Final Report

Research Grant 2021

ASIAN TRANSPORTATION RESEARCH SOCIETY

Impact of COVID-19 on Carsharing Usage Behaviors

Saroch Boonsiripant
Peraphan Jittrapirom
Monthira Phamornmongkhonchai
Chuthathip Athan

Final
Report

Impact of COVID-19 on Carsharing Usage Behaviors

ASIAN TRANSPORTATION RESEARCH SOCIETY

902/1 9th Floor, Vasu 1 Building Co., Ltd., Soi Sukhumvit 25 (Daeng Prasert),

Sukhumvit Road, Klongtoey-Nua, Wattana, Bangkok 10110, Thailand

Tel. 02-661-6248 FAX 02-661-6249

http://www.atransociety.com

List of Members

Project Leader

Dr. Saroch Boonsiripant

Kasetsart University, Bangkok, Thailand

Project Members

Dr. Peraphan Jittrapirom

Radboud University, Netherlands

Monthira Phamornmongkhonchai

Kasetsart University, Bangkok, Thailand

Chuthathip Athan

Kasetsart University, Bangkok, Thailand

Advisors

Mr. Silpachai Jarukasemratana

Permanent Secretary at Ministry of Transport, Thailand

Mr. Chamroon Tangpaisalkit

Chairperson and Deputy Permanent Secretary, MOT, Thailand

Dr. Alaksh Phornprapha

Board and Director of Safety Riding Training Center,

A.P. Honda Co., Ltd., Thailand

Table of Contents

CHAPTER 1 INTRODUCTION

1.1 Background

Since its emergence in late 2019, the novel Coronavirus or COVID-19 has rapidly spread beyond nations' borders and caused significant impacts on the livelihoods of people around the world. As of early February 2021, nearly 106 million pandemic cases have been observed worldwide and resulted in 2.33 million mortalities (WHO 2021). The associated socio-economic impacts of this event have also been far-reaching as en-mass losses of employment have continued, heightening the potential large-scale collapse of global economics.

The transport sector is one among several that have been heavily affected by the outbreaks. Governments around the world have imposed travel restrictions and issued recommendations to their citizens to limit their traveling in its efforts to contain the outbreaks. The urban areas are particularly affected, several cities halt or limited the number of public transport services. The perceived risks and fear of infection that may incur during traveling (e.g., in buses and mass transit) also influence travelers to adjust their travel behavior, switching their modes of transport, commuting time, or canceling their planned trips altogether (EIT 2020). Similarly, ridership and usages of shared mobility services, such as carsharing and ride sharing are also adversely affected (FutureBridge 2021).

In the past year, literature that addresses the elucidate how coronavirus and associated mitigation measures may affect urban mobility is growing. For instance, Zhang, Hayashi, and Frank (2021) carried out an international expert survey to collect information on the subjects, including levels of preparedness, measures implemented, and possible long-term strategies. Other studies, such as Wielechowski (2020), Arellana et al (2020) and Guan et al (2020), examined the impacts to countries specific urban transport systems in (e.g., Poland, Columbia, and France). Common findings of these studies are the reduced travel demands in motorized and transit ridership within and across the cities.

In examining specifically how the public transport systems are affected by the outbreak, two studies stood out: 1) a literature review by Gkiotsalitis & Cats (2020) that provided a list of possible impacts to public transport operations and identify possible intervention measures for transport service providers and 2) a study by Jenelius & Cebecauer (2020), which analysis ridership data in Sweden to quantify the impacts to the public transport system. Their findings highlight how public transport ridership in several cities has plummeted due to the outbreaks. Additionally, there is also a trend in increased usage of private vehicles and non-motorized modes. Hensher (2020) also explore possible implications of the outbreak to public transport and Mobility as a Service (MaaS) under possible scenarios in the post-COVID-19 period.

Besides public transport, studies also reported severe impacts to shared mobility services. For instance, FutureBridge (2021) highlights the impacts on ride-hailing and their shared services and purport three possible scenarios for shared mobility, a slow return to normalcy, the collapse of shared mobility, and increase adoption of Autonomous Vehicles. A Delphi survey by Shokouhyar et al (2021) presented a set of challenges and opportunities for shared mobility services in the post-COVID era.

However, there is still a lack of academic studies that use empirical data to elucidate the impacts on shared mobility due to the outbreak. As shared mobility is an integral part of solutions to enhance sustainability and accessibility of the transport system, such a study can be highly beneficial. Transport planning agencies and mobility providers can utilize such evident-based analysis to support their efforts in responding to the changes in users' traveling behavior of shared mobility in this critical period.

This study aims to address this niche by identifying how car sharing users in Bangkok changed their behavior as a result of the outbreaks, what may be the factors (e.g., risk perception, change in work pattern, and governmental advice) that influence these changes. Moreover, it will highlight users' preference on how shared mobility should be provided in this uncertain period. The case study of this project will be a carsharing service in Bangkok city.

1.2 Research Objectives

To achieve the goal of the study, the objectives are five folds:

1) Undertake a literature review on the impacts of the Coronavirus outbreak and its effects on shared mobility with a focus on carsharing services. We look to identify trends in how travelers adjust their travel behavior and the underlying factors, such as attitudinal and preferences that influence their behaviors.

2) Identify changes in the travel behavior of car sharing users in 2020 from the past year through big data analysis and in-person survey.

3) Collect trip activity data from a carsharing operator and develop algorithms to analyze travel behavior.

4) Collect actual trip information (actual trip purpose and activity) through the questionnaire survey to validate the algorithm's results.

5) Formulate recommendations on service operations, measures, and policies using the results of this analysis and the previous outcomes of ATRANS project on carsharing group model building (2020).

The results of this study are expected to provide a better insight into how users alter the ways they use carsharing services during the COVID-19 period. This insight will help decision-makers and service providers to identify possible policies, measures, and service configurations that would enable car sharing and other sharing services to meet the changing needs of travelers.

1.3 Research Framework

This research project consists of two parts including trip chain algorithm and data analysis and recommendations.

For Part 1, there are three tasks to develop trip chain identification algorithm including:

- Task 1: Literature Review
- Task 2: Algorithm Development
- Task 3: Algorithm Validation

For Part 2, there are three tasks to analyze carsharing user behaviors and provide recommendations including:

- Task 4: Behavior Analysis
- Task 5: Policy Development
- Task 6: Reporting

The research framework is illustrated in Figure 1-1.

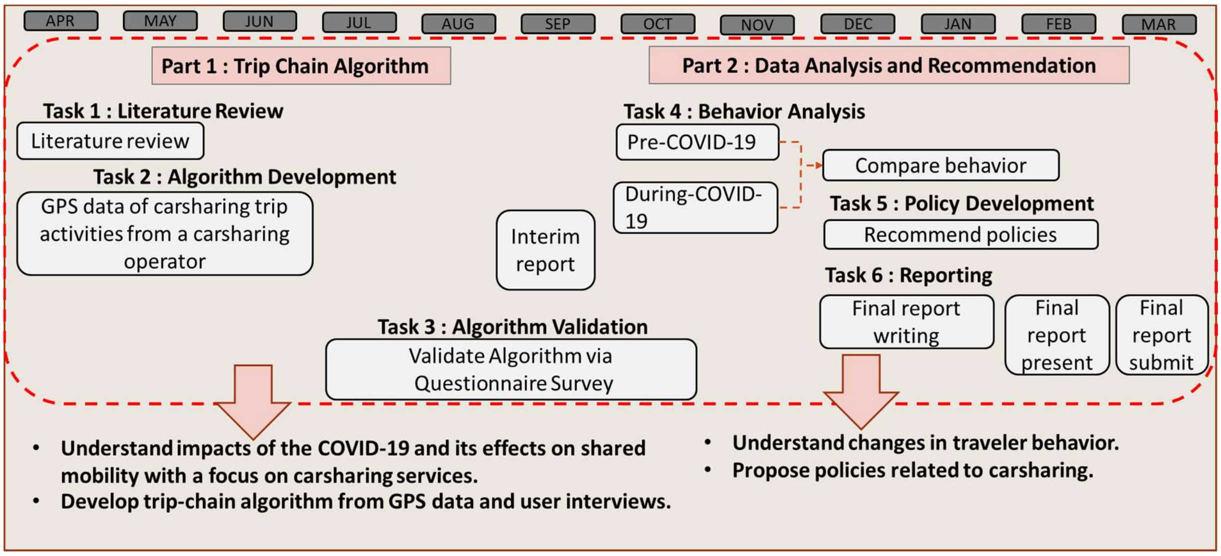


Figure 1-1 Research design framework

This research is composed of 5 key tasks including developing travel pattern identification algorithms, validating the proposed algorithms using survey data, analyzing trip activity data, and finally, developing policies for decision-makers and carsharing operators to cope with new travel patterns affected by COVID-19. The details are as follows:

Task 1: Literature Review

In the first step of this research, we undertook a literature review on the impacts of the Coronavirus outbreak and its effects on the following elements:

- Shared mobility
- Travel behavior, and
- Factors that effect on behaviors

Task 2: Trip Chaining Identification Algorithm Development

To have an understanding of what users rent carsharing for, we developed an algorithm to automatically identify trip destinations and trip chaining from carsharing trip activity data. GPS data attributes used in this study include latitude and longitude, speed, engine status, and timestamp. This information enables us to deduce destination activity based on nearby Point of Interests (POIs), stop time, and stop duration. For example, if one trip stopped at a Restaurant/Cafe at 6 pm for a period of 2 hours, the user likely stopped at this location for a dinner (see Figure 1-2).

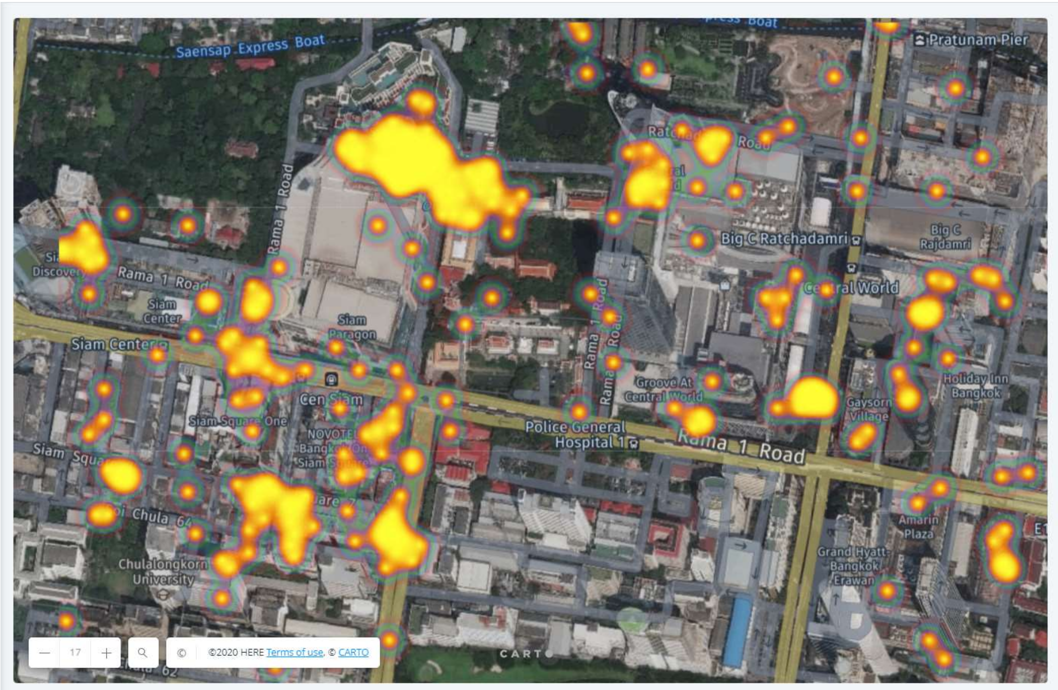


Figure 1-2 Example of GPS data points showing where users stopped for activities

Several tasks are required to determine the trip activity type include:

- Acquiring GPS data of carsharing trip activities from a carsharing operator
- Cleaning GPS data
- Identifying POI/destination type via Google Place APIs
- Identifying activity type (based on POIs and other attributes such as time of day, day of the week, activity duration, etc.), and
- Determining trip chaining of each reservation.

Task 3: Algorithm Validation: Questionnaire Survey

Once the algorithms have been developed from the first step, it is crucial to verify the accuracy of the algorithm. Algorithm Validation based on the actual users. The questionnaires include the following topics:

- Destination type validation: Where did the user go?
- Activity type validation: What did the user do at the destination?
- How COVID-19 affected their general travel behaviors in terms of perception, preference, and behaviors?
- How COVID-19 affected their carsharing usage behaviors in terms of perception, preference, and behaviors?

The user interview was conducted via phone. Our target is to validate 150-200 trips. The actual trip data were compared with the results generated from the algorithm. The algorithm was then fine-tuned based on the interview evidence.

Task 4: Behavior analysis

Once we have fine-tuned the algorithm, the behavior analysis was be conducted to determine the impact of COVID-19 on travel patterns of carsharing users in Bangkok. Two sets of data will be processed:

- Pre-COVID-19 analysis - Trip data in 2019
- During COVID-19 analysis - Trip data in 2020

Next, we compared the changes in characteristics between 2019 and 2020 data, as well as data obtained from the questionnaire.

Task 5: Policy development

In the final step, the research team proposed policies based on the findings in Task 4 and built on the outcomes of the previous project in 2020.

CHAPTER 2 LITERATURE REVIEW

This section presents a literature review on three main topics including carsharing in Bangkok and factors affecting carsharing and mobility usages.

2.1 Shared Mobility

Share mobility is one of sections of sharing economy. Shared modes have the potential to reduce traffic congestion and the need of parking area, giving rise to a decrease of number of vehicles. Shared mobility also solutions have the potential to offer environmental gains and address social aspects.

Shared mobility is the shared use of vehicle such as car, bicycle, scooter, etc. It is innovative transportation strategy that enables users to have short-term access to a mode of transportation when required, and can increase multimodality, reduce vehicle ownership, vehicle miles/kilometers raveled, and cam provide new ways to access goods and services (Machado et al. 2018).

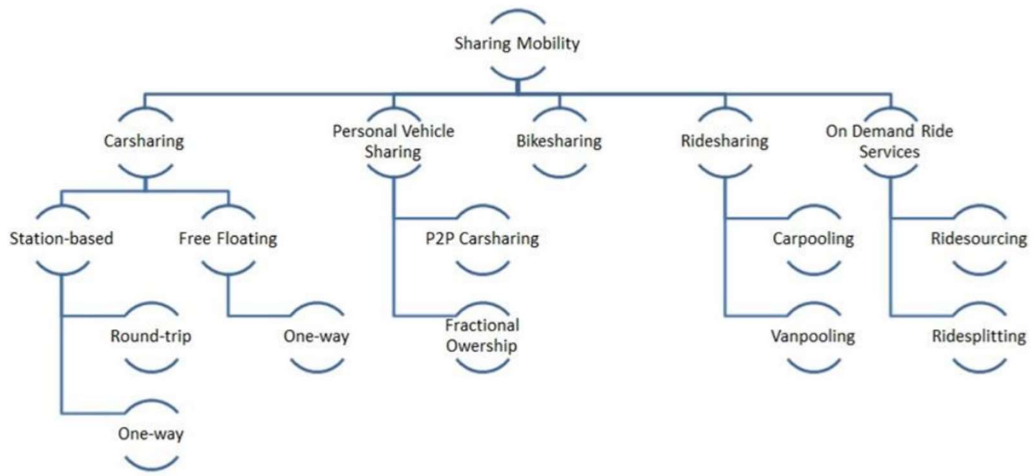


Figure 2-1 Shared mobility and its modalities

2.2 Carsharing in Bangkok

Bangkok is the capital of Thailand and is part of the country's largest urban agglomeration called Bangkok Metropolitan Region (BMR). The city is often cited as an example of a poorly organized and unplanned urban transport system (OTP, 2015). Cars and motorcycles are essential modes of transport for Bangkokians. With more than 6 million cars and nearly 4 million motorcycles registered in Bangkok, around 64% of daily trips are made by these private transport modes (OTP, 2018). The government of Thailand has sought to address the dependency of these private modes through various means, such as constructions of Bangkok's mass rapid transit system, and the reorganization of the city's public bus network. In the recent years, the government has also proposed several sustainable transport measures, such as the promotion of walking and cycling and implementation of car sharing system as solutions to address Bangkok’s transport issues (OTP, 2015).

Car sharing system in Bangkok city is still at an early stage with only a handful of service providers, such as Ha:mo by Toyota, asap GO, and Haupcar. Haupcar is the main carsharing operator in Bangkok. The company has provided station-based carsharing services since 2016 and currently has 140 carsharing stations serving more than 16,000 members. The majority of the stations are located near mass transit stations (33%) or shopping malls (24%) and provide a round-trip service (A-to-A) except for ten stations that also provide a one-way service (A-to-B). The service has more than 300 vehicles with vehicle selection ranging from economy, sub-compact, compact, and SUV. The business model of Haupcar is B2B2C, i.e., it provides carsharing services to general customers using vehicles from traditional car rental and leasing companies. This model is different from other carsharing operators, which typically own and have full control over their vehicle fleet.

2.3 Travel Behaviors

The COVID-19 has changed people’s travel behavior around the world (Irawan et al. 2021). Awad-Núñez et al. (2021) found that number of trips has changed due to the changes in activities before and after COVID-19 outbreak. So, the workers were expected not to return to their job, and mainly work from home. In addition, the number of unemployed increased from 5% to 10% after COVID-19.

Shakibaei et al. (2021) noted that work and shopping trip frequency in many countries reported to be decreased in public transportation trips. Behavioral changes were triggered by both people’s self-regulation and the government measures.

2.4 Factors Affecting Carsharing and Other Shared Mobility Use Behaviors

Several researchers studied on the factors that effects on carsharing use behaviors. Filippo Lerro (2015) studied users' behavior and factors of adoption of carsharing service. Several interesting outcomes are such as:

- Usage of private vehicles: the mostly users that traveled less than 10,000 km/year these used carsharing services.
- Costs: the respondents awareness about fixed costs related the car owning represent, services and the possible associated savings of carsharing may be convinced to forego the purchasing of a car and choose economic alternative transportation modes, including car-sharing.
- Multimodality: the satisfaction towards the available public transport modes that influence on the propensity to carsharing service.

2.5 Big Data for Travel Behavior Analysis

Understanding travel behavior is important for transportation planning. However, traditional survey data is expensive and is prone to errors. With advances in data collection techniques and data analytic approaches, big data is currently generated in relation to volume, variety, and speed, producing new possibilities for applying big data for travel behavior research such as GPS data.

GPS data in enabled devices was used for the availability of urban. It is potential more than traditional data. It contains longitude, latitude, altitude, direction, trip time, and travel speed. These data have been used in several research studies such as GPS trackers to record users' locations and corresponding time, making it possible to infer transportation modes and travel priority (Wang and Hess 2021), analysis of opportunistically collected mobile phone location data to estimate a population's travel demand in terms of origins and destinations of individual trips (Calabrese et al. 2011).

CHAPTER 3 COVID-19 SITUATION IN THAILAND

We collected carsharing usage data from a carsharing operator in Thailand, Haupcar company limited. The dataset was then split into several phases based on the COVID-19 situation in Thailand (Wikipedia 2021) (see Figure 3-1). The four phases can be described as follows:

3.1 Phase 0: Before the COVID-19 outbreak

Phase 0 includes carsharing usage data before the COVID-19 outbreak starting from January 2019 to February 2020.

3.2 Phase 1: First wave of the COVID-19 outbreak

Phase 1 includes carsharing usage data between the first outbreak in Thailand (Lumpinee Boxing Stadium cluster) and right before the second wave outbreak. Phase 1 starts from March 2020 to November 2020.

3.3 Phase 2: Second wave of the COVID-19 outbreak

Phase 2 includes carsharing usage data between the second wave outbreak in Thailand (Samut Sakhon seafood market cluster) and right before the third wave outbreak. Phase 2 starts from December 2020 to March 2021.

3.4 Phase 3: Third wave of the COVID-19 outbreak

Phase 3 includes carsharing usage data from the third outbreak (Thonglor and Klong Prem Central Prison) to the time of this study. Phase 3 starts from March 2021 to mid-June 2021.

Thai government has ordered several measures to control the epidemic situation of COVID-19. The measures in Thailand are shown in Table 3-1 (Wikipedia 2021).

Table 3-1 Summary of COVID-19 pandemic measures in Thailand

Measure	Phase 1									Phase 2				Phase 3			Phase 4			
	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Declared a shutdown of various businesses in Bangkok (only supermarkets, pharmacies, and takeaway Restaurant/Cafes allowed to open inside the shopping malls).																				
Overnight stay restrictions on travelers from risk areas.																				
Declared a state of emergency.																				
The government issued a curfew between 11pm-5am.																				
A travel bans for all foreigners entering Thailand.																				
Many airlines suspended service.																				

Measure	Phase 1									Phase 2				Phase 3			Phase 4			
	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Bangkok's entertainment venues were ordered to be closed.																				
Schools were ordered to be closed.																				
Businesses including gyms were ordered to be closed.																				
Many airlines, trains, boats and bus suspend service.																				
Restaurant/Cafes and food/beverage outlets can provide takeaway services only and must be closed by 20:00 hrs.																				
Bangkok's entertainment venues were ordered to be closed.																				

Measure	Phase 1									Phase 2				Phase 3			Phase 4			
	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Schools were ordered to be closed.																				

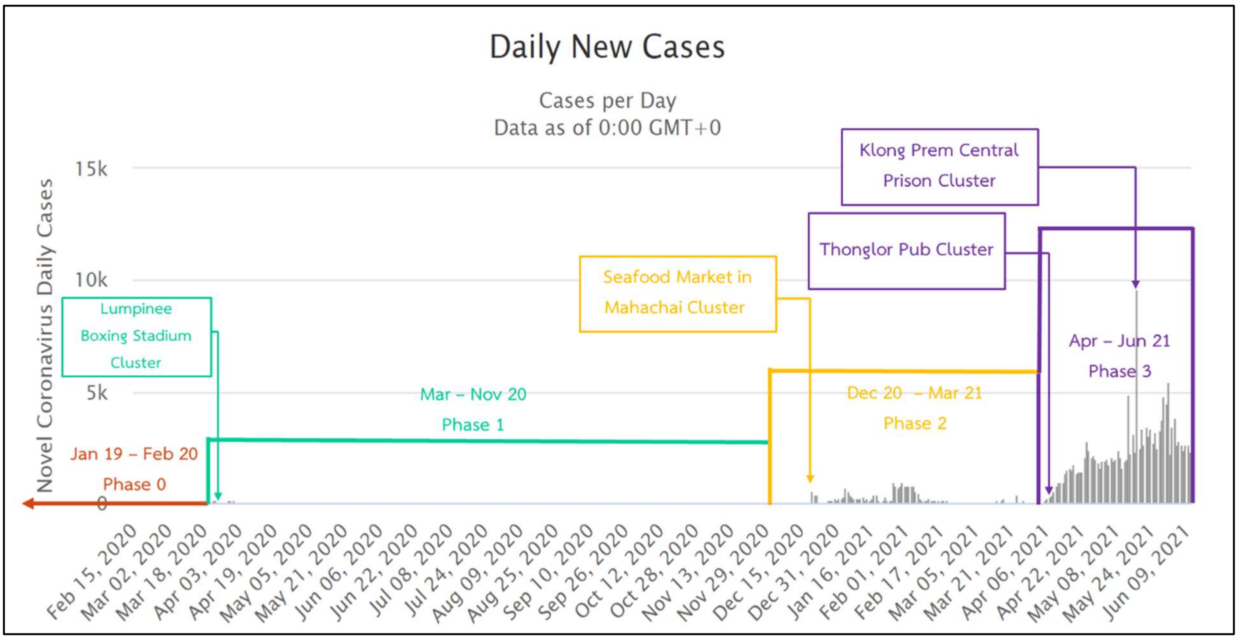


Figure 3-1 Daily cases in Thailand

CHAPTER 4 CARSHARING USAGE DATA

In this section, we described methods for collecting the data. In this study, we collected two types of data including ground truth data and GPS data. The ground truth data was obtained by phone interview with the carsharing users, and the GPS data was obtained from the carsharing operator’s database.

4.1 Ground truth activity data

The ground truth data was conducted through phone interview between August and November 2021. A list of reservations was obtained daily from a carsharing operator in Bangkok, Haupcar Company Limited. The research team validated if the reservations were paid reservations (as opposed to promotional reservations and internal staff reservations) and were hourly and daily reservations (as opposed to monthly and yearly reservations).

4.1.1 Interview questionnaire design

The questionnaire is structured into 3 parts including:

- Socioeconomic Data
- Carsharing Usage Data
- Impact of COVID-19 on the user’s travel behaviors

The questionnaires used during the phone interview attempted to answer the following questions:

- Destination data: Where did the user go?
- Activity data: What did the user do at the destination?
- General travel behavior: How does COVID-19 affect their general travel behaviors in terms of perception, preference, and behaviors?
- Carsharing usage behavior: How does COVID-19 affect their carsharing usage behaviors in terms of perception, preference, and behaviors?

We planned to validate at least 200 trips from the carsharing users. The interview questions are in the Google sheet format so that it can be filled in systematically.

4.1.2 Interview questions

The interview questions are composed of 3 parts including carsharing usage data, questions about impacts of COVID-19, and socioeconomic data. The details of each section are as follows:

4.1.2.1 Part I – Carsharing Usage Data

This part dealt with the usage of carsharing services. 5 questions were asked to understand the trip chain of each user.

Q1: Where do you live?

Q2: How did you access the carsharing station?

- Car
- Motorcycle
- Walk
- Taxi
- Motorcycle taxi
- BTS/MRT/ARL
- Bus/Minibus
- Bicycle
- EV scooter
- Van
- Other

Q3: Where did you go?

- Restaurant/Cafe
- Hotel
- Shopping mall
- Gas station
- Resident
- Transit
- School/University
- Office
- Bank
- Post office
- Hospital/Heath station
- Tourist attraction
- Religious place
- Bus station
- Government agency

Q4: What are you traveling with?

- Carsharing
- Others

Q5: What is the purpose of the trip?

- Back home
- Rest
- Work-Meeting
- Shopping
- Study
- Socialize
- Travel
- Financial transactions
- Delivery
- Errands
- Pick up
- Return the car
- Buy food
- Drinks
- Food pickup/Ordering
- Exercise/Leisure activities
- Others

4.1.2.2 Part II – Impact of COVID-19

In part II, we asked questions regarding the change in travel behavior due to COVID-19 pandemic.

Q6: From scale 1 (lowest) to 5 (highest), how much does the COVID-19 affected your carsharing usage?

Q7: From scale 1 (lowest) to 5 (highest), how concerned are you regarding using carsharing service during the COVID-19?

Q8: How does COVID-19 pandemic affect your carsharing service?

Q8A: For those who answered "increase" - why did you increase your carsharing usage during COVID-19?

- ○ Avoiding public transport
- ○ Carsharing was a lower risk of infection
- ○ Need for travel during outbreak
- ○ Marketing campaign
- ○ Others

Q8B-1: For those who answered “decrease” - why did you decrease your during the COVID-19 outbreak?

- ○ Concern disease in vehicle
- ○ Decrease in income
- ○ Others

Q8B-2: Did you replace carsharing with other modes of transportation?

- ○ Private car
- ○ Private motorcycle
- ○ Taxi
- ○ Bus mini
- ○ BTS/MRT/ARL
- ○ Bicycle
- ○ EV Scooter
- ○ Motorcycle taxi
- ○ Van taxi
- ○ Others

Q8C: For those who answered “stay the same” - why are you using carsharing the same during the COVID-19 outbreak, and how has your travel demand changed?

Q9: In the next few years, if the situation is stabilized with vaccine and effective medical treatments, will you use carsharing service?

- Increase
- Decrease
- Stay the same

Q10: If the spread of COVID-19 continues (more than 10,000 new cases per day), will you continue to use carsharing service?

- Continue to use carsharing service
- Not use carsharing service
- What do you think measures that helps you to have more confidence in used the carsharing service?

4.1.2.3 Part III – Socioeconomic Data

In part III, the participants were asked about their socioeconomic information such as:

- Gender
- Age
- Education level
- High school
- Vocational Certificate
- High Vocational Certificate
- Bachelor's degree
- Master's degree
- Doctor of Philosophy
- Number of cars
- Number of motorcycles
- Occupation
- Student
- Private employee
- Government employee
- Own business
- State enterprise employee
- Income
- Less than 15,000 THB
- 15,000-20,000 THB
- 20,001-25,000 THB
- 25,001-30,000 THB
- 30,001-50,000 THB
- Not specified

4.1.3 Interview process

Interview process consists of three parts including export reservation data, contact carsharing users and record data from interview.

The interview process is illustrated in Figure 4-1.

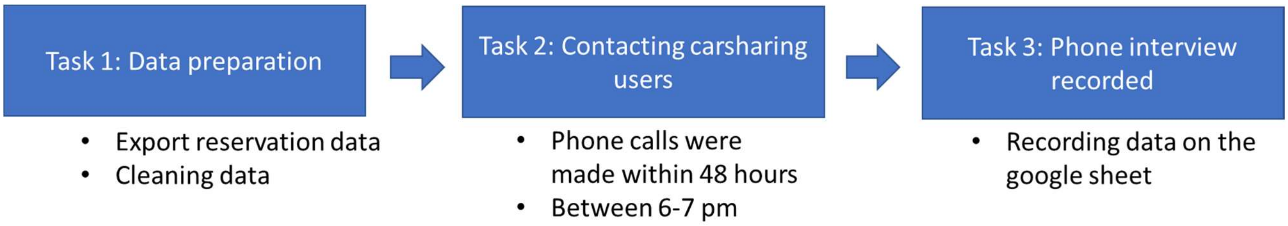


Figure 4-1 Interview process

Task 1: Data preparation

Before contacting carsharing users for phone interview, the research team exported reservation data and verified whether the reservation data including reservation duration and driving distance are available and accurate. Most of the phone calls were made within 48 hours after the reservations ended.

Task 2: Contacting carsharing users

After prepared data for contracting carsharing users. First, our research team contact the carsharing users by telephone and Line chat asking if they are available for an interview. If a carsharing customer is willing to participate in the interview but he/she is not convenient during the time of contact, the interview team would arrange another interview time slot.

At the beginning of the interview, the interview team explained the research objectives and process. Carsharing credit voucher of 300 THB is offered if a carsharing customer decides to participant in the research interview. Each of the users will be asked for permission to use their carsharing usage data in this research before phone interview. Our research team asks questions as listed in section 4.1.2.

Note: The interviews took place between 6 pm and 7 pm to increase the chance that the carsharing users are available for an interview.

Task 3: Phone interview recorded

The data were collected using the Google Sheet. We found that phone calls made during weekends received a lower response rate while Monday and Tuesday yielded higher responses rates. Out of 484 attempts for 4 months, there were 217 (use only one of these numbers) respondents from the phone interview used in the analysis. Note that some of the respondents refused to provide information regarding their personal data such as income, number of vehicles in the household, and education.

4.2 GPS Data

This section describes vehicle activity data collected from GPS-equipped vehicles. We collected carsharing usage data from 4 databases including reservation data, vehicle interval log data, user data and Point-of-Interests (POIs) data. The vehicle activity data were split into 4 phases as described in Chapter 3.

4.2.1 Reservation database

Reservation database contains carsharing reservation information such as reservation number, vehicle ID, customer ID, reservation duration in hours, and start time/stop time of each reservation. The example of reservation data is shown in Table 4-1 and the descriptions of the data attributes are depicted in Table 4-2.

Table 4-1 Example of reservation data

reservationno	userid	reservestarttime	reservestoptime	reservehours	startkm	stopkm	actualhours	chargetotal	actualkm
102219	47379	4/4/2021 9:00	4/4/2021 22:30	13.5	172842.5	173101	13.45	763.00	258.53
123255	114316	4/1/2021 15:30	4/3/2021 17:45	50.25	172633.7	172850	49.00	2981.50	216.3
123543	123547	4/6/2021 7:00	4/6/2021 22:00	15	173092.3	173390	12.90	964.00	297.67
123625	122928	4/14/2021 6:00	4/15/2021 22:00	40	176841.1	177217	28.18	3678.00	375.95
124471	124276	4/17/2021 6:00	4/17/2021 18:00	12	175068	175378	9.70	1460.00	310.03
125259	114055	4/8/2021 10:10	4/9/2021 10:10	24	173381	173724	23.90	1744.80	342.99
125711	124140	4/13/2021 9:40	4/14/2021 22:00	36.33	174187.9	174706	34.42	2608.00	518.09
126249	113086	4/10/2021 3:00	4/10/2021 5:05	2.08	173723	173756	1.60	508.33	32.96
126431	75791	4/11/2021 16:30	4/11/2021 18:30	2	173754.7	173833	1.87	558.00	78.28
126441	124975	4/12/2021 7:00	4/13/2021 7:00	24	173827.1	174200	24.18	1590.00	372.86

Table 4-2 Data descriptions of reservation data

Attributes	Descriptions
reservationno	Reservation number
userid	Carsharing user ID
reservestarttime	Reservation start date and time
reservestoptime	Reservation end date and time
reservehours	Reservation duration (hrs)
startkm	Vehicle odometer at the reservation start time (km)
stopkm	Vehicle odometer at the reservation end time (km)
actualhours	Actual usage duration (hrs)
chargetotal	Rental fee (THB)

Attributes	Descriptions
actualkm	Driving distance (km)

4.2.2 Vehicle interval log database

Vehicle interval log database contains vehicle status and movement information at every 30 seconds such as latitude/longitude, vehicle speed, engine state (on/off), and door lock state (locked/unlocked). The example of vehicle trajectory data is shown in Table 4-3 and its attributes are explained in Table 4-4. Reservation number can be used to link the vehicle trajectory with the reservation information.

Table 4-3 Example of the vehicle trajectory data

reservationno	logtime	latitude	longitude	speed	doorlockstate	enginestate
71867	4/1/2021 0:05:30	13.8623838	100.6651506	0	LOCK	STOP
71867	4/1/2021 1:05:46	13.8623801	100.6651441	0	LOCK	STOP
71867	4/1/2021 8:14:33	13.8604370	100.6655620	28	LOCK	START
71867	4/1/2021 8:15:33	13.8572648	100.6650731	31	LOCK	START
71867	4/1/2021 8:16:34	13.8538730	100.6658663	5	LOCK	START
71867	4/1/2021 8:17:33	13.8534181	100.6662238	0	LOCK	START
115111	6/2/2021 18:31:42	13.6504755	100.5737193	0	UNLOCK	STOP
115111	6/2/2021 18:31:48	13.6504755	100.5737193	0	UNLOCK	STOP
115111	6/2/2021 18:38:00	13.6505355	100.5733908	12	LOCK	START
115111	6/2/2021 18:40:06	13.6477185	100.5726503	22	LOCK	START

Table 4-4 Descriptions of the vehicle trajectory data

Attributes	Descriptions
reservationno	Reservation number
logtime	GPS sampling timestamp (at every 30 seconds)
latitude	Latitude of the vehicle's current position
longitude	Longitude of the vehicle's current position
speed	Driving speed (km/hr)
doorlockstate	Lock state of vehicle (LOCK and UNLOCK)
enginestate	Engine state of vehicle (STOP and START)

4.2.3 User database

User database contains carsharing user information such as user ID, gender, and type of user (general/student/corporate). The example of user data table that used in this study and the data descriptions are shown in Table 4-5 and Table 4-6, respectively.

Table 4-5 Example of the user data

userid	age	usertype	registedtime	foreigner	gender
47379	31	GENERAL	8/31/2019 17:28	0	female
114316	42	GENERAL	1/13/2021 19:22	0	female
123547	37	GENERAL	4/1/2021 14:43	0	female
122928	43	GENERAL	3/28/2021 2:46	0	male
124276	25	GENERAL	4/6/2021 13:18	0	male
114055	19	STUDENT	1/8/2021 1:39	0	male
124140	23	GENERAL	4/5/2021 15:08	0	male
113086	24	GENERAL	12/23/2020 18:58	0	male
75791	30	GENERAL	12/23/2019 13:01	0	male
124975	31	GENERAL	4/10/2021 17:47	0	male
124975	31	GENERAL	4/10/2021 17:47	0	male

Table 4-6 Descriptions of the user data

Attributes	Descriptions
userid	Carsharing user ID
age	Age of user as of June 2021
usertype	User type (GENERAL and STUDENT)
registedtime	Membership registered time
foreigner	Foreiger user (1 = foreigner, 0 = non-foreigner)
gender	Gender of user

4.2.4 Point of interests (POIs) database

POI database contains location names, latitude/longitude, and place type on the map. We obtained POI data from Google Map and Baania Company Limited. The example of POIs data is shown in Table 4-7 and the descriptions of data of the data attributes are described in Table 4-8.

Table 4-7 Example of POIs data

Reservation_ID	STOP_ID	LAT	LON	name_en	category	province_en	distance
112	1	7.883097	98.3981	PHUKET LOCAL TELEVISION STATION	government offices	PHUKET	35.25768
112	1	7.883097	98.3981	HONDA	showroom car service center	PHUKET	10.77422
112	1	7.883097	98.3981	HONDA	showroom car service center	PHUKET	1.914234
112	1	7.883097	98.3981	AIG FINANCE (THAILAND) PLC.	office	PHUKET	89.58833
112	1	7.883097	98.3981	PHONSAK ELECTRIC	office	PHUKET	78.21122
112	1	7.883097	98.3981	ATM KASIKORN BANK	restaurant	PHUKET	75.92867
112	1	7.883097	98.3981	SAMSUNG SERVICE CENTER	office	PHUKET	39.23165
112	1	7.883097	98.3981	ACER PHUKET SERVICE CENTER	office	PHUKET	43.36353
112	1	7.883097	98.3981	SONY	office	PHUKET	59.32078
112	1	7.883097	98.3981	KPP TV STATION	office	PHUKET	61.99416
112	1	7.883097	98.3981	SIT TELECOM PHUKET	office	PHUKET	41.45429
112	1	7.883097	98.3981	S.V.O.A. PLC.	office	PHUKET	94.30669
2303	1	8.108186	98.30866	TOUR OFFICE CENTER	office	PHUKET	94.0695
2303	1	8.108186	98.30866	RESCUE AND FIRE BRIGADE STATION	office	PHUKET	97.40508
2027	1	7.887878	98.2938	7-ELEVEN	convenience store	PHUKET	45.39693
2027	1	7.887878	98.2938	LABAYA	restaurant	PHUKET	28.39235
2027	1	7.887878	98.2938	ANDAMAN ORCHID HOTEL	resident	PHUKET	55.77943
2027	1	7.887878	98.2938	HOLIDAY INN RESORT PHUKET HOTEL	resident	PHUKET	37.57218
2027	1	7.887878	98.2938	ATM BANK OF AYUDHYA	cash machine	PHUKET	45.39693
2027	1	7.887878	98.2938	PHUKET GRAND TROPICANA HOTEL	resident	PHUKET	38.15149
2189	1	7.867046	98.37379	VETERINARY CLINIC	hospital	PHUKET	43.80088
2189	1	7.867046	98.37379	DAO RUNG KANCHANG GARAGE	general place	PHUKET	35.18808
2189	1	7.867046	98.37379	RUNGRUEANG DI CAR ACCESSORIES	general place	PHUKET	21.42999

Table 4-8 Descriptions of the POIs data

Attributes	Descriptions
Reservation_ID	Reservation number
STOP_ID	Number of stop points
LAT	Latitude of stop point
LON	Longitude of stop point
name_en	Name of place within the 100 meters of the stops
province_en	Province of place within the 100 meters of the stops
distance	Distance of place within the 100 meters of the stops from stop point

CHAPTER 5 CARSHARING PHONE INTERVIEW RESULTS

In this chapter, we analyzed data obtained from the carsharing user interview. There are 2 sections in this chapter including socioeconomics of the respondents and carsharing users' attitudes.

5.1 Respondents' socio-demographics

The descriptive statistics for the socio-demographic attributes are summarized in Figure 5-1 to Figure 5-7. The results showed that the majority of the respondents were men (67%), with age less than 30 years old (60%) which represents the carsharing user population in Bangkok. Eighty-eight percent of the respondents had at least a bachelor's degree. Ninety percent of the respondents had at least a personal car or motorcycle. Fifty eight percent of the respondents were engaged in private business and government employees and 24% had incomes ranging from 30,000 to 50,000 THB.

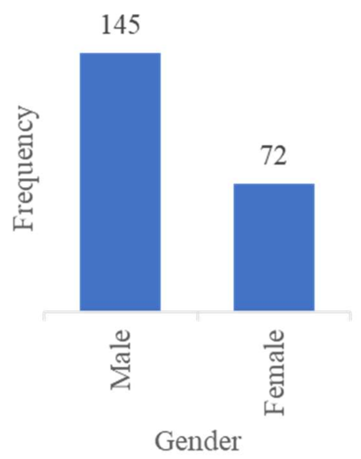


Figure 5-1 Gender distribution of the 217 carsharing users

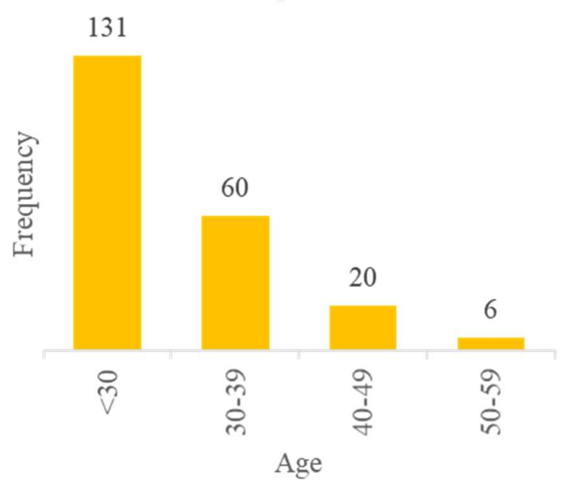


Figure 5-2 Age distribution of the 217 carsharing users

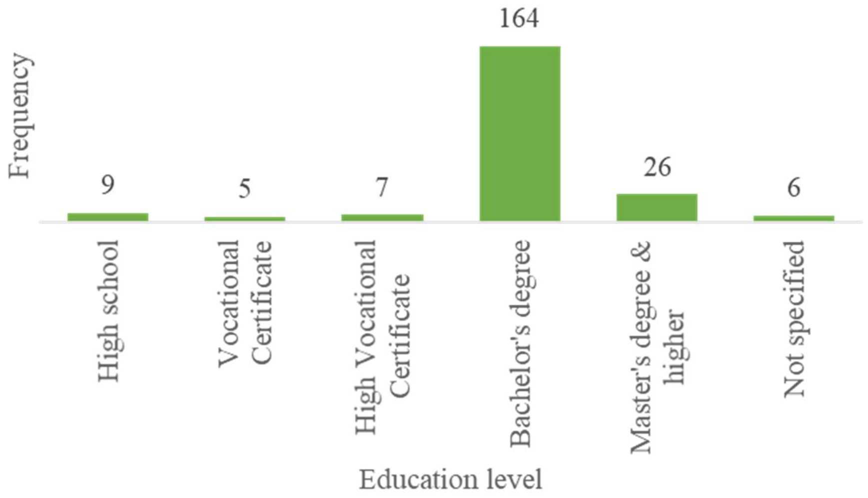


Figure 5-3 Education distribution of the 217 carsharing users

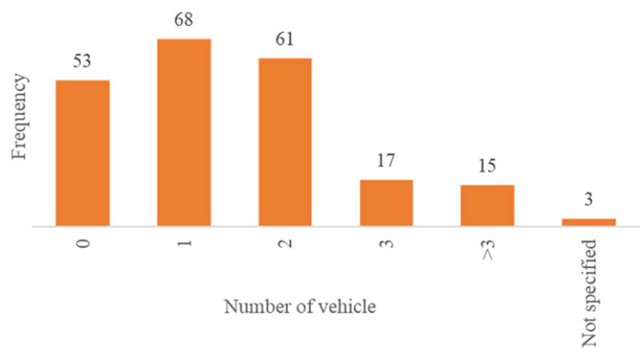


Figure 5-4 Vehicle ownership in a household distribution of the 217 carsharing users

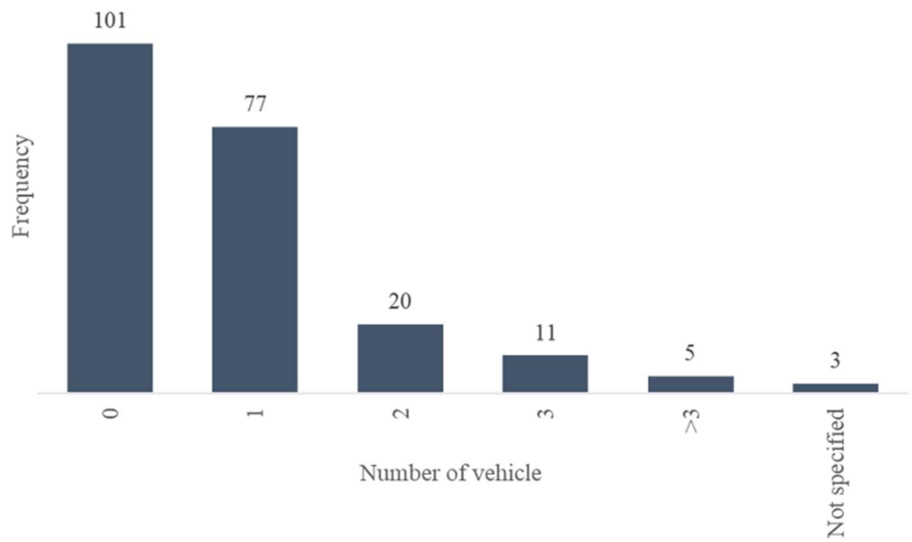


Figure 5-5 Motorcycle ownership per household of the 217 carsharing users

Figure 5-6 Occupations of the 217 carsharing users

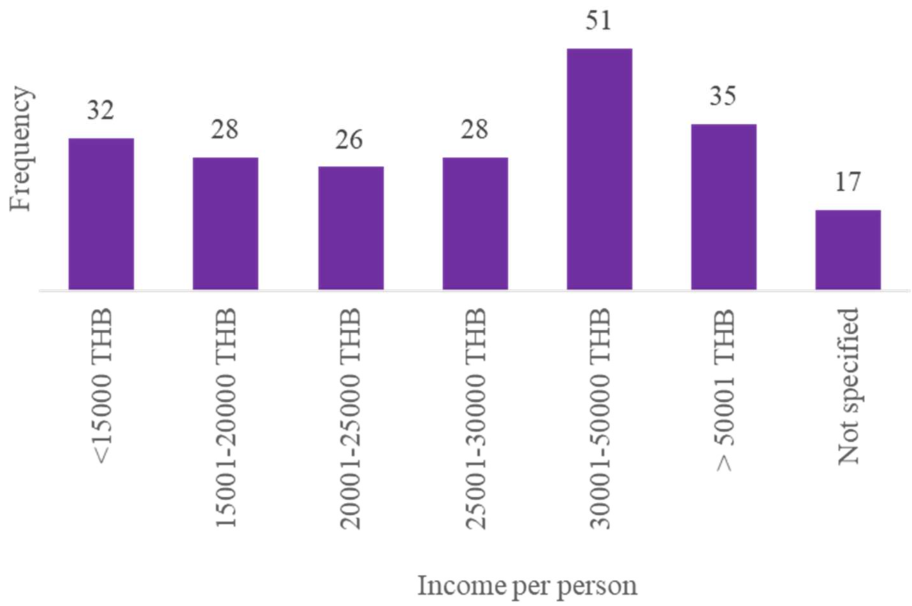


Figure 5-7 Income per person of the 217 carsharing users

5.2 Carsharing users' attitudes towards the COVID-19 situation

Two questions were asked to the 217 carsharing users regarding their attitudes towards the COVID-19 situation. The first question is "How much COVID-19 situation impact your carsharing usage?". We deployed a 5-point Likert scale to measure the magnitude of impact, where the score of 1 denotes "no impact" and the score of 5 denotes "highly impact". During the interview, the word "impact" was described as a demand for carsharing usage. A high impact would mean that the users significantly increase/decrease their carsharing usage. No impact means the users did not change their behavior in using carsharing at all.

The second question is "How concerned are you regarding using carsharing services during the pandemic?" Respondents would also answer on a 5-point Likert scale from 1 for "unconcerned" to 5 for "strongly concerned". During the interview, the word "concerned" was described as the users' concerns regarding the sanitization and cleanliness of the shared vehicles.

The results showed that the respondents, who thought the COVID-19 had no impact on their carsharing usage (no impacts = 1) still had concerns about their cleanliness and safety from infection as shown in Figure 5-8.

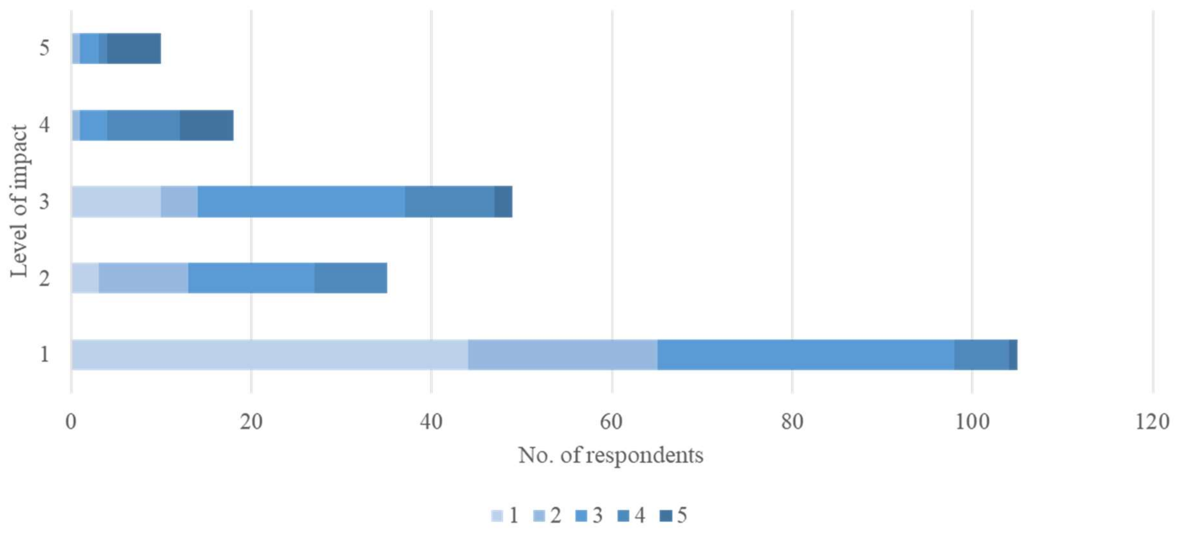


Figure 5-8 Relationship between impact and concern of carsharing usage during COVID-19 pandemic

Next, we used the socio-demographic data to group the impact and concern during the pandemic as shown in Figure 5-9 to Figure 5-13. The results showed that the COVID-19 pandemic equally affected the carsharing usage of male and female users. However, male users were more concerned about vehicle sanitization than female users.

In terms of age, the respondents with ages between 50 and 59 perceived that COVID -19 had affected their carsharing usage more than did other age ranges. They were also more concerned about the risk of infection during the carshare usage than other age ranges.

In terms of education, the respondents who had at least a bachelor's degree thought COVID -19 had affected their carsharing usage and were more concerned about cleanliness and sanitization than other respondents.

In terms of occupation, the business owner respondents thought COVID-19 had affected their carsharing usage than other respondents, but on average, students had the highest concern.

In terms of income, the respondents with high income thought COVID-19 had affected their carsharing usage and were more concerned about cleanliness and sanitization than other respondents.

We also asked for the trip purpose from respondents to determine the relationship between trip purpose and the impact and concern during the pandemic period. The results showed that the respondents who used carsharing during the COVID -19 pandemic seemingly were unaffected from COVID-19 and did not concern or had few concerns about carsharing usage.

We also asked a question regarding the trip purpose of their carsharing usage. Some of the most frequently mentioned answers include shopping, pick up or sending goods (21%), travel/religious activities (20%), meeting/work (16%), and work/errands (7%). Interestingly, the respondents who used carsharing to get vaccinated tended to be more affected by COVID-19 in using carsharing service and are more concerned about the risk of infection than other respondents as shown in Figure 5-14.

We considered carsharing based on interview results. By comparing before the COVID-19 outbreak and during the current COVID-19 outbreak, the changes in the usage of carsharing are shown in Figure 5-15. Thirty-five percent of respondents used carsharing more, the same (46%) and decrease (19%). The reasons why respondents chose carsharing are shown in Figure 5-16. The reason of respondents for the increased use of carsharing was a lower risk of infection (91%), avoiding public transport (89%), marketing campaign (68%), and need for travel (43%). In Figure 5-17, alternative transportation modes that carsharing users consider to switch to were passenger cars (31%), motorcycle (26%), BTS/MRT/ARL (21%), taxi (21%), and motorcycle taxi (3%).

Long-term behavior might affect the future policy. Therefore, we added a question “In the next few years, if the situation is stabilized with vaccine and effective medical treatments, will you use carsharing service? And if the spread of COVID-19 continues (more than 10,000 new cases per day), will you continue to use carsharing service?”. The result showed that 30 percent will use carsharing service to increase if the situation is stabilized with vaccine and effective medical treatments and 93 percent continue to use carsharing service if the spread of COVID-19 continues.

In addition, we collected reservation duration (hours) and driving distance (km) of carsharing usage to compare with the perceived impact and concern during the pandemic period. The result found that the level of concern and the level of impact on carsharing use during the COVID -19 pandemic have irrelevant with the reservation duration and the driving distance as shown in Figure 5-20 and Figure 5-21.

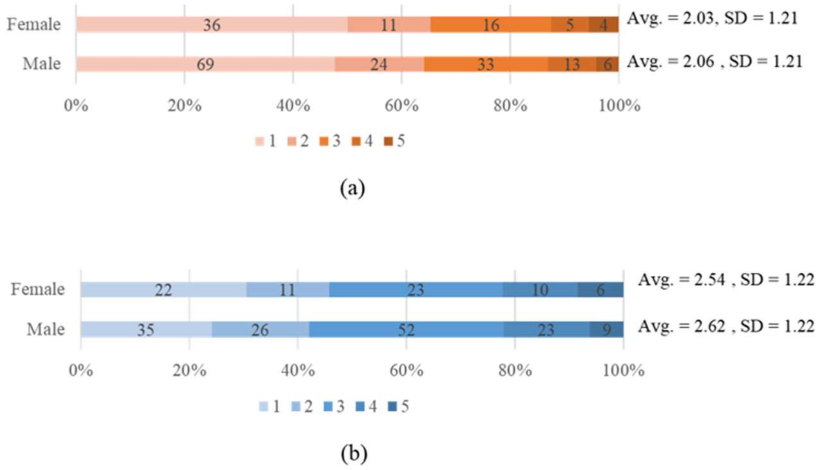


Figure 5-9 Five-point Likert scale of (a) the perceived impact of COVID-19 to respondent's carsharing usage and (b) the level of concerns to COVID-19 during carsharing usage, grouped by gender

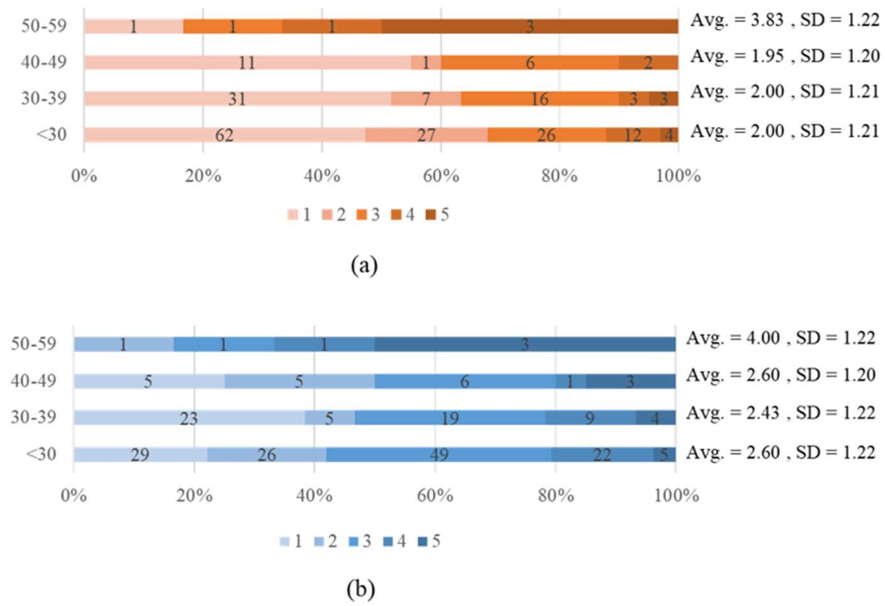


Figure 5-10 Five-point Likert scale of (a) the perceived impact of COVID-19 to respondent's carsharing usage and (b) the level of concerns to COVID-19 during carsharing usage, grouped by age

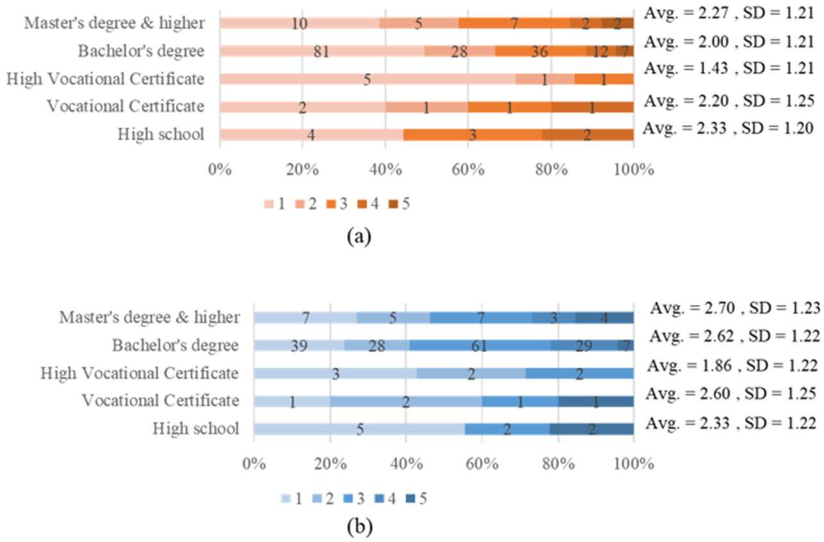


Figure 5-11 Five-point Likert scale of (a) the perceived impact of COVID-19 to respondent's carsharing usage and (b) the level of concerns to COVID-19 during carsharing usage, grouped by education

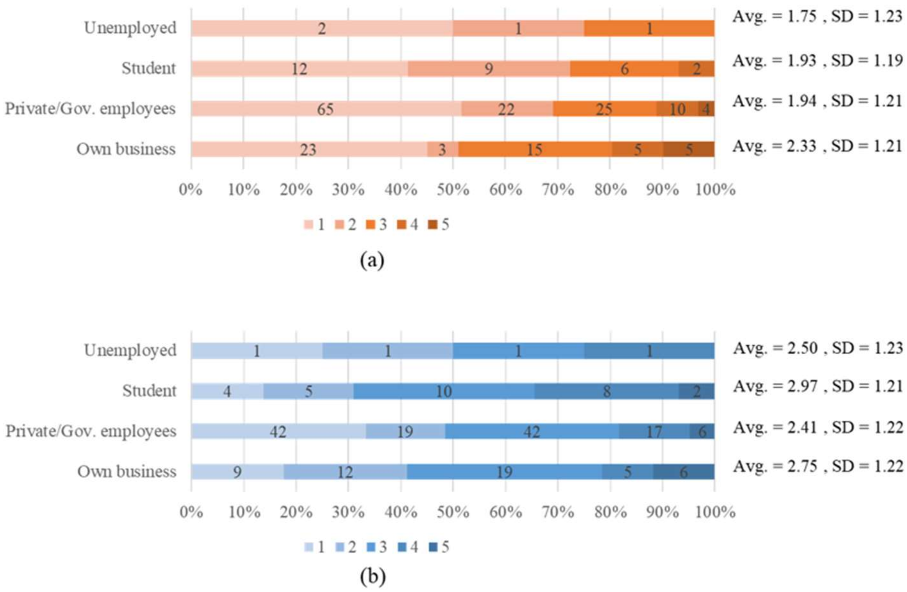


Figure 5-12 Five-point Likert scale of (a) the perceived impact of COVID-19 to respondent's carsharing usage and (b) the level of concerns to COVID-19 during carsharing usage, grouped by occupation

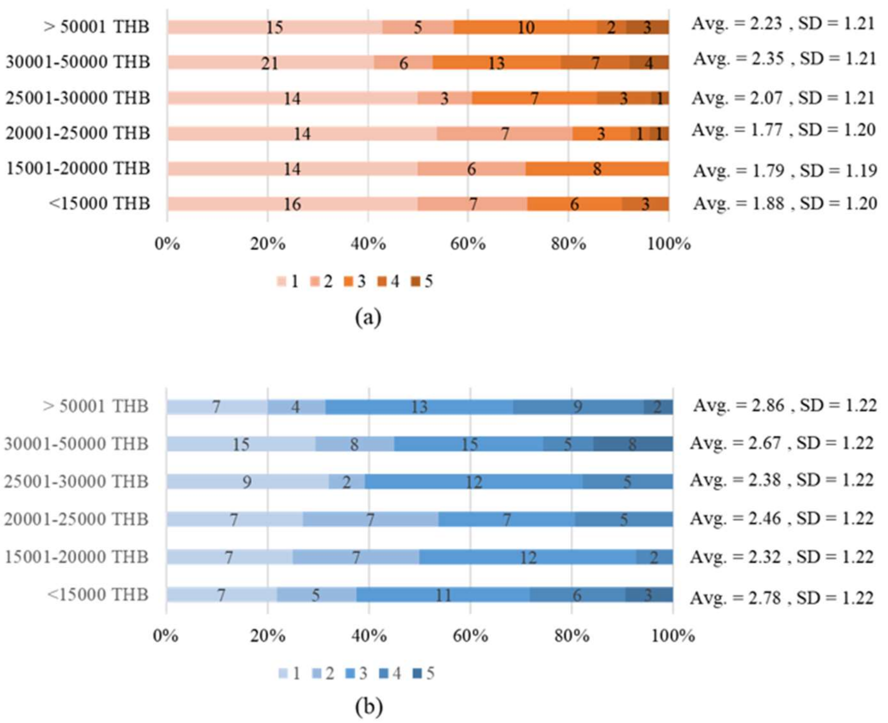


Figure 5-13 Five-point Likert scale of (a) the perceived impact of COVID-19 to respondent's carsharing usage and (b) the level of concerns to COVID-19 during carsharing usage, grouped by income

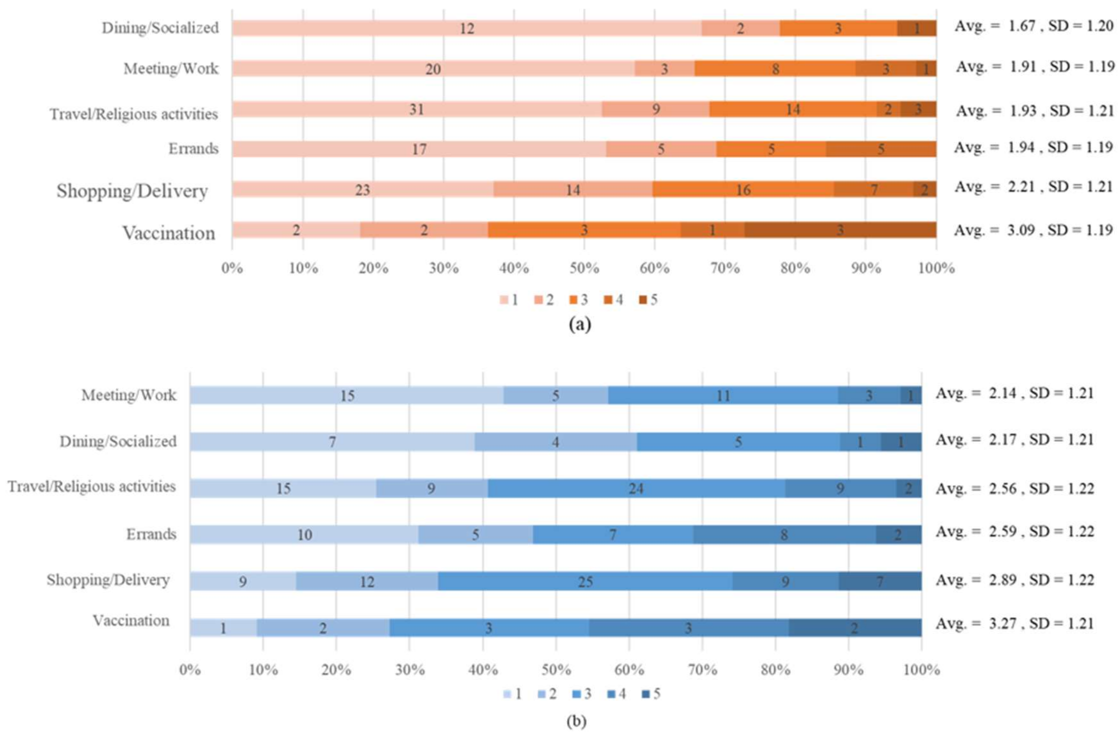


Figure 5-14 Trip purpose and (a) the perceived impact of COVID-19 to respondent's carsharing usage and (b) the level of concerns to COVID-19 during carsharing usage

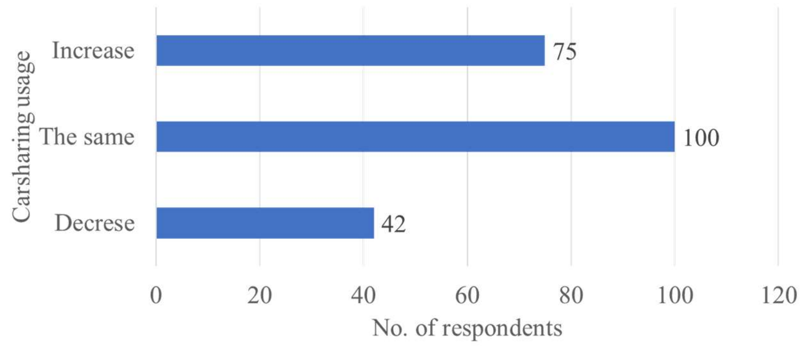


Figure 5-15 Changes in carsharing usage due to COVID-19 situation

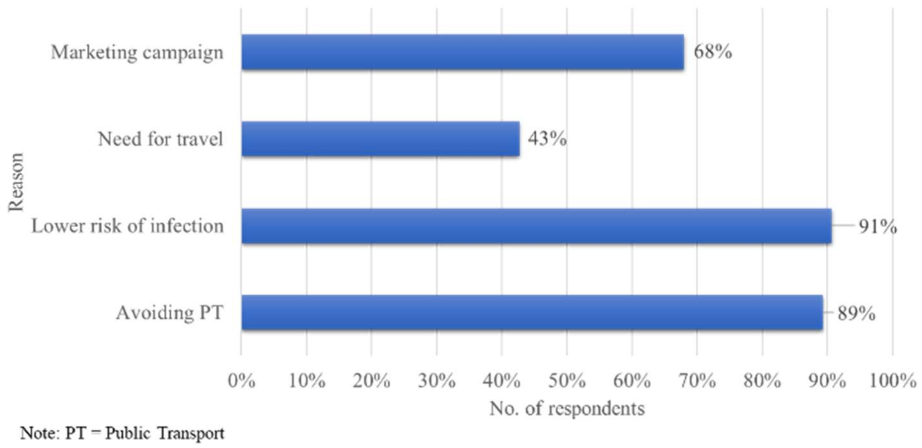


Figure 5-16 Reasons for choosing carsharing service over other transportation modes during COVID-19 pandemic (for those who answer "Increase in carsharing usage")

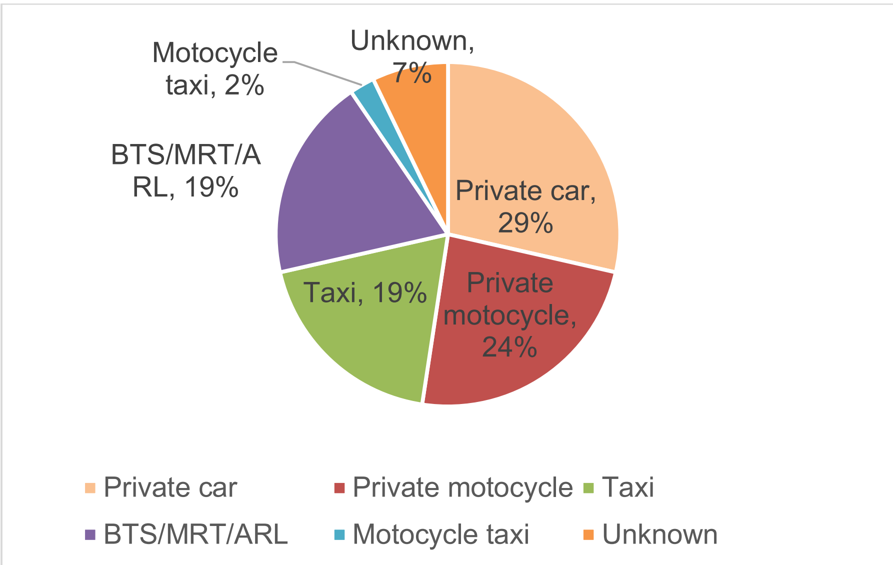


Figure 5-17 Proportion of alternative transportation modes that carsharing users consider

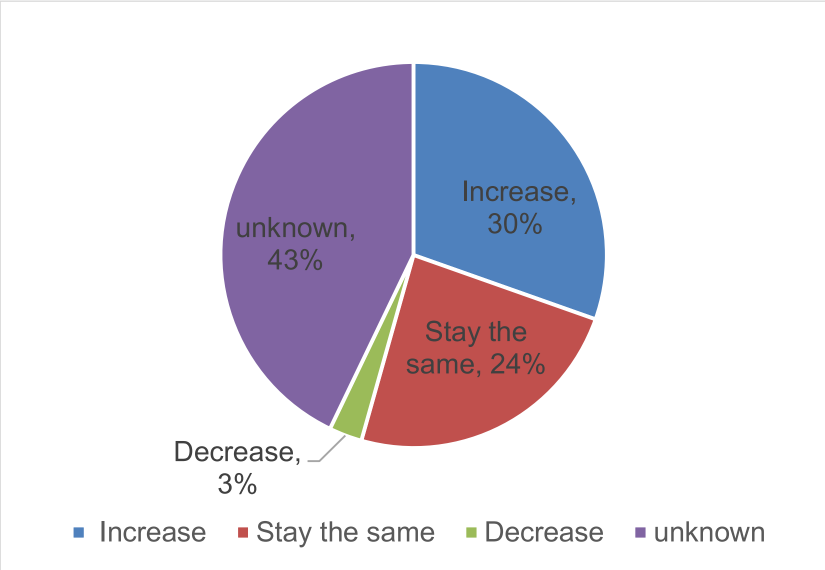


Figure 5-18 Changes in carsharing usage if the situation becomes stable

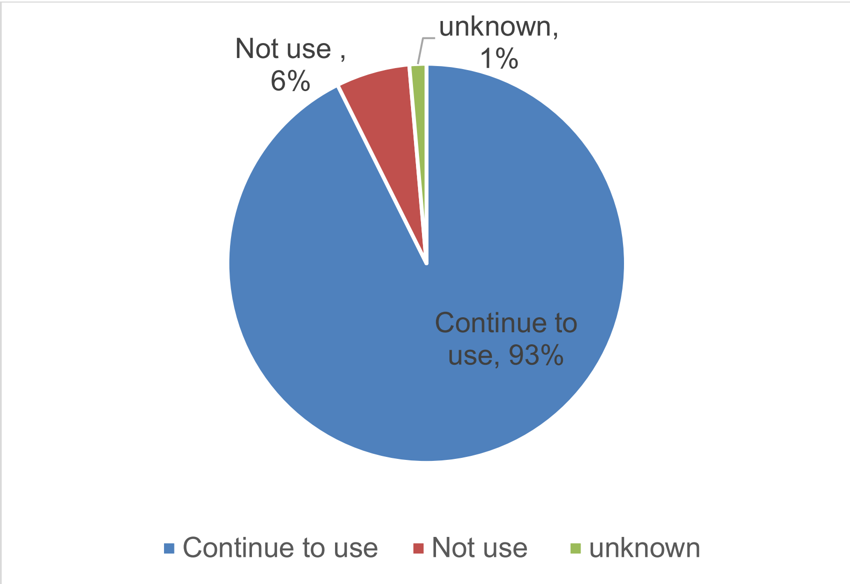


Figure 5-19 Changes in carsharing usage if the pandemic continues

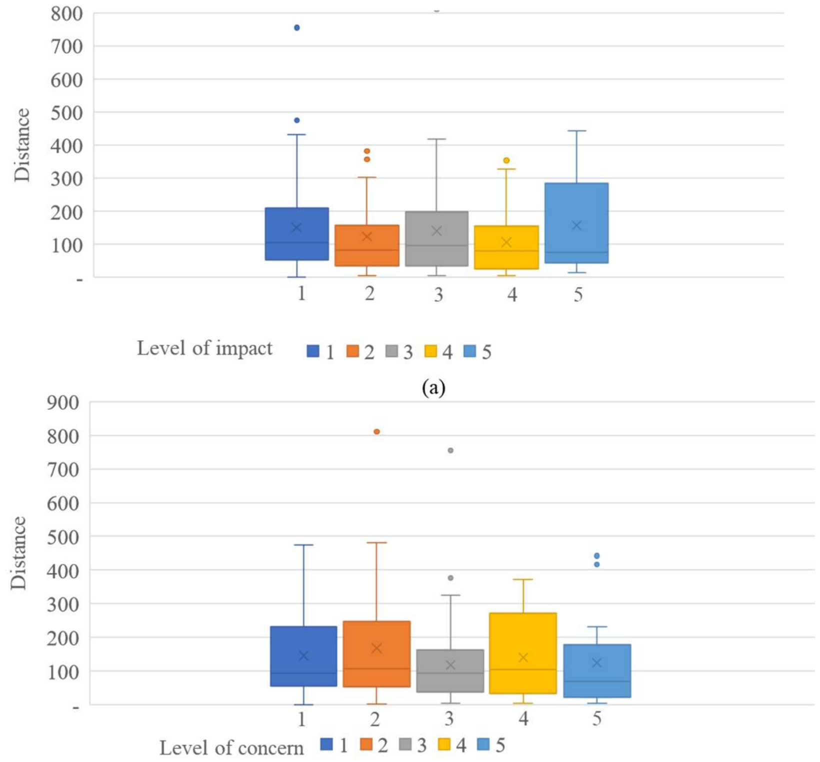
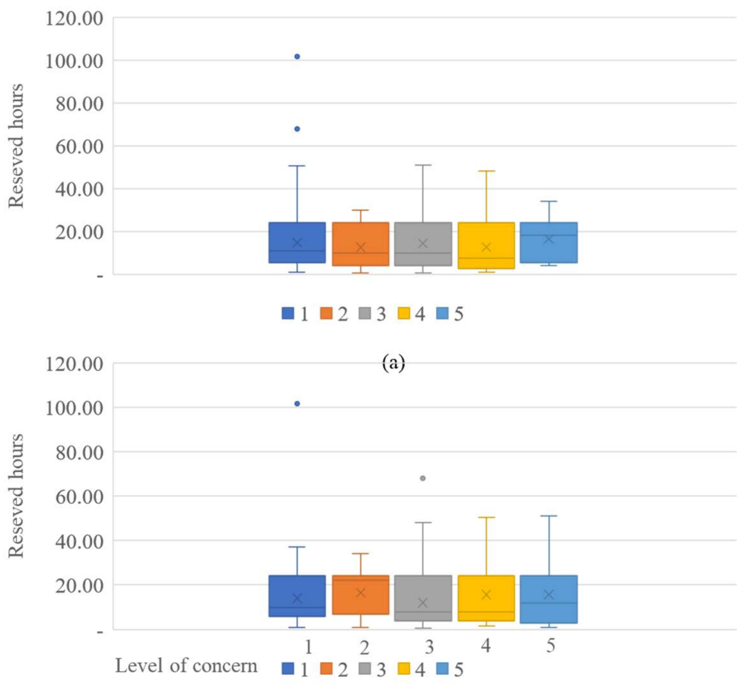


Figure 5-20 Driving distance and (a) perceived impact, and (b) perceived concern



(b)

Figure 5-21 Reservation hours with (a) perceived impact of COVID-19 to respondent's carsharing usage and (b) the level of concerns to COVID-19 during carsharing usage

5.3 New users of carsharing service during COVID-19

In this section, we analyzed the number of new users carsharing service during COVID-19 outbreak. In this analysis, new users are the carsharing users who register after the COVID-19 outbreak, i.e., since March 2020. The results showed that fifty-nine percent (128 users from 217 users) were users that registered during COVID-19 period (see Figure 5-22). Among the 128 new users, 50 respondents (39 percent) reported that they used carsharing more often during the COVID-19. The reasons for the increasing carsharing usage during COVID-19 are grouped into two categories: COVID-related and increase in individual travel demand during COVID-19 as shown in Figure 5-23. Most of the respondents (49 out of 50 persons) reported that their carsharing usage increase due to COVID-19 situation.

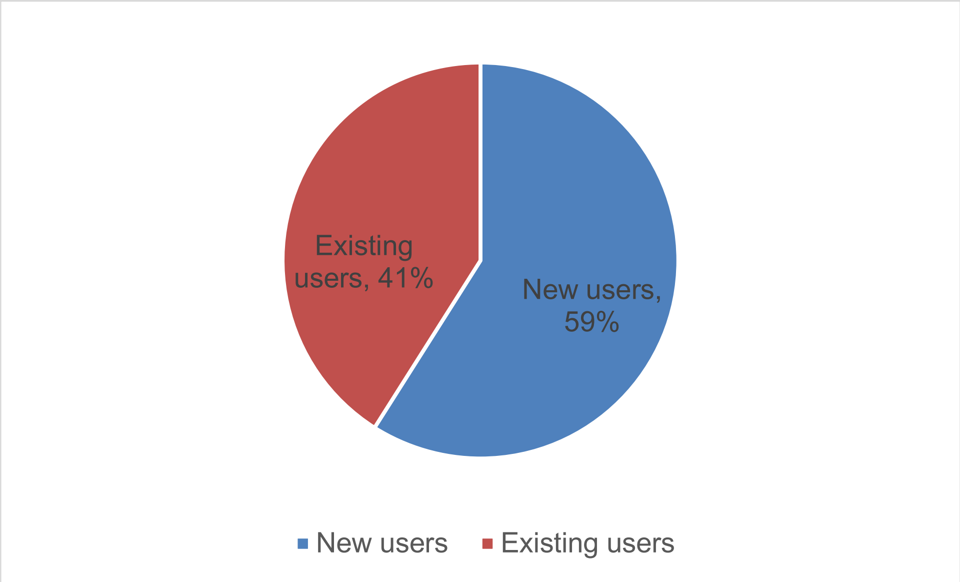


Figure 5-22 Number of new users and existing users

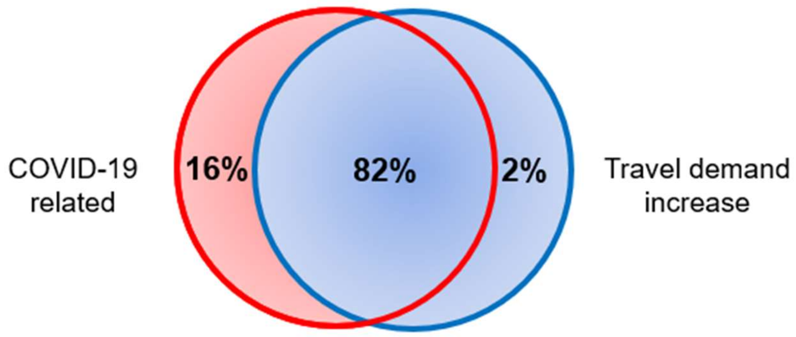


Figure 5-23 Reasons for increasing usage of carsharing during pandemic

CHAPTER 6 ALGORITHM DEVELOPMENT

In this chapter, we developed an algorithm to determine activity types of carsharing users at their destinations based on the trip trajectories collected by an on-board device inside the shared vehicles. The resulting trip activities of the 217 reservations were then compared with the interview results to determine the performance of the algorithm.

6.1 GPS data preparation

The first step is to acquire GPS data of the 217 reservations that we had interviewed in Section 4.1.3. Then, we filtered out some reservations that did not have GPS data for the whole reservations which were caused by the GPS device errors or the customer did not return the vehicle to the designated station by the end time. Finally, there are 210 complete reservations ready for the next step.

6.2 Vehicle stop determination

In this step, we determined whether a car stops at a red-light signal or at a destination. In a normal case, when a car stops at an intersection, the engine would be idling. In contrast, if a car reaches a destination, the engine would normally be turned off.

Additionally, we are interested in two events when the vehicle stops at the destination including:

- **The beginning of the stop** is defined as the first data point when the vehicle changes its state from moving to stopping. Based on this logic, the algorithm would check for the first record that has engine_state = OFF and speed is not greater than 5 km/hr. In this case, the algorithm would assign this record as the beginning of the stop, i.e., vehicle_state = STOP_BEGIN. The beginning of the stop is illustrated as point number 1 in Figure 6-1.

- **The end of the stop** is defined as the first data point when the vehicle changes its state from stopping to moving again. However, some customers turned the engine on and off multiple times at the same destination without moving the vehicles. This results in mistakenly identifying multiple stops at the same location and might lead to a misunderstanding of the carsharing usage. Therefore, the algorithm avoids using the engine_state data and would only consider the distance between the current record and the first location where the vehicle came to stop (i.e., the beginning of a stop). If the distance between the current record and the first stop location is greater than 50 meters, the algorithm would assign the previous record (the last point within the 50-m radius of the first stop location) as the end of the stop, i.e., vehicle_state = STOP_END. The end of the stop is illustrated as point number 7 in Figure 6-1.

Both the beginning of the stop and the end of the stop can be used to calculate two key parameters as follows:

- **Stop duration** is defined as the time spent at a destination, which is the time difference between the beginning of the stop and the end of the stop, i.e., t(STOP_END)-t(STOP_BEGIN)
- **Stop number** is defined as the sequential number of the stops made by a carsharing user during a single reservation.

Note that another potential attribute called door lock state (locked/unlocked) was initially included in the algorithm. However, due to the compatibility between the door lock sensor and the vehicle electronic control unit (ECU), the door lock sensor data is not reliable enough to distinguish the driver's behavior, and therefore, this attribute was dropped from the analysis.

Based on the 210 reservations, we obtained the total of 961 stops made during the reservations.

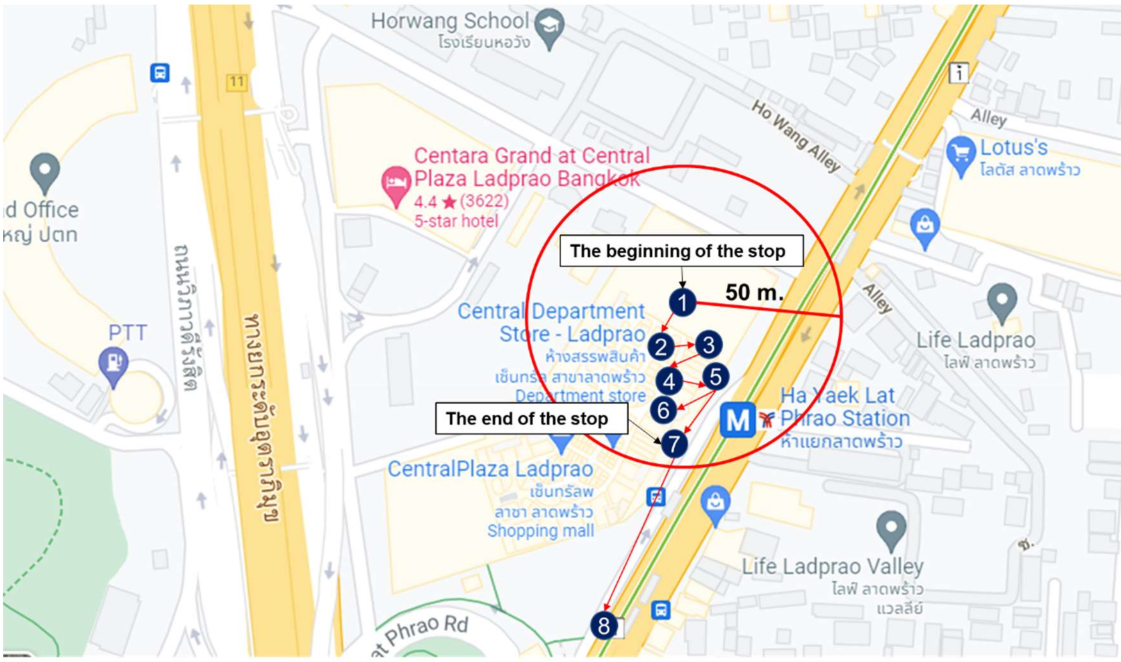


Figure 6-1 GPS data with the beginning of the stop and the end of the stop

6.3 Point of interests (POIs) matching

After we determined vehicle stops, we determined the possible destinations near the stop locations by automatically matching with two POIs databases (see Figure 6-2) including Baania database and eyeballing. The eyeballing database consists of 100 POI locations based on the top 100 highest frequency of stops in Bangkok using eyeballing method, i.e., manually looking at the google map to determine the location type.

Baania database has 71 POI categories as follows:

POIs categories from Baania	
A	**M**
Airport	Market
Apartment	Military
ATM	**N**
Auto Dealer	National Park
B	**O**
Bank	Office
Beach	Outdoor
Border Crossing	**P**
Bridge	Park
Building	Parking
Bus Terminal	Pharmacy
C	Pier
Cafe	Police Station
Cinema	Post Office
Clinic	**R**
Company	Railway Station
Condominium	Rail Transit
D	Resident
Department Store	Resort
Dormitories	Restaurant
E	River
Embassy	**S**
Entertainment	School
Event Venue	Shopping
F	Shopping mall
Factory	Shopping Mall
Food Manufacturing Supply	Sport
G	Subway Station
Garage Shop	Supermarket
Gas Station	**T**
Gas/Toilet	Temple
Government Agency	Toll road rest stop
Grocery	Tourist Attraction
H	Train Station
Health	Truck Terminal
Health Station	Tunnel
Historical Landmark	**U**
Hospital	University
Hotel	Utility Office

POIs categories from Baania	
Hotel/Apartment	**W**
I	Worship
Industry	**Z**
Intersection	Zoo
L	
Library	
Lodging	

Next, we determine an effective distance from the parked vehicle (the beginning of the stop) to the nearby POIs. Based on previous studies, the relationship between access mode shares and distance to a transit station. As can be seen in, the walking share decreases with distance, and it drops sharply beyond the distance of 0.4 kilometers (see Figure 6-3) (Chalermpong and Wibowo 2007). The walkable distance to the mass transit stations in Bangkok is from 100 to 300 meters (Vinitpittayakul and Siridhara 2018). Therefore, we chose 100 meters as the maximum radius from the parked vehicle to the possible POIs queried from the two databases and example of POI query are shown in Table 6-1.

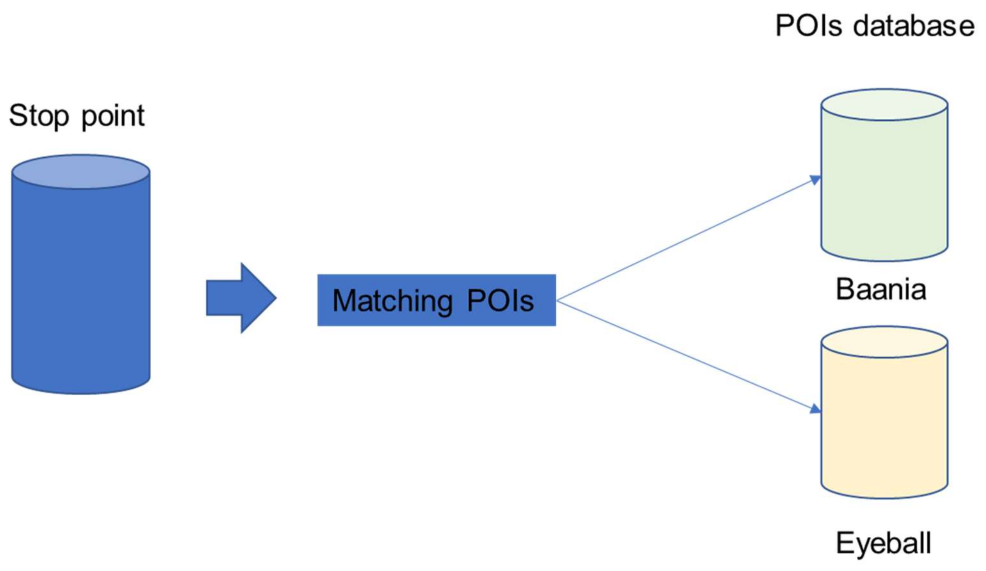


Figure 6-2 Point of interests (POIs) databases for matching with stop locations

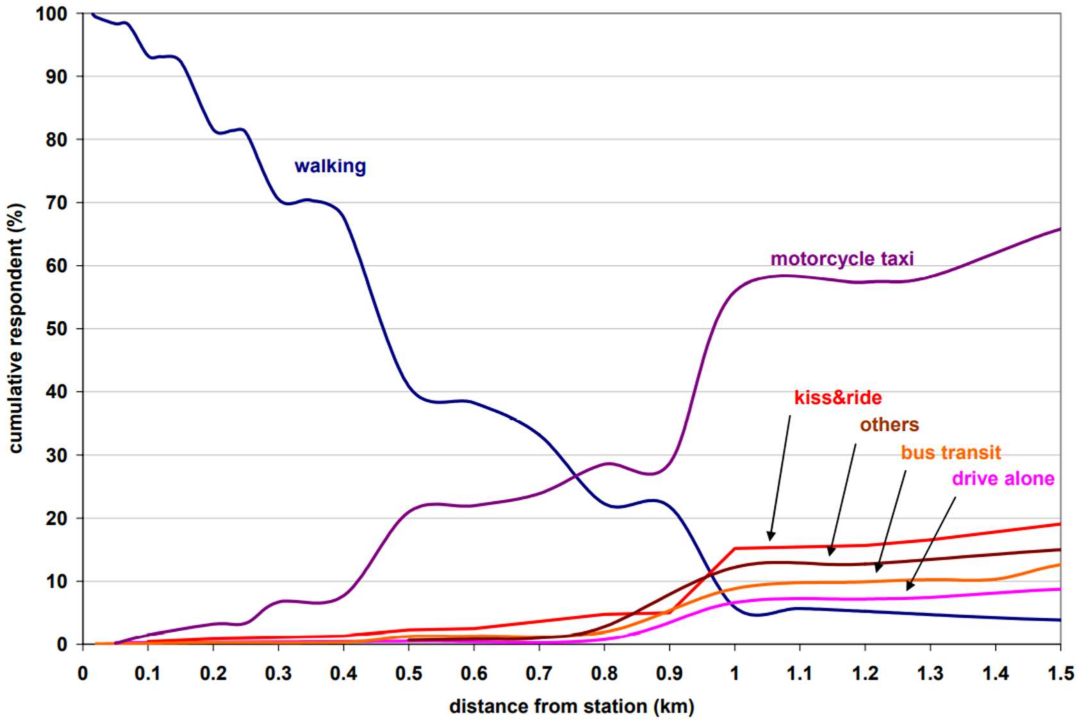


Figure 6-3 Relationship between access mode share and distance from station

Source: Chalermpong and Wibowo (2007)

Table 6-1 Example of matched POIs database

Reservation No.	Stop ID	Stop Begin	Stop End	Duration (min)	POI_category
61048	1	3/29/2021 19:35	3/30/2021 7:23	708.47	Company
61048	1	3/29/2021 19:35	3/30/2021 7:23	708.47	Company
61048	3	3/30/2021 11:59	3/30/2021 17:18	318.83	Restaurant/Cafe
61048	3	3/30/2021 11:59	3/30/2021 17:18	318.83	Building
61048	3	3/30/2021 11:59	3/30/2021 17:18	318.83	Restaurant/Cafe
69491	1	7/5/2021 7:26	7/5/2021 7:31	5.12	Civil/School/Worship
69491	1	7/5/2021 7:26	7/5/2021 7:31	5.12	Bank
69491	1	7/5/2021 7:26	7/5/2021 7:31	5.12	Company
69491	1	7/5/2021 7:26	7/5/2021 7:31	5.12	Company
69491	1	7/5/2021 7:26	7/5/2021 7:31	5.12	Shopping
69491	1	7/5/2021 7:26	7/5/2021 7:31	5.12	Hospital
69491	1	7/5/2021 7:26	7/5/2021 7:31	5.12	Gas/Toilet

Reservation No.	Stop ID	Stop Begin	Stop End	Duration (min)	POI_category
69491	1	7/5/2021 7:26	7/5/2021 7:31	5.12	Company
69491	1	7/5/2021 7:26	7/5/2021 7:31	5.12	Restaurant/Cafe
69491	1	7/5/2021 7:26	7/5/2021 7:31	5.12	Shopping

6.4 Activity types

Based on the interview data, we decided to revise the activity category into 5 groups (see Table 6-2) including:

- Shopping (A1) – the activities included in this group are such as shopping in the department store or market or store etc.
- Travel/Religious activity (A2) - the activities included in this group are stops located near tourist attractions and temples. The examples of this category include visiting tourist attractions, visiting family, and doing religious activities (e.g., making merit and going to a funeral).
- Dining (A3) - the activities included in this group are such as visiting restaurants and coffee shops.
- Work/Errands (A4) - the activities included in this group are such as delivery, mail/post office, study, meeting, work, pick-up/drop-off etc.
- Overnight stay (A5) - the activities in this group include staying overnight at a residential POI. Note that staying overnight outside Greater Bangkok is defined as Travel/Religious activity in this study.

Table 6-2 Revised activity categories

Activity from phone interview	Revised activity category
Buy a tree	Shopping
Shopping	Shopping
Staying at a hotel	Travel/Religious activity
Visiting family	Travel/Religious activity
Go to funeral	Travel/Religious activity
Religious activity	Travel/Religious activity
Taking photos at tourist attractions.	Travel/Religious activity
Travel	Travel/Religious activity
Buy food from restaurant	Dining
Buy drink from café/restaurant	Dining
Dining	Dining
Contacting government agency	Work/Errands
Delivery	Work/Errands

Activity from phone interview	Revised activity category
Stopping by gas station	Work/Errands
Errands	Work/Errands
Going to school/university	Work/Errands
Work out at the gym	Work/Errands
Refueling at gas station	Work/Errands
Financial services at banks	Work/Errands
Meeting	Work/Errands
Visiting doctor	Work/Errands
Working	Work/Errands
Visiting Park	Work/Errands
Moving to a new apartment/dorm	Work/Errands
Pick up friends/family	Work/Errands
Pick up/Delivery packages	Work/Errands
Meet friends	Work/Errands
Study	Work/Errands
Vaccination	Work/Errands
Look for new homes/condos	Work/Errands
Withdraw money from ATM	Work/Errands
Staying overnight at home/lodging	Overnight stay

We analyzed all the activities obtained from the phone interview. They can be grouped into 5 categories including:

As a result, the 961 stops can be categorized into 5 groups as shown Figure 6-4.

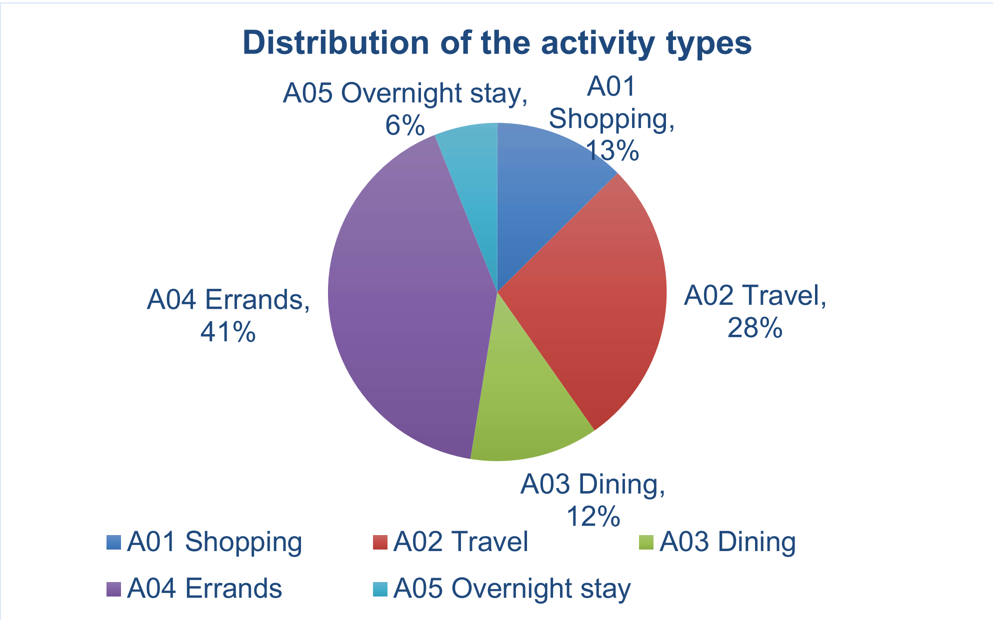


Figure 6-4 Distribution of the activity types of the 961 stops made by the phone interview participants

In the next two sections, we determine the likelihood of the activity types based on three variables including stop time, stop duration, and point of interest. Stop time and stop duration of the 961 stops were grouped together to develop the probability of stop time and duration as shown in Section 6.2. Additionally, POIs within the 100 meters of the stops were also used to create a probability table of nearby points of interest as described in Section 7.6.

6.5 Probability tables of stop time and duration

As a results from interview, after we determined category of activity and match POIs database. And then, we created probability for used in prediction activity of algorithm. We analyzed probability of stop point by using frequency of activity based on time of day and duration. There is a total of 5 tables based on the 5 activity categories.

6.5.1 Stop time and duration for shopping (A1)

Shopping activity is an activity that consists of shopping in shopping mall, department store, shop or in the market. The probability table and contour map shown in Table 6-3 and Figure 6-5.

Table 6-3 Probability of shopping activity

TOD/ Duration	15	30	45	60	75	90	105	120	135	150	165	180	240	255	270	285	300	420
00	0.0096	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
05	0.0096	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
07	0.0096	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
08	0.0000	0.0096	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0096	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
09	0.0000	0.0096	0.0000	0.0000	0.0000	0.0000	0.0096	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10	0.0000	0.0385	0.0000	0.0096	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0096	0.0000	0.0000	0.0000	0.0096	0.0000
11	0.0000	0.0096	0.0096	0.0000	0.0000	0.0096	0.0000	0.0000	0.0000	0.0192	0.0000	0.0000	0.0000	0.0096	0.0000	0.0000	0.0000	0.0096
12	0.0096	0.0000	0.0000	0.0096	0.0096	0.0000	0.0000	0.0096	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
13	0.0096	0.0000	0.0192	0.0096	0.0288	0.0096	0.0000	0.0000	0.0000	0.0000	0.0000	0.0096	0.0000	0.0000	0.0000	0.0096	0.0000	0.0000
14	0.0385	0.0385	0.0096	0.0096	0.0000	0.0000	0.0096	0.0000	0.0096	0.0000	0.0096	0.0000	0.0000	0.0000	0.0000	0.0096	0.0096	0.0000
15	0.0192	0.0192	0.0385	0.0000	0.0096	0.0096	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0096	0.0000	0.0096	0.0000	0.0000	0.0000
16	0.0192	0.0288	0.0192	0.0096	0.0096	0.0096	0.0000	0.0096	0.0096	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
17	0.0192	0.0096	0.0192	0.0288	0.0000	0.0096	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
18	0.0000	0.0385	0.0000	0.0096	0.0000	0.0096	0.0096	0.0000	0.0000	0.0000	0.0096	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
19	0.0096	0.0000	0.0096	0.0385	0.0192	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
20	0.0000	0.0096	0.0096	0.0096	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0096	0.0000	0.0000	0.0000	0.0000	0.0000
21	0.0000	0.0096	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

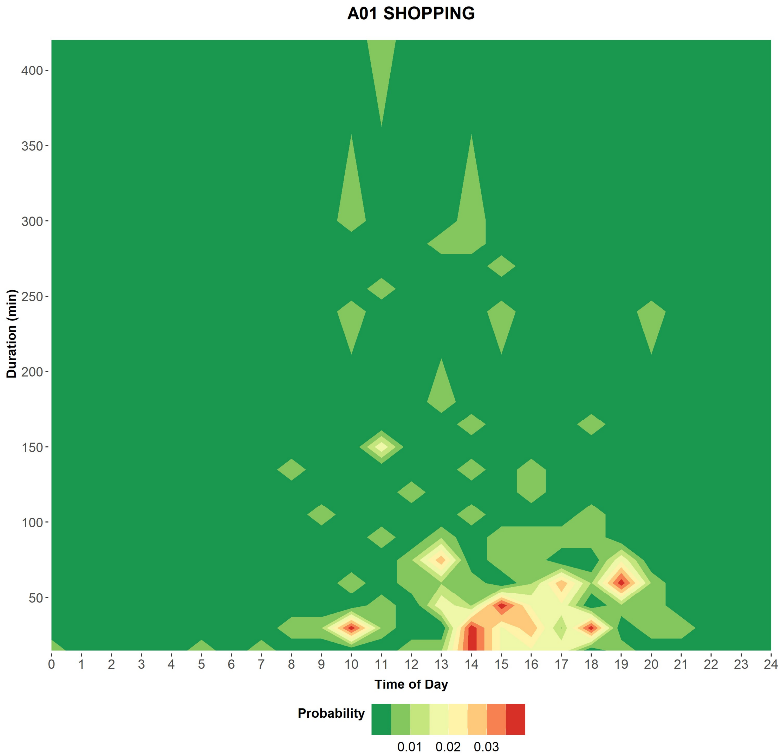


Figure 6-5 Contour map of shopping activity

6.5.2 Stop time and duration for travel Travel/Religious activities (A2)

Travel activity is an activity that consists of traveling and religious. The probability table and contour map shown in Table 6-4 and Figure 6-6.

Table 6-4 Probability of travel/religious activities activity

TOD/ Duration	15	30	45	60	75	90	105	120	135	150	165	180	195	225	240	255	375	435	450	495
06	0.0000	0.0052	0.0000	0.0052	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0052	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
07	0.0000	0.0000	0.0000	0.0000	0.0052	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0052	0.0052	0.0052
08	0.0000	0.0052	0.0208	0.0052	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
09	0.0052	0.0104	0.0052	0.0052	0.0208	0.0052	0.0000	0.0052	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10	0.0104	0.0208	0.0104	0.0052	0.0104	0.0052	0.0000	0.0000	0.0052	0.0000	0.0000	0.0000	0.0052	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
11	0.0469	0.0000	0.0000	0.0052	0.0052	0.0000	0.0104	0.0000	0.0104	0.0000	0.0000	0.0000	0.0000	0.0000	0.0052	0.0000	0.0000	0.0000	0.0000	0.0000
12	0.0313	0.0104	0.0052	0.0052	0.0052	0.0000	0.0000	0.0000	0.0104	0.0052	0.0000	0.0052	0.0000	0.0000	0.0000	0.0052	0.0000	0.0000	0.0000	0.0000
13	0.0573	0.0313	0.0313	0.0208	0.0000	0.0052	0.0000	0.0052	0.0000	0.0052	0.0000	0.0000	0.0000	0.0000	0.0000	0.0052	0.0000	0.0000	0.0000	0.0000
14	0.0469	0.0208	0.0260	0.0156	0.0000	0.0052	0.0000	0.0000	0.0052	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0052	0.0000	0.0000	0.0000	0.0000
15	0.0104	0.0156	0.0208	0.0156	0.0000	0.0104	0.0000	0.0156	0.0052	0.0000	0.0052	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
16	0.0521	0.0156	0.0052	0.0052	0.0000	0.0104	0.0052	0.0000	0.0052	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
17	0.0260	0.0000	0.0208	0.0104	0.0052	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
18	0.0156	0.0000	0.0052	0.0000	0.0052	0.0104	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
19	0.0104	0.0052	0.0052	0.0052	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
20	0.0156	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0052	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
21	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0052	0.0000	0.0000	0.0000

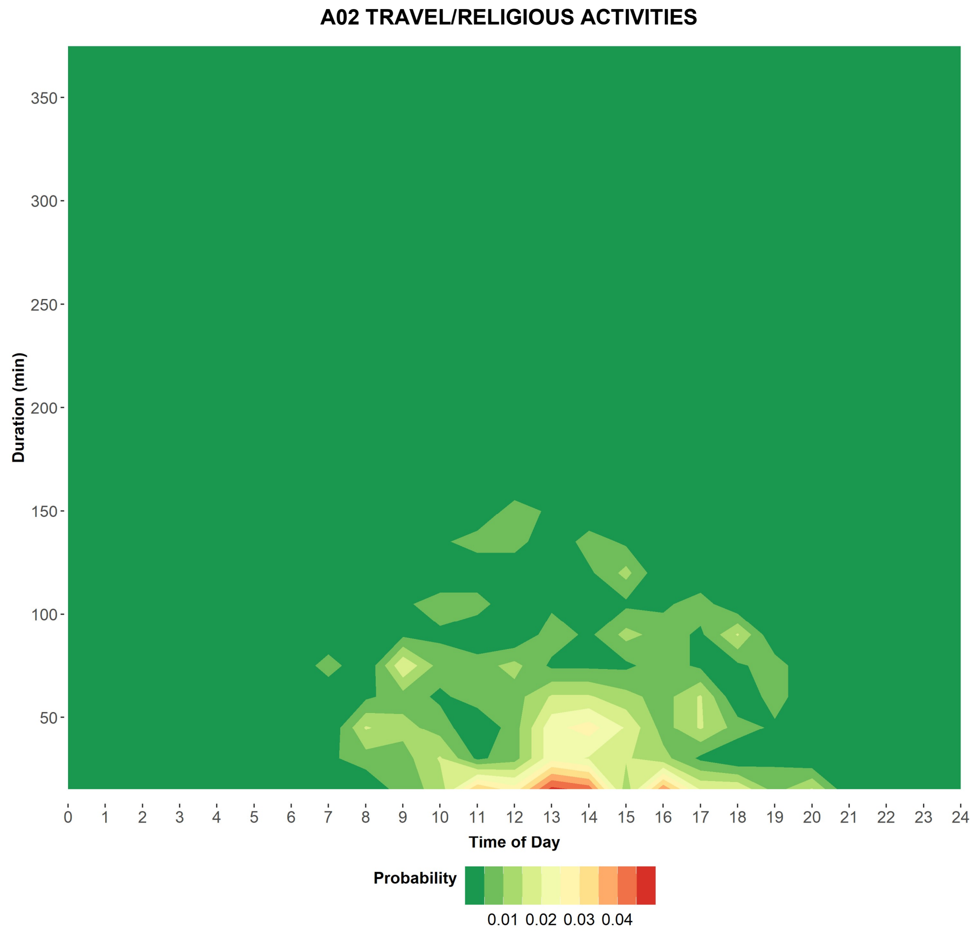


Figure 6-6 Contour map of travel/religious activities activity

6.5.3 Stop time and duration for dining (A3)

Dining activity is an activity that consists of dining in Restaurant/Cafe or cafe. The probability table and contour map shown in Table 6-5 and Figure 6-7.

Table 6-5 Probability of dining activity

TOD/ Duration	15	30	45	60	75	90	105	120	135	150	165	180	195	210	225	255
02	0.0000	0.0071	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
06	0.0071	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
07	0.0000	0.0071	0.0000	0.0000	0.0071	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
08	0.0071	0.0071	0.0142	0.0000	0.0071	0.0000	0.0000	0.0000	0.0000	0.0000	0.0071	0.0000	0.0000	0.0000	0.0000	0.0000
09	0.0071	0.0000	0.0213	0.0071	0.0071	0.0071	0.0071	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10	0.0071	0.0071	0.0071	0.0000	0.0142	0.0000	0.0142	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0071
11	0.0071	0.0071	0.0284	0.0142	0.0142	0.0000	0.0071	0.0000	0.0071	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
12	0.0142	0.0000	0.0355	0.0142	0.0142	0.0000	0.0000	0.0000	0.0000	0.0071	0.0000	0.0000	0.0000	0.0071	0.0000	0.0000
13	0.0071	0.0142	0.0213	0.0071	0.0142	0.0071	0.0071	0.0071	0.0071	0.0000	0.0000	0.0000	0.0071	0.0000	0.0000	0.0000
14	0.0142	0.0071	0.0213	0.0071	0.0071	0.0071	0.0071	0.0071	0.0071	0.0000	0.0000	0.0071	0.0000	0.0000	0.0000	0.0000
15	0.0071	0.0071	0.0071	0.0071	0.0142	0.0142	0.0142	0.0000	0.0000	0.0000	0.0000	0.0071	0.0000	0.0000	0.0000	0.0000
16	0.0000	0.0071	0.0142	0.0071	0.0213	0.0142	0.0071	0.0071	0.0071	0.0071	0.0071	0.0000	0.0000	0.0000	0.0071	0.0000
17	0.0000	0.0071	0.0000	0.0142	0.0071	0.0071	0.0142	0.0071	0.0000	0.0071	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
18	0.0213	0.0000	0.0142	0.0213	0.0000	0.0355	0.0000	0.0071	0.0000	0.0142	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
19	0.0000	0.0142	0.0000	0.0071	0.0213	0.0000	0.0000	0.0071	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
20	0.0071	0.0000	0.0000	0.0071	0.0071	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
21	0.0000	0.0000	0.0071	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
23	0.0000	0.0071	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

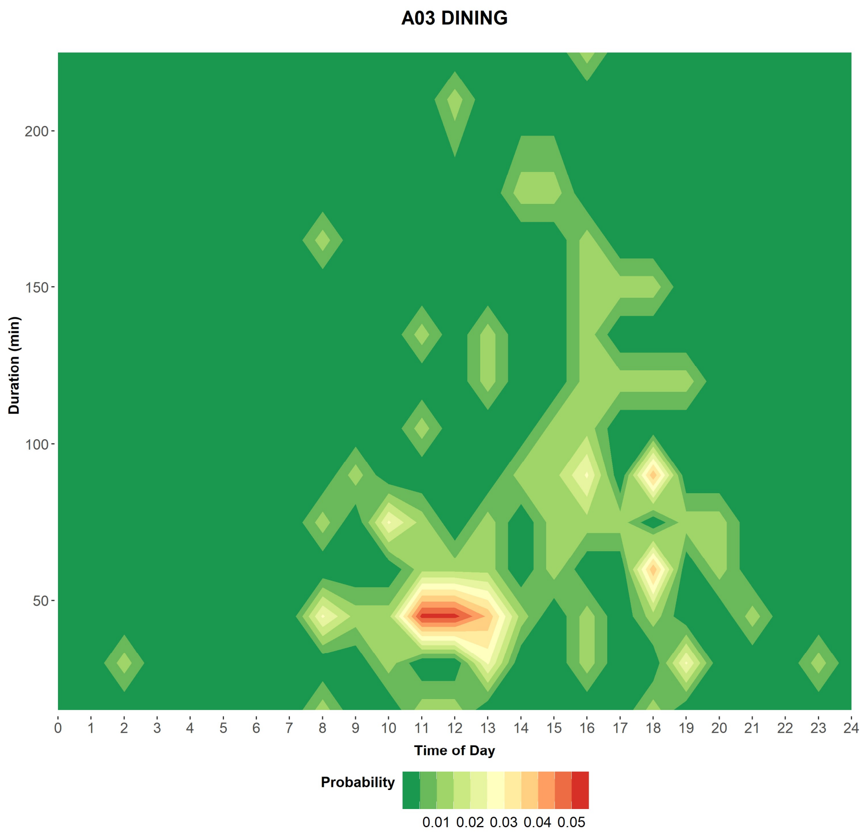


Figure 6-7 Contour map of dining activity

6.5.4 Stop time and duration for work/errands (A4)

Errands activity is an activity that consists of doing errands such as financial transactions, delivery, pick-up, fill-up, meeting, work, study, meet-up or other activities that use a short duration of activity. The probability table and contour map shown in Table 6-6 and Figure 6-8

Table 6-6 Probability of work/errands activity

TOD/ Duration	15	30	45	60	75	90	105	120	135	150	165	180	195	210	240	255	330	375	405	450
00	0.0033	0.0000	0.0000	0.0000	0.0016	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
01	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0016	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
02	0.0000	0.0000	0.0000	0.0016	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
03	0.0033	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
04	0.0000	0.0033	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
05	0.0000	0.0000	0.0016	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0016	0.0000	0.0016	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
06	0.0033	0.0065	0.0000	0.0000	0.0016	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0016	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
07	0.0195	0.0098	0.0033	0.0000	0.0016	0.0016	0.0016	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
08	0.0163	0.0065	0.0033	0.0049	0.0033	0.0033	0.0000	0.0033	0.0000	0.0016	0.0000	0.0016	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
09	0.0553	0.0163	0.0065	0.0016	0.0033	0.0000	0.0000	0.0033	0.0033	0.0016	0.0000	0.0000	0.0033	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10	0.0618	0.0228	0.0016	0.0049	0.0065	0.0033	0.0000	0.0016	0.0000	0.0000	0.0016	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
11	0.0325	0.0195	0.0033	0.0016	0.0049	0.0033	0.0000	0.0016	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0016	0.0033	0.0016	0.0000	0.0000
12	0.0195	0.0130	0.0049	0.0033	0.0065	0.0000	0.0016	0.0049	0.0000	0.0000	0.0000	0.0000	0.0000	0.0016	0.0000	0.0000	0.0000	0.0000	0.0000	0.0016
13	0.0293	0.0163	0.0049	0.0033	0.0000	0.0033	0.0049	0.0065	0.0033	0.0016	0.0016	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0016	0.0000
14	0.0520	0.0130	0.0081	0.0000	0.0033	0.0033	0.0000	0.0000	0.0016	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
15	0.0358	0.0130	0.0000	0.0065	0.0033	0.0033	0.0000	0.0016	0.0000	0.0000	0.0049	0.0000	0.0000	0.0016	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
16	0.0228	0.0130	0.0016	0.0049	0.0000	0.0016	0.0016	0.0000	0.0000	0.0000	0.0000	0.0000	0.0016	0.0000	0.0016	0.0000	0.0000	0.0000	0.0000	0.0000
17	0.0390	0.0098	0.0033	0.0000	0.0033	0.0049	0.0000	0.0000	0.0000	0.0033	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
18	0.0618	0.0195	0.0033	0.0016	0.0000	0.0000	0.0000	0.0000	0.0016	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0016	0.0016	0.0000	0.0000	0.0000
19	0.0488	0.0033	0.0016	0.0000	0.0000	0.0000	0.0016	0.0016	0.0000	0.0000	0.0016	0.0000	0.0000	0.0000	0.0000	0.0016	0.0000	0.0000	0.0000	0.0000
20	0.0195	0.0098	0.0016	0.0033	0.0016	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
21	0.0163	0.0000	0.0016	0.0016	0.0016	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
22	0.0033	0.0000	0.0016	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0016	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
23	0.0033	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

A04 WORK/ERRANDS

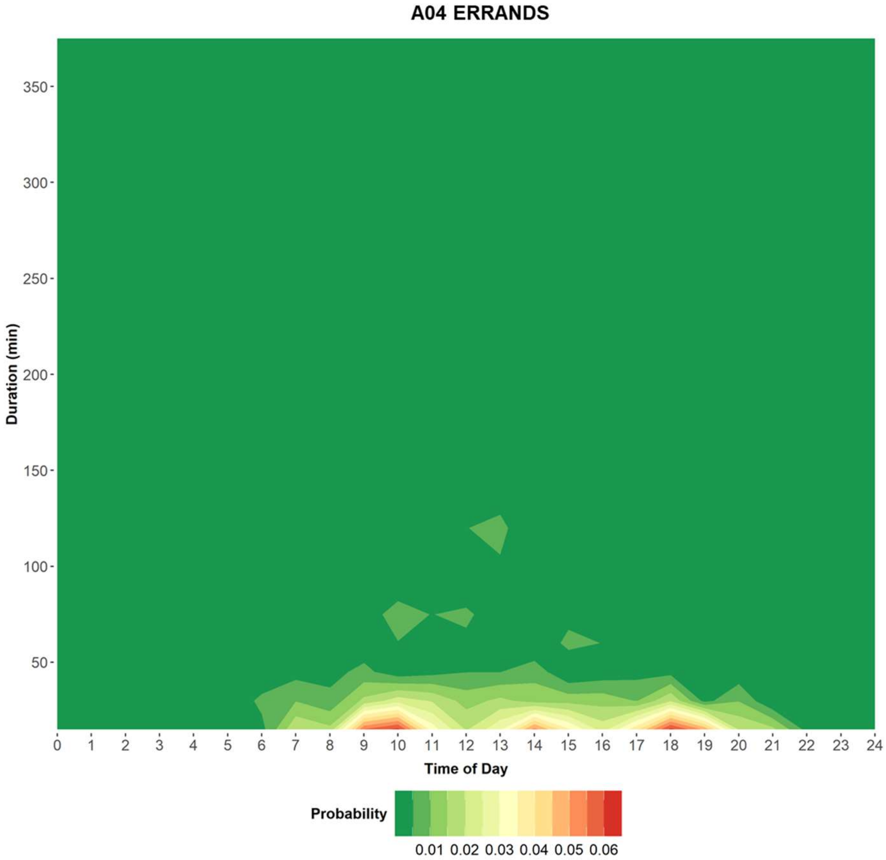


Figure 6-8 Contour map of work/errands activity

6.5.5 Stop time and duration for overnight stay (A5)

Overnight stay activity is an activity that overnight stay at a house, hotel, someone's house, etc. The probability table and contour map shown in Table 6-7 and Figure 6-9.

Table 6-7 Probability of Overnight stay activity

TOD/ Duration	165	180	240	300	375	450	480	495	525	555	570	600	615	630	645	675	690	705	720	720Up
00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0172	0.0000	0.0000	0.0172	0.0000	0.0000	0.0000	0.0000	0.0000
03	0.0000	0.0172	0.0172	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
04	0.0172	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
05	0.0000	0.0000	0.0000	0.0000	0.0172	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
12	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0172
14	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0172
15	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0172
17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0690
18	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0517
19	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0172	0.0000	0.0000	0.0000	0.0000	0.0172	0.0172	0.0000	0.0000	0.0000	0.0172	0.0862
20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0172	0.0000	0.0172	0.0000	0.0172	0.0000	0.0345	0.0000	0.0172	0.0000	0.0172	0.0345	0.1207
21	0.0000	0.0000	0.0000	0.0000	0.0000	0.0172	0.0000	0.0172	0.0000	0.0000	0.0000	0.0172	0.0000	0.0172	0.0000	0.0345	0.0000	0.0172	0.0000	0.0000
22	0.0000	0.0000	0.0000	0.0172	0.0000	0.0000	0.0172	0.0000	0.0000	0.0172	0.0000	0.0000	0.0172	0.0000	0.0172	0.0172	0.0172	0.0000	0.0000	0.0000
23	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0345	0.0000	0.0000	0.0172	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

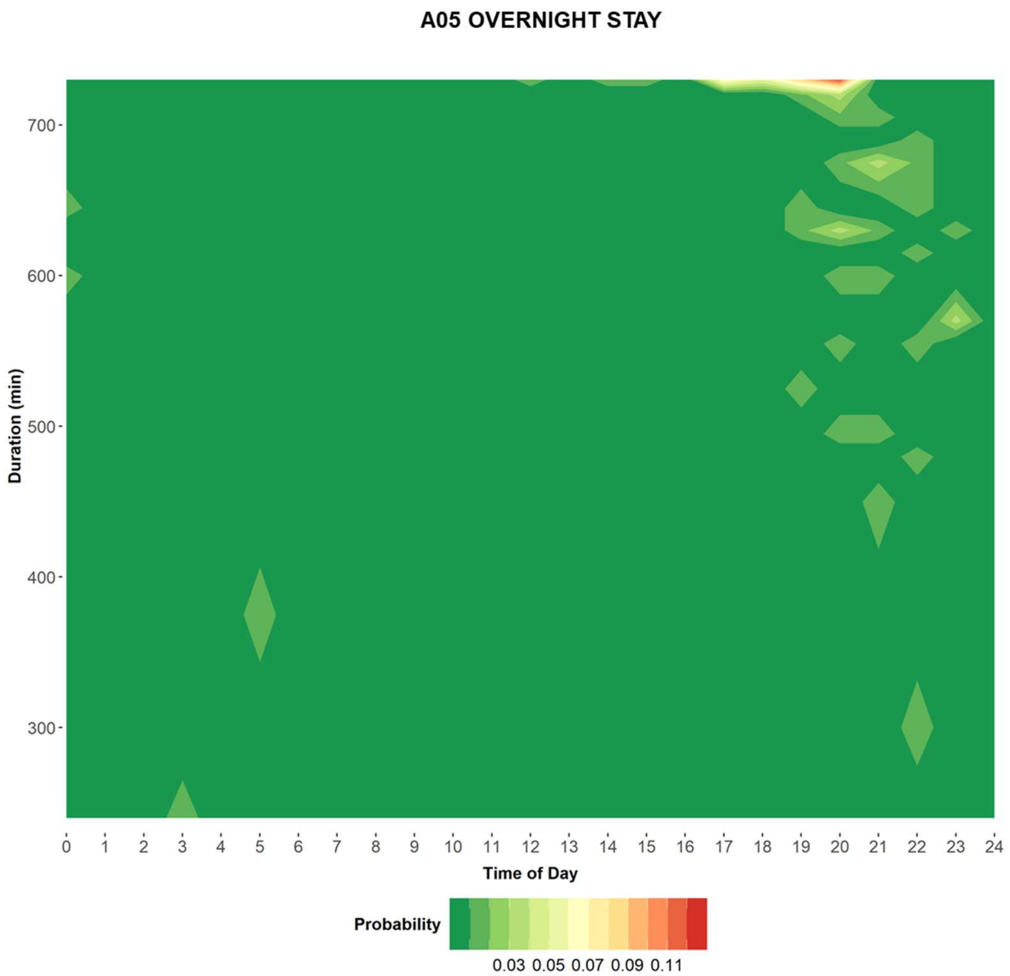


Figure 6-9 Contour map of overnight stay activity

6.6 Probability tables of nearby point of interest

We analyze probability of point of interest by using frequency of POIs within 100-m radius around destination stops in each activity (see Table 6-8 to Table 6-12).

Table 6-8 Probability of point of interesting of shopping

Activity	POIs	Prob
Shopping	Shopping/shopping mall/Market/Department Store/สรรพสินค้า	0.482512846
	Restaurant/Cafe/ร้านอาหาร	0.34775402
	บริษัท	0.048234709
	Health/โรงพยาบาล แพทย์ สุขภาพ	0.047074424
	Civil/School/Worship/สถาบันการศึกษา	0.020885132
	Hotel/Apartment/ที่พัก/ที่พัก ที่อยู่อาศัย/บ้าน	0.016078236
	ร้านสะดวกซื้อ	0.008619261
	แหล่งบันเทิง	0.00497265
	Station	0.004475385
	สถานที่ทั่วไป	0.00430963
	เครื่องเบิกเงินสด	0.0033151
	ธนาคาร	0.00265208
	Gas/Toilet/สถานบริการน้ำมัน ก๊าซ	0.002486325
	Outdoor	0.001160285
	unknown	0.00099453
	อาคาร	0.00099453
	สถานีขนส่ง	0.000828775
	ตำรวจ	0.000497265
	หน่วยงานราชการ	0.000497265
	เส้นทางคมนาคม	0.00033151
	แหล่งท่องเที่ยว	0.00033151
	โชว์รูม ศูนย์บริการ รถยนต์	0.00033151
	กีฬา	0.00033151
	โรงงาน	0.000165755
	สถานที่ทางศาสนา	0.000165755

Table 6-9 Probability of point of interest of travel/religious activities

Activity	POIs	Prob
Travel/Religious activities	Restaurant/Cafe/ร้านอาหาร	0.312707917
	Shopping/สรรพสินค้า	0.192947438
	บริษัท	0.125083167
	Hotel/Apartment/ที่พัก/ที่พัก ที่อยู่อาศัย/บ้าน	0.097804391
	unknown	0.075182967
	Health/โรงพยาบาล แพทย์ สุขภาพ	0.057218896
	ร้านสะดวกซื้อ	0.027278776
	ธนาคาร	0.020625416
	สถานที่ทางศาสนา	0.019294744
	Civil/School/Worship/สถาบันการศึกษา	0.015302728

Activity	POIs	Prob
	สถานที่ทั่วไป	0.011310712
	หน่วยงานราชการ	0.007318696
	Gas/Toilet/สถานบริการน้ำมัน ก๊าซ	0.00665336
	เครื่องเบิกเงินสด	0.005988024
	เส้นทางคมนาคม	0.00332668
	แหล่งท่องเที่ยว	0.00332668
	แหล่งบันเทิง	0.002661344
	ไปรษณีย์	0.002661344
	Station	0.001996008
	ตำรวจ	0.001996008
	Pier	0.001330672
	Toll road rest stop	0.001330672
	กีฬา	0.001330672
	อาคาร	0.001330672
	Outdoor	0.000665336
	Temple	0.000665336
	โชว์รูม ศูนย์บริการ รถยนต์	0.000665336
	โรงงาน	0.000665336
	ไฟฟ้า ประปา โทรศัพท์	0.000665336
	ทหาร	0.000665336

Table 6-10 Probability of point of interest of dining

Activity	POIs	Prob
Dining	Restaurant/Cafe/ร้านอาหาร	0.383191981
	Shopping/shopping mall/สรรพสินค้า	0.314186584
	บริษัท	0.099460293
	Health/โรงพยาบาล แพทย์ สุขภาพ	0.056669237
	Hotel/Apartment/ที่พัก/ที่พัก ที่อยู่อาศัย	0.040863531
	Civil/School/Worship/สถาบันการศึกษา	0.030069391
	ร้านสะดวกซื้อ	0.020817271
	สถานที่ทั่วไป	0.008095605
	แหล่งบันเทิง	0.00693909
	Gas/Toilet/สถานบริการน้ำมัน ก๊าซ	0.006553585
	ธนาคาร	0.006553585
	unknown	0.005011565
	หน่วยงานราชการ	0.005011565
	Station	0.00385505
	อาคาร	0.002698535
	เครื่องเบิกเงินสด	0.001927525
	เส้นทางคมนาคม	0.00154202
	โชว์รูม ศูนย์บริการ รถยนต์	0.001156515
	สถานที่ทางศาสนา	0.001156515
	Outdoor	0.00077101
	โรงงาน	0.00077101
	กีฬา	0.00077101

Activity	POIs	Prob
	แหล่งท่องเที่ยว	0.000385505
	ไฟฟ้า ประปา โทรศัพท์	0.000385505
	ตำรวจ	0.000385505
	ทหาร	0.000385505
	สถานีขนส่ง	0.000385505

Table 6-11 Probability of point of interest of work/errands

Activity	POIs	Prob
Work/Errands	Shopping/shopping mall/สรรพสินค้า	0.302327998
	Restaurant/Cafe/ร้านอาหาร	0.301392642
	บริษัท	0.145292039
	Health/โรงพยาบาล แพทย์ สุขภาพ	0.069320308
	Hotel/Apartment/ที่พัก/ที่พัก ที่อยู่อาศัย/บ้าน	0.061941384
	Civil/School/Worship/สถาบันการศึกษา	0.027021409
	ร้านสะดวกซื้อ	0.020681771
	สถานที่ทั่วไป	0.013718562
	แหล่งบันเทิง	0.012159634
	unknown	0.008833922
	Station	0.006443567
	ธนาคาร	0.005196425
	หน่วยงานราชการ	0.004364997
	Gas/Toilet/สถานบริการน้ำมั้น ก๊าซ	0.004261068
	อาคาร	0.00342964
	เส้นทางคมนาคม	0.002598212
	ไฟฟ้า ประปา โทรศัพท์	0.002182498
	สถานที่ทางศาสนา	0.00207857
	เครื่องเบิกเงินสด	0.001662856
	โชว์รูม ศูนย์บริการ รถยนต์	0.001558927
	ตำรวจ	0.001039285
	Outdoor	0.000831428
	ไปรษณีย์	0.000415714
	กีฬา	0.000415714
	โรงงาน	0.000311785
	สถานีขนส่ง	0.000311785
	สถานฑูต สถานกลศุล	0.000207857

Table 6-12 Probability of point of interest of overnight stay

Activity	POIs	Prob
Overnight stay	Restaurant/Cafe/ร้านอาหาร	0.26481715
	Shopping/สรรพสินค้า	0.238335435
	บริษัท	0.19924338
	Hotel/Apartment/ที่พัก/ที่พัก ที่อยู่อาศัย/บ้าน	0.098360656
	Health/โรงพยาบาล แพทย์ สุขภาพ	0.045397226
	Civil/School/Worship/สถาบันการศึกษา	0.032786885

Activity	POIs	Prob
	แหล่งบันเทิง	0.026481715
	สถานที่ทั่วไป	0.020176545
	unknown	0.015132409
	ร้านสะดวกซื้อ	0.015132409
	ธนาคาร	0.008827238
	Gas/Toilet/สถานบริการน้ำมัน ก๊าซ	0.007566204
	หน่วยงานราชการ	0.005044136
	Station	0.003783102
	ไฟฟ้า ประปา โทรศัพท์	0.003783102
	อาคาร	0.003783102
	เส้นทางคมนาคม	0.002522068
	ไปรษณีย์	0.002522068
	ตำรวจ	0.002522068
	โชว์รูม ศูนย์บริการ รถยนต์	0.001261034
	โรงงาน	0.001261034
	สถานที่ทางศาสนา	0.001261034

6.7 Matching duration and stop begin with probability of stop point

In this step, we used data from the interview including stop duration and stop beginning time of each stop. Next, we matched duration and stop begin with probability table in each activity to determine the likelihood of being in each activity. The result from this step, we got probability values in each activity of stop ID (see Figure 6-10).

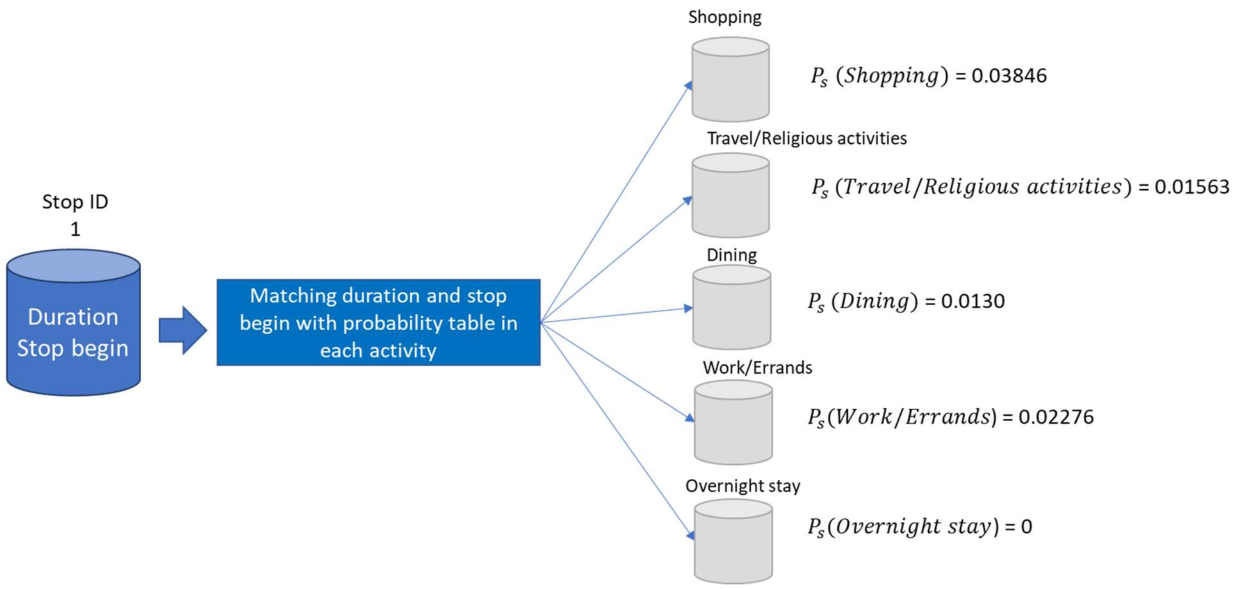


Figure 6-10 Matching duration and stop begin with probability of stop point

6.8 Match POIs of stop ID with probability of point of interest

Within the 100-m radius, there are many POIs. Therefore, in this step we matched POIs of stop ID with probability of point of interest to determine possible activities of each stop ID (see Figure 6-11).

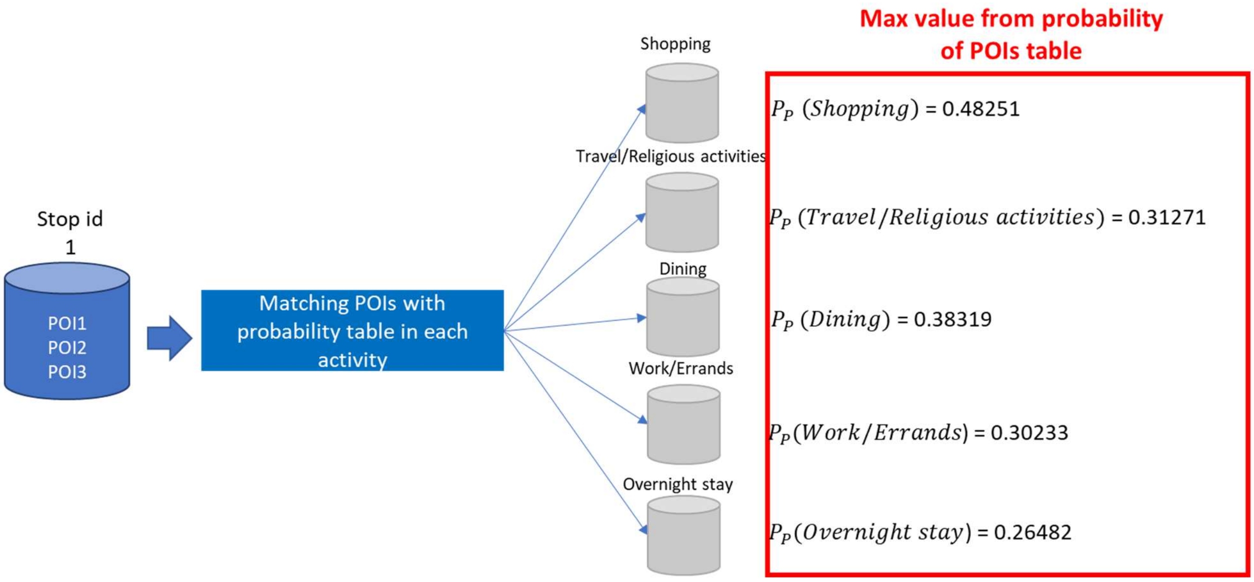


Figure 6-11 Matching POIs of stop ID with probability of point of interest

6.9 Activity determination

After we got prob of stop point and prob of point of interest, and then we multiplied stop-based probability with the POI probability. Then, we chose the max value and assign the most probable activity (see Figure 6-12).

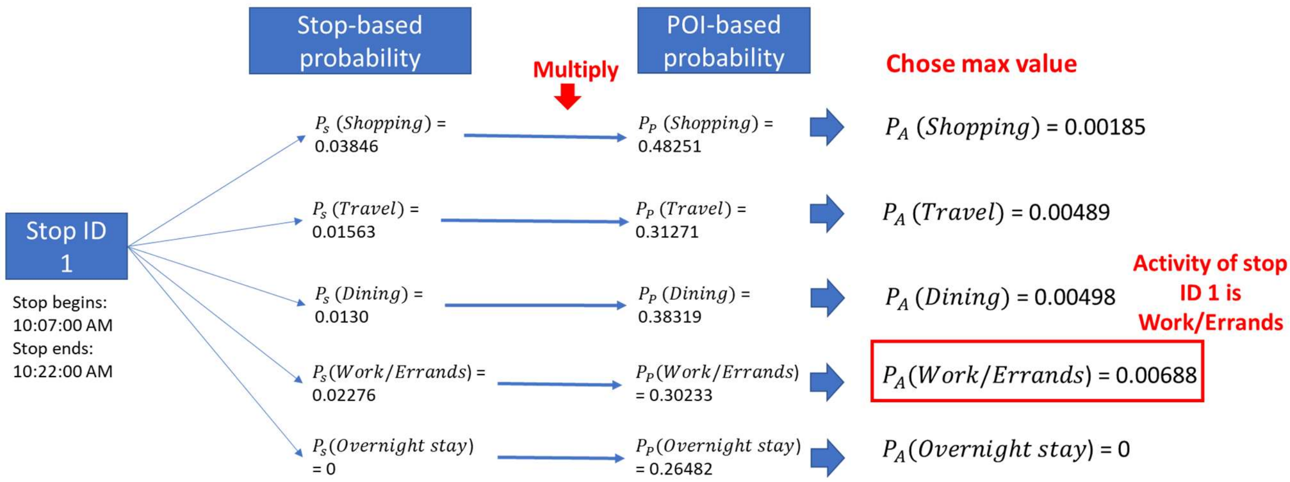


Figure 6-12 Prediction activity of stop point

6.10 ALGORITHM VALIDATION

we compared the activities determined by our proposed algorithm with ground truth activity data obtained from the phone interview.

6.10.1 Comparison of ground truth data with the algorithm results

After we predicted possible activity, and then we compare the results of prediction with ground truth. The results as shown in Table 6-13 and accuracy of algorithm is 81.2 percent as shown in Table 6-14.

Table 6-13 Results of prediction with ground truth

Activity	Shopping	Travel/ Religious activities	Dining	Work/ Errands	Overnight stay	Total
Shopping	64	19	4	34	-	121
Travel/ Religious activities	12	254	-	-	-	266
Dining	10	4	58	46	-	118
Work/Errands	18	19	15	346	-	398
Overnight stay	-	-	-	-	58	58
Total	**104**	**296**	**77**	**426**	**58**	**961**

Table 6-14 Accuracy of predict from algorithm

Activity	Shopping	Travel/ Religious activities	Dining	Work/ Errands	Overnight stay
Shopping	6.7%	2.0%	0.4%	3.5%	0.0%
Travel/ Religious activities	1.2%	26.4%	0.0%	0.0%	0.0%
Dining	1.0%	0.4%	6.0%	4.8%	0.0%
Work/Errands	1.9%	2.0%	1.6%	36.0%	0.0%
Overnight stay	0.0%	0.0%	0.0%	0.0%	6.0%

6.10.2 Identify possible activity in each phase

After we had the algorithm with accuracy is 82.1 percent. And then, we applied the algorithm to run the data in each phase to compared differences travel behavior in pre-epidemic and during outbreaks. The process as following:

6.10.2.1 Data collection

We collected data that consist of reservation data, user data, interval vehicle log data, and POIs data by split data into 4 phases.

6.10.2.2 Cleaning data

After collected data from databased, we are cleaning data for filter out internal used and reservation that have not income by conditions following:

- Reservation state with “COMPLETE” and “FINISH”
- Filter out of Reserve hours >= 720 hours
- Filter out of internal used
- Filter out of charge less than or equal 0
- Filter out of actual distance less than or equal 0
- Filter out some strange information such as Enginstate = 0 but vehicle have speed

6.10.2.3 Matching data

In this step, we matched 3 database including reservation data, user data, and interval vehicle log data. Next, we matched latitude and longitude of reservation with POIs database.

6.10.3 Possible activity in each phase

We used the algorithm for identify activity in each phase. The number stop in each trip split by activity as shown in Table 6-15 and percent of activity in each phase as shown in Table 6-16

Table 6-15 Number of activities in each phase

Phase	Shopping	Travel/ Religious activities	Dining	Work/ Errands	Overnight stay	Total
0	9,099	16,138	6,147	25,179	1,523	58,086
1	4,614	7,920	3,680	16,163	1,158	33,535
2	1,761	3,445	1,482	5,741	468	12,897
3	838	1,347	719	3,000	308	6,212
Total	**16,312**	**28,850**	**12,028**	**50,083**	**3,457**	**110,730**

Table 6-16 Percent of activities in each phase

Phase/Activity	Shopping	Travel/Religious activities	Dining	Work/Errands	Overnight stay
0	15.7%	27.8%	10.6%	43.3%	2.6%
1	13.8%	23.6%	11.0%	48.2%	3.5%
2	13.7%	26.7%	11.5%	44.5%	3.6%
3	13.5%	21.7%	11.6%	48.3%	5.0%

6.10.4 Data Description

From the analysis, it was found that the number of reservations during COVID-19 pandemic (phase 1 to phase 3) decreased from the number of reservations in before COVID-19 phase (see Figure 6-13). In addition, we determined number of reservations in each month and each phase (see Figure 6-14 to Figure 6-16). It was found that number of reservations decrease according with government measures in Thailand.

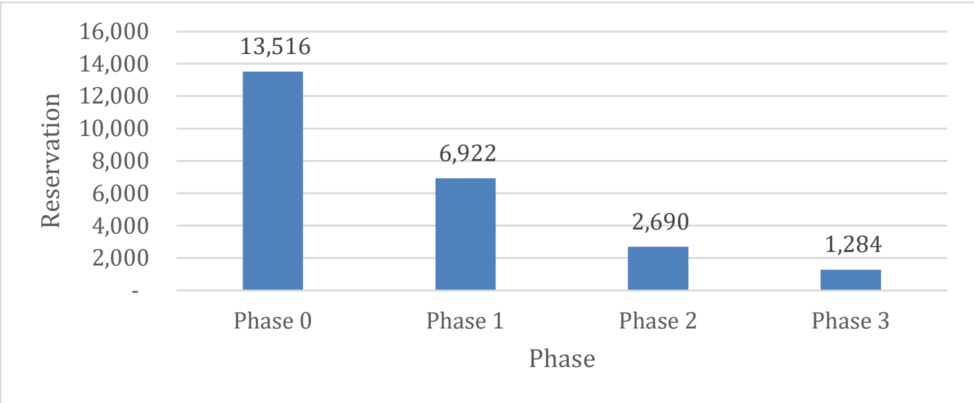


Figure 6-13 Number of reservations in each phase (each phase has different duration)

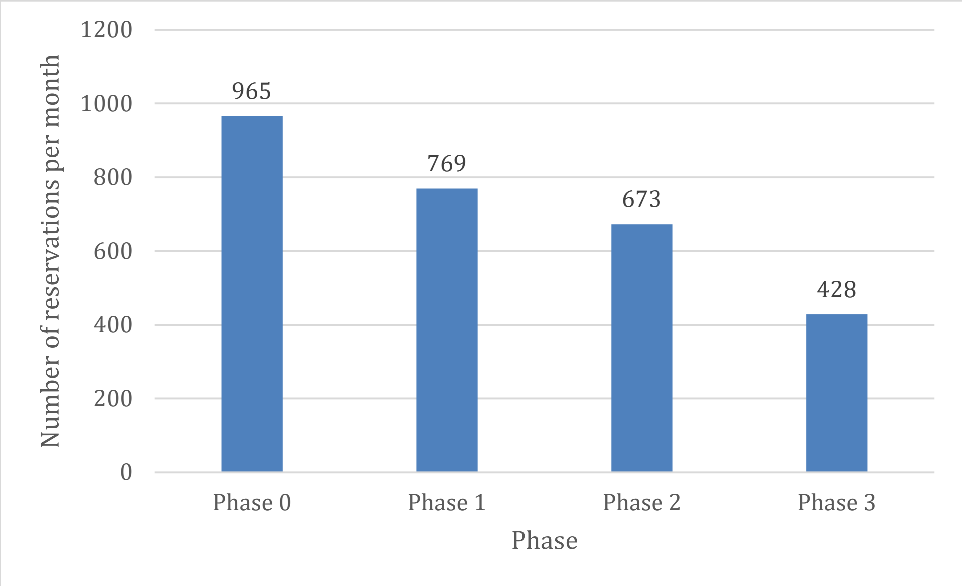


Figure 6-14 Average numbers of reservations per month

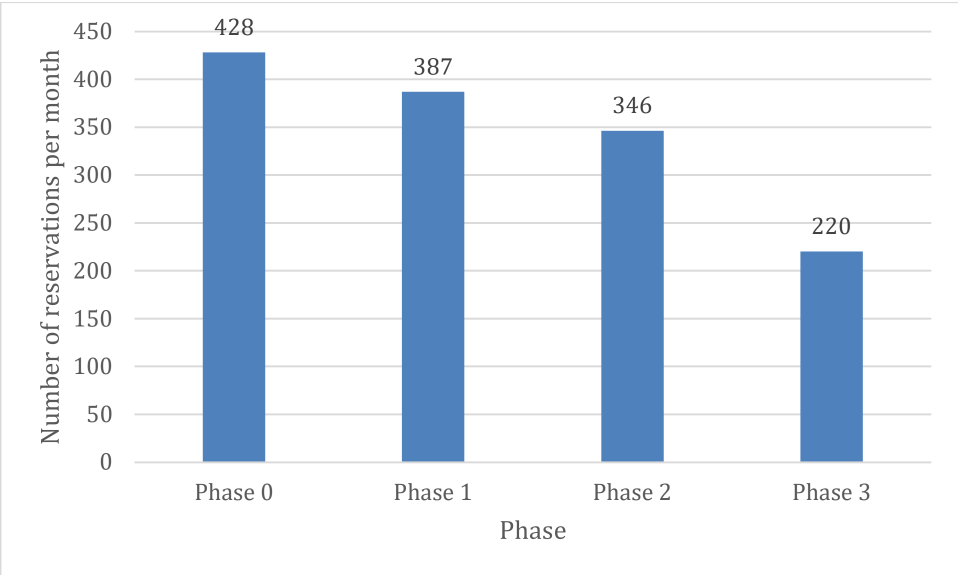


Figure 6-15 Average numbers of daily reservations per month

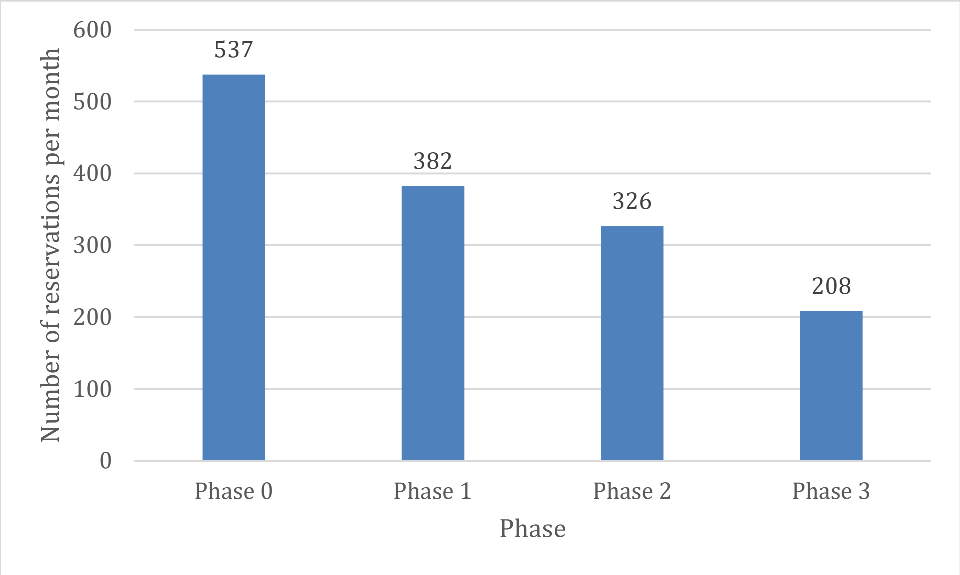


Figure 6-16 Average numbers of hourly reservations per month

And then we are finding carsharing user's behavior by focus only user that used from before COVID-19 phases and still used in during COVID-19 phase (see on Table 6-17).

Table 6-17 Usage data of carsharing user in each phase

Phase comparison	Item	Phase 0	Phase 1	Phase 2	Phase 3
0→1	No. of reservations/Month	456	435		
	Reserved hours/Reservation/User	17.6	20.1		
	Actual distance/Reservation	179	187		
0→2	No. of reservations/Month	192		221	
	Reserved hours/Reservation/User	18.7		23.7	
	Actual distance/Reservation	180		230	
0→ 3	No. of reservations/Month	113			117
	Reserved hours/Reservation/User	17.2			24.1
	Actual distance/Reservation	181			178
0→1→2	No. of reservations/Month	174	224	188	
	Reserved hours/Reservation/User	17.4	22	24.6	
	Actual distance/Reservation	174	195	243	
0→1→ 2→ 3	No. of reservations/Month	90	121	99	79
	Reserved hours/Reservation/User	15.3	20.3	22.6	21.9
	Actual distance/Reservation	159	157	198	165

Next, we determined number of new users that started to use carsharing services during COVID-19. As a result, the total of carsharing users during COVID-19 are 4,419 users, of which 1,427 are the existing users and 2,992 are the new users (see Table 6-18 to Table 6-19 and Figure 6-17).

Table 6-18 Number of users in each phase

Phase	Number of users
Phase 0	4,023
Phase 1	2,347
Phase 2	1,325
Phase 3	747
Total (Unique IDs)	6,537

Table 6-19 Number of new and existing users in phases 1, 2, and 3

Phase	Existing users	New users	Total
Phase 1	917 (39%)	1,430 (61%)	2,347
Phase 2	342 (26%)	983 (74%)	1,325
Phase 3	168 (22%)	579 (78%)	747
Total	**1,427 (32%)**	**2,992 (68%)**	**4,419**

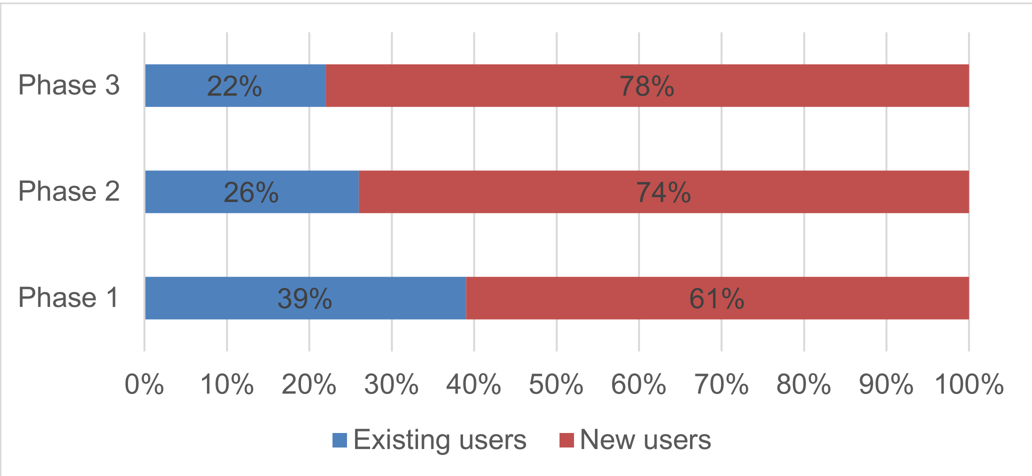


Figure 6-17 Number of new and existing users in phases 1, 2, and 3

6.10.5 Travel Demand in Bangkok during COVID-19

In this section, we summarized travel demand in other transportation services such as motorways and MRT, as well as the number of private cars sold. This would help us understand the transportation demand in Bangkok compared with carsharing demand we analyzed earlier.

We considered the number of reservations each month by using the number of reservations in 2019 as the baseline, found that the volume of reservations dropped significantly in April. Due to lockdown measures and a curfew from the government and gradually increasing due to the easing of measures (see Figure 6-18).

We considered comparison demand of carsharing with other demand of transportation mode. If the demand for carsharing decreases, we assume that this is a consequence of government measures, and we also want to consider as to other types of transport are affected as well.

We collected data of demand of other transportation including volume of motorway, volume of MRT and volume of private cars for compare with demand of carsharing (see Figure 6-19 to Figure 6-21).

Figure 6-19 illustrates the changed in demand of motorway traffic volume with the demand of carsharing as same as the demand of MRT (Blue line) (Figure 6-20). While the demand of private cars inverses with the demand of carsharing (Figure 6-21).

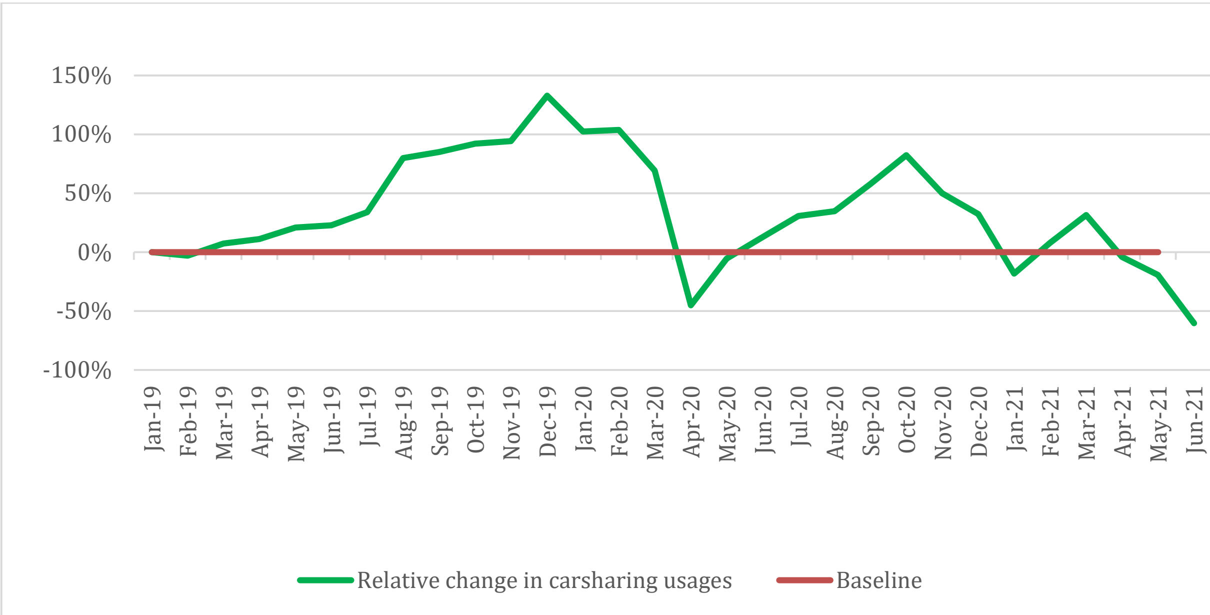


Figure 6-18 Relative change in carsharing usage

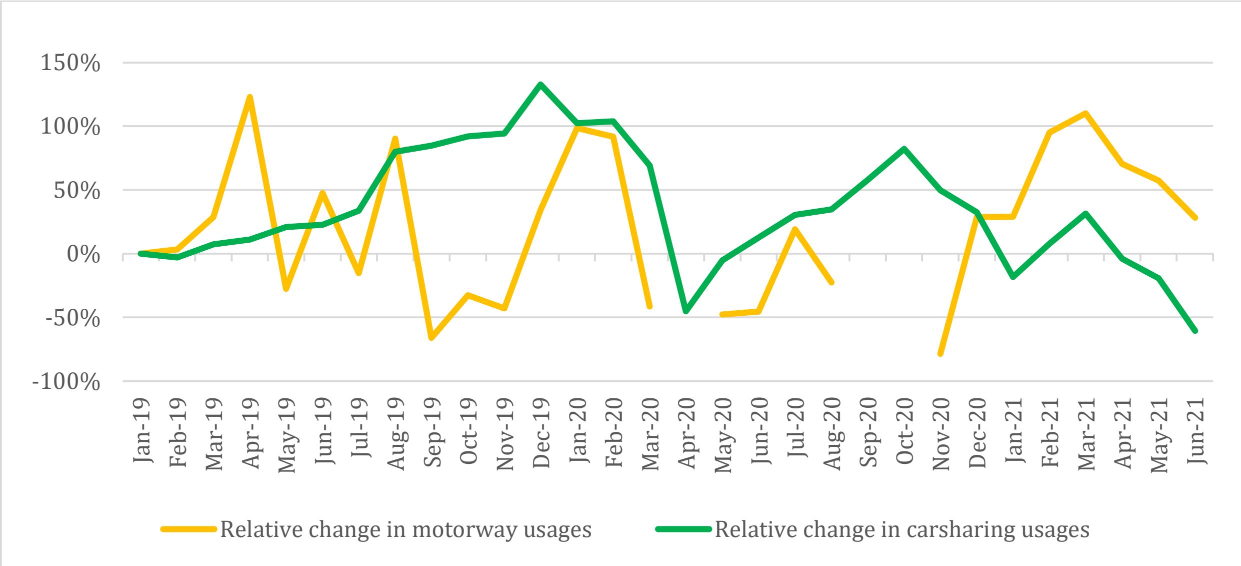


Figure 6-19 Percent change of traffic volume of Motorway and Carsharing usage

Note: Broken orange lines are due to missing monthly volume data.

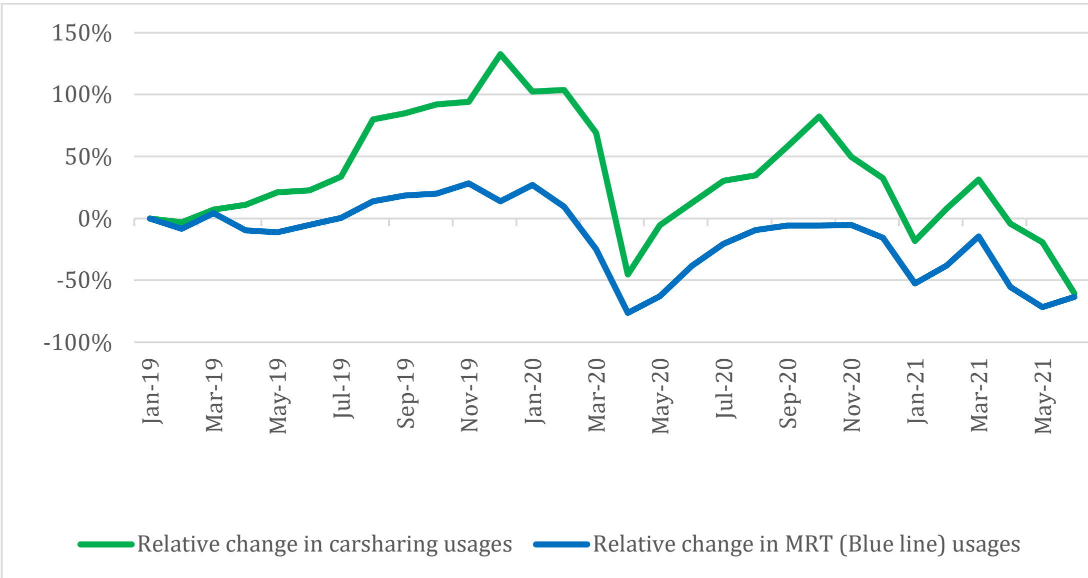


Figure 6-20 Percent change of ridership of MRT (Blue Line) and Carsharing usage

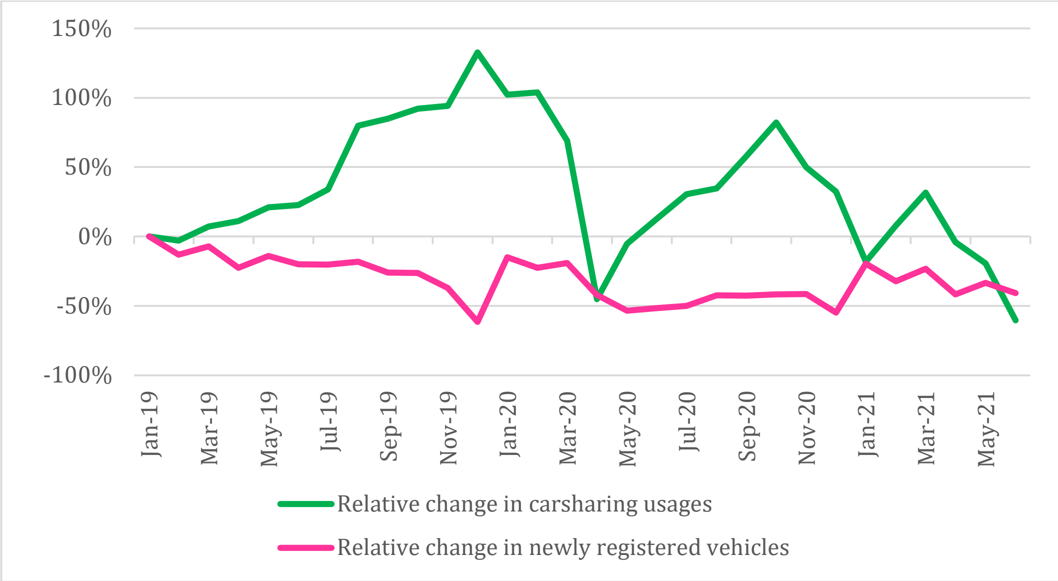


Figure 6-21 Percent change of number of newly registered vehicles and carsharing usage

CHAPTER 7 RESULTS AND CONCLUSION

In this section, we analyzed trip chain of carsharing user by number of destinations stop data and type of activities of users.

7.1 Carsharing activities during 4 phases

We analyzed carsharing usage data in 4 phases. The results described changes in activities that occurred before the outbreak and during each phase of the outbreak (see Figure 7-1). As a result, outdoor activities such as travel/religious activities, shopping and dining decreased in early epidemic (phase 1), while short duration activity such as errands increased from early epidemic (phase 1) as well as overnight stay activity.

After the early epidemic (phase 1), people have adapted themselves to deal with COVID-19 and government eased its measures. The outdoor activity increased from phase 1 and the change of activities in other phases increased and decreased according to the several of epidemic and measures from the government.

Figure 7-1 Percent of activity in each phase

7.2 Changes in activity time and duration

In this section, we discuss the distribution of the 5 activities by time of day and activity duration in each phase as follows:

7.2.1 Time of day of activity in each phase

We summarized the start time of activity in each phase as shown in Figure 7-2 to Figure 7-6. The activity distributions throughout time of day are not significantly different among 4 phases. However, it seems that during the outbreak phase all activities are dropped during the government curfew policy, except overnight stay activity.

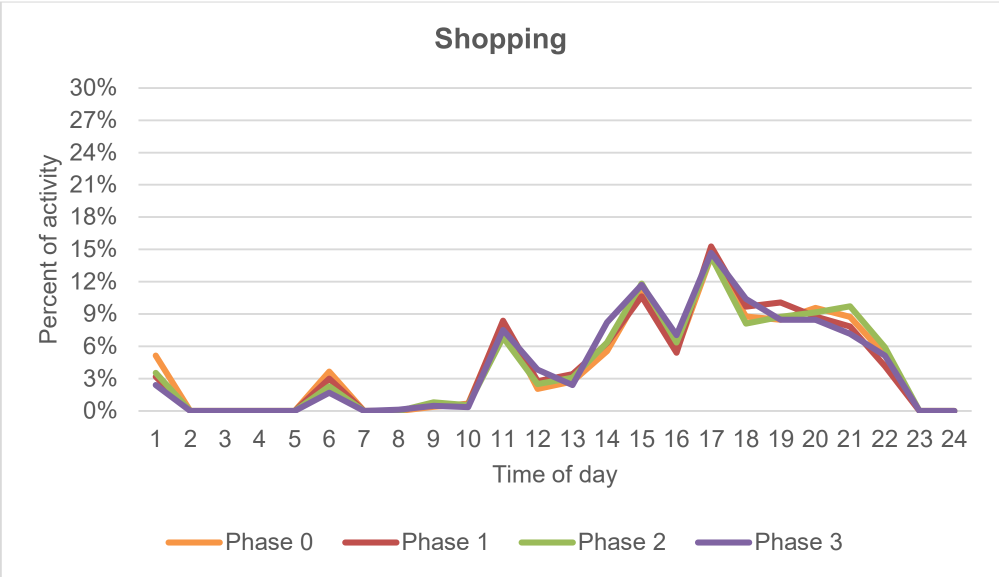


Figure 7-2 Start time of shopping

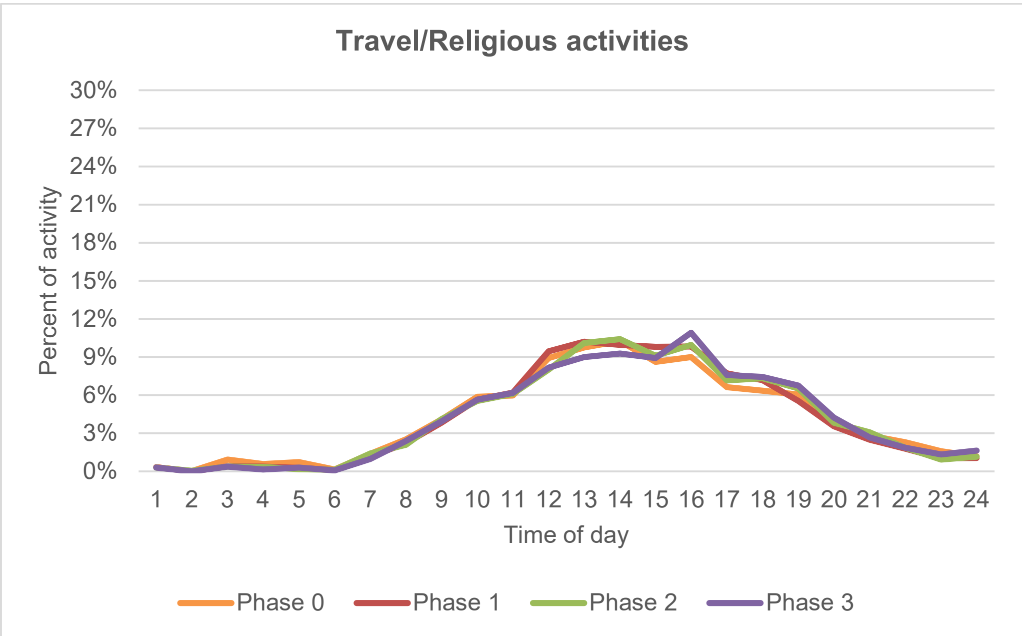


Figure 7-3 Start time of travel/religious activities

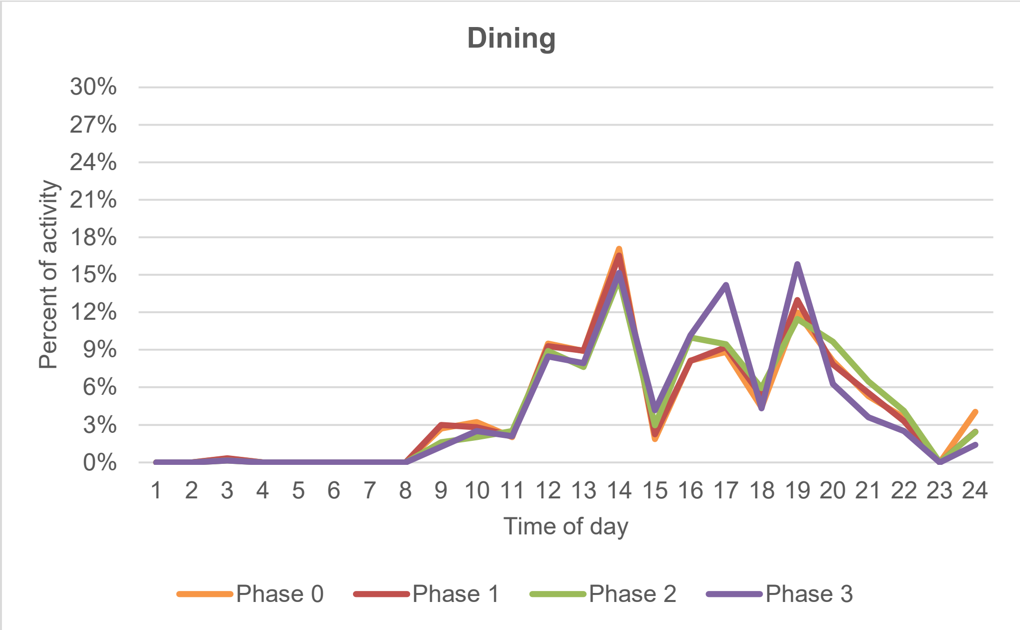


Figure 7-4 Start time of dining

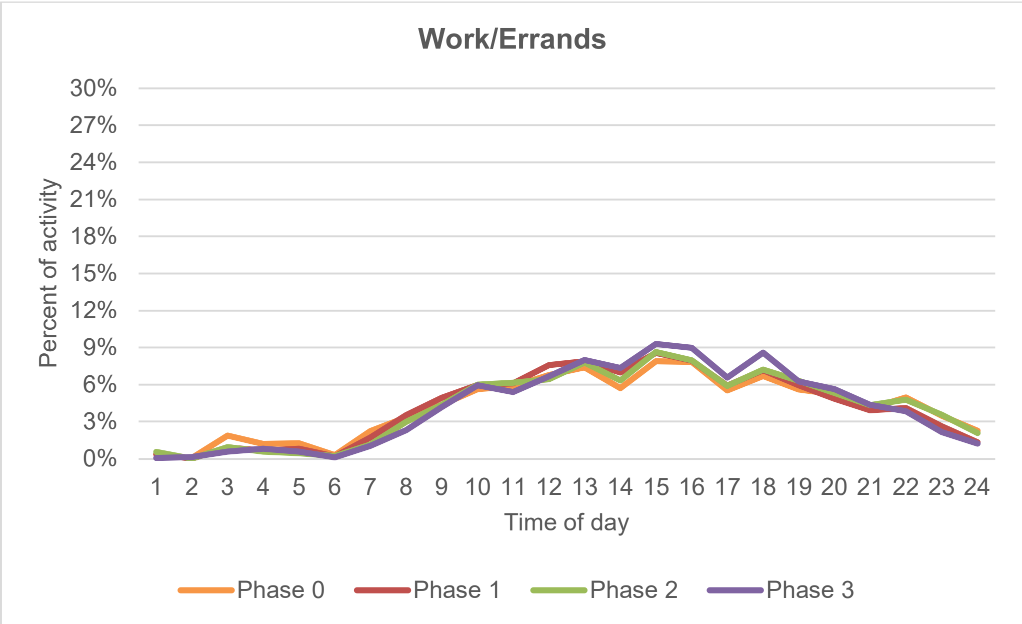


Figure 7-5 Start time of work/errands

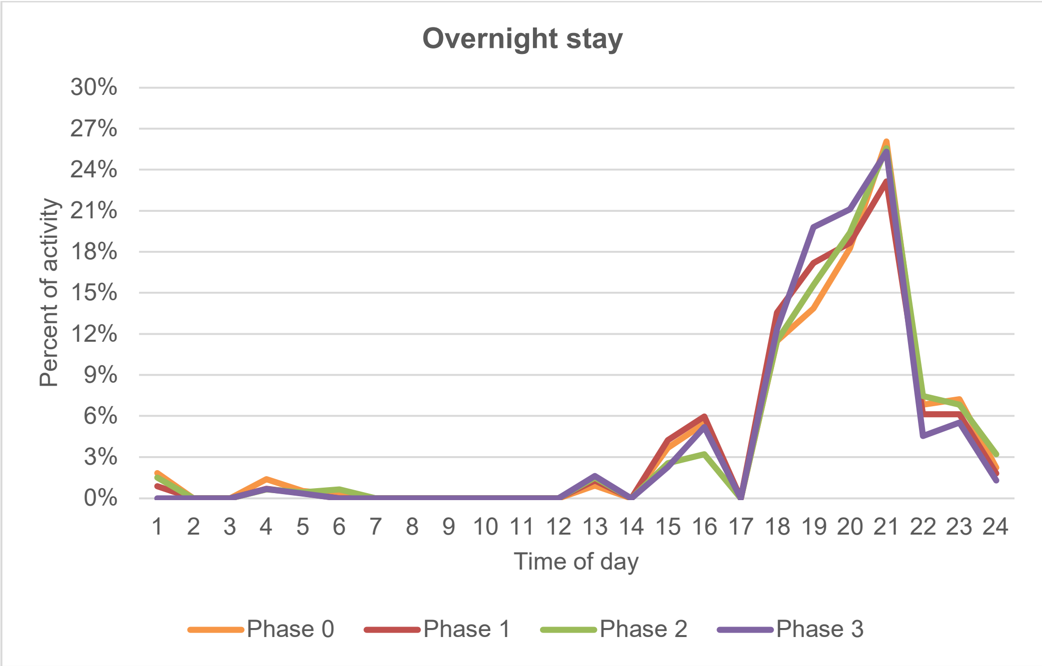


Figure 7-6 Start time of overnight stay

7.2.2 Duration of activity in each phase

We summarized the distribution of activity duration in each phase as shown in Figure 7-7 to Figure 7-11. The result is not different in duration.

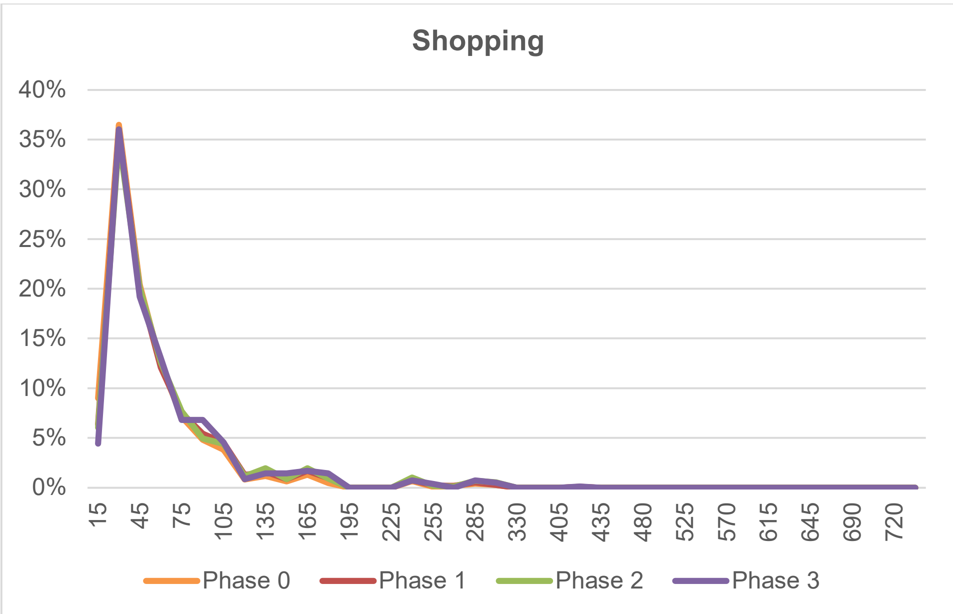


Figure 7-7 Duration of shopping

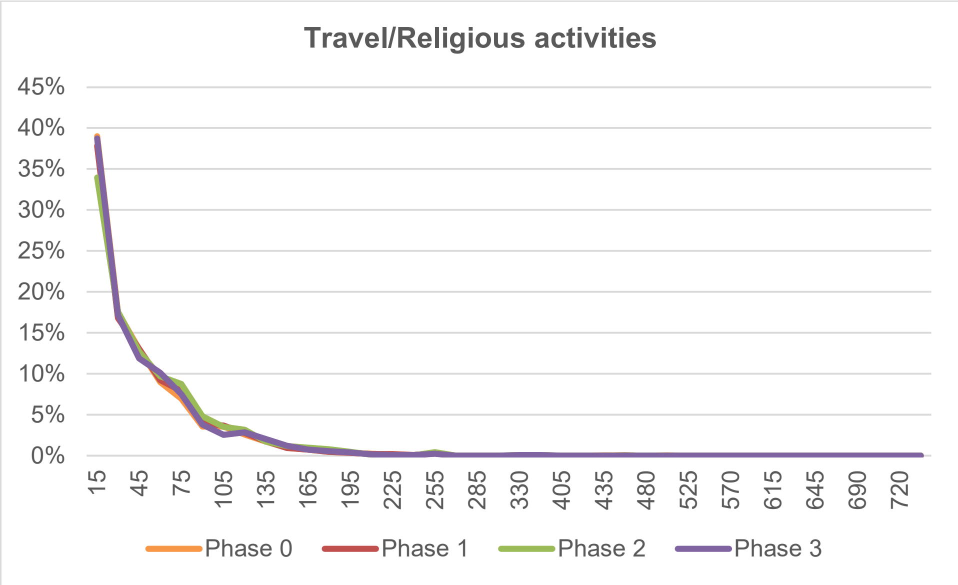


Figure 7-8 Duration of travel/religious activities

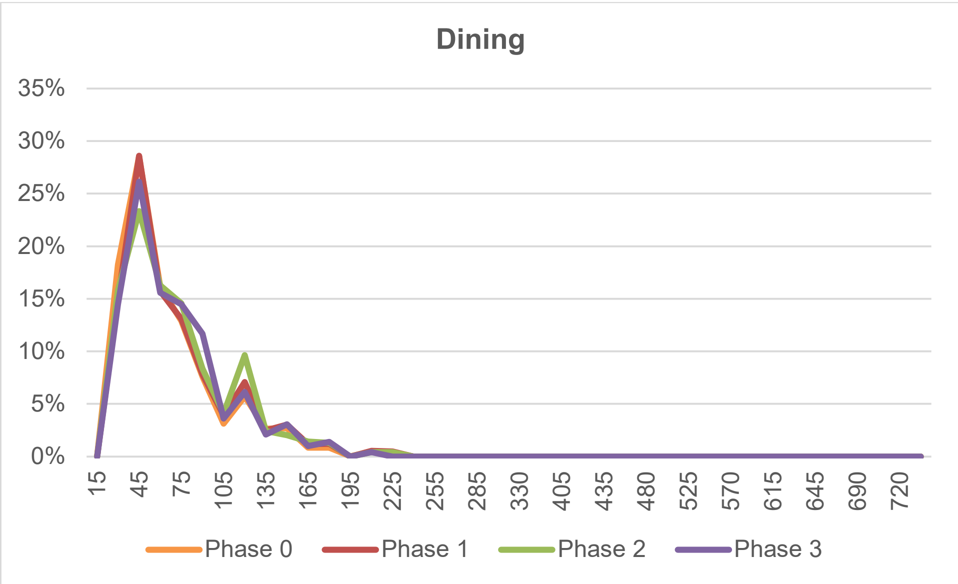


Figure 7-9 Duration of dining

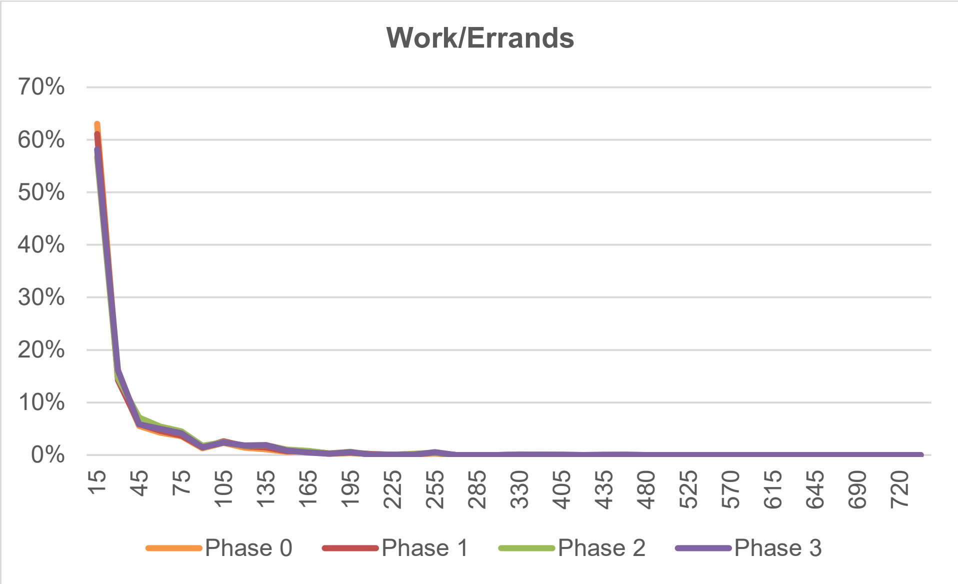


Figure 7-10 Duration of work/errands

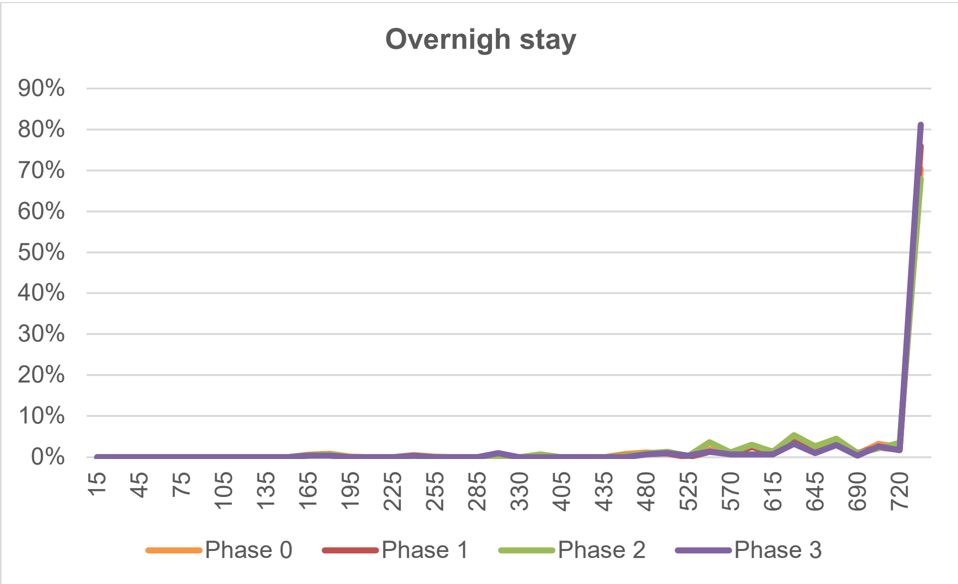


Figure 7-11 Duration of overnight stay

7.3 Activity in each phase

The number of activities in each phase is different. According to the severity of the epidemic and the government measure are shown in Figure 7-12.

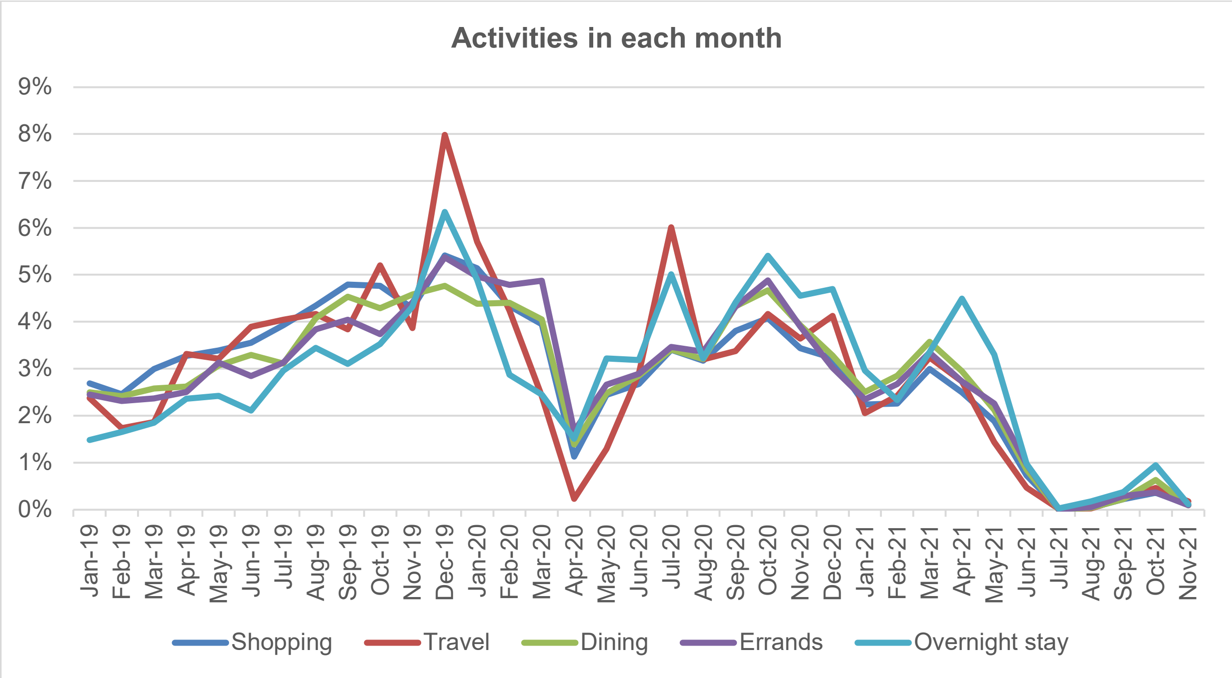


Figure 7-12 Activities in each month

7.4 Research Limitation

In this research, we capture the demand increase and decrease throughout the pandemic through the trip trajectory data collected by GPS on-board device. This research analyzed the changes in carsharing behavior between before and during the pandemic, rather than the causes of the changes. There are several factors affecting carsharing demand. The positive factors are such as the growth in carsharing adoption of Thai people and concerns of infection from other public transportation services. Negative factors are such as changes in travel behavior form e-commerce and work from home policy as well as increase in private car ownership due to concerns from using shared public transportation services. However, it is challenging to identify the causes of such demand change from GPS data.

CHAPTER 8 POLICY DEVELOPMENT

In this section, we detail the implications of our research's findings to policymaking and practice. The implications suggested here are also based on the outcomes and knowledge we developed from the previous ATRAN project (project number 2020/005) in 2020, in which the subject of our study was the operation of carsharing in Bangkok.

We identify the change in the travel behavior of our respondents that they are more likely to work from home as they try to avoid the risk of getting infected by COVID-19 during their commuting. However, should they need to travel – it appears that carsharing is one of the modes of transport that the respondents would consider as an alternative to public transport. As carsharing enable individual to access car at a lower cost, this preference may be an early indicator that there will be a wave of public transport user to shift toward the private vehicle. The shift could be detrimental to Bangkok city's effort to enhance the sustainability of its transport system. Particularly, if individual purchases a car and is lock-in to private car use.

The government can consider making carsharing more accessible and affordable by promoting the service and provide incentives for carsharing operations. An increase in carsharing fleets can help to delay commuters' decision to purchase personal cars until the pandemic subside or new vaccinations become available. Such as approach can also help introduce a new group of users to shared mobility and help to set a new trend in their sustainable consumption and behavior.

The government can also consider making new regulations and incentives to make it more favorable for employers and employees to enable working from homes, such as tax incentives or subsidies. Such new legislation and regulation can help to reduce the need for physical commuting, thus reducing peak-hour congestion, energy consumption, and environmental impacts associated with car travel. The pandemic appears to provide a window of opportunity for a change in the way people commute to work. This can be encouraged by the government's policy to support remote work. Also, the governments should encourage other travel options to increase the choice for the people, such as car sharing for the people by support to connectivity between carsharing and other transport services and promoting car sharing.

For carsharing operation, cleanliness of vehicle and its facilities need to be of a high standard. As the respondents expressed deep concern about the level of hygiene, service providers must ensure that this is of a high standard, this can be done by using different operational measures (e.g., self-cleaning robot, certified cleaning scheme, tracking and tracing) or information and marketing scheme to help to ease users and potential consumers' concerns. Disinfection measures such as the provider should be cleaned and disinfected daily, provide hand sanitizer or alcohol spray, etc.

Finally, the usage data show that there are changes in the way consumers use carsharing such as longer rental period. The service providers should analyze the data to adjust their tariff and promotions to ensure that the services can be adjusted to the change in consumer behavior during and after the pandemic phase. Other agencies can play a part in this to encourage or induce use of car sharing by jointly promoting carsharing with its businesses, such as tourism.

CHAPTER 9 RESPONSES TO IATSS COMMENTS

From the meeting on September 24, 2021, the IATSS advisors had several useful comments. We had responded each comment/question as shown in Table 9-1.

Table 9-1 Comments and questions from the committee members and advisors on September 24, 2021

Comments and Questions	Actions
Under the COVID-19 situation some users of car-sharing use more car-sharing or some other people who used to ride the public transport, tend to use car sharing. There are different two groups, I guess. How about the situation in Thailand? No newcomer? - Summarize newcomers and long-term users in your report.	We analyzed new users and long-term users by filtering the data from database and summarized the results in Section 6.10.4 In summary, there are 4,419 users during COVID-19 pandemic. 1,427 users (32%) are existing users, and 2,992 users (68%) are new users.
Compare the travel behaviors of private car users and also public transportation passengers. - For identify some specific characteristics of car-sharing industries.	We collected the data of demand of other transportation mode and describe in Section 6.10.5. The public transportation ridership and the carsharing demand showed a similar trend. The motorway traffic volume and the carsharing demand also have the similar trend. However, the new vehicle registration does not have the same trend as the carsharing demand.
Within two years, our perception and attitude toward COVID-19 have changed. Are you going to consider that change in our perception?	Yes, we considered the perception change in our questionnaire survey. The question of Part II – Impact of COVID-19 in the questionnaire were included to collect the changes in behavior due to COVID-19 (Section 4.1.2).
One reason why carsharing increase? Because of COVID-19 there is another reason, just the growth or spread of car-sharing services compared to other transportation modes. - Check the other transportation mode demand data Clarify the difference between these two changes in your interview.	We collected the data of demand of other transportation mode and describe in Section 6.10.5. The public transportation ridership and the carsharing demand showed a similar trend. The motorway traffic volume and the carsharing demand also have the similar trend. However, the new vehicle registration does not have the same trend as the carsharing demand. There are several factors affecting carsharing demand. The positive factors are such as the growth in carsharing adoption of Thai people and concerns of infection from other public transportation services. Negative factors are such as changes in travel behavior form e-commerce and work from home policy as well as increase in private car

Comments and Questions	Actions
	ownership due to concerns from using shared public transportation services. It is challenging to identify all the factors from the GPS data we have. Therefore, we addressed this in the research limitation section.
-Long-term behavior might affect the future policy.	We have addressed this comment by adding a question in the phone interview questionnaire. The question number 9 and 10. The result showed that 30 percent will use carsharing service to increase if the situation is stabilized with vaccine and effective medical treatments and 93 percent continue to use carsharing service if the spread of COVID-19 continues. (Section 5.2)
COVID-19 offset the car-sharing bubble; the influence of COVID-19 can be considered that it stabilized the car-sharing market. It's avoided the risk of a car-sharing bubble.	We think the carsharing market in Thailand has not reached its bubble situation yet. As there are only a few carsharing companies with less than a thousand carsharing stations. The services are also available mainly in Bangkok and not other major cities yet. But it is true that COVID-19 pandemic slowed down the carsharing demand growth.
Do you have any assumption or scenario on the future situations brought by COVID-19 based on which you will predict the future influence of COVID-19 on car sharing?	We have addressed this comment by adding a question in the phone interview questionnaire. The question number 9 and 10. The result showed that 30 percent will use carsharing service to increase if the situation is stabilized with vaccine and effective medical treatments and 93 percent continue to use carsharing service if the spread of COVID-19 continues. (Section 5.2)

From the meeting on February 25, 2022, the IATSS advisors had several useful comments. We had responded each comment/question as shown in Table 9-2.

Table 9-2 Comments and questions from the committee members and advisors during the final report presentation on February 25, 2022

From	Comments and Questions	Actions
Prof. Nakamura	How many seconds of GPS data (the interval of the time of GPS data) did you get? In the IATSS project this year, we used the GPS data collected in Japanese market, but the interval of GPS data is too long and it's really difficult to detect the purpose of the people's moving. I am just interested in your data interval.	The GPS data sampling interval in this project is 30 seconds to one-minute. This is sufficient to determine trip activity types in this study. The GPS data interval is described in Section 4.2.2.
	The main topic of today's presentation is your model you built for determining the purpose of the trip. I'm interested in whether your model can be applied to the situation after the COVID-19. If you have the GPS data, after the COVID-19, you can also determine the purpose of each person's trip, and you can compare the behavior change during the COVID-19 and post-pandemic. It's really useful to research on the situation during the pandemic, but our main focus will be the situation after COVID-19, which is related to the policy the government will consider. So I would like to ask you about the availability of your model in the post-COVID-19 situation.	Presumably, the carsharing users' behavior will change after the COVID-19 pandemic has lessened. The current algorithm can be used for the new GPS dataset. However, the probability matrix (section 6.5) will need to be updated to reflect the change in users' stop behaviors and POI distribution. The probability tables can be updated by interviewing carsharing users again for their trip purpose after the pandemic.
Dr. Yoshida	I would like to see data on changes in travel behavior during a pandemic. If we can find out what kind of people started to use car sharing and how the pandemic affected it, we can find out if they need government support.	We added a preliminary analysis to show the user's longitudinal data in section 6.10.4 (Data Description). However, to answer your question, we requested additional data from the carsharing company to check the user information who started using carsharing during the pandemic. We will update the report once we obtained data from the carsharing company.

From	Comments and Questions	Actions
Prof. Fukuda	Is it possible to compare movement of the same person before and during COVID19?	Yes, it is possible. We requested additional data from the carsharing company to check the user information who started using carsharing during the pandemic. We will update the report once we obtained data from the carsharing company.

References

Arellana, Julian, Luis Márquez, and Victor Cantillo. 2020. “COVID-19 Outbreak in Colombia: An Analysis of Its Impacts on Transport Systems.” *Journal of Advanced Transportation* 2020: 1DUMMMY.

Awad-Núñez, Samir et al. 2021. “Post-COVID-19 Travel Behaviour Patterns: Impact on the Willingness to Pay of Users of Public Transport and Shared Mobility Services in Spain.” *European Transport Research Review 2021 13:1* 13(1): 1–18. https://etrr.springeropen.com/articles/10.1186/s12544-021-00476-4 (July 13, 2021).

Calabrese, Francesco, Giusy Di Lorenzo, Liang Liu, and Carlo Ratti. 2011. “Estimating Origin-Destination Flows Using Opportunistically Collected Mobile Phone Location Data from One Million Users in Boston Metropolitan Area.” *IEEE Pervasive Computing* 10(4): 36–44.

Chalermpong, Saksith, and Sony Wibowo. 2007. “Transit Station Access Trips and Factors Affecting Propensity To Walk To Transit Stations in Bangkok, Thailand.” *Transit Station Access Trips and Factors Affecting Propensity To Walk To Transit Stations in Bangkok, Thailand* 7(April): 1806–19.

EIT. 2020. “COVID-19: What Is Happening in the Area of Urban Mobility | European Institute of Innovation & Technology (EIT).” https://eit.europa.eu/news-events/news/covid-19-what-happening-area-urban-mobility (February 10, 2021).

Filippo Lerro. 2015. “Car-Sharing Services: Users’ Behavior and Factors of Adoption.” https://www.researchgate.net/publication/283900323_Car-sharing_Services_Users’_Behavior_and_Factors_of_Adoption (June 10, 2021).

FutureBridge. 2021. “Impact of COVID-19 on Shared Mobility - FutureBridge.” https://www.futurebridge.com/industry/perspectives-mobility/impact-of-covid-19-on-shared-mobility/ (February 11, 2021).

Gkiotsalitis, Konstantinos, and Oded Cats. 2020. “Public Transport Planning Adaption under the COVID-19 Pandemic Crisis: Literature Review of Research Needs and Directions.” *Transport Reviews*: 1–19. https://www.tandfonline.com/doi/full/10.1080/01441647.2020.1857886 (February 11, 2021).

Guan, Lina et al. 2020. “Transport Effect of COVID-19 Pandemic in France.” *Annual Reviews in Control* 50: 394–408.

Hensher, David A. 2020. “What Might Covid-19 Mean for Mobility as a Service (MaaS)?” *Transport Reviews* 40(5): 551–56. https://www.tandfonline.com/action/journalInformation?journalCode=ttrv20 (February 11, 2021).

Irawan, Muhammad Zudhy et al. 2021. “Exploring Activity-Travel Behavior Changes during the Beginning of COVID-19 Pandemic in Indonesia.” *Transportation* (0123456789). https://doi.org/10.1007/s11116-021-10185-5.

Jenelius, Erik, and Matej Cebecauer. 2020. “Impacts of COVID-19 on Public Transport Ridership in Sweden: Analysis of Ticket Validations, Sales and Passenger Counts.” *Transportation Research Interdisciplinary Perspectives* 8: 100242.

Machado, Cláudia A.Soares, Nicolas Patrick Marie de Salles Hue, Fernando Tobal Berssaneti, and José Alberto Quintanilha. 2018. “An Overview Acof Shared Mobility.” *Sustainability (Switzerland)* 10(12): 1–21.

Shakibaei, Shahin, Gerard C. de Jong, Pelin Alpkökin, and Taha H. Rashidi. 2021. “Impact of the COVID-19 Pandemic on Travel Behavior in Istanbul: A Panel Data Analysis.” *Sustainable Cities and Society* 65(November).

Shokouhyar, Sajjad, Sina Shokoohyar, Anae Sobhani, and Amirsalar Jafari Gorizi. 2021. “Shared Mobility in Post-COVID Era: New Challenges and Opportunities.” *Sustainable Cities and Society* 67: 102714.

Vinitpittayakul, Kanjanawan, and Siradol Siridhara. 2018. “A Study of Shopping Trip Parking Behavior Using Choice Model.” *Suranaree Journal of Science and Technology* 25(3): 247–56.

Wang, Chihuangji, and Daniel Baldwin Hess. 2021. “Role of Urban Big Data in Travel Behavior Research.” *Transportation Research Record* 2675(4): 222–33.

WHO. 2021. “Coronavirus Disease (COVID-19).” https://www.who.int/csr/don/archive/year/2021/en/ (February 11, 2021).

Wielechowski, Michał, Katarzyna Czech, and Łukasz Grzęda. 2020. “Decline in Mobility: Public Transport in Poland in the Time of the COVID-19 Pandemic.” *Economies* 8(4): 78. https://www.mdpi.com/2227-7099/8/4/78 (February 10, 2021).

Wikipedia. 2021. “COVID-19 Pandemic in Thailand.” https://en.wikipedia.org/wiki/COVID-

Final Report

Research Grant 2021

ATRANS