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Doctoral Dissertation

Human-centered ITS development in Thailand focusing on last-mile mobility

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CHAPTER 1: INTRODUCTION

1.1 Research Background

With the plan of action for people and planet and prosperity by the United Nations named the sustainable development goals (SDGs) [1], there were 17 goals, 169 targets, and 231 unique indicators to recognize what the world essentially needed to end poverty, improve health and education, reduce inequality, accelerate economic growth, and also tackling climate change and preserving our nature. There were some targets that this study would be able to contribute in order to reach the 2030 Agenda, which was target 11.2, "By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons" and the indicator 11.2.1 "Proportion of population that has convenient access to public transport, by sex, age and persons with disabilities."

In the target 11.2, a number of factors needed to be considered, such as safe, affordable, accessible, and expanding public transportation. While making the transport system affordable might be beyond this study's scope, safer and more accessible were. Also, growing public transportation might sound a little bit far-fetched, but in reality, giving the knowledge of the availability of transit choices was one important aspect to expand the service as well, which indeed could very well be within the means of this study. Nonetheless, it would not be a good idea without understanding the current situation in order to improve in any aspects. Road safety always was an issue because the number did not lie. The number of road traffic deaths was around 1.35 million each year or about 18 deaths per 100,000 populations. [2] Although the number of fatalities comparing the number of vehicles seemed to be improving, there was not enough to lower the total number of deaths at all.

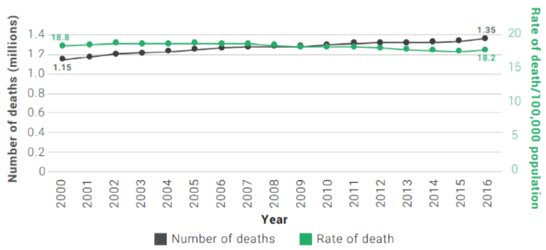

Figure 1.1 Number and rate of road traffic death per 100,000 population between 2000-2016

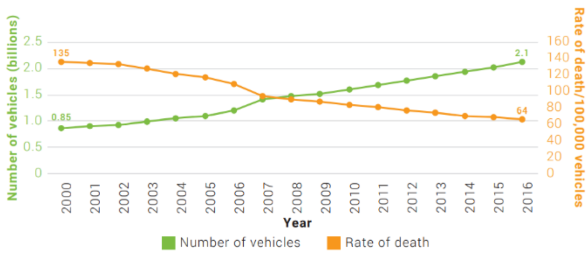

Figure 1.2 Number of motor vehicles and the rate of road traffic death per 100,000 population between 2000-2016

The SDG target 3.6 called for a reduction in the number of deaths by half by 2020, which was the year of this writing. Commonly, without real data, it was suggested that the target would not be able to meet statistically. However, with the COVID-19 pandemic and without any significant safety mitigation, this SDG target 3.6 might be possible after all. Unfortunately, the real issue still remained and needed to be addressed.

Road traffic injuries were the 8th leading cause of death in 2016, resulting in 2.5% of total death worldwide. However, the situation was worse in the middle- and low-income countries since the number was continually increasing while it was decreasing in high-income countries. By the current World Bank classification [3], Thailand was in upper-middle-income economies. The other countries in the region, Southeast Asia, were spreading across lower-middle- and upper-middle-income with the exception of Singapore and Brunei being high-income countries. Figure

1.3 [4] showed that the number of deaths in this region was facing a serious road safety issue unavoidably. Unfortunately, it was even worse if using the number of deaths per capita (100,000 people) shown in Figure 1.4 because this was the only region that had a rising number of deaths per capita. However, this number alone was not enough to find a solution. Figure 1.5 showed that the South/Southeast Asia region had a unique characteristic: the majority of the deaths were from motorized 2-3 wheelers and much less of 4 wheelers. [2] Thus, the solution would have to address the issue specifically.

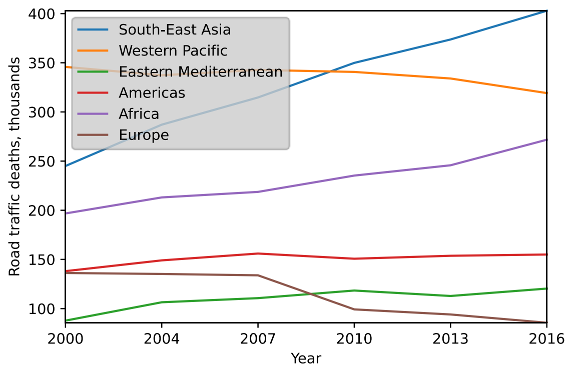

Figure 1.3 Road traffic death by regions

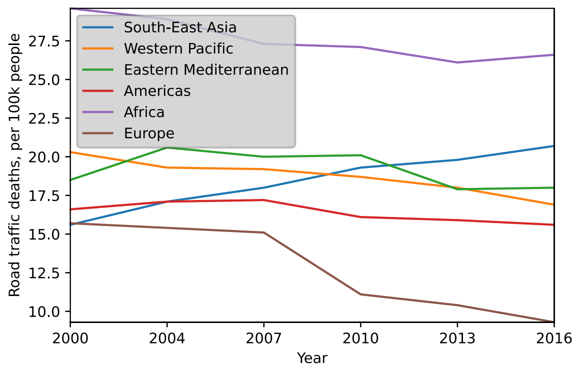

Figure 1.4 Road traffic death by regions per 100,000 people

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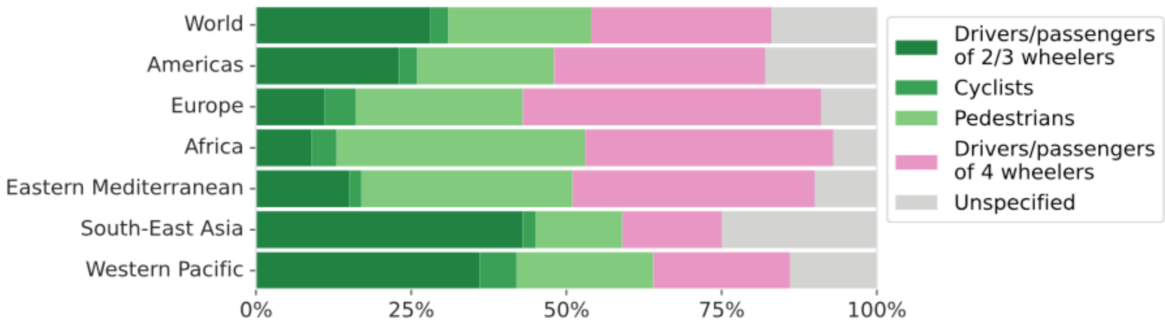

Figure 1.5 Death by vehicle types in South-East Asia region

Accessibility was another issue for the SDG 11.2 target. With the current urbanization trend, which the cities tended to have more and more people in, the city's higher densities became, the more demand for urban accessibility followed. Even in the developing countries, they were more inclined to the urban planning and transport planning altogether approach. That resulted in better and more coverage of public transportation. Figure 1.6 showed that the growth in metro transit development was promising. [5] It confirmed that there would be more accessible to public transportation; however, infrastructure was not the only factor. As the transit system got bigger and more complex, the information provided to ensure that people used the service efficiently was as essential as the service availability. This was the part that information technology (IT) worked the best because not only could it provide the necessary information, but it also interacted and adapted the information to suit people's requests, which would get into detail in the next section.

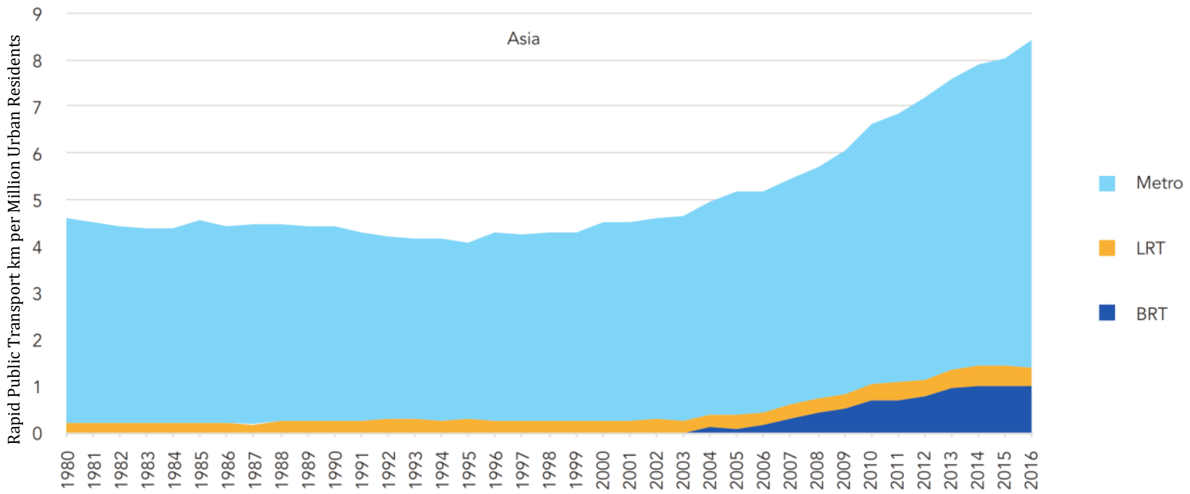

Figure 1.6 Metro transit growth in Asia

1.1.1 Intelligent transportation system (ITS)

ITS used to refer to intelligent traffic systems before since it was a technology that improved or managed traffic mostly such as an automated traffic light, toll booths, or railway crossing. These applications were used to manage traffic so that it would flow smoothly and more efficiently. However, with the advancement of technology over the past decades, traffic then became the bigger point of view, transportation. Also, the emergence of various sensor systems, such as GPS devices, LiDAR, and road cameras, created a wide range of possibilities to monitor and improve transportation systems as a whole. ITS nowadays included traffic and mobility optimization, assisting drivers and managing vehicles' movement, enhancing infrastructures, and integrating transport information.

The applications of ITS from upgrading existing infrastructures to be smarter, such as traffic estimation and prediction systems which cooperated with smart traffic light or intelligent speed adaptation with road weather information systems, to better vehicles on the road such as automatic parallel parking, driving assistants to autonomous vehicles. Nonetheless, the biggest addition to ITS was the one that was available to all road users, not only the traffic managers or the car users, transport-related information. The ability to realize what was ahead of us came to reality. In the past, people needed to have one map book or sheet for a specific area or country in order to find a direction from places to places. Now, all that information around the world was on the smartphone. Better yet, there were traffic congestion or accident alerts, so people could optimize the way to suit them best without even realizing how complicated it would be to gather that information and be available for everyone. It was indeed one of the critical factors of globalization. In this study, we explored this angle of ITS since it would benefit every type of road user.

Bangkok, Thailand, had a lot of progress on mass rapid transit development with 159 km from 5 lines in operation as of the time of writing, November 2020, another 136 km under construction and according to plan, it would be a total of 11 lines and 540 km in length in 2029. [6] While the project seemed to be very positive, according to history, there was likely no plan to connect to other public transportation systems, which was worrisome. For instance, when the Bangsue station on the blue line (MRT) was first operated, besides the location that was not close to any communities, there were no kinds of feeders besides taxis and motorcycle taxis. The nearest bus stop was approximately 800m on foot. After a while, some nearby bus lines needed to alter their routes to stop by at the station, one stop alone, which would add around 1.2 kilometers and take at least 15 minutes to every single line. In short, although mass rapid transit might be available in a developing country like Thailand, it would take time for each station to develop and properly connect to the surrounding property. In the meantime, last-mile mobility would still be a significant obstacle in order to promote transit.

1.2 Research Objectives

From the reasons above, not only had Thailand faced the road traffic safety issue, Thailand was in need to start planning public transportation as a whole and lessen people's burdens of last connecting dot between mobility hubs to people's destinations. While road traffic safety problems could be very well beyond this study's scope, this research would instead focus on improving the public transportation situation, which could indirectly mean a safer trip by helping people take less of the motorcycle that was the primary cause of accidents in the region. This study took the ITS approach by spreading the information through mobility-as-a-service to see how much people changed their travel behaviors after realizing the data they did not become aware of before. Moreover, this study would also address a last-mobility issue with a hope to boost transit usage concurrently.

1.2.1 Mobility-as-a-Service (MaaS)

While most of the ITS applications answered to infrastructure managers or transport providers, Mobility-as-a-Service or MaaS for short was a consumer-centric service. MaaS was another layer on top the existing transport infrastructures. In the user's eyes, everything seemed to be one coherent transport. On the other end, MaaS integrated a variety of transport services such as car-sharing, bike-sharing, taxis, rental cars, and all available transits. Then, they provided those services through a single application as if those were as one. [7] [8] [9] [10] The idea of MaaS typically started with a journey planner that answered users' requested, which might sound simple. Still, the itineraries were suggested based on all possible options, user's preferences [11] and real-time conditions throughout the related transport networks. Also, MaaS would facilitate seamless payment to create an even more convenient trip.

However, the first idea of MaaS was to create an alternative to a private vehicle. The whole system needed to provide transport which was as convenient as driving their own cars. [12] This meant to be the best balanced and value proposition by helping people meet their mobility needs, easing traffic congestion, and balancing or reducing transport capacity constraints. In the end, its effectiveness would yield better overall efficiency and more affordable for all. Advantages had not stopped there since this also brought new business models, created ways to operate multiple transport options, and organized them to improve according to the user demand or fulfill the unmet desire from users.

A data analytical part was another upside. With MaaS, service providers would be able to collect people's movement to understand travel patterns across the transportation network. This helped not only to adjust and satisfy both demand and supply, but also optimize the network easier. [13] Although this might seem to be very promising, it required a lot of resources, collaboration, and last, but not least, a good number of user base to have a viable and self-sustainable system or nothing else would happen.

In theory, MaaS seemed to check every box and should be able to solve the increasing mobility needs in the city. However, there were not that many MaaS operators in the past five years, and most of them were in Europe. Other transport-related ICT growth tended to be on the individual service, such as Uber, Lyft, or Grab. Apparently, MaaS ideology somehow seemed to have difficulty to materialize as well, which would be discussed in the next chapter. However, if MaaS could be appropriately used, it would be an excellent opportunity to promote public transportation and initiate people's travel behavior changes to the safer one.

1.2.2 Last-mile mobility

When talking about last-mile, although it would scope the topic from the mobility hub to the final destination, it was always related to public transportation issues. Usually, the last-mile referred to the difficulty of getting people moving from either the hub to their places or the other way around, which might be called the first-mile, but in the end, these were the same problem. In developed countries, last-mile issues could be found in the suburbs with low-density populations. Thus, the distance between the hub to the destination was likely too long to walk comfortably. This would eventually lead to an automobile dependency culture, which would end up with the urban sprawl because when cars became a necessity, the distance seemed to be shorter. Then people would be fine living further away. However, in developing countries, the same problem might result a bit differently. For instance, most people would have to rely on a motorcycle instead because they could not afford to drive a car, but that came with much riskier conditions. Another scenario would be the lack of parking space at the hub and left people no choice but to walk, which was impossible due to the greater than comfortable walking distance. Then they would have to take a motorcycle taxi, which yielded the same or more risk as to the previous scenario. However, this was not over. Another scenario was the cost of the last-mile trip plus transit fare was more expensive than using a private vehicle, whether it was a car or motorcycle. That forced people to use a car or motorcycle as their primary mode of transport and ditched transit altogether. Those who had to ride a motorcycle resulted in the worst as far as safety was concerned. By the way, considering the cause of these scenarios, there were interesting factors that differentiate developing countries and developed one. Firstly, fare. Somehow in the developed countries, transit fare would be well-positioned considering the wage and all. However, in the developing ones, the fare was always not the case, probably due to the subsidization the government could not provide, but that was something beyond this study's mean. Secondly, the completeness of the mobility hub. In a well-developed country like Japan, the train station had all the essential elements such as a facility to promote more comfortable last-mile mobility like parking space for bikes or car and bike rental service, or transit mall which provides places, stores, restaurants, or shops for people to create communities around. On the contrary, most of the metro stations in Thailand were not connected to anything around, did not have any space for parking, nor provide any service besides the transit.

Over the past years, there were also many attempts to bring new mobility services to address last-mile mobility. The technology brought the unique possibility of the dockless system into the existing options. Bike-sharing, for example, regarded as one of the effective ways to relieve traffic congestion, came with the flexibility of a dockless station, which allowed bikes to be picked up and dropped off virtually anywhere. As a result, bike-sharing had over 2,000 bike-sharing systems worldwide as of 2020 [14] and that included over 9 million active bikes. The market value was around 2.7 billion USD in 2018 and was expected to grow twice as large in 2025. Electric scooters (E-scooter) [15] also emerged as another alternative with the same dockless system and the freedom technology brought to it. Although this was very new, over 60 e-scooter providers in 2019 in over 30 countries, covering more than 150 cities worldwide. The two biggest shared scooter providers had a market value of up to one billion USD.

With the rise of new last-mile mobility improvements, though it sounded like the last-mile problems should probably be resolved, they were not, at least in the developing countries. Ofo, one of the bike-sharing providers, was invested in 2 cities in Thailand around the end of 2017 but eventually terminated the project in less than a year. The same story was repeated with oBike and mobike around the same period of time. [16] They briefly reported that they could not find a way to monetize their services in the country. Neuron Mobility and some other companies also introduced e-scooters in Bangkok, but all of them were in limited areas, and there was no sign of expanding. That would essentially leave last-mile options for people in Thailand with only the existing ones which were walk, paratransit, and motorcycle taxi. With these available options, they all came with some sort of price. First, walking was always an option, but it was most likely to be the least comfortable one due to the weather, lacking walking amenity, and obstacles along the way. Second, if the area were a bit dense, there would be some paratransit services available. For example, Songthaew, which was basically an adapted pick-up or truck with the benches installed on the back for passengers, operated as a bus with a longer headway. This option was affordable and feasible for most cases, but a long headway was why people go for the last option, motorcycle taxi. While motorcycle taxis tended to overcome many issues in Thailand, such as traffic congestion and low-frequency transit service, they instead brought probably the most significant issue, safety, on the table.

In this study, it was essential to understand what drove people's decision to walk, and then this study would propose a solution for better and safer mobility.

1.3 Research Framework

This research focused on road safety and improving the mobility integration which Thailand lacked, including improving public transportation, utilizing ICT, and introducing an alternative transport choice like a shared smart vehicle. Figure 1.7 explained the anticipated outcome of this study.

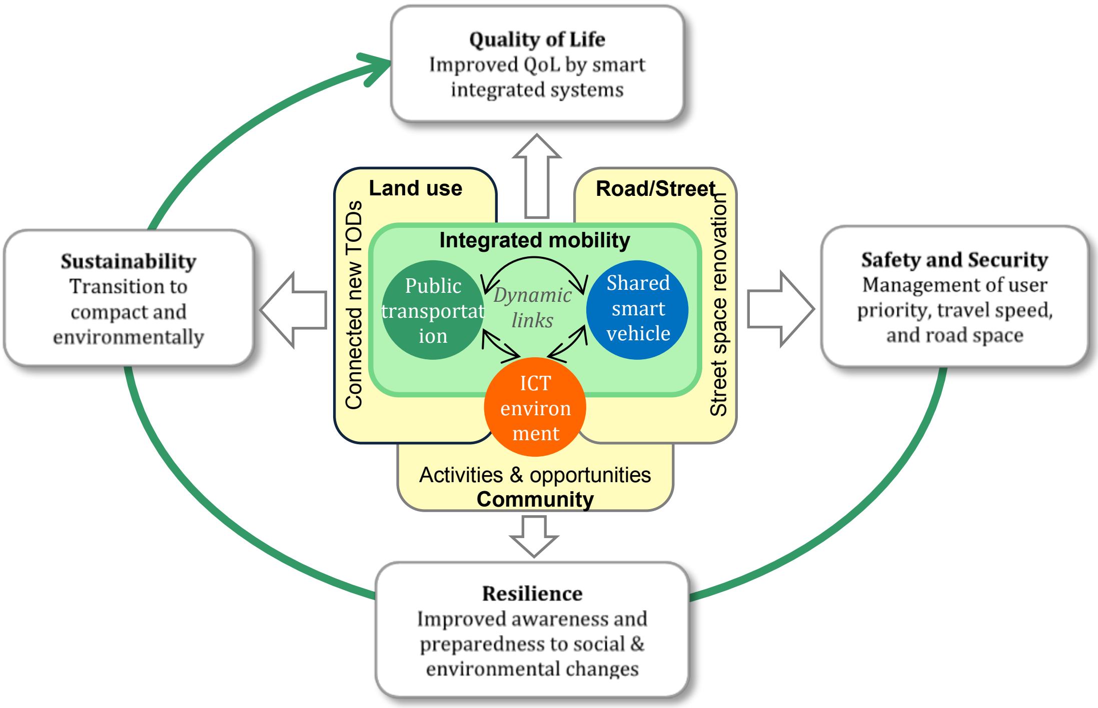

Figure 1.7 Outcome framework

With public transportation improvement, a transit-oriented development (TOD) that welcomed more transit users or supported users' activities such as transit malls or walkable public spaces would follow and eventually led to a sustainable environment. ICT utilization also created new activities and opportunities, such as a dockless bike and scooter sharing or hailing service like Uber and Grab which helped society prepare and know what to come better. The vehicle sharing model could transform the current situation into a higher utilization per vehicle and less demand for owning cars. If this trend continued to grow, there would be less vehicle or congestion and eventually restoring car-centric streets to space for all road users. The street space renovation would result in a safer space for everyone because the concern focused not only on how fast the car could flow but also on all road users. In the end, all these improvements eventually contributed to a better quality of life.

Figure 1.8 indicated the study's goal and what had been done. This study aimed to promote public transportation use by integrating available mobilities with MaaS and raising people's safety awareness. The research introduced safety and walkability indexes to be easy, comprehensive indicators to reflect the area's current situation. Moreover, this research also evaluated last-mile mobility options and proposed a better alternative to increase public transit at the same time.

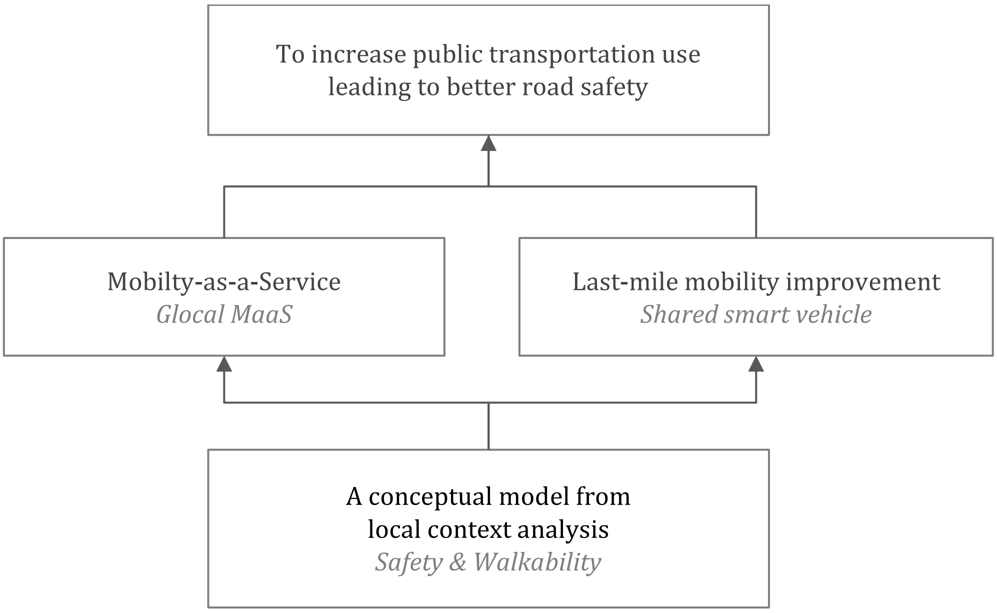

Figure 1.8 Thesis framework

The rest of this thesis would be as follows. Chapter 2 explored the previous studies of what had been done before. Chapter 3 covered a conceptual model as far as the local context was concerned to use as a foundation for the next two chapters. Chapter 4 was a case study on the experiment on Glocal MaaS, while Chapter 5 propose the solution for the last-mile mobility improvement from the case study, the decision factors in walking in Bangkok, Thailand

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CHAPTER 2: LITERATURE REVIEW

2.1 MaaS Classification

There were many studies reviewing MaaS implementations and categorizing them to evaluate and see the potential of each level. Jittapirom et al. [17] identified nine core characteristics of MaaS, which were (1) integrations of transport modes, (2) tariff option, (3) one platform, (4) multiple actors, (5) use of technologies, (6) demand orientation, (7) registration requirement, (8) personalization, and (9) customization. With these core characteristics, each MaaS could be classified into schemes accordingly. Kamarigianni [7] evaluated MaaS differently by having a MaaS integration index, including ticket integration, payment integration, ICT integration, and mobility package integration. This MaaS integration index indicated how advanced integration each implementation was; generally, the higher score implied the higher level of mobility integration. Nonetheless, Sochor [18] proposed another topology of MaaS, which was classified by the integration of societal goals each MaaS had, as shown in Figure 2.1. This classification consisted of level 0, which was no integration. Level 1, which had an integration of information. Level 2 included booking and payment integration. Level 3 was the integration of the service bundle offer and the top level. Lastly, level 4 or the integration of society goals included policies and incentives as well. From the above classifications, it would appear that the simplest one, which did not concern about many technicalities, would likely be the most suitable one so far.

Figure 2.1 Sochor's proposed topology of MaaS level 0-4

2.2 MaaS Deployment

Table 2.1 showed popular and current MaaS operators, including the level of integration, the city, the beginning year, and description. According to Sochor's MaaS topology levels, as of the time of writing this, October 2020, there were no MaaS, which was up to level 4. In other words, there was no public sector acting or involving directly as MaaS operators yet. However, some were operating at level 3. For example, Ubigo, the first MaaS, had a trial run in 2013 that reported that it initiated the behavioral changes to transport mode choices. It also helped people aware of the transport options available in Gothenburg, Sweden. [19] However, after the trial, Ubigo stopped the operation for many years with the intention of re-launching the service commercially somewhere in Sweden in 2017 after reported a successful co-operation with Ericsson [20], it was postponed until 2019 before its reboot for real in Stockholm, Sweden. [21] Next, the most well-known one, Whim operated by MaaS Global. It first operated in Helsinki, Finland, in 2016 and offered bundles including public transportation, taxi, rental car, and bike. Whim reported that users already booked 3 million trips [22] and would be expanding to other places, including both

US and Singapore [23]. HANNOVERmobil, initiated by ÜSTRA, public transport company, was the start point for Mobility Shop, which first began as an add-on to the annual public transport pass that included car-sharing and rail discount. It, then, developed into a MaaS application with a subscription offering at 9.95 EUR a month. Mobility Shop has been operational in Hannover, Germany since February 2016, with 28,000 registered users and 1,500 new users every month. [24] [25]

Table 2.1 MaaS operators

Name	Level	Location	Year	Description
Ubigo	3	Gothenburg, Sweden	2013	Car-shaing, car rental, taxi, bike-sharing, transit (Trial)
Mobility Shop	3	Hanover, Germany	2016	Car-sharing, car rental, taxi, transit
Whim	3	Helsinko, Finland	2018	Car rental, taxi, bike-sharing, transit
Smile	2	Vienna, Austria	2014	Car-sharing, taxi, bike-sharing, transit (Trial [26])
REACH NOW (formerly Moovel) [27]	2	Stuttgart & Hamburg, Germany	?	Car-sharing, taxi, e-scooter, transit
Go LA [28] [29]	2	Los Angeles, US	2016	Car-sharing, taxi, transit *ceased the operation sometimes in 2017*
WienMobil Lab [30]	2	Vienna, Austria	2016	Car-sharing, bike-sharing, taxi, and transit
My Cicero [31]	2	Italy	2016	Parking, transit
Qixxit [32] [33]	2	Germany	2016	Car-sharing, bike-sharing, and transit *Acquired in 2019 and stopped operation*
Communauto [34]	2	Quebec, Canada	2017	Car-sharing, bike-sharing, and transit
Google Maps	1	Worldwide	2008	
City Mapper	1	Worldwide	2011	
Apple Maps	1	Worldwide	2012	

There were many MaaS applications with level 2 or booking or payment integration such as Moovel, Go LA, Smile, Qixxit, Communauto, WienMobil Lab, Tuup, or My Cicero. These apps initially offered both transit and other modes or benefits for car owners like parking lots. [17] While some of these applications had a short life for many reasons, some applications like REACH NOW, which formerly was Moovel, WienMobil, My Cicero, and Communauto, were still operational at the time of writing. For short-life operations, Smile was a research project funded by the Austrian Federal Government as a part of the "Austrian Electric Mobility Flagship Projects" program to evaluate whether the mobility platform could lead to a more environmentally-friendly mobility behavior. Go LA, a commercial project partnered with Xerox, was active for less than two years for undisclosed reasons. Qixxit by Deutsche Bahn, on the other hand, was acquired by the travel-related company, lastminute.com Group, and ceased the mobility-centric application.

For level 1, there were map applications with a trip planner feature such as City Mapper, Google Maps, and Apple Maps. These apps included public transit information, but at this level, there was no quality of service. Thus, accuracy might not need to be at the same level as higher ones.

2.3 The transport-related ICT applications

While MaaS was progressing, there were many transport-related ICT applications as well as shown in Table 2.2. While these services did not focus on utilizing the existing infrastructures, they invented a new way to move people from places to places. Ride-hailing service was the majority in terms of both ridership, and financial since most of these services were commercial from the beginning. Uber was found in 2009 started with a hailing service on the mobile app. As of 2020, it expanded to 69 countries, three more services, which were food delivery, package delivery, and freight transport. The market value was over 60 billion USD. Lyft was the second biggest ride-hailing service in the US and expanded to scooter and rental car service with the market value of around 12 billion USD. Grab followed the same path by adding a food delivery service and operated in Southeast Asia, mostly with a valuation of over 10 billion USD.

Table 2.2 Transport-related ICT applications

Name	Location	Description
Uber	US and many countries	Ride-hailing service
Lyft	US	Ride-hailing service
Grab	Southeast Asia region	Ride-hailing service
Waymo	Arizona, US	On-demand autonomous taxi
Beeline	Singapore	Crowdsourced bus services Shutdown in 2020
Kutsuplus	Helsinki, Finland	On-demand transit service (Trial in 2015)
Bridj	Massachusett, Kansas, Washington, DC, US	On-demand shuttle service

Besides ride-hailing, there were on-demand services which had yet to explode in term of success. Waymo, backed by Alphabet Inc (or Google), started pursuing autonomous taxis and was open to public in 2018 in the greater Phoenix, Arizona in the US. Initially, instead of full driverless service, there would be a person sitting in a driver seat as assistant because, according to the US laws, humans behind the wheel were still required. Next, Beeline, backed by government agencies, academia, and private sectors, introduced a crowdsourcing bus service which did not have a fixed route, but it would accumulate all demands and suggest new optimized to serve the community. This service began in 2015 but ended the service at the end of 2019. Analysts suggested that it was not profitable due to the service's nature, which was very difficult to meet the demand to be a better alternative to bus or taxi. [35]

Kutsuplus, backed by the government, was similar to Beeline, but it had no fixed route. It would roam around the city and go pick-up nearby passengers as they requested via an application and dynamically adjust the course according to demands. Nonetheless, it was shut down in 2015, around 2 years of operation [36] [20] There were suggests [37] why it failed due to the limited budget to start with 10 minibuses (later expanded to 15) to cover 100 square kilometers which was not quite enough to satisfy people's needs and with having government backing up, there were too many interventions. For instance, the agency forced Kutsuplus to build the system to let users hail the van by text message before building a mobile app, which caused unexpected time and resources.

Bridj, which started in Boston, was another implement of on-demand service. Still, it only focused on commuters by letting people make a reservation with an app. Bridj would optimize supply such as vehicle size, pick-up, drop-off location, and route to serve those demands, which should be a more efficient trip than the traditional transit. [38] Bridj turned to be economically sustainable and expanded to Kansas City and Washington, DC, later on.

2.4 MaaS and other transport-related ICT service issues

Arias-Molinares [9] reviewed the studies regarding MaaS to understand what MaaS really offered. Besides providing transport services, MaaS was still developing because it did not seem to be able to conclude the definition with the current ever-changing phase. With the limited number of active MaaS deployments, the impact was still doubtful.

2.4.1 Data and security issues

With the basic idea of MaaS and its collaborations with other transport providers and operators, MaaS tended to contain and collect much information such as personal information, ride-sharing information, location tracking data, commute behavior, life-style pattern, and payments detail. With this much information, they were definitely useful or analytical purposes. MaaS operators, however, should have a solid plan to keep these secure from any outsiders. This valuable data attracted the attackers, and there was quite a bit of issue that arise internally. For example, what kind of information should be collected and by whom? Who should take responsibility for this data? What type of data should be distributed among the MaaS partners? How much information should MaaS operators provide to transport providers or other parties? Should or how transport provider hand back the user activity to MaaS operators? It seemed to be a very complicated data ownership issue, and this tended no to be the first topic when talking about MaaS. [39]

2.4.2 Law & regulation issues

The reason behind the Ubigo trial that went offline after six months and could not get it to start in a timely manner was related to the regulation issues. Since taxes subsidized public transportation in Sweden, it meant that MaaS would also be funded partly by taxes as well. It was no issue while conducting the trial run because it was non-profit; however, it caused an unsolvable problem due to laws and regulations at the time when Ubigo wanted to turn to a commercial service. As a result, it took over five years before Ubigo could restart the service. [40]

While regulations slowed down the progress of MaaS, other transport-related ICT services also faced similar issues, but as private companies, they acted differently. For example, Uber was first regarded as an unregulated taxi service. That itself was breaking quite a few regulations, yet laws and rules seemed ineffective in controlling them. Tzur [41] found that in almost 80% of the US's examined cities, regulators favored new emerging transportation network companies (TNCs) over the existing incumbents. Although Uber operated illegally, they usually did not face any strict enforcement. The reason behind this was that Uber managed to function normally and, at the same time, have an effective strategy to orchestrate the public to act in support of regulatory changes. With its growing popularity, it mostly worked out. In the end, in Colorado, US, for example, it was the first state to pass legislation authorizing ridesharing services such as Uber and Lyft in 2014 because rules should not burden businesses or create barriers (old regulations) to entry. [42]

On the contrary, MaaS that had a public transit as a backbone did not have that luxury because most of the public transit was funded by the government. MaaS operators had to pursue the regulatory changes before they could do anything about it.

2.4.3 Financial issues

Again, in the case of Ubigo, the consequence of the regulation issues also impacted a financial part. From the prototype in the trial to a full commercial service, the requirement increased significantly to continue providing the same service level. Nevertheless, at the time, neither the government nor stockholders was willing to back Ubigo financially due to unresolvable regulation issues, although Ubigo received excellent feedback from the trial.

While Go LA seemed to have a reliable backup from Xerox, it stopped the service pretty early. However, there was much positive feedback that proved that this operation could not meet the expectation financially. [28] Qixxit also chose to be acquired totally after almost 3 years of operation. [33]

2.5 Technology influences

The essential factor that made MaaS possible was a smartphone. Not only had it become more powerful, but it was also affordable to all people. With the smartphone ubiquitousness, everything then took the opportunity to use smartphones as a medium to convey information to people directly since recent findings found that mobile applications' influence played a significant role in travel behavior changes. [43] For instance, the Smile project reported that people increased public transportation usage by 26% while reducing the use of taxis by 22% and private cars by 21%. [26] Ubigo trial results also showed that on average, 86% of the monthly public transportation services purchased through monthly subscriptions were utilized, as opposed to 69% of the car services. [20] In other words, people used cars less than their expectations while almost entirely used up the transit quota. MaaS could even potentially initiate travel preferences, especially for those who young and tech-savvy. [13] [44] At the same time, urban lifestyles had been the favorite among younger generations comparing living in a suburb. Consequently, owning a car was not as necessary as it once was. [45] These changes then forced the transport sector to accommodate new conditions. Each transport provider could operate separately in the past, but with more demand, each provider alone could not supply or meet the increasing demand efficiently. The integration between providers then started to form to achieve better performance and utilization, especially any obstacles between different transport modes [7]. From simple cooperation between companies to provide incentives like discounts, a universal smartcard to access across the services to a multi-modal trip planner and eventually MaaS application included everything from a ticket payment, package subscriptions, to reserve a rental car. [38] Nevertheless, studies found that the more accurate the information was, the more people would trust the application, which led to more engagement. [44] [46]

In the context of Thailand, which was part of Southeast Asia, the primary concern was safety. The overusing motorcycle in commute as door-to-door movement solution instead of using it as only last-mile mobility would expose the vulnerability nature. Fenwick et al. [47] showed that safety was one of the factors that public transportation could be a preferred choice over a private vehicle. Doi et al. [48] also found that a transition to a safer street, risk recognition, and safety awareness were vital. As a result, in this study, MaaS was developed to address and alleviate the issues, specifically in Thailand.

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CHAPTER 3: LOCAL CONTEXT ANALYSIS

This study deemed to alleviate the primary problems in Thailand which were road traffic safety and walkability. While these two issues were well-known, yet there was no easy way to present the situation tangibly. This study believed that it would be much more useful and informative to quantify the situation and introduce to people as intuitive as the level of traffic congestion in the current map application nowadays. This chapter, then, proposed a conceptual model to formulate indicators to those issues.

3.1 Thailand background

As far as the local context was concerned, Thailand, which was the study area, was a part of Southeast Asia. It's a developing country with a GDP per capita of around 7,000 USD (~80th rank in the world or ~30% below the world's average GDP per capita). [49] Regarding the mean of transport, there are 4,507 km of train track (excluding sky train and subway track) and 390,000 km of highways as of the year 2017, comparing to 30,625 and 55,222.3 km of train track and highways consecutively in Japan. It showed that Thailand was still in a motorization era. With this limitation, people needed to rely on road transport primarily, which came with road traffic safety issues. According to a WHO report [50], road traffic injury was ranked the 8th leading cause of death for people of all ages; however, it was the first cause of death for children and young people aged-29 [51]. The situation was a bit different in the South and Southeast Asia region though; motorcycles or 2/3-wheelers were the primary vehicles for the majority of the people since those vehicles were in the affordable range due to the lower GDP per capita, unlike the situation in Europe or America. From the WHO report in 2015 [52] [Figure 3.1], motorcyclists accounted for 1-third of a road traffic fatality in the region. Unfortunately, Thailand was an extreme case with the highest motorcycle-related fatality ratio, 70%, to all road traffic deaths in Figure 3.2.

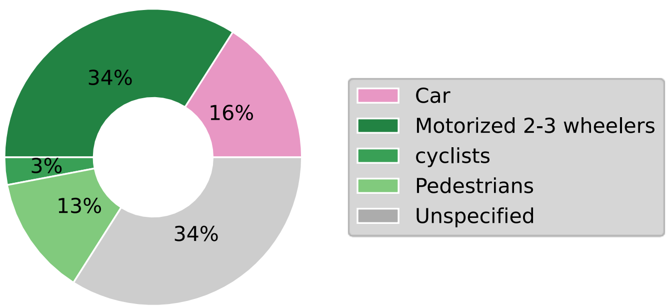


Figure 3.1 Deaths by road user type in Southeast Asia in 2015

From Thailand's traffic accident data [53] which were collected by Thai Road Safety Collaboration (ThaiRSC) by Road Accident Victims Protection Co., Ltd, it concurred with WHO's data that most of the road traffic accidents were involved with motorcycles. The fatality rate of the motorcyclist was too high also. From all the above reasons, it was concluded that safety was one of the factors we needed to consider, chiefly protection for motorcycles and their surroundings.

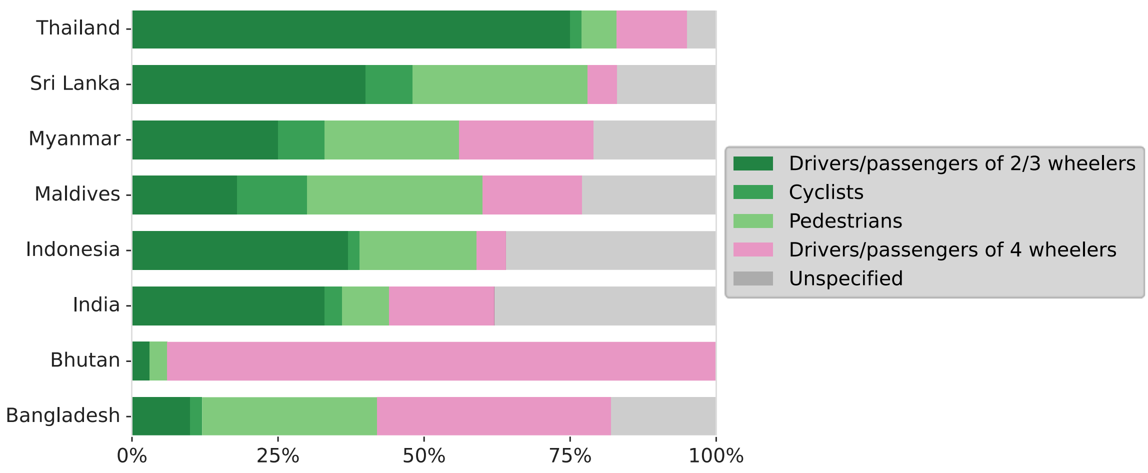


Figure 3.2 Distribution of road traffic deaths by type of road user in 2013

The safety hexagon [54] [Figure 3.5] explained that there were 3Es that would alleviate safety issues, including engineering, enforcement, and education. Due to the scope of the study, although enforcement would be beneficial if enforced strictly, it required to collaborate with the enforcer and monitor the situation closely, which was beyond this study's mean. Regarding the engineering, it was likely that we would have to focus on a specific case to improve specific situations that could be difficult to generalize and implement to improve the situation in general, which again might not suit this study's purpose. The last E, which is education, was likely to be the solution for all places to implement, and it could result in both short- and long-term outcomes. Indeed, knowledge could guide and suggest aligning with ITS and MaaS direction that this study moved toward.

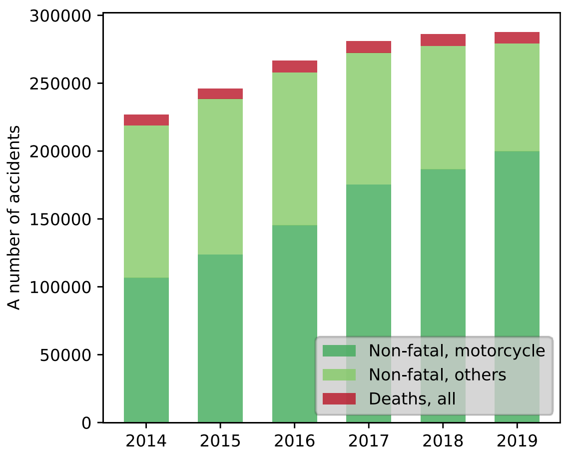


Figure 3.3 Accidents and fatality rate by motorcycle or else in Thailand

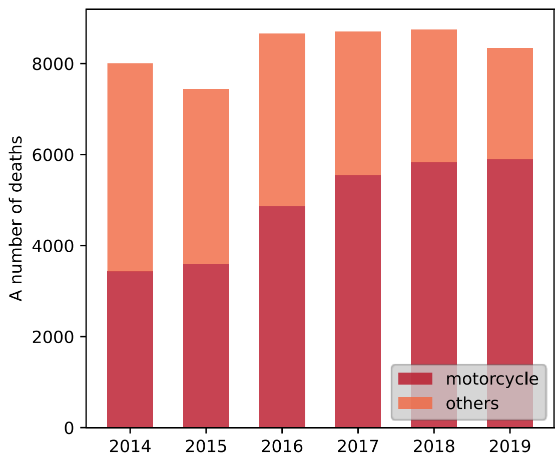


Figure 3.4. Deaths by motorcycle-related accidents or else in Thailand

From the conclusion above, we decided to create a way to inform and suggest people a safer way to travel by creating an index called the safety index. The safety index here would help people visualize how dangerous or risky it was to travel on specific paths or vehicle types. People could then be more aware of the accidents or find a better and safer alternative so that their travel would be more pleasant. Technically, we made use of the data we could gather to formulate the index, which was traffic accidents and traffic volumes around the area.

Another issue in Thailand that could not be overlooked was how low transit ridership and ineffective public transportation were. From Figure 3.7 [55] [56] [57], Bangkok, which was by far the province with the most public transit coverage, has around 8 to 9.5 million population between 2012 and 2018, yet overall transit ridership was only around 25% at best, and there was no promising sign of increasing until now. Although the city train system, which included sky trains and subways, had been improving the network intensively over the last ten years and the train ridership was on the way up, it was not enough to stop the overall ridership, especially bus ridership, from falling down. There were a number of reasons why the situation had been like this. Firstly, the inconsistency of service. There was no timetable for all public transit in Thailand, unfortunately. Traffic congestion was always the reason why a rigid timetable was not possible on the day that Thailand had no train system. However, when BTS (sky train) was introduced in 1999, it did not help and was still no timetable. Everything was operating as the operator saw fit. There was only a guideline such as a train headway during peak and non-peak hours, but there was no promise. The situation had not changed at the time of writing. Secondly, the fare was definitely unreasonable for mass. Although the government bus service, BMTA, was always affordable to every people, it was a different story with the train service. Most of them costed almost the same as an hour of basic wage or more, which was around 3 or 4 times higher than any city at the comparable size, as shown in Figure 3.6. The black line in the figure showed the range from the cheapest to the most expensive rate. The worst thing was the highest fare with could just be a ride from one side of the city to another, which could cost almost twice as a minimum hourly wage, and that did not cover any transfer. This surely limited regular riders to solely white collars or middle-class people or better. Thirdly, there were no seamless connections between each service and no thought of the last-mile mobility. For example, although the interchange station's idea existed on the map, there was almost no link between the services. By the word, no link, it meant that there was no physical connection or a transferable ticket at all. In other words, it was like two stations that were built independently next to each other. There was not even a connected roof or shade for any transferrer. Fortunately, the situation got a little bit better as time went by. There was no evidence of why this happened, but it seemed to be a void as far as cooperation between different transit companies was concerned.

Furthermore, most of the time, the train station would locate as further away from an ideal walking path as possible. The issue might seem to be a disagreement between parties involved around the area or the train operator deemed to let the city evolve around the station instead. For example, the skywalk around BTS Siam station, a crowded station, developed over 15 years after the first operation to make the surrounding area more walkable. So far, train operators in Thailand did not seem to plan ahead to be an initiator to improve surroundings. Whether these reasons were the cause of low ridership or the low ridership was the cause of the descending situation, people still needed a mean to move from place to place, which was shown in figure 3.8 that people did not satisfy with either train or bus services enough, so that half of the people forced to take alternatives such as taxi or hailing services like Grab instead. Thus, it was up to nearby parties to collaborate and make the area better. Within the scope of this study, we believed that providing information regarding walkability would be helpful not only to people who wanted or might consider taking transit but also to the stakeholders who had the wills and resources to change for the better. Suppose there was good enough information about where is good or not so good to walk. In that case, people might feel more comfortable with the last-mile part, and it might help the stakeholders prioritize what they could do to improve the situation better.

This study introduced two indicators to address both safety and walkability issues. The definition of the two would be described in the following sections.

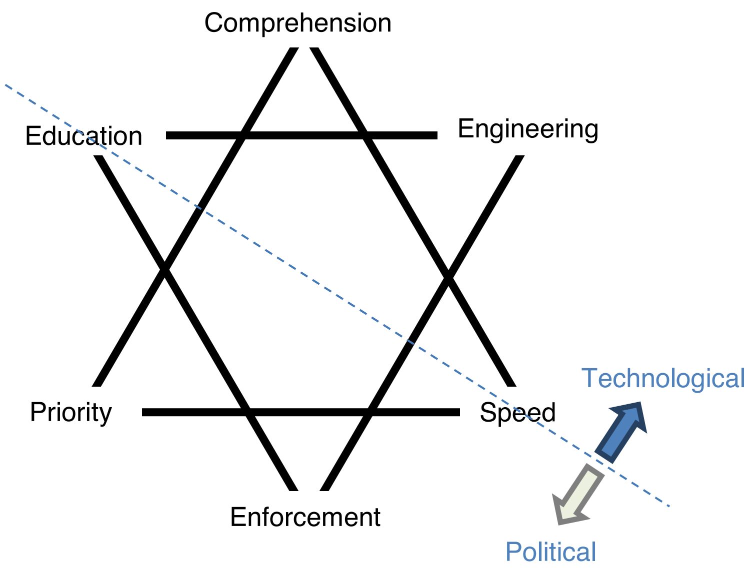


Figure 3.5 Safety Hexagon

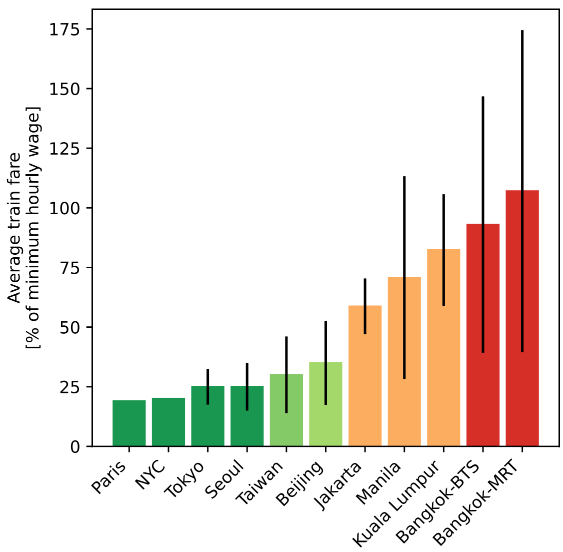


Figure 3.6 Average train fare comparing to minimum wage

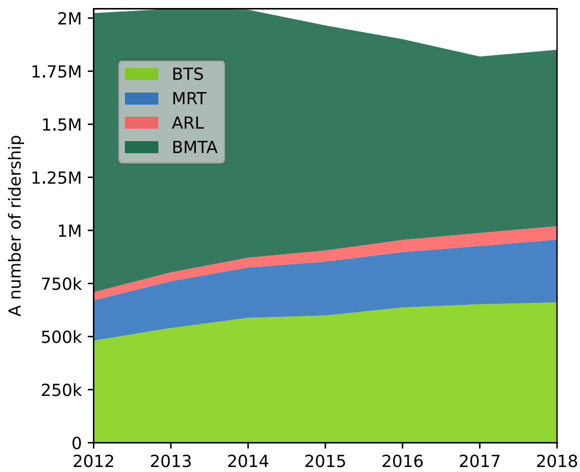


Figure 3.7 Transit ridership in Bangkok, Thailand

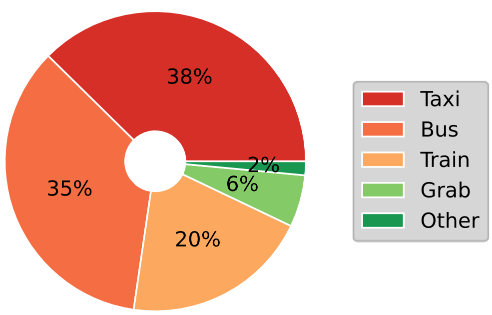


Figure 3.8 Distribution of transit choices in Bangkok in 2019

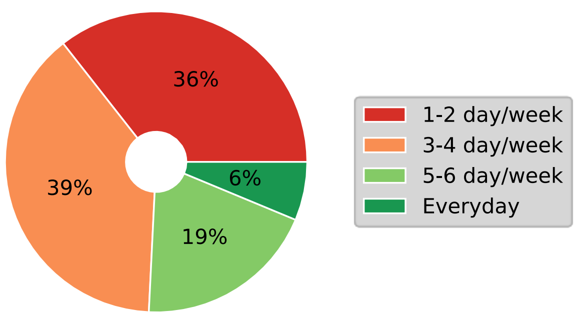


Figure 3.9 Transit ridership frequency in Bangkok 2019

3.2 Safety

Traffic accident records in Table 3.1, originally from ThaiRSC, were collected from either no-fault or fault state claimed since they were a piece of information from insurance companies categorized by vehicle type, brief accident description, location, time, and fatality. While traffic volume data, shown in Table 3.1, were processed by the traffic surveillance CCTV system, which was operated by Thailand's National Electronics and Computer Technology Center (NECTEC). The system was capable of both identifying vehicle type and counting traffic volume. However, the coverage was only on trunk roads.

Table 3.1 Safety index data source

Data type		Total
Traffic accident in 2018		5,231
Traffic volume in 2018		
	Motorcycle	18,168,952
	Car	20,306,458
	Pickup	10,331,351
	Van	4,419,123
	Bus	1,275,455
	Truck	2,836,076

While the number of accidents mattered, it was not logically fair to assume that 100 accident incidents on a trunk road with 100,000-vehicle passing by a day and the same number of accidents on a local road with 100-vehicle passing a day would yield the same meaning of safety. Figure 3.10 showed evidence that each vehicle type yielded the risk differently. Motorcycle tended to have a chance to be in the accident more than a car. The bus was accounted for accidents less than 0.2% each year. That was why we needed to use traffic volume here was the normalization across all the streets. Fortunately, while we did not have all the traffic volumes on all the roads, we had enough cov erage to cover all the public transportation routes in the area in this study.

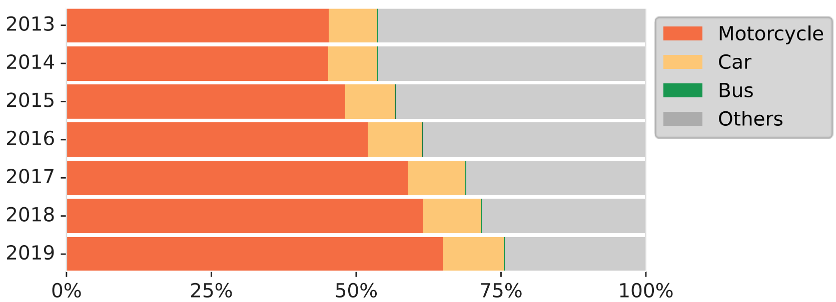


Figure 3.10 Accidents by transport mode

Safety index

The safety index measured how safe each trip was using accident statistics and traffic volumes in the area. Fundamentally, it derived from a chance of an accident on each road segment. Each transport mode was categorized individually, and a fatal accident weighted 50 times higher than a regular one to reflect a higher impact.

In practice, there was no trip that consisted of only a road segment and each a road segment's chance of an accident (E_s) was mutually independent. As a result, a trip's Safety index was a product of a chance of not having an accident from each road segment $(1 - E_s)$.

$$E_s = \frac{A_{is}}{V_{is}} \qquad (1)$$

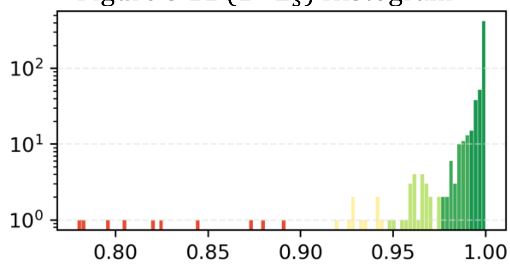
$$Safety\ Index = \prod_{i=1}^{n} P(1 - E_{is}) \qquad (2)$$

where E_s was a chance of having an accident on each road segment (s)
A_{is} was a number of accidents for a vehicle type (s) on a road segment (i)
V_{is} was a number of traffic volume for a vehicle type (s) on a road segment (i)

Table 3.2 Safety index scale

Safety index	(1 - E_s) equivalent
A	0.990729 - 1.000000
B+	0.973988 - 0.990729
B	0.943796 - 0.973988
C+	0.891772 - 0.943796
C	0.000000 - 0.891772

Figure 3.11 (1 - E_s) Histogram



Safety index provided in a 5-point grading system, i.e., A, B+, B, C+, and C, which required little to none knowledge to interpret, as shown in Table 3.2. A Natural Breaks (Jenks) classification was used to arrange risk values into groups [Figure 3.11]. The reason why Jenks was used due to the resulting minimal variation in each group and maximize variation between groups, which served the purpose well for the Safety index. The result was shown in Figure 3.12 and Figure 3.13.

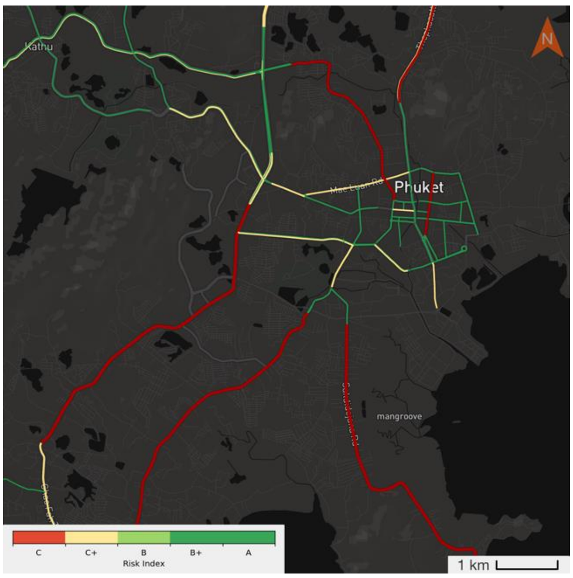


Figure 3.12 Safety index for motorcycle

Figure 3.13 Safety index for car

3.3 Walkability

Walkability always referred to how walkable the street would be, but what made the street walkable would depend on a variety of factors. Jeff Speck [58] outlined the key factors to make a city favorable to pedestrians, which are useful, safe, comfortable, and enjoyable. First, streets should have a function to serve pedestrians well, not exacerbate them in any way. Second, the street should have a design that protects pedestrians from any vehicles and does not make them feel vulnerable. Third, the street should not be an empty space, but make people feel comfortable like walking in their own backyard and last, but not least, the sidewalk should give pedestrians a sign of liveliness and humanity by having a variety of buildings, shops, and other pedestrians around. Although these factors were rational, most of them were quality toward feeling, which could be challenging to be qualitative. There were attempts to create this kind of index. For example, WalkScore [59] was a commercial indicator used to rate and create a value-added in the real-estate business. This utilized how good pedestrian amenities in the area were, the availability of public transit, bike accessibility, nearby businesses, and also job accessibility. Yael Golan et al. [60] also formulated the Women's Walkability Index (WWI) in the San Francisco area by using a type of business, crime, homeless people, street cleanliness, graffiti, vehicle speed limit, parking lot, and geological data. Safety was one of the primary factors in WWI since it was for women. It showed that walkability should be varied according to the target group. Thus, in this study, the index would focus primarily on walking to public transit to improve or boost transit ridership.

Walkability index

The walkability index in this study measured how overall walkable the area was by including multiple factors such as transit connectivity, interesting surroundings, level of comfort, and how safe the area was to pedestrians. To allow each factor comparison, each factor data was rescaled from 0 to 1, with 1 representing the best-case scenario for a walk and 0 representing the scenario that has little to none support for a walk as shown in Table 3.3 and the overall average of these four factors was Walkability index.

Table 3.3. Walkability factor scale definition

	Scale	Definition
Transit connectivity	0	No transit available
	0.5	Viable transit connectivity which means there are at least 1 choice of transit available
	1	Good transit connectivity which means there are at least 2 choices of transit and average headway of 10 minutes or less
Interesting surroundings	0	No business around
	1	The highest density of business in the study area
Level of comfort	0	Walking distance is 800m or more
	1	Walking distance is 400m or less
Safety	0	The highest density of pedestrian accidents in the study area
	1	No accident

Transit connectivity indicated how well public transit availability was in the area as shown in Figure 3.14. In Thailand, there was not much of a variation. As a result, this would be close to discrete values in 3 scenarios: first, the score of 1, an ideal condition, would be a least few options of transport with 10 minutes or less waiting time. Secondly, the score of 0.5 or an acceptable condition would have some sort of public transit available, whether it was paratransit or a bus.

While thirdly, the score of 0 would mean no public transit available in the area at all. Taxi, motorcycle taxi, hailing service, or private vehicle needed to start to go somewhere. Interesting surroundings, Figure 3.15, indicated how dense business in the area included shops, cafes, restaurants, hotels, etc. The number of businesses was scaled between 0-1 between no business around to the highest density of business. The level of comfort, Figure 3.16, indicated how far the walking distance was. According to TCRP Report 165 [61], 80% of transit users walked 400m or less to the bus stops with a maximum of 800m. Thus, we used these two numbers as upper, and a lower threshold for the level of comfort with any distance which was 400m in length or less or around 5-10 minutes walk would yield a score of 1, and any distance which was further than 800m or over 15 minutes walk would yield a score of 0 consecutively. Lastly, Safety indicated how safe the streets were for pedestrians as shown in Figure 3.17. This score would be calculated the same way the Safety Index did with only accident statistics that involved pedestrians.

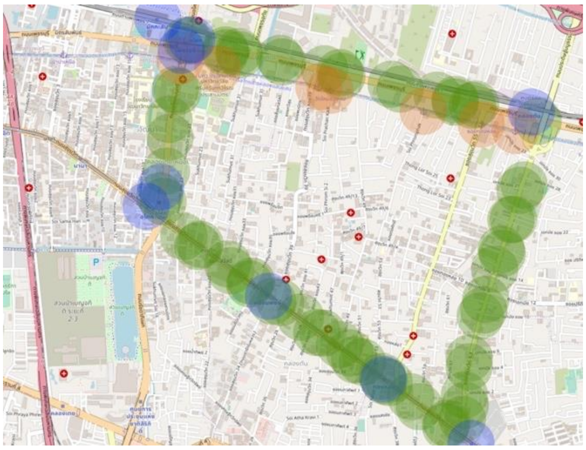


Figure 3.14 Transit connectivity layer

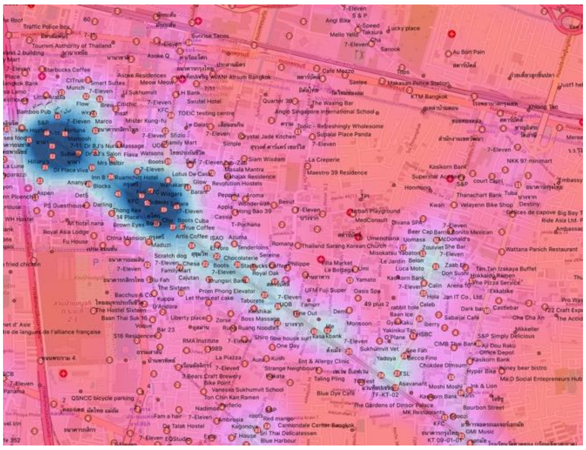


Figure 3.15 Interesting layer

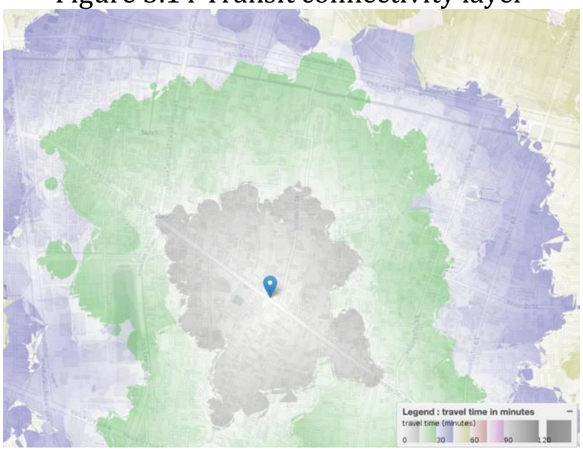


Figure 3.16 Comfort layer

Figure 3.17 Safety layer

In this study, the assumption was that these four factors including transit connectivity, interesting surrounding, level of comfort, and safety, were equally as important, Figure 3.18. To calculate the Walkability index, all four factors then had to come into the considerations. First, each factor would be calculated based on the path or location individually to represent each situation and concern. Consequently, the result of Walkability index was the arithmetic of each factor value.

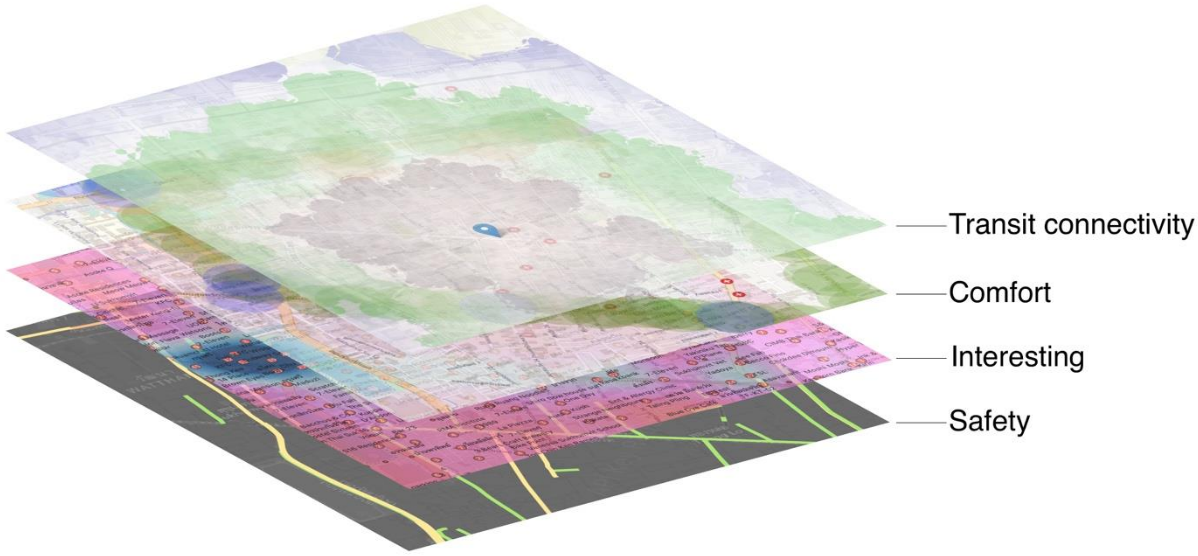


Figure 3.18 Walkability index in layers

The formula for Walkability index

$$Walkability\ Index = \frac{1}{4} \times \ (W_t + \ W_i + W_c + W_s) \tag{3}$$

where W_t was transit connectivity value

W_i was interesting surroundings value

W_c was level of comfort value

W_s was safety value

3.4 Summary

With both safety and walkability indexes, the current situation, whether it was good or bad, could be shown accordingly. While they might not be able to represent every single aspect of the issues, they covered all available information within the limited duration of this study. Initially, these two indicators would be using in the Glocal MaaS experiment in the next chapter and the social experiment with smart shared vehicle (SSV) in chapter 5.

There was an idea from feedback after the experiment that these indexes did not concern user preferences. For instance, the value of 400m walking distance used in this study would not help to differentiate walkability's comfort since one might have a longer comfortable walking distance such as 2 km, for example. Also, some might not concern regarding the surroundings as much as safety. The future iteration of these indexes could likely be adjustable indexes such as each factor's weight or some of the value's threshold, to suit each user's the best while still reflecting the current situation.

3.5 References

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CHAPTER 4: MOBILITY-AS-A-SERVICE (MAAS)

4.1 Background

With the possibility that MaaS could offer to the transport system as a whole, especially improving the system efficiency and offering a seamless integration among various transport operators, it was imperative that the experiment should have been conducted in Thailand. While it would have been ideal to do so in Bangkok, a city with the highest number and coverage of transport operators, the collaboration in Bangkok did not come to fruition. Back in 2017, while there was no public GTFS feed available in Thailand, information such as timetable, stop, and the route was a mandatory set of data to be able to construct the GTFS feed. I then first contacted all transport operators in Bangkok asking for required information and with some knowledge of the availability of real-time tracking data was available on every single Bangkok Mass Transit Authority (BMTA) bus. Consequently, what I found was one out of three train operators who were Airport Rail Link (ARL) in the Bangkok area had a timetable available on the website at the requested date (in 2018). It took 133 days with a number of contacts to get a good response from Bangkok Mass Transit System (BTS) (including them updating this information on the website), and there was no response at all from Bangkok Expressway and Metro (BEM) regarding MRT train headway. While asking, BMTA was elevated into another story, as shown in Table 4.1. Long story short, the conversation was breaking down to 2 parties. Firstly, a data owner, BMTA, and, secondly, Viabus, a company who got the right to use BMTA's through an agreement between Chulalongkorn University and BMTA. In my opinion, I did not find any rationale behind this obstacle besides BMTA, which could not officially deny collaboration with the academic project had no resources and skills to provide the requested data by themselves. Then they requested a 3rd party, Viabus, to do the job. Yet, Viabus, which did not need to obey any requests from BMTA, did not care to cooperate with anyone, especially a project like MaaS, which Viabus could foresee that this might be a competitor at the end. All in all, without any open data act, MaaS would always find trouble like this. For all these reasons, I found that it would require too many collaborations and eventually took time longer than it was worth doing the MaaS introduction experiment in Bangkok.

Therefore, Phuket was selected to be a study area due to a number of reasons. Firstly, although Phuket was an isolated island focusing on tourism primarily, it had full coverage of public transportation. Not all provinces in Thailand had this, which this study would intend to study on. Secondly, Phuket shared the same road traffic accident characteristics with a very high rate of motorcycle-related accidents. So, it could represent the situation in Thailand well. Thirdly, since Phuket was a tourist destination with around a fifty-fifty population ratio between locals and tourists, that would ensure that there should be a variety of transport needs during a period of experiments. Last but not least, the operators there cooperated with researchers willingly.

Table 4.1 Information request log from transit operators in Bangkok

Date	Updates
BTS	
2018-01-27	Asking for train timetable and frequency and a possibility to connect with BTS's rabbit payment service to official BTS contact email: btsmailcenter@bts.co.th
2018-03-01	Repeat the same request since there was no response
2018-04-01	Phone call to ask if there was any response to the request.
2018-05-22	Phone call again to ask if there was any progress, but got a response that mail was lost somewhere; please send mail again.
2018-05-30	Successfully received timetable (first train and last train) and train frequency during each hour (peak or not); yet no progress on the Rabbit payment service
MRT (BEM company)	
2018-01-22	Asking for train timetable and frequency
2018-03-01	Repeat the request
2018-04-02	A phone call to ask if there was any progress. / None
2018-04-04	Repeat the request / No response
2018-05-01	Last phone call to which they responded with using the updated information on the website, but the train headway was not available to the public.
BMTA	
2017-12-21	Asking for bus information such as timetable, frequency, and the possibility of obtaining real-time information. / No response
2018-01-20	Repeat the same request
2018-02-06	Response: set a meeting on 2018-02-26
2018-02-26	Meeting with BMTA IT department director; Everything seemed to be in good agreement since there was no policy conflict with any academic project. The request was in motion to the upper level.
2018-05-09	Phone call with the director's assistant: No further progress
2018-05-10	Contact the director asking for any progress via email.
2018-05-17	The director's assistant asked to contact the company, Viabus, who got the real-time information and a company under Chulalongkorn University startup program.
2018-05-17	Contact Viabus and start from the beginning again. There were more than 20 emails and many messages for months. While having ongoing conversations with Viabus, I did try to contact BMTA directly again too, but the result was like the permission was already granted; it was only technical issues that I would need to solve with Viabus directly.
2018-11-28	Viabus asked to sign a blank contract in order for them to grant permission to use the data. Then I decided to stop pursuing this set of data.

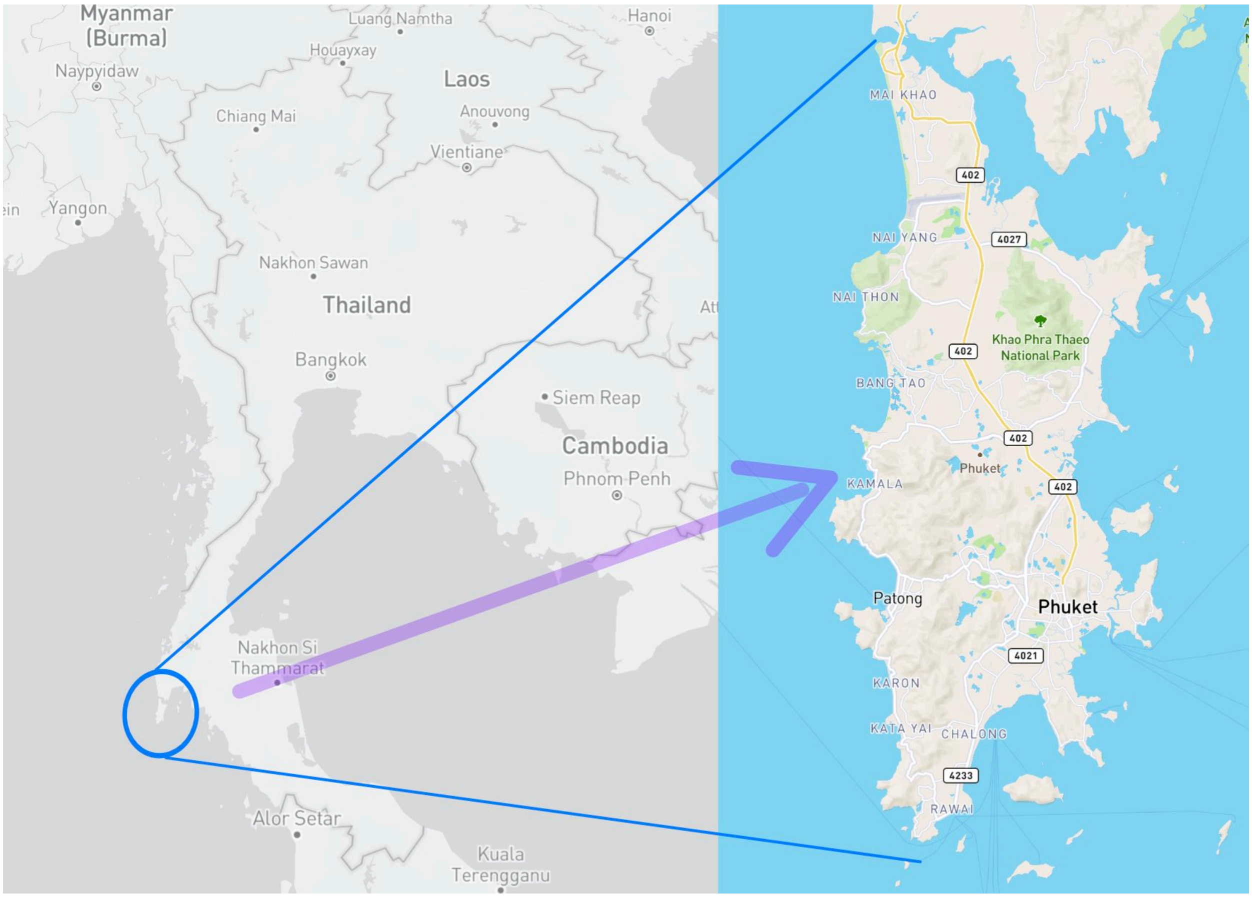


Figure 4.1 Phuket, Thailand

Figure 4.2 [53] showed that traffic accidents in Phuket had very similar characteristics to that of the country. However, motorcycles tended to be more problematic in this area with the growing in both total number and the ratio of all accidents over the past years. Considering the severity of the accident, motorcycle-related accidents were accounted over 80% of traffic-related death in 2018 and almost half of those numbers were a motorcycle-to-motorcycle one as shown in figure 4.3. With these characteristics, it was concerning, but Phuket indeed portrayed the country and also the region well.

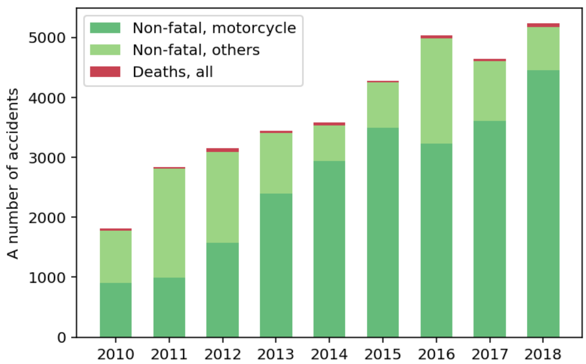


Figure 4.2 Total number of accidents in Phuket

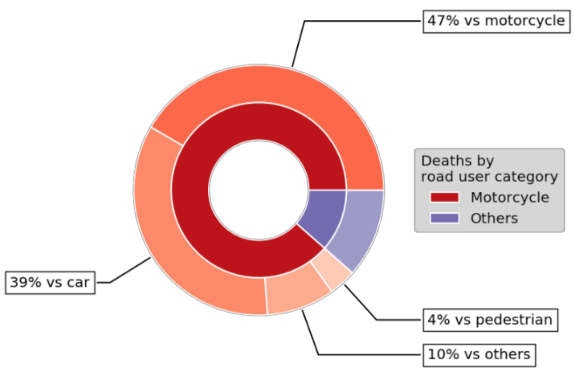


Figure 4.3 Fatality detail in Phuket, 2018.

4.2 Methodology

4.2.1 MaaS development

On the development of MaaS, it consisted of 3 main phases as follows:

1. Design
2. Data collection
3. Implementation

4.2.1.1 Design

While MaaS was introduced in many places from different companies around the world, the core components were pretty much the same, which included a map service, payment service, routing component, and user interface. In this study, we introduced the Glocal MaaS. The definition of the word "Glocal" was relating to the interconnection of global and local factors or issues. Thus, Glocal MaaS was a Mobility-as-a-Service that concerned with local contexts as well as improving transportation with the latest global technology.

There were several essential parts to consider when building the Glocal MaaS. First, using open-source projects would be able to help shorten some development time with the price of un-unified format due to different developer's preferences. Second, to alleviate the issue from multiple opensource projects. Developing a gateway was required. This would consolidate data from multiple projects in various formats and return as unified resources, which would ease the development of the client-side or the user interface part later on. Third, the unknown such as undocumented payment services, which was potentially the best one for researcher and transport operator in Thailand since it had no fee at all, but that would require time and collaboration between local banks in Thailand. Consequently, the decision was to prepare for the worst-case which was having both well-documented payment services like PayPal, which had around 3-5% fee per transaction, and working on Thai QR payment service at the same time. Which all these decisions, we came up with the architecture shown in Figure 4.4, which consisted of a user interface, a gateway, map services, a routing service, payment services, and a search service or Place API in the figure.

The local concerns in chapter 3, which included two indexes that would help people aware of riskiness that they might encounter during each trip and how walkable their walking path was. These two indexes became parts of a routing service in the Glocal MaaS in this study as well.

In this study, we would name the Glocal MaaS as GoTH for the less ambiguous with the general name like MaaS and easier to recognize for testers.

4.2.1.2 Data collection

MaaS, in general, consisted of multiple components from map, routing, trip planner, and a user interface. The data source to make this happen was collected from several sources and manually on the field. Basic map information, including geographical database, road, and terrain type, was from OpenStreetMap [62] and GeoNames [63], which were publicly available. Next, point of interest (POI), which contains buildings, shops, restaurants, businesses, and other facilities, were extracted from both OpenStreetMap and GoodWalk.org [64].

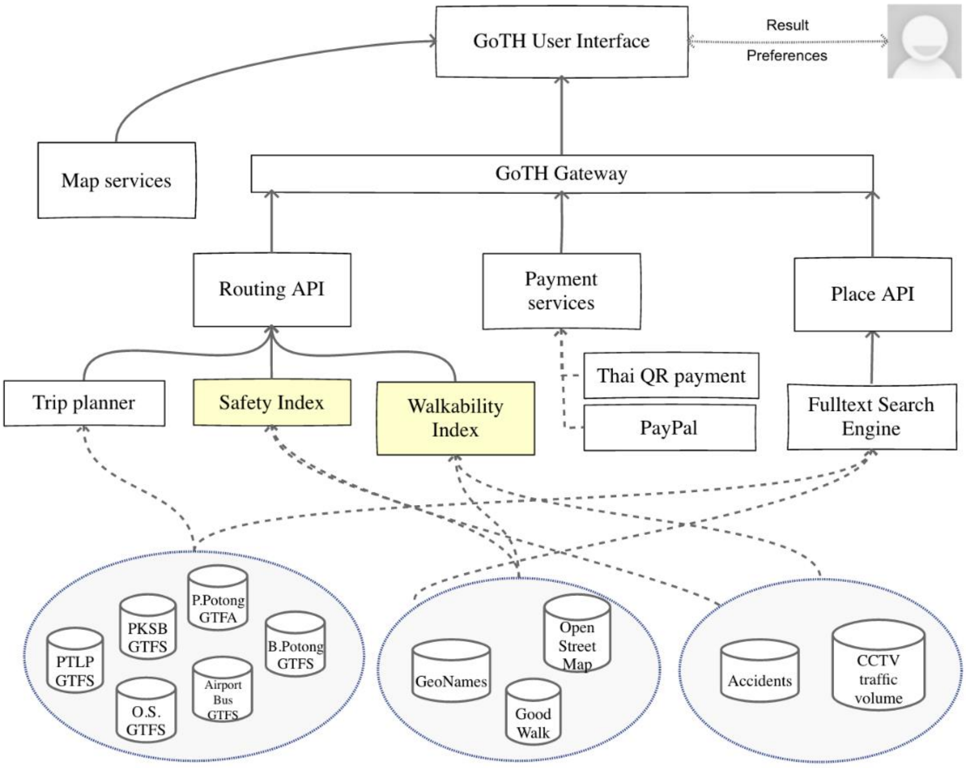


Figure 4.4: MaaS-LC Architecture

Furthermore, transit data also needed to create a trip planner. In this study, we would create public transportation schedules in General Transit Feed Specification (GTFS) [65] format, which primarily included stop, route, frequency, and a timetable for each trip. Initially, the request to all available transport operators was made, but the only couple of them responded with enough information to make a complete GTFS feed. The rest, which included 3 agencies and 12 bus lines, required a manual collection since there were no public data about them at all. The whole process was started by asking the bus drivers and riders in person. However, oddly enough, most of the riders did not know all the information regarding the route they took; they only knew the information between their usual origin and destination, which did not cover everything. Regarding the drivers, they usually did not cooperate in giving the information much, and one interesting thing we found out was some of the bus line operated without any proper management. In other words, each bus was acting like an individual bus running on the same route. They had a queue at the terminal (in the city) which only allowed to leave one by one, but that was about it. During the way to the end of the route, they could decide to terminate at any point, especially when all passengers were gone, without any notice. To terminate, it could mean either having a break from the job or starting a new trip back to the terminal in the city. It was an unfortunate act, but the driver claimed that this was the right call since there would be no passenger anyway on the way to the end. This would make it a lot more difficult to make a rigid timetable since there was none in practice. Nonetheless, most services operated in a regular manner with the exception of a few. As a result, the only way to collect all the route information was to follow them from start to end to record all the information needed. The operation took 4 days, driving around 6 hours from 131, 170, 92, and 88 km from day 1 to day 4 consecutively. The reason why it took so long was not only the issue mention earlier, but after we had an early termination, the headway between each trip was around 20 minutes also. In the end, all the routes were completed. Yet, while the proper transit elsewhere might have stops along the route, in Phuket, stops meant every place along to route. The rider could press the buzz at any point to get off or could give a signal on the side of the road to get on. Though from the observation, these were not that random since they were likely to be at the intersection or at each Soi. With this information, we could create a virtual stop in GTFS format.

There was another thing in GTFS format, which was stop_times containing information regarding arrival and departure time for each stop along to route. This proved to be a difficult task as far as the nature of service in Thailand was concerned. We then came up with another system to predict the arrival time from statistics information.

From Figure 4.5, the Deep neural network used in the model, which input layer comprises eleven features with seven types, as shown in Table 4.2. A rectified linear unit (ReLU) is used as its activator function with adaptive gradient (AdaGrad) optimizer [66]. As a result, the optimal number of layers was four hidden layers with seven nodes on each layer.

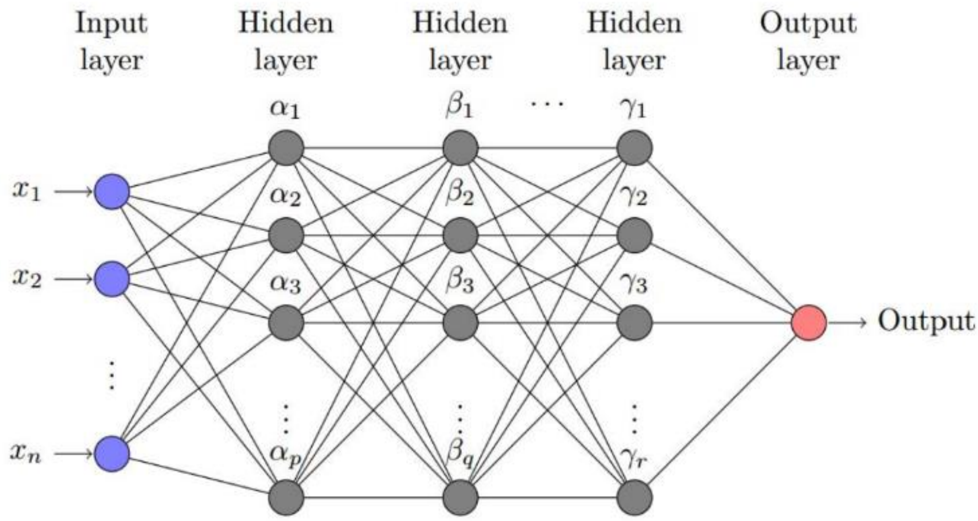


Figure 4.5: Deep neural network structure

Table 4.2 Variables used as input of Deep neural network model

#	Variable	Description
1	Current location	Current bus travel progress on the route
2	Target location	Percentage of the target location along to route
3	Distance	Distance between the bus to target
4	Instantaneous speed	The current speed from the GPS module
5	X GPS points averge speed	Average speed of the previous X GPS location (Including the current location)
6	Hour of day	Hour of day [0-23]
7	Day of week	Day of week [0-6]

4.2.1.3 Implementation

Thus far, we had collected all the resources to have a MaaS application from the earlier section. This section would explain what made use of those data. From Figure 4.4, the circles with gray background were the data. Each of them is used as a data source for different components.

Map services utilized the data from OpenStreetMap to serve the map as tile and show the route on the screen. This services ran with the openmaptiles project with the OSM Bright style.

The trip planner, which was the backbone of MaaS, was responsible for finding available itinerary choices that the user requested. This component required all GTFS feeds to calculate the best place and time for nearby transit. Safety Index and Walkability Index components utilized geographical and accident information to formulate the index, as explained in chapter 3. These three components fed their outputs to the Routing API component. Itinerary choices included both indexes, the walking path between the origin point and the beginning of the transit part and the end of transit to the destination. Figure 4.6 displayed the data flow in the trip planner from the raw data to the end. Three routing machines were running Open Source Routing Machine (OSRM) and Open Trip Planner (OTP) responsible for finding the best possible routes. OSRM calculated the way for motorcycle and walking while OTP took charge of routes for car and transit. The two indexers got the courses and added safety and walkability values before entering the last part of the trip planner, GraphQL gateway, and appearing on the user's screen.

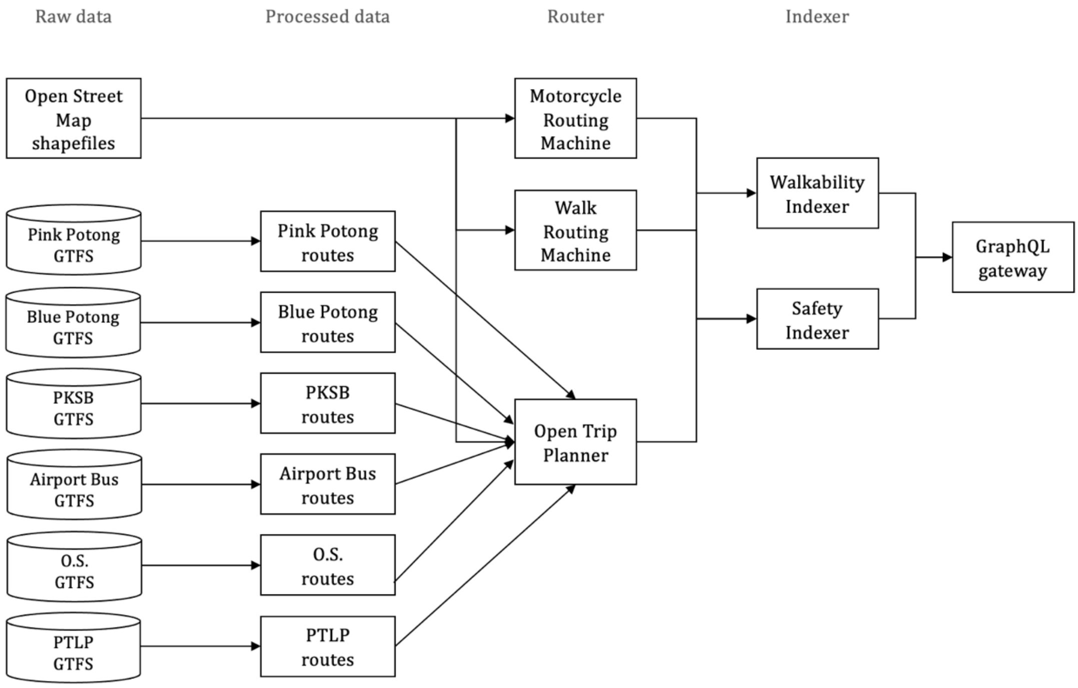


Figure 4.6 Trip planner data flow

Regarding payment services, this was developed to work with Thai QR payment through the service of Siam Commercial Bank (SCB), which there was no fee, and PayPal, which would accept credit card which had a certain amount of fee.

For Place API, it was responsible for both translate GPS coordinates (latitude and longitude) to human-readable address and a business name to GPS coordinates for other components to process. This component relied mainly on Point-of-Interest information, which was extracted from OpenStreetMap and GoodWalk.org. This component was developed on top of the opensource projects named ElasticSearch and Pelias.

GoTH gateway was an intermediate layer that connected both a frontend side or GoTH user interface to a backend, which included Trip planner, payment services, and Place API.

The last component was the GoTH user interface. This interface was a web application built on top of the React framework, developed by Facebook. This ensured the compatibility and ease of use for people to try out the application since all smartphones, both iPhone and Android, nowadays had an internet browser anyway. Moreover, with the limited resource of the study, developing once and using anywhere were not a bad idea.

All above components were opensourced and available on github.com/goth-glocal-maas which more details could be found in the appendix.

Table 4.3. Data used in this research

Data type		Total
Point of Interest		
	OpenStreetMap	2,039
	GeoNames	1,886
	GoodWalk.org	12,413
Public transportation		
	Agency	6
	Transit line	16
	Stop	412

The application itself was rather simple to use, especially if a user was familiar with another trip planner like Google Maps or Apple Maps. The steps to get itinerary choices were selecting origin and destination. That was it mandatorily. However, there would be optional such as modes of transport, which included 4 modes: transit, walking, motorcycle, and car. Departure time also was another option that was only a concern for transit that relied on timetable since, in this application, there was no traffic congestion in the consideration.

The features in the application were (i) finding places, (ii) finding direction from place to place, (iii) comparing each trip by mode, time, cost, safety, and walkability.

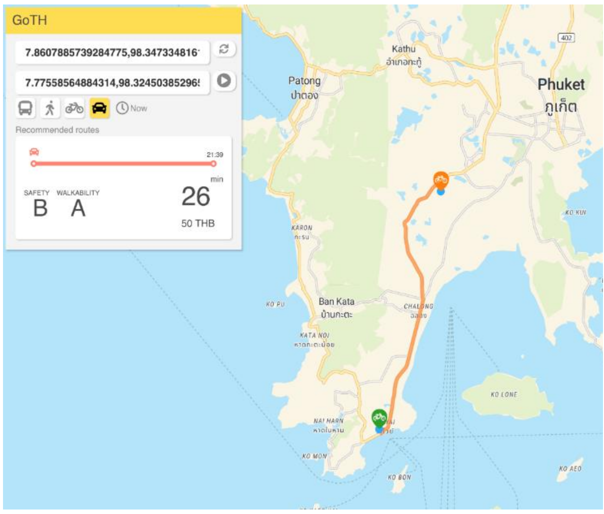


Figure 4.7 Application screenshot

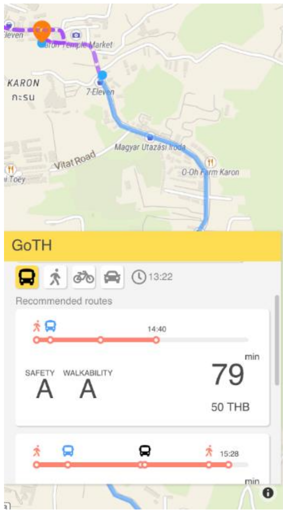


Figure 4.8 Application screenshot

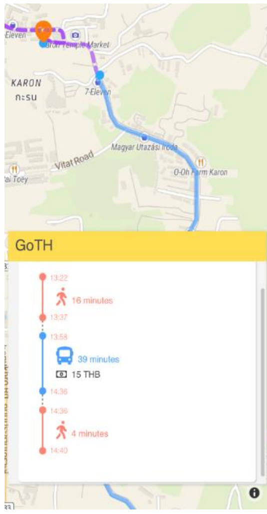


Figure 4.9 Application screenshot

There were things to consider before picking the trip, as shown in Figure 4.7-4.9, which were a trip start time, trip duration, line, fare, Walkability index, and Safety index. For example, in Figure 4.9, the first choice seemed to depart from the airport soon, and it would take about 70min to the Patong area with 50THB fare. Both walkability and Safety indexes were great, while the second choice was likely to be the next one available in around 40-50 mins. This trip would cost more at 140THB and take a bit more time, 76 mins, to reach the destination. There was no difference as far as walkability and safety were concerned. The reason why the Safety index here was A because, according to the statistics, a bus accident in the Phuket area, like most places, rarely happened. Consequently, risk values were very low, and then the Safety index yielded the highest.

Walkability around the beach was also within a comfortable distance, great business availability, and many transit options. Thus, it was the highest value of the Walkability index.

4.2.2 Questionnaire survey

In the experiment, we would conduct a survey to see the impact this MaaS application had on the people who spent time using it. The survey was conducted in the study area, Phuket, Thailand. The questionnaire was spread by two methods. First, an in-person interview was conducted around the Phuket international airport and downtown Phuket. Second, the online survey was distributed to students at Prince of Songkla University, Phuket campus. The questionnaire contained two main sections, which included background and basic attitude toward transportation before trying the application. Then, the respondents were asked to try the application for a week and complete another section to see the impact of the application on the respondents' decision.

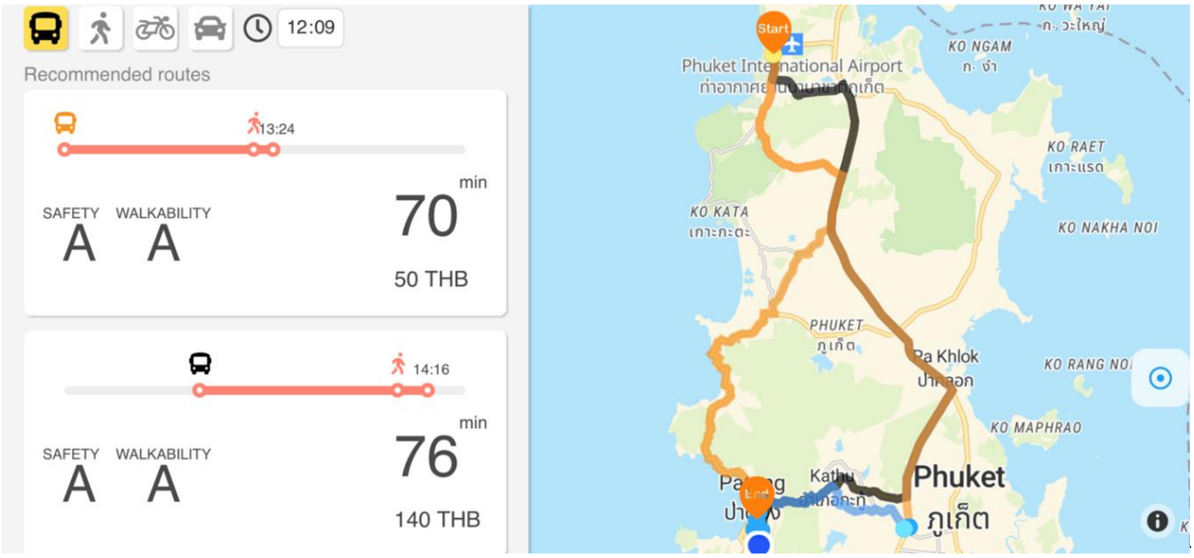


Figure 4.10 Example of route recommendation (from the airport to Patong beach area)

Questions in the questionnaire were asked as follows:

- Personal background included sex, education, current transport mode of choice, a familiarity of the mobile application or any trip planner, and the knowledge and expectation of Mobility-as-a-Service (MaaS) in general
- Application impact section included how usable the application was, how useful the data in this application provided was, whether the data was accurate or not, whether safety and walkability awareness played any role in the decision-making process, and what the influential factors were before and after using the application.

Chi-square tests of independence were applied to determine the relationship between multiple pairs of questions. First, whether the app usability was related to traffic behavior change, safety recognition, and app retention. Second, whether a piece of useful information on the app was related to app retention and the change of behavior. Third, whether a consideration of walkability related to people who did not use public transportation.

4.3 Result

There were 69 people who completed both sections of the questionnaire. According to the personal background section, the result [Figure 4.11] showed that 61% of participants were in a groupage 20-29. 52% were local people [Figure 4.13]. A majority, 65%, used their own vehicles, which took over an hour for their daily commute [Figure 4.12]. While [Figure 4.15] almost all participants, 88%, were familiar with a trip planner, especially Google Maps, they were not using the app on a regular basis [Figure 4.16]. 87% of participants found that finding direction was the most useful feature. Both direction and time comparison was the second most useful features, with almost 60% of participants. A real-time bus location was the least useful one with 1.4% or exact 1 participant.

4.3.1 Respondents' attributes

Figure 4.11 Respondent's age

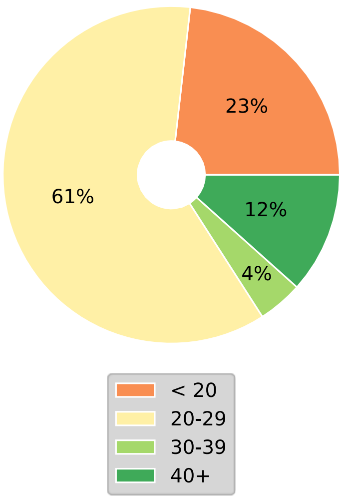


Figure 4.12 Respondent's primary mode of transport

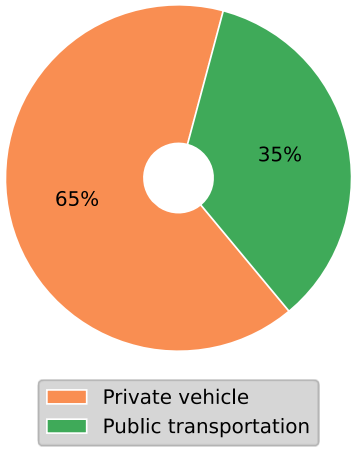


Figure 4.13 Respondent's population type

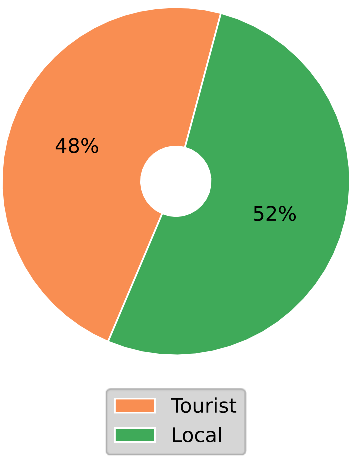


Figure 4.14 Respondent's weekly transport expenses

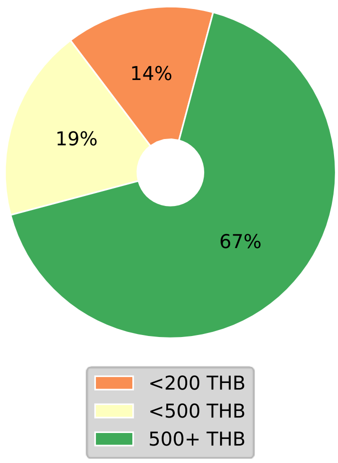


Figure 4.15 Respondent's familiarity to Trip planner applications

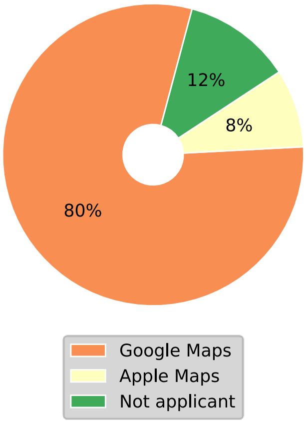
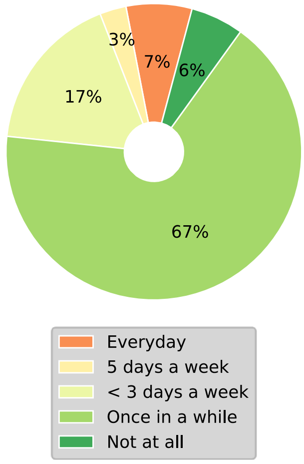


Figure 4.16 Respondent's trip planner usage



After giving GoTH a try, the results [Table 4.4] showed how usable and useful the GoTH was as follows: 68% of participants found that this app was easy to use, and 59% wanted to continue using it after the trial ended. While 45% did not find this app provided any more useful information than they already knew, 42% agreed that this app gave the information they could not find anywhere else. Regarding how accurate the time and cost information in the app was, although 46% found the app was good, half of the participants either found that it was inaccurate or did not mind checking at all.

4.3.2 User evaluation and awareness-behavior changes

Table 4.4. Application evaluation results

	Agree	Neutral	Disagree	Not sure
The app is easy to use	68.12%	4.35%	20.29%	7.25%
This app provides information I cannot find anywhere else	42.03%	7.25%	44.93%	5.80%
Time and cost information provided by this app is accurate	46.38%	2.90%	39.13%	11.59%
I want to continue using this app	59.42%	0%	36.23%	4.35%

Table 4.5. Awareness and behavior changes by using the application

	Yes	No	Not sure
Have you taken a bus following the information this app provided?	27.54%	68.12%	4.35%
Have you changed your mind not to use a bus because I found using a bus worse option than others?	50.72%	34.78%	14.49%
Have you changed the route or traffic mode because the app provided good trip options	39.13%	44.93%	15.94%
Have you thought of safety when you choose the trip option?	78.26%	17.39%	4.35%
Have you thought of walkability when you choose the trip option?	79.71%	13.04%	7.25%

In the last section, the results [Table 4.5] showed that half of the participants found the bus was an inferior choice compared to other modes; only 27% took a bus from the information this app gave. Nonetheless, this app instead suggested 39% switched to another route or transport mode since there were better alternatives. In addition, a majority of participants started to think of safety (78%) and walkability (80%) in order to pick their trip.

Table 4.6. Chi-square test of independence between app usability and others

		I want to continue using this app		Have you taken a bus following this app?		Have you thought of safety when choosing a trip?	
		Yes	No	Yes	No	No	No
The app is easy to use	Yes	36	11	18	29	42	5
	No	5	17	1	21	12	10
		X^2=15.869, p=0.000, DoF=1		X^2=6.948, p=0.008, DoF=1		X^2=8.729, p=0.003, DoF=1	

Table 4.7. Chi-square test of independence between useful information and others

		I want to continue using this app		Have you changed the route or traffic mode because the app provided good trip options	
		Yes	No	Yes	No
This app provides useful information	Yes	26	3	16	13
	No	15	25	11	29
		X^2=16.864, p=0.000, DoF=1		X^2=4.305, p=0.038, DoF=1	

Table 4.8. Chi-square test of independence between walkability and decision not to use transit

		Have you changed your mind not to use a bus because I found using a bus a worse option than others?	
		Yes	No
Have you thought of walkability when choosing a trip?	Yes	33	22
	No	2	12
		X^2=7.591, p=0.006, DoF=1	

A chi-square test of independence was performed against pairs of the survey. The result [Table 4.6] showed there were statistically significant between app usability and traffic behavior change (X^2=15.869, p=0.008), recognition of safety (X^2=6.948, p=0.008), and application usage retention (X^2=8.729, p=0.000). This implied that the usability of the app was important since it had an influence on all three values. Similarly, if users thought the app provided useful information [Table 4.7], that would influence both a retention rate (X^2=16.864, p=0.000) and a traffic behavior change (X^2=4.305, p=0.038). The result additionally revealed that walkability consideration was one of the factors for people who decided not to take public transportation (X^2=7.591, p=0.006). This might imply that having a low Walkability index could cause people to avoid transit [Table 4.8].

The most negative feedback for the app was search results for places or specifically POI data. Participants found that this app lacked information in this area and, consequently, they could not find places they wanted, including hotels and tourist attractions. The other significant feedback was the language in which GoTH had an English interface only. While English seemed to be the right balance between users, including local people and foreign and Thai tourists, Thai people wanted the app in Thai.

4.4 Summary

A first attempt to build the Glocal MaaS app in Phuket was rough but showed good potential. In other words, since this was not yet a complete package which including payment, users directly compared to other well-established trip planner apps like Google or Apple Maps. Yet, people were interested in trying and recognizing public transportation availability, which other apps did not have. Although this app was yet to satisfy people thoroughly, it showed that giving people information like Safety Index would help them recognize and raise their awareness before picking their route or trip.

Still, only introducing the app with only information integration might not have enough impact on people's safety awareness or willingness to change their behavior to use public transportation. This MaaS would have to improve not only its weakness from feedbacks but also add new features such as payment integration to smoothen their transit experience and information accuracy to make people believe data provided in the app to boost people engagement as Andersson et al. and Durand et al. found in their studies. [46] [44] Lastly, the biggest problem in this development was collaboration and openness between transport providers since in order to have all updated data, all actors would need to be willing to share and update their information accordingly. In short, the introduction of Glocal MaaS showed positive feedback and was able to promote public information visibility, improve usability, and formulate people's attitude toward safety.

4.5 References

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CHAPTER 5: LAST-MILE MOBILITY IMPROVEMENT

5.1 Background

From the previous chapter, Mobility-as-a-Service, the results were indicated that walkability was strongly linked with how people made their decisions to take a public transportation route instead of a private vehicle. This chapter then focused on how to tackle this issue and improve the overall last-mile experience with the framework as a guideline, as shown in Figure 5.1. The framework included (1) identifying the factors that were relevant to the decision people made when they chose to walk to the transit or not. This would help understand the people better since people were different based on a variety of factors such as background, culture, demography, education, welfare, and the surrounding environment. (2) concluding the solutions from the most influential factors to come up with a better design of mobility. Then (3) starting the experiment base on the solutions from (2) to see whether there were any changes to people's decisions and behaviors. Also, whether the changes were induced by new solutions or not. This study would focus on Bangkok, Thailand, and the study area would be in the Sukhumvit area, which was considered as downtown with relatively the best transit connectivity.

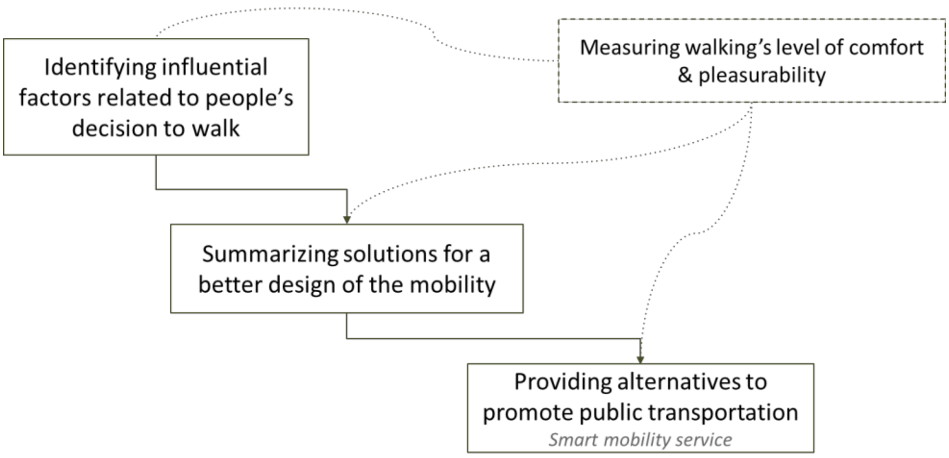

Figure 5.1 Framework for this chapter

The factors that could be influential to pedestrians were different based on the environments. Bivina [67] found that the influential attributes for pedestrian satisfaction were safety and infrastructure, while convenience also had some impacts on the decision to train station in Delhi, India. Also, Park [68] suggested an acceptable walking distance could be more significant by the perception and improvement along the walking path. In other words, some of the factors could likely be varied by the environment or the perception of each person to the environment. There was also another aspect of walking factors as Alfonzo [69] depicted the walking needs in the form of Maslow's hierarchy of needs. This explained how people come to a decision of whether to walk or not psychologically. The interest in the hierarchy was although there were five levels of needs, it could be categorized briefly into two levels, which were limits and needs in urban form or this could be explained that there was no reason to bother finding other factors if the walking feasibility was still the limit in the area. The feasibility could be interpreted as the most basic need to refer to the viability or practicality to walk. For example, if there was no slope to get on and off the sidewalk for the wheelchair, then disabled people could definitely not make it. Also, if the walking duration was longer than what people could spend, that would directly affect the decision. However, Alfonzo explained that not all walking needs must be fully satisfied to process to the upper level besides the limits. For example, people might not need to fully appreciate the current accessibility situation to start considering safety.

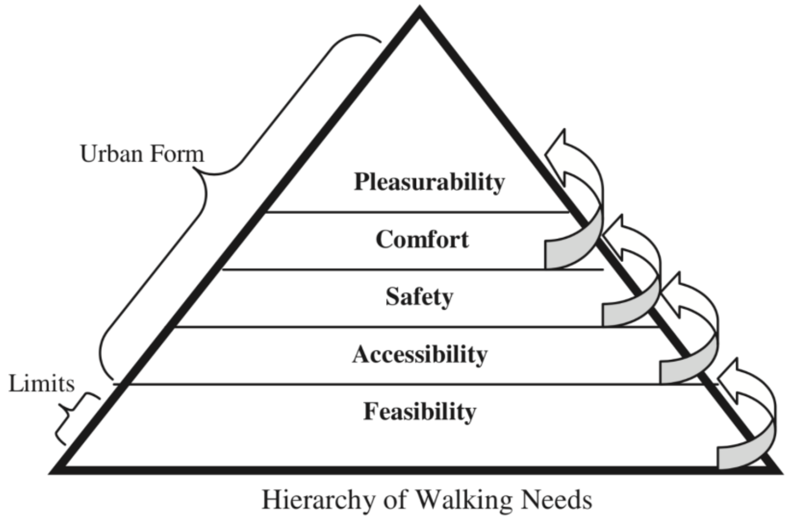

Figure 5.2 Alfonzo's Hierarchy of Walking Needs

While walking was essential to any trip, studies [70] showed that commuters tended to walk for at least one leg of their multimodal journey, but they also tried to balance between cost and time for other legs. Thus, other options needed to be considered to improve last-mile mobility, including non-motorized and motorized ones. The only non-motorized transport besides walking was a bicycle. Studies [71] indicated that bicycles acted like an effective feeder in Europe, and the perception toward the connectivity, such as bike parking lot, and train quality or cost were influential factors. [72] The motorized options were paratransit, motorcycle, and motorcycle taxi. Paratransit or micro-transit was another option that could act as a feeder. In some setups, like fixed routes and fixed schedules, it looked like a direct competitor to the bus. While the motorcycle was a popular transport mode in Thailand, it rarely acted as the last-mile connector. On the other hand, motorcycle taxi was one of the very first choices as a feeder to transport hub, but, as mentioned in the previous chapter, it was the one to avoid for overall traffic safety.

Shared mobility modes also targeted at the last-mile. Studies [15] [73] showed that e-scooter could potentially serve as first- and last-mile connections to public transit. However, it had yet to prove to a well-recognized option due to the small availability comparing to others. Bike-sharing also had the potential to act as a last-mile connection, but studies [74] [75] had the mixed results between bikes as a supplement to the existing public transportation but instead acting as a competitor to bus in China.

Additionally, on-demand ride services like Uber, Lyft could also function as a feeder to connect to public transit. Although they mostly complemented the public transportation network by filling the gap during the off-peak hours with less frequent train service, some studies [76] found that these services appeared to be a substitute for private vehicles more than one for public transit.

As far as Thailand was concerned, bicycles that appeared to be beneficial in various places could hardly be the solution at the time of writing. According to previous studies [72] [74], Thailand did not have a critical factor in the thriving bicycle environment. There was no infrastructure to facilitate the seamless connection between bicycle and transport hubs. As far as safety was concerned, both motorcycle and motorcycle taxi should not become a favorite option. That would leave shared mobility and on-demand services as viable options.

5.2 Methodology

This study was based on an online questionnaire survey of people living in the Bangkok area. The total number of respondents was 1,000. The survey contents included necessary information such as age, income, rent, commute detail, mode of transport, and the preference regarding walking and surrounding areas. Regarding the preferences, it would be a selection between two scenarios that had different attributes. This would enable this study to learn what attributes people valued more relative to other factors, not the decisions that were made independently. Hopefully, that could come to the conclusion of influential factors related to people's decision to walk. The attributes were as follows: walking duration, sidewalk's width, crowdedness of the sidewalk, crossing availability, brightness of the sidewalk (and the road) at night, shade or cover availability, tree availability, and the liveliness along the way.

5.3 Result

5.3.1 Respondents' attributes

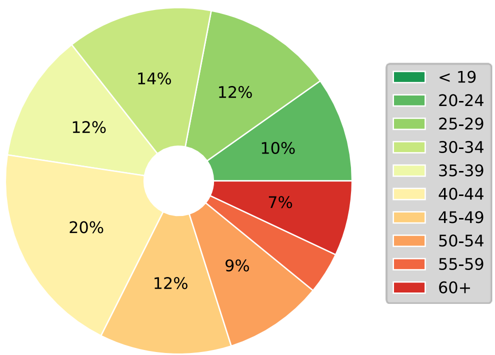

Figure 5.3 Respondents' age

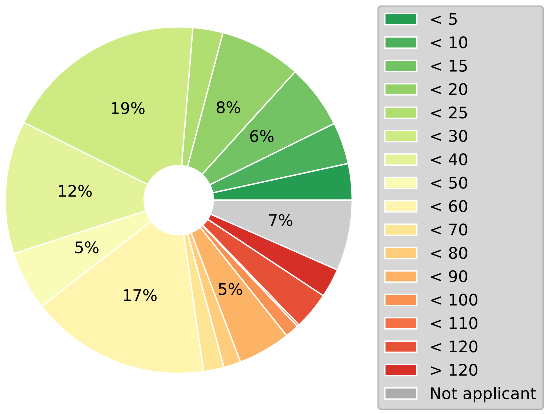

Figure 5.4 Respondents' average commute time (Minute)

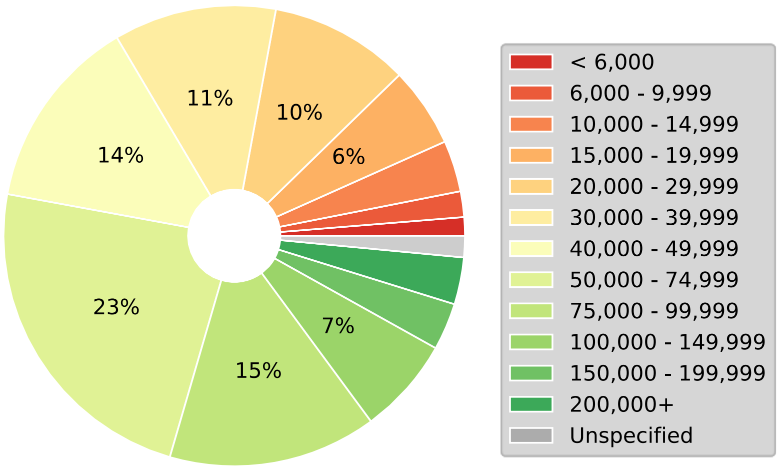

Figure 5.5 Respondents' salary (THB)

Figure 5.3, 5.4, and 5.5 showed the respondents' age, monthly income, and average commute time. All of them lived in the Bangkok metropolitan area, which paid rent around 7,889.63 THB per month on average with a standard deviation of 8,209 THB, which meant the group of respondents was dispersed as far as the financial background was concerned. However, most respondents were of working ages since more than 80% were in the age of 25-59. Regarding the economies, respondents could be classified into three income groups as follows:

1. Low-income group which had less than 20,000 THB a month,
2. Middle income: 20,000 – 74,999 THB a month, and
3. High income: 75,000 THB a month or more.

With this classification, there were 128, 582, and 280 respondents in the low-, middle-, and high-income groups, respectively.

5.3.2 Factor analysis

To understand what had influenced people to decide to walk or not, we examined the correlation across variables in the questionnaire to find potential factors hidden underlying. All the answers translated to numbers with a greater number always interpreting better and a lower number as worse. The analysis was processed in R studio with the lavaan package version 0.6-5.

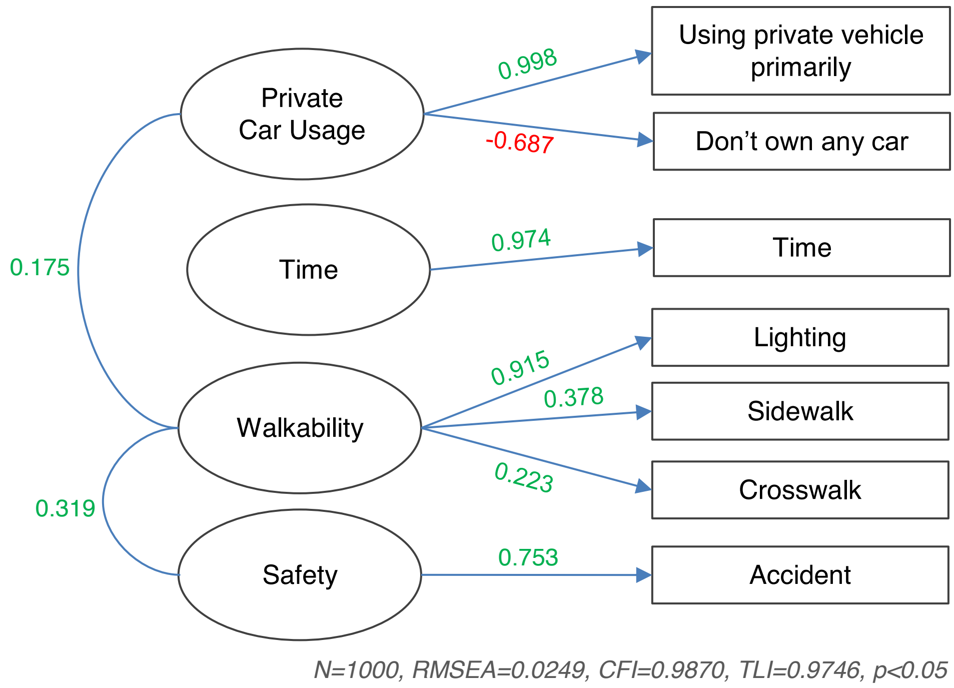

Figure 5.6 Factor analysis for all respondents

Figure 5.6 showed the factor analysis for all thousand respondents. The latent variables found in the factor analysis were (1) private car usage, (2) time, (3) walkability, and (4) safety. First of all, we found that people valued time as much as using a private car. In other words, if there were an alternative that could save people time, people might be willing to drop their private vehicle usage. According to the hierarchy of walking needs, time was the necessary level of need. In this case, in order to increase the chance of walk, then time was definitely the first breakthrough. This finding could suggest that while the bus-like service with headway might not answer to what people wanted, an on-demand service was likely to solve the problem, and there was a possibility that an on-demand hailing service that gave people a ride directly to the train station could work. Next, for people to walk, lighting at night was what people were concerned about the most, which probably meant that they needed some sort of security during nighttime as well. If people felt secure, it was likely that people would start to walk. How good the sidewalk and how good the crosswalk availability also had some influences, but not as important as feeling secure. Regarding safety, people liked to avoid accidents, which was common sense.

However, with the greatly distributed groups of respondents, it was necessary to explore more into groups of people to see whether there were any differences or similarities as far as the economic status was concerned. The respondents in each income group would be separately analyzed to see how the same variables would yield any different latent variables or not.

5.3.2.1 Factor analysis for low-income group

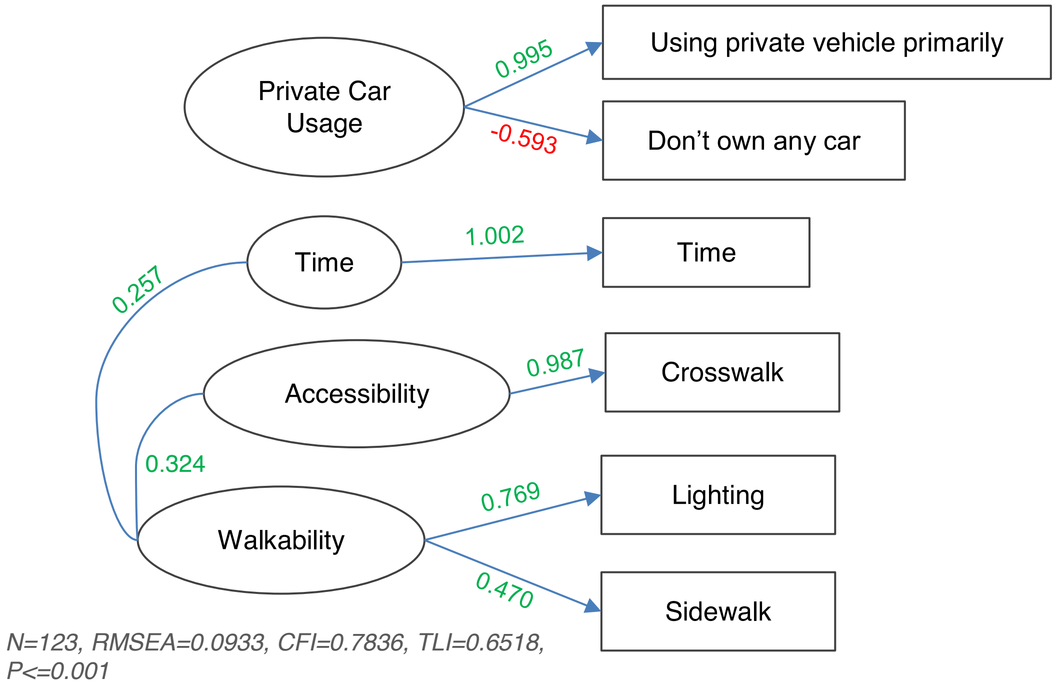

Figure 5.7 Factor analysis for low-income respondents

Uniqueness

accident	time_1	crosswalk	sidewalk	lighting	time_2	private_car	no_car
0.839	0.005	0.005	0.806	0.352	0.811	0.005	0.637

Loading

	Factor1	Factor2	Factor3	Factor4
accident	-0.016	0.174	-0.295	-0.093
time_1	0.059	1.002	0.054	0.012
crosswalk	0.001	0.059	0.987	0.058
sidewalk	-0.031	0.202	-0.110	0.470
lighting	0.010	-0.029	0.088	0.769
time_2	-0.132	0.255	0.100	-0.280
private_car	0.995	0.050	0.001	0.014
no_car	-0.593	0.003	-0.001	0.066

	Factor1	Factor2	Factor3	Factor4
SS loadings	1.365	1.146	1.094	0.907
Proportion Var	0.171	0.143	0.137	0.113
Cumulative Var	0.171	0.314	0.451	0.564

Factor correlations

	Factor1	Factor2	Factor3	Factor4
Factor1	1.000	-0.058	-0.043	-0.091
Factor2	-0.058	1.000	0.112	0.257
Factor3	-0.043	0.112	1.000	0.324
Factor4	-0.091	0.257	0.324	1.000

Test of the hypothesis that 4 factors are sufficient.
The chi-square statistic is 3.57 on 2 degrees of freedom.
The p-value is 0.168, *which means we could not reject that 4 factors are sufficient.*

5.3.2.2 Factor analysis for middle-income group

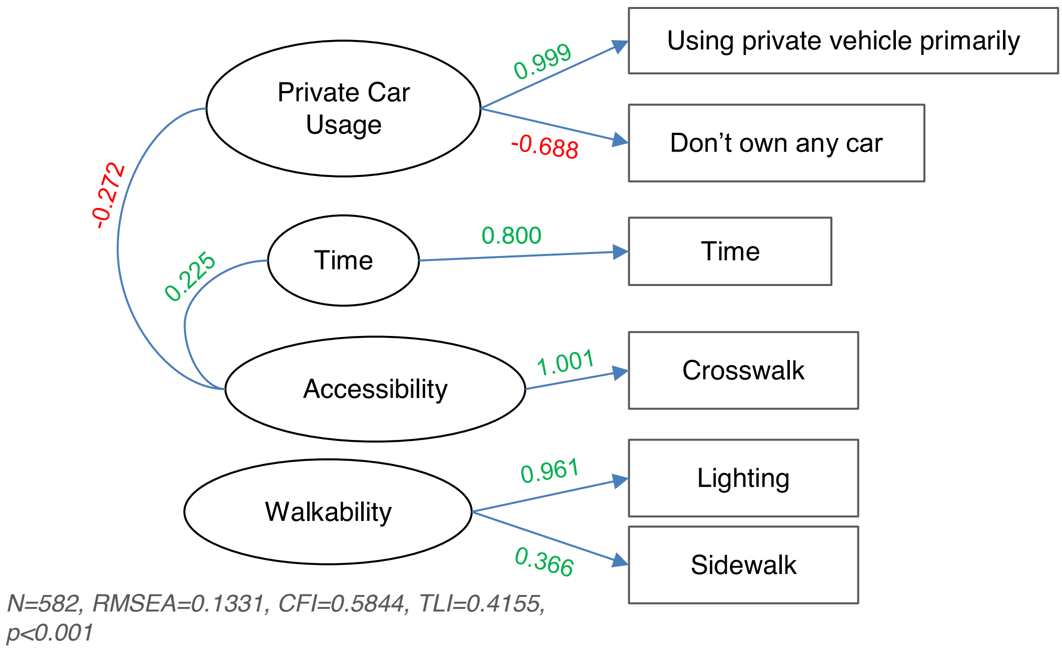

Figure 5. Factor analysis for mid-income respondents

Uniqueness

accident	time_1	crosswalk	sidewalk	lighting	time_2	private_car	no_car
0.966	0.301	0.005	0.864	0.005	0.893	0.005	0.517

Loading

	Factor1	Factor2	Factor3	Factor4
accident	-0.022	-0.027	-0.175	-0.014
time_1	0.009	-0.122	-0.001	0.800
crosswalk	0.011	-0.009	1.001	-0.001
sidewalk	0.036	0.366	0.009	0.168
lighting	-0.002	0.961	-0.008	-0.134
time_2	0.039	0.052	-0.019	0.335
private_car	0.999	0.005	0.015	0.021
no_car	-0.688	0.028	0.026	0.055

	Factor1	Factor2	Factor3	Factor4
SS loadings	1.474	1.076	1.033	0.803
Proportion Var	0.184	0.135	0.129	0.100
Cumulative Var	0.184	0.319	0.448	0.548

Factor correlations

	Factor1	Factor2	Factor3	Factor4
Factor1	1.000	-0.064	-0.272	-0.057
Factor2	-0.064	1.000	0.039	0.015
Factor3	-0.272	0.039	1.000	-0.225
Factor4	-0.057	0.015	-0.225	1.000

Test of the hypothesis that 4 factors are sufficient.
The chi-square statistic is 1.75 on 2 degrees of freedom.
The p-value is 0.417, *which means we could not reject that 4 factors are sufficient.*

5.3.2.3 Factor analysis for high-income group

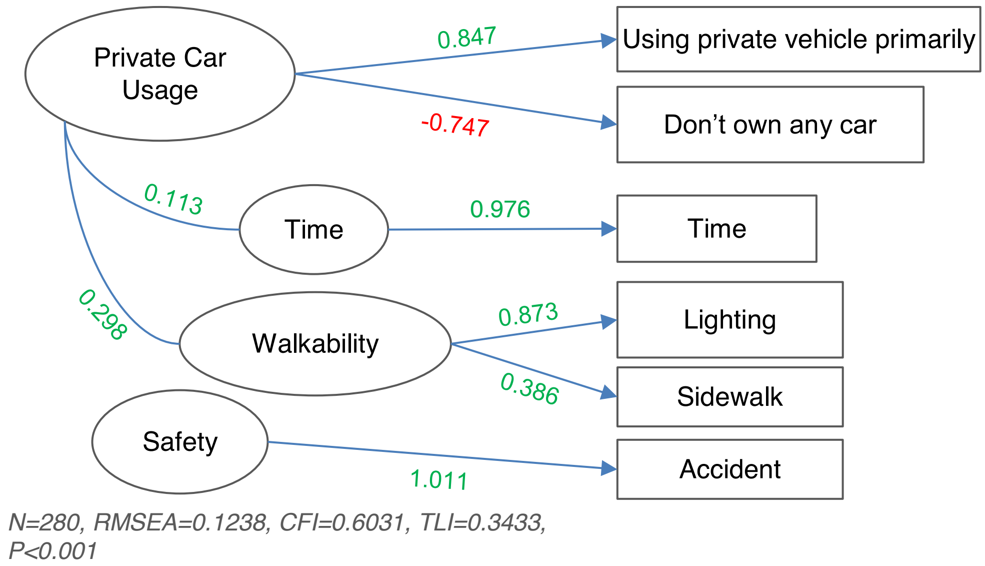

Figure 5.9 Factor analysis for high-income respondents

Uniqueness

accident	time_1	crosswalk	sidewalk	lighting	time_2	private_car	no_car
0.966	0.301	0.005	0.864	0.005	0.893	0.005	0.517

Loading

	Factor1	Factor2	Factor3	Factor4
accident	-0.022	-0.027	-0.175	-0.014
time_1	0.009	-0.122	-0.001	0.800
crosswalk	0.011	-0.009	1.001	-0.001
sidewalk	0.036	0.366	0.009	0.168
lighting	-0.002	0.961	-0.008	-0.134
time_2	0.039	0.052	-0.019	0.335
private_car	0.999	0.005	0.015	0.021
no_car	-0.688	0.028	0.026	0.055

	Factor1	Factor2	Factor3	Factor4
SS loadings	1.474	1.076	1.033	0.803
Proportion Var	0.184	0.135	0.129	0.100
Cumulative Var	0.184	0.319	0.448	0.548

Factor Correlations:

	Factor1	Factor2	Factor3	Factor4
Factor1	1.000	0.113	-0.079	0.298
Factor2	0.113	1.000	-0.076	-0.088
Factor3	-0.079	-0.076	1.000	0.045
Factor4	0.298	-0.088	0.045	1.000

Test of the hypothesis that 4 factors are sufficient.
The chi-square statistic is 1.1 on 2 degrees of freedom.
The p-value is 0.576, *which means we could not reject that 4 factors are sufficient.*

From the factor analysis in each group of respondents based on their income, one similarity across three different groups was the same with the analysis with all respondents which they thought of the time was as essential as driving their own vehicles. When they think of walkability, what came through their minds first was lighting at night or feeling secure at night time. However, there were some differences among groups as well. The high-income group cared about safety since they were concerned about accidents a lot. The low- and middle-income group tended to focus on accessibility since they wanted more crosswalks and had no interest in accidents.

5.4 Summary

As a result, this would mean that if we wanted to promote public transportation and want people to use less of their own vehicles, the alternative would have to save their time. In other words, a regular shuttle service with fixed schedules that connected their apartment or house to the train station might not cut it, yet on-demand service surely would satisfy all groups of people.

Nevertheless, the study area, which was the Sukhumvit area, had more high-income people. From what we've learned, this group would be not bear on accidents. Thus, a professional driver for the service should be a logical option to ensure their peace of mind and make sure that they would have no problem picking the service over their own cars. Moreover, the service should be available and have full coverage to satisfy the rest of the people who cared about accessibility.

From all the above reasons and viable last-mobility options, we could conclude other shared mobility might not be enough to justify the time and health especially during the COVID-19. An on-demand shared smart vehicle (SSV) was likely the be the best option to provide what people needed the most.

5.4.1 Shared smart vehicle (SSV) service

Figure 5.10 FOMM, the small electric vehicle used in the experiment

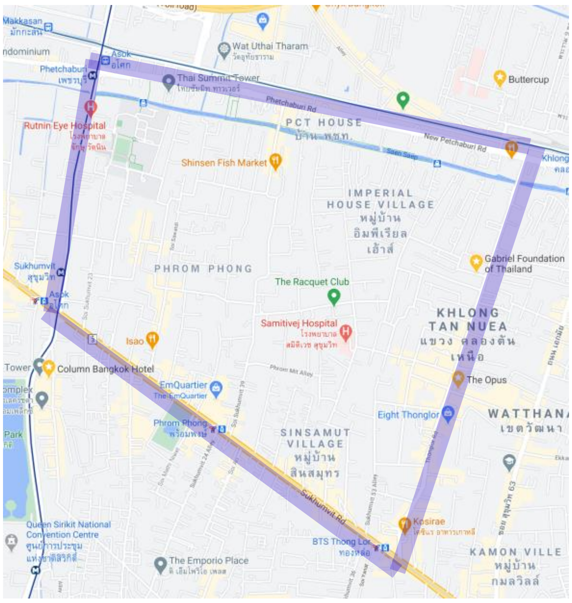

Figure 5.11 Social experiment area. Sukhumvit, Bangkok, Thailand

This social experiment was originally planned to start in May 2020. However, the unexpected COVID-19 was emerged and caused the world to shut down literally, so did this. While the preparation was put in motion as before, the current concerns like social-distancing, no close contact, frequently cleaning, and disinfect were all included in the plan as well. Moreover, it might even push this service faster since this service would be using FOMM vehicle, as shown in Figure

5.10, which was small and compact. This would not allow more than a couple of passengers, which was a good thing in 2020. The service introduced a much safer ride in both road traffic safety and COVID-19 prevention comparing previously available service like motorcycle taxi, which passengers needed to sit next to the driver inevitably. The target area shown in Figure 5.11 was in the center of downtown Bangkok, and the area coverage was around 5 square kilometers, and there were five train stations around the corners from the two main lines, which were BTS (light green) and MRT (blue). Initially, the plan was to deploy 4 FOMM to serve around 200 people in the area, and it would be expanded later if the feedback was positive.

This was a service calling with the application only, similar to Uber service, which would save time and people regarding on-demand service. Since people in Thailand were familiar with the LINE application, this service initially utilized LINE chatbot to answer and accept the reservation. However, the driver side application was a native application on iOS because of the limitation that the LINE application could not give precise and up-to-date locations at all times. The applications on both passenger and driver's sides were as follows.

5.4.1.1 Driver app

The application contained 2 main pages: Job queue, which had all active reservations for the driver to accept, and Job page, which provided necessary details such as pick-up location, destination, pick-up time, and the passenger's contact.

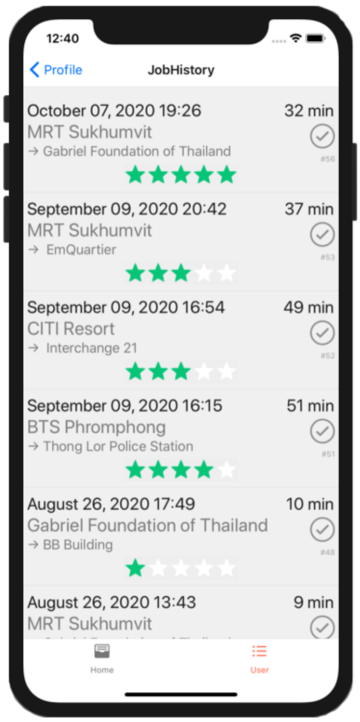

Figure 5.12 Driver app's screenshot

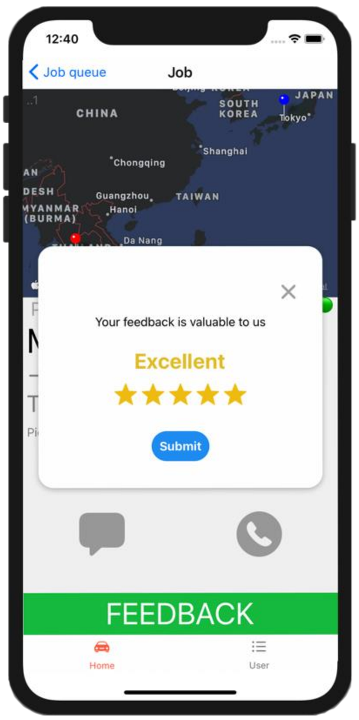

Figure 5.13 Driver app's screenshot

This application was constantly logged real-time locations, accelerations, and all actions between the ride for analysis purposes.

5.4.1.2 User's LINE chatbot

The reservation process was all in the LINE application which users could start the reservation via the menu or just start typing. Then, the chatbot would ask for all necessary information until completed. Then it would suggest walking as alternative to the service since the duration between walking and taking a ride might not be that different during the peak hour in some cases due to traffic and FOMM availability. After finishing the ride, there would be feedback from both sides for improving the service.

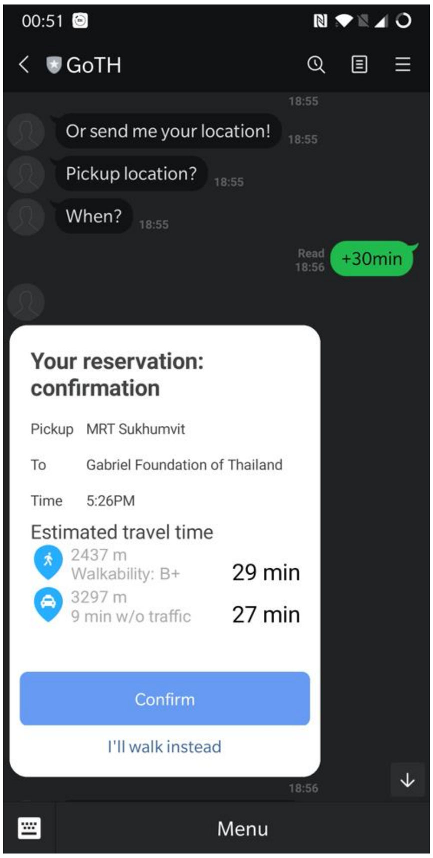

Figure 5.14 Line chatbot which was in the process of making a ride reservation

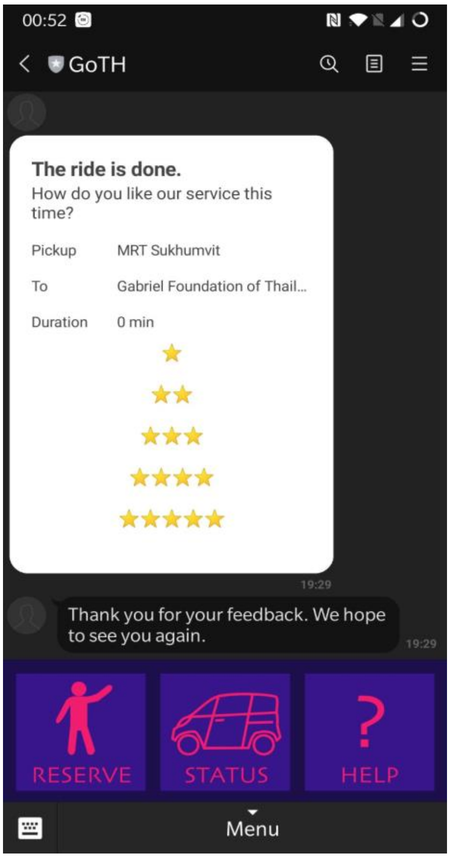

Figure 5.15 Line chatbot – Rich menu that had shortcuts for easy access

5.4.1.3 Updates

Although the original plan, May 2020, needed to postpone due to the COVID-19 pandemic, Thailand started the country lockdown in April 2020. It was not certain yet when this will be over. Nonetheless, everything for the experiment was prepared and ready for the first opportunity.

5.5 References

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CHAPTER 6: DISCUSSIONS AND CONCLUSIONS

6.1 Overview of the study

6.1.1 MaaS experiment

There were two distinct parts of the MaaS experiment since this study was to develop and conduct the experiment. On the development part, MaaS, which obviously relied on data from several sources, including transport providers, depended much on collaboration. In transport operators' fresh eyes, which had no clue of what MaaS really was, it was an offensively overtaking the business. Thus, the collaboration needed to be a languid pace and do the balancing act between what MaaS required from them and what they could take advantage of from MaaS. Since this study was an academic project, the leverage on the business was next to negligible. Although the providers consequently did not see this as any threat, most of them did not want to invest any time and resources as well. I personally did not see this would happen easily in the developing country where research collaboration tended not to exist as they saw no value would come out at the end, which was partly true in their point of view. However, most of the successful collaborations in this study were working with a new company with younger managers because they opened to talk and negotiate what they could get in return, such as teaching them some pieces of knowledge that they definitely needed. For example, two bus providers were willing to collaborate after they came to realize that the fundamental component of MaaS was a trip planner, which required GTFS feed to run. That feed was not only helpful to this study but also useful for other stuffs like gaining more visibility when publishing their GTFS feed to Google Maps. Once they got past their benefits, they then had a will to join the experiment eagerly.

Due to the nature of an academic project, it was difficult because it never required to have a polished or 100% finished product to get the result for analysis, but on the software development side, there always was something more to fix, to add, or to improve as many might see as never-ending development cycle. For something like MaaS, it was not a small-scale application. Most of the development time was meeting/cooperating time with other parties. Moreover, it was harsh to see those left hanging after finishing with the academic side with all the successful collaborations. The question in at least my point of view was, "if feature A had implemented in time, how would it affect the result?"

According to the MaaS experiment in Phuket, the result showed a positive effect on the information provided in the application. People's travel behavior changes were influenced by that information. It was great to understand that walkability could be a vital key factor in the decision of whether to use a private vehicle or take transit. On the other hand, Safety, which the result showed that the app could raise some awareness, had yet to show a significate influence on the people to switch to public transportation. One of many reasons could be the motorcycle, which was the primary mean of transport in Phuket, was too convenient and took much less time from door-to-door comparing to long headway as far as Phuket's transit was concerned. Until the transit improved the service quality, the motorcycle was likely still the first choice for many people.

While improving transit might beyond the scope of this study, providing an important reason for people to use application more such as improving usability like Thai interface, or introducing a ticket or a bundle offer system that would either give users more incentive or comfort might be able to help sway some people from taking their private vehicles.

6.1.2 Safety and walkability indexes

This study proposed the methodology to build and indicators to see how safe and walkable the area was, fortunately, after having the experiment using this concept. There were some thoughts and feedback to improve them, as well. First, with the methodology formulating the safety index, it could be said that the study area was perfect because there was enough information, including accidents and traffic volume. However, in practice, not every road had traffic volume data, not to mention that the dataset in the study was the volume by vehicle type, not aggregated one, which made the index in this study very accurate by design. The question was how to make it better or comparable with less of the data. Then this could be used anywhere without any restriction since this index proved to be useful and did make a difference to gain people's awareness. While there was no feedback or suggestion on the safety one, the walkability was totally different. Walkability was a product of four factors combined, which were transit connectivity, surrounding, comfort, and safety. These values reflected a considering as a good level according to multiple studies. Nonetheless, walking was much more personal or subjective than other road activities. For example, although driving at 100kmph might sound like fast for some people, some did not feel the same. Yet everyone could agree on one thing that at 100kmph, the danger was real, and if that happened, it would be no less than severe. With the walk, things were different. There was no danger involved, and everything was purely to each own. Short or long walk, slow or fast pace, these were all possible without any consequences. That was not all. An equally-weighted average of four factors meant that all four factors were equally important, but different people surely did have their own preferences. Comfort might be more important than safety for some, while it might be the other way around for another. There was no easy way to please or satisfy everyone with the current methods. As a result, some people would likely see the possibility to adjust the relative importance of each factor and also tweak the threshold for each attribute.

6.1.3 Last-mile mobility

From the finding in the influential factors toward decisions to walk, it was interesting to see that in Bangkok, people that owned cars almost definitely would drive. However, there was a possibility that they might not choose to drive if they find that they had an alternative which could save time, and this applied to every single one from the low-, middle-, to high-income. Fortunately, this result indicated that there was a good chance that in the future, people would drive much less due to the availability of a rapid transit system, which currently was expanding at the fastest rate ever in Bangkok. According to the current plan, the whole system would be complete in 2029 with 540km of the track as opposed to the current 154km in length. By that time, the situation might be much better already. Although there were many unknown factors, it surely did look better than it was in the past. Under the current circumstance, time was still a factor that forced the majority of people in Bangkok, without short access to train, to drive inevitably since there would be no time saving by taking a bus comparing to a private vehicle because time was one of the limits or feasibility in the hierarchy of walking needs. The differences between each income group were all in urban forms. Low- and middle-income groups sought better accessibility while high-income ones searched for a safer environment. Hopefully, these differences would be clearer once the social experiment with shared smart vehicle (SSV) started since this trial would take place in the center of Bangkok with high availability of rapid transit, which was pretty much like the demonstration of what Bangkok in the next 10 years could be. In this experiment, the first assumption was that time would no longer consider as a burden with the help of SSV, and that would make public transportation as viable as a private vehicle. People should start to take more transit, and then, the decision to walk would be solely according to needs in urban form level and their socioeconomic status.

Regarding the last-mile mobility improvement or the SSV's development, it was close to an ideal condition because it was a controlled environment and a new introduction of SSV. Everything was well prepared, and the agreement to collaborate was established. This began as a research project; there was a plan to continue operating this after collecting enough information for analysis purposes. The situation was totally different and great. However, due to the coronavirus pandemic situation, this social experiment was put on hold for the time being. Hopefully, the situation would get better, and could be able to start the long-waiting experiment soon.

6.2 Recommended for the future researches

Although the MaaS experiment in this study did give a glimpse of its impact, it should have been better if there was a real business model behind it so that the collaboration would have been a lot smoother. Considering the experiment in any developing country, trying to aim for level 3, which was MaaS with a bundle or subscription model, was likely giving a much better response because, in this study, respondents always compared this MaaS to Google Maps, which it would fail due to the development time and resource in the study compared to what Google had put into. However, if the main focal point of MaaS were how to get the most out of the bundle service, it would have changed the anticipation of the app entirely. People were likely not to juxtapose the application to the best alternative like Google Maps could offer; instead, people would focus on the app's offers purely. That might have much more unique feedback to the MaaS trial. In other words, let people expect to see MaaS as the service, not an enhanced trip planner.

If possible, try to collaborate with the local government the earliest. It was likely that some local government units were trying to achieve the same thing, but not enough resources were allocated to a research project. The collaboration would likely help all parties. This study was a bit too late since the Office of Transport and Traffic Policy and Planning (OTP), Thailand, had initiated the trip planner project before our first contact in 2018. They already partner with a public company.

Regarding the walkability index, since this indicator was purely personal, it might be better to build with some flexibility in mind, which would reflect the situation the best for each person.

APPENDIX A

Questionnaire survey detail

Chapter 4 questionnaire survey

Questionnaire

1. Age

   ☐ < 20 ☐ 20-29 ☐ 30-39 ☐ 40+

2. Nationality __________

3. Sex ☐ Male ☐ Female ☐ Unspecified

4. Are you a tourist? ☐ Yes ☐ No

5. What is your primary mode of transport?

   ☐ Private vehicle ☐ Public transportation

6. How much do you spend on your commute weekly?

   ☐ < 200 THB ☐ < 500 THB ☐ 500+ THB

7. How much time do you spend on your daily commute (back & forth) ?

   ☐ < 30 minutes ☐ < 1 hour ☐ 1 hour or more

8. (For tourist) What is your preferred transport mode while travelling here?

   ☐ Rental car ☐ Limousine ☐ Taxi ☐ Bus

9. Do you use a trip planner application (i.e. Apple map or Google map) ?

   ☐ Yes, I use ____________________ ☐ No

10. How often do you use a trip planner application?

    ☐ Everyday ☐ 5 days a week or more ☐ Less than 3 days a week

    ☐ Once in a while ☐ Not at all

11. What would be features you find them beneficial to you?

    (more than 1 answer is possible)

    ☐ To find a direction to destination

    ☐ To compare route direction

    ☐ To compare trip durations between different routes or modes

    ☐ To find or compare trip fares

    ☐ To share trip to others

    ☐ To bookmark places

    ☐ To make a payment via an app

☐ Others, please specify ____

12. Are you interested in mobility-as-a-service (MaaS) application pilot test?

☐ No ☐ Yes, please let us know your email ______________________

<u>After using the app</u>

Please give us your opinion on the app

	Agree	Neutral	Disagree	Not sure
1. This app is easy to use.				
2. This app provide information I can't find from the other ways.				
3. The information of time and cost provided by this app is accurate.				
4. I want to continue use this app.				

If you don't want to continue using this app, please let us know why

____

Please tell us about the experience of using this app.

1. Have you used buses following the information this app provided?

   ☐ Yes, I have. ☐ No, I haven't. ☐ I'm not sure.

2. Have you changed your mind not to use a bus because I found using a bus worse option than using taxi, rental car, car-sharing or something?

   ☐ Yes, I have. ☐ No, I haven't. ☐ I'm not sure.

3. Have you changed the route or the traffic mode because the app provided good trip options.

   ☐ Yes, I have. ☐ No, I haven't. ☐ I'm not sure.

4. Have you thought of safety when you choose the trip option?

   ☐ Yes, I have. ☐ No, I haven't. ☐ I'm not sure.

5. Have you thought of walkability when you choose the trip option?

   ☐ Yes, I have. ☐ No, I haven't. ☐ I'm not sure.

Please give us the advice/suggestion to this app.

____

Are there any information you want get from this app other than travel time, cost, safeness, and walkability?

____

____

The example of the result from the survey
The following data is the first 15 records from the survey. Some questions are removed due to the format on this document.

#	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
1	<20	Thai	Male	No	Transit	<200 THB	< 30 min	
2	<20	Thai	Female	No	Transit	500 THB or more	1 hour or more	rental car
3	<20	Thai	Female	No	Transit	500 THB or more	1 hour or more	rental car
4	<20	Thai	Male	No	Transit	500 THB or more	< 30 min	taxi
5	<20	Thai	Male	Yes	Transit	500 THB or more	< 1 hour	rental car
6	20-29	Thai	Male	Yes	private vehicle	<500 THB	< 30 min	Bus
7	<20	Thai	Female	Yes	Transit	<200 THB	1 hour or more	Bus
8	<20	Thai	Male	Yes	Transit	500 THB or more	< 1 hour	Bus
9	<20	Thai	Male	Yes	Transit	500 THB or more	1 hour or more	Bus
10	<20	Thai	Female	Yes	Transit	<500 THB	1 hour or more	Bus
11	20-29	Thai	Female	No	private vehicle	<200 THB	< 30 min	rental car
12	20-29	Thai	Male	No	private vehicle	<200 THB	< 30 min	Limousine
13	20-29	Thai	Female	Yes	private vehicle	500 THB or more	< 1 hour	taxi
14	30-39	Thai	Male	No	private vehicle	<200 THB	< 30 min	
15	40+	Thai	Female	Yes	private vehicle	500 THB or more	< 1 hour	rental car

#	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17
1	Yes	Google Maps	Once in a while		Agree	Agree	Agree	Agree	
2	Yes	Google Maps	Once in a while		Neutral	Neutral	Neutral	Neutral	
3	Yes	Google Maps	Once in a while		Agree	Agree	Agree	Agree	
4	No	Google Maps	Never		Agree	Agree	Agree	Agree	
5	Yes	Google Maps	< 3 days a week		Agree	Neutral	Neutral	Neutral	
6	Yes	Google Maps	Once in a while		Agree	Agree	Agree	Agree	
7	Yes	Google Maps	Once in a while		Agree	Agree	Agree	Agree	
8	Yes	Google Maps	< 3 days a week		Neutral	Not sure	Not sure	Agree	
9	Yes	Google Maps	Once in a while		Agree	Neutral	Neutral	Neutral	
10	Yes	Google Maps	< 3 days a week		Neutral	Neutral	Agree	Agree	
11	Yes	Google Maps	Once in a while		Neutral	Neutral	Agree	Neutral	
12	Yes	Google Maps	Once in a while		Neutral	Neutral	Neutral	Neutral	
13	Yes	Google Maps	Once in a while		Agree	Neutral	Neutral	Neutral	
14	Yes	Google Maps	< 3 days a week		Agree	Disagree	Not sure	Not sure	
15	Yes	Google Maps	Everyday		Agree	Agree	Agree	Agree	

#	Q18	Q19	Q20	Q21	Q22	Q23	Q24	Q25
1	Yes	Yes	Yes	Yes	Yes			Not interested
2	No	No	Not sure	Not sure	Not sure			Not interested
3	No	Yes	Yes	Yes	Yes			Interested
4	Yes	Yes	Yes	Yes	Yes			Not interested
5	No	Not sure	No	Yes	Yes			Not interested
6	No	Yes	Yes	Yes	Yes			Interested
7	Yes	No	Yes	Yes	Yes			
8	No	No	No	Yes	Yes			Interested
9	No	No	No	Yes	Yes			Not interested
10	Yes	Not sure	Yes	Yes	Yes			
11	No	No	No	No	No			
12	No	No	No	No	No			Not interested
13	No	Yes	No	Yes	Yes			Interested
14	Yes	Yes	Yes	Yes	Yes			Interested
15	No	Yes	No	Yes	Yes			Interested

However, the full result from the survey can be downloaded at the URL as follows.

https://docs.google.com/spreadsheets/d/1TEO0s_22MEXZ6o8-zA07SKPq_CHkzR76v5MP8dAKOvo/edit?usp=sharing

Chapter 5 questionnaire survey

Questionnaire

1. Country of residence

   ☐ Japan ☐ Germany ☐ UK ☐ France ☐ China ☐ Thailand

2. City of residence ______________________________

3. Sex

   ☐ Male ☐ Female

4. Age

   ☐ < 19 years old
   ☐ 20 – 24 years old
   ☐ 25 – 29 years old
   ☐ 30 – 34 years old
   ☐ 35 – 39 years old
   ☐ 40 – 44 years old
   ☐ 45 – 49 years old
   ☐ 50 – 54 years old
   ☐ 60 years old or more

5. Occupation ______________________________

6. Commute time (one-way)

   ☐ < 5 minutes
   ☐ < 10 minutes
   ☐ < 15 minutes
   ☐ < 20 minutes
   ☐ < 25 minutes
   ☐ < 30 minutes
   ☐ < 40 minutes
   ☐ < 50 minutes
   ☐ < 60 minutes
   ☐ < 70 minutes
   ☐ < 80 minutes
   ☐ < 90 minutes
   ☐ < 100 minutes
   ☐ < 110 minutes
   ☐ < 120 minutes
   ☐ > 120 minutes
   ☐ Not applicant

7. Monthly rent or estimated market value in the area if living in your own house

   ____

8. Family monthly income

   ☐ < 6,000 THB
   ☐ 6,000 – 9,999 THB
   ☐ 10,000 – 14,999 THB
   ☐ 15,000 – 19,999 THB
   ☐ 20,000 – 29,999 THB
   ☐ 30,000 – 39,999 THB
   ☐ 40,000 – 49,999 THB
   ☐ 50,000 – 74,999 THB
   ☐ 75,000 – 99,999 THB
   ☐ 100,000 – 149,999 THB
   ☐ 150,000 – 199,999 THB
   ☐ 200,000 THB or more
   ☐ Don’t know / Don’t want to answer

9. Select a choice that suits you best as far as car use is concerned.

   ☐ Own a car
   ☐ Use car sharing
   ☐ Use ride sharing
   ☐ Do not use any of the above

10. Family type
    - ☐ Single
    - ☐ Childless Family
    - ☐ Nuclear family (you are the parent)
    - ☐ Nuclear family (you are the kid)
    - ☐ Extended family
    - ☐ Others

    Nuclear family = traditional families, consist of two parents (usually married or common law) and their children.
    Extended family = families with two or more adults who are related through blood or marriage, usually 3 generations or more.
11. Education
    - ☐ Elementary school
    - ☐ Secondary school
    - ☐ High school
    - ☐ Diploma
    - ☐ Bachelor's degree
    - ☐ Master's or Doctoral degree
    - ☐ Others
12. Housing type
    - ☐ House
    - ☐ Townhouse
    - ☐ Apartment / Condominium
    - ☐ Others
13. Please pick the most common transport mode for each activity.
    Commute
    ☐ Transit ☐ Car ☐ Motorcycle ☐ Walk ☐ Others ☐ N/A
    Daily routine during *weekday* (such as buying grocery)
    ☐ Transit ☐ Car ☐ Motorcycle ☐ Walk ☐ Others ☐ N/A
    Daily routine during *weekend* (excluding leisure activities)
    ☐ Transit ☐ Car ☐ Motorcycle ☐ Walk ☐ Others ☐ N/A
    Remote working (Long distance, approximately 100km away)
    ☐ Transit ☐ Car ☐ Motorcycle ☐ Walk ☐ Others ☐ N/A
    Traveling, Leisure activity (Long distance, approximately 100km away)
    ☐ Transit ☐ Car ☐ Motorcycle ☐ Walk ☐ Others ☐ N/A
14. Please choose your preferred choice out of two scenarios.
    Indicators includes duration, sidewalk width, crowdedness, crosswalk availability, and lighting at night

14.1	*Duration*: 10 minutes on average *Sidewalk*: 2-meter width (fit 3 people) *Crowdedness*: within the eye of the crowd *Crosswalk*: one in 500 meters range *Light*: No lighting at night	*Duration*: 20 minutes on average *Sidewalk*: 0.5-meter width (fit 1 people) *Crowdedness*: No people around *Crosswalk*: one in 100 meters range *Light*: Enough lighting at night
14.2	*Duration*: 10 minutes on average *Sidewalk*: 0.5-meter width (fit 1 people) *Crowdedness*: No people around *Crosswalk*: one in 100 meters range *Light*: Enough lighting at night	*Duration*: 20 minutes on average *Sidewalk*: 2-meter width (fit 3 people) *Crowdedness*: within the eye of the crowd *Crosswalk*: one in 500 meters range *Light*: No lighting at night

14.3	*Duration*: 10 minutes on average *Sidewalk*: 0.5-meter width (fit 1 people) *Crowdedness*: No people around *Crosswalk*: one in 500 meters range *Light*: No lighting at night	*Duration*: 20 minutes on average *Sidewalk*: 2-meter width (fit 3 people) *Crowdedness*: within the eye of the crowd *Crosswalk*: one in 500 meters range *Light*: Enough lighting at night
14.4	*Duration*: 20 minutes on average *Sidewalk*: 2-meter width (fit 3 people) *Crowdedness*: No people around *Crosswalk*: one in 100 meters range *Light*: No lighting at night	*Duration*: 10 minutes on average *Sidewalk*: 0.5-meter width (fit 1 people) *Crowdedness*: within the eye of the crowd *Crosswalk*: one in 500 meters range *Light*: Enough lighting at night
14.5	*Duration*: 20 minutes on average *Sidewalk*: 2-meter width (fit 3 people) *Crowdedness*: No people around *Crosswalk*: one in 500 meters range *Light*: Enough lighting at night	*Duration*: 10 minutes on average *Sidewalk*: 0.5-meter width (fit 1 people) *Crowdedness*: within the eye of the crowd *Crosswalk*: one in 100 meters range *Light*: No lighting at night
14.6	*Duration*: 10 minutes on average *Sidewalk*: 0.5-meter width (fit 1 people) *Crowdedness*: within the eye of the crowd *Crosswalk*: one in 100 meters range *Light*: No lighting at night	*Duration*: 10 minutes on average *Sidewalk*: 2-meter width (fit 3 people) *Crowdedness*: No people around *Crosswalk*: one in 500 meters range *Light*: Enough lighting at night
14.7	*Duration*: 10 minutes on average *Sidewalk*: 2-meter width (fit 3 people) *Crowdedness*: within the eye of the crowd *Crosswalk*: one in 100 meters range *Light*: Enough lighting at night	*Duration*: 20 minutes on average *Sidewalk*: 0.5-meter width (fit 1 people) *Crowdedness*: No people around *Crosswalk*: one in 500 meters range *Light*: No lighting at night
14.8	*Duration*: 10 minutes on average *Sidewalk*: 0.5-meter width (fit 1 people) *Crowdedness*: within the eye of the crowd *Crosswalk*: one in 500 meters range *Light*: Enough lighting at night	*Duration*: 10 minutes on average *Sidewalk*: 2-meter width (fit 3 people) *Crowdedness*: No people around *Crosswalk*: one in 100 meters range *Light*: No lighting at night

15. Please choose your preferred choice out of two scenarios.
    Indicators includes duration, protection, tree, pedestrian amenity, land use variety

15.1	*Duration*: 10 minutes on average *Protection*: Covered walkway *Tree*: some street trees *pedestrian amenity*: Not available *land use variety*: only 5% of the whole length	*Duration*: 20 minutes on average *Protection*: Not available *Tree*: no street tree *pedestrian amenity*: Some available *land use variety*: 50% of the whole length
15.2	*Duration*: 10 minutes on average *Protection: Not available* *Tree*: some street trees *pedestrian amenity*: Some available	*Duration*: 20 minutes on average *Protection*: Covered walkway *Tree*: some street trees *pedestrian amenity*: Not available

	land use variety: around 50% of the whole length	*land use variety*: only 5% of the whole length
15.3	*Duration*: 10 minutes on average *Protection: Not available* *Tree*: no street tree *pedestrian amenity*: Not available *land use variety*: only 5% of the whole length	*Duration*: 20 minutes on average *Protection*: Covered walkway *Tree*: some street trees *pedestrian amenity*: Some available *land use variety*: 50% of the whole length
15.4	*Duration*: 20 minutes on average *Protection*: Covered walkway *Tree*: no street tree *pedestrian amenity*: Some available *land use variety*: only 5% of the whole length	*Duration*: 10 minutes on average *Protection*: Not available *Tree*: some street trees *pedestrian amenity*: Not available *land use variety*: 50% of the whole length
15.5	*Duration*: 20 minutes on average *Protection*: Covered walkway *Tree*: no street tree *pedestrian amenity*: Not available *land use variety*: 50% of the whole length	*Duration*: 10 minutes on average *Protection*: Not available *Tree*: some street trees *pedestrian amenity*: Some available *land use variety*: only 5% of the whole length
15.6	*Duration*: 20 minutes on average *Protection*: Not available *Tree*: some street trees *pedestrian amenity*: Some available *land use variety*: only 5% of the whole length	*Duration*: 10 minutes on average *Protection*: Covered walkway *Tree*: no street tree *pedestrian amenity*: Not available *land use variety*: 50% of the whole length
15.7	*Duration*: 10 minutes on average *Protection*: Covered walkway *Tree*: some street trees *pedestrian amenity*: Some available *land use variety*: 50% of the whole length	*Duration*: 20 minutes on average *Protection*: Not available *Tree*: No street trees *pedestrian amenity*: Not available *land use variety*: only 5% of the whole length
15.8	*Duration*: 20 minutes on average *Protection*: Not available *Tree*: some street trees *pedestrian amenity*: Not available *land use variety*: 50% of the whole length	*Duration*: 10 minutes on average *Protection*: Covered walkway *Tree*: no street tree *pedestrian amenity*: Some available *land use variety*: only 5% of the whole length

The result from the survey

The result format is not suited here. Thus, the full result from the survey can be downloaded at the URL as follows.

https://docs.google.com/spreadsheets/d/1SU-xKPZ5iClUyRJJ2Y32hkNpy7qmE7uvGtTskEGupd4/edit?usp=sharing

APPENDIX B

Glocal MaaS deployment

This document contains all codes using in the experiment and the idea of how to get Glocal MaaS working. While the MaaS architecture is illustrated in Figure 4.4 in Chapter 4, the code repositories are not constructed that way due to the convenience of development in limited time. In other words, the functionality remains the same, yet many components in Figure 4.4 are merged in the same box or a single code repository shown in Figure B.1.

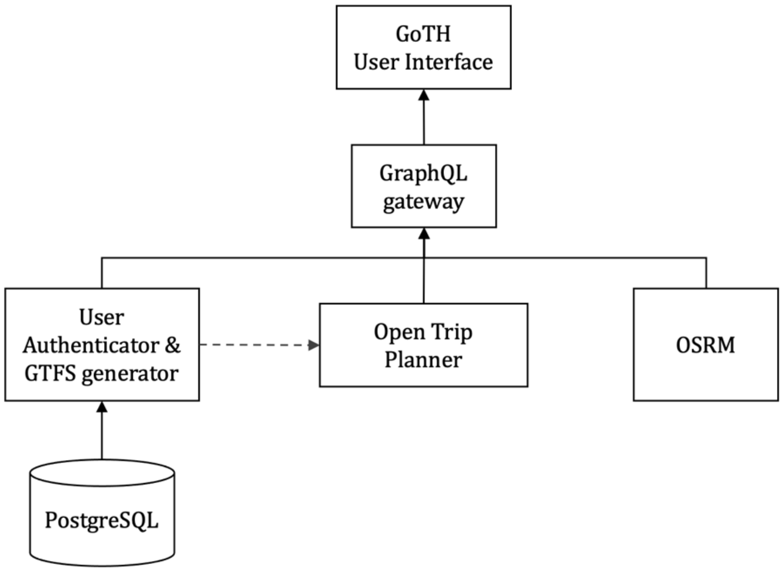

Figure B.1 Glocal MaaS deployment architecture

There are five components with one database to get this Glocal MaaS started.

1. GoTH User interface, https://github.com/goth-glocal-maas/goth-ui
2. GraphQL gateway, https://github.com/goth-glocal-maas/gql-gateway
3. User authenticator & GTFS generator, https://github.com/goth-glocal-maas/gtfs-grunt
4. OpenTripPlanner, https://github.com/goth-glocal-maas/docker-opentripplanner
5. OSRM, https://github.com/goth-glocal-maas/gql-gateway
6. PostgreSQL

GoTH User interface

This is a React (DOM) application. It uses Apollo client for all communications with the backend and MapboxGL for map rendering. This will need to build locally and deploy a build version to production.

GraphQL gateway

This requires both prisma and graphql-gateway to work concurrently to serve all APIs and translate REST API from User authenticator, OpenTripPlanner 1.4 and OSRM to GraphQL format.

User authenticator & GTFS generator

This is a Django 1.11 application which is written in Python 2.7 because transitfeed from Google only supports python 2.7 at that time. This is for manage all transit feeds and have GTFS as output for OpenTripPlanner. However, the management UI for GTFS is on another repository which is https://github.com/goth-glocal-maas/grunt-front which is also a React application

Note: python 2.7 is deprecated since January 2020. It is still functional, but no security patch since then.

OpenTripPlanner

This is the opensource project to combine transit, pedestrian, and car to find suitable itineraries. However, we need to supply our own OpenStreenMap shapefile and other transit information such as GTFS feed which is generated by the previous component.

OSRM

This is another opensource project. Open source routing machine (OSRM) which finds the route between 2 points. In this project, the tweak for a suitable motorcycle route is made to have a desirable output as far as the study area condition is concerned.

PostgreSQL

This is where the data stored. It required to have PostGIS enabled to work properly.

APPENDIX C

SATREPS SSV Mobility Service deployment

This document contains all codes using in the experiment and the idea of how to get SSV mobility service working. In this project, there are five mandatory components to get this running.

1. ssv-driver, https://github.com/goth-glocal-maas/ssv-driver
2. ssv-backbone, https://github.com/goth-glocal-maas/ssv-backbone
3. ssv-chatbot, https://github.com/goth-glocal-maas/ssv-chatbot
4. ssv-osrm, https://github.com/goth-glocal-maas/ssv-osrm
5. ssv-liff, https://github.com/goth-glocal-maas/ssv-liff

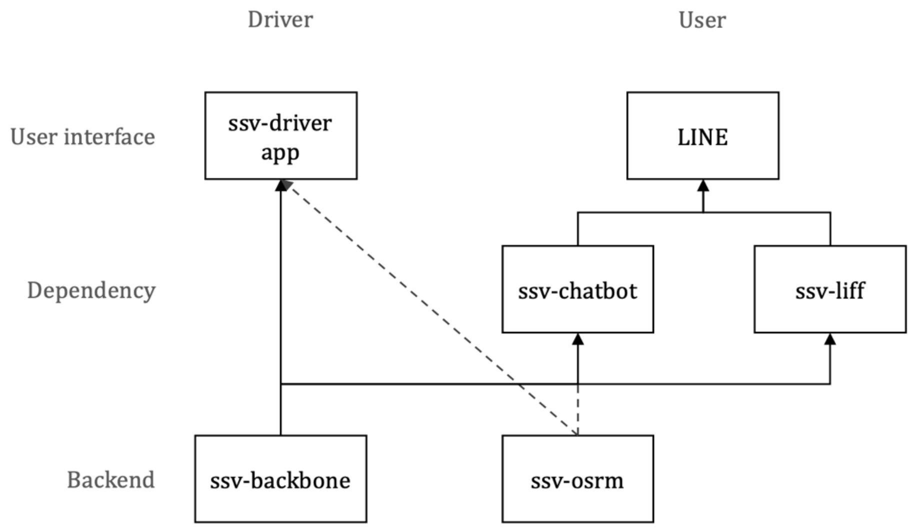

Figure C.1 SSV Mobility service deployment architecture

ssv-driver

This is a native application for the driver. It was built with react-native framework which is in javascript mostly. To build this application, macOS and XCode are required.

ssv-backbone

This is a backend system containing

1. database: PostgreSQL
2. cache: Redis
3. proxy web server: Caddy
4. API server: Hasura
5. Authenticator written in JavaScript

Everything supposes to run with a single command with the help of docker-compose.

```
docker-compose up -d
```

ssv-chatbot

Chatbot is written in go. This uses Redis as cache for faster processing while responding to the user's requests. However, when the manipulation with the reservation needed, everything will be written in PostgreSQL for a long-term storage.

ssv-osrm

ssv-osrm contains two open-source routing machines which are responsible for finding the best route for car and walk in the study area. This also supposes to run in docker-compose for easy management.

ssv-liff

ssv-liff runs insides LINE chat to check more information regarding the reservation. This uses React framework, so it will need to build and deploy separately.

one more component which is ssv-dash, https://github.com/goth-glocal-maas/ssv-dash. This is an optional component which uses to monitor all reservations and progresses in real-time.

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