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RESEARCH ARTICLE

Conception of Personalized Parking Assistant Application

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Abstract

Since assessment of entire travel chains (ETC) depends on the properties of its elements, information provision in final phase of driving, namely parking movements is required. In order to enhance perceived quality, a personalization method for parking assistant applications (PAA) has been devised. Several PAAs have been compared and the parking habits and expectations of the travellers have been revealed.

As it turned out all of the innovative properties are still not combined into one PAA, they can be found only partially. Furthermore, personalized information is considerably important for travellers, however the diversity of their needs is less than it was supposed at the beginning of the research. Based on these results conception of the parking assistant system (PAS) has been framed. For demonstration of the operation an application has also been developed. Finally the directions of the further research have been discussed.

Keywords

Intelligent Transportation System · mobile application · parking management · personalization · travel behaviour

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1 Introduction

Nowadays, urban mobility demands are not primarily satisfied with the extension of the transport network, but with the **development of transportation management**. More and more attention is paid to devices and procedures that aid travellers with intelligent solutions. A significant part of urban road traffic is caused by vehicles cruising for car park [2, 14]. These vehicles not only make confused unnecessary movements, but their uncertainty induces disturbances and enhances the risk of accidents as well. There are two main types of measures to manage this problem:

1 pricing policy and/or

2 **intelligent transportation systems**.

Volume of cruising traffic can be moderated by introduction of parking charge and increasing fees [15]. This measure is not a primary solution, because only the symptoms and not the source of the problem is treated [19]. Origin of the problem: the travellers do not receive personalized information aiding their decisions regarding (among other transportation related issues) parking at the right time.

Microscopic methods that are more flexible and effective on a certain area have been superseded by macroscopic policies that are simplified and aggregated [3].

Ideally, travellers are supported by route planners that plan the ETC and assist its realization. Such complex route planners are still not in widespread public use. Their realization has been hindered by several obstacles (often conflicts between the transportation operators). For individual travellers, one of the **most critical phases** of the ETC is **accessibility to free parking spaces** [14]. Successful execution of this phase greatly facilitates the optimal (personalized) realization of the ETC.

Urban road traffic volume can be significantly reduced by dynamic (using real-time data) parking management [4, 5, 9, 11]. This statement has also been proved by results from the San Francisco real-time parking management system [12]. Real-time parking space occupancy can be effectively collected by local sensors. Conception of intelligent parking management using sensor network has been already realized [17]. Parking management is part of the entire infrastructure management. State of the art booking theory regarding the infrastructure elements has already been devised [16]. The dynamic capacity and usage level of the parking systems greatly depend on their accessibility, which is affected by both physical barriers and a lack of information. The accessibility of information can be significantly improved by personalized information, parking facility booking and advanced fee collection (payment) functions [6].

Our recent research focused on parking planning and the related traveller habits. Modern and widespread applied **parking assistant applications (PAA) have been investigated and compared**. It has been kept in mind that parking management should be integrated into the entire transportation management [13].

It is an existing problem that travellers are provided with collective information instead of personalized information. The revealing of travellers' demands should be considered with higher importance during the development of the PAS [18]. For this purpose **travellers' parking habits and expectations have been surveyed**. Personalized PAAs may also reduce travel time and energy consumption [8].

Based on these results structural and functional **conception of the advanced PAS has been framed**. The information provision service has been devised in details and **a muster application has been developed**. It aids travellers before and during their movements. The applied terminal is a **mobile smart device** (for example smartphone).

2 Situation analysis

Situation analysis has been executed in the following regards:

1 Comparative analyses of PAAs.

2 Online questionnaire in order to get acquainted with traveller's expectations.

These tasks have been performed in parallel. Based on the results, the most important requirements towards PAAs have been identified. The innovative properties have been derived from these requirements. Presence of these properties in the existing applications has been reviewed and the obstacles of their spread have been identified.

2.1 Comparative evaluation of PAAs

10 PAAs have been analysed and compared. Criteria for selection of applications:

1 **market leaders** in a particular area and/or

2 having some **promising properties**.

Table 1 shows the evaluated PAAs and their URL.

Table 2 shows the evaluation criteria of PAAs. A 4-point rating scale (0 – 3) has been applied to assess the presence of criteria in the applications. Figures indicate the following:

- 0: not specific,
- 1: hardly specific,
- 2: rather specific,
- 3: mostly specific.

Scores have been summarized by evaluation aspects. Total scores regarding each aspect indicate prevalence of the certain aspects. Fig. 1 shows the proportion of total scores and maximum possible scores as a percentage. **The most significant deficiency is multimodality**. PAAs tend to not have assistance in planning the rest of the ETC. Booking is only possible in a few cases, which increases uncertainty. Navigation is also not common, because most of the PAAs do not have a route planning function. The main reason for the deficiencies is that organizations managing the transportation modes have different interests. Due to the development of infocommunication technology (e.g. smart phones, internet) the "crowd sourcing" function becomes more and more common.

2.2 Revealing travellers' habits and expectations

160 people have been interviewed to get to know their expectations and habits as well as the characteristics of their decisions. The distribution of the respondents according to employment was the following: 43 % student, 51 % worker, 1 % retired, 3 % other. The distribution of the base aspects among travellers was the following: 36 % travel time, 44 % travel costs, 20 % security. 66.5 % of the respondents were between the age of 18 and 35. 28.5 % of the respondents were between the age of 36 and 53. The other respondents (5 %) were between the age of 54 and 71.

Owing to the **online questionnaire**, a high proportion of the respondents had the necessary computer knowledge and/or was frequent users of existing route planners, therefore they may be potential users of PAAs as well. Consequently, potential users' habits and expectations have been surveyed in our questionnaire. The questions related to the parking habits and the process of parking movements, which almost all people have an opinion about, regardless of whether they have a driving license and usually drive or not. Both drivers' and potential drivers' opinions have been considered.

The composition of the respondents was not influenced by us. The questionnaire was available to anybody on the Internet. Nearly third of the respondents were students and employees of Budapest University of Technology and Economics, Department of Transport Technology and Economics. The questionnaire consisted of the following question groups in order to develop the proposed PAA's properties and features:

a) age,

b) employment,

c) disability,

d) travel motivation,

Tab. 1. Compared PAAs and their URL

Park Me	*http://www.parkme.com/*	Neoparking	*http://en.neoparking.com/*
Park Me Right	*http://parkmeright.com/*	SF Park	*http://sfpark.org/*
Best Parking	*http://www.bestparking.com/*	Voice Park	*http://www.voicepark.org/*
Park Up	*http://www.park-up.com/*	Central Parking	*https://find.parking.com/*
Parkopedia	*http://www.parkopedia.co.uk/*	TRANS Park	*http://www.iru.org/transpark-app*

Tab. 2. Evaluation criteria of PAAs (source: own)

Evaluation aspects	Description
I. Multimodality	Planning with consideration to several transportation modes (e.g. private, public transport, pedestrian traffic).
II. Real-time/estimated data	For example: occupancy level of parking facility, indication of unoccupied parking spaces.
III. Personalization	Selecting car parks by various personalized criteria.
IV. Free of charge	The application can be downloaded and used free of charge; data supply is also free.
V. Availability for mobile device	The mobile device limits are not exceeded by the application requirements. It has ease of use.
VI. Visualization on map	Input data and/or results are displayed on map.
VII. Compact user interface	Application menu is simple. All necessary information appear on one side.
VIII. Crowd sourcing	Travellers share their information (opinions) with community (active mode). Data collected about travellers' habits (passive mode).
IX. Outdoor navigation	Navigation on the planned route to the entrance of the car park.
X. Indoor navigation	Navigation inside car park (from entrance to free parking space and return).
XI. Booking	Booking a parking space is possible before arrival.

e) the importance of security, cost and time,

f) the expected properties of PAA,

g) the expected operational functions of PAA and

h) potential parameters of PAAs' algorithm.

There were some multiple choice questions (a.-e. groups consisting of 5 questions) with single or multiple answers. Most of the questions (f.-g. groups consisting of 38 questions) had a 5-point rating scale (1 – 5) to rate the importance each of the aspects.

The answers for e. group have revealed the ranking of traveller's expectations for the three basic aspects (security, cost and time). Based on the results of f. group we have identified the proposed properties of the PAA. The operational functions of the PAA have been developed according to the results of g. group.

The most important question group is h. group regarding the key issues: algorithm parameters' importance. Personalized information packages are selected based on these results. The remaining question groups have been considered to the PAAs' **database and user interface** design.

User groups have been formed by b., c. and d. question groups, whose answers have been examined separately. If definite differences between certain user groups' expectations had been noticed, group-specific settings would have been developed in the application. However, the results showed just the opposite: the survey did not reveal such significant differences. **User groups' expectations are similar to the common expectations rather than to the individual expectations.**

Answers from travellers with dissimilar travel motivations are illustrated using an example (regarding the most important questions, namely the h. question group). For example, there has been little difference between the travellers' answers with dissimilar travel motivation and the average of all the traveller's answers on the key issues. The key issues are the following:

26 planned duration of parking,

27 fee rate,

28 street parking,

29 park and ride,

30 parking garage,

31 other types of parking,

32 transport hub,

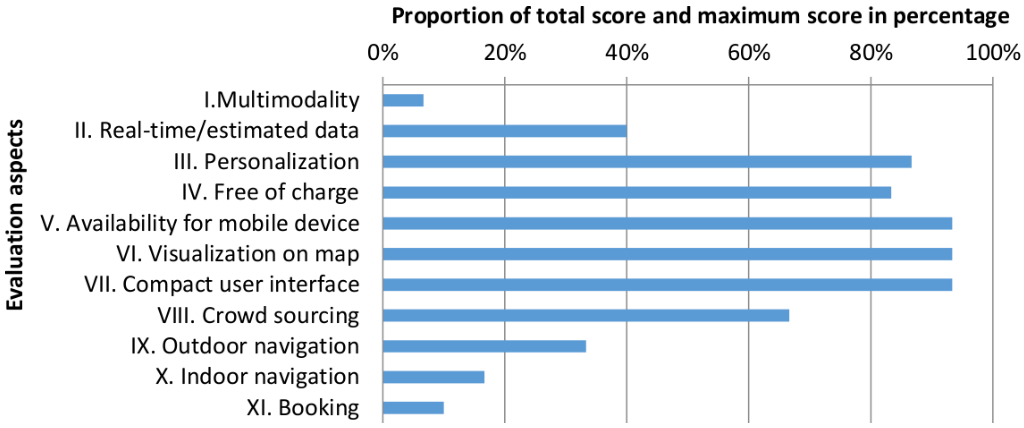

Fig. 1. Prevalence of evaluation aspects in PAAs (source: own)

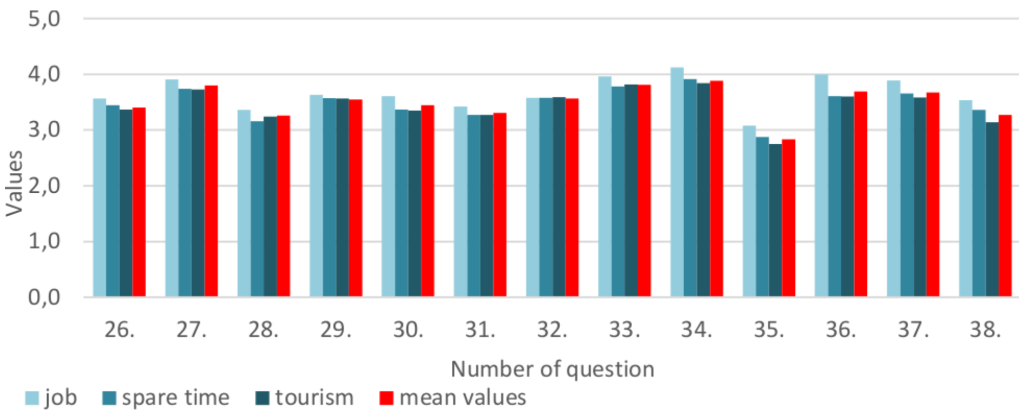

Fig. 2. Value of answers of the traveller groups with dissimilar travel motivation and the their mean values (source: own)

33 distance between parking facility and destination,

34 travel/walking time between parking facility and destination,

35 popularity of parking facility among travellers,

36 actual parking availability,

37 safety and

38 parking facility pre-booking.

These issues have been assessed by a 5 point rating scale (1 – 5), where '5' means it is very important and '1' means it doesn't matter. Fig. 2 shows the value of the answers of the traveller groups with dissimilar travel motivation and their mean value. There are not significant differences between the values (differences are unremarkable); accordingly it is not worth separating groups according to their motivation. This statement is also true for all other user groups.

Table 3 shows the value of the answers of the traveller groups with dissimilar travel motivation and the mean value of the answers regarding the key issues.

2.3 Innovative properties of the proposed PAA

The research has revealed important properties, which are clearly necessary in an advanced PAA. These properties are widely applied in the examined applications and/or being particularly important for the travellers by the survey. These innovative properties are the following

1 **personalized information**,

2 **map display**,

3 **parking fees** information and

4 **simple user** interface, which can be easily used on mobile device.

Accordingly, **quality perceived by travellers** is influenced by several interrelated aspects.

3 Results

Result of the research is the conceptual design of PAS. It contains:

- structural and functional plan of proposed PAS,
- design of functions and user interface of the proposed PAA.

Planning of parking must not be separated from planning of other phases of ETC. Therefore, **architecture of the PAS is opened for both public transportation and private transportation.**

3.1 Proposed PAS

The proposed PAS assigns travel/parking demands to the available parking capacity in real time. The personalized information provision function has been devised; however the PAS will be extended with further functions (functional modules) in

Tab. 3. Value of answers of the traveller groups with dissimilar travel motivation and their mean values (source: own)

Question number	26.	27.	28.	29.	30.	31.	32.	33.	34.	35.	36.	37.	38.
Job	3,6	3,9	3,4	3,6	3,6	3,4	3,6	4,0	4,1	3,1	4,0	3,9	3,5
Spare time	3,4	3,7	3,2	3,6	3,4	3,3	3,6	3,8	3,9	2,9	3,6	3,7	3,4
Tourism	3,4	3,7	3,2	3,6	3,3	3,3	3,6	3,8	3,8	2,7	3,6	3,6	3,1
Mean values	3.4	3.8	3.3	3.5	3.4	3.3	3.6	3.8	3.9	2.8	3.7	3.7	3.3

our research. The information provision is the basic functional module in our approach. Fig. 3 shows the further development modules. In the most advanced stage the 'Traffic Management with integrated Parking Management' function requires several data sources, including e.g. data of traffic loading of used road network.

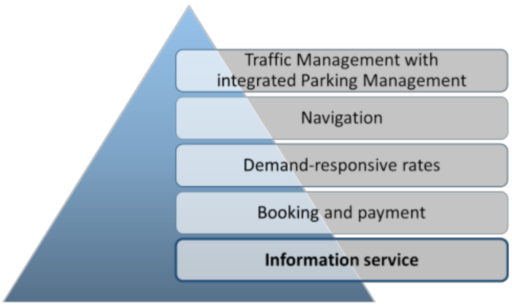

Fig. 3. Further functional modules of the PAS

Fig. 4 represents our PAS model, with the key components and information management operations. PAS has two "outer" components, namely travellers and parking facility operators. Information is exchanged between the two. The "core" subsystem is **Parking Management Centre (PMC)**, where data flows from the mentioned components are coordinated and raw data is processed. Supply and demand data of parking facilities are met in PMC. Ideally, PMC is both functionally and in some cases also physically part of the transportation management centre. In this way parking management is not an isolated process, but can be coordinated by the information management of ETC. PAS transmits data in general via internet [20].

PAA requires a feasible mobile device with internet access (e.g. 3G mobile network or faster, Wi-Fi) to provide real-time data for the traveller. **The planning is performed on the mobile device**. An internet connection is primarily required to update real time occupancy data. Secondly, collecting anonymous information about travellers and updating static parking information also require internet access. In online mode relevant data is updated during the parking search process initiated by traveller. Only data around the destination should be updated. The destination surroundings (and relevant parking facilities) are defined by maximal walking distance assigned by traveller. In this way volume of updated data can be significantly decreased. PAA can be operated also in offline mode, but in this case real time data is unavailable of course. To let PAS provide reliable information it is recommended to update static data on the PAA regularly (e. g. every few days). Data collection about travellers' expectations and habits in the PMC is useful for statistical purposes and improvement of the PAS.

Parking facility operators collect event-driven data by sensors installed at car parks and/or parking facility's entrances and exits. For this purpose a **Wireless Sensor Network (WSN)** is the most appropriate solution. Sensors detect vehicles being in car parks or vehicles passing through entrances and exits. Currently, a wide range of WSN solutionsare available [1].

In order to measure the **actual occupancy** of parking facilities, the mobile phone payment data can also be used. In the case of indoor parking facilities automatic registration of vehicles passing through entrances and exits is also an effective solution, because it is not tied to the payment procedure, so it can be used also in free of charge parking facilities [7]. This kind of "registration" cannot be applied in the case of outdoor parking spaces (on street).

Raw data of parking facility operators are stored in their own database and are transmitted to the PMC with about 5 to 15 minutes frequency in order to realize the real-time information service. Static data is transmitted only after occasional changes.

The information provision is **free of charge** for travellers. Since personal data is also collected in PAS, they are to be treated anonymously. Detailed, personalized information provision is beneficial also for parking facility operators, because their parking facilities are preferred as a consequence. Both the real time information about actual occupancy of parking facilities and the pre-booking result in additional benefits.

3.2 Proposed PAA

Travellers can access to the services of the PAS by an application called PAA. Personal expectations of travellers are managed by this application.

The **application** executes a multi-criteria analysis during operation, where the traveller adjusts the values of the criteria. Parking facilities are the possible alternatives. **Data filtering** has been found to be the most efficient method for selection of the appropriate alternatives. Namely travellers feel more confident about the results filtered by different criteria at the same time, rather than results computed by weighted criteria. Traveller can adjust extreme values to the following criteria:

- distance between parking facility and destination,
- actual occupancy,
- popularity of parking facility,
- incidence rate of crime,

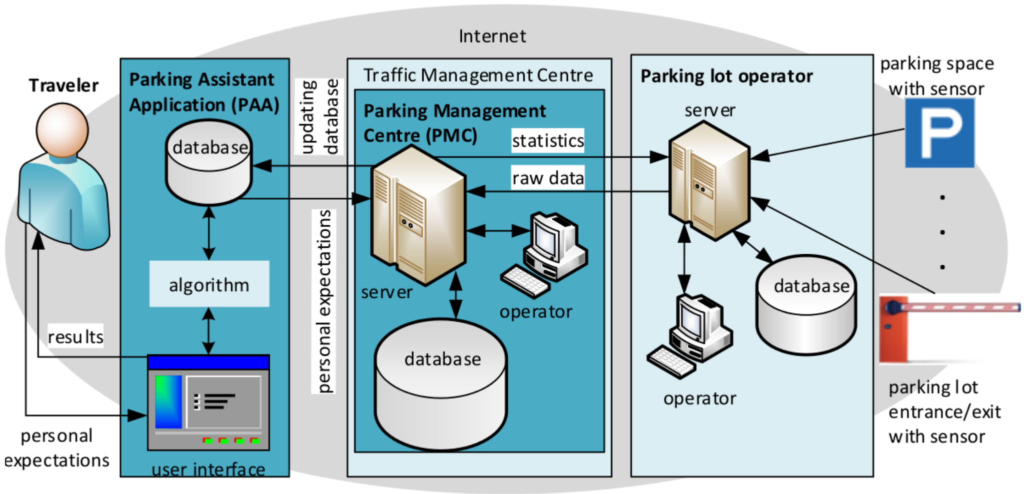

Fig. 4. Structural model of PAS (source: own)

- outdoor/indoor parking facility,
- arrival and departure time,
- the rate of the fee depending on the duration of parking.

The range of data and frequency of data collection depend on these criteria. For example actual occupancy is real-time data, which has to be collected periodically, with an appropriate sampling time cycle. Transmission time between parking facility and the PMC as well as the data updating time cycle in the PMC have also been taken into account.

The application has to have an **ease of use** considering it will be usually run on a mobile device during travel. The menu contains a minimum number of items; travellers can save their destinations and personal settings for later use.

Fig. 5 illustrates the menu options of the PAA. Blue boxes represent the forms (1-3.) with input and output data. Functions and data management operations (A-H) are indicated by arrows between boxes. The open and close (A, B) functions are available on the initial form, called "Favourites" (1). The traveller can create (C) favourites based on his or her regular travel motivations and expectations also on this form. Destinations are not included here. When editing a favourite, extreme values of the filtering criteria are adjusted. Only one favourite can be selected for one data filtering (D). A separate form is used for typing the destination (2). The destination can be also saved (E). It can be a postal address, POI data, GPS coordinates for example. After selection of a favourite and the destination has been entered, data filtering (F) can be performed. Search results for parking appear in the next form (3). After one parking facility has been selected from the results, its data can be also saved (G). This data can be exported to file (e. g. PDF) or navigation can be started by the address. When data filtering does not result in any appropriate parking facility, the traveller can return to the initial form (H), where the filtering criteria may be readjusted.

For testing the operation of the PAA, a prototype has been developed using Microsoft Access. As a result of the development so far the prototype can manage the following data:

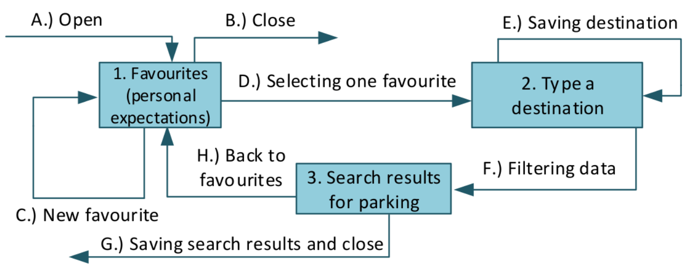

Fig. 5. Menu options of the personalized PAA (source: own)

- basic **expectations of travellers**,
- data of **parking facilities** and
- data of **destinations** (location coordinates, address).

Sample data of the database is originated from the city of **Győr**. All options in the application can be demonstrated by this data. Results of our survey have also been considered for default settings.

Data elements on the initial form (Fig. 6) appear in the following format:

- **Name of favourite:** name of the regular travel motivation.
- **Distance between parking facility and destination**: straight line distance is calculated between parking facility and destination by GPS coordinates.
- **Occupancy**: 5 values (up to 60%, 70%, 80% or 90% utilization) can be selected. The application does not suggest a parking facility with occupancy of more than 90%.
- **Popularity** (based on the feedback of travellers): traveller can choose a value from 1 to 5 (1: eligible all, 5: only the most popular ones) depending on the expected minimum popularity. For easier use these values are indicated by colour codes.
- **Criminal offences:** parking facilities can be filtered by security and safety. The method is the same as the method at the popularity. Values between 1 and 5 can be chosen. For easier use these values are also indicated by colour codes.

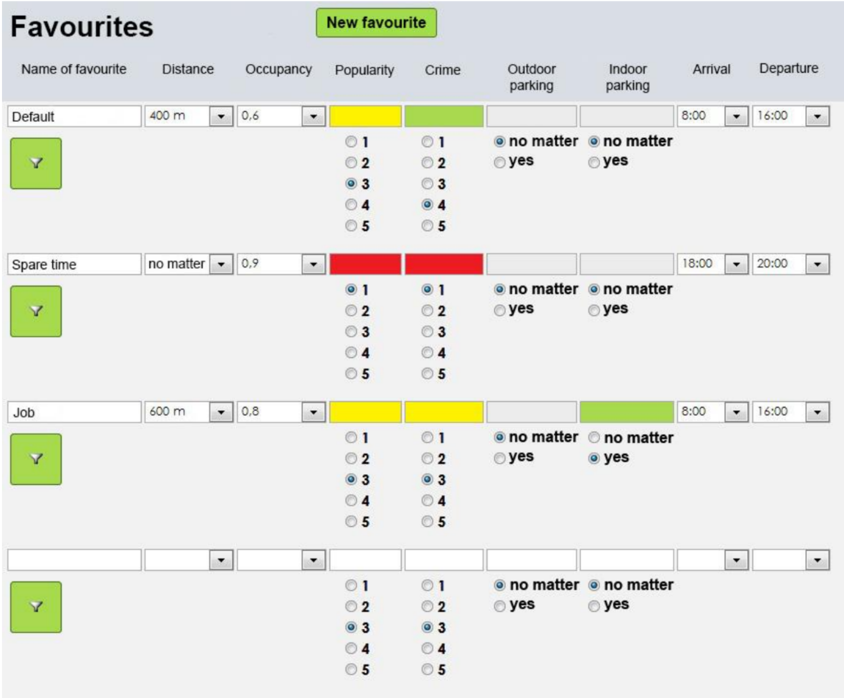

Fig. 6. "Favourites" (initial) form (source: own)

- **Outdoor/indoor parking:** the traveller may set a preference for either of them in any particular situation [10].
- **Arrival and departure time:** arrival and departure times can be set by drop-down menus with hour accuracy.

All created favourites have a green button on the left hand side (with filter icon) to start the data filtering. Then the destination name or address is to be specified in a pop up window (Fig. 7), and the data filtering is completed. The destination is not included in the favourites, because it depends on the actual travel.

Fig. 7. Destination input (source: own)

Following attributes of the parking facilities are stored in the database of PAA:

- **GPS coordinates**: for calculation of air distances.
- **Address of parking facility**: name of the public space (e.g. street), where the parking facility is located.
- **Hourly rate:** results are in ascending order by hourly rate.
- **Opening and closing time:** these time values are compared to the time appointed by the traveller.
- **Actual occupancy**: if the value is less than or equal to the maximum occupancy tolerated by the traveller, the parking facility is appropriate in this regard.
- **Popularity** (based on the feedback of travellers)**:** it may vary among 5 values. If this value is less than the value specified by the traveller, the parking facility is not adequate in this regard.
- **Safety and security:** it may vary among 5 values. If the value is less than the minimum level of security required by the traveller, the parking facility is not appropriate in this regard.
- **Outdoor parking facility:** if the parking facility is located outdoors, then this value is "1" otherwise "0". Traveller selects either "yes" (value: 1) or "it does not matter" (value: 0). The parking facility is appropriate if this value is greater than or equal to the value specified by the traveller.
- **Indoor parking facility:** if the parking facility is located indoors, then this value is "1" otherwise "0". Traveller selects either "yes" (value: 1) or "it does not matter" (value: 0). The parking facility is appropriate, if this value is greater than or equal to the value specified by the traveller.

Only the parking facilities that meet all expectations of traveller are listed. Fig. 8 shows a list of recommended parking facilities. The results can be saved as PDF file and the application can be closed, or new planning can be started with modified criteria.

4 Conclusions

Urban mobility management requires the use of advanced information technologies. Aiding the ETC with information in real time is a rather complex task, requiring extensive integration of the subsystems. One crucial phase of this task is the parking management. PAS is an effective solution in passenger transportation, which requires relatively low operational costs

Fig. 8. "Search results for parking" (output) form (source:own)

compared to other management systems or measures. Our proposed PAS and its services can be integrated into the information system covering ETC.

The proposed PAS provides real time information before and during travel, also considering personal expectations. A limited number of personal setting options in the PAA may already sufficiently aid travellers. Results of our survey have clearly highlighted the promising features that can significantly improve traveller satisfaction during the search for a parking space.

Our future research work will focus on management of real time and/or estimated occupancy data and incorporation of this data into traffic management in order to minimize unnecessary cruising for unoccupied parking spaces. Our aim is the elaboration of urban parking aiding strategies depending on travellers' actual demands and expectations in a transport network approach.

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