INTEGRATION INDEX FOR MOBILITY AS A SERVICE

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Abstract

The integration in transport informatics is facilitated by the rapid development of Information and Communication Technology. One of the realizations of the integration is Mobility as a Service (MaaS), which is proposed as a data-driven, user-centric, personalized mobility service. It integrates various forms of mobility services covering the entire travel chain. Qualitative methods have been applied in existing studies to analyse the integration of MaaS. However, a comprehensive quantitative method is still missing, which could be introduced as a supplementary tool to compare MaaS services. Therefore, we have developed a weighted elaboration method to calculate the complex integration index for MaaS systems. Three aspects are determined as variables, which are the functions of the MaaS application, involved transport modes as well as the tariff structure. Moreover, the organization as the backbone of such integration is considered as the fourth aspect. The integration phases of MaaS are introduced regarding these four aspects, then the calculation method of the complex index is developed by considering the weighted variables. Fourteen MaaS services are evaluated with the method and categorized by organization aspect. We found that public authority is proposed to be the inter-city MaaS operator, and the private company is proposed to be the MaaS operator in intra-city or national level. Our method may support decision-makers to have an abstract overview of MaaS and identify the possible development stage.

Keywords: mobility as a service, integration phases, organization, integration index

1 Introduction

Various mobility services are available, but efficient integration of them is still missing. Integration facilitates the opportunity to use the entire public transport system across a local, regional, even international area. Independently from modes, tariffs, fares, schedules, ticket systems, etc. Integration is needed to improve comfort level, the quality of information, as well as to reduce travel time, and the cost of mobility services [1]. Mobility as a Service (MaaS) is a user-centric mobility service based on smart solutions, which is proposed to facilitate the integration of mobility services. Cooperation is managed systematically by the third party MaaS operator, users experience the 'one-stop-shop' service provided by different 'service providers'. The service supplied to users through a single digital platform integrating all travel related functions, e.g. planning, booking, ticketing, payment. Users purchase bundled services from MaaS operator and pay service fare to this operator. Thus, MaaS is identified as a seamless integrated door-to-door mobility service [2].
Qualitative approaches to analysis the transport integration have been presented [3], [4], but quantitative method is missing. In order to introduce a supplementary approach, our objective is to develop a quantitative method to study the integration index of transport system.

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We take the MaaS operator, this organization into consideration. In addition, an objective weight assignment approach is introduced. The research questions are:

- What aspects are taken into consideration regarding integration?
- How is the phase of integration identified?
- How to assess MaaS in integration point of view?

The remainder of the paper is structured as follows. State of the art is summarized in Section 2. In Section 3, the variables are determined, the phases of integration are introduced. The assessment method of integration is elaborated in Section 4. Fourteen MaaS services are considered; the discussion of the assessment is presented in Section 5. The paper is completed by the concluding remarks.

2 State of the art

The integration of mobility services is to be enhanced by several aspects. Collaboration between public and private service providers increase the possibilities to integrate transport modes, and it facilitates the introduction of MaaS operator in organizational structure [5]. The MaaS is introduced to meet subscription-based, monthly mobility plan too [6]. In addition, mobility data sharing platform enhance the realization of functionalities regarding smartphone application, especially incorporation of payment function into MaaS application [2]. However, MaaS implementation still remains at a rudimentary level, governance and legislation issues have not comprehensively studied yet [7].
Typically, an index is introduced to evaluate phenomena comprehensively, e.g. smartness, sustainability, liveable city index. An index is calculated by aggregation of weights multiplying scores of relevant indicators (variables in this context) [1], [8], [9], [10]. Various index calculation methods are applied in evaluation or benchmarking of comparative studies [10], [11]. Several researchers have studied the sustainability index of transport regarding cities [1], industries [9], freight transport [10], etc. Mostly, fuzzy logic approach was applied to reveal the uncertainties of respondent's responses [9], [10].
MaaS implementation is significantly facilitated by transport informatics. We develop an assessment method to evaluate the 'backbone' informatics integration of MaaS regarding the organizational role of MaaS operator.

3 Phases of integration

3.1 Selection of variables

To describe the integration of MaaS, three aspects as variables are determined based on literatures and MaaS implementations: function, mode, tariff structure. The development tendency of the variables is presented in Fig. 1.

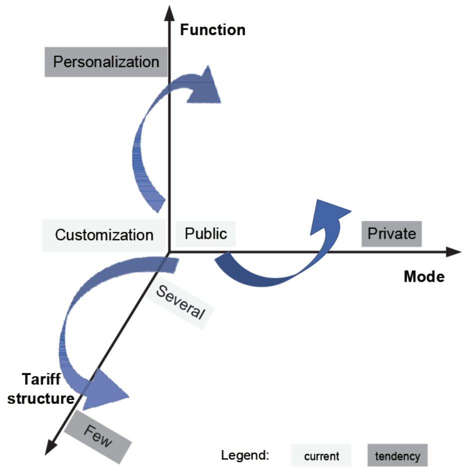

Figure 1 Development tendency of variables

Customized functions require input about users' preferences manually, e.g. preferred mode; usually predefined options are available. By contrast, personalized functions apply artificial intelligence, users' preferences are set automatically considering behaviour and habits, e.g. the recommended route with preferred mode. The functions of smartphone applications vary from basic customized functions towards the advanced personalized functions.
The boundary between public and private modes become not so clear because of the rise of shared mobility. Typically, high volume of passengers is transferred by the public transport (PT) modes. However, the taxi can be regarded as the most flexible public transit mode. Car/bike-sharing are transitional modes. Since the essence is the information platform, ridesharing and ride-sourcing are categorized into private modes. The incorporate tendency of modes into MaaS is firstly public ones and then private modes.
Mobility plan is introduced as the combination of several transport modes into a package and provided by MaaS, the complex tariff structure is packaged and delivered to users 'as a whole'. From the travellers' point of view, the journey is payed 'as a whole' as well. Travellers do not need to deal with the detailed tariff structure of each mode, in this sense, tariff structure is much more simplified.
Since MaaS operator plays a significant role, the 'organization' is also introduced as the fourth aspect. Typically, the third party MaaS operator is either public authority or private company. Determined variables are summarized in Table 1.

Table 1 Variables of integration analysis

Variables			Description
Integration	A_1	Function	mapping, planning, booking, ticketing, payment, reminding, etc.
	A_2	Mode	involved transport modes
	A_3	Tariff structure	pricing, fare collection methods, e.g. subscription of mobility plan, passes, pay-as-you-go
	A_4	Organization	private company or public authority

3.2 Identification of phases

Integration phases considering identified variables are summarized in Fig.2. The differences between the term 'integrator' and 'operator' in MaaS are the following: Integrator provides an established platform to collect the available mobility service websites, users purchase mobility services from service providers by clicking and turning to the corresponding websites. Operator has a higher organizational role. A unified interface for service providers and users is provided. Users purchase mobility services from MaaS operator.

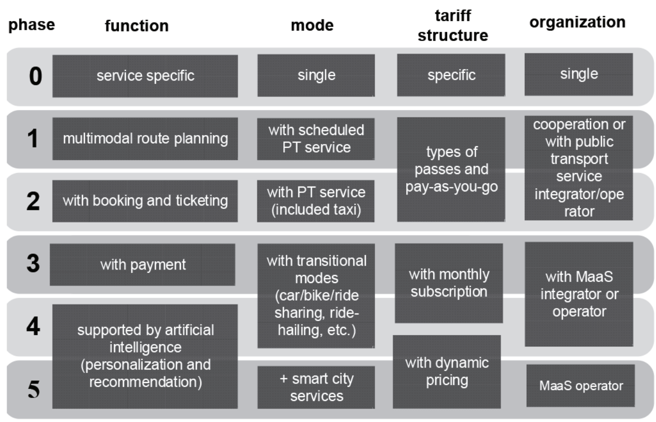

Figure 2 Identified phases of integration of MaaS

Phase 0: non integration: Integrated route planning, booking, ticketing and payment are available only for one specific service (e.g. ride-sourcing); modes or services of transport are operated separately; ticket system and fare collection are managed separately.

Phase 1: scheduled public transport service integration: Function of multimodal journey planning is available for public transport modes, e.g. combination of bus, tram, metro. Various types of public transport passes are provided; cooperation is mainly among pubic transport modes.

Phase 2: entire public transport service integration: Additional functions, such as booking and ticketing, payment, are available provided by a third party. Usually, taxi service is integrated, several public transport service providers cooperate. A common interoperable platform is available. The role of public transport service operator in organization is significant.

Phase 3: partial public-private transport service integration: Journey planning, booking, ticketing and payment functions for various transport modes are integrated in one application. Bike-sharing, car-sharing such transitional services are integrated. Advanced tariff options are provided, e.g. pay-as-you-go and monthly subscription. MaaS integrator or MaaS operator are introduced.

Phase 4: entire public-private transport service integration: Additional functions, such as reminder and PoI (Point-of-Interest) recommendation are provided. Practically almost all modes are integrated. More options for combinations are listed in monthly subscription; dynamic pricing is applied. MaaS integrator or MaaS operator manages the services.

Phase 5: fully integrated mobility service: Personalization and recommendation are introduced. All modes are integrated, even aircraft services; monthly subscription is widely available, pay-as-you-go is suggested for tourists. The organizational role of MaaS operator is significant.

4 Assessment method

The steps of integration index calculation are: Step 1: determination the weights of variables; Step 2: determination the scores of variables; Step 3: calculation the index value by aggregation of scores.

Step 1: Discrete weights W_i (from 0.1 to 0.4) are assigned to variables A_j referring to the identified phases of integration (phase 1 to phase 4), respectively. The values and scales of variables are presented in Table 2. The aspect 'organization' is not considered in index calculation, it is used for classification purpose in demonstration of the applicability method.

Table 2 Weights and scores of variables

Phase	Weight of variable	Scales assigned to variable A_j					
		A_1 Function	Score	A_2 Mode	Score	A_3 Tariff	Score
1	W_1=0.1	Mapping Journey planning	1 or 2	Scheduled intercity PT service (short distance)	1	Public passes	1
2	W_2=0.2	Booking Ticketing	1 or 2	Additional taxi service	1	Pay-as-you-go	1
3	W_3=0.3	Payment	1	Additional car/bike sharing service	1	Monthly subscription	1
4	W_4=0.4	Additional advanced functionalities	Each one count 1	Additional private service, or with scheduled intracity PT service (long distance)	Each one count 1	Dynamic pricing	1

Step 2: The availability of variables in each phase could be checked on corresponding smartphone applications, accordingly, the objective scores are assigned during assessment regarding specific service. For example, a service application is selected, when W_1=0.1, regarding A_1, if function of mapping and journey planning are both available, then scales=2 is assigned, if only one of them is available, then scales is 1. The similar checking of A_2 and A_3, then for W_2, W_3, and W_4, same checking rounds are performed. Scores of variables are obtained.

Step 3: Generally, existing approaches are applied to rank MaaS services according to identified phases; however, we assign weights to variables according to different phases. The integration index is calculated with eq (1).

$$I = \sum_{i=1}^{4}\left(W_i \cdot \left(\sum_{j=1}^{3} A_j\right)\right) \tag{1}$$

Where:
'I' - represents the integration index,
'W' and 'A' - represents the weight of variable and the variable, respectively.
'i' - indicates the phase; i = 1, 2, 3, 4.
'j' - indicates the variable; j=1, 2, 3.

Simply, first summarize the scores of variables, then multiply the summarized scores with the weights according to the phases. The result of index calculation is the aggregation of results obtained from step 2. Phase 0 and 5 should be eliminated, as integration is not available in the former, fully implemented integration is not available in the later.

5 Result and discussion

Fourteen smartphone applications of MaaS service, which are available in northern and central Europe, have been selected. The corresponding services are assessed by the developed method. The selected services are summarized in Table 3. The MaaS operator is either public service provider (indicated by bold letter) or a third-party private company.

Table 3 The selected MaaS services

I	II	III	IV	V	VI	VII
Moovel	Qixxit	HVV	GVH Hannover-mobil	Leipeig-mobil	Moovit	Urbi
VIII	IX	X	XI	XII	XIII	XIV
Mozio	Smile	Wien-mobil	Nordest-mobil	Ubigo	Whim	Kyyti

Relevant functionalities, i.e. availability of variables, have been tested. The result regarding scores of variables is presented in Fig. 3.

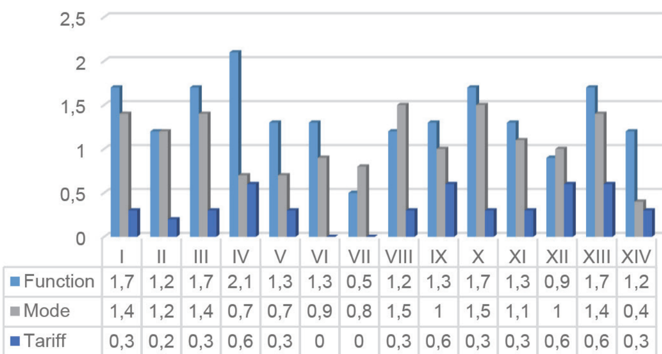

Figure 3 Value of variables

Function (A_1): GVH Hannovermobil (IV) application obtains the highest score as besides basic, three additional functions are incorporated in it: saving favourite locations and routes, reminder about service alterations, environmental footprint (CO_2 consumption). Mode (A_2): Mozio (VIII) and Wienmobil (X) applications obtain relatively high scores as mapping of charging points and parking facilities, long-distance bus service and, scooter service are also considered. Tariff structure (A_3): GVH Hannovermobil (IV), Smile (IX), Ubigo (XII), Whim (XIII) obtained higher scores as monthly mobility package is available. The result of aggregated index values is presented in Fig. 4.

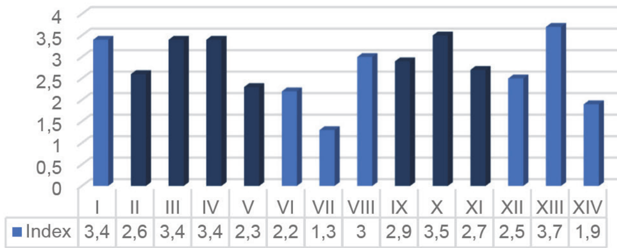

Figure 4 Aggregated value of index

The highest value of index is obtained by Whim (XIII), in which the MaaS operator is a private company. Whim is evaluated as the benchmarking in the integration studies [3], [4] as well. In addition, Whim (https://whimapp.com/) is available in Helsinki, West Midlands, Antwerp, Vienna, Tokyo, and Singapore as an application of international mobility service. Referring to the operational area, the MaaS services are operated in wider range by private companies (e.g. I. Moovel, VI. Moovit, VII. Urbi, XIII. Whim), in intra city or even in national level.

6 Conclusion

MaaS is developed under a mixture of information technology and innovative mobility services. The characteristic of transformation from vehicle ownership to service usership is expected to be met. Developing an assessment method to determine the integration index of MaaS services is main contribution of our work. Accordingly, the variables and integration phases are determined. Since MaaS operator has a key role in MaaS, the 'organization' aspect is highlighted. We have found that:
- involved functions and modes depend highly on the operational area,
- the monthly subscription of mobility package is a possible improvement direction, this function is only available in 4 applications out of 14,
- the third party MaaS operator is a public service provider in local or inter-city level, thus a private company in national and cross-border level.

We faced, as a lesson learnt, that developing an objective approach to assign weights to variables is rather complicated work. Our further research direction is to calibrate the method with the application of sensitivity analysis.

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