Periodica Polytechnica
Transportation Engineering

44(2), pp. 97-104, 2016
DOI: 10.3311/PPtr.8570

RESEARCH ARTICLE

Multicriteria Analysis of Hungarian Journey Planners

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Received 16 September 2015; accepted 16 November 2015

Abstract
For planning and realization of travel chains journey planners can be used, but these often offer only partial solutions, especially considering the domestic operators. In order to reveal the improvement opportunities of the journey planners an evaluation method was developed. Using the method the journey planners can be compared in a quantitative way and ranked by functional, operational and visualization features. Journey planners of bus transport operators (Volán) in Hungary were analyzed and evaluated, some top features were also highlighted. The evaluation was performed taking the preferences of certain user groups into consideration, thus the values and ranking varied. The novelty of the paper is the application of our general evaluation method for Hungarian operators and the ranking among them, which provides input for development measures. The spatial properties of the journey planners were also represented in order to highlight the geographical differences.

Keywords
journey planner, multicriteria analysis, evaluation, bus operators

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1 Introduction

The growth of travel needs, which are preconditions and consequences of economic development (White paper, 2011), raises an increased challenge towards the passenger transport system. Since the capacity of the transport system is limited, the increase of passenger transport performance is primarily attainable by the enhancement of the public transport's share (Mátrai et al., 2013). That is why providing a high quality in public transport is necessary. The actions have to be executed on two levels: on physical level, which involves for example creating new bus lines and manipulation of traffic lights at the intersections (Tettamanti et al., 2008), and on information level, which involves route planning with computer programs and location-based information services during the journey (Csiszár et al., 2011).

In this paper we have dealt with the latter one, because due to the development of the info-communication technologies and the expansion of the available information's amount on the internet, the passengers' expectations also increased, and some optimization questions came into view regarding journey planning and execution.

The passengers want to reach their travel destination in the most favourable way considering their personal preferences (Földes and Csiszár, 2015; Golob, 2003; Nadi and Delavar, 2011; Winkler, 2010), which usually means the least possible travel time, the minimum number of transfers or using only low-floor vehicles in case of disabilities. Nevertheless the travellers are not certainly in possession of all the needed local knowledge and information about the whole travel space, and occasionally they also have to adapt to rapidly changing traffic situations (Zhang et al., 2010).

Passengers want to obtain personalized and supplementary information, which is especially important in case of long-distance journeys. After the survey of international journey planners (Esztergár and Csiszár, 2015) we wanted to put emphasis on the domestic journey planners, primarily on the systems of bus transportation operators (Volán). Prior to this study no comparison was available in Hungary, which deals with functionalities and other features of journey planners.

The aim of the research was to present a qualitative evaluation method to compare different operators. Having the evaluation results the main strength and weaknesses of the operators were highlighted from the passenger point of view. With the results of our analysis the operators can improve their service according to passengers' requirements.

The comparison was realized for the old organizational structure of Volán operators containing 24 companies, in order to reveal differences among operators in a more detailed way. Meanwhile the organizational structure of the bus companies was reorganized (creating larger companies with their integration), however the information handling and journey planning functionalities did not change significantly. The integration does not have effect on the journey planning services yet. In order to provide comparability to the new structure, the new Volán operators are also represented.

The paper is structured as follows: the method of evaluation is described including the aspects and the calculation model. Then specific information is presented about the Volán operators, which is followed by the evaluation and the ranking considering also the preferences of user groups. Finally ideas of future trends are discussed.

2 Evaluation method

The analysis aspects were classified (Table 1). The 5 main categories were: route-planning services, booking and payment, handled data and operational features, comfort service information, supplementary information (Easyway, 2010).

In the first group we handled data input opportunities (e.g. address, GPS coordinates, facilities), different planning aspects (e.g. duration, cost, number of transfers, P+R opportunities), the displayed data for the passengers and the design and visualization of information. The second group contains features of booking information and payment services, as tariff information (e.g. zones, prices), data input modes and payment options (e.g. printed, mobile ticket). The third group is about static and dynamic data. Static data information can be the timetable and the travel conditions (e.g. maximal size of the luggage), while dynamic data mean restrictions, delay info, information about alternative routes. In the fourth group the passengers may receive information about comfort services at the stops (e.g. WiFi, luggage storage) and on board (e.g. electrical supply). Additional services were also included, as weather forecast, opening hours of shops. The fifth group contains information about environmental impacts, available information in foreign languages, customer service connections (e.g. via telephone, e-mail or social media) and opportunities for disabled persons (e.g. low floor vehicles).

Since the appreciation of the information service depends significantly on the personal characteristics of the passengers, we have created user groups from the passengers by their age (old or young), their mobility features (work or leisure based) and their motion abilities (without problem or handicapped). The following user groups were formed using the combination of these three points of view: student, worker, tourist, businessman and pensioner.

In the course of the analysis we adapted and implemented a Multi-Criteria Analysis (MCA) method, because this produces clear and well-comparable results (van Delft and Nijkamp, 1977; DCLG, 2009). MCA methods are easy to compute and widely used. They are based on scoring (general evaluation number) and weighting (average evaluation number).

2.1 Scoring

The multimodal journey planners (j) were evaluated on a 0-10 valued rating scale according to their correspondence to the certain aspects (i). To each route planner belong I pieces of evaluation number belong to each journey planner. From the evaluation numbers an I*J sized evaluation matrix is defined, in which the elements are signed by p_{ij}. Summing up the evaluation numbers given to the aspects, a general evaluation number can be provided for the certain multimodal journey planners (u_j).

$$u_j = \sum_{i=1}^{I} p_{ij} \tag{1}$$

- i – aspects, i =1,..,I,

Table 1 Classification of the aspects regarding multimodal journey planners

1. Route-planning services	2. Booking and payment	3. Handled data, operational features	4. Comfort service information	5. Supplementary information
ways of data input	tariff information	static data	services at the stations/ stops	environmental impacts
planning aspects	method of booking and payment	semi-dynamic data	services on borad	information in foreign languages
displayed data	payment options	dynamic and estimated data	additional services	customer service
perspicuity of displayed data		personal data		information of equal opportunity

- j – multimodal journey planners, j=1,..,J,
- p_{ij} – elements of the evaluation matrix,
- u_j – general evaluation number for the j multimodal journey planner.

2.2 Weighting

The general evaluation number is already useful by itself, but it does not take into account the differences between the systems and the different preferences of the certain user groups (k). The solution is presented by using normalization and weighting, thus the original uj values can be updated. Weight numbers belong to all user groups and aspects, these are the so called preference values (s_{ki}), which form a K*I sized weight matrix. The values of the elements in this matrix can be determined by a detailed passenger questioning.

From the evaluation matrix and the weight matrix a K*J sized qualifier matrix can be generated, that takes into account the different preferences of the user groups. Its elements, which are the qualifier values (u_{ki}) for a certain multimodal journey planner and a certain user group, are to be calculated in the following way. We generate the summed product from the elements of the j^{th} column of the evaluation matrix (p_{ij}) and from the elements of k^{th} row of the weight matrix (s_{ki}), which value is then divided by the summed product of the maximal given evaluation numbers (p_i^{max}) and the corresponding weights.

$$u_{kj} = \frac{\sum_{i=1}^{I} s_{ki} * p_{ij}}{\sum_{i=1}^{I} s_{ki} * p_i^{max}} \quad (2)$$

- k – user groups, k=1,..,K,
- s_{ki} – elements of the weight matrix,
- p_i^{max} – the maximal given evaluation number according to the i^{th} aspect,
- u_{kj} – elements of the qualifier matrix.

Knowing the qualifier values (u_{ki}) for the multimodal journey planners and the transportation share (r_k) of the user groups the average evaluation number (u_j*) can be determined, which is referred to all the passengers and takes into account the special expectations of the certain user groups at the same time.

$$u_j^* = \sum_{k=1}^{K} r_k * u_{kj} \quad (3)$$

- r_k – transportation share of the k^{th} user group,
- u_j* – average evaluation number for j^{th} multimodal journey planner.

3 Evaluation of the Hungarian journey planners

In Hungary bus transportation is one of the most important transportation modes with a share of 2/3 within public transportation, but also with most differences in service quality among the operators (László, 2013). In the last decades operators worked with different operational conditions, internal structure and fleet sizes, which is a consequence of dissimilarities of the served areas. For example the average number of employees was ca 700, but was 10x more for Volánbusz, than for Hatvani Volán. Concerning the financing the income from the tickets covered only 25-30 % of the total expenses. The difference had to be covered by governmental subsidies, therefore the development of modern passenger information systems was not possible without national or EU funds. The new organizational structure of Volán operators was introduced in 2014, which aimed at:

- the reduction of redundancies,
- more balanced number of employees,
- more efficient operation,
- more uniform service level for passengers.

7 regional operators were introduced by merging 2-6 previous operators (Fig. 1), which are as follows:

- ÉNYKK (Northern-Western Hun. Transport Center),
- KNYKK (Middle-Western Hun. Transport Center),
- KMKK (Middle-Eastern Hun. Transport Center),
- ÉMKK (Northern Hungarian Transport Center),
- DDKK (Southern-Transdanubia Hungarian Transport Center),
- DAKK (Southern-Great Plain Hung. Transp. Center),
- Volánbusz (in Budapest and Pest County).

Fig. 1 Spatial representation of new organizational structure (László, 2013)

All journey planners of Volán operators were studied, that are available by passengers on the internet and important for the domestic use. Each operator is regional, uses only buses and is service provider dependent. Although there are now 7 regional operators, the integration of the journey planners is not realized yet, therefore the strengths and weaknesses of the original 24 operators were surveyed. With the multi-criteria evaluation the evaluation numbers and the weights were determined by making estimations for the user groups. Finally, the journey planners were ranked by the given average evaluation numbers.

Table 2 Features of journey planners of the Hungarian bus operators

Name of operator before integration	Volánbusz	Kisalföld Volán	Balaton Volán	Bakony Volán	Somló Volán	Vasi Volán	Zala Volán	Vértes Volán	Alba Volán	Nógrád Volán	Mátra Volán	Hatvani Volán	Agria Volán	Jászkun Volán	Borsod Volán	Szabolcs Volán	Hajdú Volán	Kapos Volán	Gemenc Volán	Pannon Volán	Bács Volán	Kunság Volán	Tisza Volán	Körös Volán
Name of operator after integration	Volánbusz			ÉNYKK				KNYKK				KMKK				ÉMKK			DDKK			DAKK		
1. Route-planning services	X	X	X	X	-	X	-	X	-	-	-	-	-	-	X	X	X	-	-	-	-	X	-	-
2. Booking and payment	X	-	-	X	X	X	X	-	X	-	-	-	-	-	X	-	-	-	-	-	-	X	X	-
3. Handled data, operational features	X	X	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-
4. Comfort service information	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5. Supplementary information	X	X	-	-	-	-	-	X	X	-	-	-	-	-	X	-	-	-	-	-	-	-	X	-

3.1 Features of the journey planners

Considering features the journey planner of Volánbusz provides the most advanced service for passengers (Table 2). This operator provides information about all stops in Hungary, saves previous searches and during the planning it takes into account the number of transfers, the waiting times and the walking distances. Furthermore it has ticket purchase and seat reservation functions. The tickets can be purchased by mobile phone and the displayed electronic receipt is enough for inspections.

It should be mentioned that most Hungarian bus operators do not provide an own journey planner for long distance travel, because a common journey planner for the whole country is operated by CDATA and is linked by the bus operators' web sites. Therefore some systems support only urban transport, which implies that some examined aspects (e.g. booking and payment) are not that relevant for these systems.

The Kisalföld Volán has an extraordinary journey planner, developed by IQSYS and HC-Linear companies. The system can find the closest stop and transport service between two arbitrary chosen points on the map. The Vértes Volán and the Kunság Volán use the same planner as Kisalföld Volán, but its functionality and manageability lag behind the previous system. Nevertheless uniquely among the Volán operators some POIs can be shown, such as sightseeing places, health care facilities and shops. The Borsod Volán, the Hajdú Volán, the Jászkun Volán, the Balaton Volán, the Bakony Volán and the Vasi Volán do not provide journey planning service, only map visualization of stops and vehicles.

The Tisza Volán developed easy and well working seat reservation and online ticket purchase system for all lines with the option of selecting the exact seat. The Alba Volán and the Kunság Volán provide chip card pass for the passengers. The Borsod Volán, the Bakony Volán, the Somló Volán, the Vasi Volán and the Zala Volán use the seat reservation system of Volánbusz through a link.

Real-time information is handled only by the Kisalföld Volán and the Vasi Volán, the former sends warning in case of delay. The Agria Volán shows the delays using a very simple method (arrival times with colour code). In most of the cases the customer services are suitable, there is a forum for passengers developed by Volánbusz, Kisalföld Volán and Tisza Volán. The Volánbusz, the Kisalföld Volán, the Vértes Volán, the Borsod Volán and the Tisza Volán show the low floor buses as icons, while the Alba Volán established a homepage for disabled passengers.

3.2 General evaluation of the journey planners

The evaluation numbers are presented and summarized in Table 3. The rows represent the aspects (i) and the columns represent the chosen journey planners (j). The general evaluation numbers of the journey planners (u_j) are calculated by the summation of the evaluation matrix's elements (p_{ij}) by columns. The maximum reachable points were 180, which includes values for the 18 single aspects added up. For each single aspect the maximum value was 10. The values were assigned to operators based on how much the chosen aspect was realized. For example Volánbusz got 25 points for route-planning services (which is a main aspect of 5 single aspects with a maximum of

Table 3 Evaluation of journey planners of the Hungarian bus operators

Name of operator before integration	Volánbusz	Kisalföld Volán	Balaton Volán	Bakony Volán	Somló Volán	Vasi Volán	Zala Volán	Vértes Volán	Alba Volán	Nógrád Volán	Mátra Volán	Hatvani Volán	Agria Volán	Jászkun Volán	Borsod Volán	Szabolcs Volán	Hajdú Volán	Kapos Volán	Gemenc Volán	Pannon Volán	Bács Volán	Kunság Volán	Tisza Volán	Körös Volán
Name of operator after integration	Volánbusz			ÉNYKK				KNYKK				KMKK				ÉMKK			DDKK			DAKK		
1. Route-planning services	25	26	3	5	0	3	1	25	0	1	0	0	1	3	3	1	3	0	0	0	0	25	1	1
2. Booking and payment	25	7	7	17	17	17	17	7	10	7	7	7	7	7	17	7	7	7	7	7	7	10	22	7
3. Handled data, operational features	14	20	12	11	11	11	11	13	6	6	9	6	14	12	11	11	12	6	11	11	11	11	13	11
4. Comfort service information	3	1	0	0	0	1	0	2	0	0	0	0	0	1	0	1	1	0	0	0	0	1	1	0
5. Supplementary information	16	10	4	4	4	4	4	8	5	2	4	4	4	4	8	4	4	4	4	11	4	11	6	4
General evaluation number	82	64	26	26	37	36	33	55	21	16	20	17	26	27	39	24	27	17	22	29	23	60	41	23
%	46	36	14	14	21	20	18	31	12	9	11	10	14	15	22	13	15	10	12	16	13	33	23	13

50 points), because starting points of a journey could only be searched by stops, but route-planning aspects were detailed and a good visualization of the routes was present.

According to the evaluation it can be stated that Volánbusz offers the highest level of information services because of its seat reservation module and foreign language information. Its journey planner function obtained also high score, but in this area Volánbusz is still not the best.

The Kisalföld Volán attained to the 2nd place with its outstanding route planning function and handling of dynamic data. Not far behind are the Vértes Volán and the Kunság Volán, which use the same route planner. The latter journey planner obtained a higher rank because of its chip card pass system and foreign language opportunity. The Borsod Volán, the Bakony Volán, the Somló Volán, the Vasi Volán and the Zala Volán reached middle level points. These operators enable the online ticket purchase through a link to Volánbusz, but do not have route planning service, foreign language information or equal opportunity information (except for Borsod Volán). Concerning the further operators in many cases even static maps are not available, or there is no information about the planned restrictions (e.g. road works in 2 weeks), thus the results of these operators are obviously weak. Only Pannon Volán reaches up to the middle level because of foreign language information.

4 Evaluation considering the preferences of the user groups

The exact quantification of the user groups' preferences would require questioning survey based on a representative sample. Estimated weights were assigned to the main aspects based on engineering considerations, where the following definitions were used: 0,1 – not interested, 0,2 – moderately interested, 0,3 – very interested. Table 4 shows the weight matrix, in the rows the user groups (k) and in the columns the main aspects (i). The weights of the sub aspects (s_{ki}) are calculated by the equal distribution of the main aspects' values. The values of transportation share (rk), which are shown in the last column of the table, are based on the results of the National Traffic Data Survey (Miksztai and Szele, 2008).

The qualifier matrix (Table 5) can be calculated by weighting the operators according to the user groups' expectations and normalizing these values (u_{kj}). On the basis of that the operators' judgment was modified. The percentage values were calculated considering how close they are to the maximal given value of the certain aspect, which is therefore a relative value. In the last row of the table the average evaluation number (u_j*) is shown referred to all passengers.

In the case of route planning services and booking and payment some journey planners performed well, but concerning

Table 4 Weights of the main aspects according to the user groups and the transportation shares

	Route-planning services	Booking and payment	Handled data, operational features	Comfort service information	Supplementary information	Transportation share
Student	0.2	0.15	0.3	0.25	0.1	0.3
Worker	0.3	0.2	0.25	0.1	0.15	0.3
Tourist	0.25	0.3	0.15	0.2	0.1	0.15
Businessman	0.25	0.1	0.15	0.3	0.2	0.1
Pensioner	0.3	0.1	0.1	0.2	0.3	0.15

Table 5 Evaluation of Hungarian journey planners considering user groups

Name of operator before integration	Volánbusz	Kisalföld Volán	Balaton Volán	Bakony Volán	Somló Volán	Vasi Volán	Zala Volán	Vértes Volán	Alba Volán	Nógrád Volán	Mátra Volán	Hatvani Volán	Agria Volán	Jászkun Volán	Borsod Volán	Szabolcs Volán	Hajdú Volán	Kapos Volán	Gemenc Volán	Pannon Volán	Bács Volán	Kunság Volán	Tisza Volán	Körös Volán
Name of operator after integration	Volánbusz			ÉNYKK				KNYKK				KMKK				ÉMKK			DDKK			DAKK		
Student	80	67	29	39	34	39	35	57	21	17	22	17	30	30	39	27	30	17	25	28	26	59	43	26
Worker	84	68	26	39	33	37	34	58	20	16	20	16	26	27	39	23	27	16	22	26	23	63	41	23
Tourist	87	58	25	43	38	42	39	53	23	18	19	17	24	26	43	23	26	17	21	24	22	58	49	22
Businessman	82	66	22	31	24	30	26	59	17	13	16	14	21	24	32	21	24	14	17	25	19	63	33	19
Pensioner	85	67	20	29	22	28	23	61	16	12	15	13	18	22	32	18	22	13	16	26	17	66	31	17
Average evaluation number	83	66	26	37	31	36	33	57	20	16	19	16	25	27	38	23	27	16	21	26	22	62	40	22

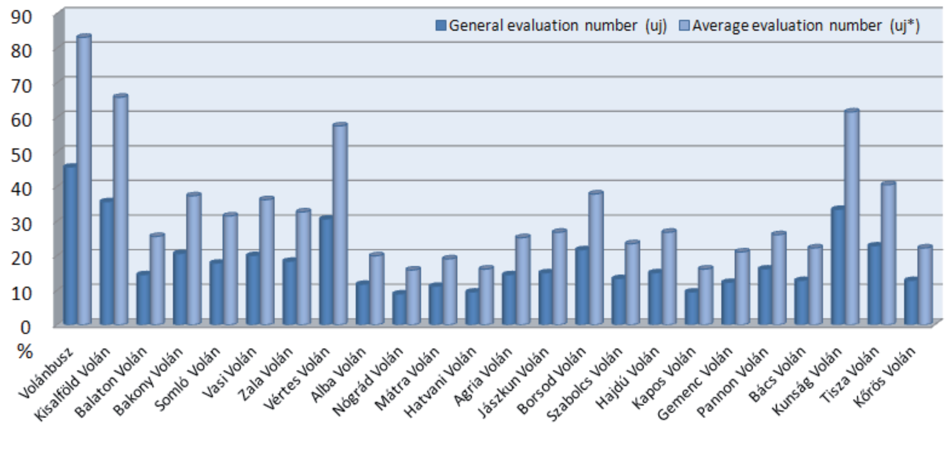

Fig. 2 Comparison of the general evaluation numbers and average evaluation numbers

the maximal obtainable values all operators reached low points. Therefore weighting the results of the journey planners, big differences occurred because of the many aspects, where none of the journey planners were given the maximal available points. It can be observed that the best operator (Volánbusz) attained only 83 percent, which means that for some single aspects there was another operator, which preformed better. Concerning the average evaluation number (Fig. 2) the ranking did not change.

The spatial representation of the results was also executed. The information service levels are very different considering spatial distribution (Fig. 3). The darker the colour, the better is the result. The operators located close to the capital, in the western and surprisingly in the southern area of Hungary provide much higher service level than operators from the north-eastern part of Hungary. The results do not correlate with the average GDP or number of inhabitants of the area, because for example in the southern counties more people live, than in the service area of Kisalföld Volán (most western area on the map). Concerning the disparities within the new operational structure the biggest differences can be found in the case of ÉNYKK, KNYKK and DAKK.

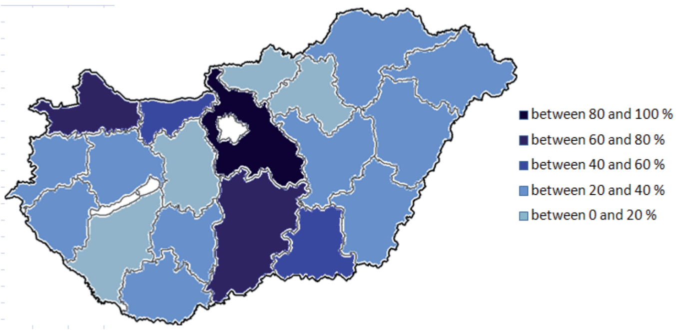

Fig. 3 Spatial representation of the average evaluation numbers of Hungarian bus operators

5 Trends of development

After deeper investigation of the top solutions both national and abroad, we have determined the development trends. These are as follows:

- multimodality (intermodality),
- real-time data,
- location based services,
- personal preferences,
- functional integration (especially e-ticketing),
- collection of data of travellers (crowd-sourcing),
- journey planning based on activity chains,
- premium information.

Most of the functions are available in certain systems, but not in an integrated way. The new generation solutions should take into account the expectations of each user group in a complex way. The data collection could be realized by FCD (Floating Car Data), by using mobile cell or BlueTooth device information (Tettamanti et al., 2012). In order to receive travel information GPS devices can be also used to determine travel times and delays (Bauer, 2013), while the provision of punctual bus operation is supported by transport priority measures (Kalasova et al., 2014).

Multimodality is a specially important issue for the bus operators, because either the destination of the passengers falls outside of their service area or bus transportation has a feeder role (for train service). Accordingly a journey planner including more transportation modes is more attractive. The railway, the urban transportation, the P+R, the B+R systems and shared mobility services, as car-sharing and bike-sharing should be integrated, thus realizing a comprehensive information service (Spitadakis and Fostieri, 2012).

In route planning the extension of the optimization possibilities with fare calculation improves its usefulness. It is essential to provide information not only in the pre-trip phase, but also during the trip (e.g. alerts), thus supporting selection of alternative routes in case of accidents or traffic jams (Horváth, 2012). Alerts can be shown directly on the mobile phone or on VMS tables or screens in the stops (Patten et al., 2003). It is also beneficial for passengers, if a good visualization of alternative routes is presented. Collecting passengers' routes the operators can derive mobility patterns (Kamruzzaman et al., 2011).

The most revolutionary development should be realized in the area of comfort service information, because the operators obtained very few points regarding this aspect. There is also place for development concerning the supplementary information and handling of dynamic data (Seongmoon et al., 2005).

6 Conclusion

The development of traveller information services regarding comprehensive route planning and travel execution (guiding) is driven by the technological development and the increase of travellers' expectations. The novelties of this paper are determining a framework of evaluation aspects and using MCA with weights for Hungarian bus operators. The required development directions have been derived from these results.

The main contributions of the paper are:

- Method development for evaluating and comparing the functionalities of journey planners,
- Evaluation of the Hungarian journey planners (VOLÁN bus operators) considering also the special requirements of the user groups.

The key findings of the paper are:

- The larger is a company the more advanced (more complex and user-friendly) is its journey planner.
- Consideration of requirements of the user groups does not influence significantly the original ranking, however some changes of the points can be observed.

The lessons learnt:

- The introduction of a unified framework of aspects needed comprehensive literature review and forethinking of possible user requirements.
- As more operators used the same developer, the comparison was easier between those journey planners, but the comparison was harder between different developers.

Further research directions:

- A questionnaire is to be created, which represents the requirements of the user groups.

- The weighting factors have to be chosen thoughtfully regarding the analysis, as they may have a significant effect on the final results.
- A detailed geospatial analysis should be conducted in order to reveal connections between socio-economical factors and spatial distribution of the journey planner evaluation.
- With crowd-sourcing methods a continuous refinement of the questionnaire's results could be performed, where users could give their answers through a mobile application.
- A guideline for operators is to be elaborated, which deals with functionalities needed by most user groups.
- The evaluation aspects could be extended based on passenger feedback.
- Urban and long distance services could be compared separately.
- The evaluation could be performed on mobile applications, as even more travellers tend to use smart phones for planning.

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