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Research article

Mobility as a service for road traffic safety in a high use of motorcycle environment

Sippakorn Khaimook [a,*], Kento Yoh [a], Hiroto Inoi [b], Kenji Doi [a]

[a] Graduate School of Civil Engineering, Osaka University, Osaka 565-0871, Japan
[b] Faculty of Sustainable Design, University of Toyama, Toyama 930-8555, Japan

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ABSTRACT

Mobility as a service is expected to contribute to a safer, more efficient and sustainable transport by putting the right modes in the right places and connecting them intermodally. The aim of mobility as a service in a local context (MaaS-LC) is to build safety awareness and enhance road traffic safety, and it was developed by combining both a Safety Index and a Walkability Index. The Safety Index was derived from traffic accidents and volume data while the Walkability Index is the result of connections and places in the surroundings. As a case study, a trial experiment was conducted in Phuket, Thailand, which depicted the characteristics of the South and Southeast Asia region. The results showed that the usability and useful information on the MaaS-LC application could influence and change the travel behavior of people. Moreover, the difference between transit users and private vehicle users was how they considered walkability. This study concluded that this app could raise people's safety awareness. Nonetheless, it has yet to show an influence on people regarding their choices of transportation.

1. Introduction

With the economic growth in the South and Southeast Asia region in recent years, the inevitable consequences have been urbanization and motorization. As cities get bigger, car ownership grows as a consequence. Road infrastructure development, then, is focused on accommodating the rising demand for transportation and alleviating the traffic congestion dilemma. Nonetheless, most of the road infrastructure has been designed to prioritize vehicles of four wheels or more, at the expense of vulnerable road users like pedestrians, cyclists, and motorcyclists. Consequently, according to the WHO's road safety report [1], among 316,000 global road traffic deaths each year, about 20% occur in South and Southeast Asia with the largest portion of deaths in the region are among motorcyclists (34% and 43% in 2013 and 2016, respectively) as shown in Fig. 1. Considering the majority of countries in regions where there are low and middle-income countries, a fast and affordable mode of transport like a motorcycle easily becomes the most dominant mode of transport. These make up 75% of all SE Asian registered vehicles for 2014. Without alternative means of transport such as public transportation and proper road safety legislation and regulation, this trend will continue.

In order to reduce both traffic congestion and accidents, public transportation improvement always comes up as one of the solutions. It might not solve both problems directly, but the fact is that increasing the number of passengers on public transportation does not always mean having more traffic congestion. Better yet, the travel time is likely to be the same because it would take the same amount of space on roads. This is unlike any other mode of transport for which the number of people who move from place to place and the road space needed to conduct them are directly correlated. Thus, finding a way to make public transportation more efficient is likely to be the key to achieving our goal.

2. Literature review

Recently, there have been many changes, among which are smartphone advancements that have made them much more powerful, affordable, and ubiquitous. Everything is evolving around this and toward taking advantage of new opportunities now available to people. Additionally, urban lifestyles have become preferred by younger generations rather than living in suburban or rural areas. As a result, cars are not as necessary as they once were [2]. These changes are forcing the

* Corresponding author.
E-mail addresses: khaimook.sippakorn@civil.eng.osaka-u.ac.jp (S. Khaimook), yoh.kento@civil.eng.osaka-u.ac.jp (K. Yoh), inoi@sus.u-toyama.ac.jp (H. Inoi), doi@civil.eng.osaka-u.ac.jp (K. Doi).
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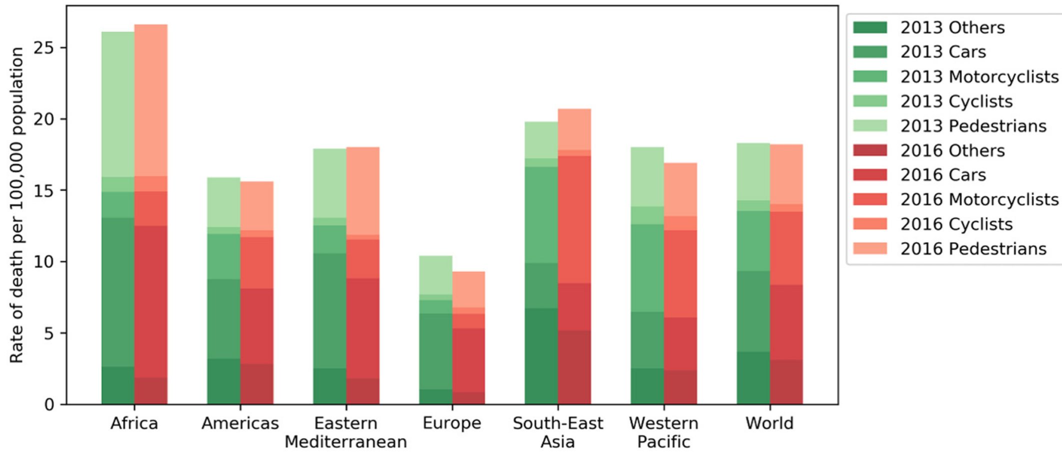

Fig. 1. Road traffic deaths per 100,000 population by WHO.

transport sector to adapt and embrace the new opportunities as well. Traditionally, there was no level of integration between transport providers resulting in inefficiency for both providers and customers. Recently, transport integration has started to remove obstacles between transport modes for better utilization [3]. This trend is moving from basic integration toward such as cooperation between agencies to provide discounts and a universal smartcard to access all modes. Ultimately, projections include Mobility-as-a-Service (MaaS) by which everything could be done in one single application including planning multimodal trips, paying tickets or fares, and even subscribing to a bundle to use unlimited transit, bike, taxi, and rental cars [4]. Recent findings also support the notion that mobile applications (apps) could significantly change travel behavior [5], particularly with a high level of engagement [6] and that MaaS has the potential to influence travel preferences, especially for those who are young and comfortable with advanced technology [2,7,8].

While MaaS is an idea for uniting many modes of transport and providers through a single portal, MaaS options have been categorized by their level of integration, herein defined as: (1) Level 1 provides integration of information, (2) Level 2 adds payment integration, (3) Level 3 adds to the other levels of service, the option of service bundles, and last, (4) Level 4 includes integration of transport with societal goals such as those usually tightly coupled with local or higher policies [9]. Currently, Whim is one form of Level 3 MaaS. It has been operated in Helsinki, Finland since 2016 and offers bundles including public transportation, taxis, rental cars, and bikes. Whim officials have reported that users have already booked 3 million trips [10] and that it will be expanding to other places, including both North America and Asia [11]. Mobility Shop is another Level 3 MaaS with a subscription cost of 9.95 EUR. Mobility Shop has been operational in Hanover, Germany since February 2016, has 28,000 registered users, and is adding 1500 new users every month [12]. There are many MaaS apps with payment integration (i.e., Level 2) such as Tuup, My Cicero, Moovel, and WienMobil Lab. All of these apps offer public transportation and some other modes or perks for car owners, like parking [13]. A trip planner app like Google Map belongs in a Level 1 MaaS, providing information integration. At this level, it is significantly different than higher levels of integration because it is unlikely to have any quality of service involvement.

Within the context of South and Southeast Asia, the main issues are lack of provisions for information. This forces people to use private vehicles and to overuse motorcycles as door-to-door movement solutions. It would be better to use motorcycles only for last-mile transport due to their vulnerabilities (e.g., accidents and exposure to weather). The study by Fenwick et al. [14] showed that safety is one of the factors that make public transportation preferred over private vehicles and Doi et al. [15] found that for a transition to safer streets, risk recognition and safety awareness were important. MaaS in a local context (MaaS-LC) has the aim of resolving this issue in South and Southeast Asia.

In this study, we developed MaaS by combining two indicators. First, a Safety Index would let people know how safe each trip is at a glance. Therefore, they could decide if transport being considered is worth the risk or if they should find a safer alternative. Second, the Walkability Index would tell people how walkable the destination area is, so that they could have a better last-mile experience. It was expected that our app would be able to enhance the safety awareness of travelers and let them have a better and safer travel experience than before MaaS.

3. Methodology

3.1. Local context and MaaS architecture

As a study area for MaaS-LC development and experimentation, Phuket in Thailand was selected because Thailand is an extreme case as far as road traffic issues are concerned. Thailand leads the world in the number of road accident deaths (fatality rate of 36.2 per 100,000 population) while the global rate is 17.4. Phuket, which is one of the biggest tourist attractions in Thailand shares the same characteristics. For the past seven years, as shown in Fig. 2, accidents have increased >1.8 times and in 2018, 86% of those accidents were motorcycle related. Moreover, 87% of road traffic deaths in 2018 involved motorcycles. Furthermore, although there is public transport all over the area, their efficiency of provision is low. The primary choices of transport for local people and for tourists are private vehicles and rental cars. For these reasons, we aimed to provide MaaS-LC as a countermeasure and see the effect it might have under such conditions. In this trial experiment, we named the application GoTH.

The data used in this study consisted of traffic accidents, traffic volumes, points of interest, and public transportation as shown in Table 1. First, traffic accident data were collected under the name of Thai Road Safety Collaboration (ThaiRSC) by Road Accident Victims Protection Co., Ltd., which is Thailand's insurance agency association. Accidents were recorded as either no-fault or fault claims categorized by vehicle type, brief accident description, location, time, and whether fatal. Second, the traffic volume data were provided by the traffic surveillance CCTV system operated by Thailand's National Electronics and Computer Technology Center (NECTEC). The system was capable of both identifying vehicle types and counting traffic volume. However, the coverage included only trunk roads. Third, point-of-interest data were collected from multiple sources including OpenStreetMap, GeoNames, and GoodWalk.org. Last, public transportation data were initially collected from permit documents from the Department of Land Transport (DoLT). However, those documents were outdated and inaccurate. As a result, new data collection had to be performed because

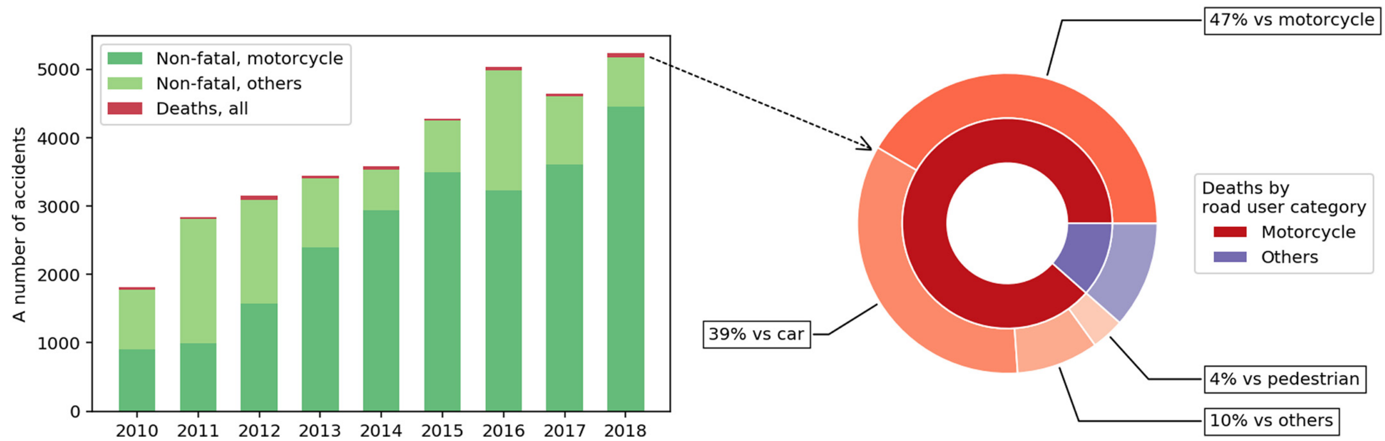

Fig. 2. Accidents and road traffic deaths related to motorcycles in Phuket.

there was no such data available elsewhere. The collection started by asking transit agencies directly to record manually all the information needed. It took >5 days and 400 km driving to obtain the final routes and stops.

The architecture included a user interface able to interact with users and many services, as shown in Fig. 3. Most of the MaaS services were similar to others; however, GoTH introduced two unique services to target local issues: the Safety Index and Walkability Index.

3.2. Safety Index

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

In practice, there was no trip that consisted of only a single road segment and the probability of an accident on each road segment (E_s) was mutually independent. As a result, the Safety Index of a trip was the probability of not having accident, calculated using the probabilities for each road segment ($1 - E_s$).

$$E_s = \frac{A_{is}}{V_{is}} \tag{1}$$

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

where E_s was the probability of having an accident on each road segment (s)

A_{is} was the number of accidents for a vehicle type (s) on a road segment (i)

V_{is} was the traffic volume for a vehicle type (s) on a road segment (i)

The Safety Index was provided as a 5-point grading system (i.e., A, B+, B, C+, and C) that required little to no knowledge to interpret, as shown in Table 2. A Natural Breaks (Jenks) classification was used to arrange risk values into groups (Fig. 4). The reason why Jenks was used was to minimize variation within each group and maximize variation between groups, which served well the purpose of the Safety Index. The results are shown in Figs. 5 and 6.

3.3. Walkability Index

From the assumption that a willingness to walk the last mile was on the most influential factors on the lower ridership of public transport in Thailand, the Walkability Index was introduced. It helped examine the sensitivity of walkability to the choices of transport mode and also measure how walkable the area was overall. This index included multiple factors such as transit connectivity, interesting surroundings, level of comfort, and how safe the area was for pedestrians. Each factor had its own scale of 0 to 1 as shown in Table 3, and the overall average of these four factors was the Walkability Index.

The study area was not a big city, thus transit choices were available but limited. Transit connectivity would be closer to qualitative than quantitative. For other factors, the scale was quantitative. Interesting surroundings showed how dense business (including shops, cafes, restaurants, hotels, etc.) was in the area. Next, according to the TCRP Report 165 [16], 80% of transit users walked 400 m or less to the bus stops, to a maximum of 800 m. As a result, the level of comfort showed how comfortable (from 0 to 1) it was to walk based on distance from 800 m to 400 m, respectively. Last, the Safety Index represented how safe the streets were for pedestrians by considering accident statistics that involved pedestrians.

The formula used to calculate the Walkability Index was

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

where W_t was transit connectivity value
W_i was interesting surroundings value.
W_c was level of comfort value.
W_s was safety value.

Table 1
Data used in this research.

Data type	Total
Traffic accident in 2018	5231
Traffic volume in 2018	
Motorcycle	18,168,952
Car	20,306,458
Pickup	10,331,351
Van	4,419,123
Bus	1,275,455
Truck	2,836,076
Point of Interest	
OpenStreetMap	2039
GeoNames	1886
GoodWalk.org	12,413
Public transportation	
Agency	6
Transit line	16
Stop	412

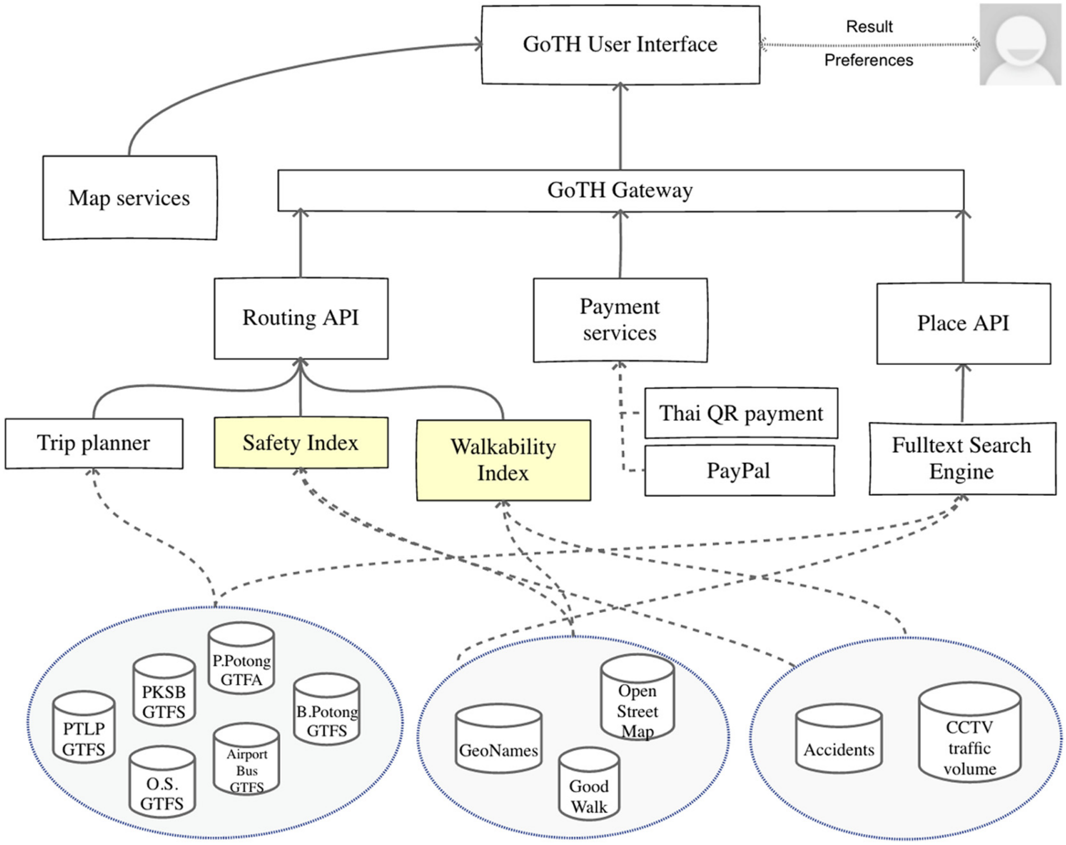

Fig. 3. MaaS-LC architecture.

3.4. User survey

A survey was conducted in Phuket by interviewing people at the airport and in downtown Phuket, and also by distributing questions to students at Prince of Songkla University, Phuket Campus. Participants were asked to try GoTH for a couple of days and then completed the questionnaire. Questions focused on how usable the application was and whether the information would be useful in order to pick any mode of transportation. The survey consisted of three main sections: (i) personal background regarding trip planner applications and MaaS, (ii) usability and usefulness of GoTH, and (iii) public transportation and safety awareness. Each section is described below.

First, the personal background section included sex, education, current choice in transport mode, familiarity with mobile applications, especially trip planners and MaaS in general, and also expectations regarding the MaaS features. Second, the usability section inquired about how easy it was to navigate within the app, whether the information the app provided was new or useful, and also the level of user satisfaction. Last, the awareness section included a user's point of view before and after using the app, and factors that influenced decisions before picking one trip over another, including time, cost, safety, or walkability.

Table 2
Safety Index scale.

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

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

4. Results of the trial experiment

4.1. Trial experiment using the GoTH app

GoTH was a web application and supported responsive design that could adequately adapt itself to suit either a large or small screen on computers and phones. This was supposed to enhance usability and lower the barrier for people to try it out. GoTH features were (i) finding places, (ii) finding directions from place to place, and (iii) comparing each trip by mode, time, cost, safety, and walkability.

There were things to consider before picking the trip, which included trip start time, trip duration, line, fare, Walkability Index, and

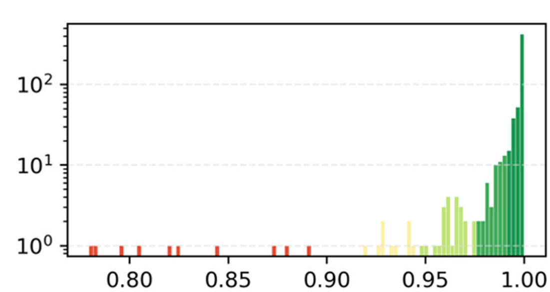

Fig. 4. $(1 - E_s)$ Histogram.

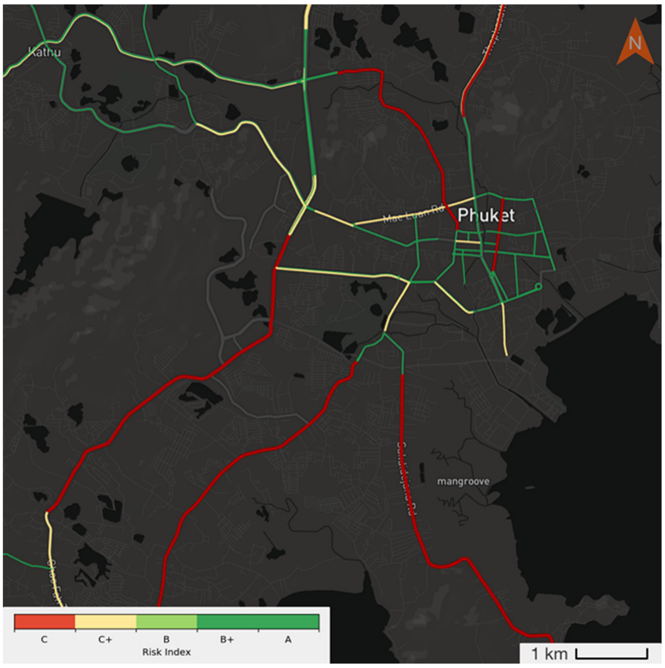

Fig. 5. Safety Index for motorcycles.

Safety Index. For example, in Fig. 7, the first choice seemed to depart from the airport soon and would take about 70 min to the Patong Beach area and have a fare of 50 THB. Both Walkability and Safety indexes were great, while the second choice was likely to be the next one available, in around 40–50 min. This trip would cost more (140 THB) and would take a bit more time (76 min) to reach the destination. There was no difference as far as walkability and safety were concerned. The reason why the Safety Index here was A is because, according to the statistics, bus accidents rarely happen in the Phuket area (in most places). Consequently, risk values were very low, so the Safety Index was as its highest value. The walkability around the beach was within

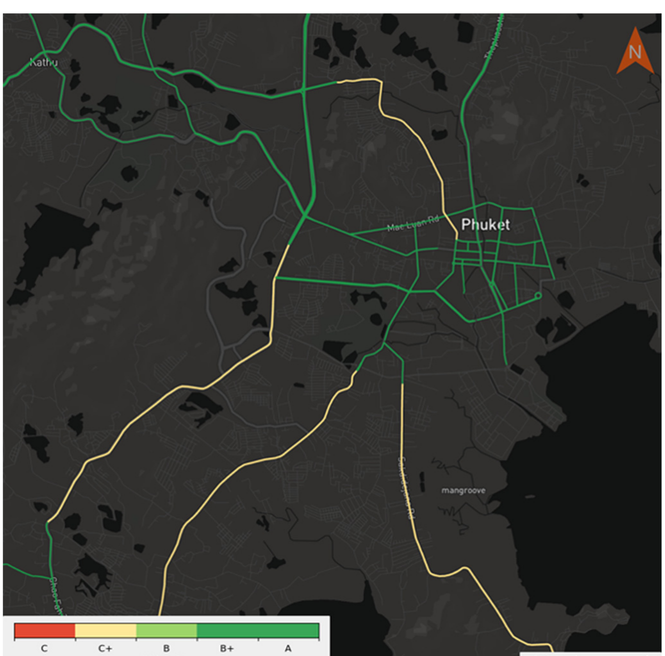

Fig. 6. Safety Index for cars.

Table 3
Walkability factor scale definition.

	Scale	Definition
Transit connectivity	0	No transit available
	0.5	Viable transit connectivity, meaning there is at least 1 choice of transit available
	1	Good transit connectivity, meaning there are at least 2 choices of transit and average headway of 20 min or less
Interesting surroundings	0	No businesses around
	1	The highest density of business in the study area
Level of comfort	0	Walking distance is 800 m or more
	1	Walking distance is 400 m or less
Safety	0	The highest density of pedestrian accidents in the study area
	1	No accidents

a comfortable distance, had great business availability, and many transit options. Thus, the Walkability Index was also at its highest value.

4.2. User evaluation and awareness-related changes in behavior

Out of 181 people, which the questionnaire had been initiated, 105 participated in the first section and 69 participants completed the survey including taking time to try the app. According to the personal background section, the results (Table 4) showed that 60% of participants were in the age group 20–29, and 52% were local people. A majority, 65%, used their own vehicles, with which their daily commute took over an hour. While almost all participants (88%) were familiar with a trip planner, Google Maps in particular, they did not use the app on a regular basis. Most (87%) participants found that finding directions was the most useful feature. Comparison of directions and time was the second most useful feature, according to almost 60% of participants. A real-time bus location was the least useful feature, appealing to 1.4% (exactly 1 participant).

After giving GoTH a try, the results (Table 5) showed how usable and useful the GoTH was as follows: 68% of participants found that this app was easy to use and 59% wanted to continue using it after the trial ended. In contrast, a large minority (45%) did not find this app provided any more useful information than they already knew; however, 42% agreed that this app gave information they could not find anywhere else. Regarding how accurate the time and cost information in the app was, although 46% found the app was good, half of the participants either found that it was inaccurate or did not care to check.

In the last section, the results (Table 6) showed that half of the participants found that buses were an inferior choice compared to other modes; only 27% took a bus based on the information this app gave. This app suggested that 39% of users switch to another route or transport mode because there were better alternatives. In addition, a majority of participants started to think of safety (78%) and walkability (80%) in order to select their trips.

A chi-square test of independence was performed against pairs of the survey. The results (Table 7) showed there was statistical significance for relationships between app usability and traffic behavior change ($X^2 = 15.869$, $p = .000$), recognition of safety ($X^2 = 6.948$, $p = .008$), and application usage retention ($X^2 = 8.729$, $p = .003$). This implied that the usability of the app was important because it had an influence on all three values. Similarly, if users thought the app provided useful information (Table 8), this would influence both retention rate ($X^2 = 16.864$, p $= .000$) and a change in traffic behavior ($X^2 = 4.305$, $p = .038$). The result additionally revealed that walkability was one of the factors considered by people who decided not to take public transportation ($X^2 = 7.591$, $p = .006$). This could imply that areas having a low Walkability Index would be avoided by people in transit (Table 9).

The most negative feedback for the app was about search results for particular places (specific Points of Interest data). Participants found that this app lacked adequate information in this area and,

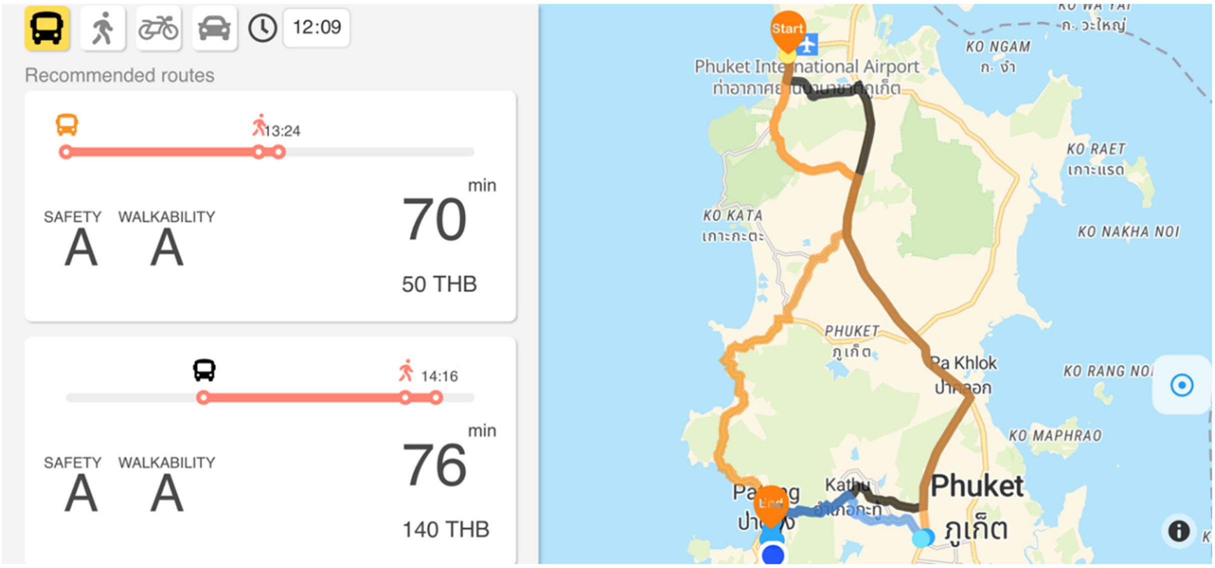

Fig. 7. Example of route recommendations (from the airport to Patong Beach area).

consequently, that they could not find places they wanted to go, including hotels and tourist attractions. The other significant feedback was about language: GoTH only had an English interface. While English seemed to be a good balance between users who included local people and tourists who were both foreign and Thai, Thai people wanted the app in Thai.

5. Discussion and conclusions

In this study, a MaaS application to begin transitioning to safer travel choices was developed and had a trial experiment in Phuket, Thailand. The area has characteristics that well represent the South and Southeast Asia region, especially regarding motorcycles, which are involved in the majority of accidents and road traffic deaths. From the experiment, the results showed that the usability of the app and useful information could elicit changes in the travel behavior of users. Walkability was also a key difference between those using public transit and those using private vehicles. Although the app did raise safety awareness, it did not show sufficient influence over people that they would utilize public transportation in their commutes. One of the reasons for this could be that motorcycles were the primary means of transport available. They were the most convenient choice and would take the shortest time from door-to-door, particularly compared to mass transit. Additionally, to increase influences, the app might need to supply some incentives to secure more reasons people would open the app.

Therefore, if we want people to break their habits based on this app, it will have to improve in many ways in the future. First, the data accuracy must be sufficient to gain the trust of the people; then, we might expect more popular engagement. Second, attractive reasons must be provided for people to use MaaS, such as ticket or bundle offers that would either give users more comfort or better solve their problems. Third, the usability of the app would need to improve. This is because the result revealed that the easier an app is to use, the more influence

Table 4
Survey results.

Demographic	Percentage of total
Age	
<20	23.2%
20–29	60.9%
30–39	4.3%
40+	11.6%
Tourist	
Yes	47.8%
No	52.2%
Primary mode of transport	
Private vehicle	65.2%
Public transportation	34.8%
Weekly travel expenses	
<200 THB	14.5%
<500 THB	18.8%
500+ THB	66.7%
Familiarity with MaaS or any trip planner	
Google Maps	80.0%
Apple Maps	8.4%
None	11.6%
MaaS or trip planner usage frequency	
Everyday	7.2%
5 days a week	2.9%
<3 days a week	17.4%
Once in a while	66.7%
Not at all	5.8%

Table 5
Application evaluation results.

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

Table 6
Changes in awareness and behavior from using the application.

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

Table 7
Chi-square test of independence between app usability and others.

		I want to continue using this app		Have you taken a bus following this app?		Have you thought of safety when choosing trip?	
		Yes	No	Yes	No	Yes	No
The app is easy to use	Yes	36	11	18	29	42	5
	No	5	17	1	21	12	10
		X^2=15.869, p = .000		X^2=6.948, p = .008		X^2=8.729, p = .003	

Table 8
Chi-square test of independence between useful information and others.

		I want to continue using this app		Have you changed the route or traffic mode because the app provided good trip options	
		Yes	No	Yes	No
This app provides useful information	Yes	26	3	16	13
	No	15	25	11	29
		X^2=16.864, p = .000		X^2=4.305, p = .038	

Table 9
Chi-square test of independence between walkability and decision not to use transit.

		Have you changed your mind not to use a bus because you found using a bus worse option than others?	
		Yes	No
Have you thought of walkability when choosing trip?	Yes	33	22
	No	2	12
	X^2 = 7.591, p = .006		

the app can provide. Last, better collaboration with all parties is required to ensure timely service alerts and data updates.

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