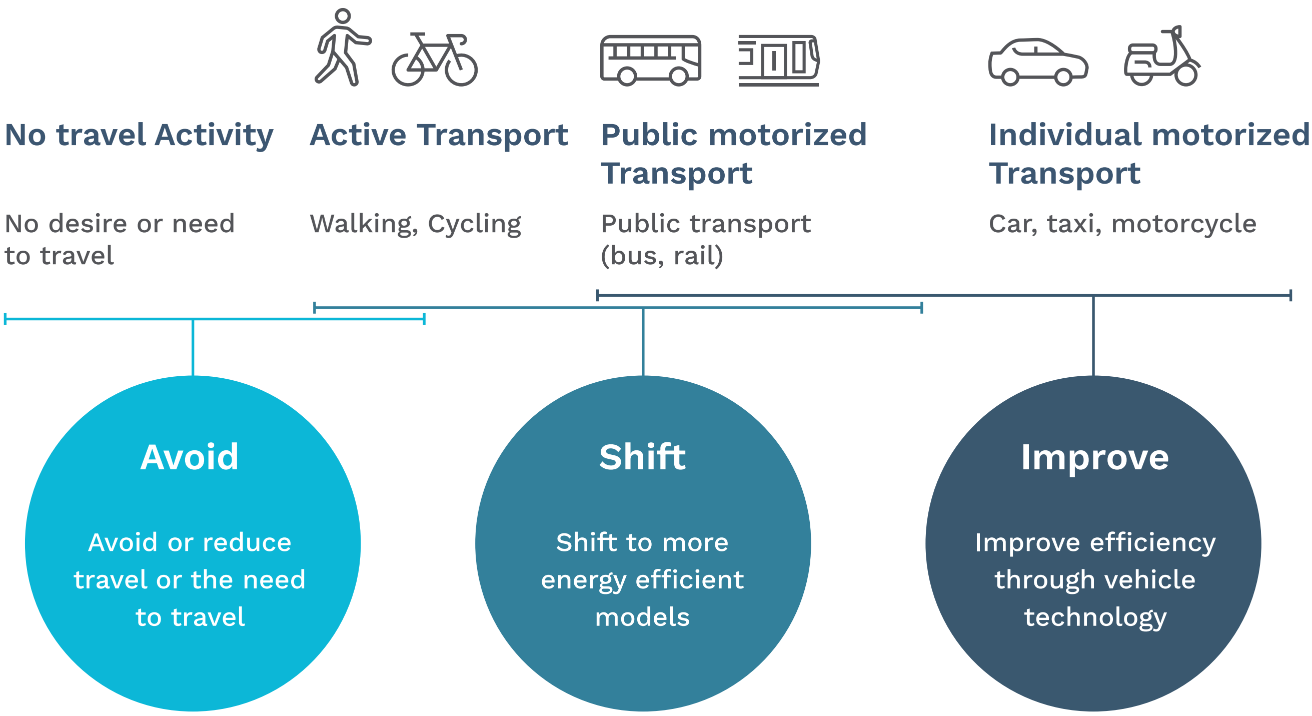


Figure 3. ASI approach instrument
Source: Bongardt et al., 2019

The Avoid, Shift, and Improve (A-S-I) approach is another transportation measure related to climate change mitigation, emphasizing the reduction of environmental effects from the transportation sector (Bakker et al., 2014). According to Dalkmann and Brannigan (2007), the limitations of GHG emissions for transportation sector were carried out using the following steps, (a) avoiding the need to drive through improvements in urban planning and communication options, (b) shifting, using cleaner and more efficient transit modes, such as public, non-motorized, and other vehicles, and (c) improving transportation technology improvements, including the provision of energy-efficient vehicles and lower carbon.

National Monument with blue sky background

METHODS

A mixed-method research is implemented, as described in Figure 4. The quantitative focused on emissions calculations and scenarios while the qualitative approach is utilized in prioritizing the present and future transport preferences, expectations, and recommended actions. Data were obtained through primary sources, such as questionnaires, interviews, and FGD with the people, government, private sector, and other actors. The public perceptions, preferences, and expectations of future transportation synthesized from primary data were implemented to generate appropriate scenarios. Data was also obtained from the secondary sources such as government reports, regulations, statistical information, company annual reports, policy plans, and other relevant documents. Further primary sources through qualitative approach also conducted through discussions with various stakeholders to finalize the emissions formulation and consolidation of action recommendations.

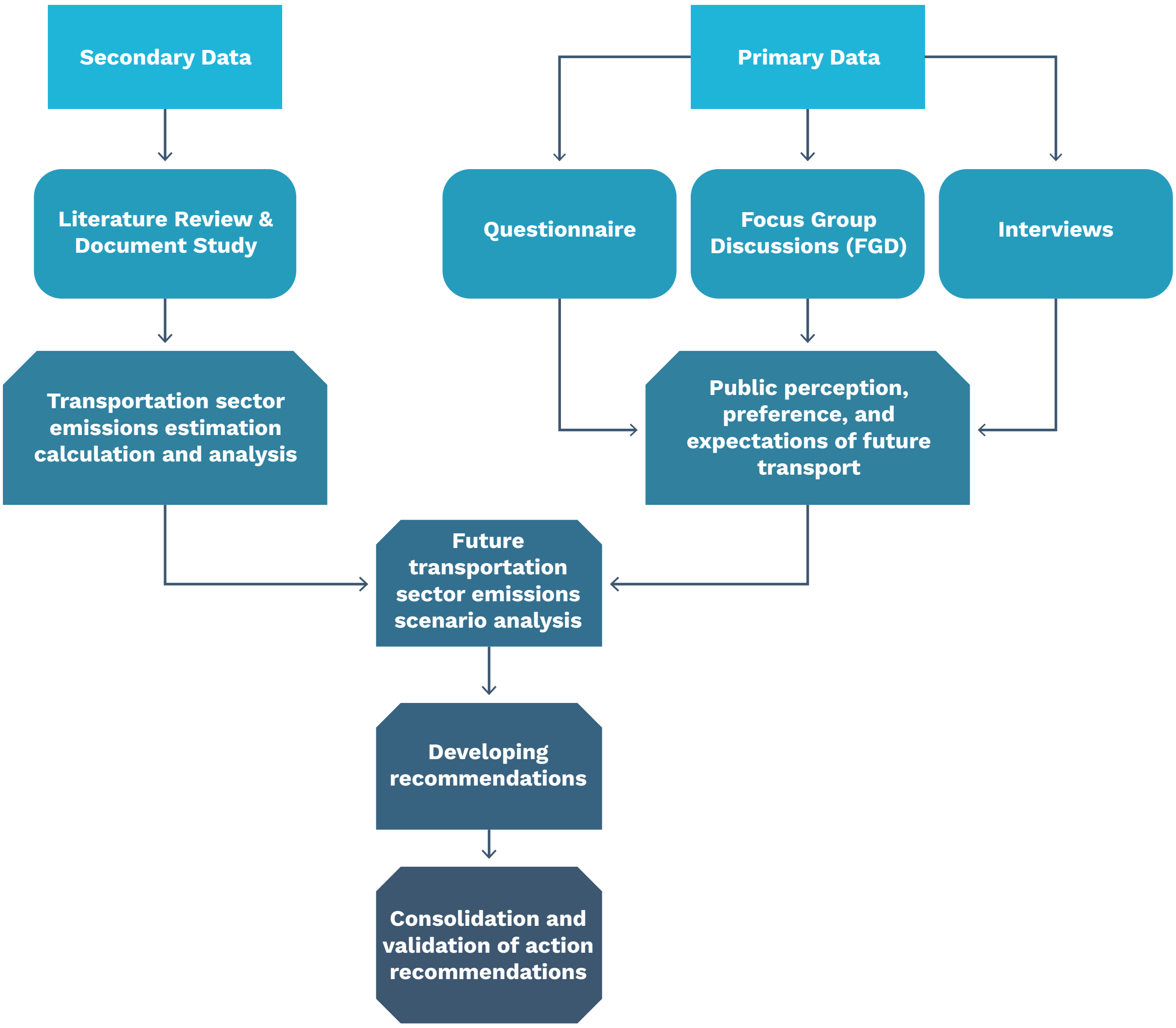


Figure 4. Research steps in formulating NZE action recommendations

Data Analysis Technique

Baseline emissions data for the year 2020, is calculated through the mobility activity data, energy intensity, and emissions per fuel type. This showed that activity data were obtained from questionnaire outputs and relevant secondary information, emphasizing key factors such as vehicle count, fuel economy, annual distance traveled, and fuel-based emissions. Besides, discharges were also determined through the suitable demand approach. The assumptions for the baseline emissions estimation are the following:

1. Emissions only considered data from road transportation and did not include aircraft, ships, or regional trains between provinces.
2. The number of vehicles in the initial year (2020) as the value of automobiles with activities in the DKI Jakarta.
3. Activity data for public transportation used information in 2019 or 2021 as a reference to avoid/reduce the bias of the pandemic conditions limiting public mobility.

The emissions estimation from the transportation sector in DKI Jakarta were calculated under several scenarios. The following provides a detailed explanation of each scenario, with subsequent details for all assumptions in each scenario is illustrated in Table 1.

1. **Scenario I: No Intervention (Business as Usual/BaU)**

   The BaU scenario assumed no changes, considering present trends with minimal intervention from transportation actors and stakeholders.

2. **Scenario II: Government Program and Policy Interventions**

   This scenario calculation assumes that all related established government programs were implemented, including increased public transportation use, additional green spaces, electric vehicles, and energy mix adjustments. The changes in the people of DKI Jakarta's mobility behavior were also considered.

3. **Scenario III: Electrification and Renewable Energy Use**

   The Electrification and Renewable Energy Use Scenario considered the reduction targets as stated by relevant international organizations. This electrification estimation is accompanied by a more massive use of public transportation, as well as a reduced and restricted number of private vehicles. Energy efficiency was also initiated by advancing and using innovative technologies.

4. **Scenario IV: Towards NZE 2050**

   The "Towards NZE 2050" scenario set more ambitious and progressive emissions reduction targets by promoting increased use of public transportation and electric/zero-fuel vehicles, reducing the number of private automobiles, and adopting a cleaner energy mix. This scenario aimed to achieve near-zero emissions by 2050 through ambitious targets.

Table 1. Assumptions of the scenario

Assumption	BAU	Government Program and Policy Interventions	Electrification and Use of Renewable Energy	Towards NZE 2050
Public transportation users	Growing in line with the population growth at a target of about 1 million users per day by 2050.	Increase in the number of people shifting public transportation to reach 1.5 million per day by 2050.	Increase in the number of people shifting public transportation to reach 2.54 million per day in 2050.	Increase in the number of people shifting public transportation to reach 3.35 million per day in 2050.
Electric vehicle - EV	Possessing 0.5% of total vehicle units (cars and motorcycles).	By 2050, 50% vehicles are Electric Vehicles (EV)[b].	In 2050, 100% vehicles are EV, with the energy mix consisting of 50% RE. For public transportation already using 100% RE.	By 2050, 100% vehicles are EV, and almost all of the energy mix is 100% RE[g].
Network emissions factor	Existing emissions 0.87 tons CO_2/Mwh[a].	Reduced according to PLN RUPTL (0.788 CO_2/Mwh by 2030)[c].	Reduced to 20% per 10 years (0.445 tons CO_2/Mwh-by 2050)[i].	Reduced by 30% per 10 years (0.282 tons of CO_2/Mwh-by 2050)[i].
Technology efficiency	Efficiency of 1% per yeard[d].	Efficiency of 1% per year.	Efficiency of 1.5% per year[h].	Efficiency of 2% per year[h].
Growth in the number of cars	Grew by 4.8%[e].	Growing at 4.8% per year and reducing to 2% and 1% by 2030 and 2040, respectively.	Growing at 4.8% per year and reducing by 2030 to 2% and 2040 to 1%.	Private cars in 2030 reached 5 million then reduced to 4.2 and 2.5 in 2040 and 2050, respectively.
Growth in the number of motorcycles	Grew by 3.73%[f].	Growing at 3.73%, reducing to 2% and 1% by 2030 and 2040, respectively.	Growing at 3.73%, reducing to 2030, 2%, and 2040 to 1%.	Private motorcycles will reach 20.7, 21, and 12.5 million by 2030, 2040, and 2050, respectively.

a. GHG emissions factor 2019 (Ministry of Energy and Mineral Resources)
b. Adapted from EBTKE Connex presentation material - Planning for NZE Scenario Towards Indonesia 2045 (Bappenas)
c. PLN RUPTL 2021-2030 (PLN)
d. EBTKE Connex presentation - Planning for NZE Scenario Towards Indonesia 2045" (Bappenas)
e. Car growth trend for the last 5 years (BPS DKI Jakarta Province)
f. Motorcycle growth trend for the last 5 years (BPS DKI Jakarta Province)
g. IEA. (2021). Net Zero by 2050: A Roadmap for the Global Energy Sector
h. Adapted from IEA energy efficiency data (2022) which averages 1.3% and is at most 2.3%
I. Adapted from electricity emissions factor data of developed countries that are already near 100% renewable energy (Covenant of Mayors for Climate & Energy)

Direct emissions from various transportation modes were considered by the above scenarios regarding the following data: (1) the number of vehicles in 2020 (private and public); (2) the average distance per vehicle; (3) the fuel used per km per vehicle type; and (4) the 2020 electricity demand for public transportation. Emissions factors per fuel type and electricity grid were also used to continuously translate emissions quantities. In addition, all obtained data and information were processed in the calculation of discharge quantities, using the Low Emissions Analysis Platform (LEAP) software.

Emission estimation scenario from 2020 to 2050 was developed using the ASI framework shown in Figure 5. This framework was implemented to reduce the environmental effects of transportation (Dalkmann and Brannigan, 2007, Bakker et al., 2014). A projection scenario up to 2050 was also developed to accommodate strategic policy recommendations for a measurable time horizon appropriate to the need and capacity. The "Shift" approach was also carried out by implementing additional public transportation, with "Avoid" increasing low-carbon modes, such as the non-motorized transport (NMT) comprising cycling and walking. Meanwhile, the "Improve" approach focused on the consideration of low-carbon transportation technologies, including electric vehicles.

© Bagus upc / Shutterstock

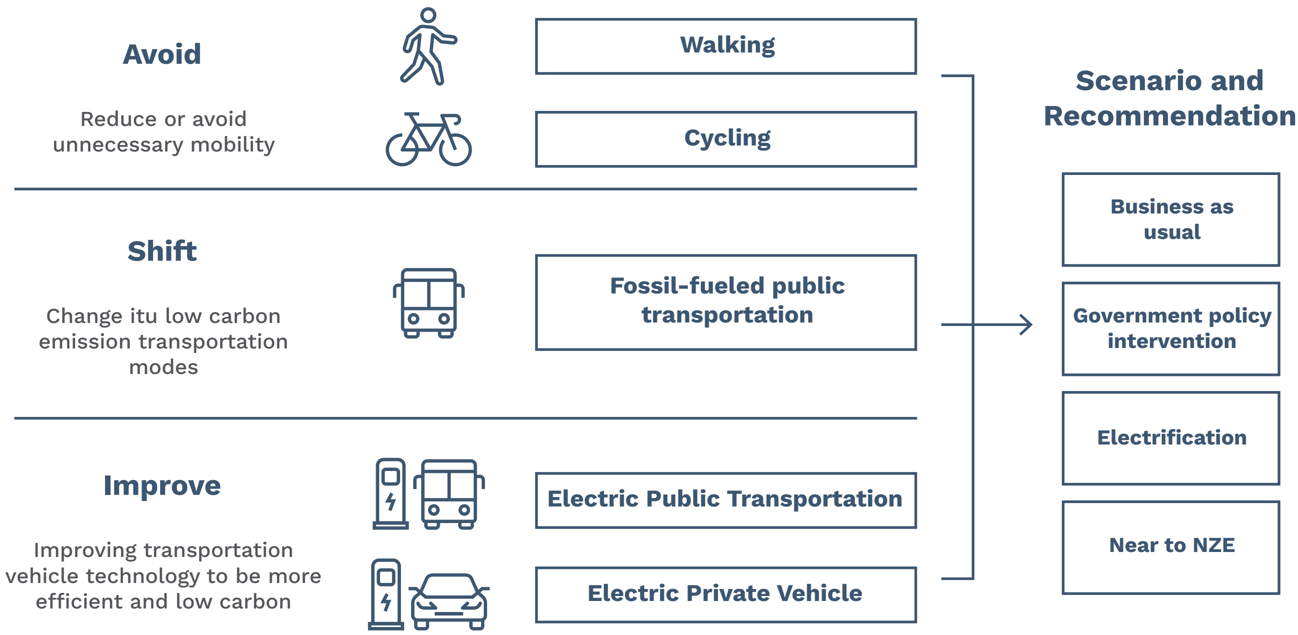


Figure 5. Approach to Developing NZE Action Recommendations

Based on the scenario analysis and literature review, a gap was observed among emissions reduction targets. To reduce the gap, the action recommendations for the government and the people of Jakarta were formulated.

Data Collection

Data were obtained through online questionnaires, FGD, and interviews with key stakeholders from the transportation sector. A review of relevant literature was also conducted to enrich the information, data, and related outputs. The FGD was initially conducted to obtain primary data before consolidating recommendations with relevant stakeholders. The FGD included around 20-25 participants from the local community, provincial government, non-governmental organizations, transport service providers, and other relevant parties within the research area. The participants were also sought to ensure consistency and coherence in responses and input.

The interviews were subsequently conducted online, using the Zoom meeting platform. In this context, the several institutions selected as informants were the Women Research Institute, Persatuan Tunanetra Indonesia/Pertuni (the Indonesian Blind Association), GERKATIN (Gerakan untuk Kesejahteraan Tunarungu Indonesia/Movement for the Indonesia Deaf Welfare), Bike-2-Work (B2W) Indonesia, and Perkumpulan Penyandang Disabilitas Indonesia/PPDI (Indonesian Disabled Persons Association). The data from the interviews were also analyzed to understand the development of a more inclusive and sustainable transportation sector in Jakarta. Moreover, online questionnaires were distributed to determine changes in behavior and perceptions of the city people. This information instrument was distributed through Greenpeace Indonesia publication channels, including

Twitter, Facebook, and Instagram. The promotional features of Facebook and Instagram were also adopted, targeting individuals matching the characteristics presented in Table 2.

Table 2. Social Media Advertisement Push Target Criteria

Category	Criteria Group 1	Criteria Group 2
Group Name Criteria	Gen Z audience[10] with an interest in mobility issues.	The general adult population of Jabodetabek.
Location	DKI Jakarta; Bekasi*; Bogor*; Depok*; Tangerang*	DKI Jakarta; Bekasi*; Bogor*; Depok*; Tangerang*
Age Restrictions	21-40	18-50
Topic of interest	GrabTaxi, Brompton Bicycle, Electric car, Air pollution, GoCar (carsharing), Free public transport, Public transport, Climate change, Grab (software), Bicycle, Carsharing or Go-Jek.	All topics.
Behaviour	Commuter.	All behaviors.
*Located within a 25-mile radius or about 40 km from the city center		

Questionnaire collection through the KoBoToolbox platform was carried out between January 21 and February 9, 2022. Figure 6 comprehensively presents the daily increasing number of participants during the online questionnaire distribution phase. This showed that the increase in participants from January 26 to 31, 2022, prioritized the publication on Greenpeace Indonesia social media platforms. The subsequent rise in the number of informants from January 31 to February 7, 2022, was also influenced by the use of advertising features on Facebook and Instagram channels.

[10] Experts refer to Gen Z as the generation born in the late 90s (Dimock, 2019, Rue, 2018). This generation is referred to as the generation born in the information age and digitally innate, or in other words, very close to the digital world. On the one hand, this is in line with the collection technique used, which uses the online questionnaire feature. On the other hand, along with the massive information about the environment in general and low-emissions transportation in particular to reduce contributions to the climate crisis, this generation is also referred to as a generation that is active in advocating changes to lead to a more sustainable life (Tyson et al., 2021).

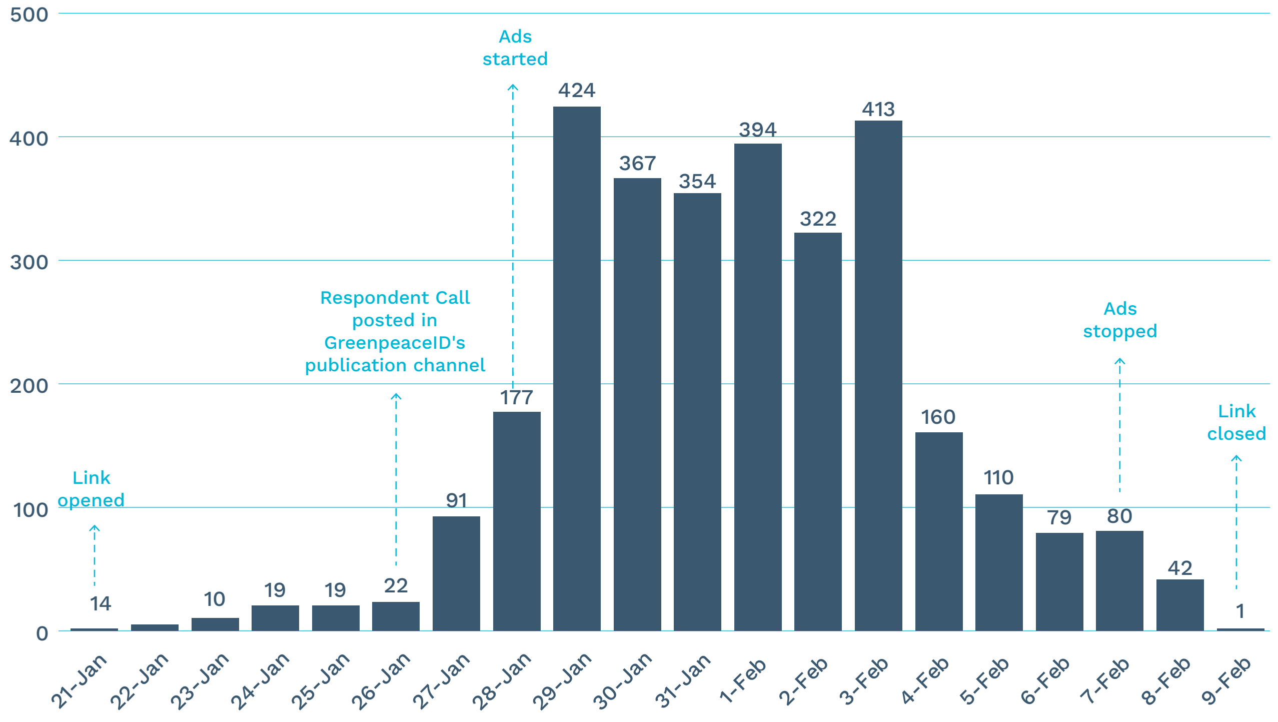


Figure 6. Daily increase in respondents

The questionnaire was filled out by 3,097 participants and not all the entries were valid and in line with the experimental requirements. The criteria used for data validity selection also included the occurrence of duplication, incomplete responses, mismatched domicile, activity locations, and excessively quick response duration. In addition, 2,097 questionnaires were considered valid for analysis regarding the above criteria.

Research Limitations

This research focused on the calculation of emissions produced by vehicle operations. This showed that the emissions obtained from vehicle operations were direct (burning fossil fuel vehicles) or indirect (the electrical power needed for vehicular movement). However, emissions from other transportation activities were not considered, such as vehicle manufacturing, disposal, maintenance, as well as the management and construction of related infrastructure, including roads, bridges, and toll routes. In this case, the calculations only focused on a portion of the total discharges produced or affected by commutation activities. The changes in emissions due to the pandemic (reduced travel frequency and intensity) or the potential migration of Jakarta population to the new National Capital were also not considered.

Figure 7 comprehensively presents a comparison of emissions for various transport modes from their vehicle operational activities and other stages of life cycle emissions such as manufacture. In this context, a patrol car produced operational emissions of 161.8 g/pkm[11], while providing additional discharges of 48.1 g/pkm. These conditions were different from

[11] Pkm (passenger kilometer) is a unit for describing transportation activities, where 1 pkm is when one passenger covers a distance of one kilometer.

the emissions of electric cars, which were estimated to produce operational emissions of 13.4 g/pkm, with other activities of 86 g/pkm. Based on the comparative analyses, the designed emissions calculation scenarios produced smaller numbers than the actual ones. This situation was specifically observed for electric vehicles (cars and motorcycles), where manufacturing and disposal emissions exceeded the operational discharges.

Ranking urban transport modes

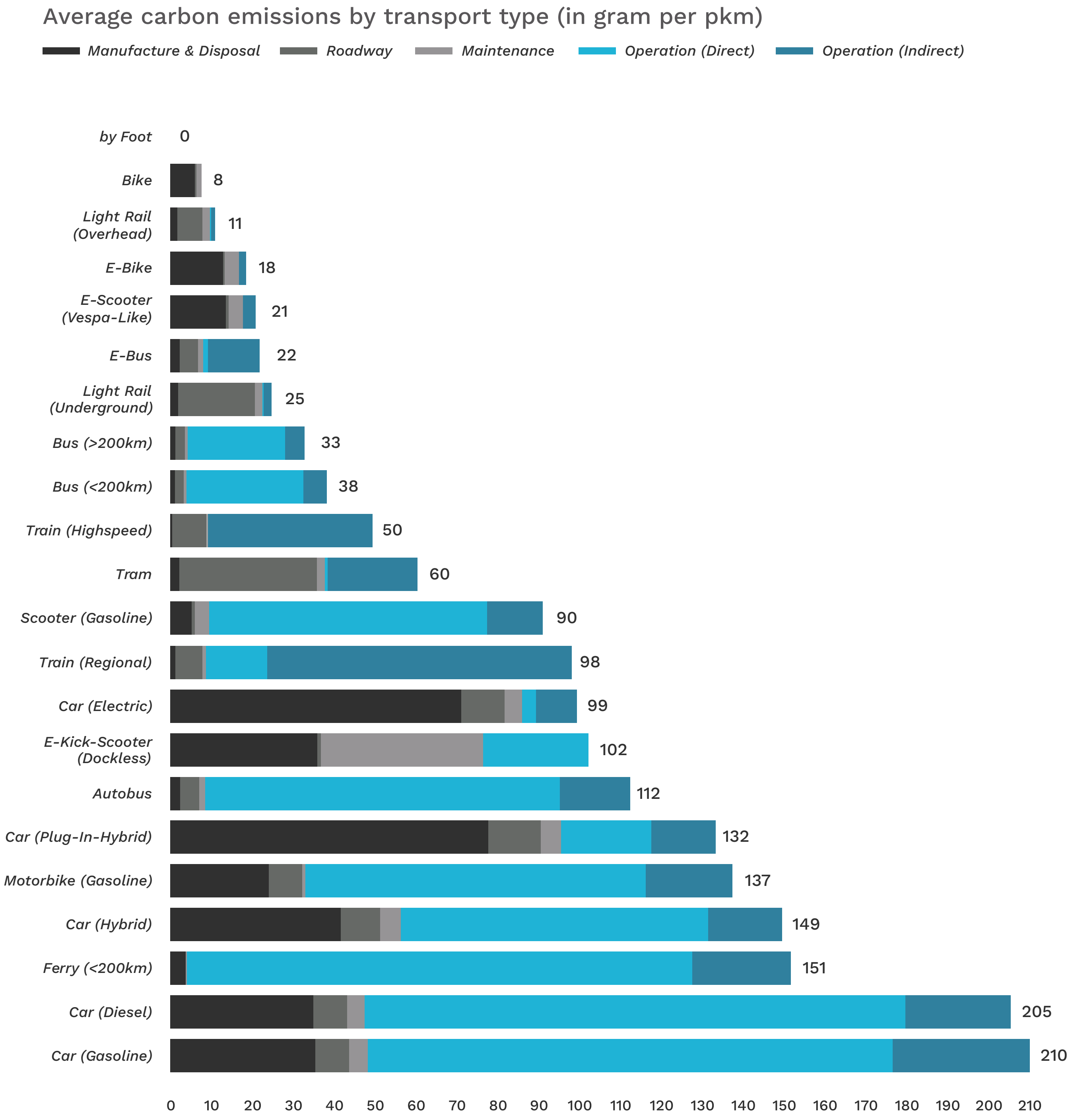


Figure 7. Estimated total direct and indirect emissions from various transportation modes
Source: Lufthansa Innovation Hub Analysis, TNMT.com

Passengers get off the Jakarta Mass Rapid Transportation (MRT)

© Adhi Wicaksono / Greenpeace

Current Conditions: Overview of Transportation Behavior in DKI Jakarta

Transportation plays a significant role in urban citizens. It is able to ensure interconnectivity between social, educational, health, and economic places. This connectivity contributed directly to economic productivity and recreational activities, determining people's quality of life, welfare, and happiness. From this context, a good transportation system should have minimal congestion, allowing people to reach their destinations without causing physical or emotional fatigue. This showed that the expected trip duration for the individuals being transported was not insignificant. According to Uber with BCG (2017), the average travel duration for Jakarta citizens was 68 minutes, with an additional 21 minutes spent searching for parking. Several previous analyses on congestion also showed a 34% increase in travel duration, proving that commuting in the city required 34% more time than congestion-free conditions. In addition, the trip duration was capable of increasing by 67% during peak hours, specifically 5-7 pm[12].

Transportation systems depending on private vehicles subsequently had the highest congestion risk due to their greater per capita space requirements. For example, cars commonly transported only one person during rush hours while buses simultaneously accommodated up to 40 passengers. This difference presented the increased spatial

[12] Data taken from Jakarta in Traffic Index 2021 by Tomtom Traffic Index https://www.tomtom.com/en_gb/traffic-index/jakarta-traffic/

demand for moving 40 individuals by car than a bus, as described in Figure 8. Therefore, public transportation generally proved to be 12 times more effective in reducing congestion than private vehicles (Kimber et al., 1985 as cited in Ortuzar, 2019).

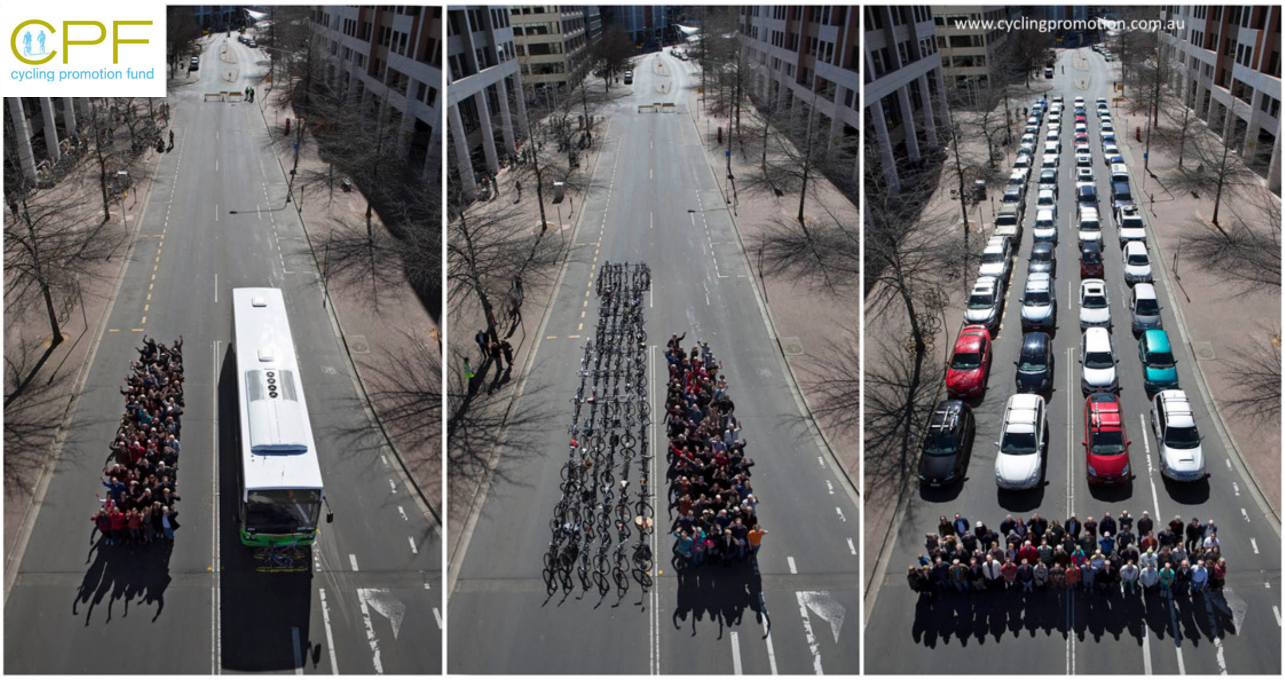


Figure 8. Comparison of road space between cars, buses and bicycles
Source: Australia's Cycling Promotion Fund (2012)

Besides causing congestion, private vehicles also reduced available land for public spaces (parks, playgrounds, sports areas, and public facilities) and environmentally friendly infrastructure (GOS, pedestrian walkways, and cycling lanes). At present, only about 34 km² of green open spaces (GOS) was available in Jakarta, while the area allocated to roads exceeded 46 km² in 2018, excluding vehicle parking locations (Open Data Jakarta, 2014 and Statistik DKI Jakarta, 2018). This situation showed that private vehicle infrastructure competed with green infrastructure. Meanwhile, the provision of cycling and walking infrastructure serving as GOS supported the increased implementation of public transportation facilities (Rietveld et al., 2001; Loo, 2021). This proved that cycling enhanced health and relaxation, specifically when routes were filled with vegetation (Marquart et al., 2022). In this case, adequate walking and cycling infrastructures were essential in strengthening the motivation of people toward the transition to low-carbon transportation, compared to expanding space for private vehicles and threatening GOS availability.

Current Preferred Transportation Mode

Based on the valid questionnaire data, the main transportation modes utilized were public vehicles (40.18%) and private motorcycles (39.51%). This showed that Transjakarta (39.1%) and Commuter Line (35.7%) were the public transportation frequently used by participants (Figure 9). Meanwhile, LRT was not highly considered (3%) due to the limited routes presently available (Figure 10).

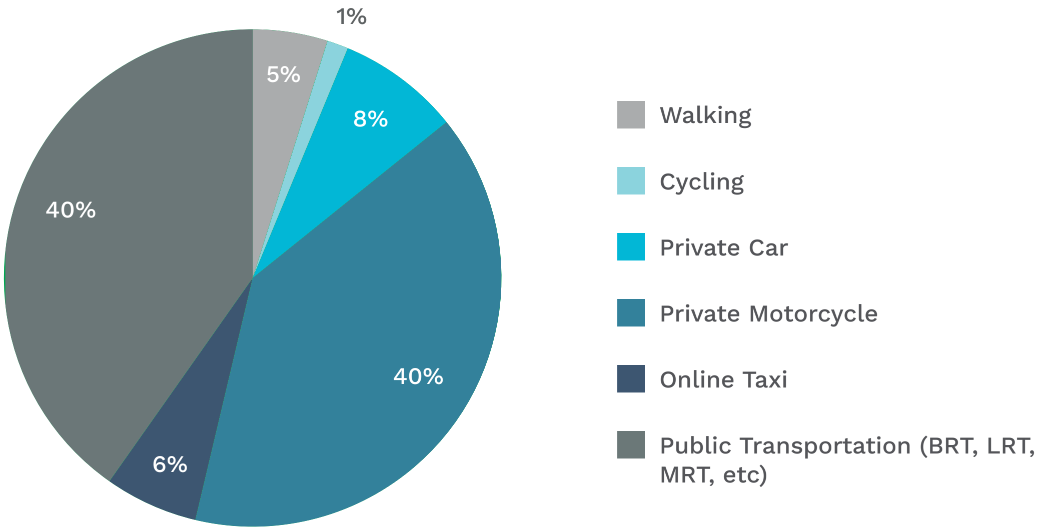


Figure 9. The main mode of transportation for Jakarta people

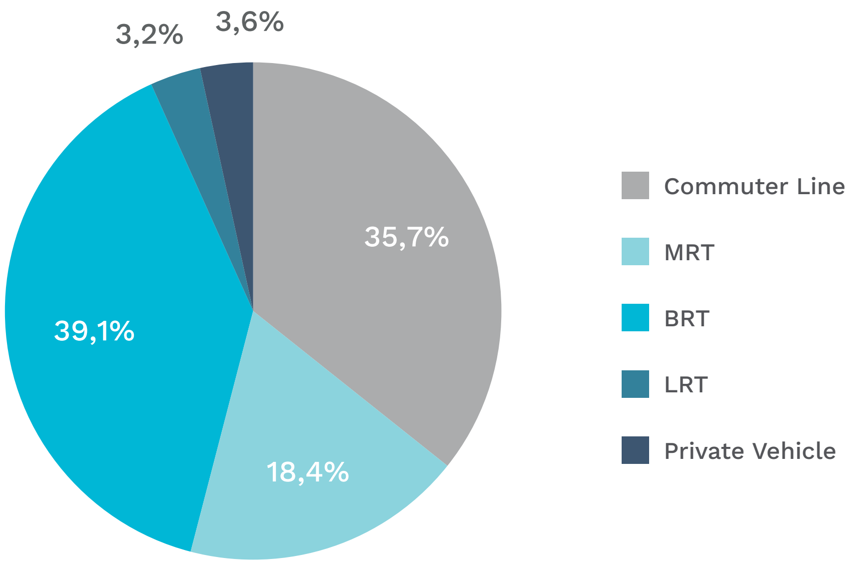
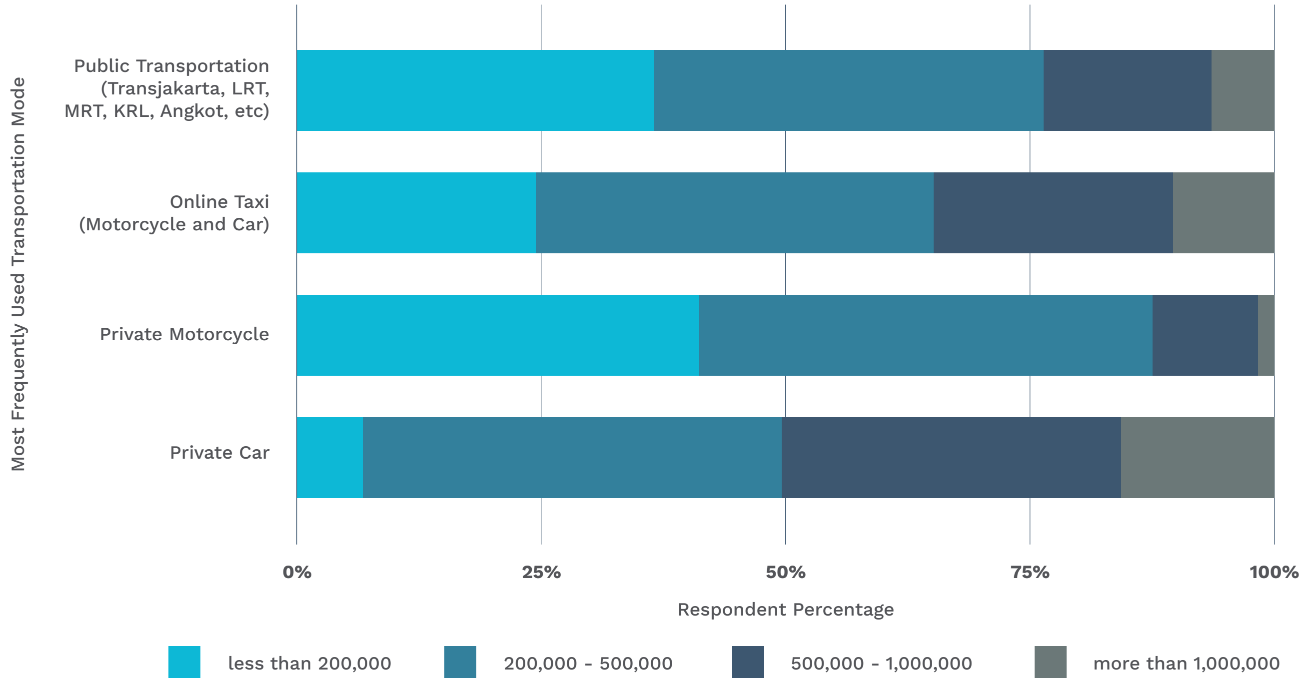


Figure 10. Choice of public transportation modes

Most respondents spent around Rp 200,000-Rp 500,000 per month on transport. Online taxis and private cars were the two modes of transport most frequently reported as relatively expensive. Correlation analysis shows that users of both costly modes incur costs in the higher range of Rp 500,000 and more than Rp 1,000,000 per month. As shown also in the graph below, private motorcycles are still reported to be one of the cheapest modes of transport. About 6% of public transport users reported high travel costs. On the other hand, 36.27% of public transport users reported that they could afford less than 200,000 per month (Figure 10)[13]. This is in line with the results of the FGDs, which also mentioned that public transport in Jakarta has an advantage in terms of economic value, as the cost of traveling by public transport from Bodetabek to Jakarta is only Rp. 4,000-6,000 per day. However, the lack of integration between public transport modes could be one of the reasons for this high cost, as users still need to supplement it with other relatively expensive modes of transport such as online taxis.

[13] For the record, most of the respondents in this research had a monthly income of IDR 2-5 million (32%) or under IDR 2 million (30%). The rest have income between IDR 5-10 million (27%).



The costs shown in this graph are a range of transport costs, not actual costs. This graph represents the percentage of respondents who reported a range of costs for each mode. The costs reported by the public transport user group may include a mix of other modes such as online taxis or other vehicle rentals (bike sharing, etc.).

Figure 11. Monthly transportation costs

Based on duration, public transportation was more popular as a long-distance travel mode with an average duration of 62 minutes. This was accompanied by private cars and motorcycles with periods of 44 and 34 minutes, respectively (Figure 12). The average participants also walked for 15 minutes or cycled 22 minutes to work or school. However, both cycling (1.38%) and walking (4.86%) were not considered the preferred mode of transportation (Figure 13) due to inadequate supporting infrastructure and air pollution.

Gender subsequently affected walking and cycling preference, with women often walking more than men.[14] From this context, 76%-80% of the participants who considered walking more were women. This was in line with Jieun Lee, Vojnovic, and Grady (2018), where men had more dominant rights in using the family car, enabling the females to depend more on public transportation. Another reason stated that women possessed more complex travel patterns, they are, mothers often observed multiple stops when commuting, to accommodate dropping off or picking up their children from school or daycare before reaching the office. However, men (59%) used bicycles daily than women (38%) in cycling transportation, expressing consistency with Heesch et al. (2012). This was due to the safety concerns possessed by women, such as harassment, assault, or robbery when traveling alone by bicycle (Lily et al., 2018).

[14] The effect between the two variables is carried out through binary logistic regression analysis to explain the relationship between the response variable in the form of binary data and the independent variable in the form of interval or categorical scale data.

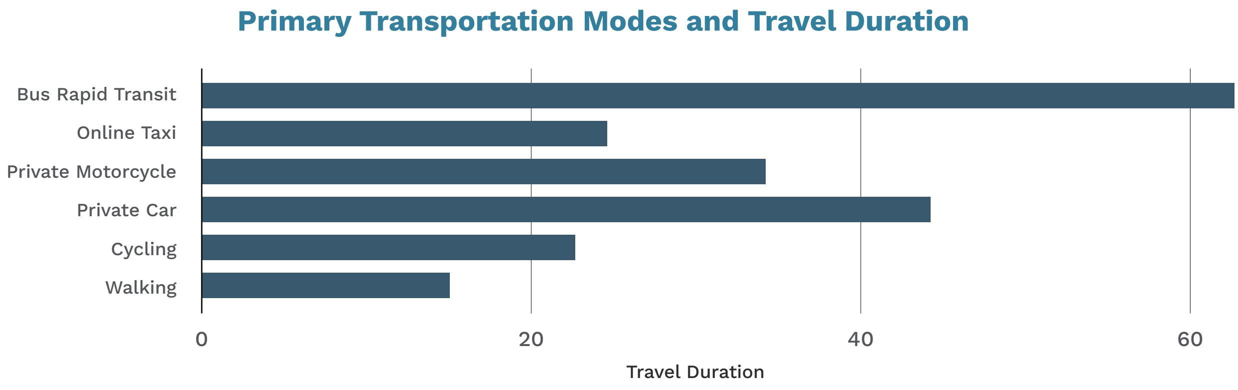


Figure 12. Primary vehicle modes and average travel duration

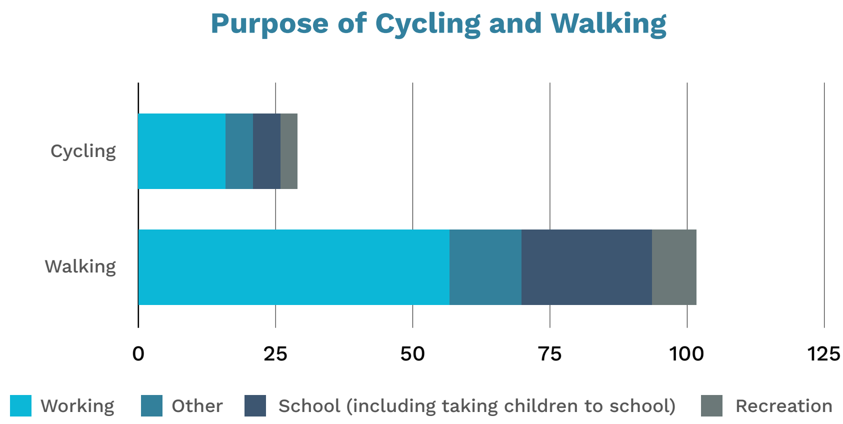


Figure 13. Purpose of cycling and walking

First Mile-Last Mile

The stages of transportation were identified to determine the shift in commuting modes, from the initial point to the nearest mass transit facility (first mile) and the final destination (last mile). Based on the questionnaire, most participants changed their transportation mode 2-3 times (Figure 14). This multi-mode transport behavior pattern was important for interconnecting commuting modes, especially within the Transit-Oriented Development (TOD) plan, as observed in various regions along the Jakarta MRT corridor. To reduce private vehicle usage and promote more intensive use of public transportation, several factors were also considered, such as the existing people's transit behavior and intermodal integration combination, feeder facilities provision, and pedestrian infrastructure provision in TOD areas (IUTRI, 2016).

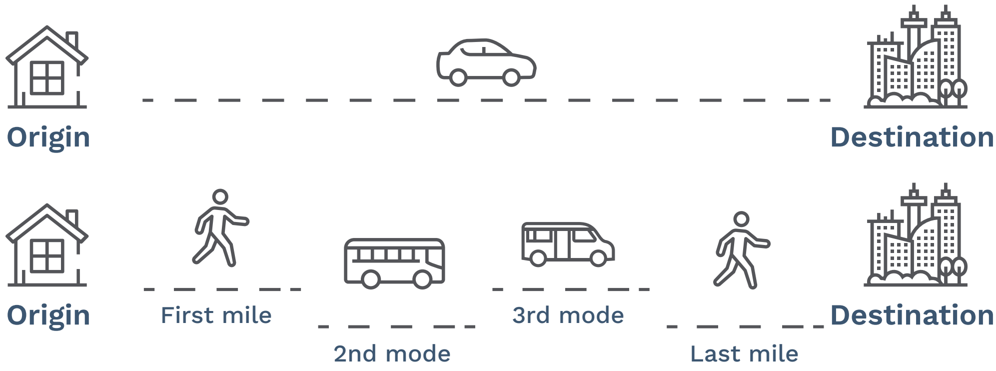


Figure 14. Illustration of first mile and last mile transportation mode shift

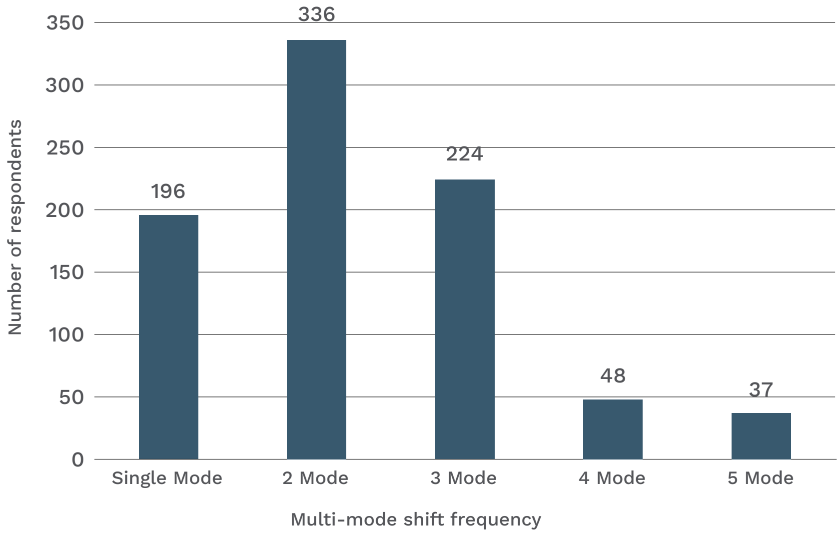


Figure 15. Frequency of transportation mode shift

According to the mode transfer intensity, motorcycle taxis were the most widely used first-mile mode of transportation. This finding was in line with Tjahjono et al. (2020), where the implementation of motorcycles was more popular as the first mile to reach the next mode in Jakarta people travel patterns. The second commonly used commuting medium (second mile) was walking (32%) or public transportation (39%), with the most preferred last mile transport mode being online motorcycle taxis (50%). The analysis shows that 23% of the respondents used motorcycle taxis for modal shift. Most of them (50%) used it for the last mile, 32% of them used online motorcycle taxis for the second mile and 19% of them used it for the first mile. The longest duration of using the commuting mode was also 45-90 minutes (45%) for the first mile and 0-15 minutes for the second and last miles. This condition interestingly showed that motorcycle taxis occupied a larger portion than the private motorbikes only used by 20% of participants.

The results also showed that walking had a fairly large portion in participants' daily mobility as it is chosen to be used in the first (19%), second (32%), and last (18%) miles, with a walking travel time of 15 minutes. This duration included a reasonable walking duration in urban areas, to directly reach the final destination (Poelman, 2018). Therefore, people preferred to walk when the travel time was less than 15 minutes and use a motorcycle taxi when the travel time was more than 15 minutes. The shift in mode by most was also an opportunity for the government to encourage the use of NMT, such as cycling or walking. This was supported by the high percentage of the individuals implementing public transportation. In this context, the multi-modes transportation integration plan should be directed toward a combination of mass transit and cycling or walking when the government aims to achieve the NZE target. However, the present state of the DKI Jakarta transportation system lacked sufficient integration, with distances exceeding 15 minutes between relevant commuting modes. Inadequate pedestrian and cyclist infrastructures, leading to the extensive reliance on motorcycle taxis.

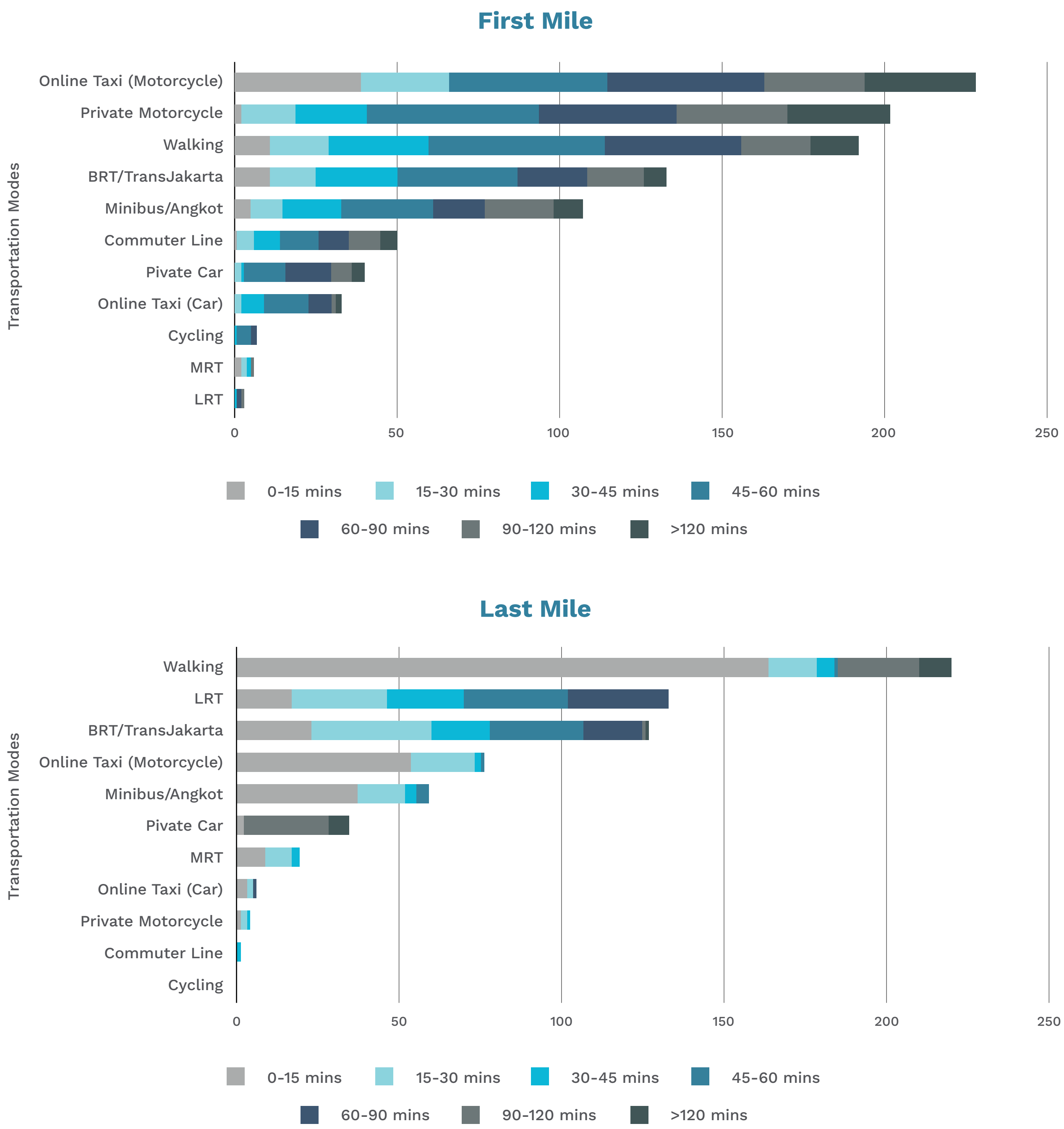


Figure 16. Types of First Mile and Last Mile Modes Shift

Based on the questionnaire data, walking is the most widely used last mile mode, emphasizing the encouragement to provide and improve the infrastructure quality. The pedestrian facilities available in Jakarta were also presently occupied by various non-walking activities, such as street vendors and parking, as well as public meeting points. Moreover, several issues and challenges related to crossing facilities, specifically pedestrian bridges (JPO/Jembatan Penyeberangan Orang), were also causing the less effectiveness of the walking travel distance and time. In this case, the enhancement of facility quality prioritized various measures toward catering to the various needs of pedestrians, including (1) restricting on-street parking, (2) installing supporting amenities such as lights, bollards, and benches, and (3) upgrading crossing facilities to improve safety and comfort (ITDP, 2021). From the analysis, the factors influencing participants' choice of transportation modes varied depending on their selected mode (Figure 16). However, the primary reasons for selection included cost (27%), punctuality (32%), convenience, and route availability (17%) (Figure 17). These factors should be focal points for improvement in transportation, to incentivize a shift in transportation modes.

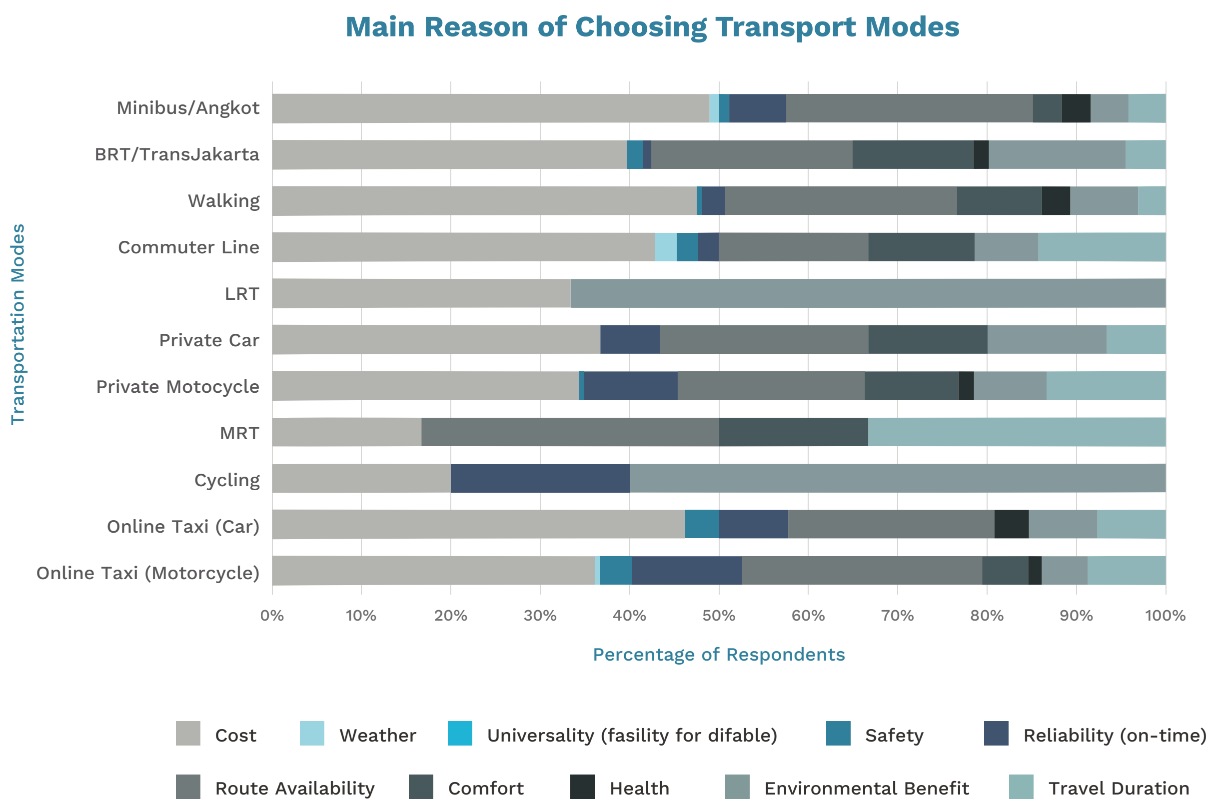


Figure 17. Main reasons for choosing transportation mode

4

Walking and cycling on a car free day along Jendral Sudirman street sunday morning.

Public perception of future transportation behavior

According to public perceptions regarding transportation modes shift (Figure 18), only 4.2% of people were reluctant to change or decide to use private vehicles. This showed the significant changes for private motorcycle users that expressed a desire to cycle more often or use mass transit. Public transportation users also anticipated the adoption of low-emissions mobility options in the future, with many planning to change toward walking (6.7%) and cycling (11%).

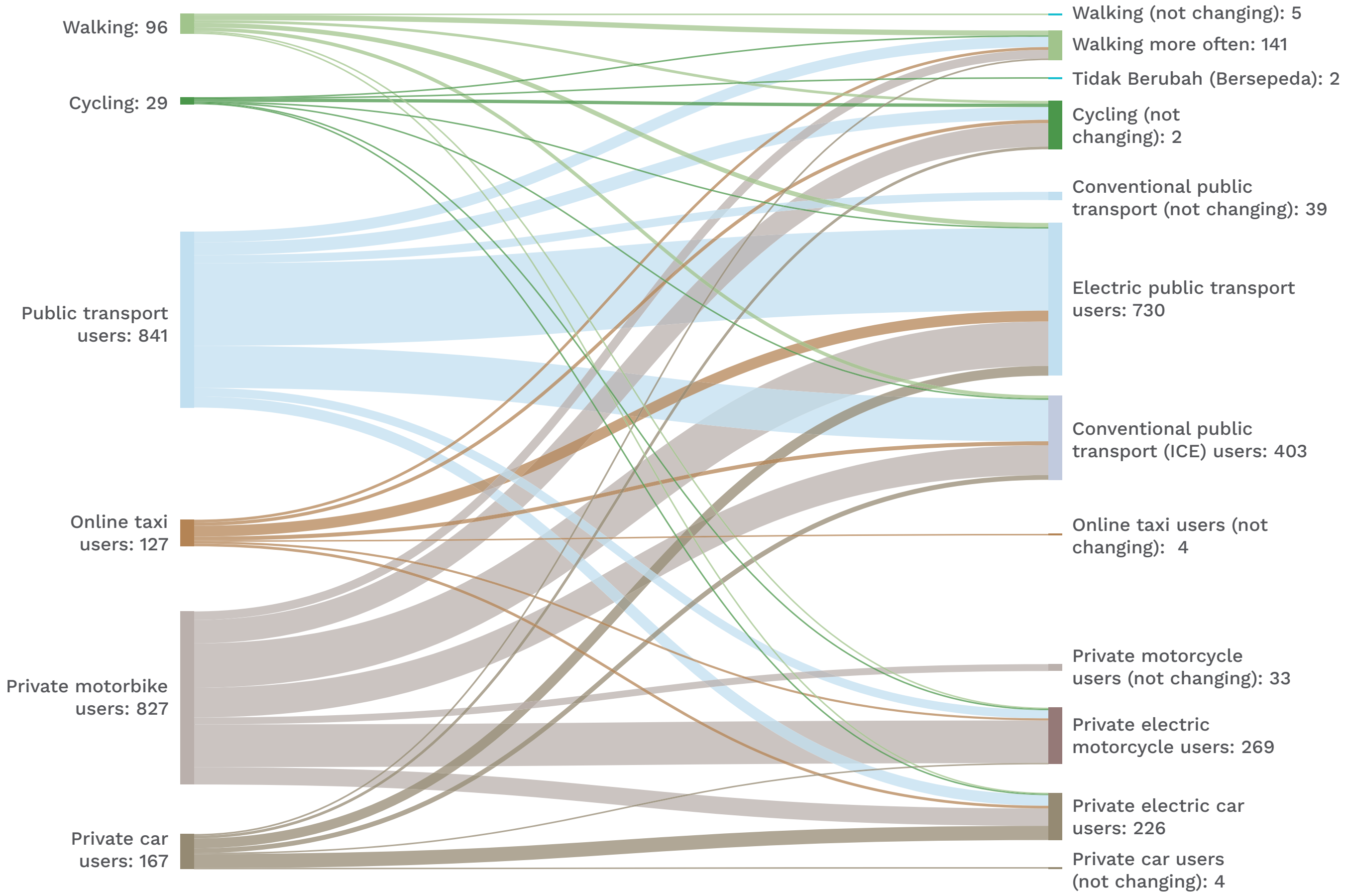


Figure 18. Respondents' aspiration regarding transportation mode shift

In Table 3, most of the reasons for reducing the use of motorcycles in the future by shifting to using public or non-motorized transportation (NMT) were due to pollution reduction. Another reason considered cost, showing that people had good environmental awareness (reducing pollution) and the benefits of walking or cycling (health). These two elements were considered the driving forces in changing the behaviors of individuals toward an NZE transportation sector.

Table 3. Changes in behavior of private motorcycle users and the reasons

Behavior change	Total respondents	Reason
Use electric public transportation more often.	73	Reduces pollution (64%).
Frequently implement public transportation through fossil fuels.	42	Cost (40%), reduce pollution (40%).
Frequent cycling.	21	Decreases pollution (76%).
Electric powered personal motorcycles.	13	Mitigates pollution (54%).
Electric powered private car.	10	Reduce pollution (40%), comfort (40%).
Walk more often.	9	Health (78%).
No change.	4	No.

Based on Figure 19, electric-powered transportation mode was one of the main selections of the participants' mobility preference in the future. This showed that Transjakarta buses were the key commuting mode targeted for transfers (55%), with 27% and 28% of people preferring the fossil and electric fuel types, respectively. Meanwhile, another targeted future preference for transportation activities was the Commuter Line (26%).

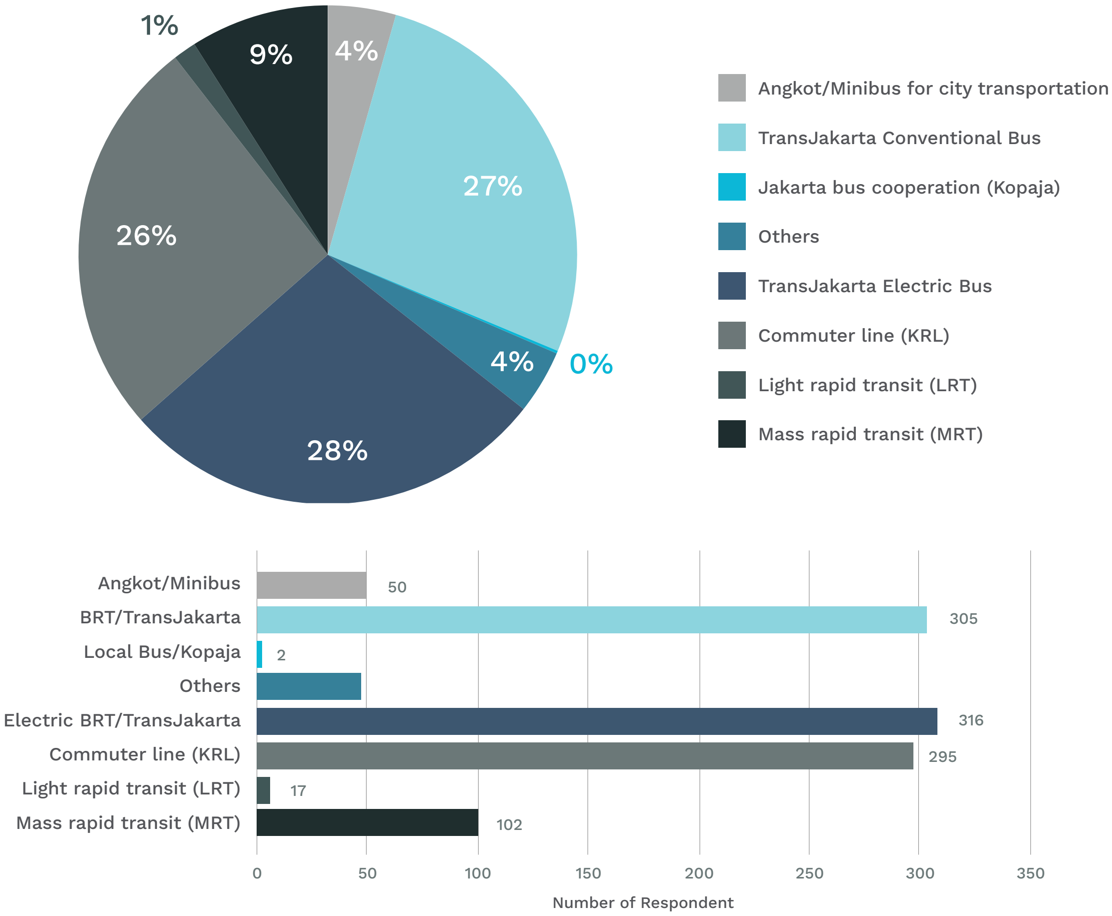


Figure 19. Type of preference for shift to public transportation mode

Figure 20 comprehensively states the reasons people often shifted to public transportation. This showed that almost half of the participants decided to shift because public transportation is considered a low emission transportation which contributed to the reduction of pollution (58%). Besides, factors such as cost (18%) and comfort (13%) were also influential in the decisions.

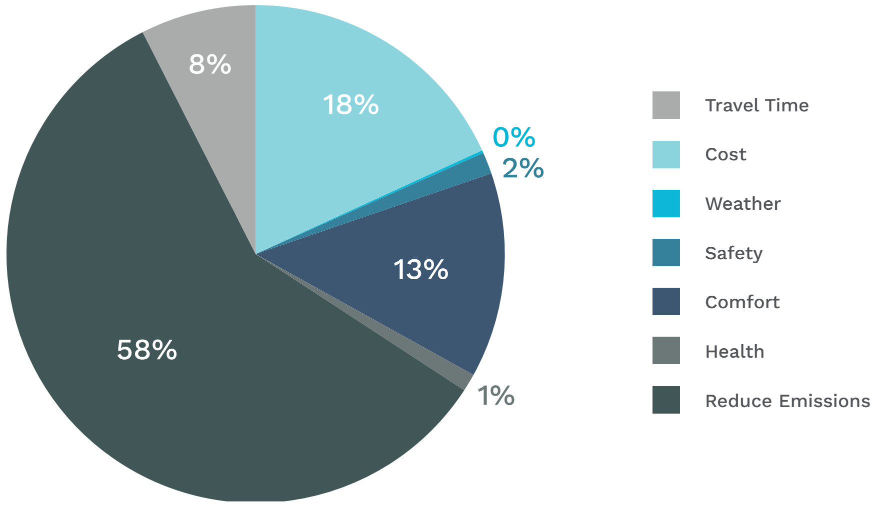


Figure 20. Reasons for shifting to public transportation

In Figure 20, the willingness to reduce air pollution was the main aspiration of participants to change their most preferred daily transport mode into public transportation, emphasizing the support for their perceptions of vehicle fuel use. Although most people still used the petroleum-fueled vehicle (81%), almost everyone still agreed that the transportation vehicles should be powered by electricity from renewable energy (93%) (Figure 21). The participants also provided the plans to use more environmentally friendly and healthy transportation (97%)[15].

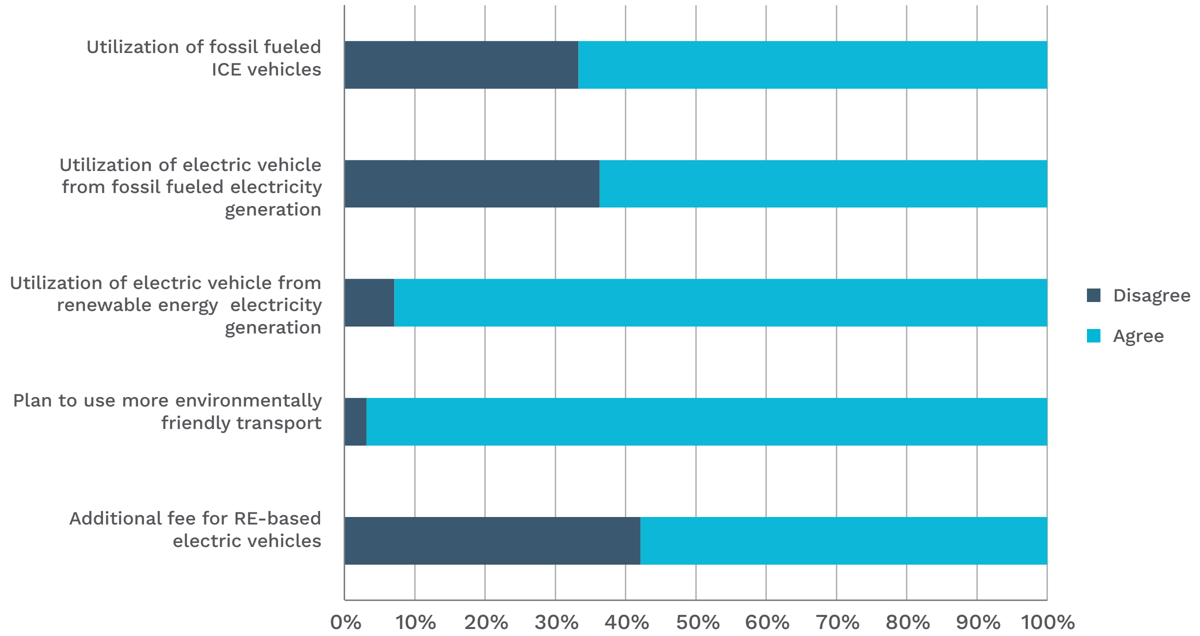


Figure 21. Respondents perceptions of vehicle fuel use

[15] This result is independent of respondents' knowledge about the characteristics, price, and other things about renewable energy.

Performance Indicators and Preferences

Table 4 explains the performance and preferences for using transportation modes in Jakarta's assessment from the respondents. These data were useful as a point of attention in improving the quality of transportation infrastructure.

Table 4. Performance indicators of transportation modes in Jabodetabek

<table>
<tr><th>Selected Mode of Transportation</th><th colspan="3">Performance Indicator Assessment</th><th colspan="3">Expectation Indicator Assessment</th></tr>
<tr><th>Public Transportation</th><th>Cost</th><th>Convenience</th><th>Cost</th><th>Cost</th><th>Convenience</th><th>Comfort</th></tr>
<tr><td rowspan="2">Fossil fuels</td><td rowspan="2">Ticket prices are appropriate.</td><td rowspan="2">Waiting time, ease of access, and travel distance to the closest station/terminal are appropriate.</td><td rowspan="2">The level of safety and comfort is appropriate and can meet user needs during extreme weather, although provided a relatively large amount of pollution.</td><td>Ticket prices are expected to be cheaper.</td><td rowspan="2">Improvements in waiting time, ease of access, and travel distance to the closest station/terminal.</td><td>• Improved security and comfort levels.
• Observation of a reduction in air pollution.</td></tr>
<tr><td>Users tend to agree to add IDR 10,000 to the normal price for electric-powered public transportation.</td><td>Use of clean and low emissions energy sources.</td></tr>
<tr><td rowspan="2">Electric based</td><td rowspan="2">Ticket prices are appropriate.</td><td rowspan="2">Waiting time, ease of access, and travel distance to the closest station/terminal are appropriate.</td><td rowspan="2">The level of safety and comfort is appropriate and can meet user needs during extreme weather, although portrayed a relatively large amount of pollution.</td><td>Ticket prices can be even cheaper.</td><td rowspan="2">Improvements in waiting time, ease of access, and travel distance to the closest station/terminal.</td><td>• Improved security and comfort levels.
• Provision of a reduction in air pollution.</td></tr>
<tr><td>Users want to add IDR 10,000 to the normal price for electric-powered public transportation.</td><td>Use of clean and low emissions energy sources.</td></tr>
</table>

Selected Mode of Transportation	Performance Indicator Assessment			Expectation Indicator Assessment		
Electric Car				**Charging Costs**	**Tax Reduction**	**Subsidize Battery Charging Equipment**
	-	-	-	Implementation of a policy of charging costs for electric vehicles that are cheaper than fossil fuels.	The policy of reducing taxes, tax exemptions, lower toll road rates, and free parking for electric vehicles in public facilities is implemented.	Implementation of battery charging equipment subsidy policy.
Electric motor				**Subsidies for Battery Charging Equipment**	**Charging Costs**	**Tax Reduction**
	-	-	-	Implementation of battery charging equipment subsidy policy.	Implementation of a policy emphasizing charging costs for electric vehicles cheaper than fossil fuels.	Implementation of tax reduction policies, tariff exemptions, and free parking for electric vehicles in public facilities.
Bicycle	**Bicycle Parking**	**Condition of Bicycle Lane**	**Bicycle Lane at Crossroads**	**Bicycle Parking**	**Condition of Bicycle Lane**	**Bicycle Lane at Crossroads**
	The availability of safe bicycle parking at stations, terminals, or offices is appropriate.	The availability of protected bicycle lanes, connected to public transportation, equipped with lighting, directional signs and trees is appropriate. However, the bicycle lanes that are not directly connected to the main location are observed.	The availability of bicycle lanes that protect cyclists from other vehicles at road intersections is appropriate.	Improvements in the availability of safe bicycle parking at stations, terminals, or offices.	Improvements in the availability of protected bicycle lanes, connected to public transportation and key location destinations, as well as equipped with lighting, directional signs, and trees.	Improvements in the availability of bicycle lanes protecting cyclists from other vehicles at road intersections.

Selected Mode of Transportation	Performance Indicator Assessment			Expectation Indicator Assessment		
On Foot	**Air Pollution**	**Support Facilities for Pedestrians with Special Needs**	**Pedestrian Lane Safety**	**Pedestrian Support Facilities**	**Availability of Pedestrian Lane**	**Pedestrian Lane Safety**
	Air pollution, uncomfortable weather and temperatures are still felt, as well as a lack of GOS and trees.	Lack of availability of supporting facilities for pedestrians with special needs.	Inadequate availability of pedestrian lanes, safety from other vehicles, as well as supporting facilities including lighting, directional signs, and trash cans.	Reducing air pollution, improving weather and temperature conditions, as well as increasing the availability of GOS and trees.	Improvements in the availability of supporting facilities for pedestrians with special needs.	Improvements in the availability of pedestrian lanes, as well as safety from other vehicles, supporting facilities including lighting, directional signs, and trash cans.

According to the summary of participants' expectations for transportation infrastructure improvements, presently available commuting modes were in line with their preferences. This showed that public fossil-fueled or electric-based vehicles met user needs regarding cost, convenience, and safety. However, fossil fuel-based mass transit should enhance its performance, specifically in reducing air pollution. Another resolution option was also the transitioning to electricity-based transportation, which depended on clean and low-emissions energy sources.

Similar to public transportation, the assessment of cycling modes was subsequently considered appropriate concerning parking spaces, protected bicycle lanes, and routes at road intersections. Meanwhile, a need to enhance cycling mode performance was observed, specifically in connecting bicycle lanes to key destinations. In 2019, the existing cycling routes only covered 63 km within Jakarta and were primarily concentrated on major roads. Plans were also in place to expand the distance to 196 and 690 km by the end of 2021 and 2030, respectively (Dinas Perhubungan DKI Jakarta, 2021). This was in line with an ITDP report (2022), where several existing sections of bicycle lanes required quality improvements, specifically for protected routes, signs, and markings. However, the consideration of walking as a mode of transportation focused on inadequate performance, regarding air quality, safety, and the provision of facilities for pedestrians with special needs. In this pedestrian infrastructure case, general comprehensive performance improvements were necessary in all aspects.

The quality of non-motorized vehicle infrastructure in Indonesia also served as a significant challenge to encouraging environmentally friendly transportation mode choices. This was because inadequate infrastructure often hindered the safety of road users. Based on Unterman (1984) in Frans et al. (2016), the specific safety in the presence of protective elements was important for pedestrians due to preventing various walking lane issues. In this context, enhancing the quality of cycling and walking infrastructure was anticipated to stimulate greater adoption of NMT modes (Table 5).

Tabel 5. Preferensi parameter moda transportasi di Jabodetabek

Modes of transportation	Parameter	Preference
Fossil fuel-based public transportation	Waiting time.	A total of 0-10 minutes (76%).
	Paying more for electric-powered transportation.	Approximately 82% of participants were willing to add up to IDR 10,000 from the normal price.
Electric-powered public transportation	Waiting time.	A total of 0-10 minutes (79%).
	Paying more for electric-powered public transportation.	Around 85% of participants were willing to add up to IDR 10,000 from the normal price.

Modes of transportation	Parameter	Preference
On foot	Distance.	About 500 m - 1 km (41%)
	Frequency.	Three (23%) or five times (21%) a week.
	Crossing facilities.	Pelican Crossing (zebra cross equipped with additional facilities) (79%).
Bicycle	Distance.	About 1-6 km (61%).
	Frequency.	Three (22%), two (19%), or five times (17%) a week.
Electric car	Maximum travel distance satisfaction of 160 km.	Approximately 64% of participants felt satisfied/very satisfied.
	Charging time satisfaction of 3-4 hours.	About 49% of participants felt satisfied/ very satisfied. Around 20% of informants felt slightly dissatisfied.
	Price.	< Rp. 300 million (65%)
	Type.	*Plug-in Hybrid* (42%)
	Availability of purchasing a 7 kW charging point at home.	Approximately 87% of participants were willing.
	Manufacturing country.	41% of respondents stated that it had no effect
Electric motorcycle	Maximum travel distance satisfaction of 120 km.	About 66% of participants felt satisfied/very satisfied.
	Kepuasan waktu pengisian daya 3-4 jam	Around 29% of informants selected acceptable A total of 19% participants felt slightly dissatisfied.
	Price.	IDR 10,000,000 - IDR 15,000,000 (65%).
	Availability of purchasing a 7 kW charging point at home.	Approximately 82% of informants were willing.
	Manufacturing country.	36% of respondents stated that it had no effect

Aerial View from the top of the Semanggi flyover highlights Jakarta's air pollution in the afternoon.

Emissions Estimation Analysis Results

Based on questionnaire data, 97% of participants had a plan or willingness to use low-emissions modes of transportation. This condition led to the following question, "Can the change in the people's mobility behavior and the existing government programs in DKI Jakarta achieve the NZE target?" In this context, the carbon emissions already existing in the environment were only reduced through plant absorption or stored in underground geological layers (Carbon Capture Storage/CCS). Although plant absorption was a much cheaper approach with high benefits than CCS technology, it was still very limited for implementation. Since trees averagely absorbed only 25 kg of CO_2 in one year, at least 530 million plantations were required to assimilate around 13.27 million tonnes of CO_2 (DLH, 2018). When one tree required a square meter, the area necessary to absorb carbon emissions in 2018 was subsequently 530 km^2, constituting 80% of the total locations in DKI Jakarta (661.5 km2). Presently, GOS also approximately covered 34 km^2, equivalent to about 5.1% of the city (Open Data Jakarta, 2014, and Statistik DKI Jakarta, 2018). These results showed that the GOS target (30%) only reduced 37% of the total emissions in 2018, amounting to 4.9 million tons of CO_2. In this case, the development of a strategy was important to minimize carbon emissions from the transportation sector.

The effectiveness of low-carbon strategies in the transportation sector was also assessed concerning the total amount of emissions produced from each scenario. This section focused on emissions produced in the initial year (base year) regarding several future simulations. Transportation emissions reduction scenario analysis was subsequently developed by estimating discharges for thirty years, prioritizing the implementation of 2020 and 2050 as the base and end years, respectively. Moreover, the emissions calculation scenario was divided into four categories, namely (1) No Intervention, (2) Government Program and Policy Intervention, (3) Electrification and Renewable Energy Use, and (4) Towards NZE 2050.

These categories possessed the assumptions that became variables in estimating emissions potentially produced. Overall, the no-intervention or business as usual scenario used the basic assumption from any actor and followed existing trends. The basic consideration for the second scenario also focused on the implementation of government policies, programs, and targets, as references to relevant estimates. The more ambitious target on the electrification and renewable energy use simulations is deployed in the third scenario. This scenario applied baseline assumptions with future targets proposed at the international level, specifically the estimates from relevant agencies or institutions. Lastly, the toward-NZE scenario was the most ambitious scenario in this research which aims to maximize effort in achieving minimum or near-zero discharges by 2050.

Estimated Present Transportation Emissions (Base Year)

The actual emissions estimate for the road transportation sector in the base year 2020 was the reference for present discharges. This calculation formed the foundation for projecting scenarios in 2050, regarding various assumptions. The choice of data from 2020 was also justified by its recency and comprehensiveness, as information for 2021 remained incomplete in several aspects during the analysis. However, references from 2021 and 2019 were used for comparison when considering driving behavior, specifically in public transportation. In the initial year, emissions calculations primarily focused on activity data, including the vehicle counts, annual mileage, and fuel efficiency transformed through relevant discharge factors. The value of vehicles within the city was also obtained from several organizations, including the DKI Jakarta Central Statistics Agency and Transportation Service, PT. Jakarta Transportation, PT. Indonesian Commuter Train, PT. LRT Jakarta, and PT. MRT Jakarta. Furthermore, the data prioritizing the number of vehicles and users were publicly accessible, as observed in annual reports from each service provider institution or other statistical information published on their official websites.

The driving behavior data for individuals residing in DKI Jakarta was subsequently acquired from questionnaire responses, providing insights into daily travel distances, transportation choices, weekly trip estimates, and other relevant information. This activity data facilitated the estimation of fuel or electrical power consumption, which was converted into emissions factors determined through the Indonesian Ministry of Energy and Mineral Resources, as well as interrelated international institutions.

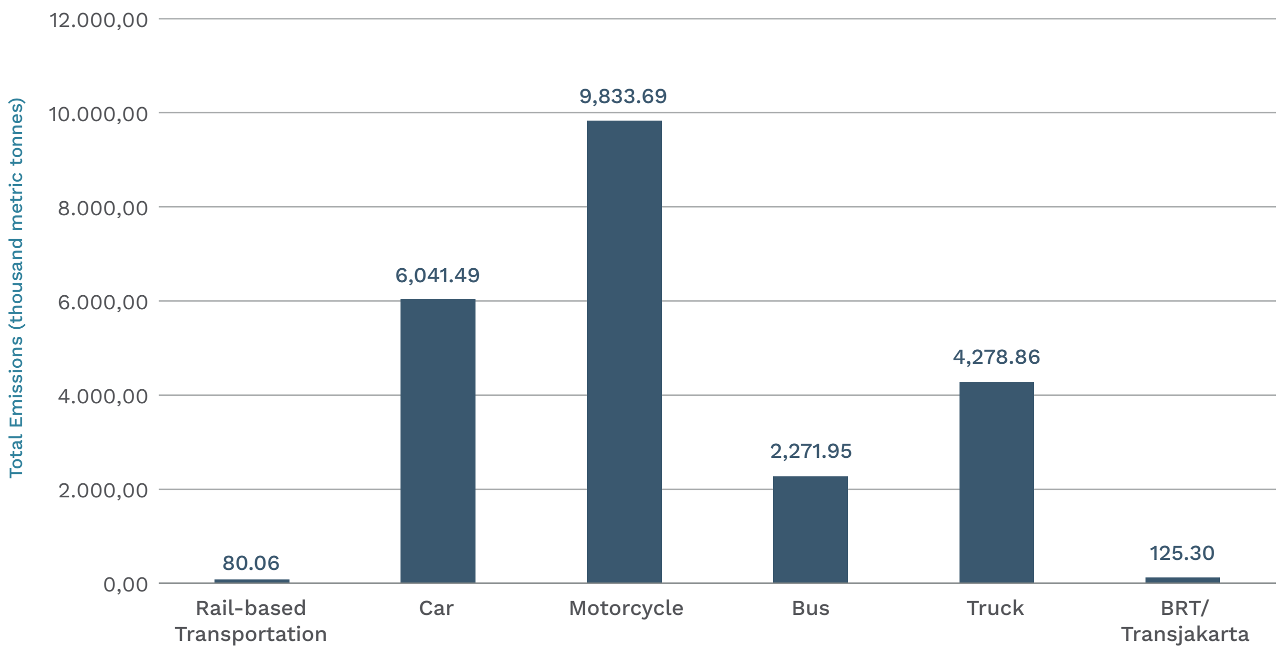


Figure 22. Estimated Emissions (thousand tonnes of CO_2e) produced by vehicles in Jakarta (2020)

From the estimated actual emissions (base year) in 2020, the road transportation sector in DKI Jakarta produced discharges of 22,815,356 tonnes CO_2e. These discharges were estimated to be 16.12% (157,771,000 tons CO_2e) when compared with the national data in 2019 (KLHK, 2020). Emissions were also much larger in DKI Jakarta than other cities, such as Semarang. This was because the commuting sector for Semarang City was estimated to produce only 824,129 tonnes of CO_2e discharges in 2018 (DLHK Kota Semarang, 2019). However, the amount calculated differed from the estimate issued by the DKI Jakarta Environmental Service (2019) for 2018, namely around 13,270,900 tonnes of CO_2e. This was due to the different approaches used, with the calculation for the transportation sector implementing fuel sales during the year in DKI Jakarta.

The largest contributor to emissions subsequently originated from fossil fuel vehicles, namely petrol (16,566,857 tons CO_2e) and diesel (5,920,637 tons CO_2e). This showed that electric transportation modes only contributed 327,853 (1.43%) tons of CO_2e, with most of the outputs originating from electric-powered public vehicles, such as the Commuter Line, LRT, and MRT. In this context, fossil fuel vehicles provided almost all emissions from the public transportation sector. Private vehicles such as motorcycles and cars were also the largest contributors to relevant discharges (motorcycles-43.1% and cars-26.48%) (Figure 22). Motorcycles and cars dominated the vehicle movement of the transportation sector activities in DKI Jakarta at 16.14 million (76%) and 4.05 million (19%), respectively. This number of vehicles was one of the factors causing congestion and worsening emissions in the city. The emissions from cars were relatively greater than the motorcycles. However, the direct emissions of the motorcycles were almost twice as large because their quantity was four times that of cars.

Public transportation (rail-based transport including MRT, LRT, Commuter Line and the bus rapid transit namely Transjakarta) subsequently represented 0.90% of the total direct/operational emissions in the DKI Jakarta transportation sector (Figure 22). This showed that rail options such as LRT, MRT, and the Commuter Line contributed less than the Transjakarta influenced by various factors, including service coverage, vehicle numbers, and fuel type. When comparing emissions per person for different vehicles, public transportation also significantly reduced emissions. During a single trip, the users of the public transit in DKI Jakarta produced approximately 0.778 and 0.948 Kg CO_2e/person for rail and Transjakarta, both significantly lower than motorcycles (1.802 Kg CO_2e/person) and cars (3.579 Kg CO_2e/person). The Commuter Line emits the lowest emissions at 0.345 Kg CO_2e/person, due to its relatively higher carrying capacity.

Scenario 1: No Intervention (Business as Usual)

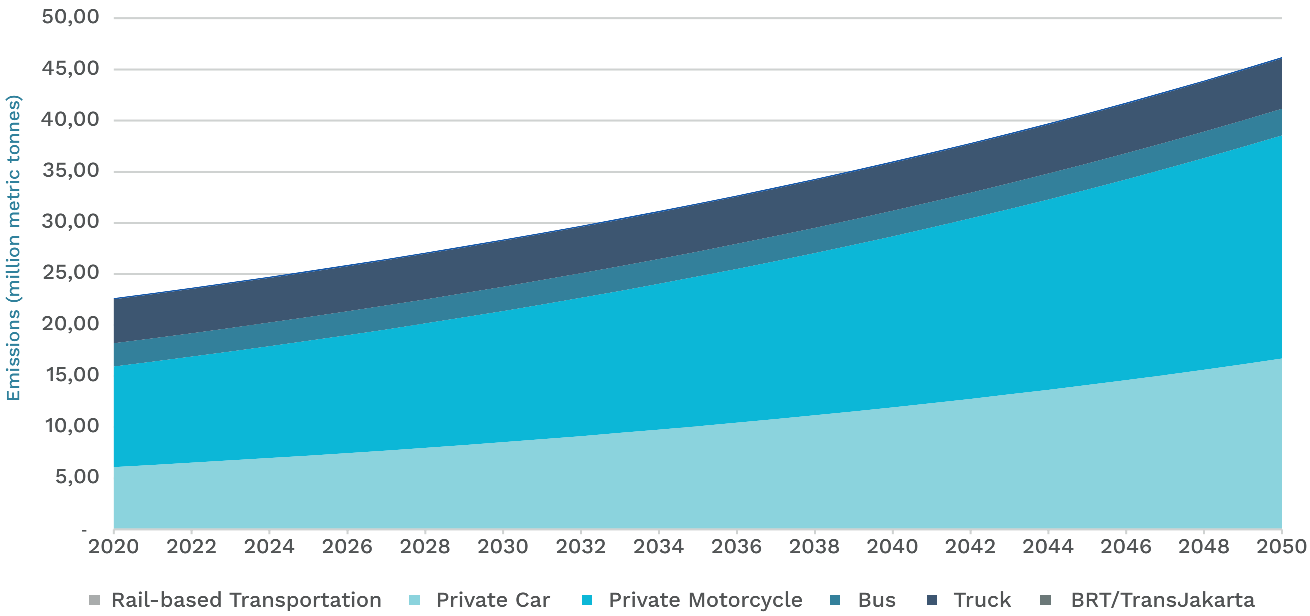


Figure 23. Estimated emissions (million tons CO_2e) of no intervention scenario generated by vehicles in DKI Jakarta during 2020-2050

Based on Table 1, the "No Intervention" scenario assumed an uninterrupted increase in the number of vehicles and users, accounting for population effects as described by previous trends. This scenario considered no changes or interventions aimed at emissions reduction from any entity. It also served as the benchmark to reflect and estimate future discharge conditions in the absence of intervention or constraints deviating from existing trends. In Figure 23, the generation of emissions across various transportation modes in DKI Jakarta was illustrated, emphasizing rail transportation (KRL, MRT, and Commuter Line), Transjakarta, cars, motorcycles, buses, and trucks. This proved that the emissions were on a relative increase, specifically for cars and motorcycles, with their additions supporting the vehicle growth trend of the previous five years. The vehicular additions were also influenced by the population increase at the existing growth rate.

The "no-intervention" scenario was subsequently expected to yield 46 million tons of CO_2e by 2050 (Figure 23). This was because cars and motorcycles were the predominant emitters, contributing significantly at 36% and 47%, respectively. The vehicles also provided practicality regarding transportation from one point to another. In this context, motorcycles were supported by the lower middle class due to their relative affordability and convenience in enabling access to various locations, especially narrowed roads in Jakarta's urban kampung. However, survey analysis showed a willingness among the respondents to transition from the private motorcycle to mass transit. Car users also expressed their intention to continue using their preferred vehicles in the future, providing reasons such as practicality, cost, and convenience (Figure 17). Regarding the encouragement of people to shift to public transportation, relevant challenges were observed when considering the reasons for mode choice. This was found in the present time reliability of mass transit, which was inadequate than the provision of private vehicles. Meanwhile, greenhouse gas (GHG) emissions were set to reach alarming levels when the use of private automobiles strongly supported the present trend, exceeding the modern discharge extents by more than double.

Scenario 2: Government Program and Policy Interventions

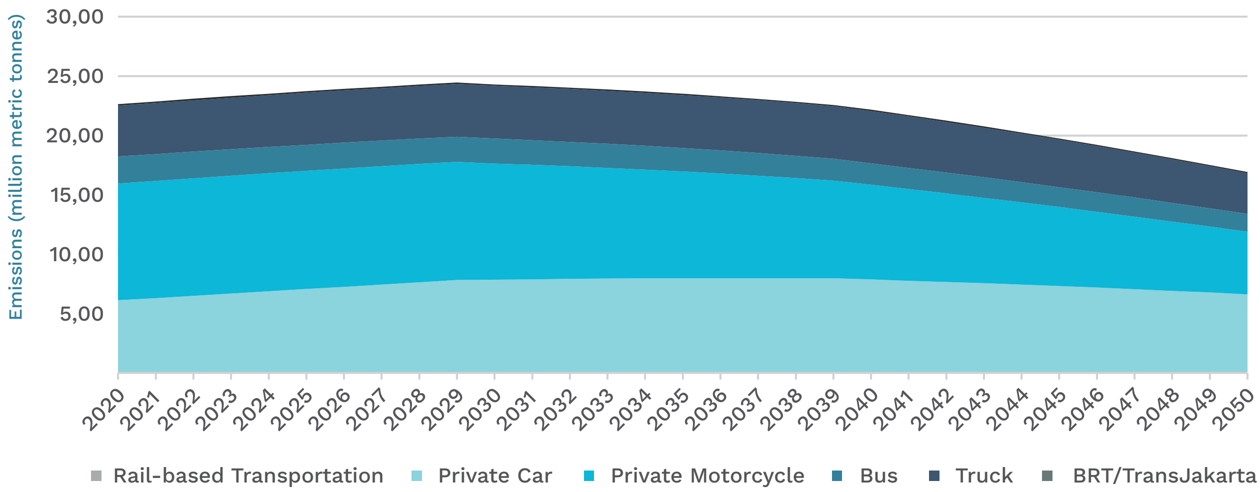


Figure 24. Estimated emissions (million tons CO_2e) scenario intervention of government programs and policies generated by vehicles in DKI Jakarta in 2020-2050

In this scenario, the government effort to reduce emissions was the Bappenas program entitled, "Planning for NZE Scenario Towards Indonesia 2060 and PLN Electricity Supply Business Plan (RUPTL) for 2021-2030". This program aimed to achieve a future where electric-based vehicles constituted 50% of the automobile fleet and implemented a 1% yearly improvement in technological efficiency. Meanwhile, the target of PLN RUPTL was to reduce the grid emissions factor by 0.788 CO_2/Mwh in 2030. Another assumption focused on the increase in public transportation users by 1.5 million per day in 2050. From this context, the annual growth rates for cars and motorcycles at 4.8% and 3.73% were reduced to 2% and 1% by 2030 and 2040, respectively. When these objectives were achieved, operational discharges in the transportation sector were likely to reach 17 million CO_2e by 2050 (Figure 24). In this case, the government targets that were used are the targets which were established before 2022, at the time of the present analysis.

Based on the scenario, emissions were predicted to reduce by 4.5 million tons compared to 2020. This 25% reduction was observed with a rise in the daily count of public transportation users to 1.5 million people, a significant increase from the present 643 thousand daily operators. The mitigation was also consistent with a decline in vehicle usage, as the annual growth of cars and motorcycles was predicted to decrease. This decreased condition was driven by policies and road capacity prioritizing public and NMT.

Compared to the no intervention scenario, emissions were subsequently reduced by 63% or 29 million tons in 2050. Moreover, the year 2030 was considered a turning point for discharge reductions, where several targets to decrease the energy mix were expected to be achieved (Figure 24). The expected growth of cars and motorcycles was also part of the reduction plan for 2030, including the transition to mature electric vehicle technology for public use.

The future targets of the government were subsequently capable of reducing emissions in the DKI Jakarta transportation sector. However, the targets need to be translated into specific programs and activities, specifically in decreasing fossil fuel usage and promoting renewable energy. The incorporation of renewable energy into the electricity mix for both public and private transportation is also a very important strategy for emissions reduction, requiring cooperation at the provincial and national level. The enhancement of the public transit services quality was subsequently essential to decrease emissions through private vehicle use reduction, focusing on timeliness and comfort. According to the FGD outputs, people were aware of the importance of shifting to mass transit, with the progress challenged by inadequate facilities. This proved that the government facilitated the integration of public transportation, enabling the ease for individuals to make decisions regarding suitable requirements and destinations. The transition to Non-Motorized Transportation (NMT) also proved that the government should construct extensive infrastructure and supporting facilities to reduce people's dependence on private vehicles.

In the road map to NZE developed by the Ministry of Energy and Mineral Resources presented at EBTKConnex 2021, several strategies were observed for the transportation sector at the national level. These strategies included the following, (1) stopping fuel imports by 2030, (2) maintaining a 30% biodiesel implementation rate, aiming for 100% electric motorcycle sales in 2040, and (3) targeting 100% electric car sales by 2050. The phasing out of power plants was also part of the national strategy, starting in 2030 as planned by PLN. These national-level measures significantly affected emissions development in DKI Jakarta, specifically in the transition to renewable energy. However, the programs were far from 100% emissions-free targets at the national and provincial levels. This prioritized the necessity for the government's stronger commitment to achieve the established targets, emphasizing investments, infrastructure financing, and incentives to achieve relevant goals.

Scenario 3: Electrification and Renewable Energy Use

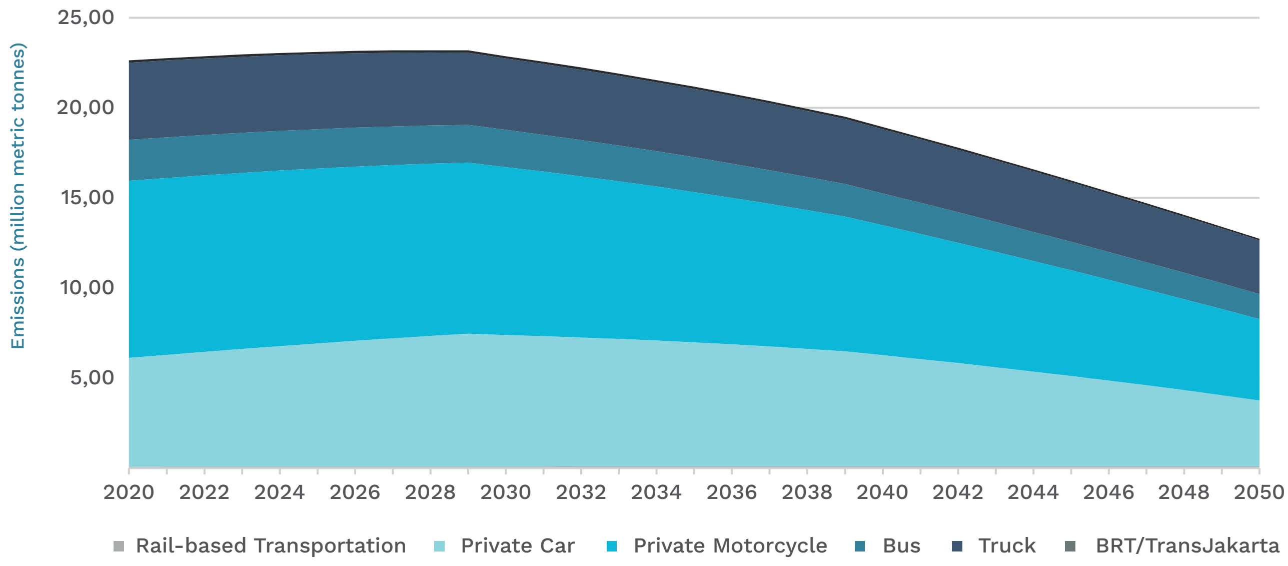


Figure 25. Estimated emissions (in million tons CO_2e) scenario of electrification and use of renewable energy produced by vehicles in DKI Jakarta in 2020-2050

In this scenario, the assumption stated that the number of people shifting to public transportation reached 2.54 million per day in 2050. This assumption prioritized the continuous growth of cars and motorcycles, as shown in the second scenario. In this context, the achievement of 100% electric-based vehicles was presented, with 50% and 100% of private and public automobiles powered by renewable energy, respectively. The grid emissions factor was also expected to reduce by 20% every decade, with technological efficiency increasing by 1.5% annually. This showed that the implemented assumptions were more ambitious than the previous targets. However, several consistencies were observed with the targets stated at the international level, to reduce the climate change effect.

According to the Nationally Determined Contribution (NDC) document containing a country's climate commitments and actions communicated to the world through the UNFCCC (United Nations Framework Convention on Climate Change), Indonesia underwent a significant transformation. From this context, the target was to achieve a primary energy supply mix, with renewable energy, oil, coal, and gas contributing at least 31%, 20%, 25%, and 24% by 2050, respectively. In comparison, China, the world's largest emitter, was expected to achieve an 80% renewable energy mix by 2060, primarily solar and wind power. Regarding the international targets, Indonesia's emissions reduction target was even higher when attempting to achieve NZE. For example, the electrification of commuting units and the support by the use of renewable energy sources in electricity supply were considered in the transportation sector.

Emissions from the road transport sector were also estimated at 12.9 million tons CO_2e for the moderate scenario in 2050, using the assumptions described. This value was about

5 or 10 million tons CO_2e less than the government intervention scenario or the 2020 or baseline estimates, respectively (Figure 25). Despite a more ambitious approach to change and intervention than the government targets, emissions remained in equilibrium between those generated up to 2030 and reduced since the period. The prioritization of public transportation was also very important, with the objective of achieving 2.54 million daily users requiring a shift of nearly 2 million people per day from present conditions. In this context, the daily average for the users only focused on 643 thousand people. To promote non-motorized vehicles for short distances, the passenger increase estimates by 60-100 thousand each year was subsequently very essential. Therefore, a total of 700-800 and 800-900 thousand daily users should be achieved in 2021 and 2022, respectively, till a daily passenger of 2.54 million is achieved. Additional public transportation routes and coverage also need to be carried out to improve services and meet requirements in 2050. This addition was achieved by enhancing transport capacity with a focus on public comfort, encouraging people to use public transportation more frequently.

Public transportation service providers subsequently formulated strategies and programs to reduce emissions, by improving services, technology, and energy sources. Based on the FGD outputs, BPTJ prioritized the issuance of regulations and strategies for using renewable energy sources (EBT). In this case, PT. MRT established terminals equipped with eco-friendly supporting facilities while PT. Transjakarta introduced electric buses after the completion of charging station construction. However, public transportation remained dependent on electricity generated from fossil fuels. The results also proved that the direct emissions from the transportation sector were already relatively lower, or around 675,000 tons of CO_2e. This was because the majority was indirect emissions from electrical energy of around 12 million tons of CO_2e. In this case, GHG discharges remained existent with the operation of the coal-fired power plants around DKI Jakarta. Therefore, the conversion of the existing power plants to renewable energy is highly necessary.

Scenario 4: Towards NZE 2050

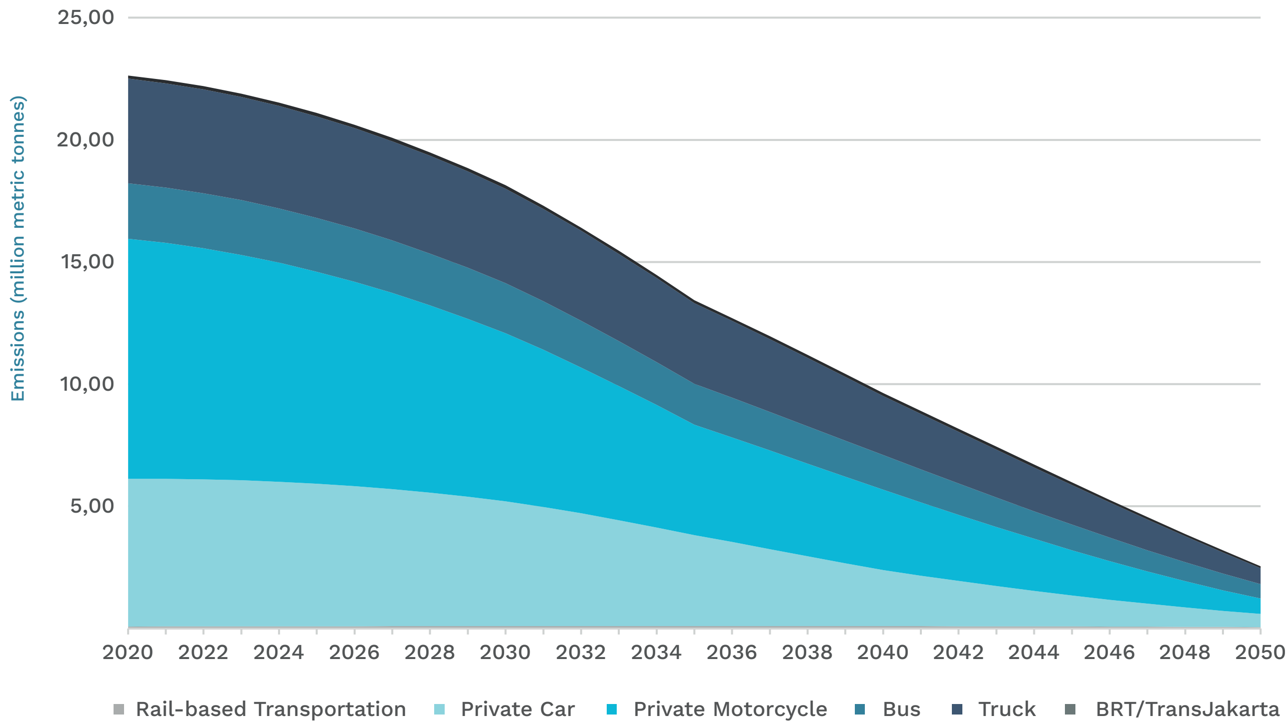


Figure 26. Estimated emissions (in million tons CO_2e) scenario Towards NZE produced by vehicles in DKI Jakarta in 2020-2050

In Figure 26, the most ambitious scenarios were unable to reach full Net Zero Emissions (NZE). This indicated the instability of achieving NZE, even when considering government program targets and a 30% increase in green spaces. A significant effort was also essential to transition from private to public transportation on a large scale. Based on the scenario, the assumption stated that the daily number of people transitioning to public transportation reached 3.35 million by 2050. This focused on the prediction of private car growth to reach 5; 4.2; and 2.5 million vehicles in 2030, 2040, and 2050, respectively. Private motorcycle numbers were also expected to increase to 20.7; 21; and 12.5 million in 2030, 2040, and 2050, respectively. Therefore, all vehicles were powered by electricity, with nearly 100% using renewable energy sources. The grid emissions factor and technology efficiency were also anticipated to decrease and increase by 30% every 10 years and 2% annually, respectively. In this case, the realization of the reduced grid emissions factor depended on the beginning of the transition to renewable energy.

The target of the scenario assumption required a significant and active transformation including various stakeholders, such as the public, businesses, mass transportation providers, and the government. This explained that the adjustment of the public behavior to reduce private vehicle use should be complemented by high-quality mass transit services. Supportive policies, including incentives and disincentives, also need to be regulated to encourage behavioral changes, such as the adoption of online work and schooling. In the Net Zero Emissions (NZE) scenario for 2050, the transportation sector continuously emitted

2.6 million tons of CO_2e, with all processes being indirect emissions. This showed that direct emissions exposing Jakarta residents were reduced to zero by 2050, although those from power plants in other regions were persistent. From this context, the achievement required significant actions, including (1) prioritizing public transportation, (2) reducing fossil fuel vehicles, (3) transitioning to eco-friendly alternatives, and (4) adopting renewable energy for power generation in the JAMALI (Java, Madura, and Bali) network. According to the survey outputs (Figure 17), significant public demand was already available for a shift to mass transportation, with many individuals considering walking and cycling as appropriate alternatives.

In the FGD discussion results, the participants agreed that public vehicles reduced emissions and congestion. This showed that an additional 90-120,000 public transportation users were needed each year, with a reduction of 1,500-180,000 cars required from 2030 to 2050. To promote global adoption of Non-Motorized Transport (NMT), various strategies were also implemented, including the engagement of bicycle communities, organizing car-free days for non-motorists, as well as providing affordable and timely mass transportation. Furthermore, the government established a plan to reduce fossil-fueled transportation production, encouraging the adoption of an Extended Producer Responsibility (EPR) system. This proved that electricity-based public transportation was expected to reach cost balance with fossil fuel alternatives.

Comparison between Scenarios

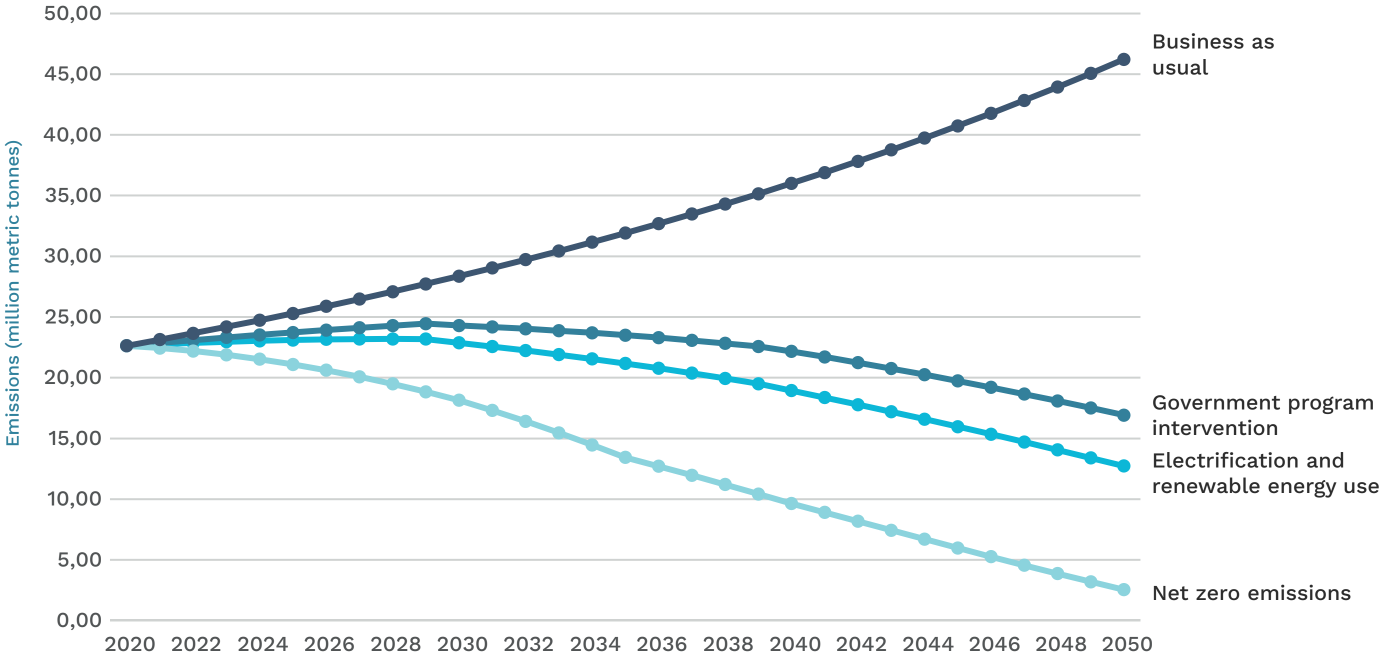


Figure 27. Estimated emissions (in million tons CO_2e) for Research Scenarios in DKI Jakarta in 2020-2050

Based on Figure 27, a comparative analysis of scenarios was observed, focusing on the patterns of emissions reduction compared to 2020/baseline estimation and also the business as usual/no-intervention category. This led to the urgency of changes in 2030, specifically for the transition of fossil and renewable energy. The "Towards Zero Emissions" scenario was also the closest to achieving NZE and had the most direct impact on emissions from the transportation sector. It was subsequently in line with the roadmap toward NZE, which was expected to be nationally and internationally realized in the future. Although emissions were prevalent, the analyzed scenario still supported societal expectations for the future, focusing on the shift towards eco-friendly transportation. This proved that the implementation of Electrification, Public Transport, and NMT was very important for appropriate goal achievement. The role of all actors was also essential for the realization of the Toward Zero Emissions scenario. This showed that the DKI Jakarta government required a strong-commitment collaboration between local and national stakeholders within the region for appropriate goal accomplishment.

The Transjakarta electric bus stopped at the Sudirman Street bus stop to pick up passengers, on a road clogged with motorized vehicles

Transportation Electrification in DKI Jakarta and Indonesia: Dilemmas and Challenges

In the initial examination, electrifying transportation seems like a convincing approach for achieving low-emissions transportation in the future. However, several issues were observed, ranging from its life cycle to the limited applicability in private vehicles, which failed to address the basic problems. This approach was vulnerable to not solving present urban mobility challenges, such as congestion and emissions, without a comprehensive understanding.

Hidden Emissions Risks

Electric vehicles (EVs) were selected as a means to reduce emissions in various analysis and development scenarios (Kurniawan et al., 2020; Aditama and Marciano, 2020). This was because the vehicles engines showed significantly higher efficiency than fossil fuel combustion machines (García-Olivares et al., 2018), leading to reduced energy consumption per kilometer traveled. Electric automobiles also provided an approach to reduce the consumption of fossil fuels, such as gasoline and diesel, due to the increased efficiency directly causing a decrease in CO_2 emissions from vehicle operations. However, the indirect emissions originating from power plants persisted at significant levels when the source of electrical energy is highly dependent on coal or other high-emissions sources. This was particularly evident in DKI Jakarta, where the prevailing electricity demand heavily required fossil fueled energy sources, with PLTGU/PLTU facilities meeting a power requirement of 5,164 MW in March 2020. The energy consumption mix was also predominantly composed of oil (42%) and coal (17%) extensively implemented by both the industrial sector and power plants.

The perceived environmental benefits of EV incentivized a shift in future mobility preference. However, the transition only reduced local (Jakarta) direct emissions and potentially increased global emissions, specifically in EV production and power plants. This showed that increased electric vehicle adoption led to the rise of the electricity demand in Jakarta. Besides obtaining its electrical energy from existing plants, DKI Jakarta also acquired power from the systems integrated into the JAMALI (Jawa, Madura, Bali) network. This proved that the anticipated energy transition affected the city and the plants across Java, Madura, and Bali. The consideration of indirect emissions was also significant throughout the EV life cycle. This was in line with the European Environment Agency (EEA, 2018), where electric vehicle production emissions were 20% lower than gasoline automobiles. However, the EVs produced twice the harmful effects on water and soil toxicity throughout the entire lifecycle, compared to fossil fuel vehicles (EEA, 2018; Skrúcaný et al., 2019; De Blas et al., 2020). In this case, the total emissions from manufacturing for EVs (8-9 tons CO_2e) exceeded the discharges for fossil fuel cars (6 tons CO_2e).

Based on several previous reports, the implementation of electric vehicle (EV) policies led to increased electricity demand and natural resources utilization (Valero et al., 2018 as cited in Dillman 2021). In this case, the natural resources are the critical minerals or metallic minerals essential for battery production, such as cobalt and manganese. These minerals likely encountered scarcity concerns during the attempt to meet the growing relevant demand (Valero et al., 2018; Tokimatsu et al., 2017), specifically when the recycling rates remained low. To accommodate the adoption of electric vehicles, resource consumption also requires further establishment of battery charging infrastructure, vehicle engine modifications (De Blas et al., 2020), and road sections expansion (Müller et al., 2013).

Imperative Energy Transition

The electric energy transition is crucial toward thoroughly reducing transportation emissions. This showed that the 2050 target of NZE required a major contribution of shifting from fossil fuels to low-emissions renewable energy. Electricity obtained from fossil fuels also produced 20 times more emissions than renewable energy (Silva et al 2022, NREL 2012). In this case, the implemented electricity should be acquired from low-emission energy sources when the target is to achieve NZE. Furthermore, electric vehicles could significantly reduce emissions when power plants used renewable energy with improved power efficiency. The fact that the electricity demand of DKI Jakarta is supplied from the JAMALI network, enabled the lengthy distance of the plants from the city. In this context, the construction of the power system with renewable energy sources was possible in other areas within the JAMALI network having various foundations. Therefore, replacing fossil-based plants, specifically coal, with low emissions energy sources in DKI Jakarta is possible.

Based on the descriptions, decarbonization of the transportation sector could only be achieved when the electricity supply industry is also decarbonized. This was in line with Brozynski and Leibowicz (2018), where the carbon reduction of the electricity sector needs to be conducted before decarbonizing the transport domain (Linton et al., 2022). Changing the source to clean energy, such as solar and wind, was also achieved by improving transmission and distribution efficiency in the power grid (Dillman et al., 2021).

Jakarta's Congestion and an urgent call to reduce Private Vehicle Volume

The shift from fossil to electric vehicles could reduce the GHG emissions. However, this measure alone could not be the one-single solution for achieving sustainable transportation in DKI Jakarta. The congestion problem in DKI Jakarta was caused by the very high number of private vehicles (as discussed in the Introduction section, Jakarta Transportation Problems). In this context, the congestion problem remained with the unchanged or increased volume of private vehicles due to the absence of a shift to public or NMT, such as cycling or walking for shorter distances.

The shift from fossil-fueled Internal Combustion Engine (ICE) to electric vehicles was not easy. This was because the initial investment to own an electric vehicle was relatively more expensive. In major Indonesian cities, electric cars were used and ownership was limited due to the starting price of around 450 million (Gaikindo, 2022). Meanwhile, electric motorcycles provided a more competitive price and were not significantly different from the fossil fuel-powered types.

Transportation Transformation Priorities: Electrification of Public Vehicles and Optimization of Non-motorized Vehicles

The electrification of the transportation sector was required to be implemented limited to public transportations. Based on the questionnaire analysis, the implementation of public transportation electrification obtained the highest positive response from the respondents (34.81%, n = 730) than other commuting mode options. In this case, 30% of the participants (n = 620) expressed the willingness to pay IDR10,000 more for additional ticket price for the electricity-based public transportation vehicles. The electrification of public transportation was also feasible to be implemented as this vehicle has ten times the carrying capacity higher than the private vehicles (Brozynsk & Leibowicz, 2018, da Silva et al., 2022). According to Kaack et al. (2018) and IEA (2019), the electrification of trains was highly suggested to achieve higher decarbonization levels. This was because trains were designed to accomplish constant speed with low rail friction, improving energy efficiency (da Silva et al., 2022). Another example was the introduction of electric buses, with a tank-to-wheel efficiency ratio of 0.5. This ratio was lower and higher than those of private (light automobiles with ICE) and comparable (diesel or gasoline-fueled buses) vehicles, respectively (de Blas et al., 2020).

The low-carbon movement to 2050 focused on the reduction patterns of personal fossil-fueled or electricity vehicles implementation. This was because the implemented resources and emissions produced were not reduced as expected, with people continuously depending on private vehicles. Therefore, prioritizing various decarbonization strategies was essential, such as improving the use and efficiency of public transport systems, especially implementing renewable energy, and providing infrastructure for walking and cycling (Campbell & Laherrère, 1998, FTF, 2011, Howarth, 2015 in Linton et al., 2022). The government should also build supporting infrastructure to improve walking and cycling activities.

Potential Inconvenience to Vulnerable People

Electric vehicles with low noise pollution were capable of affecting the visually impaired and the general public. This was because the inadequate sound of the vehicle was an endangerment to pedestrians, cyclists, or other road users. This risk is due to Individuals with visual impairments dependent on the sense of hearing to board or disembark from vehicles. Bicycle and motorcycle operators also commonly implemented the sound of surrounding vehicles to maneuver driving decisions. According to Minister of Transportation Regulation Number 44 of 2020, appropriate sound standards should be met toward avoiding the endangerment of other road users. In this case, some concerns about the extent of safety were still observed with existing regulatory standards. This proved that the implementation of the regulation needs to be reviewed and strengthened to determine the transition patterns of the technology, specifically for recent innovations such as self-driving vehicles.

7

The streets of DKI Jakarta, showing Transjakarta electric buses, cyclists passing through protected lanes and pedestrians wanting to cross using pedestrian crossings.

Transportation Transformation Strategy

To achieve the net zero emission target in DKI Jakarta in 2050, the transformation in the transportation sectors required comprehensive, collaborative, and strong commitment of all stakeholders, including the government, people, transportation technology, and service providers. This achievement process focused on the consideration of two elements toward decarbonizing the commuting system, namely public transportation and energy transition. From this context, the use of public transportation should be supported by pedestrian and cycling infrastructure as a link among mass transit, to appropriately achieve emissions-free innovations for DKI Jakarta transport system. The results were also consistent with several previous analyses in eight major cities in Europe and North America (Linton et al. 2022), where each city had its characteristics and priorities in achieving NZE. However, all the cities aimed to similarly achieve increased walking, cycling, and public transportation.

1. Shifting to Low-carbon Modes of Public Transportation

Based on the IPCC report (2018), the most realistic emissions reduction strategy started from the most viable sector, the highest emissions contribution (Linton et al., 2022). This showed that the reduction process should initially decarbonize electricity generation (Brozynski and Leibowicz, 2018). However, decarbonization also requires changes in people's mobility behavior in DKI Jakarta, regarding the selection of appropriate transportation modes, including public transport, walking, and bicycles. This condition is characterized by the many positive responses from participants (95.8%), who show willingness toward shifting into lower carbon commuting modes.

Public transportation also played a key role in transitioning to a sustainable mobility future. This showed that high service frequency, reliability, and availability of mass transit closer to homes and offices/workplaces were needed to attract people toward using transportation mode. However, the questionnaire analysis showed that the public transportation mode had an unsatisfactory record regarding waiting time (score 6 out of 10). This focused on the need for mass transportation services to ensure that appropriate transport modes arrived within a maximum of 10 minutes, as expected by 76% of participants. Investment in sidewalks, bicycle lanes, and TOD infrastructure should be increased to support the smooth transfer of mass commuting modes.

2. Improve Non-Motorized Transport Infrastructure Quality

NMT was expected to be the choice of the public when shifting or performing short-distance commutation, to achieve optimal decarbonization of the transportation sector. The NMT, including walking and cycling, is the least emitting commuting mode compared to other transportation modes. However, NMT modes were only suitable as transit and not the main or lengthy commuting systems. This was because people were only willing to walk 500 m (49%) or cycle 3 km (31%) in a one-time travel distance. From this context, the NMT infrastructure should be supported to increase people's interest in walking and cycling, as well as improving connectivity with public transportation.

Government performance in the provision of pedestrian sidewalks also needs to be improved. This was because the participants on average assessed that the walking infrastructure was still inadequate, expressing a score of 5 out of 10 and showing a need for improvement. The most significant concerns were also related to the availability of comprehensive pedestrian facilities and air pollution, both scoring 4 out of 10. Furthermore, the questionnaire showed that at least 32% of the respondents should engage in at least 15 minutes of daily walking. This value was expected to increase with the enhancement of appropriate walking facilities, satisfying inter-mode connectivity requirements. The facilities were also very important for people with disabilities, specifically wheelchairs. The disabled groups stated that the infrastructures available on public transportation were better than previous observations, specifically the MRT and Transjakarta buses. However, the need to increase the variety of supporting infrastructure was found, such as visual cues for deaf people.

3. Incentive Policies to Encourage the Use of Low-carbon Transportation

Based on Linton et al. (2022), almost all the cities implemented various approaches to avoid private vehicles through high taxes. For example, several strategies played a significant role in promoting behavioral shifts in mobility, such as (1) increasing parking fees (Park City), toll prices (Oslo), and congestion pricing (New York), (2) providing fee waivers to public transportation users (Park City), and (3) incentivizing the people engaging in car-free activities (Lahti and Guelph). The positive acknowledgment of individuals also served as a valuable approach to induce the transition strategy. This was supported by the interview sessions with the cycling community, where people expressed interest in the public activities enabling positive acknowledgment from fellow members.

4. Realizing an Inclusive Transportation System

The realization of a low-emissions transportation system in DKI Jakarta was supported by providing inclusive services and infrastructure. This showed that the transport sector should be equitable while considering the needs of all users, such as women, children, and the elderly with special needs. In this context, all levels of society were capable of participating in the achievement of NZE. The infrastructure for pedestrians, cyclists, or public transportation should also be considered toward development, without focusing on only motorized vehicle amenity.

8

Aerial view of GBK Senayan Stadium, with the bright sky of Jakarta in the background and visible mountains in the distance.

Conclusion & Recommendation

In conclusion, the transportation sector was one of the main sources of GHG emissions in DKI Jakarta. Similar to economic development and population growth, transport activities were also continuously enhanced in the city and surrounding regencies. Furthermore, emissions continuously increased 3.8 (2030) and 6.2 (2050) times higher than the 2010 emissions of around 7.49 Mton CO_2. In this context, the plan of DKI Jakarta to achieve NZE transportation by 2050 proved to be hardly achievable even with the presently proposed policies and programs. This limitation originated from the specific research focus on operational emissions within the transportation sector.

Drawing insights from emissions reduction best practices, one of the key strategies in achieving net zero emissions is addressing the most achievable sector. This aligned with the questionnaire analysis, where a significant portion of Jakarta population are willing to adopt appropriate changes. In this context, a more rapid behavioral transformation should be realized by providing supporting infrastructure, such as sidewalks, green spaces, and bicycle lanes. Therefore, the smooth integration of public transportation with cycling and walking is needed to cater to both long and short-distance requirements. This showed that the occurrence of behavioral shifts became significant in the implementation of the corresponding policies, services, and infrastructures.

Table 6 Action recommendation for transportation stakeholders

DKI Jakarta Government

- Conduct emissions testing for vehicles in DKI Jakarta.
- Provide supporting infrastructure for electric vehicles, specifically public transportation, such as charging stations.
- Design TOD in various areas to integrate with the existing public transportation.
- Build green infrastructure that supports the development of non-motorized transport modes (specifically pedestrian) while limiting enhancement for motorized vehicles.
- Provide transportation policies that are inclusive to all groups of people, including children, women, special needs individuals, and the elderly.
- Promote remote working policies to reduce the distance traveled by DKI Jakarta people, which on average is 34-40 km per day.

People

- Prioritize public transportation and Non-motorized transportation/NMT (walking or cycling) for long and short distances for multi-modes travels.

- Reduce vehicle use for non-essential travel and opt for online communication.
- Implement low-emissions technology and fuel for personal transportation when public or non-motorized options are unavailable.
- Reduce private vehicle ownership from 15 to 8 motorcycles and 4 to 2 cars for 10 people by 2050, shifting to public transportation and NMT use.

Public Transportation Service Provider

- Provide transportation modes with environmentally friendly technologies and fuels (100% renewable energy by 2050).
- Provide public services and signage that are inclusive and convenient for everyone, such as audiovisual signage and staff proficient in sign language staff.
- Provide 4 times the current capacity of the mass transport services by 2050.
- Optimize access to convenient and timely public transit, with waiting periods not more than 10 minutes.

State Electricity Company (PLN)

- Provide electrical energy that is transitioning from fossil fuels to 100% renewable power.
- Present universal and standardized electric refueling facilities.
- Reduce grid emissions factor by 30% over 10 years and increase generation efficiency by 2% per year.

Ministry of Energy and Mineral Resources

- Promote and encourage the transition of fossil energy sources to at least 31% renewable power, accompanied by the support of strong and committed financing schemes and policies.
- Develop formal policies to facilitate the transition of public behavior towards cleaner energy adoption. These policies included standardizing refueling procedures, battery technologies, as well as implementing effective incentives and disincentives.

Business Entity

- Reduce sales of fossil-fueled vehicles and shift to providing automobiles that use environmentally friendly technologies and fuels.
- Design environmentally friendly vehicles that consider the needs of disabled people.

© DafaMiftah / Shutterstock

According to the results, private vehicles should be highly reduced to 25% and 39% for motorcycles (8/10 people) and cars (2/10 people) of present numbers, respectively. The immediate implementation of low-emissions fuels and technologies is also a very important priority. From this context, the electric vehicles using renewable energy need to be significantly considered for public vehicles. Moreover, appropriate regulations should be innovatively developed to respond to changes in transportation behavior and technology. These regulations need to be implemented to support the achievement of emissions reduction, which considers the requirements of all people moving to DKI Jakarta without exception. In this case, the NZE transportation system in the city required active participation from various stakeholders, including the government, transport service providers, and relevant actors. External parties such as neighboring city and regency governments, as well as public and energy service providers were also engaged in the commuting sector (Table 6). Therefore, the effective collaboration among the relevant participants significantly contributed to considerable reductions in emissions.

View of the city of DKI Jakarta, showing tall buildings, the National Monument, densely populated housing with a mountain backdrop

References

Adiatma, J. C., & Marciano, I. (2020). *The role of electric vehicles in decarbonizing indonesia's road transport sector.* Climate Transparency. Jakarta: Institute for Essential Services Reform (IESR).

Andani, I. A., Geurs, K., & La Paix Puello, L. (2019). Effects of toll road construction on local road projects in Indonesia. *Journal of transport and land use*, 12(1), 179-199.

Alam, P., Pramadewi, M. D., Purba, A., & Fuady, S. N. (2017). Efektivitas pembangunan underpass dalam mengatasi kemacetan lalu lintas pada ruas jalan zainal abidin.

Archer, D. (2011). *Global warming: understanding the forecast*. John Wiley & Sons.

Australia's Cycling Promotion Fund. (2012). *Walking, Riding and Access to Public Transport* https://apo.org.au/sites/default/files/resource-files/2012-10/apo-nid31849.pdf

Azis, R, A, Firdhayanti R, A, Susetio W, and Saudi, M, H. (2021) Accessibility for Physical Disabilities People to engage with Transjakarta Bus: (Case Study on Seskoal and Tirtayasa Corridors of South Jakarta). R*eview of International Geographical Education (RIGEO),* 1 1 (6), 1469-1476. DOI: 10.48047/rigeo.11.06.161

Bakker, S., Zuidgeest, M., De Coninck, H. and Huizenga, C. (2014). Transport, development and climate change mitigation: Towards an integrated approach. *Transport Reviews*, 34(3), pp.335-355.

Bappeda DKI Jakarta. (2017). *RPJMD Provinsi Daerah Khusus Ibukota Jakarta Tahun 2017-2022*. 624.

Bappenas. (2014). *Pedoman Teknis Pehitungan Baseline Emisi Gas Rumah Kaca Sektor Berbasis Energi*

Banister, D., (2013). 15. *City transport in a post carbon society. Moving towards low carbon mobility*, p.255.

BCG. (2017). *Unlocking Cities: The impact of ridesharing in Southeast Asia and beyond*. https://image-src.bcg.com/Images/BCG-unlocking-cities-2017_tcm93-178660.PDF

Bernard, M.R., Hall, D., Lutsey, N., (2021). Update on electric vehicle uptake in European cities. *The International Council on Clean Transportation*. Working PA, 18.

Bin, S. and Dowlatabadi, H., (2005). Consumer lifestyle approach to US energy use and the related CO_2 emissions. *Energy policy*, 33(2), pp.197-208.

Biro Analisa Anggaran dan Pelaksanaan APBN DPR RI. (2014). *Subsidi BBM: Problematika dan Alternatif Kebijakan.* Accessed on 20 April 2022 from https://www.dpr.go.id/doksetjen/dokumen/apbn_SUBSIDI_BBM_-_PROBLEMATIKA_DAN_ALTERNATIF_KEBIJAKAN20140821142950.pdf

Björnsson, L.H., Karlsson, S. (2017). Electrification of the two-car household: PHEV or BEV? *Transportation Research Part C: Emerging Technologies* 85, 363–376. doi:10.1016/j.trc.2017.09.021

Blondel et al. (2011). *Cycle more often 2 Cool down the planet: Quantifying CO_2 savings of cycling*. European Cyclists' federation ASBL.

Bongardt, D., Stiller, L., Swart, A. and Wagner, A. (2019). *Sustainable Urban Transport: Avoid-Shift-Improve (ASI).* Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH.

Brozynski, M. T., & Leibowicz, B. D. (2018). Decarbonizing power and transportation at the urban scale: An analysis of the Austin, Texas Community Climate Plan. *Sustainable cities and society*, 43, 41-54.

BPS Provinsi DKI Jakarta. (2021). *Statistik Transportasi DKI Jakarta 2020*.

Budi, D. R. et al.(2021). Cycling during COVID-19 Pandemic: Sports or Lifestyle?. *International Journal of Human Movement and Sports Sciences*, 9(4), 765 - 771. DOI: 10.13189/saj.2021.090422.

Campbell, C. J., & Laherrère, J. H. (1998). The end of cheap oil. *Scientific American*, *278*(3), 78-83.

City of Amsterdam. (2021). *Priority for Electric Vehicles.* Accessed on 4 February 2022 from https://www.amsterdam.nl/en/parking/apply-for-a-parking-permit-for/

Clean Air Asia Center. (2013). *Promoting Non-Motorized Transport in Asian Cities: Policymakers' Toolbox.* Pasig City, Philippines.

Clemens, T., Turner, S., & Dibben, C. (2017). Maternal exposure to ambient air pollution and fetal growth in North-East Scotland: a population-based study using routine ultrasound scans. *Environment international*, *107*, 216-226.

Cochrane, J. (2015). *As Indonesia Prospers, Air Pollution Takes Toll*. New York Times. Accessed on 23 March 2022 from https://www.nytimes.com/2015/09/27/world/asia/as-indonesia-prospers-air-pollution-takes-toll.html

da Silva, T. B., Baptista, P., Silva, C. A. S., & Santos, L. (2022). Assessment of decarbonization alternatives for passenger transportation in Rio de Janeiro, Brazil. *Transportation Research Part D: Transport and Environment*, 103161.

Davis, S. J., Lewis, N. S., Shaner, M., Aggarwal, S., Arent, D., Azevedo, I. L., ... & Caldeira, K. (2018). Net-zero emissions energy systems. *Science*, 360(6396), eaas9793.

de Blas, I., Mediavilla, M., Capellán-Pérez, I., & Duce, C. (2020). The limits of transport decarbonization under the current growth paradigm. *Energy Strategy Reviews*, 32, 100543.

DeFranco, E., Moravec, W., Xu, F., Hall, E., Hossain, M., Haynes, E. N., ... & Chen, A. (2016). Exposure to airborne particulate matter during pregnancy is associated with preterm birth: a population-based cohort study. *Environmental Health*, *15*(1), 1-8.

Diansya, Irfan. (2015). *Penilaian Jalur Pedestrian oleh Masyarakat Urban dan Kriteria Jalur Pedestrian yang Ideal Menurut Masyarakat*. Institut Teknologi Bandung.

Dimock, M. (2019). D*efining generations: Where Millennials end and Generation Z begins*. Accessed on 6 April 2022 from https://www.pewresearch.org/fact-tank/2019/01/17/where-millennials-end-and-generation-z-begins/

Dishub DKI Jakarta. (2021). *Jakarta Ramah Bersepeda*. Accessed on 20 March 2022 from https://ppid.jakarta.go.id/download/c8c64ef0e1a44f7c4ce8f48b4b0a167aeecda2162e17bc5796ab30c54abf952ee5f06794d3e94fbadccebc7fdbc330bc5dc28a2911b2c053711c69c9dbbd0c964rpCZDMrEHrGWygAbcRR48XcnGJj7THsTDsylMZldRfAEaIDjCq8ds2pd7BVSS

Diskominfo DKI Jakarta. (2015). *Data Seluruh Ruang Terbuka Hijau di Provinsi DKI Jakarta*. Accessed on 17 March 2022 from https://data.jakarta.go.id/dataset/ruangterbukahijaudkijakarta/resource/716b64ee-eaab-4094-8226-67e445d287bf

Diskominfo DKI Jakarta. (2020). *Luas dan Panjang Jalan DKI Jakarta tahun 2020*. Accessed on 13 March 2022 from https://statistik.jakarta.go.id/luas-dan-panjang-jalan-di-dki-jakarta-tahun-2020/

DLH Provinsi DKI Jakarta. (2019). *Inventarisasi Profil Emisi Gas Rumah Kaca Provinsi DKI Jakarta.*

Downs, A. (2000). *Stuck in traffic: Coping with peak-hour traffic congestion*. Washington, DC: Brookings Institution Press.

Duranton, G., & Turner, M. A. (2011). The fundamental law of road congestion: Evidence from US cities. *American Economic Review*, *101*(6), 2616-52.

Egede, P., Dettmer, T., Herrmann, C., & Kara, S. (2015). Life cycle assessment of electric vehicles–a framework to consider influencing factors. *Procedia CIRP*, *29*, 233-238.

Eichhorst, U. (2009). Adapting urban transport to climate change, module 5f, Sustainable Transport: A Sourcebook for Policy-makers in Developing Cities. Division 44. *Water, Energy, Transport,* 62. doi:10.1016/j.procir.2015.02.185

EMIC. (2017). *e-mobility NSR*. Accessed on 4 February 2022 from http://e-mobility-nsr.eu/centres/amsterdam/

Frans dkk. (2016). *Persepsi Pejalan Kaki Terhadap Keamanan dan Kenyamanan Jalur Trotoar di Pusat Kota Amurang*.

FTF (Future of Transport Fuels). (2011). *Report of the European Expert Group on Future Transport Fuels*

Gaikindo. (2021). Beberapa Model Mobil Listrik yang sudah Masuk Pasar Indonesia. Accessed on 4 February 2022 from https://www.gaikindo.or.id/beberapa-model-mobil-listrik-yang-sudah-masuk-pasar-indonesia/

García-Olivares, A., Sol´e, J., Osychenko, O. (2018). Transportation in a 100% renewable energy system. *Energy Convers. Manag*. 158, 266–285. https://doi.org/10.1016/j.enconman.2017.12.053.

Givoni, M. dan Banister, D. eds. (2013). *Moving towards low carbon mobility*. Edward Elgar Publishing.

Givoni, M., 2013. 13. Alternative pathways to low carbon mobility. In *Moving towards low carbon mobility* (p. 209). Cheltenham: Edward Elgar Publishing.

Institute for Urban Strategy. (2018).*Global Power City Index 2018*.

Green, R., Sarovar, V., Malig, B., & Basu, R. (2015). Association of stillbirth with ambient air pollution in a California cohort study. *American journal of epidemiology*, *181*(11), 874-882.

Hall, D., & Lutsey, N. (2021). *Effects of battery manufacturing on electric vehicle life-cycle greenhouse gas emissions.*

Harahap, E., Suryadi, A., Ridwan, R., Darmawan, D., & Ceha, R. (2017). Efektifitas load balancing dalam mengatasi kemacetan lalu lintas. *Matematika: Jurnal Teori dan Terapan Matematik*a, 16(2).

Haryanto, B. (2007). Blood-lead Monitoring Exposure to Unleaded-gasoline Among School Children in Jakarta – Indonesia 2005. *Jurnal Kesehatan Masyarakat*. No. 5.

Howarth, R. W. (2015). Methane emissions and climatic warming risk from hydraulic fracturing and shale gas development: implications for policy. *Energy and Emission Control Technologies*, *3*, 45-54.

Hyatt et al., (2021). A Non-motorized Urban Future for Climate Resilient Cities. 14th Regional Environmentally Sustainable Transport (EST) Forum in Asia

IEA. (2019). The Future of Rail Opportunities for Energy and the Environment. Accessed on 6 March 2022 from https://www.iea.org/events/the-future-of-rail-opportunities-for-energy-and-the-environment

IEA. (2021). Net Zero by 2050: A Roadmap for the Global Energy Sector. Accessed on 12 March 2022 from https://www.iea.org/events/net-zero-by-2050-a-roadmap-for-the-global-energy-system

IEA. (2021). An energy sector roadmap to carbon neutrality in China, IEA, Paris. Accessed on 16 March 2022 from https://www.iea.org/reports/an-energy-sector-roadmap-to-carbon-neutrality-in-china

IEA. (2022). Global EV Outlook 2021 – Analysis - IEA. Accessed on 24 February 2022 from https://www.iea.org/reports/global-ev-outlook-2021?mode=overview

Indonesian Urban Transport Institute. (2016). *Penerapan Konsep TOD sebagai Instrumen Penguatan Jaringan Angkutan Massal Perkotaan*. Accessed on 12 March 2022 from http://iutri.org/wp-content/uploads/2016/03/Penerapan-Konsep-TOD-Sebagai-Instrumen-Penguatan-Jaringan-Angkutan-Massal-Perkotaan-_IUTRI_WP_04_ALV.pdf?1542798822

Institute for Transportation and Development Policy (ITDP). (2017). *Pedoman Integrasi Antarmoda.* Accessed on 23 February 2022 from https://itdp-indonesia.org/publication/jakarta-intermodal-integration-guideline-2/

Institute for Transportation and Development Policy (ITDP). (2018). Menuju Aksesibilitas dan Transportasi Publik yang Inklusif. Accessed on 8 March 2022 from https://www.itdp-indonesia.org/wp-content/uploads/2018/12/Menuju-Aksesibilitas-dan-Transportasi-Publik-yang-Inklusif.pdf

Institute for Transportation and Development Policy (ITDP). (2019). Panduan Desain Fasilitas Pejalan Kaki: DKI Jakarta 2017-2022. Accessed on 2 March 2022 from https://www.itdp-indonesia.org/wp-content/uploads/2018/08/Panduan-Fasilitas-Pejalan-Kaki-di-Jakarta-v2.0.pdf

Institute for Transportation and Development Policy (ITDP). (2020). No*n-Motorized Transport Policy Guideline For Mid-Size Cities in Indonesia*.

Institute for Transportation and Development Policy (ITDP). (2021). Jakarta, Indonesia Is What Resiliency Looks Like. Accessed on 16 February 2022 from https://www.itdp.org/wp-content/uploads/2021/03/ITDP_ST32_web.pdf

Institute for Transportation and Development Policy (ITDP). (2021). *Penataan Kawasan Pejalan Kaki: Hasil Survei Pejalan Kaki Kebayoran Baru & Simpang Senen.* Accessed on 20 February 2022 from https://itdp-indonesia.org/wp-content/uploads/2021/03/Siapa-saja-pengguna-ruang-NMT_.pdf

Institute for Transportation and Development Policy (ITDP). (2022). *Evaluasi Jalur Sepeda Terproteksi.* Accessed on 25 February 2022 from https://itdp-indonesia.org/multimedia/evaluasi-jalur-sepeda-terproteksi/

IPCC. (2007). Climate change 2007: the physical science basis. *Agenda*, *6*(07), 333.

IPCC. (2022). *Summary for Policymakers* [H.-O. Pörtner, D.C. Roberts, E.S. Poloczanska, K. Mintenbeck, M. Tignor, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem (eds.)]. In: Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. In Press

Irjayanti, A. D., Sari, D. W., & Rosida, I. (2021). Perilaku Pemilihan Moda Transportasi Pekerja Komuter: Studi Kasus Jabodetabek. *Jurnal Ekonomi Dan Pembangunan Indonesia.* https://doi.org/10.21002/jepi.v21i2.1340

Jamil, B. S. (2019). Climate Crisis: 'Listening to the Science' Not Enough. *RSIS Commentary*, *22*. https://dr.ntu.edu.sg/bitstream/10356/136658/2/CO19238.pdf

Jakobsson, N., Gnann, T., & Karlsson, S. (2016). Are multi-car households better suited for battery electric vehicles? - Driving patterns and economics in Sweden and Germany. *Transportation Research Part C: Emerging Technologies* 65, 1–15. doi:10.1016/j.trc.2016.01.018

Kaack, L. H., Vaishnav, P., Morgan, M. G., Azevedo, I. L., & Rai, S. (2018). Decarbonizing intraregional freight systems with a focus on modal shift. *Environmental Research Letters*, *13*(8), 083001.

Karlsson, S. (2017). What are the value and implications of two-car households for the electric car? *Transportation Research Part C: Emerging Technologies* 81, 1–17. doi:10.1016/j.trc.2017.05.001

Kementerian Lingkungan Hidup dan Kehutanan. (2020).*Laporan Inventarisasi Gas Rumah Kaca dan Monitoring, Evaluasi, dan Verifikasi tahun 2020*.

Kementerian Perhubungan Republik Indonesia. (2021). Strategy for converting ICE to EV. The 10th EBTKE ConEx 2021 - Parallel Session Decarbonising Transportation Forum

Knupfer, S. M., Pokotilo, V., & Woetzel, J. (2018). Elements of success: Urban transportation systems of 24 global cities. New York: McKinsey & Company.

Kostopoulos, E.D., Spyropoulos, G.C., Kaldellis, J.K. (2020). Real-world study for the optimal charging of electric vehicles. *Energy Reports*. 6, 418–426. doi:10.1016/j.egyr.2019.12.008

Kurniawan, A. Y. W., Setiawan, A. A., & Budiman, A. (2020). The Impact of Electric Vehicle on Road Transportation in Indonesia: Energy Demand and CO2 Emission. *JPSE (Journal of Physical Science and Engineering)*, 5(2), 36-45.

Kusumaningkatma, M., dan Xie, Y. (2020). *Transforming Transjakarta: First steps toward electric buses for the world's largest BRT fleet.* The International Council on Clean Transportation. Retrieved 07 23, 2021, from https://theicct.org/blog/staff/transjakarta-worlds-largest-brt-fleet-oct2020

Lah, O., Shrestha, S., Hüging, H., Decker, B., Gyergyay, B., Marhold, K., ... & Dablanc, L. (2015). Transferability of sustainable urban transport solutions. *Energy, Climate and Air Quality Challengs: The Role of Urban Trasnport Policies in Developing Countries*.

Langrish, J. P., Li, X., Wang, S., Lee, M. M., Barnes, G. D., Miller, M. R., ... & Jiang, L. (2012). Reducing personal exposure to particulate air pollution improves cardiovascular health in patients with coronary heart disease. *Environmental health perspectives*, *120*(3), 367-372.

Lee, J., Vojnovic, I., & Grady, S. C. (2018). The 'transportation disadvantaged': Urban form, gender and automobile versus non-automobile travel in the Detroit region. *Urban Studies*, *55*(11), 2470-2498.

Lee, J., Arts, J., Vanclay, F., & Ward, J. (2020). Examining the social outcomes from urban transport infrastructure: Long-term consequences of spatial changes and varied interests at multiple levels. *Sustainability*, *12*(15), 5907.

Lestari, P., Damayanti, S., & Arrohman, M. K. (2020). Emission Inventory of Pollutants (CO, SO2, PM2. 5, and NOX) in Jakarta Indonesia. In *IOP Conference Series: Earth and Environmental Science* (Vol. 489, No. 1, p. 012014). IOP Publishing.

Linton, S., Clarke, A., & Tozer, L. (2022). Technical pathways to deep decarbonization in cities: Eight best practice case studies of transformational climate mitigation. *Energy Research & Social Science,* 86, 102422.

London Electric Vehicle Infrastructure Delivery Plan Lruc.content.tfl.gov.uk. (2022). Accessed on 4 February 2022 from https://lruc.content.tfl.gov.uk/london-electric-vehicle-infrastructure-taskforce-delivery-plan-executive-summary.pdf.

Macmillen, J. (2013). 12. *Mobility as a complex system: key. Moving towards low carbon mobility*, p.190.

Mahalana, A., Yang, Z., & Posada, F. (2021). Indonesia transport electrification strategy. *ICCT WORKING PAPER* 2021-36.

Marcotullio, P. J., Sarzynski, A., Albrecht, J., Schulz, N., & Garcia, J. (2013). The geography of global urban greenhouse gas emissions: an exploratory analysis. *Climatic Change*, 121(4), 621-634, https://doi.org/10.1007/s10584-013-0977-z

Martinez, R., & Masron, I. N. (2020). Jakarta: A city of cities. *Cities*, 106, 102868. https://doi.org/10.1016/j.cities.2020.102868

Matute, J. M., Chester, M., Eisenstein, W., & Pincetl, S. (2014). *Life-Cycle Assessment for Transportation Decision Making* (No. 14-1287).

Maya, M. M. (2008). *Transportation planning and the prevention of urban sprawl*. In New York University Law Review.

McFarlane, A. G. (2021). Black Transit: When Public Transportation Decision-Making Leads to Negative Economic Development. *Iowa Law Review*. 106 (5): 2369–96.

McLaren, J., Miller, J., O'Shaughnessy, E., Wood, E., & Shapiro, E. (2016). CO2 emissions associated with electric vehicle charging: the impact of electricity generation mix, charging infrastructure availability and vehicle type. *The Electricity Journal*, *29*(5), 72-88.

McLeod, S., Scheurer, J., & Curtis, C. (2017). Urban public transport: planning principles and emerging practice. *Journal of Planning Literature*, *32*(3), 223-239.

Messagie, M. (2014). Life cycle analysis of the climate impact of electric vehicles. *Journal of Life Cycle Assessment*, *2014*, 14.

Mizdrak, A., Cobiac, L. J., Cleghorn, C. L., Woodward, A., & Blakely, T. (2020). Fuelling walking and cycling: human powered locomotion is associated with non-negligible greenhouse gas emissions. *Scientific reports*, *10*(1), 1-6.

Mogot, P. J. A., Barus, L. S., & Yola, L. (2021, March). The impact of COVID-19 on the mobility of Transjakarta passengers. In *IOP Conference Series: Earth and Environmental Science* (Vol. 716, No. 1, p. 012135). IOP Publishing.

Muller, D. B., Liu, G., Løvik, A. N., Modaresi, R., Pauliuk, S., Steinhoff, F. S., & Brattebø, H. (2013). Carbon emissions of infrastructure development. *Environmental science & technology*, *47*(20), 11739-11746.

Nadolny, A., Cheng, C., Lu, B., Blakers, A., & Stocks, M. (2022). Fully electrified land transport in 100% renewable electricity networks dominated by variable generation. *Renewable Energy*, *182*, 562-577.

National Renewable Energy Laboratory (NREL). 2012. Life cycle greenhouse gas emissions from electricity generation.

Nottingham City Council. (2021). *Financial Support for Cab Drivers,* Nottingham City Council. Accessed on 4 February 2022 from https://www.transportnottingham.com/driving/electric-taxis/support-for-cab-drivers/

Nugmanova, A., Arndt, W. H., Hossain, M. A., & Kim, J. R. (2019). Effectiveness of ring roads in reducing traffic congestion in cities for long run: big almaty ring road case study. *Sustainability*, *11*(18), 4973.

Pandey, D., Agrawal, M., & Pandey, J. S. (2011). Carbon footprint: current methods of estimation. *Environmental monitoring and assessment*, *178*(1), 135-160.

Poelman, H. (2018). *a walk to the park? assessing access to green areas in europe's cities update using completed Copernicus urban atlas data* (No. 01). Working Paper.

Powell, S., Oakes-Ash, L., Curtis, P., Harris, J., Ham, C., Osment, F., Lusby, S., Dawn, A., Welbourne, S., & Lloyd, J. (2021). *Net Zero Transport: The role of spatial planning and place-based solutions.* Royal Town Planning Institute. https://www.rtpi.org.uk/media/9233/rtpi-net-zero-transport-january-2021.pdf

Pozarny, P. (2016). *Climate change and social development: Topic guide*. GSRDC, University of Birmingham, UK. https://gsdrc.org/wp-content/uploads/2016/07/GSDRC_CC_SocDev.pdf

Prakoso, P., & Herdiansyah, H. (2019). Analisis implementasi 30% ruang terbuka hijau di DKI Jakarta. *Majalah Ilmiah Globe*, *21*(1), 17-26.

Pridemore, A., Hampshire, K., German, R., Fons, J., Unterstaller, A., Reichel, A., ... & Adams, M. (2018). Electric Vehicles from Life Cycle and Circular Economy Perspectives. *European Environment Agency: Copenhagen, Denmark*.

Provinsi DKI Jakarta, 2021, Peraturan Gubernur Provinsi DKI Jakarta No.90 Tahun 2021 tentang Rencana Pembangunan Rendah Karbon Daerah yang Berketahanan Iklim.

Putra, A. D., Sulistyorini, R., & Sebayang, S. (2012). *Pengaruh Pelebaran Ruas Jalan Terhadap Pengurangan Kemacetan di Jalan Teuku Umar Kota Bandar Lampung.*

Ramadhan, B. (2022). *DKI Targetkan Cakupan transportasi umum capai 95 persen*. Republika Online. Accessed on May 25, 2022, from https://d.republika.co.id/berita/daerah/jabodetabek-nasional/rc6iup330/dki-targetkan-cakupan-transportasi-umum-capai-95-persen

Rink, D. R., & Swan, J. E. (1979). Product life cycle research: A literature review. Journal of business Research, 7(3), 219-242.

Roberts, M., Sander, F. G., & Tiwari, S. (Eds.). (2019). *Time to ACT: Realizing Indonesia's urban potential*. World Bank Publications.

Rogelj, J., Geden, O., Cowie, A., & Reisinger, A. (2021). Net-zero emissions targets are vague: three ways to fix.

Rue, P. (2018). Make Way, Millennials, Here Comes Gen Z. *About Campus: Enriching the Student Learning Experience*, *23*(3), 5–12. doi: 10.1177/1086482218804251

Schnoor, J.L. (1996). *Environmental modeling: fate and transport of pollutants in water, air, and soil*. John Wiley and Sons.

Schwanen, T. (2013). 14. Sociotechnical transition in the. *Moving Towards Low Carbon Mobility*, 231. Edwar Elgar Publishing.

Schwanen, T. (2021). Achieving just transitions to low-carbon urban mobility. *Nature Energy*, p. 685–687.

Singh, A., & Agrawal, M. (2007). Acid rain and its ecological consequences. *Journal of Environmental Biology*, *29*(1), 15.

Siregar, D., dan Rachmita, F. (2019). *Mobilitas Perkotaan Inklusif Kolaboratif*. Friedrich Naumann Foundation Publication Accessed on 13 February 2022 from https://www.scribd.com/document/413024517/Mobilitas-Perkotaan-Inklusif-Kolaboratif-Studi-Kasus-Kota-Jakarta-Indonesia#download

Siswanto, Van Oldenborgh, G. J., Van Der Schrier, G., Lenderink, G., & Van Den Hurk, B. (2015). 26. TRENDS IN HIGH-DAILY PRECIPITATION EVENTS IN JAKARTA AND THE FLOODING OF JANUARY 2014. *Bulletin of the American Meteorological Society*, *96*(12), S131-S135.

Skrúcaný, T., Kendra, M., Stopka, O., Milojević, S., Figlus, T., & Csiszár, C. (2019). Impact of the electric mobility implementation on the greenhouse gases production in central European countries. *Sustainability*, *11*(18), 4948.

Stock, S. J., & Clemens, T. (2017). Traffic pollution is linked to poor pregnancy outcomes. *BMJ*, *359*.

Sukarto, H. (2006). *Transportasi Perkotaan dan Lingkungan*. Jakarta: Universitas Pelita Harapan.

Tamba, Jefry. (2018). Exploring The Accessibility And Facility In Railway Station Used By Persons With Disabilities: An Experience From Kebayoran Railway Station, Jakarta.*Indonesian Journal of Disability Studies (IJDS*).2018: Vol. 5(1): PP 37-46

Tanan, Natalia. (2011). *Fasilitas Pejalan Kaki.* Kementerian Pekerjaan Umum dan Perumahan Rakyat Republik Indonesia.

Thoem, James. (2019). What makes Copenhagen the world's most bicycle friendly city?. Accessed on 16 February 2022 from https://www.visitcopenhagen.com/copenhagen/activities/what-makes-copenhagen-worlds-most-bicycle-friendly-city

Thondoo, M., Marquet, O., Marquez, S., & Nieuwenhuijsen, M. J. (2020). Small cities, big needs: Urban transport planning in cities of developing countries. *Journal of Transport & Health*, *19*, 100944.

Tilman, D., & Clark, M. (2014). Global diets link environmental sustainability and human health. *Nature*, *515*(7528), 518-522.

Tjahjono, T., Kusuma, A., & Septiawan, A. (2020). The Greater Jakarta Area Commuters Travelling Pattern. *Transportation Research Procedia*, *47*, 585-592.

Tokimatsu, K., Wachtmeister, H., McLellan, B., Davidsson, S., Murakami, S., Höök, M., ... & Nishio, M. (2017). Energy modeling approach to the global energy-mineral nexus: A first look at metal requirements and the 2 C target. *Applied energy*, *207*, 494-509.

Transformative Urban Mobility Initiative. (2021). The 15-Minute City

Transport & Environment. (2020). How clean are electric cars? 1-33. Accessed on 20 February 2022 from https://www.transportenvironment.org/wp-content/uploads/2020/04/TEs-EV-life-cycle-analysis-LCA.pdf

Travel and Mobility Tech. (2021). The environmental impact of today's transport types. Accessed on 21 February 2022 from https://tnmt.com/infographics/carbon-emissions-by-transport-type/

Tsavachidis, M., & Le Petit, Y. (2022). Re-shaping urban mobility–Key to Europe´ s green transition. Journal of Urban Mobility, 2, 100014.

Tukker, A., & Jansen, B. (2006). Environmental impacts of products: A detailed review of studies. *Journal of Industrial Ecology*, *10*(3), 159-182.

Tyson, A., Kennedy, B., & Funk, C. (2021). Gen Z, Millennials Stand Out for Climate Change Activism, Social Media Engagement With Issue. Retrieved 6 April 2022, from Pew Research Center website: https://www.pewresearch.org/science/2021/05/26/gen-z-millennials-stand-out-for-climate-change-activism-social-media-engagement-with-issue/

United Nations, Department of Economic and Social Affairs, Population Division (2019). *World Urbanization Prospects 2018: Highlights* (ST/ESA/SER.A/421).

UN Environment. (2016). Global Outlook on Walking and Cycling 2016

Unterman, R. (1984). The Pedestrian and The bicyclist.Raja Grafindo, Jakarta.

Valero, A., Valero, A., Calvo, G., & Ortego, A. (2018). Material bottlenecks in the future development of green technologies. *Renewable and Sustainable Energy Reviews*, *93*, 178-200.

Wahyuni, E. S., Murti, B., & Joebagio, H. (2016). *Aksesibilitas Penyandang Disabilitas terhadap Layanan Transportasi Publik*. Surakarta: Universitas Sebelas Maret.

Wappelhorst, S. (2021). Update on government targets for phasing out new sales of internal combustion engine passenger cars. *International Council on Clean Transportation (ICCT)*.

Wiedmann, T., & Minx, J. (2008). A definition of 'carbon footprint'. *Ecological economics research trends*, *1*, 1-11.

Wismadi, A., Soemardjito, J., & Sutomo, H. (2013). Transport situation in Jakarta. Study on Energy Efficiency Improvement in the Transport Sector through Transport Improvement and Smart Community Development in the Urban Area, 29-58. https://www.eria.org/RPR_FY2012_No.29_Section_4.pdf

World Resource Institute. (1999). Urban Air Pollution Risks to Children: A Global Environmental Health Indicator. http://www.wri.org

WHO. (2005). Effect of Air Pollution on Children's Health and Development. WHO Special Programme on Health and Environment. Bonn: European Centre for Environment and Heath

WRI, C40 Cities, & ICLEI. (2014). Global Protocol for Community-Scale Greenhouse Gas Emission Inventories: An Accounting and Reporting Standard for Cities. World Resources Institute., 1–176. Retrieved from http://ghgprotocol.org/files/ghgp/GHGP_GPC.pdf

Xue, Y., Cheng, L., Wang, K., An, J., & Guan, H. (2020). System Dynamics Analysis of the Relationship between Transit Metropolis Construction and Sustainable Development of Urban Transportation—Case Study of Nanchang City, China. *Sustainability*, *12*(7), 3028.

Yazid, M. M., Ismail, R., & Atiq, R. (2011). The use of non-motorized for sustainable transportation in Malaysia. *Procedia Engineering*, *20*, 125-134.

Greenpeace Indonesia
Jl. HOS. Cokroaminoto No. 19 RT 1/RW 2
Gondangdia, Menteng District
Central Jakarta, 10350

www.greenpeace.or.id