American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-7, Issue-6, pp-37-43
www.ajer.org
Research Paper Open Access

An Evaluation of Maas Service Effect Based On Real Travel Data

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ABSTRACT : *Recently, 'Mobility as a Service' (MaaS) is being introduced from Europe. The concept of MaaS is to move quickly, cheaply and efficiently by integrating all operation platform. However, in Korea, there is no integrated transportation platform. Therefore, we analyzed the effect of using public transportation on the assumption that MaaS was introduced in Seoul. The research method assumes that buses, subways, and taxis can be transferred to each other. Also, the travel time is calculated using the transportation big data. The method of analysis is as follows, first, we select 3 agents who traveled different distance and analyze movement route. Second, we assume the situation where MaaS is applied. Finally, we analysis the effect of MaaS by analyzing the effect of reduction of travel cost. The analysis shows that the MaaS reduces costs by up to 44%. This study can be used as a basic study for the MaaS.*

KEYWORDS *-MaaS, Public Transportation, Big data, Integrated public transportation*

Date of Submission: 19-05-2018 Date of acceptance: 04-06-2018

I INTRODUCTION

1. Background and objective

Mobility as a Service (MaaS) refers to the mobility as a service, and refers to a system that integrates public transportation services from a single platform, from private cars to rental cars to taxis, public transportation, and even shared bikes. In other words, all the means of transportation available in the city are constructed as one system. MaaS started in Europe and attracted worldwide attention, and Europe has already built a platform that integrates existing public transport buses, subways, trams and shared bikes, even rental cars and taxis. Users can get traffic information such as available route and arrival time by inputting destination from smartphone through MaaS. MaaS is operated by a monthly rate plan and consists of a service-specific differential rate plan. The following table shows MaaS rates for Finland 'Whim'.

Table 1. Monthly payment of MaaS in Finland

Payment	Monthly pay	Bus/Sub	Taxi/Lease
Pay per ride	-	Pay per ride	-
Whim basic	89€	40%	Up to 39€
Whim go	149€	Unlimited	Up to 124€
Whim Business	Ask€	Unlimited	Unlimited

For example, it is composed of a differential fare system based on available services such as bus/ subway fare, bus/subway/taxi fare, bus/subway/taxi/shared bicycle fare, etc. is. Therefore, it is possible to select and use the fare that meets the usage amount of the user, that is, the traffic amount like the mobile phone charge.

By paying monthly usage fees to MaaS, you get the fastest route optimized for you to your destination. For example, when a bus or a subway takes a long time, a taxi can be automatically booked in advance so that the user can use the taxi without waiting for the taxi. The user does not have to pay a separate taxi fare because the destination of passenger has already been transferred and the fare is paid in advance by month to MaaS. MaaS is evolving from unfamiliar services in Europe to increasingly user-preferred services.

In Korea, individual transportation means is operated by each operator. The operation of individual transportation means utilizes IT technology to provide convenience to users in a very systematic and diverse way. Such as bus arrival guidance system, subway arrival guidance system, and metropolitan area integrated transportation fare system. In addition to buses and subways, Seoul has already operated a variety of public transport links including shared bicycles and taxis.

However, in Korea, there is no research on MaaS, which operates all public transportation on one platform, or the introduction of the system in Korea. Overseas, MaaS is seen as a way to solve social problems caused by traffic such as overcrowding and traffic congestion due to urbanization. However, MaaS is not able to maximize the effect because it can't integrate into a single platform like MaaS. This is the point of need. Therefore, this study analyzes and suggests the passage of individuals assuming the introduction of MaaS service that has not been introduced yet in Korea. In addition, we try to understand the effect of MaaS service on the cost of passengers by comparing the change of individual traffic pattern and the pre / post MaaS adoption situation.

II LITERATURE REVIEW

This study examines the definition of MaaS before analyzing the effect of MaaS, and examines the precedent studies on the analysis of traffic patterns using Big Data for MaaS effect analysis. MaaS is a recent issue, but it needs to know what MaaS is about because it has not been introduced or related to it.

According to SampoHietanen[1],MaaS defines transport demand that users need through one interface as a supply model that traffic services are provided by a traffic service provider. Kamargianni et al. [2]explained that it is a paradigm shift of new traffic that users use to receive transportation services rather than own personal transportation such as cars for transportation.Researchers therefore define MaaS as a mere service destination through public transport and shared cars, rather than fulfilling their desire to move through privately owned mobility. Kamau, J. et al. [3] analyzed the wait time reduction effect of DRT (Demand Responsive Transit) by applying MaaS to Dhaka City and found that the user's wait time was reduced by 44%. Therefore, the integrated MaaS service can reduce the waiting time for the user through the real-time reservation system.

However, Kamargianni et al.[4] pointed out that MaaS is a promising system for solving transportation problems, but that the integrated fare system or revenue allocation problem needs to be solved to operate the MaaS integrated system. In other words, MaaS is free to use all modes of transportation, including public transport and passenger cars, on a single platform at a monthly fee.In addition, it is expected that all the modes of transportation are reserved according to the optimal route, or the waiting time during the travel time is drastically reduced because it provides the optimal transfer point and time.

In this study, we tried to apply the MaaS defined above to the city of Seoul and try to grasp the effect of reducing the travel expenses of users. Therefore, the traffic patterns of Seoul citizens are analyzed by analyzing the smart card data, taxi, and bus operation data of Seoul. Atizaz Ali et al.[5] analyzed the traffic patterns of Seoul citizens statistically by analyzing smart card data. In addition, Kim et al. [6] analyzed the taxi movement pattern statistically by analyzing the taxi operation record data of Seoul city. Jeong et al. [7] analyzed the bus operation record data (BMS) of Seoul and analyzed the reliability of bus operation time by calculating the time required per bus route.

Thus, we analyze the smart card data of Seoul and the taxi operation records as in the previous study, and track the user 's traffic route. In addition, this study is a basic study for MaaS, and it analyzes the virtual effect of MaaS by combining taxi virtually in the integrated bus and subway metropolitan area integrated public transportation system.

III METHODOLOGY

1. Total travel time of public transportation

Manheim [8] was divided transit time for public transportation into out-of-vehicle time and in-vehicle time. The in-vehicle time is the time when the vehicle actual travels. The out-of-vehicle time consists of the access time, the waiting time and the transfer time.

Table 2. Major components of travel time (Manheim, 1979)

	Out-of-vehicle time	In-vehicle time
Access time	Walk time, Wait time	Time in feeder vehicle
Line-haul time	Transfer time	Time in line-haul vehicle

Thus, Total travel time (TTT) can be formulated as follow.

$$\text{TotalTravelTime(TTT)} = \sum IVTT_m + \sum OVTT_m \quad m = sub, bus, taxi \tag{1}$$

$$\sum OVTT_m = \sum (Access_m + Waiting_m + Transfer_m + Egress_m) \tag{2}$$

Where $IVTT\ is\ in-vehicle\ travel\ time\ of\ mode\ m$

$OVTT$ is $out - of - vehicle\ travel\ time\ of\ mode\ m$
$Access_m\ is\ accees\ time\ to\ mode\ m$
$Transfer_m\ is\ Transfer\ time\ of\ mode\ to\ mode$
$Egress_m\ is\ egress\ time\ to\ mode\ m$

2. Used data description

In this study, various traffic data related to Seoul, such as traffic card data, taxi service data, and BMS data, are utilized to investigate the effect of MaaS service application. Data is used to analyze the movement of individuals each agent. The traffic card data consists of a single pass that consists of a trip chain that includes transit, rather than individual one-card use, and consists of routes used by each trip, time of use, and a stop for getting on and off. Therefore, traffic card data can be used to track and analyze the actual individual traffic. Taxi Data DTG (Digital Tacho Graph) is data recorded by sending a taxi in real time to the server every 10 seconds, and it is recorded data. It is composed of taxi number, time zone, speed, coordinates, status (0: empty, 1: full). Using the taxi data, it is used to calculate the arrival time to the destination of the transit through the distribution of the taxi and the distribution of the status for each major transit point in the relevant time zone. BMS (Bus Management System) data is composed of bus travel time, location of bus composed of coordinates, bus stop by time zone, bus line ID, car number, etc. BMS data is used to calculate the distribution of buses and bus arrival times for major transit points in the relevant time zone. The depth of the subway station is the distance from the subway platform to the outside exit, in meters. Subway depth data is used to calculate the transfer time between subway - bus / subway - taxi. Following table is summarized the data used in this study

Table 3. Used data sets

Data	Data description	Date
Bus/ Sub	KSCC Smartcard data (Korea Smart Card Corporation)	13.10.2015 (PM 18~20)
Taxi	Seoul Taxi DTG Data (Digital Tacho Graph)	01.02.2016 (PM 18~20)
BMS	Seoul BMS data (Bus Management Service)	06.04.2016 (PM 18~20)

However, due to the limitation of collecting data in the above table, it was not possible to match every point of each data. We could not match the date due to the different collection and presentation points of each data, but the time information of each data could be matched. Therefore, the time of the analysis data was set at 18:00 ~ 20:00 which is the evening peak period. Therefore, although it is possible to trace the actual movement of an individual agents using the bus and the subway through the personal use data of the smart card. And taxi operation data (DTG) and the bus operation data (BMS) are analyzed based on the assumption that the operation pattern is similar.

3. Select agents for analysis

In this study, we set up selected agents classified by distance to track and analyse the movement of the individual.

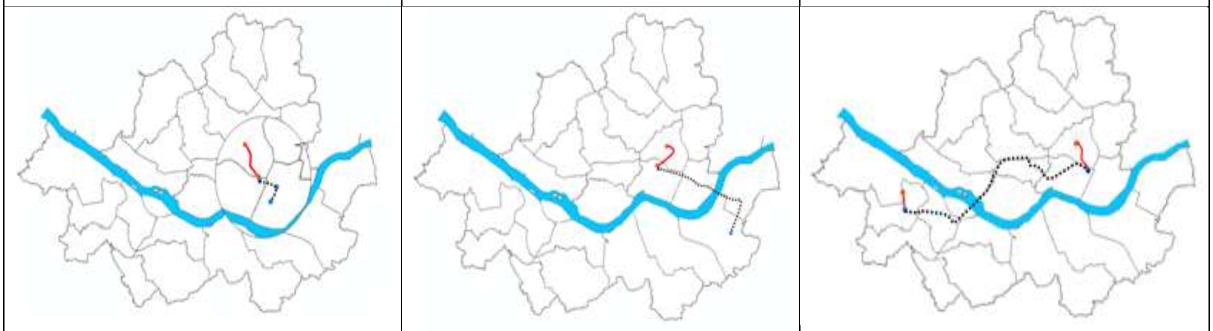
Agent1: Short trip (5km)			Agent2: Mid trip (15km)			Agent3: Long trip (25km)			
									
Trip 1	Trip 2	Trip 3	Trip 1	Trip 2	Trip 3	Trip 1	Trip 2	Trip 3	Trip 1
(Ride) 18:21:46	(Alight) 19:33:41	(Ride) 19:42:11	(Ride) 18:21:46	(Alight) 19:33:41	(Ride) 19:42:11	(Ride) 18:21:46	(Alight) 19:33:41	(Ride) 19:42:11	(Ride) 18:21:46
-	(Ride) 18:36:50	-	-	(Ride) 18:36:50	-	-	(Ride) 18:36:50	-	-

Fig 1. Path and travel time of each agent

In addition, each set agent can track the all trip through the trip chain data using the smart card data. Agents are divided into three categories: short-range agent 1 about 5 km, mid-range agent 2 about 15 km, and long-range agent 3 about 25 km. The departure time of each agent departs between 18:00 and 19:00 in the evening peak period, and it is arbitrarily set at the bus stop at the entrance of University of Seoul. Therefore, the destination is different for each agent. As a result of trip chain data analysis, the travel distance and time of Agent1 were 4.7km / 17min 16sec, Agent2 14.9km / 41min 43sec, Agent3 24.9km / 74min 05sec. The path and travel time of each agents are shown in the following figure.

4. Estimate total travel time of each agent

As shown in Formula (1) and (2), the calculation of transit time is composed of IVTT and OVTT. In this study, the IVTT was analyzed using smart card data. The calculation of the OVTT was analyzed using the collected data, but the assumption was made as to where the data collection was limited. For example, previous studies have applied weighting to the time of IVTT. Therefore, the total travel time of public transportation is calculated differently according to the application weight of the OVTT. However, in this study, the initial departure time was calculated based on the assumption that the agent started from the 21st century building in University of Seoul, and the final arrival time was assumed to be the same as the departure approach time. Respectively. Figure 2 shows the assumption of the starting distance for the initial approach time estimate. Waiting time factor 0.5 was used as the waiting time for each mode. The headway of the bus was calculated using the BMS data as shown in Table 4. The headway of the subway was calculated using the subway schedule table at that time.

ID	Time	RouteID	VehicleID	StopID	StopName
123041537	18:12:30	3216	74_4482	105000103	University of Seoul
123041048	18:24:01	3216	74_4484	105000103	University of Seoul

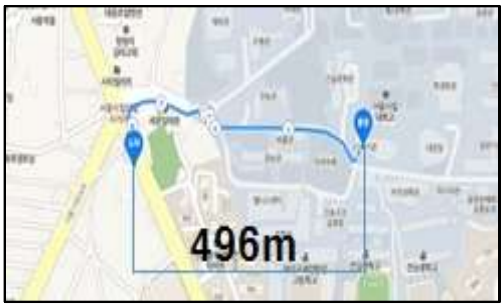


Fig 1 Assuming initial access to bus stop

5. Analysis of generalized cost

In order to quantify and compare the route of each agent on a single unit, it is necessary to convert the time and the fare for each means into generalized cost. In this study, to estimate the generalization cost, the generalization cost for each route is calculated by using the transportation value of time and current public transportation fare, which are presented by KTDB (Korea Transportation Database). Thus, in this study, generalized cost can be formulated as follow.

$$\text{Generalized cost} = \alpha * Cost + B * time \quad (3)$$

Table 4 Value of time (Unit: KRW ₩)

	Taxi	Bus	Subway
Value of time	22,775	17,260	22,775
Fare	3,000(within 2km) + 100(add every 142m)	1,200(Only Bus) +100(add every 5km)	1,250 + 100(add every 5km)

6. Application method of MaaS model

In the case of MaaS, which is assumed in this study, when the passenger enters the starting point and the destination, the optimal route is provided and the available means are three means of bus, taxi and subway. Therefore, the MaaS-usable model can be divided into three sub-routes and seven sub-routes, using a single means, and in the case of a combined means using two means, a multiple compound means route using all three means. Table 5 shows the MaaS usage model for each means of use.

Table 5 Setting the MaaS analysis model

	Sub model
Model 1: Single mode	Model 1-1: Subway Only
	Model 1-2: Bus Only
	Model 1-3: Taxi Only
Model 2: Dual mode	Model 2-1: Bus – Subway
	Model 2-2: Subway – Taxi
	Model 2-3: Bus – Taxi
Model 3: Multiple mode	Model 3-1: Subway – Bus - Taxi

IV. RESULT

1. Analysis of real travel path and cost

Table 6 Real travel path of each agent

	Total Travel Time				
Agent1 (short 5 km)	$IVTT_{bus}$	$IVTT_{sub}$	$\sum OVTT_{bus}$	$\sum OVTT_{sub}$	$Total\ Travel\ Time$
	00:11:55	00:05:21	00:15:15	00:13:37	00:46:08
Agent2 (mid 15 km)	$IVTT_{bus}$	$IVTT_{sub}$	$\sum OVTT_{bus}$	$\sum OVTT_{sub}$	$Total\ Travel\ Time$
	00:09:58	00:30:08	00:11:43	00:11:32	01:03:21
Agent3 (long 25 km)	$IVTT_{bus}$	$IVTT_{sub}$	$IVTT_{bus}$	$\sum IVTT$	
	00:11:26	00:47:33	00:05:37	01:04:36	
	$\sum OVTT_{bus}$	$\sum OVTT_{sub}$	$\sum OVTT_{bus}$	$\sum OVTT$	
	00:15:15	00:02:44	00:15:03	00:33:02	
	$\sum IVTT$	$\sum OVTT$	$Total\ Travel\ Time$		
	01:04:36	00:33:02	01:37:38		

Table 7 Analysis of generalized cost

	Generalized cost (Unit : KRW ₩)
Agent 1	(22,775 * 0.769) + (1,250 + 100*1) = 18,864
Agent 2	(22,775 * 1.056) + (1,250 + 100*3) = 25,596
Agent 3	(22,775 * 1.627) + (1,250 + 100*5) = 38,810

2. Analysis of MaaS model path and cost

Table 8 Result of model analysis (Short distance)

Model	Total Travel Time(m) and Distance(km)					
Model 1-2	$IVTT_{bus}$	$\sum OVTT_{bus}$	$Total\ Travel\ Time$	$Total\ Travel\ Dist.$		
	23:00	05:46	28:46	5.77		
Model 1-3	$IVTT_{taxi}$	$\sum OVTT_{taxi}$	$Total\ Travel\ Time$	$Total\ Travel\ Dist.$		
	21:00	00:00	21:00	5.64		
Model 2-2	$IVTT_{taxi}$	$IVTT_{sub}$	$\sum OVTT_{taxi}$	$\sum OVTT_{sub}$	$Total\ Travel\ Time$	$Total\ Travel\ Dist.$
	18:00	02:00	00:57	09:32	30:29	5.65
Model 2-3	$IVTT_{taxi}$	$IVTT_{bus}$	$\sum OVTT_{taxi}$	$\sum OVTT_{sub}$	$Total\ Travel\ Time$	$Total\ Travel\ Dist.$
	14:00	08:00	00:00	08:16	30:16	6.56
Model 3-1	$IVTT_{taxi}$	$IVTT_{sub}$	$IVTT_{bus}$	$\sum IVTT$		
	13:00	05:00	02:00	20:00		
	$\sum OVTT_{taxi}$	$\sum OVTT_{sub}$	$\sum OVTT_{bus}$	$\sum OVTT$		
	00:00	02:16	09:27	11:43		
	$\sum IVTT$	$\sum OVTT$	$Total\ Travel\ Time$			
	20:00	11:43	31:43			

Table 10 Result of model analysis (Mid distance)

Model	Total Travel Time(m) and Distance(km)					
Model 1-2	$IVTT_{bus}$	$\sum OVTT_{bus}$	$Total\ Travel\ Time$	$Total\ Travel\ Dist.$		
	56:34	13:32	01:00:06	14.51		
Model 1-3	$IVTT_{taxi}$	$\sum OVTT_{taxi}$	$Total\ Travel\ Time$	$Total\ Travel\ Dist.$		
	34:55	00:00	34:55	19.16		
Model 2-1	$IVTT_{bus}$	$IVTT_{sub}$	$\sum OVTT_{bus}$	$\sum OVTT_{sub}$	$Total\ Travel\ Time$	$Total\ Travel\ Dist.$
	18:12	30:00	7:46	6:01	01:01:59	15.19
Model 2-2	$IVTT_{taxi}$	$IVTT_{sub}$	$\sum OVTT_{taxi}$	$\sum OVTT_{sub}$	$Total\ Travel\ Time$	$Total\ Travel\ Dist.$
	10:34	29:30	00:00	6:01	46:05	15.02
Model 2-3	$IVTT_{bus}$	$IVTT_{taxi}$	$\sum OVTT_{bus}$	$\sum OVTT_{taxi}$	$Total\ Travel\ Time$	$Total\ Travel\ Dist.$
	18:12	24:22	7:53	00:00	50:27	19.79

Table 11 Result of model analysis (Long distance)

Model	Total Travel Time(m) and Distance(km)							
Model 1-2	$IVTT_{bus}$	$\sum OVTT_{bus}$	$Total\ Travel\ Time$	$Total\ Travel\ Dist.$				
	01:22:41	00:13:48	01:36:29	21.18				
Model 1-3	$IVTT_{taxi}$	$\sum OVTT_{taxi}$	$Total\ Travel\ Time$	$Total\ Travel\ Dist.$				
	00:44:21	00:00:00	00:44:21	23.23				
Model 2-1	$IVTT_{bus}$	$IVTT_{sub}$	$IVTT_{bus}$	$\sum OVTT_{bus}$	$\sum OVTT_{sub}$	$\sum OVTT_{bus}$	$Total\ Travel\ Time$	$Total\ Travel\ Dist.$
	00:18:12	00:47:00	00:13:38	00:07:58	00:02:34	00:06:02	01:25:26	27.80
Model 2-2	$IVTT_{taxi}$	$IVTT_{sub}$	$IVTT_{taxi}$	$\sum OVTT_{taxi}$	$\sum OVTT_{sub}$	$\sum OVTT_{taxi}$	$Total\ Travel\ Time$	$Total\ Travel\ Dist.$
	00:13:08	00:47:00	00:08:47	00:00:00	00:03:27	00:00:00	01:20:22	27.84
Model 2-3	$IVTT_{bus}$	$IVTT_{taxi}$	$\sum OVTT_{bus}$	$\sum OVTT_{taxi}$	$Total\ Travel\ Time$	$Total\ Travel\ Dist.$		
	01:30:26	00:09:01	00:07:12	00:00:00	01:46:39	23.96		
Model 3-1	$IVTT_{taxi}$	$IVTT_{sub}$	$IVTT_{bus}$	$\sum IVTT$				
	00:12:32	00:47:00	00:12:01	01:11:33				
	$\sum OVTT_{taxi}$	$\sum OVTT_{sub}$	$\sum OVTT_{bus}$	$\sum OVTT$				
	00:00:00	00:03:27	00:06:02	00:09:39				
	$\sum IVTT$	$\sum OVTT$	$Total\ Travel\ Time$					
	01:11:33	00:09:39	01:21:12					

Table 92 Analysis of generalized cost

	Short agent Generalized cost (Unit : ₩)	Mid agent Generalized cost (Unit : ₩)	Long agent Generalized cost (Unit : ₩)
Model 1-1	-	-	-
Model 1-2	9,475	18,489	28,955
Model 1-3	13,668	28,409	34,785
Model 2-1	18,864	22,491	27,892
Model 2-2	12,921	33,596	35,960
Model 2-3	10,968	31,586	35,708
Model 3-1	12,278	-	39,550
Average	13,029	26,914	33,808

3. Comparison of real path cost and MaaS model cost

The average cost of each agent was reduced by up to 44%. Especially in the short - distance model. On the other hand, the results show that the travel time is increased in the mid distance model. This seems to be caused by the unnecessary number of transfers and the high basic fare of the taxi. Therefore, if MaaS eliminates the taxi base fare, it is expected that the reduction of travel time will be even greater. Complete MaaS service is expected to eliminate the base fare of the taxi, so the actual travel time reduction effect will be even greater.

Table 10 Comparison of generalized cost

	Short agent Generalized cost (Unit : ₩)	Mid agent Generalized cost (Unit : ₩)	Long agent Generalized cost (Unit : ₩)
Average	13,029	26,914	33,808
Real path cost	18,864	25,596	38,810
Reduction rate (%)	-44.78%	0.05%	-14.79%

V. CONCLUSION

The purpose of this study is to analyze travel pattern in Seoul using traffic big data and to study the applying of Mobility as a Service (MaaS) which is an integrated public transportation service from Europe. The analysis was conducted as follows. First, we analyzed the actual travel patterns of short - distance, medium - distance and long - distance agents according to total travel distance, and calculated the generalization cost using travel route, travel time and fare. Second, we constructed the expected traffic pattern of public transportation using MaaS. Finally, assuming the virtual introduction situation of MaaS, we reconstructed the path of the actual agent analyzed before, and calculated the generalization cost per route.

The results of this study show that when MaaS is introduced in Seoul, the transit time and cost of public transportation users are expected to decrease considerably. Especially, if the basic fare of the taxi is lost due to the introduction of the MaaS fare system, it is expected that the demand for the taxi will be increased because the use of the taxi reduces the travel time. Therefore, if MaaS is introduced in Seoul, it is necessary to determine the appropriate fare level for Seoul city. It will also be important to determine the limit of the taxi fare for the entire fare. However, the problem of distribution of revenues as presented in the previous study may be a stumbling block to the introduction of MaaS.

According to the results of this study, if MaaS is introduced in Seoul city, it will help solve the problem of rejecting the riding taxis. In addition, it is expected that taxi rides will be increased at a distance less than the base fare, and it is expected to provide a convenient public transportation system for passengers with frequent use of taxi such as transportation vulnerable. The MaaS virtual introduction model proposed in this study can be used to improve the service of public transportation and reduce the unnecessary time of the public transportation. However, in this study, the integrated system of bus / subway and taxi was applied, but in order to include additional transportation such as public bicycle and rental car in Europe, more detailed model construction and follow-up study are needed. Also, it is necessary to follow - up the MaaS plan considering the travel patterns of the passengers considering the patterns of transport mode used.

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Doyoung Jung." An Evaluation of Maas Service Effect Based On Real Travel Data.”American Journal Of Engineering Research (AJER), Vol. 7, No. 6, 2018, Pp.37-43.