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Estimating the Environmental, Social, and Economic Impacts of Ride-Hailing Services in Metro Manila

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September 2019

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Major in System Design and Management
### SUMMARY OF MASTER’S DISSERTATION

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**Title**

Estimating the Environmental, Social, and Economic Impacts of Ride-Hailing Services in Metro Manila

**Abstract**

The poor quality and insufficient transport infrastructure in Metro Manila gives rise to billions’ worth of daily economic losses for the nation, as well as lower quality of life for the residents. The purpose of this study is to mitigate road congestion in Metro Manila. While this can be done through methods such as adding mass transit infrastructure or implementing policy changes, these two methods are difficult to rely on due to shortcomings on the side of the government.

In the past decade, ride-hailing services have been entering transport sectors around the world and is thought to be worth considering as a way to reduce the number of vehicles on the road. In this study, the logit model is used to estimate the modal share of ride-hailing services, both solo and shared, in the transport sector of Metro Manila. First, data was gathered from various sources such as government data, published studies, and surveys. Then, calculations of this logit model is done iteratively in order to see how the shifts in modal shares affect traffic conditions. After the iterations stop showing changes in modal shares and number of vehicles on the road, a quantitative assessment is conducted on the environmental, social, and economic impacts of the shifts in modal shares.

Results show a final modal share of around 9% for shared ride-hailing services. There is indeed a decrease in CO₂ and HC emissions, due to the shift of car users to ride-hailing services. However, there is also an increase in PM, SOx, and NOx emissions, due to the increase in modal shares of the bus and jeepney. Furthermore, almost 2 million hours’ worth of daily commuting time is also saved due to the shift in modal shares. It is estimated that this entails a 13% decrease in daily economic losses caused by congestion, worth 460 million Philippine Pesos.

**Key Word(5 words)**

Ride-hailing, logit model, Metro Manila, Utility Theory, road congestion
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Chapter 1: Introduction

1.1. Problem in Metro Manila

Metro Manila, the capital city of the Philippines, is known to have one of the worst urban traffic situations in the world. According to data from the United Nations, Metro Manila is one of the world’s most densely populated cities [1]. Coupling this high population density with insufficient transport infrastructure [2], traffic congestion plagues the metropolis. As a result, Metro Manila residents end up spending more than 400 hours stuck in traffic every year [3]. This inevitably has dire implications for the national economy. In February 2018, the Japan International Cooperation Agency (JICA) revealed that daily economic losses incurred by traffic congestion amounts to 3.5 billion Philippine Pesos, roughly equivalent to more than 7 billion Japanese Yen [4].

![Figure 1: Traffic along EDSA, Metro Manila's main thoroughfare](https://www.inquirer.net/)

There are many contributing factors that are behind this transport problem in Metro Manila. A transport study conducted by JICA in 2014 [5] showed that despite only
carrying 13% of person-trips in the metropolis, private vehicles occupy 70% of the road space along Manila’s main thoroughfare, EDSA Avenue. Furthermore, these private vehicles were found to have an average occupancy rate of only 1.57 persons. These numbers illustrate that there is inefficient use of road space. As of 2014, roads in Metro Manila had an average volume-capacity ratio of 1.25 [5]. Road congestion based on volume-capacity ratios is illustrated in the following figure, taken from the 2012 report by JICA and the National Economy Development Authority (NEDA) [5].

![Figure 2: Congestion of Metro Manila Road Network [5]](image)

As for rail transit options, according to the latest government statistics, train cars are also highly congested throughout the day. Data shows an average 91% load factor for Metro Rail Transit (MRT) in 2017 – hitting 102.5% by December of the same year – and 96% for Light Rail Transit (LRT) in 2014 [6]. This means that even rail transit options are already operating near, at, or even above capacity at peak hours.
Adding to the conventional road and rail transit options, ride-hailing services such as those provided by Uber and Grab have been penetrating transport sectors around the world in the past decade. These ride-hailing services provide an attractive alternative to car owners as they offer comparable degrees of comfort and convenience. As ride-hailing services were only first officially recognized by the Philippine government in 2015 [7], there has only been limited surveys, data, and research on its status and impact on Metro Manila. However, given that it is a promising way to mitigate road congestion as it can increase average car occupancy and reduce the number of vehicles on the road, it is of interest to both residents and the Philippine government to evaluate how these ride-hailing services may impact traffic conditions, as well as the environment. Ride-hailing services, both from a general and local perspective, are discussed further in Section 1.3 of this paper.

1.2. Overview of Metro Manila and its Current Transport Infrastructure

Metro Manila, also known as the National Capital Region (NCR), is the capital of the Philippines, a developing country in Southeast Asia. It is comprised of 17 municipalities. As of latest government statistics, the population of Metro Manila was at 13 million in 2015 [6]. With a land area of 620 square kilometers, the size of Metro Manila is almost identical to the land area of the 23 special wards of Tokyo. To better illustrate the study area, some basic statistics comparing Metro Manila and the aforementioned Tokyo area are provided in the following table.
Table 1: Statistics on Metro Manila and Tokyo

<table>
<thead>
<tr>
<th></th>
<th>Metro Manila</th>
<th>Tokyo (23 special wards)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land Area (sq. km)</td>
<td>619.6</td>
<td>622</td>
</tr>
<tr>
<td>Population (millions)</td>
<td>12.9</td>
<td>9.2</td>
</tr>
<tr>
<td>Road length (km)</td>
<td>4,755</td>
<td>11,870</td>
</tr>
<tr>
<td>Number of vehicles (millions)</td>
<td>2.79</td>
<td>1.96</td>
</tr>
<tr>
<td>Number of Rail Lines</td>
<td>4</td>
<td>27</td>
</tr>
<tr>
<td>Rail length (km)</td>
<td>78.39</td>
<td>292.2*</td>
</tr>
</tbody>
</table>

Sources: Philippine Statistics Authority [6], Tokyo Metropolitan Government [8], JICA [5], Statistical Handbook of Japan [9], Land Transportation Office [10]
* Covers Greater Tokyo

The railway systems of the two metropoles are illustrated below.

![Metro Manila railway system](image1)

![Tokyo railway system](image2)

*Figure 3: Metro Manila railway system  Figure 4: Tokyo railway system

Source: Urbanrail.net

Public transport in the Philippines is mostly comprised of paratransit modes such as the jeepney and tricycles [11]. Paratransit is defined as “transportation services that supplements larger public transit systems by providing individualized rides without fixed routes or timetables” [12]. Rimmer describes paratransit services to be somewhere between conventional (ex. bus, train) and personal (ex. private car, taxi) transit [13].
Among all modes of public transit in the metropolis, the “jeepney” has the highest share of commuter trips at around 20% [14]. The “jeepney” is a mode of transport unique to the Philippines. It is perhaps best described as an open-air bus made of cheap metal parts. The jeepney has been around since around World War II, when jeeps used by the then-present US military were converted to passenger transport vehicles after the war [15].

Figure 5: A typical jeepney in Metro Manila
Source: ABS-CBN News (https://news.abs-cbn.com/)

These jeepneys are joined on the road by city buses as well, illustrated below.

Figure 6: City buses in Metro Manila
Source: Rappler (https://www.rappler.com/)
1.3. Ride-hailing Services

Ride-hailing services have been gaining popularity worldwide in the past decade. Arguably the most well-known example of ride-hailing services is Uber, which started in the United States in 2010. These services are offered by “Transport Network Companies” or TNCs, a term coined by the California Public Utilities Commission (CPUC) in 2012, in order to differentiate these “new online enabled transportation services”, or OETS, from existing conventional modes of transport [16]. Three years later, in 2015, these ride-hailing services were officially recognized as well by the Philippine government as “Transport Network Vehicle Services” or TNVS [7].

As cited in the issuance by the Department of Transportation of the Philippines, according to the CPUC, these ride-hailing services are characterized as “pre-arranged transportation services for compensation using an online-enabled application or platform technology to connect passengers with drivers using their personal vehicles” [7]. This definition can be broken down into 5 key characteristics, enumerated and described below:

1. **Pre-arranged**: This refers to the aspect of the service wherein the rider must indicate their demand for the trip (i.e. current location, target destination, and at times, trip schedule). This also informs the naming of the widely used term “ride-hailing”. Furthermore, ‘pre-arranged’ also indicates that the activation and details of the service are decided before actual pick-up (e.g. fare, kind of vehicle, etc.). As such, passengers cannot avail of these services by simply standing on the street and looking for a TNC vehicle – also related to characteristics 3, 4, and 5.
2. **Compensated:** This aspect differentiates this service provided by TNCs from similar but unpaid transit activities such as ridesharing and carpooling among family, friends, coworkers, etc. The rider must pay a fare for the trip, and the driver also earns from delivering the transport service. Salary schemes vary from one TNC to another. In many cases, the fare is set prior to the trip start, informed by trip details such as source and destination, as well as the TNC’s fare scheme. However, some TNCs also employ taxi-like services wherein the fare is metered instead of pre-calculated.

3. **App-enabled:** This aspect refers to how ride-hailing services are offered and availed of through mobile applications (apps) on both the drivers’ and riders’ “smart devices” (smartphone or wifi-enabled tablets). Unlike conventional modes of transit such as buses, trains, and taxis, commuters must install the app and conduct trip orders through this digital system instead of physical infrastructure.

   However, there are also special cases in which a rider may not need the TNC app in order to avail of the trip service. One example is when another person books the trip for a rider, e.g. Person A books a trip for Person B. Person A will not be taking the ride and may be in a completely different place. Person B, even without the app, simply gets on the ride-hailing vehicle and gets off at their chosen destination. The trip booking details are all on Person A’s device, who does not need to be on said ride. Another example is when these TNCs set up ride-hailing terminals in public places such as outside malls. Commuters may simply approach the booth set up by the TNC and get on a ride, with the booking
facilitated by on-site staff or the standby driver. This allows commuters without the TNC app installed to avail of the service.

This aspect of being app-enabled also makes it possible for the service providers to add features that would not be normally found in conventional modes of transit. One example is the “rating” feature, wherein riders may evaluate drivers using a 5-star scale. This helps give commuters a better idea of the kind of service they can expect from a ride, and also incentivizes drivers to provide better quality service.

4. **Passenger-driver matching**: This aspect refers to how ride-hailing services provide both passengers and drivers with more agency in controlling the kinds of trips they take and provide. When a potential ride-hailing passenger indicates their demand for a trip, this information is relayed to TNC-registered drivers in the area through the TNC’s digital platform. The drivers then have the option of accepting the trip or not. Should the driver accept the trip order, the passenger is informed and provided with the driver details, such as vehicle model, plate number, and driver rating. The trip is then considered matched and the driver picks up the passenger. Some TNCs allow riders to confirm whether or not they are okay with the driver details before confirming the trip, while some others will immediately match the passenger with the first driver who accepts.

5. **Personal vehicles**: This aspect refers to how the vehicles used in providing ride-hailing services are owned by the drivers themselves, and not owned or provided by the TNCs. The TNCs provide the digital platform that enables the service, and control the pricing and pay schemes for the riders and drivers, but actual vehicles
used for transport are ‘provided’ by the drivers registering to work ‘for’ these TNCs. This makes the supply side of this mode of transit more flexible than other conventional modes of transit, which usually require high investment to add to their physical capacities. This is also one reason why commuters who want to avail of these ride-hailing services must usually have the TNC app installed, else they would not normally be able to distinguish ride-hailing vehicles on the road.

A distinction must also be made between ride-hailing services and “ridesharing”. While the word “ridesharing” has been used even before the advent of ride-hailing services, the term has recently been used interchangeably with the services offered by TNCs. While some ride-hailing trips may count as ridesharing, not all ride-hailing trips qualify as ridesharing and vice-versa. Along with carpooling and carsharing, these terms and concepts all fall under the concept of “shared mobility” [17]. The relationships among these concepts are illustrated in the Venn diagram in Figure 7.

Figure 7: Relationships among Ride-hailing, Ridesharing, and Carpooling
The original (i.e. prior to the advent of ride-hailing services) definition of ride-sharing is exactly how it sounds, which is the act of sharing a ride among 2 or more commuters. Thus, if a ride-hailing trip is “shared” by 2 or more passengers, then it qualifies as ride-sharing.

Another form of ride-sharing is carpooling. Carpooling is commonly known as a mode of transit wherein a car is shared among commuters (usually including the driver), who share a common destination point or area. Carpool rides are mostly organized by private groups, such as family, friends, neighbors, and coworkers. The cost of the trip, if any, is thus determined within the group, and not through a business entity.

For the three aforementioned concepts, the vehicle is often owned by the driver. There is, however, a fourth option called “carsharing”. For the purposes of this study, carsharing is defined as when commuters are able to rent a car from a private owner or a business entity, and use the car to travel from point A to point B. The singular ride or trip itself may or may not be shared; what is being shared by different commuters is the vehicle itself by allowing it to be used by non-owners at different periods of time. This entails carsharing having overlaps with ridesharing and carpooling, but not ride-hailing.

In this study, ride-hailing services are differentiated into two types: “solo” ride-hailing services that are only booked for a private individuals or groups, and “shared” ride-hailing services that are deliberately shared with other passengers who want to book the TNVS.
**Differentiation from Taxis**

While ride-hailing services may sound a lot like taxis to some commuters, especially depending on the nationality and demographic of the person asked, there are actually a number of significant differences between the two, especially given the context of Metro Manila. Some basic differences are enumerated in the following table.

**Table 2: Comparison of Taxis and Ride-hailing services in Metro Manila**

<table>
<thead>
<tr>
<th></th>
<th>Conventional Taxi</th>
<th>Ride-hailing Service</th>
</tr>
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<tbody>
<tr>
<td><strong>Fare calculation</strong></td>
<td>Meter-based *Prone to tampering</td>
<td>Pre-determined</td>
</tr>
<tr>
<td><strong>Dispatch method</strong></td>
<td>On-site hailing (physical) Phone call</td>
<td>App-enabled</td>
</tr>
<tr>
<td><em><em>Ridesharing</em> availability</em>*</td>
<td>None</td>
<td>Available</td>
</tr>
<tr>
<td><strong>Driver rating scheme</strong></td>
<td>None</td>
<td>Available</td>
</tr>
</tbody>
</table>

*For the purposes of this study, ridesharing in the table above is defined as when passenger/s may choose to make their own ride available to other commuters, whether acquainted or not. This option enables the discounting of the fare as well as increasing of vehicle occupancy.

One particular difference that may be unfamiliar to non-Manila residents is the phenomenon of “batingting” taxis. “Batingting” taxis are taxis in Metro Manila that have mechanically/electronically tampered meters. These meters run faster than the official, standard meters, thus, the passenger ends up having to pay a much more expensive fare at the end of the trip. This is only one example of common illegal activities or taxi scams being conducted by taxi drivers in Metro Manila. The Philippine National Police has even issued safety tips to help avoid these inconvenient-at-best and dangerous-at-worst situations [18]. This risk of encountering taxis with tampered meters is one problem that
the availability of ride-hailing services by TNCs in Metro Manila helps commuters avoid. In a survey conducted among commuters in 2017, almost 1 out of 5 commuters complained of getting overcharged when riding a taxi in the metropolis [19].

More differences between taxis and ride-hailing services are discussed in detail in Section 1.5.

Motivation for Choosing Ride-hailing Services among Congestion Mitigation Alternatives in Metro Manila

The Asian Development Bank (ADB) published a report in 2012 [2] assessing the state of transport infrastructure in the Philippines. A problem tree was drawn to identify the different factors contributing to “inadequate transport infrastructure and poor quality transport services”. More than half of the reasons listed point to shortcomings on the government side, as simplified and summarized in the list below:

- Weak institutional capacity in planning and implementation
- Limited resources to manage traffic systems
- Severe lack of transparency in transport project management
- Insufficient inter-agency coordination
- Weak management and quality control
- Misallocation of limited funds, diversion of funds
- Slow rate of implementation
- And many others…

A recent example of bureaucratic complications would be the case of the Bus
Rapid Transit (BRT) project, originally considered for Metro Manila and Cebu City. Despite already being allocated funds from the national budget, PHP 570 million (approx. JPY 1.2 billion) project was requested to be cancelled by transport authorities on the grounds of being “may be technically difficult to implement”. This decision was made after the same authorities requested for such funds. Along with the cancellation request, it was suggested that the funds be transferred to another agency instead [20].

While there have been government initiatives in adding to and improving existing transport infrastructure in Metro Manila, there also clearly exists a plethora of hurdles on the government side in the realization and proper implementation of these initiatives. As such, ride-hailing services pose as an attractive short- to medium-term method for mitigating road congestion in Metro Manila, by improving efficiency of existing transport infrastructure. As this mode of transport is provided by private entities, with the physical capital already existing in the form of privately-owned vehicles. This unique set-up entails more flexibility compared to other conventional modes of transport.

1.4. Research Purpose and Research Questions

The purpose of this study is to mitigate road congestion in Metro Manila, by reducing the number of vehicles on the road via ride-hailing services.
Given this, the research questions of this study are as follows:

1. How much modal shares can ride-hailing services have in Metro Manila, given certain attributes?

With the shifts in modal shares:

2. Would there be reduced vehicles on the road?
3. Would there be reduced time spent commuting?
4. Would there be a reduction in air pollutant emissions from road-based transit modes?
5. Would there be a reduction in economic losses due to road congestion?

In the list above, (3) can be thought of as a social impact, (4) as environmental impact, and (5) as economic impact.

The logic behind the aforementioned purpose and research questions are illustrated in the Figure 8.

Given the greater purpose of mitigating road congestion, various ways to do this were considered. However, given that these options are either deemed to be unrealistic or too challenging from the standpoint of a researcher, ride-hailing services were chosen. The research questions of this study were then formulated based on this decision.
Research Purpose: To mitigate road congestion

Option 1: Public transport
Option 2: Policy regulation
Option 3: Increase Occupancy Levels
Ride-hailing services

Research Questions
How much modal shares can ride-hailing services have in Metro Manila?

- With the shifts in modal shares:
  - Would there be reduced vehicles on the road? (Modal Shifts)
  - Would there be a reduction in air pollutant emissions? (Environmental)
  - Would there be reduced time spent commuting? (Social)
  - Would there be a reduction in economic losses? (Economic)

Figure 8: Research Purpose and Questions

It is hypothesized that if modal shares of ride-hailing services increase, then there would be reduced vehicles on the road, reduced time spent commuting, reduced economic losses due to congestion, and reduction in air pollutant emissions from road-based transit modes. With a reduction in time spent commuting, it is assumed that this would imply an increase in the quality of life of residents in Metro Manila, thus entailing a social benefit.

The primary target audience of this study would be the Philippine government. Given that ride-hailing services were only officially recognized in the country in 2015, the government is still wary on this new and unfamiliar mode of transit. This study aims to better inform the government on the potential of ride-hailing as a way of mitigating road congestion. Furthermore, government employees may use the methods employed in this study to adjust the attribute values of transit modes and see how these changes may
affect modal shares, and consequently, volume of vehicles, travel speeds, and travel time.

The secondary target audience of this study would be private car owners in Metro Manila. It is hoped that by presenting them with this information, they would be encouraged to consider ride-hailing and ridesharing services instead of always taking their own cars, thereby reducing the number of vehicles on the road and contributing to road decongestion.

1.5. Review of Related Literature

On Modal Shift of Private Car Users

As mentioned in Chapter 1 of this study, private cars take up to 70% of road space in Metro Manila despite only carrying a small percentage of person-trips. This indicates inefficient use of limited road space and calls for higher occupancy levels for private cars and/or modal shift of private car users to mass transit options.

Regarding the latter, a study investigating commuter behavior and mode choice preferences was conducted in Klang Valley, Malaysia in 2014 [21]. Klang Valley is the capital region of Malaysia, much like how Metro Manila is that of the Philippines. Furthermore, Malaysia has also been seeing a rapid rise of the number of vehicles in the country and on the roads – just like the Philippines.

In this study, a group of researchers conducted Stated Preference and Revealed Preference surveys to find out what factors influenced commuters’ decision-making process when choosing what mode of transport to take; the choices were (private) car, rail, and bus. The researchers used logistic regression analysis to process the survey results.
The results of the survey were unsurprising, revealing factors such as transit time and transport fare to be important to commuters.

The second part of the study was scenario modelling, wherein the researchers considered 3 different scenarios to see which one would have the greatest modal shift among commuters from private to public transportation. An interesting finding was that improvement of infrastructure of the public transport system did not guarantee a modal shift among commuters. This means that residents who would normally take their own private car would still continue to do so even after public transport services are improved. This is a key takeaway deemed to be relevant even to the case of Metro Manila. While the Philippine government has been taking measures to improve public transport services, these improvements do not guarantee modal shift of private car users, and by extension, may not necessarily mitigate road congestion.

The study found that to better ensure modal shift of private car users, there must be a simultaneous increase in utility of mass transit options, as well as decrease in utility of private cars. This can be achieved by, for example, making it more expensive to own and/or use private cars. This can be done through mechanisms such as parking costs, vehicle taxes, gasoline prices, etc.

The results of this study also show that conventional mass transit options are not as attractive to car owners. While ride-hailing services were not within the scope of this study, it is speculated that ride-hailing services will be a more feasible alternative for car owners, as taking a ride-hailing service is more similar to driving their own car compared to other conventional modes of mass transit such as bus and rail.
Advantages and Disadvantages of Ride-hailing services

A study published by the San Francisco County Transportation Authority in 2017 [22] found that TNCs operating within the city had half as much unutilized vehicle-mile-traveled (VMT), at 20%, compared to conventional taxis in the same city, at 40%. The transport authority articulates that this higher efficiency displayed by ride-hailing services are likely due to their technology-enabled way of more efficiently matching riders with available drivers.

Similar findings were found even in other cities in the United States. A study by Cramer and Krueger in 2016 [23] found that ride-hailing services (i.e. Uber) had higher capacity utilization rates than conventional taxis in four out of five cities in the U.S., namely San Francisco, Boston, Los Angeles, and Seattle. In another city included in the study, New York, Uber vehicles and taxis had roughly around the same capacity utilization rates. For the first four cities, Uber cars had 40% higher utilization rates than taxis in the same cities. This means that ride-hailing services were carrying passengers for a higher proportion of road-time than their taxi counterparts. This entails more efficient utilization of road space and vehicle-kilometers.

According to a study published in 2018, ride-hailing services are found to be usually less expensive than conventional taxis, at least in the United States. [24]

In 2016, one year after the Philippine government first officially recognized TNCs in Metro Manila, Uber conducted a survey among its users in Metro Manila and surrounding areas [25]. Of the 1,450 respondents, 43% owned a car, and among these car
owners, more than half reported driving less due to the ride-hailing services provided by Uber.

**On Differences between Conventional Taxis and Ride-hailing Services in Metro Manila**

A study conducted in 2017, two years after the Philippine government officially recognized ride-hailing services in the country, investigated the commuting experience as well as perceptions of riders of both conventional taxis and ride-hailing services in Metro Manila [19]. They surveyed 119 commuters and found that up to 57% indicated willingness to forego using their own car for a convenient mode of transportation. The rest expressed reluctance to do so due to insufficient quality of current transport infrastructure.

The study also presented findings on commuters’ perception towards and experiences with ride-hailing services versus conventional taxis in the metropolis. Results showed that passengers complain about taxis 3-4 times more often than they do for ride-hailing services, for reasons such as rudeness and reckless driving.

**Estimating the environmental effects of the car shifting behavior along EDSA**

A study on commuter behavior along the main thoroughfare of Manila, EDSA Avenue, was conducted in 2018 [26]. A Stated Preference Survey was conducted, with the survey results being used to formulate a multinomial logit model, and subsequently estimating the reduction in greenhouse gas emissions. However, the scope of the research did not include ride-hailing services.
**Estimation of Impact on Environment using Policy Scenarios in Metro Manila**

A study published in 2013 in Metro Manila [27] explored the possible impact on greenhouse gas emissions by the Metro Manila transport sector depending on various policy scenarios regarding “environmentally sustainably transport strategy measures”, such as increasing fuel efficiency, technology improvements, etc. Ride-hailing services were not included in this study, however.

**Assessment of Impact of Ride-hailing services in other cities and countries**

Similar studies were found in other countries such as France [28], Ireland [29], and China [30]. However, these countries have very different contexts compared to the Philippines, wherein public transport is mostly comprised of paratransit modes such as the jeepney and tricycles [11].

Furthermore, the Ireland study only looked at static factors such as gender, age, household size, and occupation to predict the shift in modal shares. After determining the modal shares through a single iteration (non-repetitive), the study assessed the impact on \( \text{CO}_2 \) emissions, and no other air pollutants.

The study in China also estimated the modal share of ridesharing services, and subsequently estimated the impact of the modal shift on four kinds of emissions: \( \text{CO}_2 \), PM, NOx, and SOx. They also included energy savings in their assessment. However, their estimation of the modal shift was simply estimated using a stated preference survey. It is worth noting that this study was also non-repetitive.

The latest study which was held in Paris, France in 2018 considered the cost,
travel time, and travel distance of land-based transport modes to estimate the share of ride-hailing services. The indicators they assessed were CO₂ emissions and the congestion ratios within the transport system. This study was also non-repetitive.

1.6. Research Originality

A summary of the most similar studies and how they compare to this study is illustrated in the following table.

<table>
<thead>
<tr>
<th>Factors Considered</th>
<th>Indicators Assessed</th>
<th>Location</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caulfield (2009) [29]</td>
<td>Gender, Age, Household size, Occupation</td>
<td>Environmental (CO₂)</td>
<td>Dublin, Ireland</td>
</tr>
<tr>
<td>Yin, et al (2018) [28]</td>
<td>Cost Time Distance</td>
<td>Environmental (CO₂)</td>
<td>Paris, France</td>
</tr>
<tr>
<td>Cost Time Comfort &amp; Reliability</td>
<td>Environmental (CO₂, PM, HC, NOₓ, SOₓ)</td>
<td>Metro Manila, Philippines</td>
<td></td>
</tr>
<tr>
<td>This study (2019)</td>
<td>Social (saved time)</td>
<td>Economic (loss reduction)</td>
<td>Iterative</td>
</tr>
</tbody>
</table>

Table 3: Originality of This Study
This study takes into consideration the transport cost, time, as well as comfort and reliability in estimating the modal shares of road-based transport modes, including ride-hailing services – both solo and shared. Indicators assessed include both traffic conditions, which affects social benefits, as well as emissions of not only carbon dioxide but 4 other commonly known air pollutants. The 5 air pollutants are Particulate Matter (PM), Carbon Dioxide (CO₂), Hydrocarbons (HC), Sulphur Oxide (Sox), and Nitrogen Oxides (NOx). This gives rise to new findings.

One of the causes for uniqueness of this study is that no similar study has been conducted in Metro Manila or the Philippines. There are very limited studies on ride-hailing services in the country, and no assessment of the impact of the modal shares of these services on the social and environmental context.

Other than the location-based difference from other studies, another significant cause for originality of this study is that the estimation of modal shares is iterative. This iterative aspect is discussed in detail in Chapters 2 and 3.

1.7. Thesis Structure

Chapter 1 of this paper presents an introduction to the context of this research, provides an overview of the capital of the Philippines and its current transport infrastructure, and introduces the concept of ride-hailing services. Chapter 1 also discusses the research purpose, identifies the target audience of the study, describes the originality of the study, as well as outlines research questions. Previous studies are also discussed in this chapter. Chapter 2 outlines the methods employed in this study, while
Chapter 3 illustrates how these methods were employed along with the data used and results obtained. Chapter 4 discusses these results and their implications. Chapter 5 includes the conclusions of this study, as well as difficulties encountered in the research process, and future work that could be done to improve on and build on this study.
Chapter 2: Research Methods

The flow of the methods of this research is illustrated in Figure 9:

![Figure 9: Overview of Sequence of Methods](image)

First, the “base” logit model must be created. This can be done by first identifying which modes of transit are considered of interest in this study. For this study, only road-based modes of transit are considered as it is assumed that given the highly limited rail options in Metro Manila as well as poor inter-mode connectivity, people who take mostly road-based options will not easily shift to rail-based modes and vice versa. After determining the transit modes to be considered, the actual modal shares of these existing modes must be determined, as well as the quantitative values for each attribute for each mode. Then, the beta coefficients can be determined.

Next, the attribute values of the “new” modes of transport, in this case the two kinds of ride-hailing services, solo and shared, must be determined. This will enable calculation of the new shares, which now include the two new modes. Given this modal shift, the new travel times must be recalculated given the modal shift and therefore change...
in volume of vehicles on the road, assuming flexible supply of each mode. This part is referred to as the Iterative Logit Model. These recalculations must be done until there is no more significant modal shift seen.

Once the shares and volume of vehicles finally stop changing, then impact assessment may be conducted.

Given the aforementioned steps, the relationship of data that serve as inputs and outputs in this study are illustrated in Figure 10.

Inputs for the logit model to estimate modal shares are as follows:

- Transport modes of interest and their respective shares
- Mode attributes
  - Consumer preference: indicated by comfort and reliability, gathered through a survey
  - Trip attributes: travel cost and time, gathered through various secondary sources

The output for the logit model is a new set of modal shares each time, which then can be used to determine the new number of vehicles on the road. This is used to recalculate travel time, which can then be used as input for the next iteration.

Once the results Iterative Logit Model stop significantly changing, then assessment of environmental, social, and economic impacts may be conducted. These are indicated by annual air pollutant emissions, saved time commuting, as well as reduced
As seen in Figure 10, the central method to this study is the logit model. The logit model is widely used in mode choice-related studies. The logit model was chosen as it can be used to estimate the shares of a new mode based on known attribute values. This method is discussed more in detail in section 2.2.

Before delving into details of the research methods, some indices and variables used in equations are introduced in the following tables.
Table 4: List of Indices

<table>
<thead>
<tr>
<th>Index</th>
<th>Meaning</th>
<th>List</th>
</tr>
</thead>
<tbody>
<tr>
<td>m</td>
<td>transport mode</td>
<td>1 – Private Car</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 – Taxi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 – Jeepney</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 – Bus</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 – Ride-hailing service (Solo)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6 – Ride-hailing service (Shared)</td>
</tr>
<tr>
<td>i</td>
<td>attribute in utility</td>
<td>1 – Cost per kilometer [Philippine Pesos or PHP]</td>
</tr>
<tr>
<td></td>
<td>equation</td>
<td>2 – Travel time [minutes]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 – Comfort and Reliability</td>
</tr>
<tr>
<td>j</td>
<td>air pollutant</td>
<td>1 – Particulate Matter (PM)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 – Carbon Dioxide (CO2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 – Hydrocarbons (HC)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 – Sulphur Dioxide (SOx)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 – Nitrogen Oxides (NOx)</td>
</tr>
</tbody>
</table>

Table 5: List of Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Meaning</th>
<th>Indices</th>
</tr>
</thead>
<tbody>
<tr>
<td>s(u)</td>
<td>modal share,</td>
<td>m</td>
</tr>
<tr>
<td>u(x)</td>
<td>utility, function of x</td>
<td>m</td>
</tr>
<tr>
<td>q</td>
<td>volume or number of vehicles on the road</td>
<td>m</td>
</tr>
<tr>
<td>v(q)</td>
<td>speed [kilometers per hour or kph]</td>
<td>m</td>
</tr>
</tbody>
</table>
2.1 Interviews

Interviews were conducted with commuters in Metro Manila regarding their commuting habits, opinions, and preferences. These interviewees were held to provide some qualitative understanding behind the “consumer preference” attributes of the logit model. Interviewees were chosen based on convenience sampling, and thus were acquaintances of the researcher. Interviews were held for approximately 30 minutes each with 8 interviewees over video-call. These interviews are semi-structured, with some key questions listed below:

- What mode of transport do you most frequently take?
- Why do you choose that mode of transport?
- Other than that mode, what other modes do you consider? Why?
- Are there any modes that you disregard? Why?
- What factors do you keep in mind when choosing what mode of transport to take for a trip? (e.g. cost)

Specifically for commuters with a driver’s license and access to a car:

- When and why do you choose to bring your own car?
- (If their most frequent default mode of transport is their car) When do you consider not taking your own car?
- If you don’t take your own car, what is the next most frequently considered mode of transport?
- What would encourage you to bring your own car less?
2.2 Utility Theory and Logistic Regression

It is given by the Multinomial Logit Model that the share of a mode can be expressed by the equation below.

\[ s_m(u_m) = \frac{e^{u_m}}{\sum_{1}^{M} e^{u_m}} \]  \hspace{1cm} (I)

where:

- \( m \) is the mode of transport
- \( s_m \) is the modal share of a transit mode \( m \)
- \( u_m \) is the “utility” of transit mode \( m \)

This “utility” factor comes from the Utility Theory, which states that given a set of choices (e.g. transport mode choices), a person will choose the option that gives them the highest utility. This utility is comprised of a set of attributes that the person (commuter) considers in their decision-making process. In the case of transport, this can be attributes such as cost of the trip (e.g. bus fare), travel time, reliability, etc. Furthermore, these attributes may not hold the same weights, i.e. some attributes may be prioritized more by commuters.
The equation for this utility is given below.

\[
 u_m(x_{mi}) = \beta_1 * x_{m1} + \beta_2 * x_{m2} + \beta_3 * x_{m3} + \cdots + e_m \quad (2)
\]

Where \( m \) is the mode of transport

\( i \) is the attribute

\( x_{mi} \) are the respective values for each attribute for each mode

\( \beta_i \) is the coefficient (weights) for attribute \( i \)

\( e \) represents an error constant

Taking the natural log of both sides of Equation (1) yields:

\[
 \ln s_m = u_m - \ln(\sum_1^M e^{u_m}) \quad (3)
\]

Producing the equation above for two different modes and subtracting one from the other leaves the following equation:

\[
 \ln(s_{mi}) - \ln(s_{mj}) = u_{mi} - u_{mj} \quad (4)
\]

Substituting the utility equations for 2 mode choices would produce the following equation:

\[
 \ln(s_{mi}) - \ln(s_{mj}) = \beta_1 (x_{i1} - x_{j1}) + \beta_2 (x_{i2} - x_{j2}) \\
 + \beta_3 (x_{i3} - x_{j3}) + e_{mi} - e_{mj} \quad (5)
\]

This equation was similarly derived and expressed in another published journal paper on commuter choice modeling [31].
By applying the equation above given modal shares of existing modes of transport, as well as the respective values for the attributes chosen, the beta-coefficients can be derived using linear regression analysis.

Once the beta-coefficients are determined, then the modal shares for ride-hailing services, both solo and shared, can be determined by calculating their utilities and using Equation (1).

**Iterative Logit Model**

Here begins the iterative logit model. The concept behind this method is that as modal shares of the given road-based transport modes change, so will the number of vehicles on the road. This then affects the speed of these vehicles, thereby affecting travel time. Since travel time is an attribute in the utility equations used in calculating the modal shares, then the modal shares will shift again. This cycle is illustrated in the Figure 11.
Each iteration is conducted as follows.

1. Given the share of each transit mode, let $q$ be the volume of vehicles for mode $m$ per day. This is calculated using the following equation:

$$ q_m(s_m) = \frac{s_m \times \text{COMM}}{\text{OCC}_i} $$

(6)

where $m$ is the mode of transport, $m = 1$ to $6$

$s$ is the share of mode $m$

COMM is the total number of commuters in one day

OCC is the average occupancy level of mode $i$

The values of OCC can be found in the following table.
Table 6: Average Occupancy of Each Mode [14]

<table>
<thead>
<tr>
<th>Mode</th>
<th>Ave. Occupancy (persons per vehicle)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private Car</td>
<td>1.57</td>
</tr>
<tr>
<td>Taxi</td>
<td>0.81</td>
</tr>
<tr>
<td>Bus</td>
<td>34.19</td>
</tr>
<tr>
<td>Jeepney</td>
<td>8.84</td>
</tr>
<tr>
<td>Ride-hailing (Solo)</td>
<td>1.62</td>
</tr>
<tr>
<td>Ride-hailing (Shared)</td>
<td>3.24</td>
</tr>
</tbody>
</table>

The average occupancy levels of the private car, taxi, bus, and jeepney are provided by actual data published by JICA in a nationwide transport study [14]. The average occupancy levels of solo ride-hailing services was calculated by doubling the occupancy level of taxis in Metro Manila. The reason for this is based on the findings of the San Francisco County Transportation Authority in 2017, wherein they found that ride-hailing services in the city had half as much unutilized vehicle-miles-traveled (VMT) as taxis in the area [22]. The shared ride-hailing services are assumed to have twice the occupancy level of solo ride-hailing services.

2. Derive travel speeds based on q-v graphs using number of vehicles from (1).

q-v graphs are taken from the field of Transportation Engineering, wherein q is the traffic volume or number of vehicles on the road and v is the travel speed or velocity. It is understood that as the number of vehicles on the road increase, travel speed decreases. In order to determine the q-v graphs, two things must be clarified: one is the capacity of the road/s in number of vehicles $q_{\text{max}}$, and the other is the maximum free-flow speed $v_{\text{max}}$. 
The latter is determined not just by the technically feasible maximum speed, but also by factors such as local speed limits set by transport authorities.

Figure 12: Example of a QV Function [14]

3. Calculate new travel times based on travel speed obtained in (2) and additional waiting times per mode.

4. Using new travel times as input for the utility equations, recalculate modal shares using the aforementioned equations.

5. Iterate again from Step 1 until modal shares and volume of vehicles no longer change.

After multiple iterations, once the modal shares and volume of vehicles no longer change, then the quantitative assessment of environmental and social impact can be conducted.
2.3 Assessment of Environmental and Socioeconomic Impact

*Environmental Impact: Estimation of Reduction in Emissions of Air Pollutants*

In estimating the reduction in environmental pollutants from the shift in modal shares, annual emissions of 5 air pollutants will be calculated based on annual vehicle kilometers demanded from each road-based transit mode. These air pollutants are as follows:

1. Particulate Matter (PM)
2. Carbon Dioxide (CO₂)
3. Hydrocarbons (HC)
4. Sulphur Oxide (SOx)
5. Nitrogen oxides (NOx)

The emissions factors for each pollutant type and each mode are outlined in the following table, in terms of gram per vehicle-kilometer. These factors were taken from the Vehicular Emission Control Planning Project conducted by the Asian Development Bank in 1992, as cited in a published study in the Philippine Engineering Journal [27].

*Table 7: Emission Factors (g/veh-km) [27]*

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Vehicle Type</th>
<th>PM</th>
<th>CO</th>
<th>HC</th>
<th>SOx</th>
<th>NOx</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline</td>
<td>Car</td>
<td>0.1</td>
<td>49.5</td>
<td>6.0</td>
<td>0.011</td>
<td>2.7</td>
</tr>
<tr>
<td></td>
<td>Car</td>
<td>0.6</td>
<td>1.9</td>
<td>0.65</td>
<td>0.081</td>
<td>2.0</td>
</tr>
<tr>
<td>Diesel</td>
<td>Jeepney</td>
<td>0.9</td>
<td>2.5</td>
<td>0.7</td>
<td>0.121</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td>Bus</td>
<td>1.5</td>
<td>12.4</td>
<td>3.7</td>
<td>0.374</td>
<td>12.5</td>
</tr>
</tbody>
</table>
According to this source, taxis in Metro Manila fall under “diesel cars”. For the modes of private car and ride-hailing services in this study, the modal shares of gasoline and diesel for passenger vehicles in Metro Manila will also be used in the calculations. According to 2014 statistics provided by the Land Transportation Office, among cars and SUVs in Metro Manila, gasoline has a 57.8% share while diesel has a 42.2% share. [6]

Using these emission factors, the volume of emissions is calculated using the equation below.

\[
APE_{mj} = s_m \times KMDEM \times EF_{mj}
\]  

(7)

Where APE is Air Pollutant Emissions [g]

s is share of transport mode m

m is transport mode, m = 1 to 6

KMDEM is daily demand in vehicle-kilometers in Metro Manila [veh-km]

j is the air pollutant, j = 1 to 5

EF is the emission factor for mode m and air pollutant j [g/veh-km]

Social Impact: Time saved commuting

For the assessment on social impact, the metric used will be how much time is saved commuting based on the initial and final shares of the road-based transit modes. This is calculated using the following formula:

\[
ST(s, v) = \sum_{m=1}^{6} \left( \frac{S_{mf} \times KMDEM}{v_{mf}} - \frac{S_{mi} \times KMDEM}{v_{mi}} \right)
\]

(8)
Where $ST$ is saved time commuting per day for all Metro Manila population [hours]

$m$ is transport mode, 1 to 6

$s_f$ is final share of mode $m$, $s_i$ is initial share of mode $m$

$v_f$ is final speed of mode $m$ [km/hr], $v_i$ is initial speed of mode $m$ [km/hr]

$\text{KMDEM}$ is the daily demand in Metro Manila for road-based transport [vehicle-kilometers]

**Economic Impact: Percent reduction in Economic Losses due to Road Congestion**

JICA has estimated in 2018 that traffic congestion in Metro Manila causes 3.5 billion Philippine Pesos, or approximately 7 billion Japanese Yen worth of economic losses each day [32]. In another study by the Boston Consulting Group [3], it was estimated that an average Metro Manila resident spends approximately 400 hours stuck in traffic every year. According to the Philippine Statistics Authority, the population of Metro Manila is at 12,877,253. Using these figures, an estimate on reduction in daily economic losses due to congestion can be established through the following equation:

\[
REL = ELOSS \times \left(1 - \frac{\left(\frac{\text{CONG} \times \text{POP}}{365}\right) - ST}{\left(\frac{\text{CONG} \times \text{POP}}{365}\right)}\right)
\]  

(9)

Where REL: reduction in economic losses per day [Philippine Pesos]

ELOSS: current value of economic losses per day [Philippine Pesos]

CONG: time spent in congestion by Metro Manila commuter every year [hours]

POP: population of Metro Manila

ST: saved time commuting per day [hours]
Chapter 3: Results

3.1. Preliminary Interview Results

Interviews were held with commuters in Metro Manila in order to get an idea of their commuting habits and decision-making behaviors.

Some key insights were gained during these interviews. One is that unlike some assumptions made in previous studies, driving a private car does not always entail maximum comfort for the users, or at least for the one driving. This is due to the stress induced by driving in heavily congested roads and having to maneuver given the chaotic Metro Manila roads. This idea that commuters experience stress in-transit, whether taking a public or a private mode of transit, is also reaffirmed by Caulfield and O’Mahony [33]. This stress is sometimes avoided by private car users by taking alternative modes of comparably comfortable transport such as ride-hailing.

However, while private car users may indeed consider other modes of transport, it seems to be a common pattern that cost is not much of a concern. Furthermore, comfort and reliability are still considered high priorities. Due to these conditions, conventional mass transit options such as the jeepney and rail transit are not commonly considered by heavy private car users.

3.2. Data for the Utility Equation

The modal shares for these road-based transit modes were derived from data provided by the latest nationwide transport study conducted by JICA in cooperation with
the Philippine government [14]. A summary of the sources of each piece of data is illustrated in the table below.

Table 8: Sources of Data for Attribute Values

<table>
<thead>
<tr>
<th>Mode</th>
<th>Cost</th>
<th>Waiting Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bus</td>
<td>Metro Manila Urban Transportation Integration Study by JICA (1999) [35], crosschecked with recent fares</td>
<td>Guarino (2001) [36]</td>
</tr>
<tr>
<td>Taxi</td>
<td>Gaabucayan-Napalang (2017) [19]</td>
<td></td>
</tr>
<tr>
<td>Ride-hailing (solo)</td>
<td>Derived from attributes of Ride-hailing (solo), based on information provided by TNC in Metro Manila (Grab)</td>
<td></td>
</tr>
<tr>
<td>Ride-hailing (shared)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The comfort and reliability attribute values were obtained through a survey conducted among Metro Manila residents. Respondents were chosen based on convenience sampling. Comfort refers to physical, mental, and emotional ease when taking this mode of transit. Conditions such as personal space, temperature, air quality, sense of safety and security, etc factor into this attribute. Reliability refers to the consistency of aspects such as travel cost, transit time, waiting time, mode availability, seat availability, etc. A 7-point Likert scale was used, as described in the following table.
Table 9: Likert scale for Evaluation of Comfort and Reliability

<table>
<thead>
<tr>
<th>Point</th>
<th>Comfort rating</th>
<th>Reliability rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Highly comfortable</td>
<td>Highly reliable</td>
</tr>
<tr>
<td>2</td>
<td>Comfortable</td>
<td>Reliable</td>
</tr>
<tr>
<td>1</td>
<td>Relatively comfortable</td>
<td>Relatively reliable</td>
</tr>
<tr>
<td>0</td>
<td>Neutral</td>
<td>Neutral</td>
</tr>
<tr>
<td>-1</td>
<td>Relatively uncomfortable</td>
<td>Relatively unreliable</td>
</tr>
<tr>
<td>-2</td>
<td>Uncomfortable</td>
<td>Unreliable</td>
</tr>
<tr>
<td>-3</td>
<td>Highly uncomfortable</td>
<td>Highly unreliable</td>
</tr>
</tbody>
</table>

The average values for each mode were then obtained and used for the logit model.

Table 10: Modal Shares and Attribute Values

<table>
<thead>
<tr>
<th>Mode No.</th>
<th>Mode</th>
<th>Initial Share</th>
<th>Passenger Cost (Philippine Pesos per km)</th>
<th>Travel Time (minutes)</th>
<th>Comfort and Reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Private Car</td>
<td>68.26%</td>
<td>8.99</td>
<td>89.65</td>
<td>2.58</td>
</tr>
<tr>
<td>2</td>
<td>Taxi</td>
<td>1.88%</td>
<td>28.49</td>
<td>87.76</td>
<td>-0.17</td>
</tr>
<tr>
<td>3</td>
<td>Jeepney</td>
<td>19.28%</td>
<td>2.28</td>
<td>102.2</td>
<td>-0.54</td>
</tr>
<tr>
<td>4</td>
<td>Bus</td>
<td>10.58%</td>
<td>2.60</td>
<td>105.43</td>
<td>-1.04</td>
</tr>
</tbody>
</table>

The following coefficients were obtained after conducting linear regression analysis via Excel. Their respective p-values also indicate significance, and thus these attributes can be used in the utility equation.

Table 11: Beta coefficients for the Utility Equation

<table>
<thead>
<tr>
<th>Beta coefficients for Attributes</th>
<th>Value</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Thus, the Utility function for each mode of transport is as follows:

\[ u_m = -0.16660175 x_{m1} - 0.13567873 x_{m2} + 0.2174647 x_{m3} + \epsilon_m \]  

(8)

where \( u \) is the utility of transport mode \( m \)
\( i \) is the attribute, \( i = 1 \) to 3
\( x \) is the value of attribute \( i \) for mode \( m \)
\( m \) is transport mode, \( m = 1 \) to 6

Given this utility equation as well as the attribute values for ride-hailing in Table 12, the new shares for each mode of transport, now including ride-hailing services, were then calculated using Equation (1).

<table>
<thead>
<tr>
<th>Mode</th>
<th>Passenger Cost (Philippine Pesos per km)</th>
<th>Travel Time (minutes)</th>
<th>Comfort and Reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ride-hailing (solo)</td>
<td>20.72</td>
<td>84.88</td>
<td>1.25</td>
</tr>
<tr>
<td>Ride-hailing (shared)</td>
<td>14.50</td>
<td>90.88</td>
<td>0.79</td>
</tr>
</tbody>
</table>

The results of said calculations are as follows:
### Table 13: Modal Shares including Ride-hailing for Base Model

<table>
<thead>
<tr>
<th>Mode</th>
<th>Initial Share</th>
<th>New Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private Car</td>
<td>68.26%</td>
<td>52.73%</td>
</tr>
<tr>
<td>Taxi</td>
<td>1.88%</td>
<td>1.46%</td>
</tr>
<tr>
<td>Jeepney</td>
<td>19.28%</td>
<td>14.89%</td>
</tr>
<tr>
<td>Bus</td>
<td>10.58%</td>
<td>8.17%</td>
</tr>
<tr>
<td>Ride-hailing (solo)</td>
<td></td>
<td>10.69%</td>
</tr>
<tr>
<td>Ride-hailing (shared)</td>
<td></td>
<td>12.07%</td>
</tr>
</tbody>
</table>

#### 3.3. Iterative Logit Model

In order to recalculate the travel times as modal shares shift, a QV graph was created for EDSA, the main thoroughfare in Metro Manila, which runs for 23.8 kilometers. Along EDSA, private vehicles – including taxis and ride-hailing vehicles – have a maximum allowed speed of 60 kilometers per hour. Public Utility Vehicles (PUVs), such as buses and jeepneys, on the other hand, are assigned a maximum speed of 50 kilometers per hour. This is as mandated by local traffic authorities. It is also known that EDSA has a daily capacity of 280,000 vehicles. Expressing the QV graph in terms of kilometers per hour and in thousands of vehicles, the QV graphs used for this study is shown below.
Having iterated on Microsoft Excel for 40 rounds, it was found that the modal shares as well as number of vehicles on the road stopped changing at around the 32nd iteration. While very small changes were still observed after this iteration, it was already in the decimal range.
A trend can be seen wherein the modal shares of private cars and taxis decrease while the modal shares of jeepney, bus, and both kinds of ride-hailing services increase. The final shares after the logit model stabilizes are enumerated in Table 14.

**Table 14: Initial and Final Modal Shares after 32 Iterations**

<table>
<thead>
<tr>
<th>Mode</th>
<th>Base Shares (%)</th>
<th>Initial Shares (%)</th>
<th>Final Shares (%)</th>
<th>Shift (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private Car</td>
<td>68.26</td>
<td>63.2</td>
<td>38.65</td>
<td>-30</td>
</tr>
<tr>
<td>Taxi</td>
<td>1.88</td>
<td>1.74</td>
<td>1.07</td>
<td>-1</td>
</tr>
<tr>
<td>Jeepney</td>
<td>19.28</td>
<td>17.85</td>
<td>28.15</td>
<td>+9</td>
</tr>
<tr>
<td>Bus</td>
<td>10.58</td>
<td>9.8</td>
<td>15.45</td>
<td>+5</td>
</tr>
<tr>
<td>Ride-hailing (solo)</td>
<td>10.69</td>
<td>7.83</td>
<td></td>
<td>+8</td>
</tr>
<tr>
<td>Ride-hailing (shared)</td>
<td>12.07</td>
<td>8.85</td>
<td></td>
<td>+9</td>
</tr>
</tbody>
</table>

3.4. Assessment of Environmental, Social, and Economic Impacts
Applying the calculation methods explained in Chapter 2, the results for the impact assessment on the environment is as follows:

Table 15: Change in Air Pollutant Emissions (in ’000s tons per year)

<table>
<thead>
<tr>
<th>Air Pollutant</th>
<th>Initial</th>
<th>Final</th>
<th>Difference</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particulate Matter (PM)</td>
<td>16.53</td>
<td>19.72</td>
<td>3.19</td>
<td>↑</td>
</tr>
<tr>
<td>Carbon Dioxide (CO₂)</td>
<td>651.58</td>
<td>553.95</td>
<td>-97.63</td>
<td>↓</td>
</tr>
<tr>
<td>Hydrocarbons (HC)</td>
<td>92.00</td>
<td>83.62</td>
<td>-8.39</td>
<td>↓</td>
</tr>
<tr>
<td>Sulphur Dioxide (SOx)</td>
<td>2.74</td>
<td>3.42</td>
<td>0.68</td>
<td>↑</td>
</tr>
<tr>
<td>Nitrogen Oxides (NOx)</td>
<td>97.31</td>
<td>108.91</td>
<td>11.60</td>
<td>↑</td>
</tr>
</tbody>
</table>

With the new modal shares, and given that the road-based transportation demand in vehicle-kilometers per day in Metro Manila as of 2015 is 73,927,319 km [27], it was found that 1.8 million hours of commuting can be saved per day in Metro Manila, or 677 million hours per year.

Given the estimation method described in Chapter 2, the reduction in daily economic losses is approximated at 13% reduction, or approximately 460 million Philippine Pesos.
4.1. On the Iterative Logit Model

Results of the base logit model show that ride-hailing services, both solo and shared, start out with more than 10% each of modal shares. This was expected as these ride-hailing services offer comparable comfort and reliability to the private car, for fares that are reasonable relative to the less comfortable and less reliable taxi option.

At the same time, within the first 5 iterations, the modal share of private cars see a steep decline, losing more than 10% of its initial modal share. Within the same number of iterations, the modal shares of bus and jeepney also see increases in modal shares. These modal shifts instigate a gradual decrease in the volume of vehicles. As illustrated by the q-v graphs, the decrease of number of vehicles on the road entail an increase in speed for all vehicles, whether private or public. This shortens travel time across all modes.
It is interesting to note that around the 32nd iteration, both modal shares and volume of vehicles on the road stop having significant changes. Comparing the modal shares of the first few iterations to the last, the uniqueness and value of the iterative logit model can be seen. Clearly, one round of modal shifts will not stabilize traffic conditions. By the end of the 40 iterations, ride-hailing services still turned out to have significant shares, but not as high as they did in the first few iterations.

![Modal Shares after 32nd Iteration](image)

*Figure 16: Modal Shares after Iterative Logit Model reaches stability*

4.2. On Impact Assessment

Another very interesting finding is that of the environmental impact of the modal shifts. As summarized in the table below, it can be seen that not all air pollutants see a decrease in emissions. The most commonly assessed indicator of environmental impact among the transport studies surveyed was Carbon Dioxide, and the iterative logit model results showed a 97,630 tons decrease in Carbon Dioxide emissions per year. This is due to the decrease in vehicles through the modal shifts. Hydrocarbon emissions also saw a decrease in annual emissions. However, it is interesting to note that the 3 other air
pollutants, namely Particulate Matter, Sulphur Dioxide, and Nitrogen Oxides actually saw increases in emissions. This was an unexpected finding. This result goes to show that an overall decrease in vehicles on the road does not necessarily imply decrease in emissions of all air pollutants. The increase in these 3 air pollutants can be attributed to the increase in modal shares of the bus and jeepney modes of transit, which have relatively high Emission Factors compared to the other modes. Particularly of the jeepney, this is expected as the design of the vehicle is not conducted with the environment in mind. The jeepney is known in Metro Manila as a cheap to own, cheap to run, and cheap to ride mode of transit.

<table>
<thead>
<tr>
<th>Air Pollutant</th>
<th>Difference (in ‘000s tons per year)</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particulate Matter (PM)</td>
<td>3.19</td>
<td>↑</td>
</tr>
<tr>
<td>Carbon Dioxide (CO₂)</td>
<td>-97.63</td>
<td>↓</td>
</tr>
<tr>
<td>Hydrocarbons (HC)</td>
<td>-8.39</td>
<td>↓</td>
</tr>
<tr>
<td>Sulphur Dioxide (SOₓ)</td>
<td>0.68</td>
<td>↑</td>
</tr>
<tr>
<td>Nitrogen Oxides (NOₓ)</td>
<td>11.60</td>
<td>↑</td>
</tr>
</tbody>
</table>

In order to better ensure reductions in emissions of air pollutants, it may be worth considering ways to decrease the emission factors of buses and jeepneys in Metro Manila.

4.3. Interview with Philippine government employee

On August 11th, 2019, an interview was held over voice call with Koreen Hidalgo, a member of the technical staff of the Department of Transportation of the Philippines,
the government agency in charge of overseeing the transportation infrastructure and system of the country. This interview was held in order to hear their thoughts on the state of policy-making in the transport sector in the country, on data-driven policy decisions, on ride-hailing services in Metro Manila, as well as on the state of communication and collaboration between the academe and the Department of Transportation.

Q1: Given your experience in the Department of Transportation so far, do you think that policymakers are open to ideas, suggestions, studies, etc. from outside the government agency, or from, say, new employees or young people?
A1: “The people in power or the ones in influence can sometimes be hard-headed, stubborn, and you can’t do anything about it if you’re new or too young. (…) As much as you want to make the right policies, if you can’t convince the people who have the power to affect change, things won’t go anywhere.”, she says.

She expresses some frustration regarding how ‘political will’ plays too much of a role in policy-making in the Philippine government. During inter-agency meetings, she has had some personal experience in having to pander to certain politicians and their desire to be given recognition, whether or not this is relevant. This political will can often hinder the progress of infrastructure projects, or blur the objectivity of policies

Q2: Do you think that policies and regulations in the transport sector in the Philippines are data-driven?
A2: “No.” The Metro Manila Development Authority, for example, often seems to just have a trial-and-error kind of philosophy when implementing certain rules along the city’s main thoroughfare, EDSA. She does express some optimism however: “In recent meetings, the topic of big data has come up, but it really doesn’t seem to be a top priority
right now. But we’re trying.”

Q3: “What do you think about ride-hailing services in Metro Manila, such as Grab?”
A3: “It definitely helps.”, she says. “It gives people one more option. I think it’s great that we have them, because really they’re addressing needs that the government just can’t right now. They’re borne of necessity; people (commuters) need these kinds of options, but the government can’t provide, so I think it’s good they’re here.”

Q4: (After explaining the purpose, method, and results of this research) “What are your thoughts as a government employee in the transport sector? Do you think there are ways in which studies held within the academe, such as this one, can be presented to the government -- in order for policymakers to make use of this kind of data, this kind of information, and also this kind of methods?”
A4: “The research is very interesting. Honestly, I don’t think those kinds of channels exist right now. It would be great if there was more of a collaborative relationship between the government and the academe, but as far as I know, that’s not the case right now.” Her answer once again relates to the first question of this interview, wherein she expressed that it can often be a herculean feat to get the people in power to listen, much more to get them convinced.

Conclusion of the interview:

Based on the sentiments expressed by Ms. Hidalgo in this interview, it can be said that the motivation and reasoning behind this study are valid, and the results are thought of as interesting. However, it may still take some time to have studies such as this one actually affect some sort of change within the transport sector of the Philippine
government.
Chapter 5: Conclusions

Given mode attributes of cost, time, and comfort and reliability of 4 existing road-based transit modes, the “stable” set of modal shares can be found using the iterative logit model. Comparing the results of the initial iterations and the final (32\text{nd}) iteration, the iterative logit model proves to be an invaluable tool in more realistically estimating modal shares as traffic conditions change, compared to its non-iterative counterpart.

Results have also shown that ride-hailing services, both solo and shared, are promising means to mitigate road congestion. An overall decrease in number of vehicles was found with the introduction of ride-hailing services and their respective attributes, also resulting in higher speeds and shorter travel times for all modes. After both modal shares and the number of vehicles on the road stop changing, shared ride-hailing services are seen to have around 9% modal share.

With regards to the environmental impact of these shifts, decreases in Carbon Dioxide and Hydrocarbon emissions can be seen after modal shift. However, due to the simultaneous increases in modal shares of the bus and jeepneys, Particulate Matter, Sulphur Dioxide, and Nitrogen Oxides increase. This was an interesting finding of this study. While it is undoubtedly beneficial to have less carbon dioxide emissions due to less private vehicles on the road, due to the environmentally-unfriendly engineering design of the other modes of transport (jeepney, bus) whose shares increased, the 3 other air pollutants saw higher emissions after the modal shifts.

Taking into consideration the reduction of time spent in congestion, a reduction in
economic losses was also estimated as a result of the modal shifts. This was estimated to be a 13% reduction in daily economic losses due to road congestion with a value of 460 million Philippine Pesos.

The results of this study show that the Iterative Logit Model is a promising way to more accurately estimate the shift in modal shares once a new mode is introduced. It goes without saying that this original method can be implemented in other cities as well, as long as there is data for the mode attributes. These can be gathered through primary or secondary sources.

The findings brought about by the impact assessment in the specific case of Metro Manila were also interesting, in that while there is some environmental benefit, there are also some unexpected cons to the modal shift. This can be managed by improving the technology of the transport sector in order to be more environmentally friendly.

**Challenges and Future Work**

The two greatest challenges of this study was gathering data and getting a good grasp of the “logit model”. With regards to the former, it would be promising if this study can be built on with more recent and more accurate data. More modes of transport, such as the motorcycle and rail-based options, and more attributes, such as in-transit air quality, could also be taken into account in the future. Other ways of evaluating and estimating the social, environmental, and economic impacts could also be considered.

This method also has potential in helping the government and traffic authorities figure out how to manipulate the attributes such as cost and comfort and reliability in such
a way to encourage modal shifts to certain transport modes.

Transport Network Companies (TNCs) may also use the tools employed in this study to figure out how to price their ride-hailing service fares.

It is hoped that the tools and results found in this study can be used to move towards a better and more efficient transport infrastructure for Metro Manila and for other developing countries.
Acknowledgements

First of all, I would like to thank my primary research adviser, Professor Masaru Nakano, for his guidance and support throughout my two years in Keio SDM. I sincerely appreciate all the time and effort he spent in guiding us throughout the research process. It was an honor to have been under his supervision.

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I would also like to thank Assistant Professor Mizuho Sato for her valuable advice in conducting my research in the Business Engineering laboratory. Her words of encouragement also helped me overcome the struggles of pursuing a master’s degree in Japan.

I am also grateful for the time and effort of Mr. Yusuke Mihara of BE Lab and Mr. Diego Mejia of Tokyo University. It was with their help that I was able to get a better understanding of the methods used in this research.

I would also like to thank Ms. Koreen Hidalgo of the Department of Transportation in Metro Manila, Philippines, for her cooperation in the interview.

This research would not have been possible without the financial support of MEXT. Thanks to the Top Global University Project scholarship program, I was able to focus on my studies without the heavy burden of financial worries.

Finally, I must express my deepest gratitude and appreciation for my parents, Roy and Marisol Ybañez, without whose constant support and encouragement, I would not be where I am today.
References


http://www.uncrd.or.jp/content/documents/Philippine_NESTS.pdf, Accessed on: Jun. 28, 2019


Appendices

Appendix A: Screenshots of Excel File

Screenshot of Base Logit Model in Excel

<table>
<thead>
<tr>
<th>Mode No.</th>
<th>Mode</th>
<th>Initial Share</th>
<th>Cost</th>
<th>Travel time</th>
<th>CR</th>
<th>Utility</th>
<th>e^U</th>
<th>New Share</th>
<th>Shift</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Private Car</td>
<td>0.6826</td>
<td>8.99</td>
<td>89.65</td>
<td>2.58</td>
<td>-13.10</td>
<td>0.0000020459</td>
<td>0.5273</td>
<td>15.53%</td>
</tr>
<tr>
<td>2</td>
<td>Taxi</td>
<td>0.0188</td>
<td>28.49</td>
<td>87.76</td>
<td>-0.17</td>
<td>-16.69</td>
<td>0.0000000565</td>
<td>0.0146</td>
<td>0.43%</td>
</tr>
<tr>
<td>3</td>
<td>Jeepney</td>
<td>0.1928</td>
<td>2.28</td>
<td>102.20</td>
<td>-0.54</td>
<td>-14.36</td>
<td>0.00000005778</td>
<td>0.1489</td>
<td>4.39%</td>
</tr>
<tr>
<td>4</td>
<td>Bus</td>
<td>0.1058</td>
<td>2.60</td>
<td>105.43</td>
<td>-1.04</td>
<td>-14.96</td>
<td>0.00000003171</td>
<td>0.0817</td>
<td>2.41%</td>
</tr>
<tr>
<td>5</td>
<td>Ridehailing (solo)</td>
<td>20.72</td>
<td>84.88</td>
<td>1.25</td>
<td>-14.70</td>
<td>0.00000004146</td>
<td>0.1069</td>
<td></td>
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<tr>
<td>6</td>
<td>Ridehailing (shared)</td>
<td>14.50</td>
<td>90.88</td>
<td>0.79</td>
<td>-14.57</td>
<td>0.00000004682</td>
<td>0.1207</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Screenshot of 32nd iteration

<table>
<thead>
<tr>
<th>Mode No.</th>
<th>Mode</th>
<th>Initial Share</th>
<th>Cost</th>
<th>Travel time</th>
<th>CR</th>
<th>Utility</th>
<th>e^U</th>
<th>New Share</th>
<th>Shift</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Private Car</td>
<td>0.3895</td>
<td>1.57</td>
<td>104.76.7951</td>
<td>14325,3</td>
<td>-14.325,12</td>
<td>14325,12</td>
<td>14325,12</td>
<td>-14.125,3</td>
</tr>
<tr>
<td>2</td>
<td>Taxi</td>
<td>0.3157</td>
<td>8.61</td>
<td>104.76.7952</td>
<td>40347,97</td>
<td>0.0177</td>
<td>0.0477</td>
<td>0.0577</td>
<td>0.0677</td>
</tr>
<tr>
<td>3</td>
<td>Jeepney</td>
<td>0.2953</td>
<td>8.61</td>
<td>104.76.7953</td>
<td>40347,97</td>
<td>0.0177</td>
<td>0.0477</td>
<td>0.0577</td>
<td>0.0677</td>
</tr>
<tr>
<td>4</td>
<td>Bus</td>
<td>0.2953</td>
<td>8.61</td>
<td>104.76.7954</td>
<td>40347,97</td>
<td>0.0177</td>
<td>0.0477</td>
<td>0.0577</td>
<td>0.0677</td>
</tr>
<tr>
<td>5</td>
<td>Ridehailing (solo)</td>
<td>0.0605</td>
<td>1.34</td>
<td>44079.147031, 1570.31</td>
<td>1370.31</td>
<td>1370.31</td>
<td>1370.31</td>
<td>-14.35</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Ridehailing (shared)</td>
<td>0.0605</td>
<td>1.34</td>
<td>44079.147031, 1570.31</td>
<td>1370.31</td>
<td>1370.31</td>
<td>1370.31</td>
<td>-14.35</td>
<td></td>
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</table>

Parameters

<table>
<thead>
<tr>
<th>Mode No.</th>
<th>Mode</th>
<th>Initial Share</th>
<th>Cost</th>
<th>Travel time</th>
<th>CR</th>
<th>Utility</th>
<th>e^U</th>
<th>New Share</th>
<th>Shift</th>
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<tbody>
<tr>
<td>1</td>
<td>Private Car</td>
<td>0.3895</td>
<td>1.57</td>
<td>104.76.7951</td>
<td>14325,3</td>
<td>-14.325,12</td>
<td>14325,12</td>
<td>14325,12</td>
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<td>2</td>
<td>Taxi</td>
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<td>8.61</td>
<td>104.76.7952</td>
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<td>0.0177</td>
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<td>40347,97</td>
<td>0.0177</td>
<td>0.0477</td>
<td>0.0577</td>
<td>0.0677</td>
</tr>
<tr>
<td>4</td>
<td>Bus</td>
<td>0.2953</td>
<td>8.61</td>
<td>104.76.7954</td>
<td>40347,97</td>
<td>0.0177</td>
<td>0.0477</td>
<td>0.0577</td>
<td>0.0677</td>
</tr>
<tr>
<td>5</td>
<td>Ridehailing (solo)</td>
<td>0.0605</td>
<td>1.34</td>
<td>44079.147031, 1570.31</td>
<td>1370.31</td>
<td>1370.31</td>
<td>1370.31</td>
<td>-14.35</td>
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</tr>
<tr>
<td>6</td>
<td>Ridehailing (shared)</td>
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<td>1.34</td>
<td>44079.147031, 1570.31</td>
<td>1370.31</td>
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<td>-14.35</td>
<td></td>
</tr>
</tbody>
</table>

0.0000038801
Comfort & Reliability of Road Transit options in Metro Manila

Hello!

This is a private survey I’m conducting as supplementary data for my thesis. Would really appreciate if you could spare a minute or two to help me graduate!

Kindly evaluate the road-based transit modes listed below on a) comfort and b) reliability. There will be one section for each attribute.

The modes are the following:
1. Private car (yours or household’s)
2. Taxi
3. Bus
4. Jeepney
5. Ride-hailing service, privately booked (e.g. Grabcar)
6. Ride-hailing service, shared (e.g. Grabshare)

For modes which you have no experience taking, you may evaluate them according to your perception of these modes.

Please refer to the following descriptions for ‘comfort’ and ‘reliability’:

a. Comfort
This attribute refers to physical, mental, and emotional ease when taking this mode of transit. Conditions such as personal space, temperature, air quality, sense of safety and security, etc factor into this attribute.

b. Reliability
This attribute refers to the consistency of aspects such as travel cost, transit time, waiting time, mode availability, seat availability, etc.
Comfort & Reliability of Road Transit options in Metro Manila

Evaluation of Comfort

This attribute refers to physical, mental, and emotional aspects when taking this mode of transit. Conditions such as personal space, temperature, air quality, sense of safety and security, etc factor into this attribute.

Scale is as follows:
1 - Highly uncomfortable
2 - Uncomfortable
3 - Relatively uncomfortable
4 - Neutral
5 - Relatively comfortable
6 - Comfortable
7 - Highly comfortable

1. Private Car *

   1 2 3 4 5 6 7
   Highly uncomfortable
   Highly comfortable

2. Taxi *

   1 2 3 4 5 6 7
   Highly uncomfortable
   Highly comfortable

3. Bus *

   1 2 3 4 5 6 7
   Highly uncomfortable
   Highly comfortable

4. Jeepney *

   1 2 3 4 5 6 7
   Highly uncomfortable
   Highly comfortable

5. Ride-hailing service, privately booked (e.g. Grabcar) *

   1 2 3 4 5 6 7
   Highly uncomfortable
   Highly comfortable

6. Ride-hailing service, shared (e.g. Grabshare) *

   1 2 3 4 5 6 7
   Highly uncomfortable
   Highly comfortable
# Comfort & Reliability of Road Transit options in Metro Manila

* Required

**Evaluation of Reliability**

This attribute refers to the consistency of aspects such as travel cost, transit time, waiting time, mode availability, seat availability, etc.

1 - Highly unreliable
2 - Unreliable
3 - Relatively unreliable
4 - Neutral
5 - Relatively reliable
6 - Reliable
7 - Highly reliable

1. **Private Car**

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2. **Taxi**

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3. **Bus**

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4. **Jeepney**

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5. **Ride-hailing service, privately booked (e.g. Grabcar)**

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   Highly unreliable

   Highly reliable

6. **Ride-hailing service, shared (e.g. Grabshare)**

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   Highly unreliable

   Highly reliable
Appendix C: Instructions for using the Logit Model, as conducted in this study

Refer to file “LogitModel_Sample.xlsx”
Note: These examples are for a Model with 4 existing alternatives, 3 attributes, and 2 new alternatives.
Please adjust your file according to the number of existing and new alternatives and number of attributes you will be using.
Disclaimer: This is not the only way to use the “Logit Model”. These instructions only illustrate how it was used in this particular study.
Refer to the "LogitModel_Sample.xlsx"
Click OK to conduct the Regression Analysis. Results will be on the same sheet for easy viewing.

You may choose the output range for the results of the regression analysis. It is recommended to display the results in the same sheet.

In the box for "Input X Range", choose cell range E:
- (in Source) E1:E500
- (in Source) E1:ES500

In the box for "Input Y Range", choose cell range D:
- (in Source) D1:D500

Step 5: Conduct Regression Analysis on Excel by clicking on the "Data Analysis" tab and clicking on "Regression Analysis" in the "Analysis" category on the far right end of the ribbon. A pop-up window will appear; scroll down to choose "Regression" and click OK.
Step 8: These are the New Shares, found in column H.

Step 9: To calculate the New Shares of each mode, divide each value in column G by the sum calculated in column E. This is calculated in column G. Also, get the summation of these values.

Step 8: As a step towards calculating the new shares, use the `=exp()` function in Excel to get the value of e raised to the power of the values found in column F. This will be called the “utility” of each mode, found in column F.

Step 7: Apply the utility equation to each mode by getting the EXPONENTIAL of the coefficients and the attribute values.

Note: Steps 7 and 8 may be merged but are broken down into two steps for simplification.

Step 6: The “coefficients” that come for the X variables in the 3rd table correspond to the values coefficients of each attribute or your logic model. Check if the +/- of each coefficient makes logical sense based on the attribute being considered.