









Assessment of MaaS (Mobility as a Service) Apps in Metropolitan Area of São Paulo, Brazil

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Abstract. The popularization of mobile internet and transport applications making passenger transport real-time information available to the general public. In the Metropolitan Area of São Paulo (MASP), the largest urban agglomeration in South America with 21 million inhabitants carrying out their activities every day, these systems have been changing the user's behaviour. The purpose of this study is to evaluate the perception and use of these applications called Mobility as a Service (MaaS) for the passenger in MASP. To do so, we conducted a survey with 138 respondents that live in MASP in May 2020 regarding the services: Google Maps, Moovit and Citymapper. They evaluated what the application they prefer to, how the applications functions are used by theirs and the public transportation frequency of use and after the answers were used in a descriptive statistics analysis. The results indicated a predominance of youth users that plan their trips using public transportation and seek real-time information through by these applications.

Keywords: Passenger transport · Journey planning · Mobile technology

1 Introduction

The Metropolitan Area of São Paulo is the main Brazilian metropolitan region and the largest urban agglomeration in South America. It is composed of 39 municipalities geographically interconnected to the city of São Paulo, a global metropolis that concentrates 21 million inhabitants in an area of approximately and generates approximately 18% of the Brazilian GDP [1]. This region concentrate approximately 9.4 million jobs and 5.5 million enrolled students whom generates 42 million journeys daily [2].

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MASP has its public transport network based on Subway service, Metropolitan Train and Bus. The subway network is 101 km long with six lines carrying four million passengers per day. The metropolitan train network has seven lines with 271 km of extension and 94 stations that serve 23 of the 39 municipalities of the MASP transporting over 3 million passengers per day. Finally, bus network is made up of 1,336 municipal lines and 587 intercity lines that are operated by approximately 18,000 vehicles [3–6].

With the popularization of smartphones and high-speed mobile internet several applications have emerged that allow users to make decisions based on information provided. These applications are named Mobility as a Service (MaaS) [7] and has been used by passenger in metropolitan areas.

MaaS can help users to move around making use of GPS (Global Positioning System) and information collected in real-time from operators and other passengers [8]. They can be informed of the waiting time for a certain passenger transport system or just regarding the itinerary; and those that provides services such as taxis and ridesharing.

In this article, we evaluated MaaS that works as an aid to decision-making for the transportation users. Real-time information reduces the inconvenience caused by waiting for a long time and makes them feel safer while waiting for transport [9]. Moreover, it shows in real-time the position of the transport vehicle reducing passenger wasting time [10, 11].

With these ideas in mind, the aim of this study is to analyze the perception of users of the public passenger transport system in the Metropolitan Region of São Paulo on the efficiency of three MaaS: Google Maps, Moovit and Citymapper. They were selected based on the availability in many global and important areas such as London, Tokyo and New York. And how they can assist in the user's decision-making about their daily commuting planning.

To do so, we conducted an online survey with 138 people in 2020, divided into three parts: profile of users, the main modes of transport adopted and which are the most important functions. The data were analyzed using two statistical methods: descriptive statistics and factor analysis.

The article is divided as follows: Section is formed by this introduction, Sect. 2 the methodology approach, Sect. 3 our results, Sect. 4 our main conclusions.

2 Methodology

2.1 Survey

We conducted a survey to obtain empirical information beyond those found in scientific documents on urban mobility. The purpose was to evaluate the efficiency of the use of MaaS by users of passenger public transportation in MASP.

The survey was carried out in May 2020 with 138 users living in MASP. It was divided into three parts: (i) Socioeconomic characteristics such as gender, age, educational level and income; (ii) Transport systems use such as frequency,

purpose and integration mode, transport mode, integration with other modes of transport, and travel time; and (iii) User's perception of mobile applications such as key applications used, the main objective of its use, frequency of use, and evaluation of the main services offered.

Among the MaaS offered we studied: TP = Travel planner (Routes, Timetable, Journey time, Fare); RS = Route sharing; OFFMAP = Off-line maps; JP = Journey planner: Origin and Destination; JF = Journey fare; MP = Mode preference; PC = Passenger capacity; RTI = Real time information; DF = Delay forecast; TI = Traffic information; AMI = Active mobility integration; ICA = Integration car app (ridesharing) and taxi; UCI = User Collaborative Integration.

The research sample was calculated based on Eq. 1 [12]. We considered the population in MASP, degree of homogeneity 50/50, sampling error of 10%, and confidence level of 95%.

$$n = \frac{NZ^2P(1-p)}{(N-1)e^2 + Z^2p(1-p)} \quad (1)$$

Where, n = sample size, N = population, Z = abscissa of the normal standard, p = estimated homogeneity, e = sample error.

2.2 Validation and Survey Application

Data collection was performed using an electronic form, using the Google Forms tool. First, a pre-test was carried out with seventeen (17) participants, to validate the structure. After this process, the link for participation was sent via social networks and email groups, WhatsApp, Instagram and Facebook. The volunteers, before answering the form, underwent reading about the research clarifications and guidelines, and later, signed the Informed Consent Form. The survey was only open to participants who agreed to voluntarily participate.

Data Analysis

The softwares Microsoft Excel 2016 ©and Statistics v.13.3 ©were used to tabulate and process the data, being organized as follows:

- **1st step:** Raw data were collected and participants who were not users of MaaS applications were excluded for descriptive analysis since the research interest was the group of users. Thus, 35 respondents were excluded from the sample, which totalled 103 participants.
- **2nd step:** We applied descriptive statistics to characterize the profile of users and analyze the perception regarding the efficiency of MaaS applications (Google, Moovit and Citymapper).
- **3rd step:** A processing of the normality test was carried out, observing the Kolmogorov-Smirnov test ($p > 0.05$) [13], due to the sample size. Afterwards, a non-parametric analysis was performed, using the Kruskal-Wallis [13] test to verify the occurrence of a significant difference among the perception of participants with frequencies of use of passenger public transport.

- **4th step:** A Cronbach [14], Kaiser-Meyer-Olkin (KMO) [15], Bartlett Sphericity [16] tests were performed before conduct a Factor Analysis.
- **5th step:** To perform the Factor Analysis parameterized by varimax rotation, and the extraction of factors by Principal Component, participants who did not carry out the evaluation of the applications of interest to the study were excluded, totalling 15 respondents and reducing the sample to 88 participants.

3 Results

3.1 Sample Characterization

In order to explore all participants of the research, the sample characterization examined all the 138 participants. In our survey 75% of participants express to do use of some type of MaaS application. This result indicate a dissemination of this application due to high degree of mobile phone users and internet access. In São Paulo state that include MASP, in 2019, more than 53% of 30.5 million internet users connect only through mobile phones [17].

In our survey, it is observed that 51% of MaaS users are male and 49% female. This result means the MaaS access are almost identical between gender. Moreover, around 60% are in the age group between 18 and 35 years old, with a majority of women between 18 and 25 years old, and men between 26 and 35 years old. The result is consistent with data from Brazilian Institute of Geography and Statistics who shows that 80% of people in these groups presents a high level of access a internet via mobile phones [18].

By large, 41% have a household income between 3 and 4 minimum Brazilian wages (Brazilian minimum wage is USD 188,18 in 13/03/21), Table 1.

Table 1. Sample distribution

Variable	n	Participation (%)	Variable	n	Participation (%)
Gender			Education		
Female	50	48.5	Fundamental	3	2.9
Male	53	51.5	High School	31	30.0
Age group			Undergraduate	50	48.5
<17	2	1.9	Graduate	19	18.5
18 a 25	32	31.1	Income household		
26 a 35	30	29.1	<2	26	25.3
36 a 45	24	23.3	3 a 4	42	40.8
>46	15	14.5	5 a 7	17	16.5
			8 a 9	5	4.8
			>10	13	12.6

Among the respondents 51 % are from city of São Paulo, and the others are distributed among the cities of Metropolitan Area, such as: Aruja, Diadema, Ferraz de Vasconcelos, Guarulhos, Itaquaquecetuba, Maua, Mogi das Cruzes, Osasco, Poa, São Bernardo do Campo, São Caetano do Sul and Suzano. As an expected result, we found out 52% of users use the system with the main purpose of commuting to work, followed by study, leisure and services. These results are in accordance with what was observed by Giuliano et al. [19] in which the displacement has as its main purpose work.

3.2 Descriptive Statistics

Our results indicate a preference for bus service (43%) over others such as subway (22%), train (19%), ridesharing (15%) and taxi (1%). The result prove bus service as more comprehensive system with easy access in MASP, on the other hand cause great impact in congestions [20]. More than 60% of the participants have a high frequency of public transport use service - considering people that uses it every day, six days a week and on working days. There was no significant difference ($p > 0.05$) by the Chi-square between the variables analyzed, Table 2.

Table 2. Frequency of use by transport mode

Transport mode						
Frequency	Subway	Bus	Taxi	Ridesharing	Train	Total
Everyday	21.43	64.29			14.29	13.59
Six days a week	28.57	57.14		7.14	7.14	13.59
Weekdays	31.43	48.57			20.00	33.98
Between one and three days/semana	23.08	30.77		7.69	38.46	12.62
Weekends		57.14		42.86		6.80
Rarely	10.00	10.00	5.00	50.00	25.00	19.42

In addition, we observed that ridesharing service as Uber and 99 (Brazilian local company service) have been gaining ground among users, mainly regarding of those that rarely travelled by public passenger transport and those that travel exclusively on the weekends.

When participants were query about the ways of displacement between residence to the departure point (first mile), we found that 64% travel on foot, 15.5% by bus, 12.5% by private vehicle (motorcycle) and/or car), 7% ridesharing, and 1% per local area minibuses. And when compared to the frequency of use of the public transport system, a significant difference was noted (Chi-squared = 9.93; $p = 0.0416$). Similar results were obtained when comparing the data for the last mile (Chi-squared = 11.09; $p = 0.0255$).

Regarding the last mile we identified that 66% of perform on foot, 17.5% by bus, 8.5% by private vehicle (motorcycle and/or car), 7% ridesharing and 1% per local area minibuses. The increase in the use of ridesharing is a reality that straight affect public passenger transport operators that will need to reinvent their services. Our results confirm a trend in all suburbs of the country regarding ridesharing [21].

3.3 MaaS Adoption

In this study, we query respondents based on three MaaS apps, Google Maps, Moovit and Citymapper. In Fig. 1 we have the use by level.

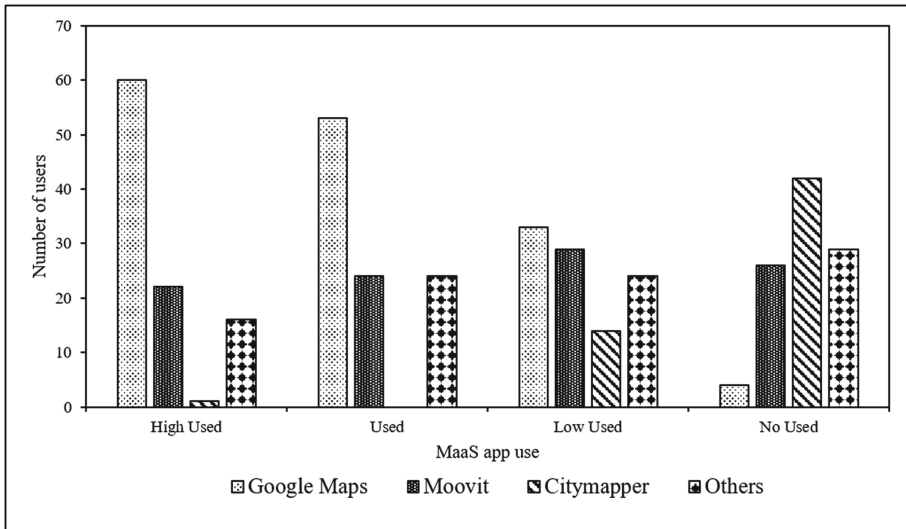


Fig. 1. Proportion of distribution of MaaS app use

The easiness of access and the multiplatform availability means Google Maps the MaaS app more utilized by sample users.

3.4 Factor Analysis

The KMO test (0.89) and Bartlett’s Sphericity test (Chi-squared = 662.37, p-value < 0.05) confirm a correlation among variables, and the Cronbach Alpha test (0.8968) results in a reliability of the data. The selection of factors considered those with eigenvalues greater than 1.0, with three factors being extracted by Principal Component (PC) after varimax rotation, Table 3.

The Factor Analysis describe the variability among observed variables and possibly correlated variables in a smaller number of variables denominated factors. We have 13 originals variables divided in 3 factors.

Table 3. Factor analysis of MaaS app assessment for a Cluster, n = 88, with 3 factor extracts by principal components

Factors		Autovalues	VExp ¹ (%)	VEAc ² (%)	Variables (Correlation)
F1	Information system of traffic and transport	6.3	48.51	48.51	PC (0.6399); RTI (0.6126); DF (0.7764); TI (0.8085); AMI (0.8380); ICA (0.6995); UCI (0.7954)
F2	Travel plan	1.44	11.08	59.59	TP (0.7363); JP (0.8006); JF (0.7809); MP (0.7848)
F3	Sharing and accessibility	1.26	9.75	69.34	RS (0.7641); OFFMAP (0.7765)

¹ VExp(%) = Proportion of explained variation (%);

² VEAc(%) = Proportion of explained variation agreggate (%)

The first factor (F1) grouped seven PC variables: PC (Passenger capacity), (RTI Real time information), DF (Delay forecast), TI (Traffic information), AMI (Active mobility integration), ICA (Integration car app) and UCI (User Collaborative Integration).

They are a explanatory factorial analysis that represent the user’s connectivity with the traffic and transport information systems, being the basis for decision-making and replanning journeys. The information available easily to the users can help to choose the best way in that moment and to be improve the quality life of the users because the save the travel time and this can be used with others daily activites or stay home. The second factor (F2) grouped TP (Travel planner); JP (Journey planner); JF (Journey fare) and MP (Mode preference). They connected user’s travel planning as essential MaaS. The third factor (F3) grouped RS (Route sharing) and OFFMAP (Off-line maps). They infer user’s sharing and accessibility of information, Table 3.

4 Conclusions

This paper investigates the adoption of MaaS systems as a way to plan journeys using public passenger transportation in MASP, Brazil. To do so, we conducted a survey with 138 respondents and applied statistical analysis.

Our results indicated that the majority of MaaS users are up to 35 years old, and their main goal is to go to work using the public passenger transport system. Also, it was found that people move on foot to access public passenger transport and sometimes substitute routes made by bus by ridesharing services.

The explanatory factor analysis variables improve passengers real time decision and can reduce the transit time on transportation. This reduction improvement the quality of life because the passengers can enjoy this time in other daily

activities. The limitation of this paper is about the number of applications studied. However, it does not invalidate the study proposed and can be made in a future research.

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