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Mobility and Associated CO₂ Emissions During and After COVID-19: A Case Study in Indonesia

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Abstract

Changes in transportation trends can occur during and after COVID-19, such as travel distance, trip, and choice of transportation mode. The positive benefits from these changes in transportation trends should be maintained, to reduce disaster risk of environmental hazards from the CO₂ emissions. Research on changes in mobility, trips, and CO₂ emissions during and after COVID-19 in Indonesia is still very limited; whereas, changes in these transportation variables can be an inspiration for determining sustainable transportation policies in the future. This study aims to compare amid COVID-19 and post-COVID-19 transportation variables—travel distances, trips, and associated CO₂ emissions. This research was conducted by giving questionnaires to 400 participants in Aceh Besar District. The questionnaire contains questions regarding the distance traveled, trips, fuel spent, and socio-economic characteristics. The CO₂ emissions were calculated using IPCC (2006). The travel distance, trips, and transportation-related CO₂ emissions during and after COVID-19 were compared respectively based on statistics. The results showed that there were significant differences in travel distances, trips, and transportation-related CO₂ emissions between COVID-19 and the post-COVID-19 situation in the District of Aceh Besar. This article also presents several recommendations based on the data analysis results linked to literature studies about the sustainability of transportation as a result of COVID-19 situation; those are: providing quality public transportation, considering teleworking, providing solutions for workers who do not have access to online work, and paying attention to increasing use of private cars and car sharing post COVID-19.

Keywords: mobility; travel distance; trips; CO₂ emissions; COVID-19.

Introduction

Many cities in the world face traffic congestion, environmental problems, urban sprawl, and limited space. Previous literature explains that switching modes of transportation from private vehicles to public vehicles and non-motorized modes is one of the solutions to the previously mentioned problems (Abenzoza et al., 2017; Wu & Hong, 2017). However, moving commuters from private vehicle modes to public transportation modes is not easy (Yu et al., 2019). People choose to use private vehicles usually because they want to maximize their individual trips; in line with that, people may not choose public transportation modes because these modes are usually better than private transportation in terms of social benefits alone (Ding et al., 2018; McCarthy et al., 2017).

CoronaVirus Disease-2019 (COVID-19), however, has changed travel patterns. Teleworking allows people to live far away from their workplaces (Vega-Gonzalo et al., 2023). A study in Australia also proved that car use during COVID-19 fell by more than 35% (Beck & Hensher, 2020).

These positive benefits—reduced use of private vehicles and improved air quality—should be maintained after COVID-19. For this reason, research on differences in travel distances, trips, and transportation-related CO₂ emissions between COVID-19 and the post-COVID-19 situation needs to be carried out. After that, changes in people's travel trends need to be studied so that the study results could become input for transportation policies.



Travel behavior

Usually, the destination of people's daily trips is outside the residential area. Thus, the overall trip distance tends to be more influenced by the distance between the residence and the main destination of the trip. However, the travel distance is also influenced to a small extent by the local built environment, such as the distance of bus stops in an area, the availability of parking locations, and the availability of local grocery stores (Mouratidis et al., 2019; Ewing & Cervero, 2010; Næss, 2012; Næss et al., 2019; Stevens, 2017).

In light of the foregoing, studies around the world have found that residents of suburban neighborhoods far from the city center have greater overall commuting distances than residents of the city center. This keeps residents of suburban neighborhoods far from the city center commuting by car. The proportion of car trips by suburban residents is higher than the proportion of car trips by city dwellers (Ewing & Cervero, 2010; Næss, 2012; Stevens, 2017).

Sustainable transportation

Geng et al. (2017) explained the relationship between psychological factors and travel behavior. Desire and emotions may not have a significant influence on all green behaviors, but they do become important indicators for people's car usage behavior (Geng et al., 2016; Hounsham, 2006). Morris & Guerra (2015) and Lancée et al. (2017) found that car passengers and car drivers both experienced more positive emotions; conversely, public transport users experience the most negative emotions. This is what might cause vehicle users who do not care about sustainability and do not transport sustainably to be more dependent on car use. Convenience is a dominant motivation of people who depend on the automobile mode. They seek less time, less effort, pleasurable emotions, social status, identity, and positive self-image (Geng et al., 2016; Hounsham, 2006; Steg, 2005; Zailani et al., 2016).

In addition to groups that do not have a green transportation vision and behavior, Geng et al. (2017) also introduce a group that does not have a green transportation vision but is forced to use green transportation at this time. This group often has many travel motives and is easily influenced by other non-environmental factors. The main motive of this group in choosing a mode of transportation is the economy. After that, comfort, convenience, safety, and lastly environmental protection are other minor factors that influence them to choose a mode of transportation. Currently, this group is passively choosing the cheaper and green mode of travel. Once the economy allows, travel goals such as comfort and convenience will quickly become the main motive of this group.

Geng et al. (2017) also found a third group, whose vision and behavior are compatible with sustainable transportation. This group has positive attitudes to government measures. Their economic conditions and pro-environmental motives are consistent, resulting in sustainable green travel behaviors.

As a result, comfort and convenience motives will determine behavior more. Therefore, policies on limiting the use of cars and the publication of information on environmentally friendly transportation are not enough to shape eco-friendly travel behavior (Geng et al., 2017).

In addition, health factors can also be the reason people use sustainable transportation (Jones & Ogilvie, 2012). Occasional increases in physical activity are often associated with walking, cycling, and public transportation use. Therefore, health motives can be important catalysts or cofactors to promote people's green travel behavior (Geng et al., 2017).

COVID-19

COVID-19 first appeared in December 2019 in Wuhan, the capital city of Hubei province in China. Wuhan was also the first epicenter of the outbreak (Zhou et al., 2020). Three months after its appearance, the virus has affected

143 countries. Thus, the World Health Organization (WHO) upgraded the status of the outbreak to a pandemic, which means the severity of the virus is worrying (WHO, 2020b).

COVID-19 has led to policies asking people to limit their travels, stay at home, and not hold activities that have a large number of participants (WHO, 2020a). This is because several factors, such as accessibility, climate, pollution, or the preparedness of the local health system, are the causes of the spread of COVID-19. For example, in Europe, the biggest victims of the first wave of the COVID-19 pandemic were areas with large, connected lands, high levels of pollution, a colder and drier climate, and a relatively poor health system (Rodríguez-Pose & Burlina, 2021).

In addition to policies by the government, changes in people's behavior during COVID-19 are also due to communication and advice within the family (Fadmawaty & Wasludin, 2021). In the early days of COVID-19, travel restriction policies were not implemented in Aceh (Sufri et al., 2021), but then people's understanding of the dangers of COVID-19 made them voluntarily limit their travels (Mukhlis et al., 2022).

Teleworking

In the context of work, work from home is widely applied during COVID-19 to create social distancing. The practice of working from home was first introduced in the early 1970s with the term telecommuting (Nilles, 1975), and then developed with various terms, such as remote working (Hardill & Green, 2003), teleworking (Alizadeh, 2012), and work at home (Baruch & Yuen, 2000; Himawan et al., 2022).

Working from home means combining work location and daily life location to optimize time, space, etc. Based on historical searches, work from home existed in the Middle Ages. At that time, people traded and opened shops in their homes (Applebaum, 1992; Hamada, 1993), so the rooms in the house were multifunctional. Then, activities in the office began to appear during the industrial revolution. At that time, workers had to go to work locations and offices to work. Thus, workers begin to work inflexibly at work sites that contain special work equipment. More flexible work arrangements then emerged when many women were working (Schonberger, 1971); it was at this time that the concept of working from home began to reappear (Himawan et al., 2022).

Travel restriction

Wang et al. (2014) inform about the practice of restricting vehicles in several places. In the early 1970s, in Buenos Aires, Argentina, about half the cars were prohibited from entering the city center on any given day. The ban is prohibited based on the odd or even number of the plate number. In the 1980s, in Caracas, Venezuela, vehicle restrictions were also implemented as happened in Buenos Aires. Similar vehicle restrictions occurred in Athens between 1985 and 1991 (De Grange & Troncoso, 2011). A one-day-per-week driving ban from 5 a.m. to 10 p.m. was implemented in Mexico City in 1989. The pattern adopted in Mexico City was followed in Sao Paulo in Brazil, Bogota and Medellin in Colombia, and Santiago in Chile. In around 2008, several cities in China also implemented driving restrictions to deal with congestion.

Experts are still debating the efficiency of driving restrictions. Economists, in general, believe that congestion rates are effective in reducing the number of cars (K.A. Small & Gomez-Ibañez, 1998; Small & Verhoef, 2007). However, in reality, people are unwilling to pay the higher price, even though they will benefit from lower congestion (Rouwendaal & Verhoef, 2006). Meanwhile, rationing policies are also considered fairer than road pricing, to reduce road congestion (De Grange & Troncoso, 2011; Rouwendaal & Verhoef, 2006); this is because the same restrictions apply to every car owner. Thus, people do not easily accept the congestion tariff strategy (Schade & Schlag, 2003; Schuitema et al., 2010). Instead, driving restrictions are more accepted by society and the government. In 2007 and 2008, Beijing introduced a policy of limiting odd-even license plates, and this policy proved to reduce congestion and pollution (Y. Wang et al., 2009).

Driving restriction policies, however, are claimed by some researchers to be unfair and inefficient (De Grange & Troncoso, 2011). The expert reasoned that people might disobey, buy a second car, or take longer trips on the days they can travel. In addition, driving restrictions are also considered not to apply the concept of willingness to pay (De Grange & Troncoso, 2011). Residents who do not have good access to public transportation nodes have less opportunity to change their mode from car to public transportation. As a result, they are more likely to disobey the driving restrictions. Moreover, public transport systems in most developing countries are not in good condition. Thus, people who are in such conditions may buy a second car to get around the policy of restricting driving (H. Goddard, 1997; H. C. Goddard, 1999). Based on the realities in Mexico City, people with higher incomes buy a second car with a different license plate to get around the no-driving policy. Thus, the number of vehicles in Mexico City actually increased (Eskeland & Feyzioglu, 1997). These additional cars are usually older, and therefore not environmentally friendly (Eskeland & Feyzioglu, 1997). Gallego et al. (2012) also found a similar phenomenon in Mexico and Santiago. Carbon dioxide per hour in Mexico and Santiago is increasing because people are buying second cars to get around the driving restriction policy. In addition, travel distances can be increased because roads are no longer congested, and car users are able to travel more quickly than before the driving restrictions policy was implemented (Downs, 2004).

Methods

There were five steps in this research. First, the number of population and samples were calculated. Second, the travel distance, trips, transportation-related fuel usage, and socioeconomic data were collected through a survey. Third, the transportation-related CO₂ emissions were calculated using IPCC (2006). Fourth, the travel distance, trips, and transportation-related CO₂ emissions during and after COVID-19 were compared respectively based on statistics. Fifth, the research results are linked with suggestions from related literature.

Population and samples

The area of study was the District of Aceh Besar in the Province of Aceh, Indonesia. The population was the households in the District of Aceh Besar. The number of samples was calculated using Slovin formula (Eq. 1). The 5% of acceptable margin of error (e) was applied in this research. The number of the household (N) in the District of Aceh Besar was 60,112; as a result, the number of samples was as follows:

$$n = \frac{N}{1 + (N \times e^2)} = \frac{60,112}{1 + 60,112 \times 0.05^2} = 397.35 = 400 \quad (1)'$$

The survey

Proportionate stratified random sampling was applied in this research. This technique is used to determine the sample in the population that is not homogeneous. Stratified random sampling is a subset of probability sampling techniques (Sugiyono, 2012). For this reason, the sub-district household was selected randomly. The participant data obtained through the survey was travel distance, trips, transportation-related fuel usage, and socioeconomic characteristics.

CO₂ emissions estimation

The IPCC (2006) formula, as presented in Eq. (2), was used to estimate the CO₂ emissions. CO₂ emissions were obtained by multiplying the fuel magnitude (fuel) and emission factor (EF).

$$\text{CO}_2 \text{ emissions} = \text{fuel} \times \text{EF} \quad (2)'$$

Statistical comparison

The parametric statistical test—paired sample t-test—was applied in this research (Ross & Willson, 2018). This test was applied because the compared variables were interrelated.

Results

The participants' socioeconomic data is presented in Table 1. Regarding the gender, 48% of participants were male; 52% were female. Regarding the age of the participants, 1% of the participants were aged 17-19 years, 53% of the participants were aged 20-29 years, 33% of the participants were aged 30-39 years, 11% of the participants were aged 40-49 years, and 2% of the participants were aged 50-59 years.

Regarding participant education, 13% of participants had basic education, 13% of participants had diploma education, 61% of participants had bachelor's education, and 13% of participants had postgraduate education. Regarding transportation mode, 57% of participants traveled by motorcycle, and 43% of participants traveled by car.

Table 1. Participants' socioeconomic data.

Characteristics	Detail	Percent
Gender	Male	48%
	Female	52%
	Total	100%
Age	17–19 years old	1%
	20–29 years old	53%
	30–39 years old	33%
	40–49 years old	11%
	50–59 years old	2%
	Total	100%
Education	Basic education	13%
	Diploma	13%
	Bachelor	61%
	Postgraduate	13%
	Total	100%
Work	Student	20%
	Businessperson	20%
	Private employees	16%
	Employees of state-owned enterprises	15%
	Housewife	6%
	Others	23%
	Total	100%
Vehicle type	Motorcycle	57%
	Car	43%
	Total	100%

Characteristics	Detail	Percent
Private car ownership	0 unit	37%
	1 unit	53%
	2 units	10%
	3 units	0%
	Total	100%
Private motorcycle ownership	0 unit	2%
	1 unit	62%
	2 units	30%
	3 units	5%
	4 units	1%
	Total	100%

Source: Authors

Regarding car ownership, 37% of participants did not own a car, 53% of participants owned 1 car, 10% of participants owned 2 cars, and no participant owned 3 cars. Regarding motorcycle ownership, 2% of participants did not own a motorcycle, 62% of participants owned 1 motorcycle, 30% of participants owned 2 motorcycles, 5% of participants owned 3 motorcycles, and 1% of participants owned 4 motorcycles.

Participants' fuel usage data was presented in Table 2. Regarding the fuel used during COVID-19, the magnitude of fuel used was 873 liters (19.2%) of dextrite, 1,352.6 liters (29.7%) of pertalite, 2,073.9 liters (45.6%) of pertamax, and 252.5 liters (5.5%) of premium. Concerning the fuel used after COVID-19, the magnitude of fuel used was 1,126 liters (18.8%) of dextrite, 1,782 liters (29.7%) of pertalite, 2,751.2 liters (45.8%) of pertamax, and 343 liters (5.7%) of premium.

Table 2. Participants' fuel usage data.

Time	Type of fuel	Fuel usage magnitude (liter)	Fuel usage percentage
During COVID-19	dextrite	873	19.2%
	pertalite	1,352.6	29.7%
	pertamax	2,073.9	45.6%
	premium	252.5	5.5%
	Total	4,552	100%
After COVID-19	dextrite	1,126	18.8%
	pertalite	1,782	29.7%
	pertamax	2,751.2	45.8%
	premium	343	5.7%
	Total	6,002.2	100%

Source: Authors

The travel distance, trips, and transportation-related CO2 emissions data was presented in Table 3. The average travel distance during and after COVID-19 was 81.9 and 127.9, respectively. The average trips during and after

COVID-19 were 25.4 and 25.9, respectively. The average transportation-related CO₂ emissions during and after COVID-19 were 42.7 and 47.3, respectively.

Table 3. Travel distance, trips, and transportation-related CO₂ emissions.

Item	N	Minimum	Maximum	Mean	Standard deviation
Travel distance during COVID-19 (km per week)	400	0.00	520.00	81.95	62.13
Travel distance after COVID-19 (km per week)	400	12.00	628.00	127.98	67.19
Trips during COVID-19 (trips per week)	400	8.00	35.00	25.40	7.67
Trips after COVID-19 (trips per week)	400	12.00	35.00	25.93	7.53
Transportation-related CO ₂ emissions during COVID-19 (tons per week)	400	4.57	102.91	42.77	23.35
Transportation-related CO ₂ emissions after COVID-19 (tons per week)	400	6.86	109.54	47.31	23.58
Valid N (listwise)	400				

Source: Authors

Statistical comparison

Based on the paired sample t-test, the travel distance during and after COVID-19 was statistically different. The trips during and after COVID-19 were also statistically different. The transportation-related CO₂ emissions during and after COVID-19 were statistically different as well. The statistical comparison is presented in Table 4.

Table 4. The statistical comparison.

The difference	T _{count}	T _{table}	Sig. < 0.05	Meaning
Travel distance during COVID-19 – travel distance after COVID-19	20.130	1.96593	0.000	Significant
Trips during COVID-19 – trips after COVID-19	2.620	1.96593	0.009	Significant
Transportation-related CO ₂ emissions during COVID-19 – transportation-related CO ₂ emissions after COVID-19	42.093	1.96593	0.000	Significant

Source: Authors

Discussion

People travel distances in the District of Aceh Besar during and after COVID-19 were statistically different. The commuter's number of trips in the District of Aceh Besar during and after COVID-19 also differed statistically.

The commuter may reduce mobility during COVID-19 due to travel restrictions. The number of trips may decrease due to the implementation of telework (Olde Kalter et al., 2021). Telework could be performed by high-income people (Olde Kalter et al., 2021). Low-income workers in most cases also reduce their number of trips, but only to a lesser extent, due to lower access to telework and private vehicles (Beck & Hensher, 2020). In addition, trips may be reduced because people are concerned about traveling with other people in the same vehicle (Vega-Gonzalo et al., 2023).

The commuters may increase their mobility due to the easing of travel restrictions after COVID-19; on the contrary. In addition, people who used to travel by public transportation or shared vehicles may purchase private vehicles during COVID-19 due to fears of spreading the virus in public transportation or shared vehicles (Basu & Ferreira, 2021). The phenomenon of this increase in private vehicles could increase post-COVID-19 mobility.

In this study, the difference between travel distances during and after COVID-19 was larger than the difference in trips during the same period. The reason for this is that people might stop their main trip—traveling to work—because they were doing teleworking activities. By not commuting to work, travel distances will decrease substantially. However, older people usually do not have access to teleworking, online shopping activities, and online social activities. As a result, older people tend not to change their trips to work and other substantial trips during COVID-19. Workers in essential sectors such as hospitals, the energy sector, staple food stores, and the sanitation sector, also did not cancel their trips to work in the office during COVID-19 (Politis et al., 2021). In addition, This variation in the implementation of trips to the office may have caused a relatively small difference between trips during and after COVID-19.

Sustainable transportation meets the mobility needs of people in a way that is least damaging to the environment and does not damage the mobility needs of the next generations (Rodrigue, 2020). In the case of transportation during COVID-19 in Aceh Besar District, people reduced their trips by changing their activity patterns. Many people in the district of Aceh Besar probably changed office activities to teleworking at that time. Likewise, the people of Aceh Besar District may abandon non-essential travel during COVID-19. These behaviors show a sustainable transportation attitude. Thus, during the time of COVID-19, the people of Aceh Besar district reduced CO2 emissions related to transportation.

The difference in CO2 emissions during COVID-19 and after the pandemic is quite large. This is because people cancel their trips to work during COVID-19. Thus, CO2 emissions due to travel will be reduced quite a lot.

Transportation-related CO2 emissions increase greenhouse gases. Excess greenhouse gases cause global warming. Global warming causes various disasters such as droughts and floods (EIA, 2022; NOAA, 2021). Since 1950, greenhouse gas emissions in the world have exceeded the limit because CO2 emissions have exceeded the ability of natural absorption (EIA, 2022).

The transportation sector contributes 28% of the total greenhouse gas emissions produced by various sectors. Transportation-related emissions from burning fossil fuels have increased by 19% from 1990 to 2021 (EPA, 2023). If transportation-related CO2 emissions do not decrease, then these CO2 emissions will cause global warming. The reduction in transportation-related CO2 emissions during COVID-19 should be maintained so that global warming can be prevented.

Vega-Gonzalo et al. (2023) suggest several recommendations so that post-COVID-19 sustainable transportation can continue. First, quality public transportation should be provided. Second, teleworking should be continued. Third, workers who do not have access to teleworking should be assisted through appropriate policies. Fourth, attention must be paid to people who switch their mode of choice from public transportation to private vehicles during and after COVID-19. Finally, COVID-19 can change people to both reduce or increase their trips by using shared vehicles.

Conclusions

The mobility—travel distance and trips—of people of Aceh Besar District during and after COVID-19 differed significantly. CO₂ emissions due to the transportation of Aceh Besar District people during and after COVID-19 were also statistically different. This shows that the transportation of people of Aceh Besar District during COVID-19 was more sustainable than after COVID-19. This sustainable transportation should be maintained. Previous literature provides several suggestions to maintain sustainable transportation after COVID-19. The recommendations are providing quality public transportation, considering teleworking, providing solutions for workers who do not have access to online work, and anticipating increased use of private and shared vehicles. In addition, studies that compare transportation behavior before, during, and after COVID-19 should be carried out.

References

- Abenoza, R. F., Cats, O., & Susilo, Y. O. (2017). Travel satisfaction with public transport: Determinants, user classes, regional disparities and their evolution. *Transportation Research Part A: Policy and Practice*, 95, 64–84. <https://doi.org/10.1016/j.tra.2016.11.011>
- Alizadeh, T. (2012). Teleworkers' Characteristics in Live/Work Communities: Lessons from the United States and Australia. *Journal of Urban Technology*, 19(3), 63–84. <https://doi.org/10.1080/10630732.2011.642569>
- Applebaum, H. (1992). The Concept of Work: Ancient, Medieval, and Modern. *SUNY Series in the Anthropology of Work*.
- Baruch, Y., & Yuen, Y. K. J. (2000). Inclination to opt for teleworking: A comparative analysis of United Kingdom versus Hong Kong employees. *International Journal of Manpower*, 21(7), 521–539. <https://doi.org/10.1108/01437720010378980>
- Basu, R., & Ferreira, J. (2021). Sustainable mobility in auto-dominated Metro Boston: Challenges and opportunities post-COVID-19. *Transport Policy*, 103(January), 197–210. <https://doi.org/10.1016/j.tranpol.2021.01.006>
- Beck, M. J., & Hensher, D. A. (2020). Insights into the impact of COVID-19 on household travel and activities in Australia – The early days under restrictions. *Transport Policy*, 96(July), 76–93. <https://doi.org/10.1016/j.tranpol.2020.07.001>
- De Grange, L., & Troncoso, R. (2011). Impacts of vehicle restrictions on urban transport flows: The case of Santiago, Chile. *Transport Policy*, 18(6), 862–869. <https://doi.org/10.1016/j.tranpol.2011.06.001>
- Ding, C., Wang, Y., Tang, T., Mishra, S., & Liu, C. (2018). Joint analysis of the spatial impacts of built environment on car ownership and travel mode choice. *Transportation Research Part D: Transport and Environment*, 60, 28–40. <https://doi.org/10.1016/j.trd.2016.08.004>
- Downs, A. (2004). *Still stuck in traffic: coping with peak-hour traffic congestion*. Brookings Institution Press.
- EIA. (2022). *Energy and the environment explained - Greenhouse gases and the climate*. <https://www.eia.gov/energyexplained/energy-and-the-environment/greenhouse-gases-and-the-climate.php#:~:text=In computer-based models%2C rising,referred to as climate change.>
- EPA. (2023). *Sources of Greenhouse Gas Emissions*. <https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions#transportation>
- Eskeland, G. S., & Feyzioglu, T. (1997). Rationing Can Backfire: The “Day without a Car” in Mexico City. *The World Bank Economic Review*, 11(3), 383–408.
- Ewing, R., & Cervero, R. (2010). Travel and the built environment. *J. Am. Plan. Assoc.*, 76, 1–30.
- Fadmawaty, A., & Wasludin, W. (2021). The Effect of the Belief System, Family Organizations and Family Communication on Covid-19 Prevention Behaviour: the Perspective of Family Resilience. *International Journal of Disaster Management*, 4(2), 9–22. <https://doi.org/10.24815/ijdm.v4i2.20411>
- Gallego, F., Montero, J. P., & Salas, C. (2012). *The effect of transport policies on car use: theory and evidence from Latin American cities*.
- Geng, J., Long, R., & Chen, H. (2016). Impact of information intervention on travel mode choice of urban residents with different goal frames: A controlled trial in Xuzhou, China. *Transportation Research Part A: Policy and Practice*, 91, 134–147. <https://doi.org/10.1016/j.tra.2016.06.031>

- Geng, J., Long, R., Chen, H., & Li, W. (2017). Exploring the motivation-behavior gap in urban residents' green travel behavior: A theoretical and empirical study. *Resources, Conservation and Recycling*, 125(April), 282–292. <https://doi.org/10.1016/j.resconrec.2017.06.025>
- Goddard, H. (1997). Using Tradeable Permits to Achieve Sustainability in the World's Large Cities. *Environmental and Resource Economics*, 10, 63–99.
- Goddard, H. C. (1999). Promoting Urban Sustainability: The Case for a Tradable Supplementary Licence System for Vehicle Use. *Urban Studies*, 36(13).
- Hamada, T. (1993). Reviewed Work(s): The Concept of Work: Ancient, Medieval, and Modern by Herbert Applebaum. *American Anthropologist, New Series*, 95(4), 1056–1057.
- Hardill, I., & Green, A. (2003). Remote working - Altering the spatial contours of work and home in the new economy. *New Technology, Work and Employment*, 18(3), 212–222. <https://doi.org/10.1111/1468-005X.00122>
- Himawan, K. K., Helmi, J., & Fanggidae, J. P. (2022). The sociocultural barriers of work-from-home arrangement due to COVID-19 pandemic in Asia: Implications and future implementation. *Knowledge and Process Management*, 29(2), 185–193. <https://doi.org/10.1002/kpm.1708>
- Hounsham, S. (2006). *Painting the town green. How to Persuade People to Be Environmentally Friendly*. Green-Engage.
- IPCC. (2006). 2006 IPCC Guidelines for National Greenhouse Inventories. In *Institute for Global Environmental Strategies*.
- Jones, C. H. D., & Ogilvie, D. (2012). Motivations for active commuting: a qualitative investigation of the period of home or work relocation. *International Journal of Behavioral Nutrition and Physical Activity*, 9, 1–12. <https://doi.org/10.1186/1479-5868-9-109>
- K.A. Small, & Gomez-Ibanez, J. A. (1998). *Road pricing for congestion management: the transition from theory to policy* (K. J. Button & E. T. Verhoef (eds.)).
- Lancée, S., Veenhoven, R., & Burger, M. (2017). Mood during commute in the Netherlands: What way of travel feels best for what kind of people? *Transportation Research Part A: Policy and Practice*, 104, 195–208. <https://doi.org/10.1016/j.tra.2017.04.025>
- McCarthy, L., Delbosc, A., Currie, G., & Molloy, A. (2017). Factors influencing travel mode choice among families with young children (aged 0–4): a review of the literature. *Transport Reviews*, 37(6), 767–781. <https://doi.org/10.1080/01441647.2017.1354942>
- Morris, E. A., & Guerra, E. (2015). Mood and mode: does how we travel affect how we feel? *Transportation*, 42(1), 25–43. <https://doi.org/10.1007/s11116-014-9521-x>
- Mouratidis, K., Ettema, D., & Næss, P. (2019). Urban form, travel behavior, and travel satisfaction. *Transportation Research Part A: Policy and Practice*, 129(October 2018), 306–320. <https://doi.org/10.1016/j.tra.2019.09.002>
- Mukhlis, H., Widyastuti, T., Harlianty, R. A., Susanti, S., & Kumalasari, D. (2022). Study on awareness of COVID-19 and compliance with social distancing during COVID-19 pandemic in Indonesia. *Journal of Community Psychology*, 50(3), 1564–1578. <https://doi.org/10.1002/jcop.22735>
- Næss, P. (2012). Urban form and travel behavior: Experience from a Nordic context. *Journal of Transport and Land Use*, 5(2), 21–45. <https://doi.org/10.5198/jtlu.v5i2.314>
- Næss, P., Strand, A., Wolday, F., & Stefansdottir, H. (2019). Residential location, commuting and non-work travel in two urban areas of different size and with different center structures. *Progress in Planning*, 128(March 2017), 1–36. <https://doi.org/10.1016/j.progress.2017.10.002>
- Nilles, J. M. (1975). Telecommunications and Organizational Decentralization. *IEEE Transactions on Communications*, 23(10), 1142–1147. <https://doi.org/10.1109/TCOM.1975.1092687>
- NOAA. (2021). *Climate change impacts*. <https://www.noaa.gov/education/resource-collections/climate/climate-change-impacts>
- Olde Kalter, M. J., Geurs, K. T., & Wismans, L. (2021). Post COVID-19 teleworking and car use intentions. Evidence

- from large scale GPS-tracking and survey data in the Netherlands. *Transportation Research Interdisciplinary Perspectives*, 12. <https://doi.org/10.1016/j.trip.2021.100498>
- Politis, I., Georgiadis, G., Papadopoulos, E., Fyrogenis, I., Nikolaidou, A., Kopsacheilis, A., Sdoukopoulos, A., & Verani, E. (2021). COVID-19 lockdown measures and travel behavior: The case of Thessaloniki, Greece. *Transportation Research Interdisciplinary Perspectives*, 10(March), 100345. <https://doi.org/10.1016/j.trip.2021.100345>
- Rodrigue, J.-P. (2020). *The Geography of Transport Systems FIFTH EDITION*. Routledge.
- Rodríguez-Pose, A., & Burlina, C. (2021). Institutions and the uneven geography of the first wave of the COVID-19 pandemic. In *Journal of Regional Science* (Vol. 61, Issue 4). <https://doi.org/10.1111/jors.12541>
- Ross, A., & Willson, V. L. (2018). *Basic and Advanced Statistical Tests: Writing Results Sections and Creating Tables and Figures*. SensePublishers.
- Rouwendaal, J., & Verhoef, E. T. (2006). Basic economic principles of road pricing: From theory to applications. *Transport Policy*, 13(2), 106–114. <https://doi.org/10.1016/j.tranpol.2005.11.007>
- Schade, J., & Schlag, B. (2003). Acceptability of urban transport pricing strategies. *Transportation Research Part F: Traffic Psychology and Behaviour*, 6(1), 45–61.
- Schonberger, R. (1971). Inflexible Working Conditions Keep Women “Unliberated.” *The Personnel Journal*, 50(11), 834–838.
- Schuitema, G., Steg, L., & Forward, S. (2010). Explaining differences in acceptability before and acceptance after the implementation of a congestion charge in Stockholm. *Transportation Research Part A: Policy and Practice*, 44(2), 99–109. <https://doi.org/10.1016/j.tra.2009.11.005>
- Small, K. A., & Verhoef, E. T. (2007). *The Economics of Urban Transportation*. Routledge.
- Steg, L. (2005). Car use: Lust and must. Instrumental, symbolic and affective motives for car use. *Transportation Research Part A: Policy and Practice*, 39(2-3 SPEC. ISS.), 147–162. <https://doi.org/10.1016/j.tra.2004.07.001>
- Stevens, M. R. (2017). Does Compact Development Make People Drive Less? *Journal of the American Planning Association*, 83(1), 7–18. <https://doi.org/10.1080/01944363.2016.1240044>
- Sufri, S., Nurhasanah, N., Nurhayati, N., Munazar, M., Mardhiah, A., Hermansyah, H., Bakri, S., Jannah, M., Dwirahmadi, F., & Rutherford, S. (2021). Missed Opportunities in the Early Response to COVID-19 in Aceh Province: January to May 2020. *International Journal of Disaster Management*, 4(3), 11–28. <https://doi.org/10.24815/ijdm.v4i3.21609>
- Sugiyono. (2012). *Memahami Penelitian Kualitatif*. Alfabet.
- Vega-Gonzalo, M., Gomez, J., & Christidis, P. (2023). How has COVID-19 changed private car use in European urban areas? An analysis of the effect of socio-economic characteristics and mobility habits. *Transportation Research Part A: Policy and Practice*, 172(April), 103679. <https://doi.org/10.1016/j.tra.2023.103679>
- Wang, L., Xu, J., & Qin, P. (2014). Will a driving restriction policy reduce car trips?—The case study of Beijing, China. *Transportation Research Part A: Policy and Practice*, 67, 279–290. <https://doi.org/10.1016/j.tra.2014.07.014>
- Wang, Y., Hao, J., McElroy, M. B., Munger, J. W., Ma, H., Chen, D., & Nielsen, C. P. (2009). Ozone air quality during the 2008 Beijing Olympics: Effectiveness of emission restrictions. *Atmospheric Chemistry and Physics*, 9(14), 5237–5251. <https://doi.org/10.5194/acp-9-5237-2009>
- WHO. (2020a). *Coronavirus disease (COVID-19) pandemic*. <https://www.who.int/>
- WHO. (2020b). *WHO Director-General's opening remarks at the media briefing on COVID-19 - 11 March 2020*.
- Wu, W., & Hong, J. (2017). Does public transit improvement affect commuting behavior in Beijing, China? A spatial multilevel approach. *Transportation Research Part D: Transport and Environment*, 52, 471–479. <https://doi.org/10.1016/j.trd.2016.08.032>
- Yu, L., Xie, B., & Chan, E. H. W. (2019). How does the built environment influence public transit choice in urban villages in China? *Sustainability (Switzerland)*, 11(1). <https://doi.org/10.3390/su11010148>
- Zailani, S., Iranmanesh, M., Masron, T. A., & Chan, T. H. (2016). Is the intention to use public transport for different

travel purposes determined by different factors? *Transportation Research Part D: Transport and Environment*, 49, 18–24. <https://doi.org/10.1016/j.trd.2016.08.038>

Zhou, F., Yu, T., Du, R., Fan, G., Liu, Y., Liu, Z., Xiang, J., Wang, Y., Song, B., Gu, X., Guan, L., Wei, Y., Li, H., Wu, X., Xu, J., Tu, S., Zhang, Y., Chen, H., & Cao, B. (2020). Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. *The Lancet*, 395(10229), 1054–1062. [https://doi.org/10.1016/S0140-6736\(20\)30566-3](https://doi.org/10.1016/S0140-6736(20)30566-3)