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社会的脆弱性と COVID-19 との関係性がマニラ在住の通勤者の交通行動と消費活動へ与える影響

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ABSTRACT

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Dianne Pacis ANCHETA

The COVID-19 pandemic has caused overwhelming economic and health costs to nations across the globe. While no country was free from the impacts of the pandemic, some populations were disproportionately affected and suffered severe consequences compared to others. Moreover, factors such as economic wealth, nature of work, and available transportation to name a few, also caused individuals to have varying responses to the implementation of lockdowns and community quarantine. In consideration of these scenarios, travel behavior and mobility during the pandemic could be different, not only at a national level among the different classes of world economies, but as well as at the community level among different socioeconomic groups.

In addition, travel activities have also significantly changed as we adapt and live through this global pandemic. In order to mitigate risks of contracting the virus by traveling, various factors such as purpose of trip and transportation mode have been carefully considered. As a result, such changes in travel choices also have corresponding implications on the commuter's expenditure activities. Analyzing these scenarios can provide evidence on whether there was a change or shift in the importance of trips or travel modes as influenced by COVID-19.

Based on these backgrounds, this research aims to provide a multifaceted perspective on how social vulnerability affects the risk of exposure to COVID-19, how various social groups differ in travel behavior, and how these are reflected in terms of commuters' expenditure. Metro Manila was selected as the case study as it provides an interesting setting on how travel activities have been affected by COVID-19 in mega cities of developing countries. This study can be viewed as a preliminary analysis of regional trends on urban mobility in developing countries as influenced by a pandemic.

Firstly, to assess the relationship of social vulnerability and COVID-19 and identify how social vulnerability affects the risk of exposure to COVID-19, data was collected from an online questionnaire survey distributed among residents of Metro Manila. To facilitate data analysis, social vulnerability was quantified by applying the concept of Social Vulnerability Index or SOVI, modal share changes between social groups was assessed, and ordinal logistic regression analysis was performed to understand the relationship between social vulnerability and COVID-19 exposure. Results showed that there was a general decrease in all trips activities as an effect of lockdown restrictions. Private vehicles were also the most common transport mode, with public transport users shifting to private vehicles during the pandemic. Women are also found to be more significantly at risk due to their general and continual use of public transport. Results also show that the ability to stay at home is affected not only by socioeconomic status but also by the type of work, as essential workers who continued to travel during COVID-19 face higher risk of virus contagion. Results from the regression analysis support previous literature which indicates that social vulnerability contributes to higher risk of COVID-19 exposure. Moreover, the indicator for *sex* (female) showed to have the strongest influence on this risk.

Secondly, the impacts of COVID-19 on travel behavior and the resulting changes in trip activities were also identified. To accomplish this, open-source data for mobility and COVID-19 patients in Metro Manila were gathered from Apple's Mobility Trends Report, Google's COVID-19 Community Mobility Reports, and the Department of Health Philippines's COVID-19 Patients Tracker. Using the aforementioned data, changes in travel activity in relation to COVID-19 patients was examined using visual representations, mobility trends influenced by COVID-19 were also identified, and multiple linear regression was applied to understand the relationship between travel behavior and the number of COVID-19 cases. Observing the mobility trend, it showed that upon the implementation of strict community quarantine policies and increase in the number of COVID-19 patients, there was a significant decrease in trips to *grocery*, *retail*, and traveling by *walking*, and an increase in the number of people who stay at home (*residential*) in comparison with recorded mobility before the pandemic. However, as the number of COVID-19 patients decreased and quarantine policies became more relaxed, residents started to engage in more travel activities. This shift in travel behavior based on risk perception of COVID-19, also known as "closed loop scenario," was also observed in Metro Manila during the first year of the pandemic. In addition, visits to *retail* and *grocery* tend to increase the number of patients while staying at home (*residential*) or traveling by *walking* contribute to the decrease in the number of COVID-19 cases. However, concluding from the resulting *r-squared 0.382* of the model, it may be reasonable to assume that the travel behavior only partially affects the number of incidences; moreover, the activities people do at the destinations may have more influence on the increase of daily patients.

Finally, this research examined the economic and monetary impacts of COVID-19 on commuters' mobility by evaluating the changes in importance of trips and modal choice, and assessing the changes in expenditure activity of commuters. To achieve this, the recorded travel activity before and during COVID-19 from the previously mentioned online questionnaire survey was again used. To compute for the importance of each trip purpose and trip mode, a multinomial logit model was formulated to estimate the parameters using the maximized likelihood function. Results show that traveling for *work*, and using *public* and *private* transport mode increased in importance during the pandemic, and that generated values are statistically significant. On the other hand, while trips to *grocery* were also found to increase in importance, its change in importance was found not to be statistically significant. Furthermore, the commuters' maximum attainable level of satisfaction was also measured by formulating the indirect utility function. By comparing the indirect utility before and during the pandemic for every respondent, results showed that the indirect utility generally decreased during the pandemic. There has been no increase in indirect utility implying that the maximum utility that can be achieved by spending the income on the consumption of transportation has decreased. In addition, it was also found that 62% of respondents with more than 50% decrease in utility have at least two vulnerability qualities; 40% of respondents without changes in utility have no vulnerability characteristics, and 64% of respondents with less than 50% decrease in utility have at least only one vulnerability. Based on these results, the level of social vulnerability shows to have an influence on the intensity of change in indirect utility.

Findings from this research provide a perspective of COVID-19 impacts in a developing country. Moreover, results can be used by policymakers as a guide in formulating pandemic response strategies which consider the most vulnerable groups, and in prioritizing developments directed towards essential trips and mass transport, while considering the mobility restrictions imposed during a pandemic.

The thesis includes five chapters. Chapter 1 discusses the background, literature review, objective and scope, and significance of this research. Chapter 2 first provides an assessment of the relationship between social vulnerability and COVID-19. Chapter 3 then covers the impacts of COVID-19 on travel behavior and how the pandemic influenced changes in mobility. Founding on the results of Chapter 3, Chapter 4 presents a more in-depth evaluation of the economic impacts on commuters' mobility. This will be evaluated by looking into how the importance of trips and modal choice has changed as influenced by the pandemic, and the changes in expenditure activity of commuters. Chapter 5 summarizes the thesis objectives and findings, and discusses the limitations and future directions of the research.

Supervisor

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LIST OF CORRESPONDING PUBLICATIONS

Bulk of the contents of Chapters 2 and 3 has been published in a journal:

Ancheta, D., Tani, R., Uchida, K., The relationship of social vulnerability and travel behavior with COVID-19 in Metro Manila, Philippines, Asian Transport Studies, Volume 9, 2023, 100093, ISSN 2185-5560, https://doi.org/10.1016/j.eastsj.2022.100093.

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Chapter 1
Introduction

1.1 Background

Changes in mobility during the COVID-19 pandemic

COVID-19 has permanently changed the way communities live, interact, and behave. Since the start of the COVID-19 pandemic, countries all around the globe have experienced overwhelming health and economic impacts that have been detrimental to national development. During the early months of the pandemic, governments have implemented various levels of lockdown policies and other mobility restrictions to contain the spread of contagion. Daily movement patterns were altered by the pandemic. In the absence of a vaccine during the early years of COVID-19, guidelines associated with non-pharmaceutical interventions required non-essential institutions and establishments such as schools, gyms, restaurants, and other commercial complexes, to be temporarily closed. People also tried to lessen their daily essential activities such as purchasing goods or refueling cars, in order to decrease the risk of infection. Such reduction in mobility could be a proxy measurement for the protective actions for reducing risk of exposure to the virus.

In the Philippines, community quarantine regulations were imposed for one and a half years, from March 2020 until September 2021, making the country hold the title for one of the world's longest lockdown periods (See, 2021). Studies have shown that the implementation of non-pharmacologic interventions such as social distancing or staying at home significantly reduced humans activities (Coleman et.al., 2021, Kartal et.al., 2021), and hence reducing possible transmission of COVID-19. However, despite the prolonged duration of mobility restrictions, over 2 million cases have still been recorded by September 2021 (CNN Philippines, 2021). The indirectly proportional relationship between the longevity of mobility constraint policies and the number of COVID-19 cases presents and stimulating area of study on how people's travel activities and behavior is associated with the different aspects of a pandemic.

Unequal impacts of the pandemic to developing countries and socially vulnerable groups

Moreover, the Coronavirus pandemic impacted nations in differing scales. These effects are a result of every country's respective resource, labor force composition, social and economic structure, among others. In addition, socio-demographic inequality has also been historically related to societal issues such as disaster recovery, educational resources, and health disparities (Cutter et.al., 2003). In the developing research literature of the COVID-19 pandemic, studies have captured the unequal impacts associated with different socio-demographic groups, both at the community and individual level. For instance, when lockdowns ad stay-at-home regulations were imposed during the early months of the pandemic, telework became the most adopted response globally in order to continue economic activities. However, the possibility of working from home is assumed mostly to be low, especially in developing countries (Asian Development Bank, 2020). In the Philippines alone, only 12% of the working force can work from home, and only 25% of the jobs in the country can be conducted via telework (Gaduena et al., 2020). These issues brought about by COVID-19 showed that the world's most vulnerable countries lack the capacity to respond to a global pandemic because of the lack of financial resources, national debt, and fragile health systems. Responses to lockdown policies depend on socioeconomic conditions. Before the pandemic, the population with better socioeconomic conditions showed higher mobility flows. Since the lockdown, mobility presents a general decrease, but the population with the worse socioeconomic conditions shows lower decreases in mobility flows (Dueñas et.al., 2020).

In addition, sustainable and efficient transport system has also been a long-standing issue in Metro Manila, and the pandemic further emphasized this deficiency as public transportation was unable to fulfill its role as a public service (Hasselwander et al., 2021). Most public transport, including mass and paratransit modes, are privately-owned; thereby, operational regulations posed a challenge to implement, causing financial strain on operators. Furthermore, the Philippines is prone to severe tropical cyclones due to its geographical location (PAGASA, 2022). This presents a two-fold challenge of keeping residents safe from both COVID-19 and the typhoon, while noting the difficulty in maintaining physical distancing in temporary shelters. Movement restrictions due to lockdowns could also impede emergency response efforts (United Nations, 2020). The Philippines' distinctive economic structure, transportation system and the overall general state provides a unique setting that can show an alternative perspective on how social vulnerabilities and travel behavior relates to COVID-19 in a developing country.

The pandemic also showed how socially vulnerable groups are affected disproportionately by the negative effects of COVID-19. The continuing lockdown policies have caused great economic impacts to the poorest of society. Unemployment rates increased and low-income households struggled financially.

1.2 Literature review

Transportation constraints in response to virus spread have resulted in radical changes in travel behavior. Non-essential workers were forced to work from home, schools shifted to e-learning, brick-and-mortar shops were required to close; consequently, consumers resorted to food delivery and online shopping (Asian Development Bank, 2020). In the Philippines, the major purpose for traveling before COVID-19 was work-related; however, it has shifted to buying essentials or for leisure since the pandemic began (Mayo et al., 2021). Social distancing, lockdowns, and transport restrictions are few of the most adapted forms of non-pharmacologic interventions to mitigate infection; accordingly, initial measures to limit human mobility resulted in decreased number of Coronavirus related deaths (Hadjidemetriou et al., 2020; Yilmazkuday, 2020). During the pre-lockdown period, people became more dependent on using private vehicles, and public transport mobility decreased due to the elevated risk of virus transmission from close contact (Meena, 2020). Other commuters also resorted to active transport, such as walking and cycling, as an economical yet safe way to travel (Koehl, 2020).

Social characteristics also seemed to play an integral role in understanding the mobility of populations during COVID-19. Marginalized populations lack resources and suffer more during a crisis like a pandemic. Inequities that they already experience will be further intensified resulting in disproportionate and often severe impacts (Weiner, 2020). This conceptual framework, also referred to as social vulnerability, refers to the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard (Wisner et al., 2005). While existing literature on social vulnerability generally has been applied to fields such as, sustainable development, and climate change, the recent pandemic event has initiated the application of social vulnerability in studies related to COVID-19. To cite examples, Coleman et al. (2021) investigated the exposure risk reduction of socially vulnerable populations due to non-pharmacologic interventions or NPIs (i.e., stay at home and social distancing policies). Results showed that socially vulnerable populations engaged in increased mobility between ZIP code areas despite the implementation of NPIs. Similarly, an increased risk exposure for socially vulnerable populations was also observed based on a greater number of visits to points of interest (POI), such as grocery stores or medical facilities, and a greater number of outflow visits from POIs to home census block groups (CBGs), which as a result also increases risk of transmission within CBGs. Lou et al. (2020) also examined how social distance behavior changes for lower income populations and found that stay-at-home policy effect on the lower-income group is smaller than that of the upper-income group by as much as 46%–54%. Furthermore, work-related trips for the very low-income groups did not reduce significantly, unlike for the middle- and perhaps high-income work trips. In the Philippines, sociodemographic groups including women, the elderly, and low-income families have dealt with stressors associated with vulnerabilities further worsened by the implementation of stringent community quarantine measures (Penalba, 2021). Vulnerable social groups can potentially be left behind by government recovery programs. Therefore, it is important to be aware of their needs, especially when resources are limited and immediate action is required.

1.3 Research objectives and scope

Considering the arguments presented in the previous Section concerning the changes in travel behavior as influenced by the pandemic, the following research objectives are devised:

1) To assess the relationship of social vulnerability and COVID-19, and identify how social vulnerability affects the risk of exposure to COVID-19;
2) Identify the impacts of COVID-19 on travel behavior and the resulting changes in trip activities; and
3) Examine the economic and monetary impacts of COVID-19 on commuters' mobility.

The scope of the topic on social vulnerability, travel behavior, and COVID-19 is very wide, which would overwhelm this research if all were considered. Therefore, this work is limited only on the given time period during the earliest year of the pandemic event when vaccine has yet to be available and does not need to be considered yet in terms of how it may affect decisions to travel. In addition, the study also limits its scope to the capital region of Metro Manila. The authors consider that every geopolitical region has its own distinct prevailing industry, which can mold and affect the general travel activity pattern. Therefore, a similar study encompassing different regions should better be approached as comparative research between mobilities in urban cities and rural regions.

1.4 Significance

The current study addresses the gap in providing research on COVID-19 impacts on developing countries. Megacities also provide an exceptional case study considering that the population density provides a conducive environment for rapid virus transmission (Desai, 2020). This research also presents a socioeconomic and transport study related to COVID-19 in the Philippine setting. Furthermore, this study contributes to the growing research on social vulnerability and transport in a pandemic context.

1.5 Structure of the dissertation

The research touches on three aspects of how transportation is influenced and impacted by the pandemic. First are the relationships between social vulnerability and travel behavior to the risk of contracting COVID-19. Second is how mobility and travel behavior has changed as people adapted their lifestyles considering the pandemic. Finally, third is how these changes in mobility have affected the expenditure activities of commuters. Following this conceptual line, the dissertation was composed of five (5) chapters. The organization and structure of the chapters is as shown in Figure 1.1.

This first chapter provides a background about the motivations of this work and outlines the objectives and scope.

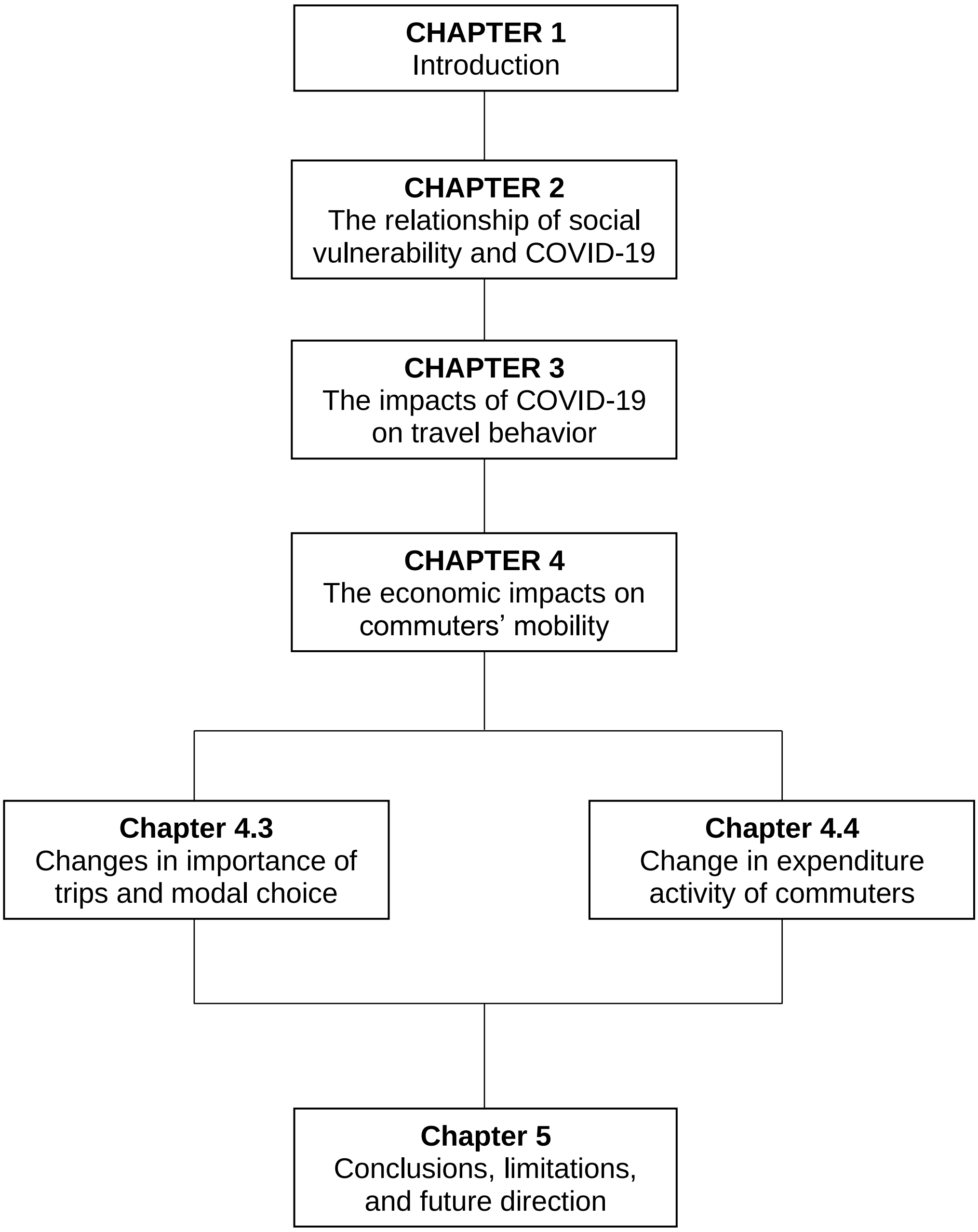


Figure 1.1 Structure of dissertation

Chapter 2
The relationship of social vulnerability with COVID-19

2.1 Socioeconomic characteristics influencing exposure to COVID-19

Social vulnerability pertains to the potential to harm people. It involves a group of factors that define the scale to which a person's life and livelihood are put at risk by a discrete and identifiable event in nature or in society (United Nations Development Program, 2016). It focuses in the political and socioeconomic status of individuals or social groups – such as sex, wealth, education, housing conditions – which affect their level of vulnerability prior to encountering a hazard event (Adger, 2006). There is a diversity of methodological approaches and techniques for quantifying social vulnerability. One of the most well-acknowledged theoretical frameworks is based on the study by Cutter et al. (2003) on social vulnerability which proposes that social characteristics, or indicators such as income level, sex, access to basic services, among others, influence the susceptibility of various groups to harm and govern their ability to respond. Furthermore, the majority of studies applying the concept of social vulnerability consider natural disasters (e.g. typhoons, earthquakes, tsunamis) as hazardous events. As part of this research's novelty, COVID-19 pandemic was considered as a dangerous event.

The consequences of stay-at-home orders are more severe for lower income groups compared to higher-income groups. The economic and work structure gap resulted in disproportionate effects on the ability of low-income workers to lessen mobility, despite stay-at-home orders (Iio et al., 2021; Politis et al., 2021; Coven and Gupta, 2020; Lou et al., 2020). Decreases in individual travel time also depended highly on the type of occupation and continuing major activity through the pandemic. People who are not working from home experienced the least total travel time reductions, especially blue-collar workers (workers using strength or physical skill) (Borkowski et al., 2021). There is also a difference in mobility behavior between male and female commuters. While men travel more for work and more women are staying at home (Pinchoff et al., 2021), women use public transport more often increasing their risk of exposure to the virus (Assoumou Ella, 2021). Likewise, the older age group faces a significant risk of developing severe illness if they contract COVID-19 because of physiological changes as a result of ageing and any possible comorbidity (World Health Organization, 2020a). Impacts of the pandemic, such as employment loss and telework, led to household crowding, a condition that can contribute to an increase in COVID-19 cases (Almagro et al., 2021). In Metro Manila where the average household size is 4.1 (PSA, 2016), and the majority of housing units are less than 20 m2 (PSA, 2013), household crowding is already a pre-pandemic issue. Furthermore, vulnerable populations, such as low-income households, tend to reside in overcrowded structures, increasing their susceptibility to infection. While current literature describes changes in travel behavior for different socioeconomic groups, majority of the studies were either conducted in the United States (Coleman et al., 2021; Lou et al., 2020; Almagro et al., 2021; Coven and Gupta, 2020; Iio et al., 2021; Roy and Kar, 2020; Huang et al., 2020; Sy et al., 2020; Weill et al., 2020), or other developed countries in Europe (Manzira et al., 2022; Assoumou Ella, 2021; Politis et al., 2021; van der Kloof and Kensmil, 2020). Very few studies have focused on developing economies (Kartal et al., 2021; Pinchoff et al., 2021), and even less for Asian countries (Fraiberger et al., 2020). This research addresses the gap and provides an additional context to describe how social vulnerability and travel behavior affect COVID-19 in developing countries.

Sociodemographic factors impact a community's ability to stay home during COVID-19 stay-at-home orders. Communities with higher social vulnerability may have more essentials workers without work-from-home options or fewer resources to stay home for extended periods, which may increase risk for COVID-19 (Fletcher, et al., 2021).

In developing countries like the Philippines, the prevalence of informal sector and low-skill jobs with little scope to work from home or while maintaining physical distance mean that people cannot afford to stay inside homes even if they want to. Many families live on a hand-to-mouth basis with insufficient savings and need to leave their homes daily to access necessities. In addition, commuters rely mainly on informal public transit modes or "paratransit" services such as jeepneys, minivans and shared vehicles. Like business everywhere, the COVID-19 restrictions have hit these modes of transport services severely. Governments have enforced a complete ban or legislated social distancing amid rising cases of COVID-19. The operators of informal paratransit are at greater risk because of their small operating profits, limited financial literacy, lack of access to finance, and fragmented ownership structures. During the pandemic, the elderly proved to be more vulnerable to COVID-19. As they have been advised to stay home, they require social care and access to food, basic supplies, money, and medicine to support their physical health. For low-income groups, working from home is often not a viable option, particularly for those in service-related jobs such as un homes, restaurants, retail, farming, and manufacturing.

Staying at home would mean losing their livelihood income. This makes it difficult for this group to take precautionary measures during a pandemic. Any disruption in the food supply or inflationary prices would affect this group most, possibly resulting in hunger. To exacerbate their problems, they are at least likely to have access to health care. Low-income groups in developing countries also have the lowest rates of access to the internet, making it hard for them to work from home or participate in online learning.

Furthermore, the research formed an additive model to produce the social vulnerability index score (SoVI) which is regarded as the relative measure of the overall social vulnerability of the observed population. This concept of social vulnerability has recently been applied in the context of the COVID-19 pandemic, and findings show a similar relationship between socially vulnerable groups and impacts of the pandemic. To cite, lower-income groups exhibit more work activity during the day making them more at-risk of COVID-19 infection (Dave et al., 2020).

2.2 Data collection and indicator selection

The data used for this analysis was based on an online questionnaire survey for households in Metro Manila, conducted from June 1 to July 31, 2021. The authors note the distinctive characteristics of this time period. Firstly, vaccines or any pharmaceutical interventions were not yet available during this time period; moreover, immunity from the virus need not be considered in studying travel behavior and patterns. Secondly, the country has since developed and implemented varying levels of community quarantine to effectively regulate mobility per geopolitical region. During the period of conducting the online survey, Metro Manila was currently under the “General Community Quarantine” (GCQ) Alert Level characterized by government offices at 100% working capacity, including more non-essential businesses opened (malls, shopping centers, and the likes), and limited public transport (IATF, 2020). With more offices and establishments allowed to continue activities, commuters have more prerogative to travel to work or not, despite the limitations of transit. Moreover, the survey questions were organized into five sections, namely: household socioeconomic characteristics, vehicle ownership, travel activity before, and during COVID-19, and COVID-19 infection status. After data screening, a total of 140 individual response sets were considered for the analyses.

Adapting social vulnerability as defined in the research by Cutter et al. (2003), six (6) social vulnerability indicators were identified from the survey each presumed to exacerbate the risk of contracting COVID-19 (Table 2.1). Indicators were selected based on previous literature identifying socio-economic qualities, travel behavior, and access to private vehicles as some of the factors influencing the risk of virus infection. These were then defined and ascertained a binarized criterion to determine how it contributes to vulnerability to COVID-19 (Table 2.2).

Below are the selected vulnerability indicators and respective literature expounding on the rationale on how each contribute to vulnerability:

Income

Lower-income travelers are more likely to make more daily trips (Lou et.al., 2020; Sy et.al, 2020; Weill et.al., 2020; Politis et.al., 2021). The policy effect (stay-at-home orders) on lower-income groups is smaller than that of the upper-income groups. Orders do not significantly reduce the work-related trips for the very low-income, while reducing middle-and high-income work trips. Orders also significantly reduce non-work mobility for middle-and high-income groups; however, do not reduce per person non-work trips and retail and recreation visits for the very low-income (Lou et.al., 2020). Higher income was associated with larger mobility reduction during the pandemic (Iio et.al., 2021).

Sex

Women are more mobile (more journeys per day) because of the chain of tasks they perform on a daily basis. Domestic responsibilities play a major role in women's mobility, regardless of their status (work, education, family, or residence). Women also show a more sustainable pattern of mobility by traveling more frequently using public transport. There is also evidence that women have experienced greater mobility than men during the pandemic – for work purposes, to do certain essential jobs and to provide food and other essential items for their families – and also used public transport more often than men (Assoumou Ella et.al., 2021; González-Sánchez et.al., 2021). The negative effects (job loss, etc.) result in the loss of women's economic resources for travel, leading to a reduction in the number of distance of journeys and the possibility of using more expensive modes of transport. For example, women are much more dependent on public transport than men, especially in the case of single-parent families, as they are less likely to have a car due to financial reasons. In countries where mobility restrictions have been tightened, public transport has been reduced or even eliminated. This makes life more difficult for women who depend on these services and need to travel to perform everyday activities (European Institute for Gender Equality, 2020).

Occupation

Main occupation is the key factor affecting travel time change during the pandemic (Borkowski et.al., 2021). Health care personnels, or other service-related jobs such as working in retails stores, or in the transportation industry, are essential jobs that cannot be forced to stay at home. This highlights the limitations of how effective stay-at-home policies and the closure of non-essential businesses could enforce social distancing (Shamshiripour et.al., 2020).

Age

Older people are facing the most threats and challenges during the pandemic. While all age groups are at risk of contracting the virus, older people face significant risk of developing severe illness if they get infected by COVID-19 because of physiological changes that come with ageing, weaker immunity, and potential underlying health conditions (World Health Organization, 2020a). Furthermore, older travelers generally maintained their mobility behavior patterns despite their higher vulnerability to COVID-19 disease (Politis et.al., 2021).

Overcrowding

After layoffs of workers decreased commuting, case growth continued through household crowding. A larger share of individuals in crowded housing, or commuting to essential and frontline work are minority and low-income groups – which contributes to disparities in disease risk (Almagro et.al., 2021).

Vehicle access

It was observed that during the pre-lockdown period, people are more dependent upon the personal mode of transportation. The use of shared mobility, such as public transport, has significantly decreased due to the high risk of virus transmission from close contact with unknown people (Meena, 2020). Furthermore, people having access to private cars do not have to limit their mobility due to service disruption because they still have access to their main means of transport (Borkowski et.al., 2021).

Table 2.1 Summary of selected social vulnerability indicators

Indicator	Vulnerability criteria	Rationale
Income	Income below the poverty line	Low-income groups do not significantly reduce work-related trips making them more exposed to higher health risk
Sex	Female	Women have experienced greater mobility and used public transportation more often than men during the pandemic and are thus more likely to be exposed to the virus
Occupation	Essential and health workers	Main occupation is the key factor affecting travel time change
Age	Over 60 years old	COVID-19 is often more severe in people who are older than 60 years
Overcrowding	Person per bedroom > 2	A larger share of individuals in crowded housing contributes to disparities in disease risk
Vehicle access	No access to private vehicle	There is a high risk of exposure for people who use public transit

Social vulnerability indicators were identified based on characteristics which increase the risk of exposure, as found in the existing literature. The final set of six (6) indicators each ascertained a criterion to determine its effect on vulnerability. Furthermore, the social vulnerability indicators were expressed as variables using a binarized point system, where 0 corresponds to non-vulnerable response and 1 to vulnerable. COVID-19 indicator was scored based on the respondent's level of actual exposure to the virus (Table 2.2).

Table 2.2. Binarization of variables (Social vulnerability analysis)

Factor	Variables	Vulnerability criteria	Scoring conditions
Social vulnerability	x_1: Income	Poor or low-income class*	Monthly family income < PHP19,040 = 1; Monthly family income > PHP19,040 = 0
	x_2: Sex	Female	Female = 1; Male = 0
	x_3: Occupation	Essential and health workers	Essential workers** = 1; Non-essential workers** = 0
	x_4: Age	Over 60 years old	60 years old and over = 1; Otherwise = 0
	x_5: Crowding	Person per bedroom > 2 (Blake et al., 2007)	Number of household members per number of bedrooms > 2 = 1; Otherwise = 0
	x_6: Vehicle access	No access to private vehicle	No access to private vehicle = 1; Otherwise = 0
COVID-19	Level of exposure	Have been quarantined or infected	Not exposed = 1; Home quarantined*** = 2; Infected = 3

**The designation of income class is based on monthly family income. PHP19,040 determines the upper limit for the low-income class group (Albert et al., 2018).*

***Essential workers are those who perform health and safety services, or those whose nature of work cannot be performed via telework (e.g., health care workers, public safety officers, transport operators, and the likes). Meanwhile, non-essential workers are those employed in non-crucial occupations and have the option to work from home (e.g., BPO employees, entertainment industry workers, hospitality workers, and the likes.).*

****People who are suspect, probable, or confirmed cases of COVID-19, and who are either asymptomatic or with mild symptoms only and controlled comorbidities, are subject to home quarantine (DOH, 2020b).*

Binarization was the choice of assessment for social vulnerability indicators considering that the nature of most variables is binary (e.g., male or female, essential or non-essential worker, above or below poverty line, senior age group or not, crowded housing or not). Furthermore, normalization of values for indices following the United Nations Human Development Index

(UNHDI) method also uses a scale value of 0 to 1 (UNDP, 2019). This process eliminates the need for normalization usually executed to combine indicators measured in varying units, and the dualistic character of both explanatory and independent variables suggests an easier use and interpretation of data analysis.

Furthermore, by drawing samples repeatedly from a population, the Central Limit Theorem states that the sampling distribution of the means of those samples will become approximately normally distributed as the sample size becomes larger, regardless of the shape of the population distribution. Specifically, the normalized sample mean will approach a standardized normal distribution as the sample size increases, notwithstanding that variable's distribution in the population. Additionally, the z-scores are defined based on the standard normal distribution, which has a mean of 0 and a standard deviation of 1. Following these concepts, the authors determined the target sample size by specifying the level of precision, level of confidence or risk, and the degree of variability in the attributes being measured following the method of population proportion estimation. Using the formula which defines the sampling error as,

$$e = z \times \sqrt{\frac{N-n}{N-1} \times \frac{q(1-q)}{n}} \qquad \text{Eq. 2.1}$$

where, z: z-score, N: total population, n: target sample size, q: degree of maximum variability, the target sample size was determined by specifying the following: sampling error, e = ±10%; z-score for 95% confidence level, z = 1.96; and degree of maximum variability, q = 0.50. Note that (N – n)/(N – 1) is set to 1 considering the actual population is significantly large in comparison with the target sample size. Using the specified criteria, the resulting target sample size is n = 96. Moreover, cross validating the result with published tables on determining sample size, using the same criteria set for sampling error, confidence level, and variability, the resulting sample size for population size >100,000 is n = 100 (Israel, 1992). From the above-mentioned mentioned conditions, the authors deem that the acquired survey responses satisfy the target sample size to obtain statistically reliable survey results.

2.3 The Social Vulnerability Index (SoVI)

Furthermore, the Social Vulnerability Index or SoVI (Cutter et al., 2003) is one of the most well-adapted theoretical frameworks in evaluating the overall vulnerability of an individual or group to natural hazards. While there are other methodological approaches in studying social vulnerability, the SoVI method best represents the available data collected from the online survey. In addition, this process is straightforward and can easily be reproduced and applied for a different scope of study or location for future comparative studies. For this study, the SoVI approach was adopted using data from a survey, and assessed in a pandemic context. In this model, the scores for each indicator were placed in an additive model to represent the relative measure of the overall social vulnerability for every response set. Furthermore, the composite social vulnerability score is computed as the right side of (Eq. 2.2), that is:

$$SoVI = \sum_{p=1}^{6} \beta_p \cdot x_p \qquad \text{Eq. 2.2}$$

The resulting SoVI score is a relative measure of the general social vulnerability of each household. While the general approach is significantly influenced by Cutter and colleagues' SoVI method, the resulting indexes created in this study are modified versions and do not necessarily precisely follow every method from the original. However, basic principles are kept and the adapted SoVI remains to be representative of the relative measure of the overall social vulnerability of each respondent.

2.4 Ordinal logistic regression

To understand the relationship of these vulnerability indicators to the risk of exposure to COVID-19, ordinal logistic regression was employed. Ordinal logistic regression is a statistical analysis method used to model the relationship between one or more explanatory variables and an ordinal response variable (Agresti, 2002). An ordinal variable is a categorical variable with a distinct order of the category levels. Furthermore, the explanatory variables can be either categorical or continuous.

Ordinal logistic regression is an extension of logistic regression where the logit (i.e., log odds) of a binary response variable is linearly associated to the independent variables. If instead the response variable has k levels, it follows that there are k-1 logits. A main assumption of ordinal logistic regression is the assumption of proportional odds, in which the effect of an independent variable remains constant for each increase in the level of the response variable.

In the case of this study, the severity of exposure to COVID-19 namely, not exposed, home quarantined, and infected (Table 2.2), represents the ordinal response variable. The parameterization of this model is represented below:

$$ln\left(\frac{P(J \leq j)}{1 - P(J \leq j)}\right) = \sum_{p} \beta_p \cdot x_p \qquad \text{Eq. 2.3}$$

where, J: random variable, j: response variable where, j = 3 (infected); 2 (home quarantined); 1 (not exposed), βp: coefficient for the vulnerability variable of x_p (p = 1, …,6).

2.5 Results and discussion

The descriptive statistics of the variables used in social vulnerability analysis are presented in Table 2.3. The most common sociodemographic characteristics are the following: 49% belong to upper middle income and above households; 58% are women; 74% belong to non-essential or non-health related occupation; 74% are middle-aged; 66% do not experience household crowding; and 79% have access to a vehicle.

In addition, the variables were evaluated whether they showed some degree of correlation (Table 2.4). Paired correlations were calculated, and the resulting correlation patterns indicate a positive correlation of the level of COVID-19 exposure with all the social vulnerability indicators. These results show that the level of income, sex, type of occupation, age group, household crowding, and lack of vehicle access all contribute to increasing the risk of exposure to the virus. Moreover, the female population (Sex, r = 0.514) appears to have the strongest correlation to this risk. Women tend to travel more for household errands, and usually use public transportation which results to added risk of infection (Assoumou Ella, 2021). These factors contribute to making women more vulnerable to the risk of infection. Lastly, none of the variables are highly correlated; thus, all the indicators can be included in the succeeding regression analysis.

Table 2.3. Descriptive statistics of variables used in social vulnerability analysis

Factor	Indicator	Percentage	National statistics*
Social vulnerability	Income	Poor to low-income: 7% Lower middle income to middle income: 44% Upper middle income and above: 49%	Poverty incidence: 7.8%
	Sex	Female: 58% Male: 42%	Female: 51% Male: 49%
	Occupation	Essential workers: 26% Non-essential workers: 74%	(No available data)
	Age	Below 18 years old: 12% 18 to 60 years old: 74% Above 60 years old: 14%	0 to 14 years old: 29% 15 to 64 years old: 68% 65 years and over: 3%
	Overcrowding	Yes: 34% No: 66%	(No available data)
	Vehicle access	Yes: 79% No: 21%	(No available data)
COVID-19	Level of exposure	Infected: 5% Home quarantined: 15% Not exposed: 80%	Infected: 0.38% (DOH, 2020c)

**Source: Philippine Statistics Authority*

Table 2.4. Paired correlation (r) analysis*

	Income	*Sex*	*Occupation*	*Age*	*Overcrowding*	*Vehicle access*	*Level of exposure*
Income	1						
Sex	0.068	1					
Occupation	0.154	-0.027	1				
Age	0.052	-0.042	0.196	1			
Overcrowding	0.096	-0.006	-0.107	-0.193	1		
Vehicle access	-0.077	0.058	-0.148	-0.105	0.071	1	
Level of exposure	0.396	0.514	0.426	0.291	0.417	0.357	1

**The correlation coefficients were interpreted as follows: ≤ 0.35= low or weak correlations; 0.36 to 0.67 = moderate correlations, and 0.68 to 1.0 = strong correlations, with coefficients ≥ 0.90 = extremely high correlations (Mason et al., 1983).*

Furthermore, it was also found that while 22% of employed individuals experienced income loss, there is no change in the composition of income status indicating that the losses are not big enough to affect or change their income level status.

Results also revealed that poor to low-income families are hardest hit by economic impacts of the pandemic with all employed members experiencing income loss, while the majority of upper-middle to rich families only had at least a member experienced income loss (Figure 2.3).

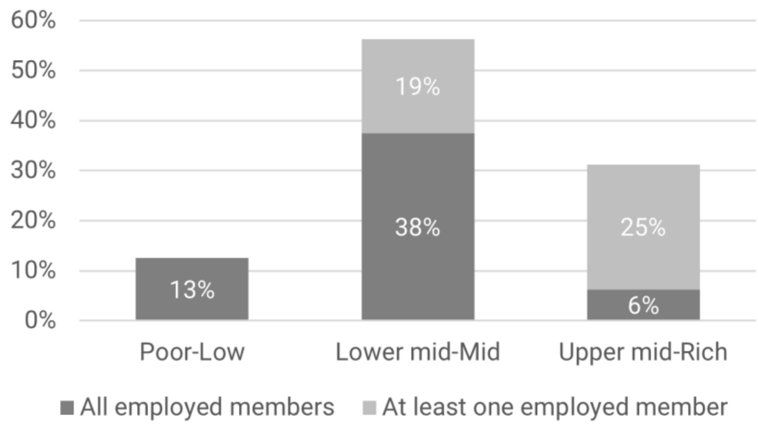


Figure 2.1 Percentage of individuals affected by income loss

Due to mobility restrictions as a response to the pandemic, travel behavior has changed drastically. Survey data showed that work, education, and grocery shopping are the most reduced travel activities since the implementation of community quarantine. Education at 100% decline shows that online learning is still strongly enforced in the country, as face-to-face classes are still suspended. Recreational trips declining at 59% also showed that unnecessary trips, such as trips for tourism, were also lessened in order to minimize risk of contagion. Work trips also decreased to 44% reflecting opposite spectrums of the impacts of the pandemic: that some people can work from home and that there are also people who lost their jobs. The decrease in grocery trips by 38% is a probable result of strict lockdown regulations and fear of contracting the virus in enclosed public areas (Table 2.5).

Table 2.5 Total trip frequency per week of all respondents before and during COVID-19

Trip purpose	Total number of trips for all respondents in a week		Decline in frequency
	Before	During	
Education	112	0	100%
Recreational	145	60	59%
Work	383	215	44%
Grocery	136	85	38%

For grocery trips, it was also observed that 67% of those individuals belong to the 20's to 30's age group. This may be due to information that older adults should avoid making trips to stores and other retail locations which are high-risk for exposure.

Data regarding travel activities before and during COVID-19, and the general change in modal choice is presented in Fig. 2.4 by using Sankey diagrams. Transport modes were categorized into three: private transport, including privately-owned cars or motorcycles; public transport, including trains, buses, taxis, and paratransit like jeepneys and tricycles; and active transport, characterized by walking and cycling. Results showed that there had been a significant decrease in the overall travel demand (55%) due to various travel restrictions implemented to mitigate virus transmission. It can also be observed that most of the commuters who continued to travel during the pandemic opted to use private transport (29%) more than other transport modes. While a significant shift to private modes due to high-risk perception in public transport was noted in other studies (Zhang et al., 2021; Abdullah et al., 2020; Bhaduri et al., 2020), only a minimum shift can be observed from the data. Upon closer observation, 82% of trips which continued to use public transport are characterized by trip durations of less than 30 min. It can be hypothesized that in modal choice, the overall benefits of using public transport, including reduced cost, unnecessary parking, convenience, and efficiency, can outweigh the risk of virus contraction, especially for short distance trips. Short trips suggest a minimal time of possible virus exposure; in addition, the risk can be minimized even further by following social distancing protocols and proper hygiene. It can also be observed that the majority of private and active transport users before the pandemic who continued to travel, did not change their transport mode, and continued to use their pre-pandemic trip mode option.

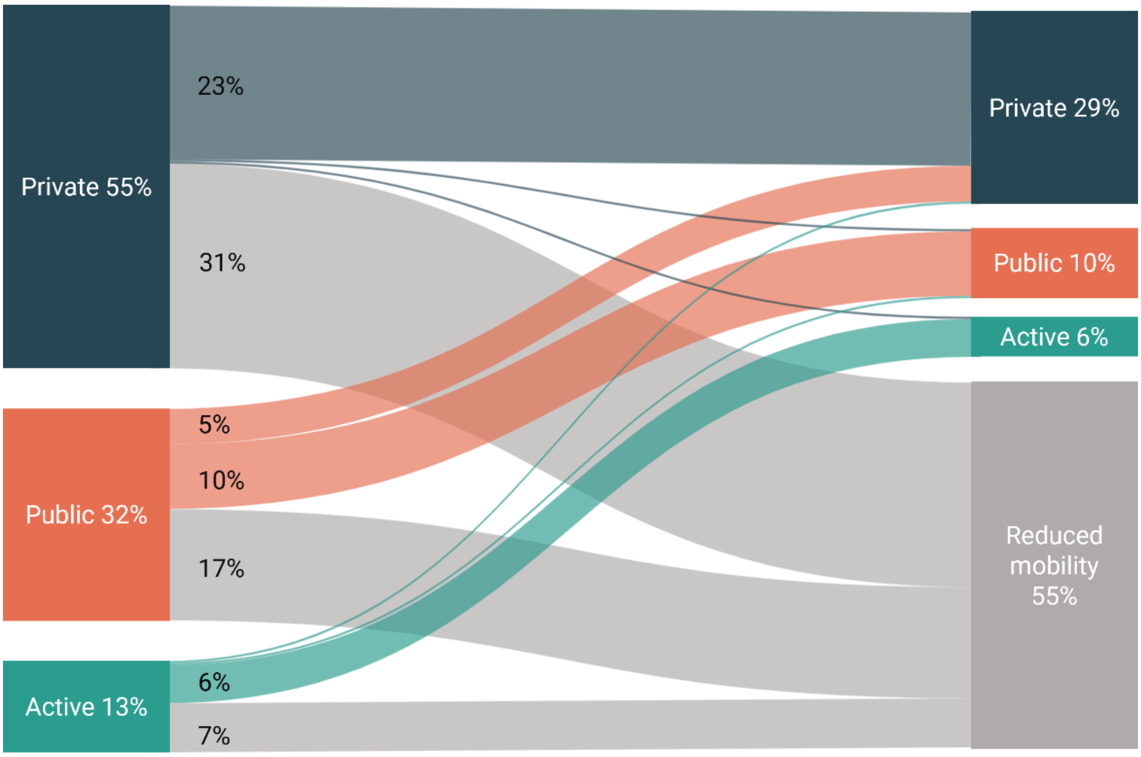


Figure 2.2. Change in modal choice from
before COVID-19 (left column) to during COVID-19 (right column)

The change in the modal choice before and during COVID-19 between essential and non-essential workers was also compared (Fig. 2.5). The increased reliance on private vehicles due to the perceived risk of public modes (Politis et al., 2021; Bucsky, 2020; Meena, 2020) was also observed in the research data. Results showed that private transport was the most preferred mode for workers who continued to travel during the pandemic, for both essential (61%) and non-essential (48%) workers. In addition, more non-essential workers reduced their mobility (32%) compared with essential workers (13%). These support previous studies stating that the capacity to stay at home during the pandemic has been constrained, not only by socioeconomic status, but also by work circumstances (Sy et al., 2020). As economic activities slowly resumed, certain service-related industries reopened following strict health protocols; however, telework continued for industries which can still function in a work-from-home setup. Thus, essential workers who continue to travel are at elevated risk of infection compared to the rest of the population (Milligan et al., 2021).

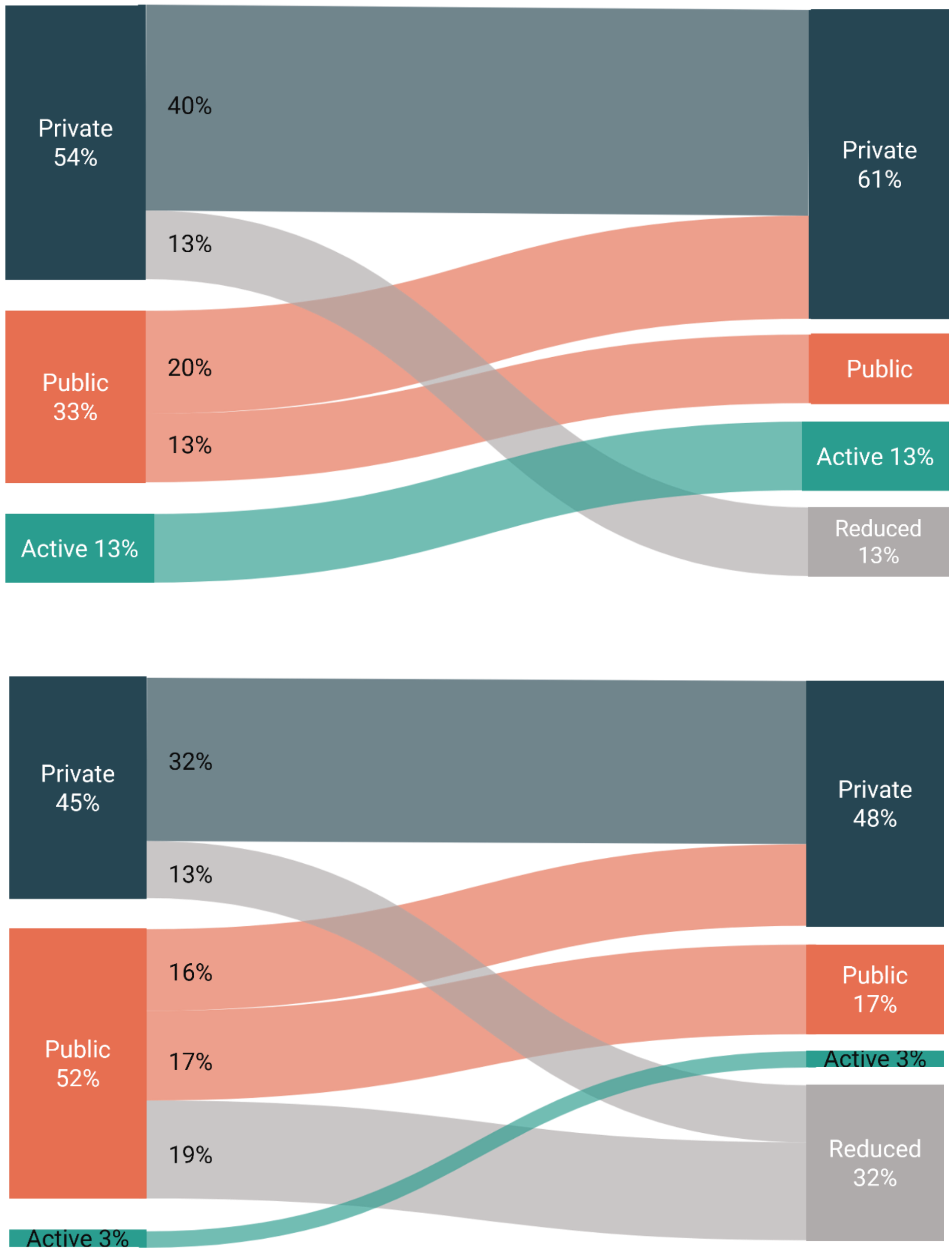


Figure 2.3 Change in the modal choice before and during the pandemic for essential workers (top) and non-essential workers (bottom)

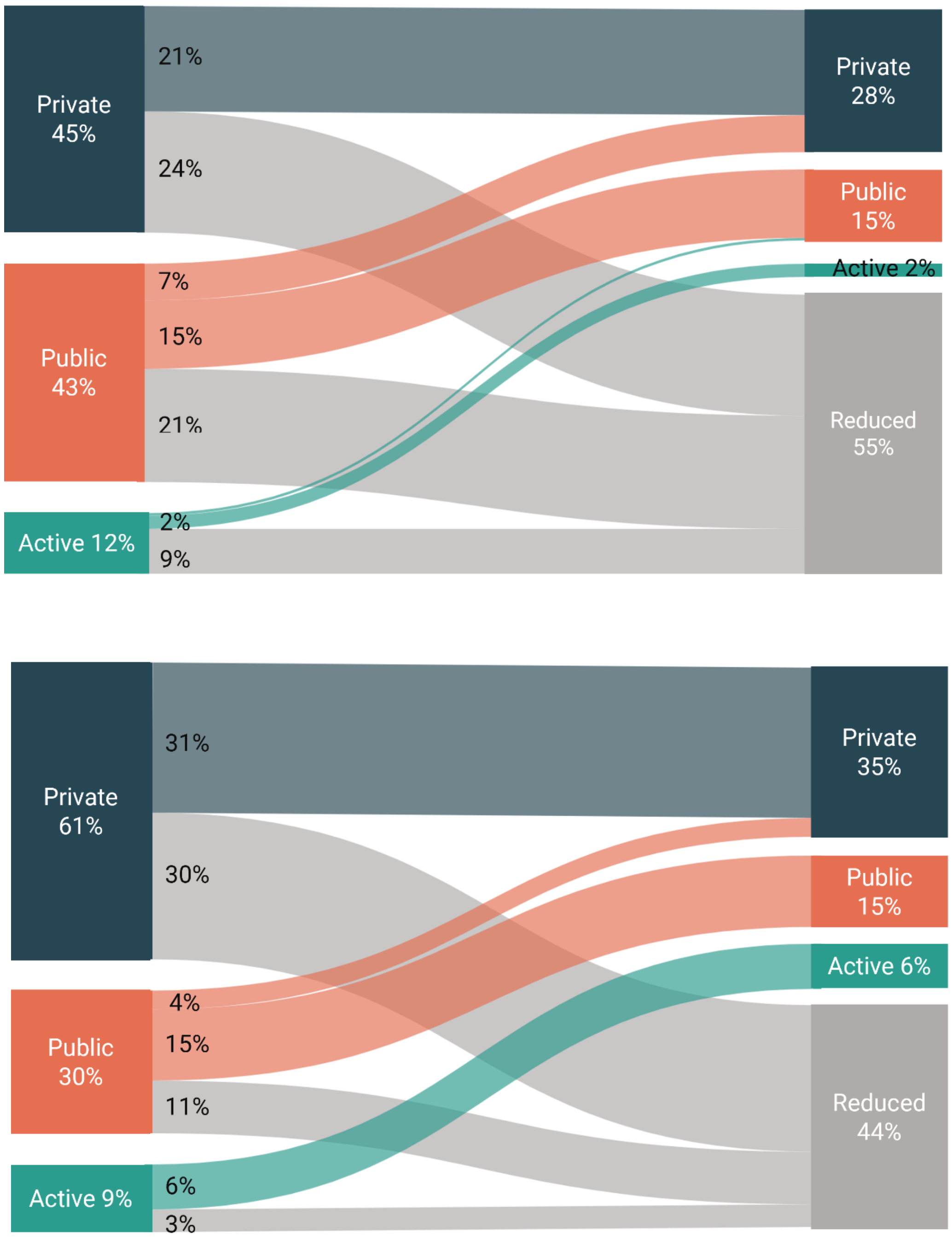


Figure 2.4. Change in the modal choice before and during the pandemic for female (top) and male (bottom)

Comparing the modal choice change between female and male commuters (Fig. 2.6), it can be observed that more women used public transport (43%) than men (30%) before COVID-19.

During the pandemic, more men continued to use private transport (35%), while fewer women did (28%). Similar to earlier studies, more women reduced mobility (55%) compared with men (41%). In Southeast Asia, the Philippines had the most displaced workers, and women were more likely to exit the labor force following job loss than men (Humanitarian Country Team, 2020). Employment loss, displacement of livelihood activities, and quarantine restrictions, whilst lessening mobility, caused women to take a disproportionate share in housework (Dizon and Medina, 2020), childcare and homeschooling, and care for ill relatives (Asian Development Bank, 2021; Humanitarian Country Team, 2020).

Finally, results of the ordinal logistic regression analysis, (R Square 0.719) (Table 2.6) show positive coefficients for all vulnerability indicators. This supports earlier paired correlation results showing that all the social vulnerability indicators promote the risk of exposure to COVID-19. Furthermore, Sex (coef 1.134, p-val 0.000), Occupation (coef 0.775, p-val 0.000), Age (coef 0.521, p-val 0.058), Crowding (coef 0.853, p-val 0.000), and Vehicle access (coef, 0.654, p-val 0.002) generated statistically significant p-value scores, further providing evidence that these vulnerability indicators have an impact on the level of COVID-19 exposure. These results concur with earlier literature stating how socio-economic characteristics affect the exposure or risk to COVID-19. Furthermore, time travel reductions are differentiated among various occupations, especially blue-collar workers (Borkowski et al., 2021). Women may also tend to use public transportation more often than men, contributing to the possibility of contagion (Assomou Ella, 2021). On the other hand, the variable Income did not generate a significant p-value. This can be attributed to the disproportionate population distribution of the response set in terms of income level where only 7% of the responses belonged to the poor to the low-income household group.

The sign of the coefficients also indicates that the results are in line with previous studies used as the foundation for defining social vulnerability as indicated in Table 2.1. Household crowding because of stay-at-home working conditions and mobility restrictions have contributed to the ease of virus transmission (Almagro et al., 2021). Despite travel regulations, lower-income groups are less likely to (be able to) follow such rules (Lou et al., 2020), and could possibly be due to the nature of their employment which do not have the option to work from home (Borkowski et al., 2021). The use of public transport has also been associated with high-risk exposure to the virus, and households who do not have access to private modes of transportation are more susceptible (Shamshiripour et al., 2020). Finally, while senior age groups or those who are 60 years old and above belong to high-risk groups of virus infection (World Health Organization, 2020), results show that younger or middle age groups are more susceptible to exposure. This may be attributed to stricter mobility regulations imposed on older age groups. These vulnerability indicators all contribute to increasing the potential risk of exposure to COVID-19.

Table 2.6. Ordinal logistic regression results

R Squared	*0.719*	Regression: F(6,27) = 54.04, $p < 0.001$		
	Coefficients	*Standard error*	*t-stat*	*P-value*
Income	0.203	0.347	0.585	0.559
Sex	1.134	0.148	7.657	0.000
Occupation	0.775	0.206	3.771	0.000
Age	0.521	0.273	1.912	0.058
Crowding	0.853	0.173	4.919	0.000
Vehicle access	0.654	0.209	3.131	0.002

Results from this study support early and current COVID-19 impacts in Metro Manila. Lower-income groups have a much harder time covering hospitalization expenses or recovering lost income due to suspension of work or unemployment. Despite increasing their exposure, households without access to private vehicles are left without any alternative options but to use public transport for distant travels, prioritizing their need to continue having income over their safety. More recent lockdown regulations have also allowed more people to travel for work, especially those in the middle age group, but remain restrictive to the mobility of senior age group.

Analyzing data on social vulnerability, results showed that Sex, Overcrowding, Occupation, and Vehicle Access are the most common vulnerability indicators among the responses, where 58% of the population are women, 34% are living in crowded housing, and 26% are essential or health workers, and 21% do not have access to a private vehicle. Furthermore, most of the population group are not socially vulnerable in terms of age (14%) and income (7%) (Fig. 2.1).

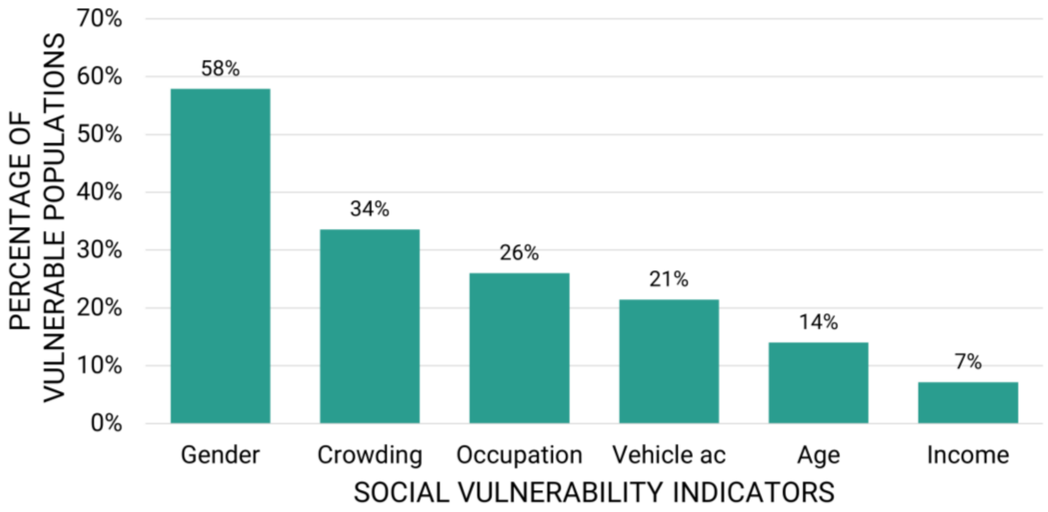


Figure 2.5. Percentage of socially vulnerable population per vulnerability indicator

Adopting the theoretical model of the Social Vulnerability Index or SoVI (Cutter et al., 2003), the relative measure of the overall social vulnerability for every response set was determined. Findings show that, from a possible maximum SoVI = 4.14, most of the responses have a low to moderate level of overall vulnerability (Fig. 2.2). This indicates that while the population is not immediately at risk, they are still characterized by vulnerability factors which make them prone to the negative shocks of the pandemic.

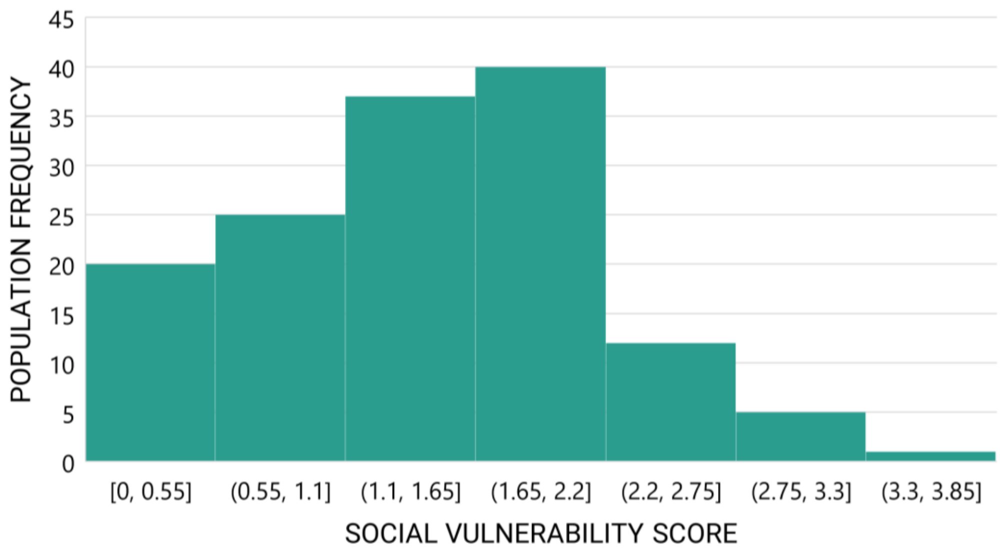


Figure 2.6 Histogram of overall Social Vulnerability Index (SoVI)

These observations underscore that socially vulnerable populations are affected disproportionately during pandemics. Furthermore, travel behavior also significantly shifts based on mobility restrictions and perceived safety of using public transit. Findings from this study can be used as an evidentiary basis for developing initiatives to mitigate the impacts of a pandemic.

Chapter 3
The impacts of COVID-19 on travel behavior

3.1 Changes in travel behavior due to COVID-19

In addition to social inequalities, recent literature also draws attention to how transport played a critical role in the spread of COVID-19. In the Philippines, lockdowns and community quarantines resulted in drastic changes in travel behavior, as well as negative economic impacts to the transport sector and socially vulnerable groups. Even though public transport has been perceived as sustainable, efficient, and an affordable mode of travel, preliminary trends in re-opened cities have shown that public transport is considered relatively risky and is not recovering as quickly compared to the use of private vehicles, cycling, and walking (Asian Development Bank, 2020). Furthermore, strict mobility restrictions and inaccessible public transport resulted in compounded negative economic shocks to poorer households who depend on using mass transport to continue working. This emphasizes how socially vulnerable groups are disproportionately affected by the impacts of the pandemic.

Transport has played a central role in the spread of the virus. It has also played a critical part in enabling frontline and essential workers get to work during the pandemic, and will continue to represent an enabler in terms of supporting the different needs of the population throughout the different stages of recovery. The pandemic's impact on passenger and freight transport has been profound. Mobility restrictions in response to COVID-19 have resulted in drastic changes in travel behavior. Swift lockdowns across the globe forced all non-essential workers to work from home almost overnight, and schools to shift to e-learning. With the closure of shops and restaurants during the containment period, consumers flocked to online shopping and food delivery. The sharp reductions in economic activity have also curbed regional and national freight transport activity. On the other hand, in many places, urban freight and coordination have prospered as a result of increased online shopping and food deliveries.

Numerous countries have taken unprecedented measures to prevent social contact and to slow down the spread of the virus, such as closing schools, shops, restaurants, and bars, prohibiting public events, and stimulating or imposing working from home. These measures can all be labeled as "social distancing," and are especially efficient for diseases (such as COVID-19) which are transmitted by respiratory droplets and require a certain proximity of people. While other countries have taken less stringent social distancing measures, some countries have enforced social distancing by imposing lockdowns in certain regions or the country as a whole.

Social distancing measures have important effects on activity participation. A lot of people are temporarily unemployed or work from home, and most out-of-town leisure activities are canceled. As a result, travel demand decreases and many countries have already witnessed spectacular drops in car traffic (strongly decreasing congestion and air pollution), and in public transport ridership (often resulting in less frequent services). Furthermore, people might still fear social contact when social distancing rules are no longer in force, affecting activity participation and travel.

As a result of social distancing, travel demand might drop due to an increased amount of working from home, e-learning, and a reduced number of public activities and events. People might be more inclined to perform activities at home with family members or close friends. This might result in less car traffic - and less congestion during peak hours - and in reduced public transport ridership. People might also be more inclined to get home-delivery of goods purchased online, resulting in fewer shopping trips. Social distancing might also influence travel mode choice. People might avoid public transport as these can be considered a breeding ground for viruses and places where it might be difficult to avoid contact with other passengers. Those that do not have other options than using public transport might try to avoid crowded buses and trains by traveling during off-peak hours. Of course, this might be difficult if public transport operators decide to decrease capacity or frequency due to low ridership. People with access to a car might be inclined to drive more, as the car “protects” them from other travelers. Because of the reduced travel demand, a higher share of car use will probably not result in more kilometers traveled by car. In fact, less driving and lower amounts of congestion can be expected. An increase in the use of taxis and ride-hailing services, especially of those typically using public transport, might also be expected. Also walking and cycling might - in the case of short trips - increase since social contact can (mostly) easily be avoided during active travel. Due to the reduction of out-of-home activities, people might also walk and cycle more recreationally.

Transportation constraints in response to virus spread have resulted in radical changes in travel behavior. Non-essential workers were forced to work from home, schools shifted to e-learning, brick-and-mortar shops were required to close; consequently, consumers resorted to food delivery and online shopping (Asian Development Bank, 2020). In the Philippines, the major purpose for traveling before COVID-19 was work-related; however, it has shifted to buying essentials or for leisure since the pandemic began (Mayo et al., 2021). Social distancing, lockdowns, and transport restrictions are few of the most adapted forms of non-pharmacologic interventions to mitigate infection; accordingly, initial measures to limit human mobility resulted in decreased number of Coronavirus related deaths (Hadjidemetriou et al., 2020; Yilmazkuday, 2020). During the pre-lockdown period, people became more dependent on using private vehicles, and public transport mobility decreased due to the elevated risk of virus transmission from close contact (Meena, 2020). Other commuters also resorted to active transport, such as walking and cycling, as an economical yet safe way to travel (Koehl, 2020).

3.2 Data collection and indicator selection

Various technological companies have provided anonymized mobility data to support pandemic response and recovery. Since then, literature utilizing such data to understand travel behavior and mobility changes due to COVID-19 has been growing (Assoumou Ella, 2021; Hasselwander et al., 2021; Iio et al., 2021; Bucsky, 2020; Lou et al., 2020; Paez, 2020). This study recognizes the data's limitations in reflecting mobility by sociodemographic; nonetheless, travel data are relevant variables for evaluating the impact of the pandemic on the travel behavior of the population, and in considering the role of transportation in spreading the pandemic. For this research, data from Apple's Mobility Trend Reports (2020) and Google's COVID-19 Community Mobility Reports (2020), aggregated open-source mobile phone and GPS data sources, were used to represent the travel behavior of Metro Manila. Both mobility reports show movement trends by region: the former, by mode of transport (Apple, 2020), the latter, across distinct categories of destinations (Google, 2020).

Apple and Google consider only data of the devices whose users allow their location and moving information to be used anonymously. Hence, Apple and Google can include those people's mobility data in the published mobility data. We know that Apple and Google mobility do not reflect all mobilities. Moreover, these data do not show why (for which purpose) people move. It is known that people move for a variety of aims. Therefore, we acknowledge that Apple and Google mobility data have some shortcomings. However, we think that Apple and Google mobility data can be considered in understanding how mobile people are in a community. Hence, we believe that these data can be used in the analysis of mobility and transport as dependable and accurate.

This study included the period from March 15 to December 31, 2020, for the following reasons: the first lockdown or 'community quarantine' was implemented on March 15, 2020; the first year well covers different epidemic phases and quarantine restrictions; and the unavailability of vaccine at the time. Data from this period can provide valuable knowledge of how people initially reacted to the pandemic solely by adjusting their travel behavior. In addition, dates with one or more missing data were removed from the analysis. Apple data was normalized to a baseline of 0 (average mobility before the pandemic) to correspond with Google's baseline and allow comparison. Positive values indicate an increase from the baseline, whereas negative values indicate a decline.

Data for the number of cases were taken from the official 'COVID-19 Tracker' website of the Department of Health – Philippines (Department of Health, 2020c). Likewise, the number of daily cases in Metro Manila by date of onset of illness was extracted for the period of March 15 to December 31, 2020. To allow comparison, evaluation, and facilitate analysis, standardized coefficients of all data sets were computed. Furthermore, the incubation period for the virus, which is the time between exposure and onset of symptom, can be up to 14 days (World Health Organization, 2020b). Considering this, changes in mobility are expected to have a lagged effect on the tally of new cases; therefore, lagged moving averages of the indicators were calculated. Moreover, there is a possibility that reports of new cases and mobility are endogenous if the population adjusts their travel activity based on reports of new infections. The use of lagged indicators also helps address this potential endogeneity (Paez, 2020). Furthermore, the extended lag time between the dramatic fall in mobility and the end of the exponential growth phase for COVID-19 cases is important for future policy because it demonstrates that if there is a resurgence, and stay-at-home orders are re-issued, cities have to wait for a few or couple of months before reported cases will plateau (Sy et.al., 2020).

Indicators were selected based on recurrent themes found in existing literature showing the relationship between travel behavior and COVID19. Findings include the following: staying at home is one of the most effective ways of reducing the number of cases (Fowler et al., 2021); there is an econometric causality relationship between the number of patients with COVID-19 and mobility, specifically going to groceries and retail shops (Kartal et al., 2021); and that there is an emerging shift to active transport modes as an alternative to using public transport or private vehicles (Bucsky, 2020). Listed in the following table are four (4) mobility variables and COVID-19 indicator variables used in the analyses (Table 3.1).

Table 3.1 Summary of variables (Travel behavior analysis)

Factor	Variables	Description	Data source
Travel behavior	z_1: Residential	Percentage of change in time spent in residences compared to the baseline days (recorded mobility from Jan 3 – Feb 6, 2020)	Google
	z_2: Retail	Percentage of change in visitors to places like restaurants, café, shopping centers, theme parks, museums, libraries, and movie theaters	Google
	z_3: Grocery	Percentage of change in visitors to places like grocery markets, food warehouses, farmers markets, specialty food shops, drug stores, and pharmacies	Google
	z_4: Walking	Relative volume of direction requests, using walking as navigation mode, compared to a baseline volume (recorded mobility on Jan 13, 2020)	Apple
COVID-19	y: Daily new cases	Total number of daily cases by date of onset of illness	DOH

3.3 Multiple linear regression

Multiple linear regression was applied to examine the underlying relationship between travel behavior and daily new cases of COVID-19. This statistical analysis method is an extension of simple linear regression which attempts to model the correlation between two or more explanatory variables and a response variable by fitting a linear equation to the observed data. Moreover, this regression can be used when the dependent or response variable is continuously distributed (i.e. a measurement variable), while the independent or explanatory variables can be continuous, dichotomous, ordinal, or categorical. For this study, the model was represented as follows:

$$y = \alpha_0 + \alpha_1 z_1 + \cdots + \alpha_4 z_4 \qquad \text{Eq. 3.1}$$

where, y: dependent variable (daily new cases), α0: y – intercept, αk: Coefficient for the behavior variable of z_k (k = 1, …,4).

3.4 Results and discussion

In the Philippines, a series of community quarantine measures was enforced by the government to preserve public health against the Coronavirus. Each quarantine level is characterized by varying degrees of restrictions and regulated establishment operations (Table 3.2). These mobility constraint policies brought a radical effect on people's travel behavior, and the relationship between these changes and resulting COVID-19 incidences was evaluated.

Table 3.2 Community quarantine restrictions in the Philippines (IATF, 2020)

Quarantine state	Label	Description	Period in 2020 (mm/dd)
Enhanced community quarantine (ECQ)	Level 5	Strict home quarantine in all households; essential establishments, such as hospitals, courier services, and other similar institutions, can operate at 100% capacity; other essential shops only at 50%; public transport suspended	3/16 to 5/15
Modified enhanced community quarantine (MECQ)	Level 4	Other essential establishments allowed to operate at 100% capacity (media, BPOs, e-commerce, and other similar institutions); non-essential businesses can operate at 50%;	5/16 to 5/3 8/4 to 8/18
General community quarantine (GCQ)	Level 3	Government offices at 100% working capacity, including more non-essential businesses (malls, shopping centers, and other similar institutions); limited public transport	6/1 to 8/3 8/19 to 12/31
Modified general community quarantine (MGCQ)	Level 2	All offices and shops at 100% capacity; mass gatherings (movie screenings, concerts, and the likes) at 50% capacity; limited in-person classes;	-
"New Normal"	Level 1	All restrictions lifted, with minimum public health standards	-

The descriptive statistics of the variables used in travel behavior analysis are shown in Table 3.3. Results show that walking as a transport mode (median − 56) and visits to retail shops (median −

56), such as restaurants and shopping centers, showed the largest reduction. In comparison, while still less than pre-pandemic mobility, grocery establishments were visited more (median − 24). In addition, there is a significant increase in time spent in residences (median 25). These results can be associated with the various community quarantine restrictions implemented across the Philippines effective throughout the year (Fig. 6). Moreover, certain community quarantine constraints did not allow businesses in leisure and entertainment to operate, and only permitted essential trips, such as traveling for health reasons or acquiring necessary goods. Sanctions, like imprisonment or monetary fines, were also imposed on violators of quarantine protocols (CNN Cable News Network Philippines, 2020). Recurrent stay-at-home orders were also put in place and employers were encouraged to opt for telework, especially during periods of exponential increase in cases (de Villa and Santos, 2022). These policies affected travel behavior and resulted in minimized leisure travel activities, moderated essential trips, and more people staying at home.

Table 3.3 Descriptive statistics of variables used in travel behavior analysis

Factor	Indicator	Std dev	Median	Min	Max
Travel behavior	Residential	7.04	25	11	47
	Retail	15.25	-56	-92	-24
	Grocery	17.82	-24	-80	25
	Walking	11.78	-57	-83	-36
COVID-19	Daily new cases	762.75	464.5	49	4174

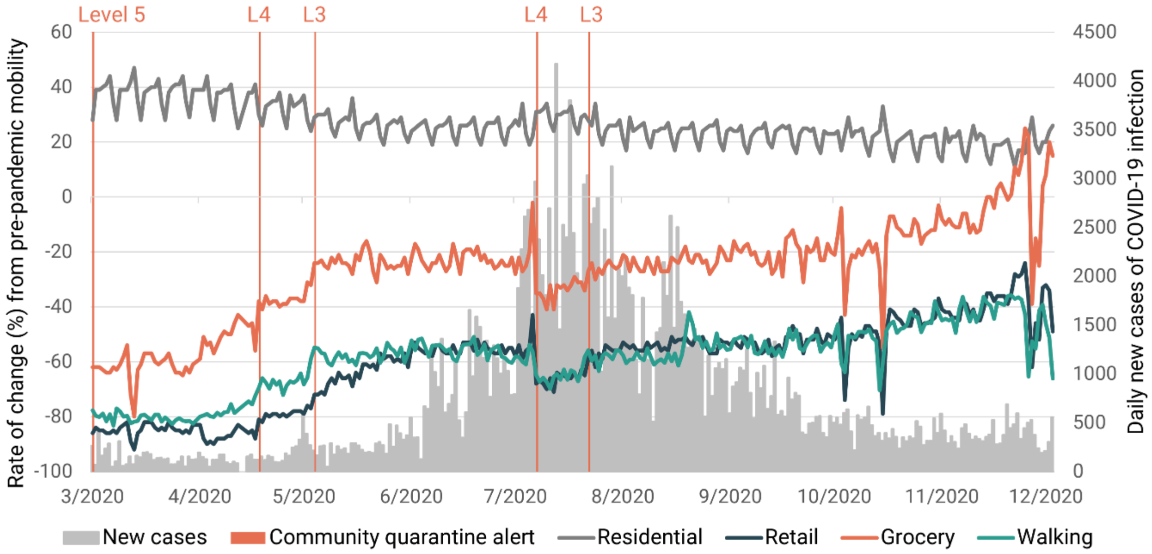
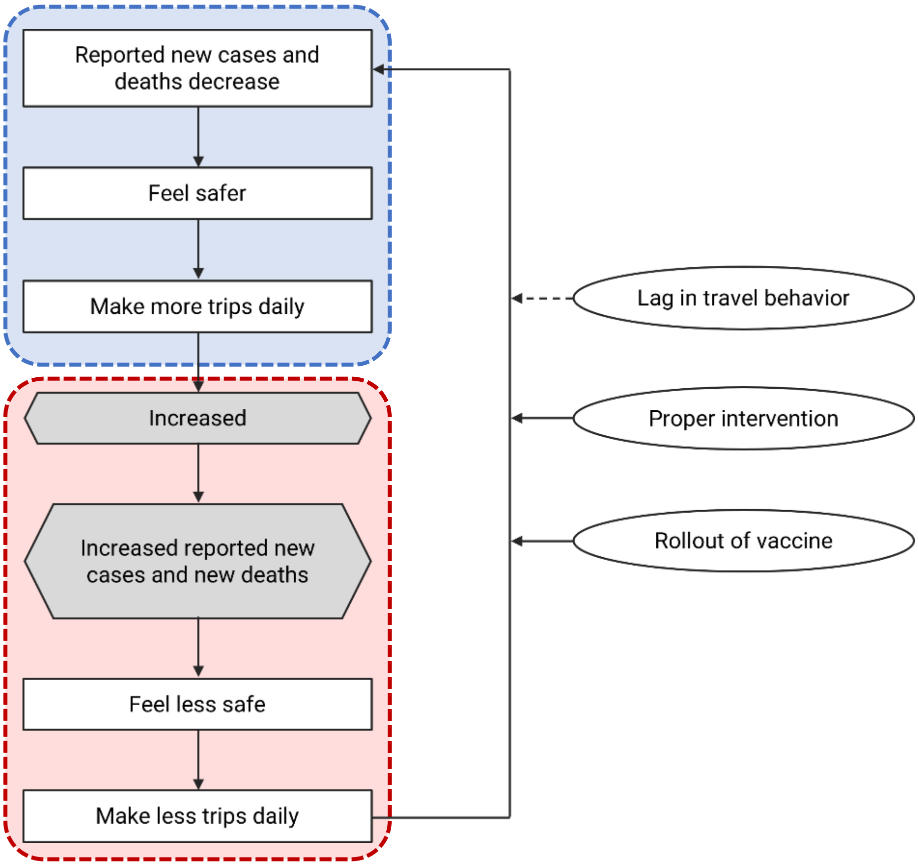


Figure 3.1 2020 Timeline of mobility trend, daily new cases, and community quarantine announcements in Metro Manila

Furthermore, Fig. 3.1 shows a more dimensional assessment reflecting mobility data and the total number of daily new cases in Metro Manila. Upon closer examination, the patterns of mobility and spread of COVID19 reveal a "closed loop scenario" (Fig. 3.2). Under this condition, the residents' travel behavior dynamically shifts based on their risk perception of Coronavirus. The decreasing number of cases and deaths creates an impression that it is safer to go out; however, as the number of trips increases, so as the risk of infection and the number of new COVID19 cases. As a result, people feel less safe and reduce their trips, which eventually leads to decreased number of cases and go back to the beginning of the loop. This behavior pattern continues in an infinite loop unless proper mitigation strategies are implemented (Truong and Truong, 2021). While lockdowns were effective in reducing COVID-19 incidence, its efficacy reduces over time (Pajaron and Vasquez, 2021). From the period of March to June when the number of cases is relatively low, an increase in mobility can be observed. When the cases began to grow exponentially between June to August, and stricter community quarantine policies were implemented, mobility declined. However, despite an unchanged alert level, mobility trends increased again from August to December as the number of cases continually dropped. These observations further highlight that community quarantine policies are effective in controlling travel behavior but decreases eventually. Therefore, mobility is also affected by the commuters' perception of how safe it is to travel. The decline of reported new cases and deaths generates an impression that it is safer to go out since the risk of contracting the virus is lower. Moreover, the 10-month long mobility restrictions could have also caused "quarantine fatigue" (Zhao et al.,

2020) among the population, where social distancing declines and mobility trends increase even before travel constraint policies are lifted.



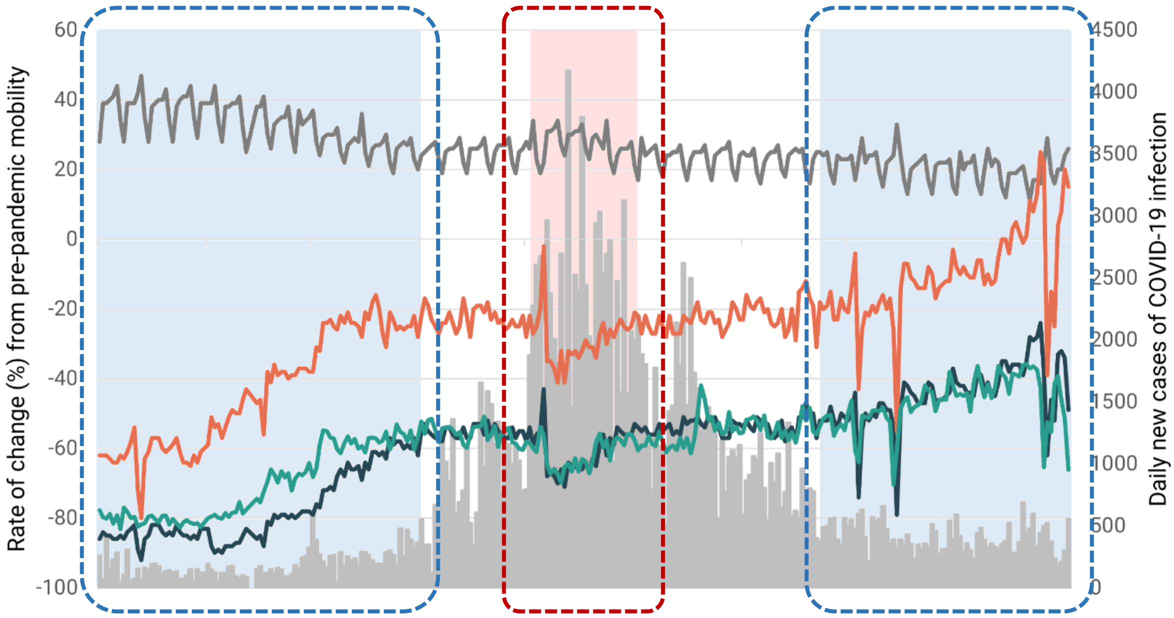


Figure 3.2 Closed loop scenario (Truong and Truong, 2021) (top), and evidence as shown in Metro Manila's mobility (bottom)

The variables were further analyzed to identify correlations (Table 3.4). Results showed generally weak relationships between all the travel behavior indicators and COVID-19. Findings also showed positive associations between the number of daily new cases with visits to retail (coef. 0.205) and grocery (coef. 0.137) stores, and mobility by walking (coef. 0.107). On the other hand, increased time at home resulted in a negative tendency compared with the number of cases. These findings indicate that an increase in trips to retail and grocery establishments, including an increase in traveling by walking, tends to increase the number of COVID-19 cases; in contrast, spending more time at home tends to decrease the number of daily cases. These results support the initial response policies of governments globally to mitigate the spread of COVID-19 by the strict implementation of lockdowns and travel restrictions (OECD, 2022).

Table 3.4. Paired correlation (r) analysis*

	Residential	*Retail*	*Grocery*	*Walking*	*Daily new cases*
Residential	1				
Retail	-0.846	1			
Grocery	-0.814	0.938	1		
Walking	-0.797	0.917	0.889	1	
Daily new cases	-0.166	0.205	0.137	0.107	1

**The correlation coefficients were interpreted as follows: ≤ 0.35= low or weak correlations; 0.36 to 0.67 = moderate correlations, and 0.68 to 1.0 = strong correlations, with coefficients ≥ 0.90 = extremely high correlations (Mason et al., 1983).*

To analyze the relationship between travel behavior and cases of COVID-19, multiple linear regression was employed (Table 3.5). From these findings, visits to retail (coef 1.268, p-val 0.000) and grocery (coef 1.139, p-val 0.000) establishments contribute to the increase in daily cases of COVID-19. Whereas, spending more time at residences (coef − 1.175, p-val 0.008) and traveling by walking (coef − 3.110, p-val 0.000) further decreases the incidences. Furthermore, an increase in visits to retail and grocery shops intensifies the number of daily cases by 1.3 to 1.1 times, while staying at home lessens the number of cases by 1.2 times. Walking as a transport mode resulted in the largest impact on the daily cases, where it can reduce the number by 3.1 times. Comparing the results from the paired correlation and multiple linear regression, it may be reasonable to assume that the travel behavior only partially affects the number of incidences. Moreover, the activities people do at the destinations have more influence on the increase of daily cases. While the resulting R squared is relatively not high (R Squared 0.382), it may be realistic in that, 40% of variability of the number of new cases can be explained by the people's travel behavior, and that there are other external factors to be considered in for a more holistic representation. Correlation results showed that traveling by walking has a weak tendency to increase the number of cases; in contrast, the regression analysis showed an opposite tendency. Overall, findings show that walking is one of the most effective transport modes in preventing the spread of coronavirus. Although walking can somewhat still expose commuters to contagion, simultaneously considering multiple travel behavior factors showed that, walking can still be regarded as a much safer transport mode in comparison with other options, such as private vehicles or public transport.

Table 3.5. Multiple linear regression results

R Squared	*0.382*			
	Coefficients	*Standard error*	*t-stat*	*P-value*
Residential	-1.175	0.438	-2.680	0.008
Retail	1.268	0.295	4.295	0.000
Grocery	1.139	0.264	4.318	0.000
Walking	-3.110	0.288	-10.816	0.000

Walking (and cycling) are sound land use solutions as they ensure social distancing at scale while maintaining connectivity and limiting the need for complex governance and street redesign (Koehl, 2020).

As the lockdown draws longer, mobility towards retail and recreation facilities is ticking upwards. This is an indication that people need to get necessities and earn a living, movement cannot be effective if there are no alternatives to earn and secure daily needs.

Mobility towards transportation hubs may indicate that people are beginning to accept the risk and travel more. In essence, people are making decisions (to travel) despite the constraints – the risk of exposure, potentially lack of full understanding of the disease, and their chances of survival. The mobility trend for the workplaces indicated that fatigue is taking hold, and more people are moving towards their workplaces. This could be a result of the overwhelming population of people who need to earn daily to survive despite the risk. People are venturing out more as the fatigue of staying at home gets overwhelming, and the need to earn a living is becoming more dominant on their mind. Overall, the increase in mobility is an indication of either poor perception of the risk posed by increased mobility and/or adoption of risk avoidance (non-pharmaceutical) measures. While some can afford to stay at home, many cannot as they must earn their living every single day evidently, the mobility restriction is a luxury for some and a severe cost for others. Prolonged lockdown without adequate provision to manage their individual challenges posed to many households will likely witness the waning of compliances as observed. This category of households as well as the rural dwellers were least compliant with the measures. It is well established that vulnerability and extent of the impact of disaster or hazard are a function of location as well as the socioeconomic circumstances of the people affected.

Chapter 4
The economic impacts on commuters' mobility

4.1 Changes in trip priorities and modal choice due to COVID-19

Trip activities, travel behavior, and transport mode preference have significantly changed as we tried to adapt and live through the COVID-19 pandemic. Commuters' travel choices have since then been affected and shaped not only by mobility restrictions in effect, but also by a combination of their socioeconomic group, and their own assessment of prioritizing trips in order to minimize risk of exposure to the Coronavirus.

Transportation constraints in response to virus spread have resulted in radical changes in travel behavior. Non-essential workers were forced to work from home, schools shifted to e-learning, brick-and-mortar shops were required to close; consequently, consumers resorted to food delivery and online shopping (ADB, 2020). Furthermore, various studies have shown significant differences in travel activities and modal choices between socioeconomic groups which affect their risk of exposure to Coronavirus. For instance, women use public transportation more often than men to travel for work increasing their probability of virus exposure (Assoumou Ella, 2021). In addition, mobility drops in France were also strongly associated with workers employed in sectors highly affected by lockdowns (Pullano et al., 2020). These studies provide evidence that changes in travel behavior may be different across different social groups.

Furthermore, non-pharmacologic interventions such as teleworking and social distancing, have been globally implemented measures to mitigate the spread of the virus. Considering various mobility restrictions, in addition to the risk of contracting COVID-19 by traveling, commuters needed to consider the importance of making specific trips and what transport mode should be used. Trip activities were prioritized and modal choice was carefully considered. As a result, a change in importance of trips and modal choice may possibly be observed among travelers.

Based on these aforementioned hypotheses, the objective of this study is to identify the changes in travel behavior among social groups, and assess the change in the importance of trips and modal choice before and during the COVID-19 pandemic in Metro Manila, Philippines.

4.2 Data source

The data used for this study was based on an online survey distributed to households residing in Metro Manila, and was conducted from June 1 to July 31, 2021. The survey includes questions on socioeconomic characteristics and the travel activities of the respondents before and during COVID-19. After data cleaning, a total of 140 responses were used in the analyses. Moreover, the travel activities recorded include work, grocery, and recreational trips, which are further described by transport mode, frequency, duration, and fare.

The mobility indicators (work, grocery, and recreation) were selected based on themes found in existing studies exploring the relationship between COVID-19 and travel behavior. For instance, the number of new COVID-19 daily infections indicates some form of positive linear correlation with visits to workplaces (Camba and Camba, 2020). In the Philippines, the major reason for traveling before the pandemic was work-related but has shifted to buying essentials or for leisure or recreation since the pandemic (Mayo et al., 2021). Such findings became the basis of formulating the hypothesis that there are changes in travel behavior due to the various mobility restrictions to mitigate virus spread, as well as the risk perception of contagion.

4.3 Changes in importance of trips and modal choice

As we change our lifestyle to adapt and live through the COVID-19 pandemic, various changes in trip activities, travel behavior, and travel mode preference has then been observed. The commuters' travel choices have been shaped and affected, not only by different mobility restrictions, but also by a combination of their socioeconomic characteristics (Ancheta et al., 2023), and their personal assessment of prioritizing trips in order to minimize the risk of exposure to the Coronavirus.

Restrictions in transportation and mobility, in response to mitigating virus spread, have resulted in radical changes in travel behavior. Schools shifted to conducting online classes, non-essential workers were required to work remotely from home, and brick-and-mortar shops were forced to close; consequently, consumers resorted to food delivery and online shopping for their daily needs (ADB, 2020). In the Philippines, work was the major purpose for traveling before the COVID-19 pandemic; however, as a result of mobility restriction, it has shifted to leisure or buying daily essentials (Mayo et al., 2021). Social distancing, lockdowns, and various transport constraints are few of the most adapted forms of non-pharmacologic interventions to mitigate virus spread; accordingly, initial measures to limit human mobility resulted in decreased number of Coronavirus related deaths (Hadjidemetriou et al., 2020; Yilmazkuday, 2020). Due to this correlation between traveling and risk of COVID-19 infection, which can lead to mortality, it became necessary for commuters to consider the importance of making specific trips and which transport mode should be used – may it be based on trip fare, commuting time, convenience, or health safety reasons. Trip activities were prioritized and modal choice was carefully considered. As a result, a change in importance of trips and modal choice may possibly be observed among travelers.

4.3.1 Multinomial logit model and parameter estimation

Firstly, the generalized cost of each respondent $k \in K$ who made trip $i \in I$ was identified and computed using the following equation:

$$g_{i,s}^{k} = c_{i,s}^{k} + \tau \cdot t_{i,s}^{k} \quad k \in K, i \in I, s \in S \qquad \text{(Eq.4.1)}$$

where,

$g_{i,s}^{k}$: generalized cost

$c_{i,s}^{k}$: trip fare

$t_{i,s}^{k}$: travel time

i : trip purpose

τ : Value of Time, valued at 121.67Php/hour (Pique, 2018)

K : set of respondents,

$I = \{w, g, r\}$: set of trip purposes, where *w* = work, *g* = grocery, *r* = recreation,

$S = \{n, c\}$: set of COVID-19 states, where *n* = normal, *c* = during COVID-19

Using the generalized cost, the utility of every trip was calculated. If the individual *k* chooses transport mode $j \in J$, the utility of the trip purpose of $i \in I$, under COVID-19 state $s \in S$, $v_{i,s}^{k}$, is:

$$v_{i,s}^{k} = -g_{i,s}^{k} + a_{i,s} + \beta_{j,s} \quad k \in K, i \in I, s \in S, \qquad \text{(Eq.4.2)}$$

where,

$a_{i,s}$: trip purpose specific constant for $i \in I$ under $s \in S$

$\beta_{j,s}$: mode specific constant for $j \in J$ under $s \in S$

$J = \{pc, pt, a\}$: set of transport modes, where pc = private car, pt = public transport, a = active transport

Next, the cumulative trips for each respondent were assessed utilizing the logit equation of probability. The model was formulated as:

$$p_{i,s}^{k} = \frac{\exp(v_{i,s}^{k})}{\sum_{l \in I} \exp(v_{l,s}^{k})} \quad \forall k \in K, \forall i \in I, \forall s \in S \qquad \text{(Eq.4.3)}$$

where,

$p_{i,s}^{k}$: probability of respondent k choosing trip purpose i under state s

Finally, to represent the importance of each trip purpose and trip mode, the following log-likelihood function was maximized:

$$\max \sum_{s \in S} \sum_{k \in K} \sum_{i \in I} f_{i,s}^{k} \cdot ln\left(p_{i,s}^{k}\right) \quad \forall k \in K, \forall i \in I, \forall s \in S \qquad \text{(Eq.4.4)}$$

w.r.t $a_{i,s}$, and $\beta_{j,s}$.

where,

$f_{i,s}^{k}$: frequency per week of each trip i under state s

Note that the coefficients for recreational trips and active transport (i.e., walking and cycling) are held constant in this analysis. This assumes that neither trips for leisure nor active transport experienced a change in importance during the pandemic. Furthermore, this analytical procedure was applied to trip activity before and during COVID-19 to compare changes in the resulting maximized functions.

4.3.2 Results and discussion

Table 4.1 Results of multinomial logit model and parameter estimation

(Likelihood ratio index 9.98e+03)

Variables	Before COVID-19 (t-statistics)	During COVID-19 (t-statistics)
Work	123.98 (56.54)	129.90 (49.80)
Grocery	349.84 (86.80)	367.93 (97.82)
Private mode	303.06 (79.60)	342.71 (81.23)
Public mode	130.52 (68.52)	155.43 (62.46)

Findings from the multinomial logit model and parameter estimation represent the importance of trips and modal choice, and are presented in Table 2. Comparing the results for the data before and during COVID-19, it can be observed that generally, all of the indicators increased in importance during the pandemic. However, only the indicators for *work*, *private mode* and *public mode* were found to be statistically significant

The importance of trips to work increased in importance during the pandemic, and this further emphasized that there is always a necessity to travel for work as a means to attain financial resources in order to support primary needs, such as food and housing. With the economic instability brought about by the pandemic, and uncertainties of when the pandemic will conclude, trips to work became more essential than ever – especially in developing countries where national resources and health support are extremely limited. Such findings demonstrate how work trips have to be considered as essential activity, and that they must be included in strategies and policymaking in order to allow work trips whilst community lockdowns are implemented.

In addition, there is also an observed increase in importance for both private and public transport modes. These results further emphasize the important role of transportation in the continuation of economic activities during a pandemic – and most especially for public transport. Considering the Philippines is a developing country where public transport is the chosen mode especially for day-to-day subsistence activities (Bandyopadhyay, 2020), those without access to private vehicles were disproportionately affected by lockdowns and mobility restrictions having less, if no, other option to travel. Moreover, only 12% of the working force can work from home, and only 25% of the occupations in the Philippines can be conducted via telework (Gaduena et al., 2020). With fewer industries which can work remotely, and more people dependent on mass transit for mobility, the importance of public transport for guaranteeing access and continuity of basic services is even further highlighted.

While trips to groceries showed an increase in importance, the effects are not statistically significant. However, it is notable how trips to grocery showed the largest magnitude. This result may be associated with the increased frequency and volume of home cooking. During the early phase of the pandemic, lockdown policies required people to stay at home, and certain businesses, like food establishments, to halt operations. More family members were expected to stay put at residences, and with no option to dine at restaurants, aside from occasional food deliveries, cooking at home became the safest and most cost-efficient way for food consumption (ADB, 2020).

The likelihood ratio index statistic test was performed to measure how well the model fits the data. The statistic measures how well the model, with its estimated parameters, performs compared with an initial model in which all the parameters are zero. This comparison is made on the basis of the log-likelihood function, evaluated at both the estimated parameters and at zero for all parameters.

The likelihood ratio index, i.e., known as McFadden's ρ^2, is represented as:

$$\rho^2 = \frac{\ln L\,(\mathbf{0}) - \ln L\,(\boldsymbol{\beta})}{\ln L\,(\mathbf{0})} \qquad \text{(Eq.4.5)}$$

where ln $L(\boldsymbol{\beta})$ denotes the value of the log-likelihood function at the estimated parameters and ln $L(\mathbf{0})$ is its value when all the parameters are set to zero. If the estimated parameters are not better, in terms of the likelihood function, than zero parameters (that is, if the estimated model is no better than no model), then ln $L(\boldsymbol{\beta})$ = ln $L(\mathbf{0})$ and so $\rho^2 = 0$. This is the lowest value that ρ^2 can take (since if ln $L(\boldsymbol{\beta})$ were less than ln $L(\mathbf{0})$, then $\boldsymbol{\beta}$ would not be the maximum likelihood estimate. Furthermore, since the resulting test statistic (ρ^2 = 9.98e+03) is greater than 0.2, the model satisfies the goodness-of-fit criteria.

Furthermore, following the z-statistic formula based on two random variables with different standard deviations and different variance, the difference of the estimated parameters was calculated. This was achieved by identifying the corresponding standard deviation of each estimated parameter, and finding the resulting difference between the values before and during COVID-19. The resulting absolute z-score are as follows: *work* = 20.33, *grocery* = 0.61, *private transport* = 4.38, and *public transport* = 7.95. From these results, it showed that the parameters for *work*, *private transport*, and *public transport* generated absolute z-scores ≥1.96, implying that the difference is significant. On the other hand, *groceries* generated an absolute z-score ≤ 1.96, inferring that the difference between parameters is insignificant. Furthermore, the resulting z-scores for all the indicators support the initial hypothesis.

Results provide empirical evidence implying the focus of infrastructure developments should be geared towards improving public transport. The authors also point out that while other studies showed a general decline in public transport use and inclination of using private modes during the pandemic (Abdullah et al., 2021; Abdullah et al., 2020; Bucksy, 2020; Meena, 2020), this study focuses on determining the change in importance, not the preference, of transport mode. Furthermore, importance and preference do not necessarily correlate; thus, further analysis is required to determine any underlying relationship between the two factors.

Moreover, the difference in tendencies between the importance and preference of transport mode choice also presents a challenging scenario in achieving sustainability in transportation. As earlier mentioned, studies showed commuters prefer private cars especially during COVID-19; however, mass shift to driving would make cities even more congested and polluted than they already are, and in many cases, not everyone can afford a car, especially in developing countries. Commuters must regain confidence in using public transport again by adopting policies and strategies which will lessen the risk of virus transmission during a pandemic event.

Furthermore, as we examine the generated values for each variable, it can also be observed that there were several factors which affected the trip choice of travelers before COVID-19. Specific constants were generated for the variables *Work*, *Private mode*, and *Public mode* which implies that these factors also influenced the trip choice of commuters before COVID-19. In comparison, the values for trip modes during the pandemic are both approaching zero. From these results, it can be hypothesized that transport mode did not significantly impact the trip choice of commuters during the pandemic. After COVID-19, only two factors, the generalized cost and purpose specific constant of *Work*, influence the commuters' trip choice. These findings further emphasize that despite mobility restrictions to mitigate virus transmission, work remains to be an important factor in trip choice even during the pandemic, and this may be due to the difference in nature of work (Sy et al., 2020). As previously stated, the capacity to stay at home is not only dependent on social status, but also on the type of work. Some occupations cannot be performed via telework; thus, depending on their job, workers still needed to make work trips despite COVID-19.

Studies have showed that due to various factors such as socioeconomic aspects, perceived risk of virus infection, and availability of transport mode, among others, the travel behavior of commuters have drastically changed since the beginning of the pandemic. To further explore on this observation, The logit equation of probability represented on Equation 2 was formulated in order to determine the probability of respondents in choosing a trip purpose considering trip characteristics before and during the pandemic situation.

4.4 Change in expenditure activity of commuters

4.3.1 Utility maximization problem and indirect utility function

The concept of a utility function as a convenient device or as an equivalent approach to describe consumer behavior, constitutes a major element of the foundations of consumer theory (Barten and Bohm, 1982). The ordinary utility function, u(x), is defined over the consumption set X and represents the consumer's preferences directly (Eilenberg, 1941). On the other hand, the indirect utility function represents the relationship among prices, income, and the maximized value of utility. Moreover, given prices p and income I, the consumer chooses a utility maximizing bundle x(p,I). The level of utility achieved when x(p,I) is chosen and thus will be the highest level allowed by the consumer's budget constraint considering prices p and income I. Different prices or incomes, giving different budget constraints, will generally give rise to different preferences by the consumer and so to different levels of maximized utility. Furthermore, the indirect utility is the maximum-value function corresponding to consumer's utility maximization problem (Cornes, 1992).

Relating the concept to this study, utility was defined as a combination of composite goods, or all goods except transportation goods (x_1) and transportation goods (x_2). Transportation goods are further categorized into two bundles of goods, namely: trips to *work* and trips to *grocery.* Furthermore, these bundles are described by each goods' respective prices, or their generalized cost.

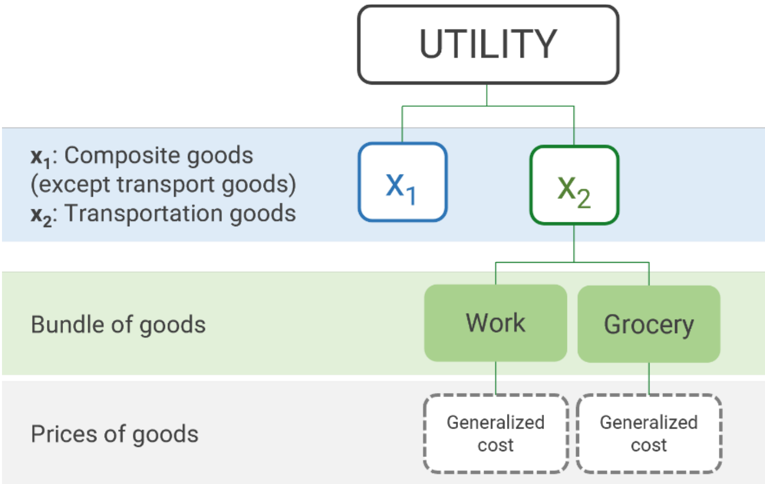


Figure 4.1 Conceptual framework for utility

Based on this framework, this research aims to evaluate how the changes in consumption of trips and goods affect commuters' utility in terms of monetary expenditures before and during the pandemic. To achieve this, an indirect utility function was represented following the CES, or constant elasticity of substitution, utility function. The utility of each individual respondent is formulated in this section to obtain their respective indirect utility before and during COVID-19.

The first level utility maximization problem is represented as:

$$max\ u_s^k\left(x_{1,s}^k, x_{2,s}^k\right) = x_{1,s}^k + \alpha_{2,s}^k \cdot {x^k}_{2,s}^{\frac{\sigma_0 - 1}{\sigma_0}} \quad \forall s \in S, \forall k \in K \qquad \text{Eq. 4.5}$$

$$s.t. \qquad I_s^k = x_{1,s}^k + p_{2,s}^k \cdot x_{2,s}^k \ \forall s \in S, \forall k \in K \qquad \text{Eq. 4.6}$$

where

$$p_{2,s}^k = \prod_{i \in I} \left(\frac{\gamma_{i,s}^k}{g_{i,s}^k}\right)^{-\gamma_{i,s}^k} \quad s \in S, \forall k \in K \qquad \text{Eq. 4.7}$$

$p_{2,s}^k$: price for composite goods for $x_{2,s}^k$ of individual k under state $s \in S$ for every respondent $k \in K$

$x_{1,s}^k$: composite goods individual k consumes under state $s \in S$ for every respondent $k \in K$

$x_{2,s}^k$: the consumption level for trip purpose $\{w,g\}$ of individual k, under state $s \in S$ for every respondent $k \in K$

$\gamma_{i,s}^{k}$: parameter gamma for the trip purpose $i \in I$ under state $s \in S$ for every respondent $k \in K$

σ^{0} : nonnegative parameter for substitution of elasticity

I_{s}^{k} : income under state $s \in S$ for every respondent $k \in K$

By solving above utility maximization problem, we obtain

$$x_{1,s}^{k} = I_{s}^{k} - \left(\frac{\sigma_0 - 1}{\sigma_0} \cdot \frac{\alpha_{2,s}^{k}}{p_{2,s}^{k}}\right)^{\sigma_0} \cdot p_{2,s}^{k} \; s \in S, \forall k \in K \quad \text{Eq. 4.8}$$

$$x_{2,s}^{k} = \left(\frac{\sigma_0 - 1}{\sigma_0} \cdot \frac{\alpha_{2,s}^{k}}{P_{2,s}^{k}}\right)^{\sigma_0} \; s \in S, \forall k \in K \quad \text{Eq. 4.9}$$

$p_{2,s}^{k}$ can be obtained by solving the following second level utility maximization problem:

$$max\ x_{2,s}^{k} = \prod_{i \in I} \left(f_{i,s}^{k}\right)^{\gamma_{t,s}^{k}} \; s \in S, \forall k \in K \quad \text{Eq. 4.10}$$

$$s.t. I_{2,s}^{k} = \sum_{i \in I} g_{i,s}^{k} \cdot f_{i,s}^{k} \; k \in K,\; s \in S \quad \text{Eq. 4.11}$$

where

$$\gamma_{i,s}^{k} = \frac{g_{i,s}^{k} \cdot f_{i,s}^{k}}{I_{2,s}^{k}} \; k \in K, i \in I, s \in S \quad \text{Eq. 4.12}$$

$f_{i,s}^{k}$: frequency per week of trip purpose $i \in I$ under state $s \in S$ for every respondent $k \in K$

$I_{2,s}^{k}$: total income used for transportation under state $s \in S$ for every respondent $k \in K$

The indirect utility function is finally calculated as:

$$v_{s}^{k} = I_{s}^{k} - \left(\frac{\sigma_0 - 1}{\sigma_0} \cdot \frac{\alpha_{2,s}^{k}}{P_{2,s}^{k}}\right)^{\sigma_0} \cdot p_{2,s}^{k} + \alpha_{2,s}^{k} \cdot \left(\frac{\sigma_0 - 1}{\sigma_0} \cdot \frac{\alpha_{2,s}^{k}}{P_{2,s}^{k}}\right)^{\sigma_0 - 1} \; \forall s \in S, \forall k \in K \quad \text{Eq. 4.13}$$

The generated values for every variable were then substituted to the indirect utility formulation, and results were compared for trip activities before and during the pandemic for each individual respondent.

4.4.2 Results and discussion

In this research, the indirect utility function describes the individual commuter's maximum attainable utility, considering prices of goods (i.e., transportation services) and a specified amount of income. This can be utilized to indicate a general overview of both the prevailing market conditions and the commuter's preferences. Furthermore, the hypothesis is founded on the idea that due to the various limitations in transport mode options and travel activities, there is a possible effect on the commuter's indirect utility, i.e., a decrease in the maximum attainable utility**.**

Looking at the results from the analysis on Section 3.4, it can be observed that generally, the resulting indirect utility became significantly less during the pandemic (Figure 4.1). There are no resulting plotted data above the 45-degree baseline, indicating that there has been no increase in indirect utility during the pandemic. Such results imply that the maximum utility that can be achieved by spending the income on the consumption of transportation has decreased as an effect of the travel behavior changes during COVID-19. It can also be observed that there were respondents whose utility did not significantly change despite the circumstances of the pandemic (Figure 4.1, bottom).

Upon closer observation of some of the respondent's trip characteristics and resulting indirect utility (Table 4.2), the abovementioned results can be further examined. While reductions in trip frequencies consequently result to decreased generalized cost, the maximum utility, or satisfaction level, attained by the respondents generally decreased in value. With the minimum wage rates in Metro Manila (for non-agriculture sectors) at PhP 570.00 (Department of Labor and Employment, 2022), it can be deduced that the diminished utility is substantial in value considering the possible daily minimum wage or income rate. It also follows that the decrease in the level of satisfaction for transportation services can affect the commuter's future trip decisions.

Moreover, the resulting indirect utility was also assessed and compared with the respondents' corresponding SoVI score. It was found that 62% of respondents with more than 50% decrease in utility have SoVI > 1.1 (i.e., at least 2 vulnerabilities; 40% of respondents without changes in utility have SoVI – 0; and 64% of respondents with less than 50% decrease in utility have SoVI < 1.1 (i.e., at least 1 vulnerability). In addition, respondents whose indirect utility did not change with SOVI = 0 are found to be generally non-vulnerable in terms of *income* and age. They also have exactly the same trip characteristics before and during the pandemic. These findings show that there may be an underlying relationship between the SoVI, or general vulnerability, of each respondent and the intensity of indirect utility loss that they experience. Furthermore, the results provide empirical evidence which may be used to provide insight for future studies on understanding transport demand during a pandemic, which accordingly affects the cost of transportation services.

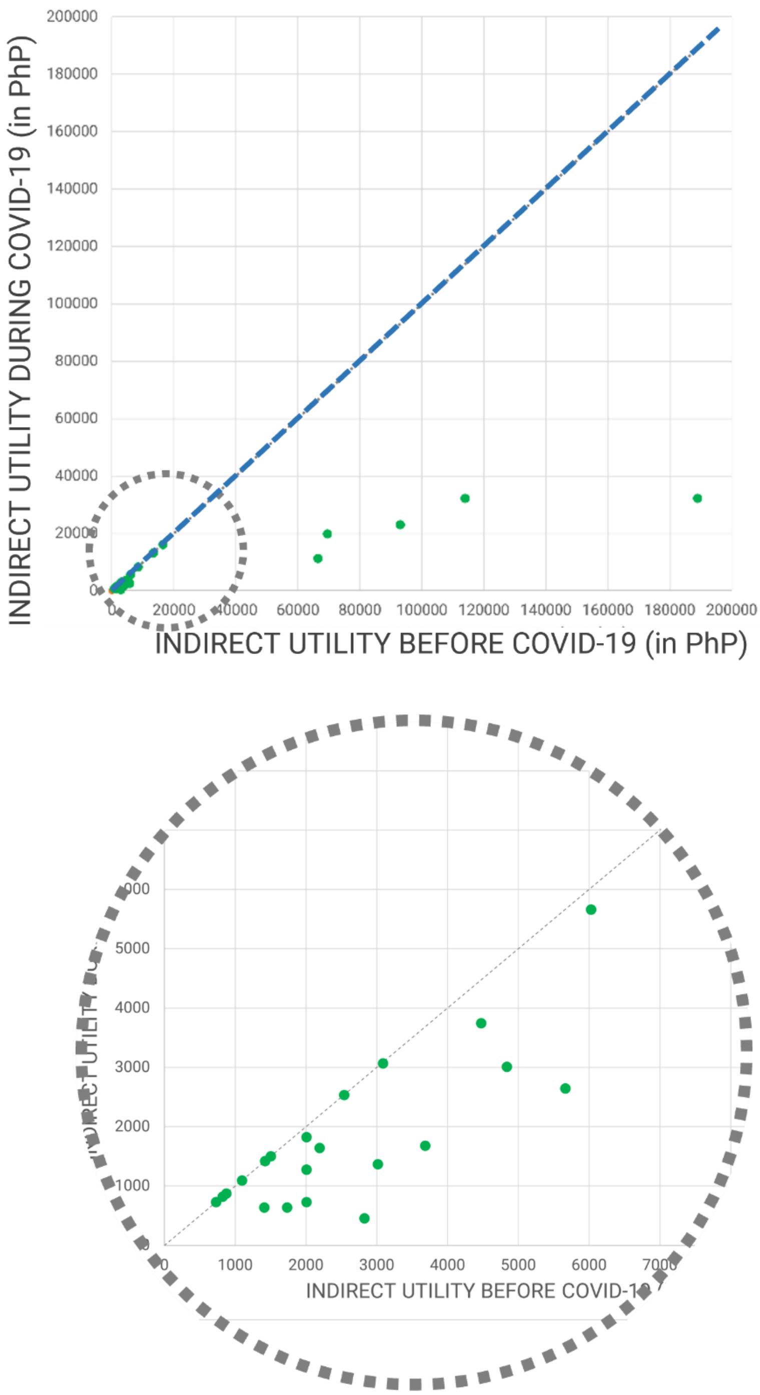


Figure 4.2 Change in indirect utility before and during COVID-19 (in Philippine Peso, PhP) – General data (Top) and Blow-up of concentrated region (Bottom)

Table 4.2 Random examples of respondents' trip activities and resulting indirect utility

Respondent	SoVI	$i \in I$	Before COVID-19			During COVID-19		
			$f_{i,s}^{k}$	$g_{i,s}^{k}$	v_s (PhP)	$f_{i,s}^{k}$	$g_{i,s}^{k}$	v_s (PhP)
k_1	SoVI > 1.1	Work	5	58.75	2825.45	3	20.3	455.75 (84%↓)
		Grocery	1	20.30		1	10.15	
k_2	SoVI = 0	Work	6	10.15	729.80	4	101.5	729.80
		Grocery	1	20.30		1	10.15	
K3	SoVI < 1.1	Work	3	60.90	2191.40	6	30.45	1643.3 (25%↓)
		Grocery	3	20.30		1	20.3	

Where i: trip purpose, $f_{i,s}^{k}$: trip frequency/week; $g_{i,s}^{k}$: generalized cost/week; v_s: indirect utility

Chapter 5
Conclusion

5.1 Objectives summary

The COVID-19 pandemic has caused commuters to re-examine their trip activities and priorities, and thereby, has led to significant changes to how people from different socioeconomic groups perform their everyday tasks. This research has set out to show the dynamics of people's mobility before and during the COVID-19 pandemic.

This thesis centers on three main works: exploring the relationships between social vulnerability and travel behavior to the risk of exposure to COVID-19, how the pandemic influenced changes in trip activities, and the implications on economic expenditures caused by the pandemic. These goals were broken down further into more specific, attainable, and measurable research objectives, and the following section discusses briefly how each goal was achieved.

5.1.1 The relationship of social vulnerability and COVID-19

The first relationship in study – between social vulnerability and COVID-19 – was analyzed by using data gathered from an online questionnaire survey, covering topics from sociodemographic characteristics, trip activities before and during the pandemic, to level of exposure to COVID-19. Social vulnerability was then quantified following the SoVI method, and their relationship was analyzed by utilizing an ordinal logistic regression model.

Findings showed that there is a correlation between social vulnerability and the level of exposure to COVID-19. Specifically, the social vulnerability indicators for income, sex, type of occupation, age group, household crowding, and lack of access to vehicles all contribute to increasing the danger of contracting the virus. Moreover, the female population appears to have the strongest correlation to this risk. Results of the ordinal logistic regression also showed positive coefficients for all indicators, thereby supporting correlation results and earlier literature stating that social vulnerability intensifies the risk of exposure to COVID-19.

The change in modal choice for various social groups were also compared. Between essential and non-essential workers, it was found that there was an increased reliance on private transport for both groups. Moreover, more non-essential workers reduced their mobility than essential workers.

As for the sex groups, more females reduced mobility compared with men. In addition, women were also found to use public transport more often than men, before the pandemic started.

These results further highlight the connections between social vulnerability and travel behavior to COVID-19. Furthermore, the identification of vulnerable groups, including their mobility pattern, could provide a foundation on creating more specific and population-targeted mobility policies in the event of another global pandemic.

5.1.2 The impacts of COVID-19 on travel behavior

To observe the effects of the pandemic on mobility patterns and travel behavior, the changes in trip activities before and during COVID-19 were assessed. For this section, mobility data from Google's COVID-19 Community Mobility Reports and Apple's Mobility Trends Report were used to represent travel activities. These were then compared with the daily trend of infection cases recorded in Metro Manila as gathered from the Philippine Department of Health COVID-19 Case Tracker. A multiple linear regression model was then applied to examine the underlying relationship between these indicators.

Results showed that there was a dramatic decrease in mobility observed since the pandemic started. However, while still less than pre-pandemic mobility, trips to grocery establishments appeared to be the highest among the location groups. Furthermore, there was also a significant increase in time spent in residences. These observations reflect the implementation of various community quarantine levels imposed on localities in order to mitigate virus spread. Telework was encouraged for industries who can adapt a work-from-home setup, and trips to groceries remain an essential trip which was allowed despite strict mobility restrictions.

Observing outcomes from the multiple linear regression model, results showed that visits to retail and grocery stores contribute to the increase in daily cases of COVID-19; whereas, staying at home and traveling by walking further decrease the incidences. Furthermore, an increase in visits to retail and grocery shops intensifies the number of cases by 1.3 to 1.1 times respectively, while staying at home lessens the number of cases by 1.2 times. Finally, walking as a mode of transport was found to have the largest impact on the daily cases, where it can reduce the number by 3.1 times.

The ”closed loop scenario” was also observed as the travel activity and number of cases was observed simultaneously. Under this condition, the travel behavior of commuters shifts based on their risk perception of the virus. The decreasing number of cases creates an impression that it is much safer to go out; however, as the number of trips start to increase, the probability of infection increases, as well as the number of COVID-19 cases. As a consequence, commuters feel at risk and reduce their trips, which in effect leads to decreased number of cases and start the closed loop cycle again. This finding also provides evidence on how the efficacy of lockdowns in reducing incidences of infection decrease over time.

5.1.3 The impacts of COVID-19 on commuters' expenditure

To quantify the impacts of COVID-19 on commuters' expenditure activity, the travel data gathered from the online survey questionnaire was used. Specifically, the recorded data for each respondent's trip activities in a week before and during the pandemic – which includes trip purpose, frequency in a week, trip fare, trip duration, and travel mode – were used in modeling the equations. Furthermore, the quantification of expenditures was expressed by conducting two separate analyses: 1) examining the changes in importance of trips and modal choice, and 2) identifying the change in commuters' indirect utility.

In examining the changes in importance of trips and modal choice, the travel activity data was used to formulate a multinomial logit model, then set parameters were estimated by maximizing the log-likelihood function. Findings show that trips to work became less important during the pandemic, while trips to groceries on the other hand increased in importance. It can be assumed that because some occupation types could be shifted to telework, the importance of traveling for work lessened. However, it must be noted that this may be true only for those whose occupation belong to non-essential industries, with the option and means to perform home-based work. On the other hand, trips to grocery showed an increase in importance, and this finding may be associated with the increased frequency and volume of home cooking. Lockdown policies during the early phase of the pandemic forced households to stay at home without any option to dine out. Aside from food delivery, cooking at home became the safest and most cost-effective way for food consumption. With the majority of household members staying at home all day, the amount of necessary food preparation increased, thus showing that trips to grocery remain a necessity even during a pandemic.

Furthermore, it was also found that the importance of private vehicles decreased, while the importance of public vehicles increased during the course of the pandemic. This result may be supported by the reliance of developing countries on public transport, especially for day-to-day subsistence activity. In addition, not all households may have access to private transport; hence, making them more vulnerable to the negative impacts of COVID-19. Such finding provides empirical evidence implying that the focus of infrastructure developments should be geared towards public transportation, as this serves as the backbone for the continuity of economic activities, even during a pandemic when mobility is highly restricted.

Finally, it can also be observed from the generated values for each variable that there were several factors which affected the trip choice of travelers before the spread of COVID-19. Specific constants were generated for the variables *Work*, *Private mode,* and *Public mode* which suggests that trips to work and transport mode have significant influence over the trip choice of commuters before the pandemic. However, during the time of COVID-19, the values for transport mode approached zero. These results show that the transport mode did not significantly impact the trip choice of commuters during the pandemic. Instead, the generalized cost and specific constant for *Work* are the only two factors which showed influence on trip choice of commuters during the pandemic. These findings further emphasize that despite mobility restrictions, work continues to be an important factor in trip choice even during the pandemic.

Identifying the change in commuters' indirect utility was expressed by evaluating how the changes in consumption of trips and goods affect the monetary expenditures before and during the pandemic. This was achieved by representing an indirect utility function following the CES, or constant elasticity substitution. The utility of each individual respondent before and during COVID-19 was obtained separately, then compared.

Based on the results, it was observed that generally, the resulting indirect utility became less during the pandemic. The findings denote that the maximum utility that can be achieved by spending the income on the consumption of transportation has decreased as an effect of the travel behavior changes brought about by the pandemic. Moreover, there were also respondents whose utility did not significantly change despite the circumstances of COVID-19.

A closer observation of some of the respondents' trip characteristics and resulting indirect utility also showed that while reduction in trip activity consequently result to decreased generalized cost, the maximum utility, or satisfaction level, attained by the respondents generally decreased in value. In addition, it can also be deduced that the diminished utility was substantial in value considering the daily minimum wage rate in Metro Manila. Furthermore, it also follows that the decrease in the level of satisfaction for transportation services can affect the commuter's future trip decisions.

5.1.4 Policy implications

One of the emerging themes from the results of this research relates to the concept of "equity." While there is an association between using public transport and the high-risk exposure to the virus, not all of the respondents may have access to alternative modes of transportation. They may not have access to private vehicles or live in areas with sufficient and effective pedestrian-oriented facilities or biking infrastructure. Findings highlight the importance of equity when designing multi-modal transportation systems, and how this importance becomes even more obvious especially during crises like a pandemic. An equitable transportation system can reduce inequalities in accessibility among residents of a region across different socioeconomic backgrounds, helping to promote convenient and safe access to opportunities such as healthcare and jobs.

Additionally, the latest COVID-19 experience showed us how inequitable certain policies such as stay-at-home order could be for various member of society based on the nature of their work – especially for essential workers, such as health care workers and those in service-related industries. With high-risk exposure to virus transmission, as well as possible job loss due to inapplicability of telework, the results highlight the need for more fair approaches to implementing work restriction guidelines in future pandemic situations.

Observations shown by this research, along with equity issues related to such policies as mentioned above, bring light on the importance of pro-actively planning for future policies towards being fairer and more effective. To improve the effectiveness and equitability of such policies, they could be formulated based on dynamic combinations of a range of strategies including suitable adjustments of the operating hours of various essential industries.

Based on this research's findings, some policy proposals which can be applicable to the Philippine context may be developed and implemented. To cite some examples, while it was found that there has been a major shift to private transport during the pandemic, this may not be sustainable in the long term. Therefore, the health and safety features of public transport should also be improved in order to encourage public use. Commuters using active transport (walking and cycling) were also found to continue using the same transport mode during the pandemic. To support this, bicycle and pedestrian lanes should be developed and designed in integration with existing road networks. Finally, trips to groceries were the least to decrease during the pandemic. This implies that mobility to groceries should be regulated especially during spikes in the daily number of cases. Trips may be scheduled per locality or limited in frequency per household.

5.2 Limitations of the research

A complete understanding of the relationship between COVID-19 infection rates and mobility is difficult to achieve. Results showed that aggregate mobility metrics are only a coarse predictor for possible risky infection transmission events. The quality and reliability of this proxy variable is subject to several confounding factors, such as individual and group behavior, that as expected also evolved over the course of the pandemic.

While they provide a robust data base, both Google and Apple's mobility trends reports do not have demographic information about its users, so it would be difficult to make any statements about the representativeness of usage against the overall population of the specified region. More significant conclusions could be drawn if the mobility data represents movement for specific sociodemographic groups. This would allow policy implementation to be more drawn towards the most vulnerable communities during a pandemic setting. The authors note however that this would not be possible for Google and Apple's mobility reports due to the strong implementation of privacy policy for its users.

5.3 Future directions

There are several opportunities to extend and advance this research.

From a data quality perspective, geographic and temporal non-stationary testing artifacts – such as differing reporting standards or availability of tests should also be considered and accounted for in when running the analysis. Furthermore, the time-varying mask variable had relatively poor coverage, especially during the early phase of the pandemic, a period during which the large drops of mobility may also have a direct relationship with the effect of wearing masks. Lastly, the analysis covered a period before vaccines were available and more infectious variants of the virus emerged.

The model can also be improved if it can explicitly distinguish transitions from susceptible, infected, and recovered subgroups of the population. Nevertheless, data limitations make such models hard to identify and estimate, hence the approach was restricted to statistical models that captured associations between infection growth rates and mobility.

Since the onset of this study in 2021, the COVID-19 landscape has greatly changed. During the first couple of years of the pandemic, vaccine efficacy and potential immunization timelines were uncertain. Studies found that respiratory virus transmission is more prevalent in colder weather or regions, and that gathering of large crowds leads to outbreaks. As a result, researchers in many countries pursued models and data which will provide early warnings of emerging outbreaks or to justify limited reopening policies.

A couple of years later, we have extremely effective vaccines available worldwide, along with the emergence of new variants with still unknown susceptibility to existing interferences. This new landscape, combined with current findings that the relationship between mobility and infection transmission is not as significant, suggests that mobility in isolation is less effective than initially thought. Nonetheless, the lessons learned from studying the evolving landscape of COVID-19 can be useful to practitioners and policymakers going forward.

For a broader perspective reflecting national-level outcomes, future studies should utilize a more inclusive and representative demographic. The data used in this study can only reflect actual conditions to a certain extent. Moreover, a linear time series approach can also show the change in travel behavior considering the implications of vaccination rollout.

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Appendix A

COVID-19 Alert and Events Timeline for Metro Manila

Date/Duration	Alert Level	Implemented mobility restriction policies
March 8, 2020	State of public health emergency	Transportation not yet restricted; Authorities can enforce mandatory quarantine for travelers and set a price freeze for essential products;
March 15, 2020	Community quarantine (first implementation of lockdowns and other mobility restrictions)	Travel restrictions by land, local air travel and local sea travel in and out of MM; Railways traversing MM — the LRT, MRT and PNR — continued operations but with proper social distancing measures observed.
March 16 to May 15, 2020	Enhanced Community Quarantine (ECQ, most restrictive)	People only allowed to leave their homes to access basic necessities; Mass public transportation services are also suspended, while land, air and sea travel is restricted; also includes transport network vehicle services such as Grab. The movement of cargo to and from Luzon still allowed.
May 16 to May 31, 2020	Modified Enhanced Community Quarantine (ECQ, restrictive)	All residents are still required to stay home except for those reporting to work or securing essential supplies. There will be limited public transport, while crossing over to other regions is still banned. Public and company shuttles will be allowed alongside private cars. Bicycles, motorcycles, and e-scooters are also allowed but should only carry the driver. Jogging, running, and biking also allowed following protocols
June 1 to August 3, 2020	General Community Quarantine (GCQ, least restrictive)	Buses will be allowed to operate at 50 percent capacity in Metro Manila, but modern jeepneys are still not allowed to operate for three more weeks. Trains and buses plying train service routes will be allowed to run immediately, along with shuttles of private companies, transport network vehicle services such as Grab Car, taxis, tricycles, and point-to-point buses.
August 4 to August 18, 2020	MECQ	Any person below 21 years old, those who are 60 and above, those with immunodeficiency, comorbidity, or other health risks, and pregnant women are required to remain in their residences,

		except when obtaining essential goods and services, as well as reporting to work
August 19 to August 31, 2020	GCQ	The dine-in option in restaurants, as well as religious gatherings at 30 percent capacity, are also allowed. Mass gatherings, including religious services, will be limited to 10 people. Local governments in Metro Manila imposed a "unified" curfew from 8 p.m. to 5 a.m. Quarantine passes will be required for residents in areas placed under granular lockdowns, or those covering a specific barangay or neighborhood. Staycations allowed for all ages except for those with underlying medical conditions (September 29)
September 1 to March 28, 2021	GCQ	The Cabinet approves one-seat distancing in public transport, raises train capacity; The Cabinet also allowed the increase in train ridership to 50 percent from the current 30 percent capacity. more provincial buses, shuttles, ride-hailing services, and motorcycle taxis will be allowed to operate to accommodate more passengers.
March 29 to April 11, 2021	ECQ	(All time high 15000 daily cases) The government plans to intensify its PDITR or Prevent, Detect, Isolate, Treat, and Reintegrate strategy, which involves visiting residents in their homes to check who has symptoms, and testing as well as isolating them.
April 12 to May 14, 2021	MECQ	Outdoor dining will be allowed in areas under MECQ but only at 50% capacity. Curfew is still implemented but authorized persons outside of residence remain exempted; From April 12: Travel was limited to accessing essential goods and for those working in permitted establishments. Businesses that allowed to operate at 50% capacity during ECQ were allowed to fully open, while other sectors such as media establishments, medical clinics, banks, and other specific establishments were allowed to reopen at half capacity.

May 15 to August 5, 2021	GCQ	Outdoor dining will not be allowed under the stricter GCQ starting July 31. Take-out and food deliveries are the only services allowed. Starting July 30, personal care services can operate up to 30% of venue or seating capacity. Indoor sports courts and venues; and indoor tourist attractions; and specialized markets of the Department of Tourism will not be allowed to operate. Public transportation will remain operational. Only authorized persons can travel into and outside NCR Plus.
August 6 to 20, 2021	ECQ	Metro Manila will enforce longer curfew hours from 8 p.m. to 4 a.m.; Imposing a liquor ban will be up to the discretion of local government units.
August 21 to 31, 2021	MECQ	Only essential travel and services are allowed to operate like those related to food and medicine. Indoor and al-fresco or outdoor dining, as well as personal care services such as beauty parlors, barbershops, and nail spas are still prohibited. Religious gatherings shall also remain strictly virtual. Individual outdoor exercises while wearing a face mask are allowed within the area of residence
September 8 to October 15, 2021	GCQ, Level 4	Granular lockdowns could be declared by mayors or governors and could be limited to as small a unit as a street or barangay, rather than an entire city or province. ALS: the new system would involve four "levels" that ranges from more relaxed to successively stricter sets of rules that could be declared over specific cities or areas in Metro Manila
October 16 to 31, 2021	Level 3	For government work, offices in areas under Alert Level 3 may operate at 30 percent on-site capacity. Some businesses and activities are allowed at a maximum of 30 percent on-site or venue capacity. The operation of the following remains prohibited: indoor entertainment venues, outdoor and indoor amusement parks. food businesses may operate in full capacity for takeout and delivery while dine-in services

		will be permitted at 30% capacity. Personal care service establishments can also fill in up to 30% of their venue capacity. The same operational capacities will be implemented in closed and crowded venues and close contact activities. However, the allowed capacities for businesses with safety seals may increase by 10%.
November 1 to December 31, 2021	Level 2	More strict mobility restrictions similar to MECQ

Appendix B
Online survey questionnaire

Understanding the changes in travel behavior of Filipino households due to COVID-19

Thank you for taking the time to participate in our survey on the travel behavior of Filipino households pre-COVID-19 and one year later into the "new normal". The objective of this survey is to clarify how the travel behavior of Filipino households have changed and adapted from their pre-COVID-19 lifestyle to one year later in the "new normal". By participating, you can help us to assess and analyze travel behavior of households and individuals from varying social groups and serve as a foundation for proposing improvements on transportation policies.

The survey is divided into five parts: (1) household characteristics, (2) vehicle access, (3) pre-COVID-19 travel activity, (4) current travel activity, and (5) COVID-19 infection. It should take roughly 20 minutes to complete. Individual respondents will not be identified in any data or reports, ensuring the confidentiality of responses. All information will be used only for academic purposes of this research.

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HOKKAIDO UNIVERSITY

Member number	Age	Gender (M/F)	Occupation*	Employment sector*	Monthly income* Pre-COVID-19	Monthly income* Current	Mobility handicap* (Y/N)
Barangay and city/province							
Part I. Household characteristics							
No. of bedrooms							
No. of household members							
01			Choose an item.	Choose an item.			
02			Choose an item.	Choose an item.			
03			Choose an item.	Choose an item.			
04			Choose an item.	Choose an item.			
05			Choose an item.	Choose an item.			
06			Choose an item.	Choose an item.			
07			Choose an item.	Choose an item.			
08			Choose an item.	Choose an item.			
09			Choose an item.	Choose an item.			
10			Choose an item.	Choose an item.			
11			Choose an item.	Choose an item.			
12			Choose an item.	Choose an item.			
13			Choose an item.	Choose an item.			
14			Choose an item.	Choose an item.			
15			Choose an item.	Choose an item.			

Part II. Vehicle ownership	
Vehicle/s owned by the household	No. of units
Car or van	
Tricycle	
Motorcycle	
Bicycle	
Others: Click or tap here to enter text.	

*Please read the following survey notes before answering.

No. of bedrooms
For purposes of this study, a bedroom is defined as a confined space which a member can use for home quarantine

No. of household members
All person whose usual place of residence is the housing unit where the respondent lives

Occupation
For more detailed descriptions of each category, refer to this link.

Occupation and Employment
If you are unsure which category to choose, please type to specify actual job description

Monthly income
This includes all income before the deduction of taxes

Mobility handicap
Household members who have any permanent physical disability

Part III. Pre-COVID-19 travel activity*					
Member number*	Travel purpose	Frequency in a week	Mode of transport*	One-way total fare* (if using public transport)	One-way total travel time (hour:minute)
	Choose an item.		Choose an item.		
	Choose an item.		Choose an item.		
	Choose an item.		Choose an item.		
	Choose an item.		Choose an item.		
	Choose an item.		Choose an item.		
	Choose an item.		Choose an item.		
	Choose an item.		Choose an item.		
	Choose an item.		Choose an item.		
	Choose an item.		Choose an item.		
	Choose an item.		Choose an item.		
	Choose an item.		Choose an item.		
	Choose an item.		Choose an item.		
	Choose an item.		Choose an item.		
	Choose an item.		Choose an item.		
	Choose an item.		Choose an item.		
Part IV. Current travel activity					
Member number*	Travel purpose	Frequency in a week	Mode of transport*	One-way total fare* (if using public transport)	One-way total travel time (hour:minute)
	Choose an item.		Choose an item.		
	Choose an item.		Choose an item.		
	Choose an item.		Choose an item.		
	Choose an item.		Choose an item.		
	Choose an item.		Choose an item.		

*Please read the following survey notes before answering.

Part III and Part IV
Including yourself, please record the travel activities of two other household members who traveled most frequently before the COVID-19 pandemic started.

Member number
Refer to Part I (page 2) and identify the assigned "Member number" (in red) of your selected individuals for Part III and IV. Please note that selected members should be the same for both Part III and IV.

Mode of transport
For trips using two or more modes of transport, please type to specify all modes used.

One-way total fare
Total fare computed from origin (home) to destination.

	Choose an item.		Choose an item.		
	Choose an item.		Choose an item.		
	Choose an item.		Choose an item.		
	Choose an item.		Choose an item.		
	Choose an item.		Choose an item.		
	Choose an item.		Choose an item.		
	Choose an item.		Choose an item.		
	Choose an item.		Choose an item.		
	Choose an item.		Choose an item.		
	Choose an item.		Choose an item.		

Part V. COVID-19 infection	
Was there any household member who tested positive for COVID-19? (Y/N)	
If yes, please indicate "Member number/s" *	
Was there any household member who had to home quarantine? (Y/N)	
If yes, please indicate "Member number/s" *	
End of survey	

*Please read the following survey notes before answering.

Member number
Indicate who tested positive or had to home quarantine. Refer to Part I (page 2) and identify the assigned "Member number" (in red) of the particular person/s.

Appendix C

Google COVID-19 Community Mobility Reports

B.1 Overview

The Google COVID-19 Community Mobility Reports provide aggregated and anonymized daily data on population patterns during COVID-19 pandemic. The data present movement trends by area or region across different categories of location. For each category in a specified region, reports show the changes in two (2) different ways:

1. Headline number: Compares mobility for the report date to the baseline day. Calculated for the report date (except when there are gaps) and reported as a negative or positive percentage.
2. Trend graph: The percentage changes in the six (6) weeks before the report date. Shown as a graph.

Personally identifiable information, such as the user's location, contacts, or movement, are not made available at any point. The reports were created with aggregated, anonymized sets of data from individuals who have turned on the "Location History" setting on their Google application.

B.2 Baseline

The data shows how visitors to (or total time spent in) categorized locations change compared to the specified baseline days. A baseline day represents a *normal* value for that day of the week. The baseline day is the median value from the 5-week period from January 3 to February 6, 2020.

For each region-category, the baseline is composed of seven (7) individual values. The same number of visitors on two different days of the week would result in different percentage changes.

However, the authors note that the specified 5-week period which determines the baseline may not represent the "normal" mobility situation for every region, at a certain time period. The selected week represents the most recent period before widespread mobility disruptions occurred as communities responded to COVID-19. Furthermore, it was necessary to note any significant events, such as public holidays, or extreme weather conditions, which occurred between January 3 to February 6, 2020, before interpreting the data per region.

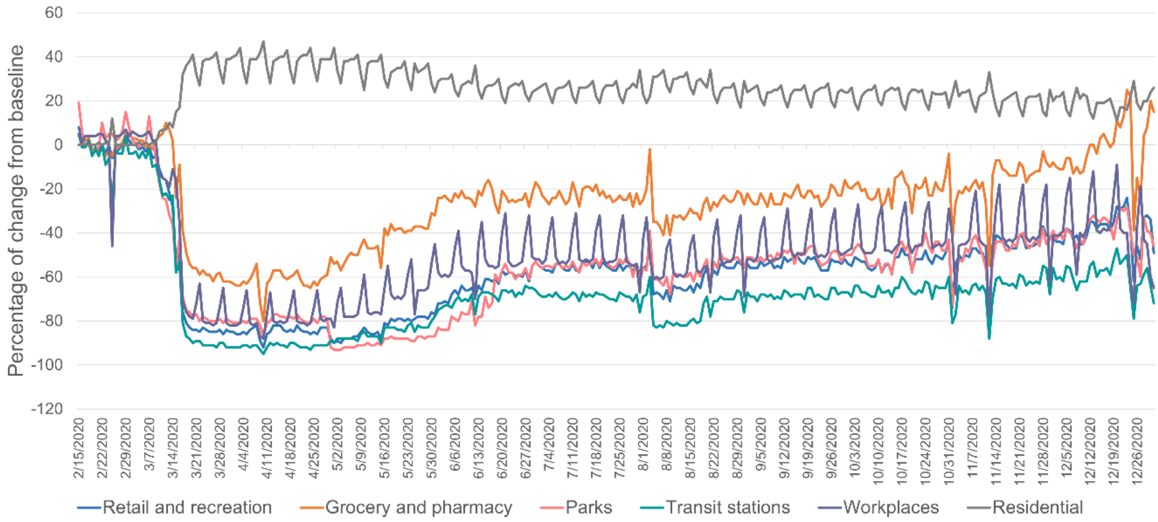
B.3 Data description

There are six (6) location categories represented, namely: retail and recreation, grocery and pharmacy, parks, transit stations, workplaces, and residential. Categories were used to group some of the places with similar characteristics for purposes of social distancing guidance. As an example, pharmacy and grocery are combined as these are usually considered as essential trips.

Location category	Subcategories/description
Retail and recreation	Restaurants, shopping centers, cafes, theme parks, museums, libraries, movie theaters
Grocery and pharmacy	Grocery markets, farmers markets, food warehouses, specialty food shops, drug stores, and pharmacies
Parks	National parks, public beaches, marinas, dog parks, plazas, and public gardens
Transit stations	Public transport hubs such as subway, train, and bus stations
Workplace	Places of work, as specified per user
Residential	Places of residence, as specified per user

The data values vary between -100 and 100, with 0 representing the baseline for the mobility pre-pandemic level. Positive variations are associated with increases to the baseline, while negative values indicate a reduction of mobility from the reference point.

The following graph shows the general mobility trend for every location category in Metro Manila for the time period of February 15 to December 31, 2020.



Appendix D
Apple COVID-19 Mobility Trends Report

C.1 Overview

The Apple COVID-19 Mobility Trends Report is an aggregated navigation data from Apple Maps which provides mobility trends for cities and countries worldwide. The data is generated by counting the number of requests made to Apple Maps for directions. The data sets are then compared to represent a change in volume of commuters' modal choice, namely: "Driving," "Transit," and "Walking" for different spatial levels, such as countries and cities. Data availability in a particular location is also subject to a number of factors, including minimum thresholds for direction requests made each day.

Similar to Google's Community Mobility Reports, the data collection system protects user privacy by continually resetting random, rotating identifiers so Apple does not have a profile of the users' movements and searches. In addition, Apple Maps has no demographic information about its users, so it cannot be used to make any statements about the representativeness of usage against the overall population.

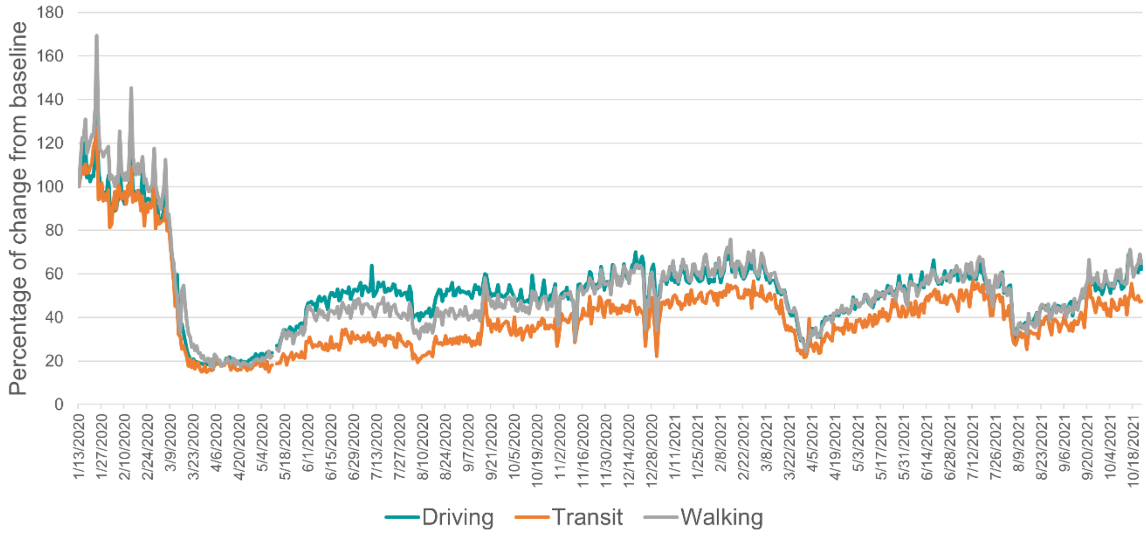
C.2 Baseline

The Mobility Trends Report shows a relative volume of route requests compared to a baseline volume set on January 13, 2020. A day was defined as midnight-to-midnight considering Pacific time. Cities are defined as the greater metropolitan area, and the geographic limits remain constant across the data set.

Again, the authors emphasize that the baseline depiction, this time set at a specific date, may not well-represent the average or normal mobility setting for every location at a certain period. While the selected date as the baseline falls before strict mobility restrictions were implemented worldwide, specifying only a date as the baseline may lead to improper interpretation of analytical results. While there can be no adjustments made to recalibrate the baseline for Apple's mobility trend report, the authors assure that January 13, 2020, could represent the normal mobility in Metro Manila for reasons being that it was a working weekday (Thursday, non-holiday), there were no extreme weather conditions, and neither any significant event in the geopolitical landscape which can alter or affect commuter mobility. Therefore, the mobility data may still be utilized to perform this study.

C.3 Data description

The values provided by Apple are founded on a macro comparable to that used by Google. However, Apple uses a baseline of 100 (unlike Google which uses a baseline of 0), with values of less than 100 below, and more than 100 values above the baseline. The following graph shows the general mobility trend for every modal choice in Metro Manila for the time period of January 13 to December 31, 2020.



In order to allow the analysis and facilitate comparison, the Apple data was normalized and set to a baseline of 0, same with Google. Furthermore, data for May 11 to 12, 2020, March 12, 2021, and March 21, 2022, are not available due to insufficient data collected, and appear as blank columns in the graph. However, the missing data is minimal and is expected to have only a marginal impact on the analysis and outputs.

Furthermore, in contrast to Google's location data, requests for route instructions in Apple data are calculated. For this study, the two data sets are therefore treated individually, since there is no equivalence between the user's actual location (Google) and the indication of an intention to travel (Apple).

Appendix E

DOH COVID-19 Case Tracker

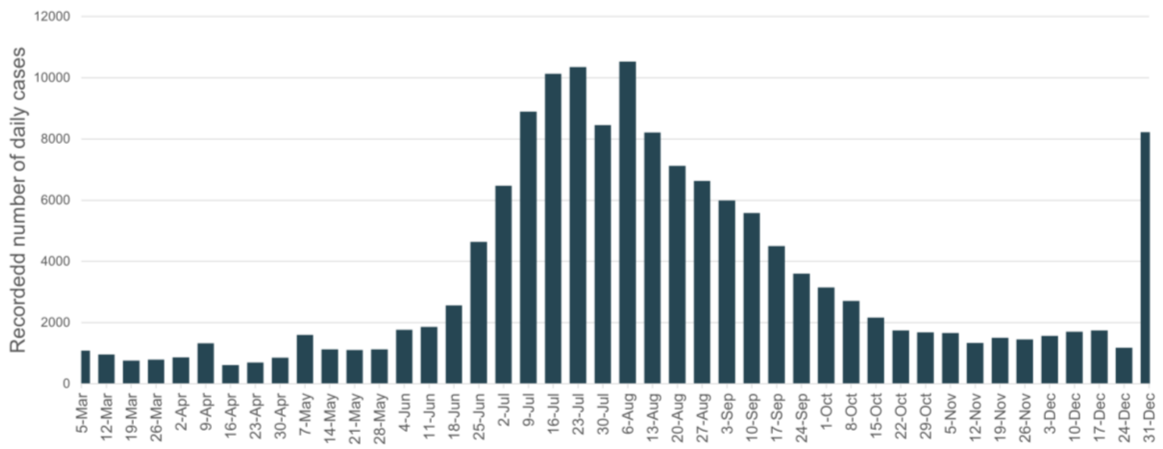
D.1 Overview

The Department of Health (DOH) Philippines COVID-19 Case Tracker is an official open-source data drop for COVID-19 related statistics. Data sets include nationwide cases data, cumulative samples evaluated, and hospital occupancy rates.

D.2 Data description

For this study, the data for “Weekly cases by date of onset of illness” was collected. Note that for cases where date of onset of illness was unreported, the date of specimen collection was used as proxy. Furthermore, the data reflected represents an accumulated 4 week moving average of the number of cases.

The graph below shows the recorded data for weekly cases by date of onset of illness from March 5 to December 31, 2020.



Provincial and regional totals may slightly change daily because by default, the current address as reported in the case investigation form is used, whenever available. Continuing follow-up of the patient after public ascertains their region where they are quarantined or admitted, and this may be different from the region of the current residence.