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Driver's Willingness to Use Parking Assistance Tools and their Expectations: A Case Study for the Cities of Munich and Athens

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Abstract

One of the major traffic challenges many cities face worldwide is the search for empty parking space. The existing parking supply is not used effectively and as a result, the continuously growing demand cannot be served. The drivers experience a time and fuel consuming search for a free parking space, while time loss has been found to be the most important consequence on the individual level. The purpose of this paper is to identify driver's willingness to use smartphone parking applications, their typical parking behavior, as well as their expectations from such parking assistance tools. For this reason, two different studies were conducted: the first one by the Technical University of Munich and the second one by the National Technical University of Athens. The results of the two studies are further analyzed and compared, revealing differences and similarities between the people living in these two different cities. Finally, a description of the technological and methodological specifications of an application for crowdsourcing in-vehicle data, to detect free on-street parking spaces when passing by, are further discussed.

Keywords: *Parking Assistance; User Requirements; Free Parking Space Detection; Smart Application; Revealed and Stated Preference*

1. Introduction

New, innovative and smart solutions for the mobility of tomorrow are among the key challenges worldwide for the upcoming decades. Due to increasing motorization, steadily growing mobility demands and continuous urbanization, the need for new concepts in the field of transportation is significantly rising. Especially, in the area of urban parking, a huge potential exists to reduce its negative impacts on traffic flow, travel times, parking search times as well as environmental emissions. Several studies have shown that between 20 and 40 % of the overall traffic in cities is generated by searching for parking spaces (Allen, 1993, Arnott et al., 2005, Axhausen et al., 1994, Bulan et al., 2013, May and Turvey, 1984, Polak and Vythoulkas, 1993, Shoup, 2006). According to a study in 2013 conducted by Apcoa, the European market leader in parking management, an average driver spends additional 4.5 km for each search for a parking space in Germany. For the driver, as well as potential passengers, this means additional travel time and additional fuel consumptions and therefore monetary costs. According to a study of Shoup in 2006, the vehicles in a small business district in Los Angeles wasted 178.000 liters of petrol and produced 730 tons of carbon dioxide only due to cruising for parking. Another study conducted by Bulan et al. (2013) states, that in San Francisco almost half of the fuel consumption is due to parking search traffic. Most studies mention a parking traffic share of around 30 % in urban agglomerations around the world, which leads to a significant impact on cities and their inhabitants by creating additional GHG and noise emissions.

One first step in trying to solve some of these major challenges in urban parking, is the implementation of smart parking assistance systems for drivers to assist them in finding a valid and free parking space, when needed. A possible solution is the use of static or mobile sensors to detect the current state of on-street parking spaces as well as off-street parking like parking garages or parking lots. Static sensors for this purpose can be installed either above ground (camera-based, infrared, radar) or in the road surface (magnetic sensors, ultrasonic sensors). Vehicles with already installed or retrofitted ultrasonic sensors can be used as mobile sensors by detecting empty gaps in on-street parking while passing by with activated sensors. Collecting and merging this information in a centralized system allows for real-time information of drivers searching for a parking space and a direct guidance to the free space without unnecessary detours.

Based on these technological novelties in collecting occupancy information for public parking spaces with a focus on on-street parking new driver assistance and information systems are under development now. This work aims at assessing the needs of potential users towards such assistance systems and evaluating their typical behavior when searching for a parking space in urban areas. Therefore, within the frame of this paper, the first part focuses on such a parking assistance system, which is already under development. Furthermore, the outcomes of two surveys are presented, which took place in Germany as well as in Greece to evaluate the differences in driver’s behavior

between these two countries in their typical search for a parking space and in their expectations towards a new technology to help them in their search.

2. *Parking Assistance Technology*

Within the frame of this work, the main research focus for detecting empty parking spaces is based on the use of floating vehicles which are used as observers to detect free spots. As a vehicle drives by a street it continuously uses the on-board ultrasonic sensors to scan both street sides for parking spaces. The outcome are point clouds for both street sides containing measurement data with information about the horizontal distance to various objects (Figure 2.1).

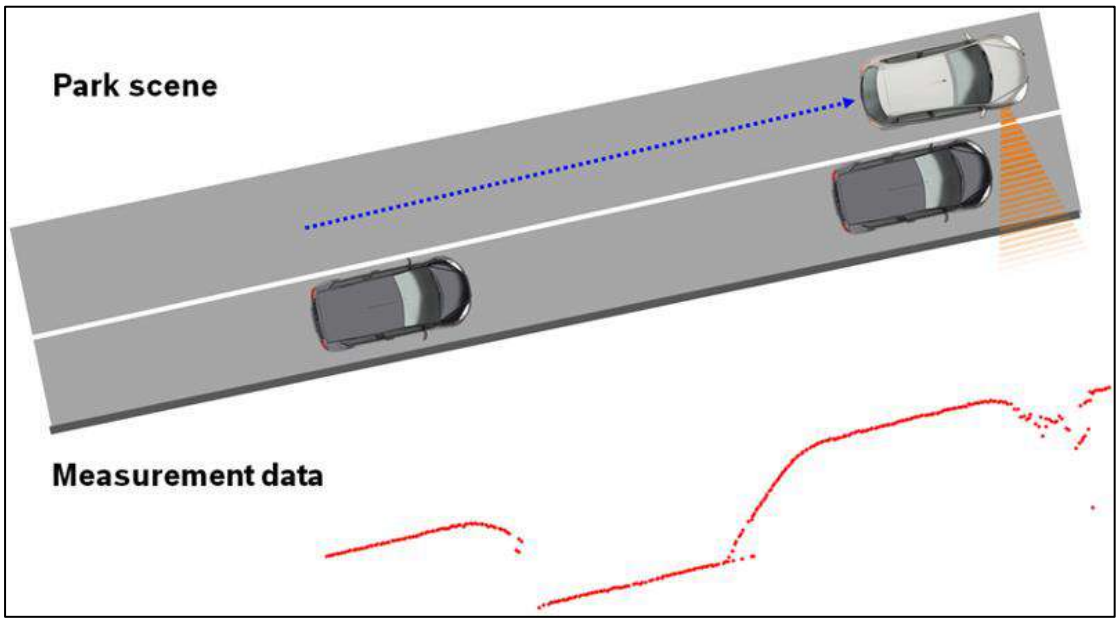


Figure 2.1: *Ultrasonic measurement principle and raw sensor data output.*

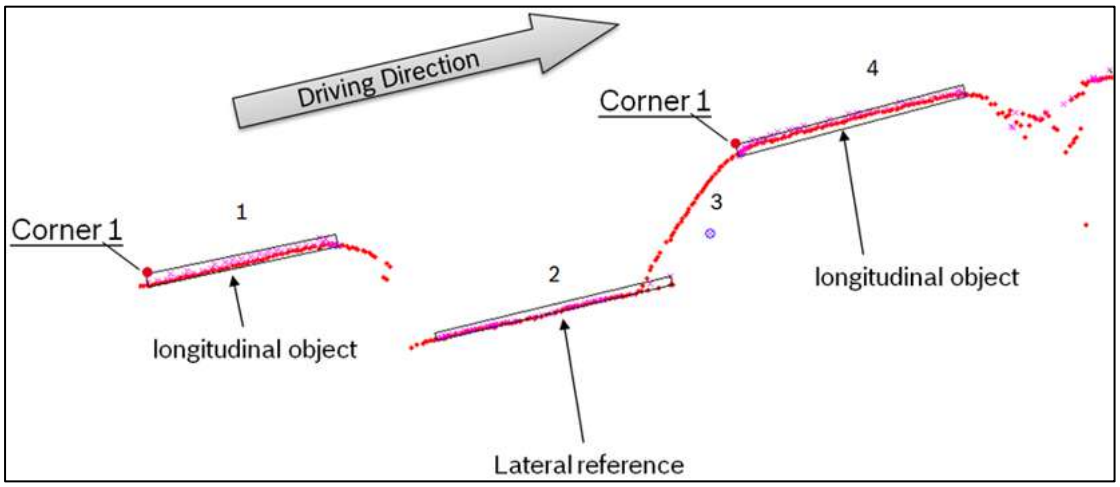


Figure 2.2: *Object localization based on raw detection data from the ultrasonic sensors.*

The raw measurement data is then used to build a map of information for the left and right side of the vehicle. Object localization algorithms determine the object dimensions and positions based on the raw data as well as a classification of the objects. Scene interpretation algorithms then analyze the object constellations to decide whether a parking space is available and extract information such as parking space length and depth, information about the curbstone (lateral reference), object types of limiting vehicles (longitudinal object) etc. (see Figure 2.2). For this approach, not only parking spaces suitable for the vehicle itself are detected, but also parking spaces suitable only for other vehicles (e.g. parking space length smaller than own vehicle). This concept is therefore called Community-based Parking.

After detection, the parking space and object data are then transmitted to a backend server, enriched by the exact GNSS position of the detecting vehicle, its current velocity, the odometry etc. The transmitted data is stored in a database and the positions are referenced to a map applying map matching and map comparison algorithms (Figure 2.3). The stored and map-referenced data is the basis to compute additional parking services such as parking prediction which are then transmitted back to the receiver vehicles and displayed on their vehicle human machine interface (HMI).

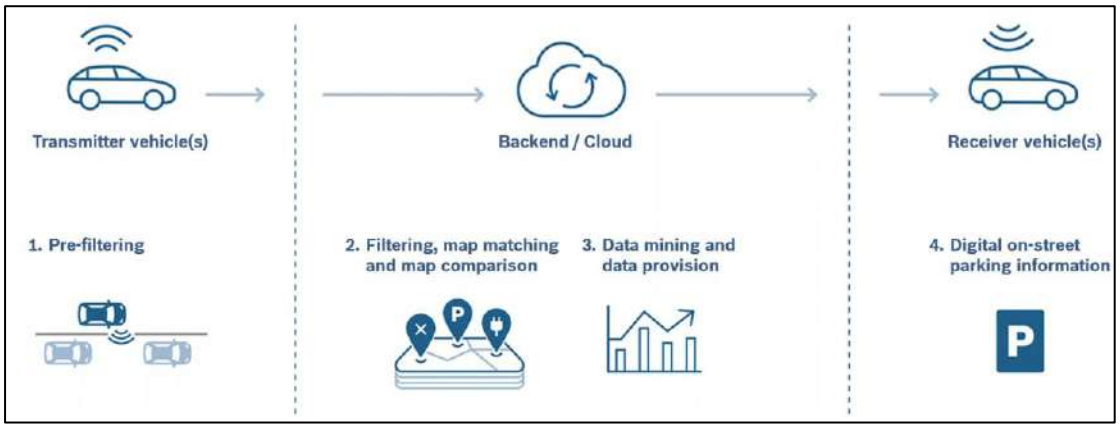


Figure 2.3: *Community-based Parking information flow.*

Based on the available data in the backend server and depending on the penetration rate of equipped transmitter vehicles amongst the overall traffic, different qualities of services can be provided (Figure 2.4). The basic service is the provision of static information on legal parking areas, which are available in the city. The next level of service is a prediction of available parking spaces in the area of choice for a certain arrival time, based on a data fusion of historic occupancy information and real-time information from available transmitter vehicles in the region. The service requiring the highest proportion of equipped vehicles is the parking occupancy map. For this one, only real-time data about detected empty parking spaces is used for an online information on the availability of parking. Enriched by the information on the parking space length, the drivers searching for parking can filter the free spots for the ones, which are large enough for their individual vehicle.

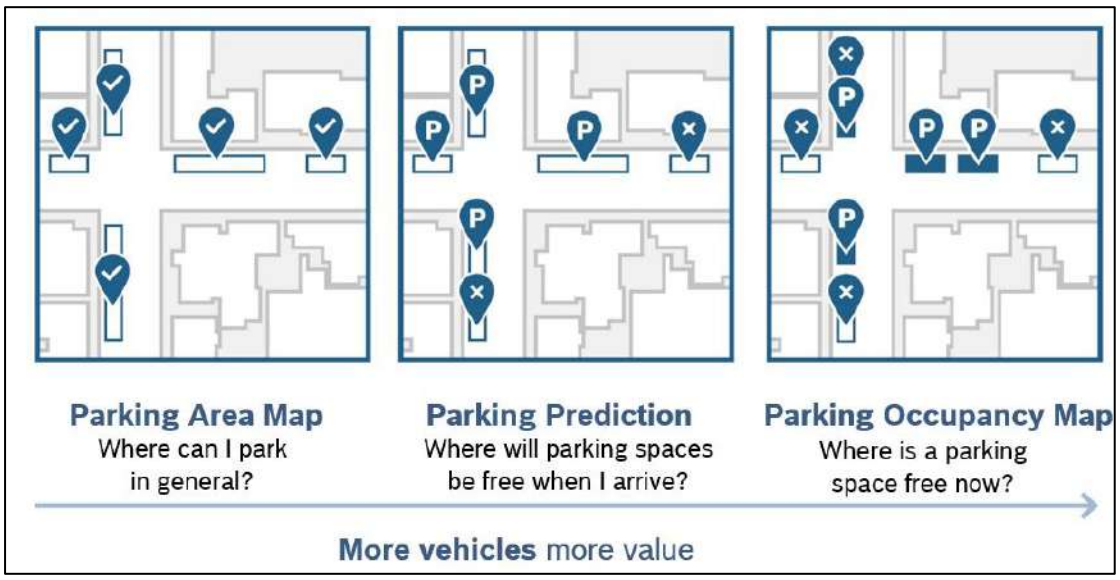


Figure 2.4: *Provided services based on penetration rate of equipped vehicles.*

3. User Survey

Based on such available sensor data on parking space availability, a smartphone application can assist drivers in finding a free parking space around their destination in less time and in a more convenient way. It is possible not only to indicate a free spot but also to guide the user towards it without being stuck in traffic. Through such applications, a more effective use of the existing supply becomes possible and the parking demand can be better served while the drivers can be informed about the cost of parking at each detected free spot.

Since 2011, the city of San Francisco (SFpark project) has installed around 12.000 on-street sensors in order to collect real-time data about the occupancy of parking spaces, the number of turnovers as well as the occupancy time. The combined analysis of real-time and historic data obtained from these sensors can lead to driver's information about the availability and location of free spots. Additionally, depending on the occurring demand, the parking prices are fluctuating within the day so that parking spaces in areas with intense traffic congestion phenomena are more expensive than in blocks where the demand is significantly lower (Shoup, 2005, Shoup, 2006). The drawbacks of on-street sensor use are the high costs of installation and maintenance and as a result, the lacking financial feasible for the majority of cities worldwide.

Therefore, the development and use of smartphone applications without the necessity of installing sensors is becoming challenging. In order to achieve a solution, which also focuses on the user's requirements while searching for a parking space, a survey was conducted to get more detailed information about the drivers' typical behavior and needs as well as their acceptance of such an application.

Because the potential users are not necessarily coming from the same country, but may have different habits and needs due to their cultural differences, two surveys were

conducted in two different countries. The first one was conducted by the Technical University of Munich (Margreiter et al., 2015, Margreiter et al., 2016) with a focus on potential users in Munich, Germany and the second one from the National Technical University of Athens with a focus on potential users in Athens, Greece. More than 1500 questionnaires were collected, around 550 from the first survey and around 950 from the second. The participants were people of both sexes, belonging to different age categories and with different educational backgrounds. The following figure (Figure 3.1) illustrates the sample distribution per gender and age both for Germany and Greece.

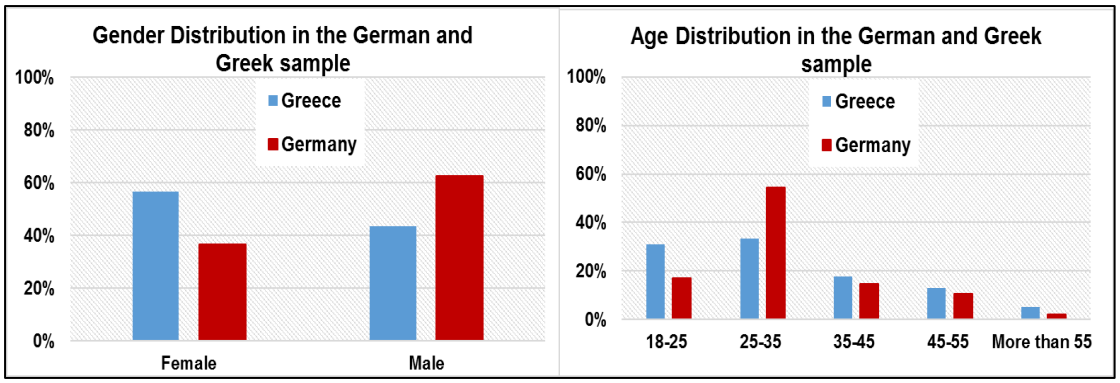


Figure 3.1: *Gender and age distribution in the Greek and German sample*

The survey was divided into three different parts: the first was related to the drivers' behavior while searching for parking, the second one reveals the drivers' expectations towards an assisting technology while the third one contained questions of general personal information. The analysis of the results of the first two parts of the questionnaire is being described in the following sections.

3.1 Drivers' Behavior

The first part of the survey is related to drivers' behavior and habits while searching for a free parking space. The results showed that most of the Greek drivers spend from three to ten minutes for searching for a parking space while the German ones are spending only up to five minutes. The acceptable duration for searching for a free space reveals also differences between the two samples, as 70 % of the German participants are not willing to spend more than five minutes in contrast to the majority of the Greek ones who seem to be more tolerable and, therefore, willing to spend up to ten minutes. It is important to mention that one out of four Greek drivers set a tolerable time limit of 20 minutes to spend for parking search. Additionally, drivers from both countries prefer to park their cars close to their destination as the tolerable walking distance between the parking space and their final destination is stated to be not more than 800 meters. These two aspects are the reason why the drivers quite often drive on a detour where the probability of free parking spaces could be significantly higher, even if this means that travel time and traveled distance may be slightly longer.

Concerning the strategy that each sample of drivers follows while searching for parking, four different options were given to the participants:

- Continuously driving around the same block.
- Passive waiting for a free parking space in the line of sight.
- Driving along the same street by making U-turns.
- Meandering driving, which means driving around different blocks.

The four different strategies are illustrated and described in Figure 3.2. The results showed that the order of preference is identical for the both countries, revealing the similarities between the different cultures also in this aspect. More than two-thirds of the Greek and German participants choose the meandering driving as their main search strategy while the second most popular option is driving continuously around the same block (the percentage is around 20 % for both samples).

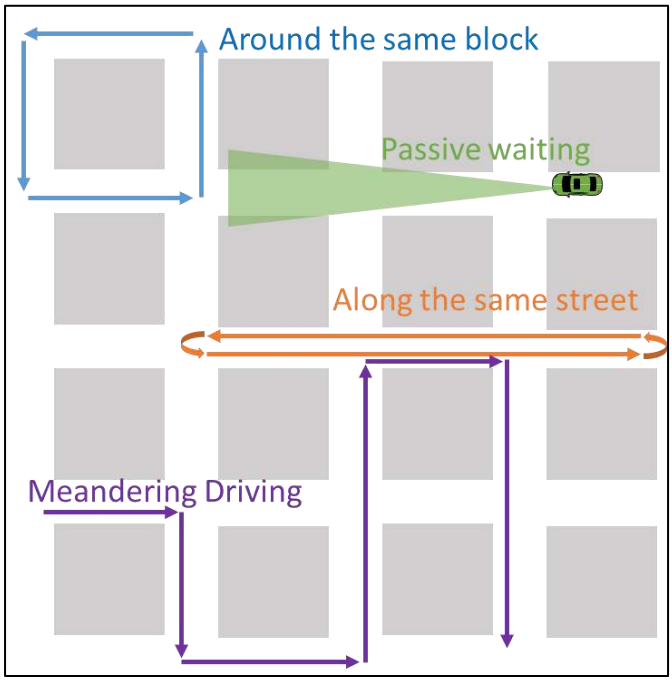


Figure 3.2: *The parking strategies introduced to the participants of the questionnaire.*

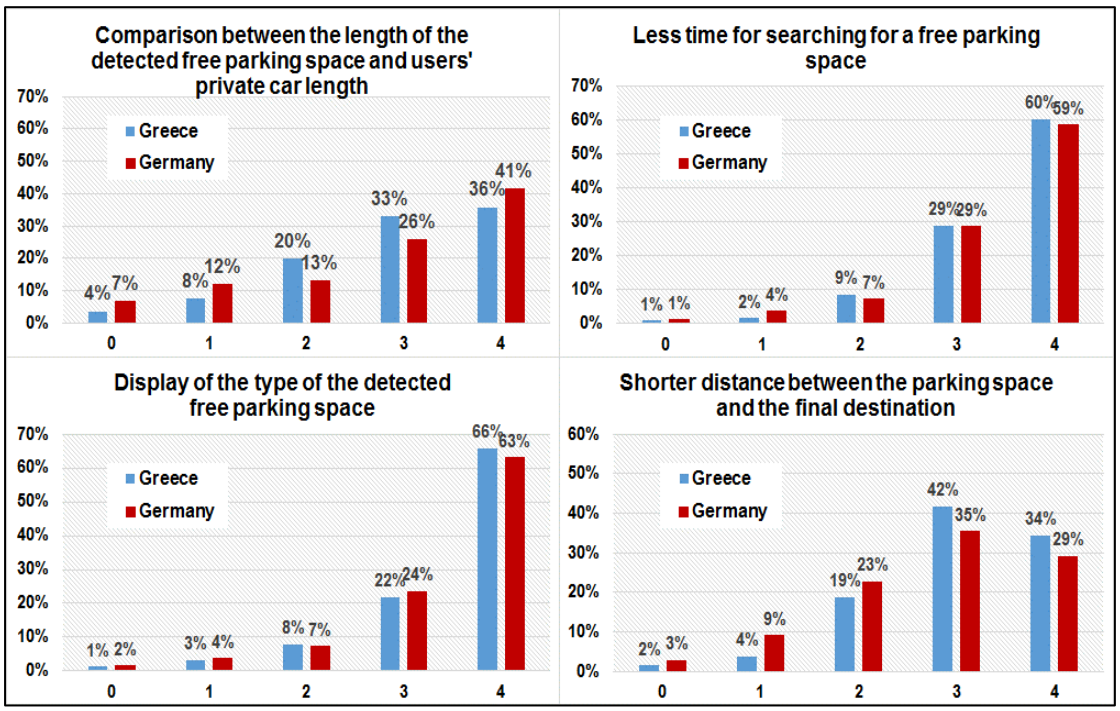
3.2 Drivers' Expectations

The second part of the questionnaire was related to the drivers' willingness to use a smartphone application when cruising for parking as well as their expectations from such an assistance tool. A very significant outcome of the survey is the fact that the majority of the participants prefer the on-street parking instead of public or private parking garages or parking lots. Therefore, providing information for on-street parking will be of high acceptance and used by the majority of the drivers. The high willingness of being assisted while searching for a free parking space is also illustrated by the fact that a high majority of participants answered that they will definitely or maybe use a smartphone application. Almost 90 % of the German participants and around 95 % of the Greek ones. It is important to mention that the percentage of the potential users that

would definitely use such a tool is around 60 % for the German drivers and around 70 % for the Greek sample, revealing a more serious parking problem in Greece. This was also observed from the fact that the Greek drivers have to spend more time in order to find a free parking space, as it was presented in the previous section.

The time point of the information arrival about free parking spaces seems also to be important for both samples as almost 65 % of the participants answered that shortly before reaching their destination is when they want to obtain the related parking information. A main issue for such a developed application is the reliability of the information it provides to its users. Therefore, the time point is not the only issue that was of importance but also the reliability of information. An information about a parking space with a chance of 50 %, or 60 % of being free is not helpful for them. Therefore, they would rather want to receive the information when the probability that the detected spot will still be free when they arrive is higher than 70 % (Greek drivers) or 80 % (German drivers).

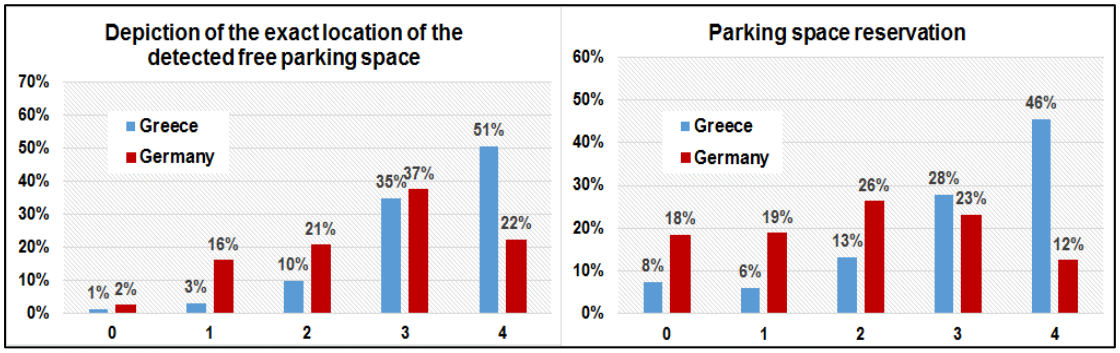
One of the main parts of the two surveys refers to the expectations of the potential users that will contribute to the development of a more user-friendly application with features that fulfil their needs. Since the proposed technology will probably be used worldwide, it is important to observe and identify the expectations among users coming from different countries and having different cultural backgrounds. The analysis of the survey results showed that for both German and Greek citizens, it is of vital importance that the proposed method will not only contribute in saving time but also in detecting and suggesting parking spaces near enough to their final destination. The survey revealed that the potential users request a really reliable application that will ensure the validity of the detected parking space rather than detecting a spot which can turn out to correspond to an exit, driveway etc. instead. Additionally, they need to be aware of the length of the space as there is a high risk that their own car could not fit in. These aspects as well as their importance for the potential users from both countries are depicted in the following figure (Figure 3.3).



*0: aspect is not important at all, 4: aspect is very important

Figure 3.3: *Importance of various application aspects rated by the participants of the survey*

Apart from the similarities in the aspects described above, there were two issues where the responses differed significantly (Figure 3.4). The detected parking space will be displayed to all the drivers searching for a parking space in the same area and thus there is a high risk that the recommended spot is already occupied by another car once the user arrives. This risk is being taken into consideration only from the Greek drivers and therefore they assess the possibility of reserving their preferred free parking space as very important. The other aspect where differences between the two samples are observed, is the depiction of the exact location of the detected gap which seems not to be such a necessary information for the Germans in comparison to the Greeks.



*0: aspect is not important at all, 4: aspect is very important

Figure 3.4: *Importance of various application aspects rated by the participants of the survey*

In conclusion, one of the most important questions the participants had to answer was related to their preference in terms of the kind of information they want to receive. Three variants, were proposed, which are illustrated in the following Figure 3.5. The first one suggests the driver an eventually longer route to the destination with a higher availability of free parking spaces (suggestion of the appropriate route). The second one depicts the availability of free parking spaces for all blocks in the area around the destination while the third one recommends one specific free parking space close to the destination. The last variant also includes the risk that another driver approaching the area may "steal" the recommended parking spot and as a result, it will be occupied when the informed user finally reaches the location. The depiction of the availability of free parking spaces for all streets around the destination (second variant) is what the majority of the drivers expects from such an advanced application as it was chosen from more than 50 % of the participants from both countries.

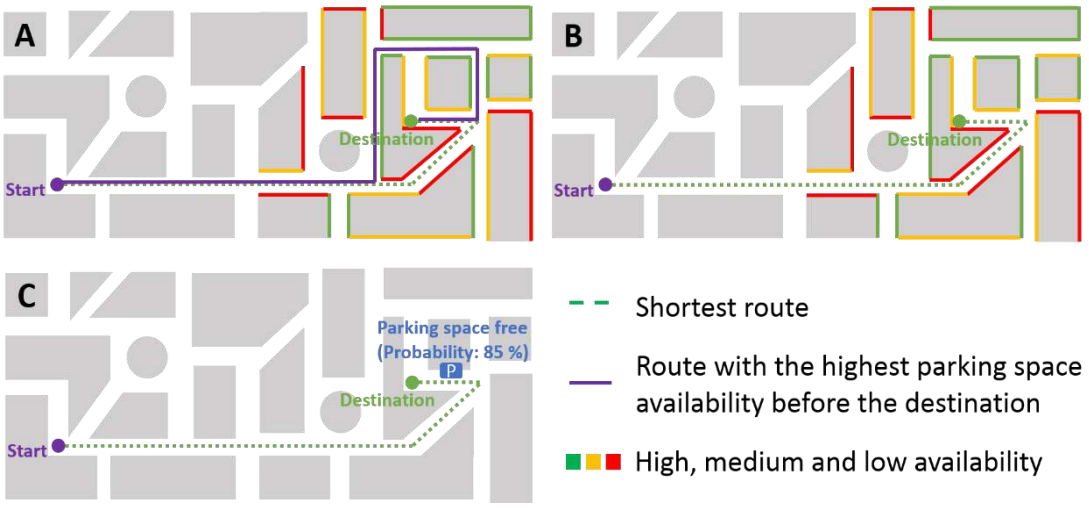


Figure 3.5: *Possible information presentation variants for free parking spaces.*

4. Conclusions

As a conclusion one can state, that nowadays the issue of searching for a parking space in urban regions contributes to a vast amount of traffic in inner cities and is therefore contributing to traffic congestion and emissions.

To be able to achieve a technological solution for reducing that kind of traffic, two questionnaire surveys were carried out in 2014 and 2016 in order to determine the demands and constraints of around 550 potential users of such a solution from Germany and 950 from Greece, respectively. The analysis revealed interesting similarities and differences between the two countries that should be taken into consideration for the further development of the proposed technology and it illustrated the importance of organizing the parking space search in a more efficient and convenient way. Greek drivers seem to be more tolerable in terms of parking search time, as their time limit is ten minutes in contrast to five minutes for the Germans. It was also showed that such a solution would have to focus on on-street parking, which is the preferable type of

parking for the majority of the users coming from both countries. According to the survey, the three most important features of a parking assistance system are the comparison between the length of the free parking spot and the length of the own vehicle, the display of the parking space type (short/long term, residential only etc.) and, as a general goal, the reduction of the time spent for the search. For the Greek participants, the possibility of reserving a free parking space and the display of its exact location are considered also to be a necessary information. An additional outcome of the questionnaire, common for both samples, was the preferred time for the information display concerning the free parking space availability, which turned out to be right before reaching the final destination. According to the majority of the German and Greek users, the information should contain the probability that the free detected parking space nearby their destination will be free in a certain time period.

Based on the distributed questionnaire a concept for an application was developed in order to assist drivers in their search for free parking spaces in urban areas. Based on vehicles equipped with in-vehicle sensors like cameras, ultrasonic and radar, free on-street parking spaces are detected by passing by parking spaces while driving. This data is enriched for example with the exact location of the detected parking spaces and additional information like the detected length of the free spots.

The further development and use of such systems will be enabled by a higher sensor penetration rate in vehicle fleets within the next years. More and more vehicles are equipped with Advanced Driver Assistance Systems (ADAS) (Diakaki et al., 2014) or advanced sensor systems used for highly automated driving. The interaction between these various technologies is very promising not only in supporting the drivers in their search for free parking spaces, but also for simplifying and improving other aspects of their everyday life within the field of transportation.

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