Assessing Driving Behavior in Macau Public Transportation Through Mobile Crowd Sensing: A Study of the Macau Bus Passenger Profile

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Abstract. This paper is part of a long-term research project on Advanced Public Transportation System (APTS), taking place in Macau, a city ranked 8 in the list of the world's most overcrowded cities as at September 2016 [1]. At this stage, a study of Macau's bus passenger profile is presented, based on their mobility method and pattern, their view of bus services and bus drivers' driving behavior and their own driving profile. Data was collected using a comprehensive online questionnaire survey with close-ended questions. The goal of this survey is to characterize the profile of the bus passengers in Macau, in particular their risk perception towards driving behavior. Statistical clustering analysis has demonstrated that risk perception is dependent on age, driving experience and other social factors.

Keywords: Driving behavior · Risk perception · Crowdsourcing
Mobile Crowd Sensing · Bus passenger profile
Advanced Public Transportation System · Smart city

1 Introduction

Macau is a special administrative region in China since the 20th December 1999. Macau has land area about 30.5 sq. km and population around 644,900 as at 2016 [2]. The lane length of public roads in Macau is just about 427.4 km long as at 2016 [2]. Thus, the transit distance in Macau is short. The available public land transportation system in Macau consists of bus, pedicab, taxi and casino shuttle bus, with the bus being the most popular and common. Nevertheless, Macau has approximately 250,450 licensed motor vehicles running around as at 2016 [2], which leads Macau into a

scenario of heavy traffic congestion and results in long traveling time inside over-crowded bus. Since this problem of traffic jam is raising, Macau Government is devising some solutions, which include, for example, the construction of a Light Rapid Transit (LRT). However, it is safe to argue that even after the conclusion of LRT, buses will continue to be one of the main transportation systems and bad traffic conditions will continue to promote conflicts between bus driver and passenger.

This paper follows the studies of [3], the concept of assessing driving behavior in Macau public transportation through Mobile Crowd Sensing. As the bus passenger is the one who assess the driving behavior of Macau bus drivers, this paper presents a survey that analyzes the profile of this target group aiming at understanding their profile, their commute method and pattern, their view of bus services and bus driver's behavior, the current satisfaction level of bus driver, their risk perception or safety level when taking a bus and their intention to install an app that can assess driver behavior that may result in improving the bus driver behavior. This survey is based on the data analysis from a questionnaire that covers different perspectives from people in Macau (a copy of the questionnaire can be found in [4]). [5, 6] are two similar studies of the bus passenger in Malaysia. To our knowledge, there is not a similar study conducted in Macau.

Risk Perception towards the bus drivers' driving behavior is also addressed in this paper. According to [7], risk perception is defined as the subjective judgment that people make about the characteristics and severity of a risk. Other papers related to risk perception in road accident can be found in [8–10].

This paper is organized as follows: it starts with the introduction of the survey development, followed by the survey methodology. Then, the results of this study are presented. Finally, a short conclusion of this study is discussed.

2 Methodology

In order to survey the population of Macau regarding their urban mobility habits, a questionnaire was created and distributed via different internet platforms, from 17th June 2017 to 7th July 2017. The data was gathered anonymously. It consists of five parts, namely demographic profile, urban mobility profile, bus passenger profile, driver profile, and respondent characterization towards driving behavior. There are three goals of this survey, the first one is to understand the bus passenger satisfaction level of bus services in Macau. The second goal is to find out their risk perception upon taking bus. The third goal is to obtain their intention in installing an application to assess the bus drivers' driving behavior in their mobile devices. This survey is totally based on an anonymous questionnaire so that respondents can answer sensitive questions, such as negative responses on bus service, freely. Otherwise, we could incur in social desirability bias or end up with most of the questions not being answered. The following sections will illustrate the design of the questionnaire (Sect. 2.1) and distribution channels (Sect. 2.2).

2.1 Questionnaire Design

This questionnaire consists of five parts. In sequence, they are: demographic profile, urban mobility profile, bus passenger profile, driver profile, and respondent characterization towards driving behavior.

Demographic Profile: It consists of seven questions include the respondents' identification, how long they have been living in Macau, gender, age, marital status, work status, and salary. All of them are multiple choice questions.

Urban Mobility Profile: This part consists of three questions that study both the usual commute and non-commute method of the respondents. They are check box questions. In addition, the favorable way to commute trip is asked in the form of multiple choice.

Bus Passenger Profile: This part gathers data of Macau bus passengers including frequency in taking bus, what hours in taking bus, bus service satisfaction level, things that like when taking a bus, things that dislike when taking a bus, safety level of taking a bus and main concern when taking a bus. There are altogether seven questions. Both multiple choice and check box are used in this part.

Driver Profile: This part is to gather driving information of the respondents. It collects five data: the respondents with driving license or not, type of their driving license, time period of holding the license, information of owning vehicles and if they have caused any accident as driver. The purpose of this part is to understand the correlation of the respondents who have driving license, how they use public bus, and how they comment on it.

Respondent Characterization Towards Driving Behavior: This is the last part of the questionnaire. There are only two questions. We simply want to learn how the respondents understanding the term aggressive driving behavior, and to see their intention to install an application in their mobile devices for assessing bus drivers' driving behavior.

2.2 Distribution Channels

This questionnaire was created in the Google Forms service and distributed through the internet, by emails, WeChat messages to friends, groups and moments; and Facebook posts in pages such as MacauBus Fans [11], and other community groups.

3 Results

The survey period ran from 17th June 2017 to 7th July 2017 and a total number of 251 responses were collected. Among the responses, 2 were classified as invalid and 249 as valid, which were used for analysis. Among those 249 respondents, there are 213 Macau residents (both permanent and non-permanent).

The general results of the three goals of the study will be presented in Sects. 3.1, 3.2 and 3.3, as follows, the results of question 13 (bus service satisfaction level) will be discussed in Sect. 3.1, while that of question 16 (safety level when taking a bus) will be

in Sect. 3.2. Finally, the findings of question 24 (intention to install a mobile app assessing driving behavior) will be in Sect. 3.3.

3.1   Bus Service Satisfaction Level

The satisfaction level of different demographic groups, high bus usage users, and respondents with driving license are shown in Table 1. Take two examples, among the 213 Macau residents who respond to this questionnaire, 114 of them feel dissatisfied, 84 think the service is acceptable. Only 11 of them satisfy with the current bus service, while 4 of them refuse to tell.

Table 1. Bus service satisfaction level.

	Bus service satisfaction level		
	Dissatisfied	Acceptable	Satisfied
Macau residents (213 pax)*4	114 (54.55%)	84 (40.19%)	11 (5.26%)
Blue card (23 pax)	14 (60.87%)	8 (34.78%)	1 (4.35%)
Other ID holder (13 pax)	8 (61.54%)	3 (23.08%)	2 (15.38%)
Live in Macau less than or equal to 7 years (47 pax)	31 (65.96%)	14 (29.79%)	2 (4.26%)
Live in Macau more than 7 years (195 pax)*4	101 (52.88%)	80 (41.88%)	10 (5.24%)
Female (94 pax)	51 (54.26%)	40 (23.08%)	3 (15.38%)
Male (151 pax)*4	84 (57.14%)	54 (36.73%)	9 (6.12%)
Age below 36 (128 pax)	71 (55.47%)	50 (39.06%)	7 (5.47%)
Age between 36 and 55 (106 pax)*4	58 (56.86%)	39 (38.24%)	5 (4.9%)
Age above 55 and unknown (15 pax)	7 (46.67%)	6 (40.00%)	2 (13.33%)
Married (104 pax)*4	53 (53.00%)	39 (39.00%)	8 (8.00%)
Single (104 pax)	53 (50.96%)	48 (46.15%)	3 (2.88%)
Other marital status (41 pax)	30 (73.17%)	8 (19.51%)	3 (7.32%)
Employee (104 pax)*2	53 (52.96%)	44 (43.14%)	5 (4.9%)
Student (54 pax)	23 (42.59%)	27 (50.00%)	4 (7.41%)
Other work status (91 pax)*2	60 (67.42%)	24 (26.97%)	5 (5.62%)
Salary less than MOP15,001 (65 pax)	32 (49.23%)	30 (46.15%)	3 (4.62%)
Salary more than MOP15,001 (105 pax)*4	63 (62.38%)	36 (35.64%)	2 (1.98%)
Prefer not to disclose salary (79 pax)	41 (51.90%)	29 (36.71%)	9 (11.39%)
High usage passengers (114 pax)	62 (54.39%)	45 (39.47%)	7 (6.14%)
Medium usage passengers – weekly (98 pax)*1	52 (53.61%)	39 (40.21%)	6 (6.19%)
Low usage passengers – monthly (37 pax)*3	22 (64.71%)	11 (32.35%)	1 (2.94%)
Have driving license and take bus (133 pax)	79 (59.40%)	47 (35.34%)	7 (5.26%)
Have driving license and seldom take bus (47 pax) *4	28 (65.12%)	14 (32.56%)	1 (2.33%)
No driving license and take bus (68 pax)	28 (41.18%)	34 (50.00%)	6 (8.82%)
Have vehicles and take bus (123 pax)	68 (55.28%)	47 (38.21%)	8 (6.50%)
Have vehicles and seldom take bus (44 pax)*3	27 (65.85%)	13 (31.71%)	1 (2.44%)
No vehicles and take bus (78 pax)	39 (50.00%)	34 (43.59%)	5 (6.41%)
No vehicles and seldom take bus (4 pax)*1	2 (66.67%)	1 (33.33%)	0 (0.00%)

*X: X respondents do not disclose satisfactory level

There are 114 respondents who take bus more than 1 time daily (high usage users), 62 of them dissatisfied with the service, 45 of them think it is acceptable. Only 7 of them satisfied.

No matter which demographic groups, or other classification of the respondents, there are more respondents who are dissatisfied with bus services in Macau than satisfied.

From Question 15, the top three points that the respondents dislike when taking a bus are:

1. the bus is not comfortable such as very crowded (27.63%);
2. the waiting time for the bus is too long (19.56%) and
3. the bus is not safe (18.06%).

This illustrates that safety is an important factor in satisfaction level.

3.2 Risk Perception Towards Driving Behavior When Taking a Bus

Question 16 requests the respondents express their risk perception towards driving behavior when taking bus. They expressed their risk perception in bus drivers' driver behavior through a 6 Likert scale question (1 = very risky to 6 = no risk at all).

There are 114 respondents who take bus more than 1 time daily (high usage users), 38 of them emphasize it is not safe, 66 think it is moderate, and 10 of them believe it is safe. The risk perception when taking bus based on other demographic factors and respondents with driving license is presented in Table 2.

Table 2. Risk Perception towards Driving Behavior when taking a bus.

	Safety level when taking a bus, 1 = very risky to 6 = no risk						
	1	2	3	4	5	6	Mean (Stdev)
Macau residents (213 pax)	31	31	59	68	23	1	3.11 (1.23)
Blue card (23 pax)	6	10	4	2	1	0	2.22 (1.09)
Other ID holder (13 pax)	0	2	4	5	1	1	3.62 (1.12)
Live in Macau for less than or equal to 7 years (47 pax)	14	10	14	7	2	0	2.43 (1.19)
Live in Macau more than 7 years (195 pax)	23	31	53	64	23	1	3.19 (1.20)
Female (94 pax)	17	13	25	34	4	1	2.98 (1.23)
Male (151 pax)	20	30	40	41	20	0	3.07 (1.24)
Age between 11 and 17 (20 pax)	0	1	5	8	6	0	3.95 (0.89)
Age between 18 and 25 (46 pax)	3	6	13	19	4	1	3.39 (1.11)
Age between 26 and 35 (62 pax)	12	11	19	15	4	1	2.86 (1.27)
Age between 36 and 45 (63 pax)	15	16	18	11	3	0	2.54 (1.18)
Age between 45 and 55 (43 pax)	6	7	5	18	7	0	3.30 (1.32)
Age above 55 and unknown (15 pax)	1	2	7	4	1	0	3.13 (0.99)
Married (104 pax)	19	22	30	21	11	1	2.87 (1.29)
Single (104 pax)	9	12	28	44	10	1	3.36 (1.11)

<div align="right">(continued)</div>

Table 2. (*continued*)

	Safety level when taking a bus, 1 = very risky to 6 = no risk						
	1	2	3	4	5	6	Mean (Stdev)
Other marital status (41 pax)	9	9	9	10	4	0	2.78 (1.31)
Employee (104 pax)	17	19	28	28	12	0	2.99 (1.26)
Student (54 pax)	3	6	17	18	9	1	3.50 (1.13)
Other work status (91 pax)	17	18	22	29	4	1	2.87 (1.24)
Salary less than MOP6,501 (39 pax)	5	4	15	10	3	2	3.21 (1.28)
Salary between MOP6,501 and MOP15,000 (26 pax)	4	6	5	7	4	0	3.04 (1.34)
Salary between MOP15,001 and MOP30,000 (46 pax)	4	7	9	19	7	0	3.39 (1.18)
Salary between MOP30,001 and MOP50,000 (39 pax)	7	8	7	13	4	0	2.97 (1.31)
Salary more than MOP50,000 (20 pax)	7	4	6	3	0	0	2.25 (1.12)
Prefer not to disclose salary (79 pax)	10	14	25	23	7	0	3.04 (1.16)
Take bus more than 5 times per day (12 pax)	2	4	2	2	1	1	2.92 (1.56)
Take bus 1 to 5 times/day (102 pax)	14	18	29	33	7	1	3.04 (1.19)
Take bus more than 1 time/week (71 pax)	9	8	23	21	10	0	3.21(1.21)
Take bus less than 1 time/week (27 pax)	3	4	6	10	4	0	3.30 (1.24)
Take bus less than 1 time/month (27 pax)	4	8	4	8	3	0	2.93 (1.30)
Never by bus (10 pax)	5	1	3	1	0	0	2.00 (1.16)
Have driving license and take bus (133 pax)	24	23	32	43	11	0	2.96 (1.25)
Have driving license and seldom take bus (47 pax)	10	11	11	9	6	0	2.79 (1.33)
No driving license and take bus (68 pax)	3	9	24	22	8	2	3.43 (1.10)
Has no driving license (69 pax)	3	10	24	22	8	2	3.41(1.10)
Has driving license less than 1 year (11 pax)	1	2	1	6	1	0	3.36 (1.21)
Has driving license for 1 to 3 years (27 pax)	2	1	12	8	4	0	3.41(1.05)
Has driving license for 3 to 10 years (32 pax)	4	8	4	14	2	0	3.06 (1.22)
Has driving license more than 10 years (110 pax)	27	22	26	25	10	0	2.72 (1.31)
Have vehicles and take bus (123 pax)	14	15	38	44	12	0	3.20 (1.14)
Have vehicles and seldom take bus (44 pax)	9	11	10	8	6	0	2.80 (1.34)
No vehicles and take bus (78 pax)	13	17	18	21	7	2	2.97 (1.33)
No vehicles and seldom take bus (4 pax)	1	0	1	2	0	0	3.00 (1.41)
No opinion in bus service satisfaction level (4 pax)	1	0	2	1	0	0	2.75 (1.26)
Very dissatisfied with the bus service (62 pax)	24	19	8	9	2	0	2.13 (1.18)
Dissatisfied the bus service (74 pax)	10	16	30	16	2	0	2.78 (1.02)
Acceptable bus service (95 pax)	1	8	24	45	16	1	3.74 (0.91)
Satisfied and very satisfied with the bus service (14 pax)	1	0	3	4	5	1	4.07 (1.27)

From Table 2, the respondents who hold blue card consider taking buses are riskier than other ID card holders. Similarly, those who live in Macau for less years also rate taking bus riskier than those who live more years in Macau. The youngest respondents group gives the higher safety scale of 3.95 among all ages groups. This scale drops till age 36 to 45 group, then increase, but drop again. It is consistent with the result of work status group in which students also gave higher scale than other work status group. Respondents with monthly salary ranged less than MOP30k gave a average scale of above 3, those earn MOP30k to 50k have an average of 2.97, and those earn over MOP50k has the average of 2.25. This means that respondents with higher salary believe bus taking is riskier. The risk perception has not much different in different gender group. Those who take bus daily feel the bus is riskier than those who take bus weekly. Yet, those who seldom take bus rate the lowest scale among all bus usage groups. Those who take bus and holding a driving license rate bus riskier than those without a driving license, and the more year holding a driving license, the less scale they rate the safety of taking bus. Whether having a vehicle or not seem has no affect in the judgement of safety level of taking bus. The safety level is also correspondent to the satisfactory level of bus service.

In order to define a respondent profile based on risk perception, we have applied descriptive statistical analysis techniques to cluster respondents around this independent variable (see Table 2). The first task was to filter out answers that had less than or equal to 30 responses, to increase the statistical relevance of the data. Secondly, we filtered out values that had the mean between 2.79 and 3.29 as they represent the valley where values tend to be close to each other. We also used these values to define the 2 main clusters: Cluster 1 (Low Risk Perception) – means between 3.30 and 6; Cluster 2 (High Risk Perception) – means between 1 and 2.78.

Applying this basic clustering algorithm to the data, the average profile for the Low Risk Perception respondent is characterized by:

- Age between 18 and 25 (46 pax)
- Age between 45 and 55 (43 pax)
- Single (104 pax)
- Students (54 pax)
- Salary between MOP15,001 and MOP30,000 (46 pax)
- No driving license and take bus (68 pax)
- Has no driving license (69 pax)
- Acceptable bus service (95 pax).

Continue with the application of the algorithm, the average profile for the High Risk Perception respondent is characterized by:

- Live in Macau for less than or equal to 7 years (47 pax)
- Age between 36 and 45 (63 pax)
- Other marital status (41 pax)
- Has driving license more than 10 years (110 pax)
- Very dissatisfied with the bus service (62 pax)
- Dissatisfied the bus service (74 pax).

3.3   Respondent Characterization Towards Driving Behavior

According to [12], driving behavior is aggressive "if it is deliberate, likely to increase the risk of collision and is motivated by impatience, annoyance, hostility and/or attempt to save time". From the answer of question 23, 38.31% of respondents make the right choice, while 27.62% select "no paying attention to surroundings when driving", 17.50% select "fast driving attitude" and 16.57% select "lack of driving skill". That mean that the respondents have different concept of aggressive driving behavior than the term defined.

Regarding the respondents' interest in installing an application in their mobile devices to assess the bus drivers' driving behavior, 8.84% absolutely are not interest, 8.41% are not very interest, 17.27% are not interest, 24.90% are interest, 13.65% are very interest, and 26.91% definitely will install. That is, there is a total percentage of 65.46% is positive to installing the mentioned application. We believe that our respondents are representative and this result reflect also the general public are willing to participate, i.e. as the crowd, of the Mobile Crowd Sensing of the driving behavior of Macau bus drivers.

4   Conclusions

Driving behavior is one of the main concerns in public transportation. In public bus transportation, good driving behavior not only can reduce the rate of accidents but also can improve the reputation of the bus companies to their bus passengers.

From the results of questions 8 and 9, they show that in Macau, public bus is the most common way to commute and to non-commute activities. Around 40% of the respondents take bus daily (quoted from the result of question 11). Besides, the usual time zones to take a bus is the time to go to school and work (7:00–10:00), and off school and work (16:00–20:00). Therefore, it is not surprise that the most favorite way to commute is to have a good public transportation system. It is interesting to discover that among the 10 respondents who never take bus, 2 of them select a good public transportation system as favorite commute way too. Beside public transports, the number of respondents who enjoy walking is quite significant. It is recommended that Macau government should aim to better public transportation development and pedestrian system as the devise of city development.

From the findings in Sect. 3, it can conclude that bus passengers generally do not satisfy with the bus service in Macau, and the safety level when taking bus is one of their concerns. Regarding to the respondents' risk perception towards driving behavior, the 3 groups: Other ID holders, students and those age between 11 and 17, gave a rating of equal or more than 3.5 (the mid of the scale), while all other groups rate taking bus less than 3.5, i.e. risky or more than moderate risky. It also concludes that the number of bus passengers who are willing to install an application in their mobile device to assess the driving behavior and collect related information is significant.

When comparing between [6] and Table 1, more than 49% of the Malaysian bus passenger from [6] dissatisfy their bus services, whereas in Table 1, more than 41% of

our respondent dislike bus services. This concludes that both the bus passengers in Malaysia and our respondents basically dissatisfy bus services.

Similarly, when comparing between [8] and Table 2, [8] studied mainly the college students with driving license to observe their risk perception in driving accidents. The result showed that they were quite optimistic in evaluating their risk of being involved in a wide variety of accidents. This is similar to risk perception of student and young age respondents in Table 2, as they fall into the Low Risk Perception group.

From the clustering results, it is interesting that people that do not learn how to drive have low risk perception, as well as students, singles and younger people. This is the group that considers Macau has an acceptable bus services. On the other side, more experienced people (older, with driving license more than 10 years) consider that the bus drivers' driving behavior is risky. They live in Macau for less than 7 yeas (so this means they are expats), they are not singles, and dissatisfy with bus services.

Derive from [13], when bus drivers know that the passengers have some ways to monitor them when driving the bus, they will pay more attention throughout their duty time. This can lower the accident rate.

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