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COMPARATIVE ANALYSIS OF MOBILE APPLICATIONS FOR URBAN TRANSPORT

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Purpose: Striving for sustainable development of cities, the change of urban transport plays an important role. An important component of this development, apart from developing its network and means of transport, is the information that supports this transport. Current traveler expectations focus on providing information via mobile devices. Therefore, the article discusses the importance of information in urban transport and presents a comparative analysis of mobile information applications for public transport passengers. The aim of the article is to assess the usefulness of selected mobile applications used to support users of urban public transport.
Design/methodology/approach: The study used an assessment based on user interviews.
Findings: The first part of the research analyzed the expectations and needs of urban public transport customers in terms of obtaining up-to-date information on its operation. Although many needs can be considered commonly known, new possibilities, such as real-time vehicle location updates, increase the range of possible functionalities of these applications. When analyzing the expectations of urban public transport users, attempts were made to take into account the importance of individual criteria. Based on the results of the expectations analysis, their fulfillment was verified for selected mobile applications that are widespread in Poland. The research carried out gives a picture of user expectations and their fulfillment by individual applications.
Research limitations/implications: Conducting research and analyzes based on interviews results in a small research sample, so research should be continued to ensure greater representativeness of the results. Since most users based their answers on the use of mobile applications in the Poznan agglomeration, it is necessary to extend the research to other regions of Poland.
Practical/Social implications: Research results not only support software developers, but can also help users choose an application tailored to their needs and limitations related to age and disability.
Originality/value: Paper compares current mobile apps based on user expectations. The results obtained can support both users and developers of these applications.
Keywords: urban transport, mobile application, smart city.
Category of the paper: Case study.

1. Introduction

The pursuit of creating components of a smart city by using various types of electronic methods and sensors to collect specific data is to be the basis for the effective management of assets, resources and services throughout the city (Goldsmith, 2021). Among the important components of the entire system is the monitoring of traffic and transport systems (Fourtané, 2018). However, the introduction of elements of such a system requires gradual actions, and in particular the preparation of residents. Moreover, even introducing certain components of these systems can provide some benefits. An example here would be the introduction of location tracking of public transport vehicles and then making this information available to passengers.

The significant development of mobile applications and their growing capabilities in terms of data processing and communication stem not only from the hardware development of mobile devices, but also from the support of dedicated servers that ensure data updates in real time. The services provided by these servers are usually platform independent and also available on mobile platforms. Examples of such services include information services, weather services - including threat alerts, stock exchange services, websites tracking the status of the implementation of ordered services, services regarding means of transport - including air, rail, bus, city in the field of public transport, availability of city bikes, scooters, taxis and car sharing. Due to the fact that these systems are fed with data in a largely automated manner, their maintenance costs, especially if we take into account the cost per user, are not very high. Therefore, these services may be offered as part of a package of other services or even free of charge. Moreover, it can be said that mobile devices allow you to track current information almost anywhere. Due to the fact that they are usually equipped with a location system, the user's position can be used to provide information appropriate to the recipient's location. These functions are constantly improved, therefore previous research on the usability of applications supporting public transport users in the face of emerging new functionalities for mobile applications requires updating and development.

Initial interviews with users indicated some randomness in the choice of the application used. Most users do not base their choice on checking the functionality of many applications, but on the short description available on the application provider's website. Others download an app recommended by friends, but usually the recommender hasn't had the opportunity to compare many products. Therefore, verification of whether the available applications meet user expectations should provide clear support to end users, which application to choose.

The aim of the research was, in the first step, to verify users' needs in terms of the expected functionality of the application, and then to analyze selected applications in terms of meeting these expectations. The selection of applications was based on their popularity, including applications used by the surveyed users in the Poznan agglomeration.

2. City transport background

Transport problems in crowded cities make people strive to implement emerging concepts and technologies to improve their functioning. One of the concepts called smart cities refers to the use of information and communication technologies (ICT) powered by data from various types of sensors in the surroundings of urban areas (Barton, Manning, 2017). ICTs are integrated into the city's energy technology and organizational strategy (Park, Pobil, Kwon, 2018).

Emerging opportunities in the area of Big Data, Internet of Things (IoT), Artificial Intelligence and ICT are the basis of the revolution in urban designs (Andersen, Ashbrook, Karlborg, 2020). However, the introduction of new technologies in the operation and control of transport can help reduce expenses for the operation and maintenance of transport systems. Moreover, preventing collisions between means of transport is important for the reliable operation of transport systems, which can also be achieved by using IoT-based systems (Punyavathi Neeladri, Singh, 2022).

Luo, Zhang, Zhang, Yu and Li (2019) present the three-tier architecture of the system based on IoT. Mentioned levels are as follows: Perception layer, Network layer and Application layer. The perception layer is the source of IoT information and includes various sensors and devices that collect data for the system. The network layer is responsible for transmitting information from the perception layer to the application layer. This layer is based on wired and wireless networks. The Application layer, on the other hand, processes data received from the perception layer and makes applications available to passengers or employees of the transport system. Of course, this model is used differently in practice for different means of transport. In the case of public transport, the information function dominates, but in the case of taxis, where individual route planning is involved, journeys may be dynamically allocated depending on all the collected data.

Ramirez-Guerrero and Toro (2020) support the introduction of an Intelligent Transportation System (ITS) involving the use of ICT technologies related to, among others, sensors, information systems, management strategies to increase transport safety, efficiency and sustainability, without the need to increase network capacity. A smart city provides an intelligent way of managing transport, energy, health and environmental systems. The data generated in these components is measured primarily by a network of sensors. These networks are already available in both industrial and consumer applications (Gaur et al., 2015). In the case of transport services, there are many applications of ITS that affect all elements of a smart city, not just the mobility element. These are: communication, data processing, vehicle detection, speed detection, environmental sensors, information transmission, positioning and location using global navigation satellite system. Generally, data can come from various sources, in addition to the previously mentioned sensors, also from sensors in vehicles or even

video detectors. However, they must be easy to understand, concise, credible and up-to-date. Zhu, Yu, Wang, Ning and Tang (2019) also point out that they must be quickly captured, be useful to the user, and not allow for different interpretations.

The transport system in a smart city is a basic component subject to improvement. It cannot function efficiently without providing up-to-date information on its functioning to the people who use it. The previously mentioned development of ICT technologies and positioning possibilities allow public transport passengers to utilize real-time data. Modern smartphones provide many services supported by mobile applications, internal sensors and communication capabilities. Most smartphones are equipped with GNSS (Global Navigation Satellite System) receivers, accelerometers, a compass and the data provided by these sensors can be used to develop ITS applications (Mostefaoui, Tariq, 2019). A smartphone can be used to provide expected travel time by combining location and speed estimation.

The technological capabilities of smartphones are the basis for creating applications for mobile devices, but the human factor cannot be ignored, in the form of expectations, limitations or perceptual capabilities of users. It can therefore be concluded that analyzing the needs of people using the application is of fundamental importance. The methodology for analyzing customer needs may be varied. For example, Strenitzerova and Stalmachova (2021) use the CTQ (Critical to Quality) diagnostic method to identify customer needs and requirements for a mobile application used in urban public transport. This method requires the identification of quality needs, then the identification of factors influencing quality, and in the last step, the identification of quality requirements. According to the author, since the participation of the application user is required at every step, the method may prove to be too burdensome for the respondent. This was confirmed by the author's comparative study of two user interfaces, where participants assessed over 30 elementary criterions for each interface and, additionally, the weight of each of these features (Hankiewicz, Prussak, 2007). Respondent fatigue may therefore lead to imprecise results.

Górniak (2022) proposes an analysis of customer needs based on the phase of the journey. The information provided to travelers is to be divided into pre-trip information (for the planning phase), information available during the trip, important information at the end of the trip, on the way back. For example, way back options are to be available only after reaching the destination, which does not seem appropriate for people planning a round trip from the beginning. After reaching your destination, you may find that there is no return connection that day. Therefore, although this division has many advantages, it does not always meet the more complex needs of public transport travelers.

However, the use of mobile applications may be difficult for older people, but it is difficult to clearly determine what age this applies to. Kubiak (2019) refers to people over 60 as seniors in his research on the use of mobile applications, including those intended to support users of urban transport. It should be noted that when dividing users into age groups, we very often forget about individual differences and health factors that influence their perception of the

environment. Therefore, perceptual and manual capabilities should always be approached individually, taking them into account in the possible application settings.

3. Research methodology

Based on previous research (Hankiewicz, Lasota, Gajšek, 2023), it can be concluded that many users found it difficult to answer many detailed questions that make up the group criteria. This could lead to not entirely accurate results. In addition, the specifics of assessing applications for mobile devices are different from websites. Certain usability categories can also be used in the case of mobile applications, but it is easier for users to focus on the overall impression of using the application. For example, for the "easiness of use" criterion, questions in the form:

- is it easy to navigate?
- isn't the application too complex?
- is the application legible, taking into account character size, font style, etc.?
- does graphical diversity help in using the application?

can be considered assessable for most users. However, only the answers regarding ease of navigation and complexity of the application are obvious to users. The remaining ones require deeper consideration and more divergent assessments are possible.

Greater difficulties arise in the case of "error tolerance". This criterion is particularly important in systems whose error consequences are significant for the operator. One such example would be purchasing a ticket in mobile applications supporting public transport users. The remaining situations do not have this rank and users are not able to comment on the level of compliance with this criterion by the application.

This research also opted for user-based evaluation. However, the analysis of the needs of application users was based on interviews. Semi-structured interviews were used. This form of interviews is intended to ensure, on the one hand, the opportunity to ask specific questions and, on the other hand, the respondents' free expression, which could go beyond the question asked. Due to the variety of available applications with similar use case and similar functionality, the form of interviews used allowed collecting a lot of information. Thanks to this, it was possible to determine which applications are currently used, which were used in the past and why users abandoned them. At the same time, it was possible to identify people who use or have used multiple applications. Opinions of such users are especially valuable as they allows for a more objective comparative analysis of how user expectations are met across different applications. It can be said that thanks to their experience in operating many applications for similar applications, they become experts in this field.

In the first part of the research, it was decided to analyze the expectations and needs of urban public transport customers in terms of obtaining up-to-date information on the functioning of means of transport. User expectations and needs were collected in the form of mobile application evaluation criteria. When examining passengers' expectations, attempts were also made to take into account the importance of individual criteria. Based on the results of the expectations analysis, their fulfillment was verified for each individual mobile application.

Interviews were conducted only with people who use mobile applications providing information about public transport and were willing to participate in the interview. No other criteria were used. In total, 46 interviews were conducted.

4. Research results

During interviews, it turned out that some applications are more popular than others. However, also taking into account the less popular ones, 9 applications were selected for comparative analysis. They were:

As users expected, only free version apps were included. No comments were obtained for paid versions because it was not possible to find users of the application in such versions.

The application evaluation criteria are divided into three levels of importance. Respondents classified the following as very important criteria:

- ability to designate a route from stop to stop,
- ability to calculate a route based on the starting and ending location,
- information about the actual departure/arrival time of a given means of transport based on the vehicle positioning system,
- available map to verify the location and directions to the stop,
- information about facilities for people with physical disabilities,
- stop and line timetable,
- available carrier announcements.

The respondents classified the following as important criteria:

- using the same application in many cities,
- searching for alternative connections,
- information about the total travel time,
- possibility of purchasing a ticket,
- availability of timetable information without an Internet connection (offline access),
- availability of applications for various system platforms (Android and IOS),
- ability to define favorite stops and lines,
- no advertising or the use of advertising that does not obscure the presented content.

Respondents classified the following criteria as less important:

- availability of different language versions of the application,
- ability to find connections with the fewest number of transfers,
- ability to stop loading the map with slow internet connections.

The fulfillment of the needs of urban public transport users by selected mobile applications in terms of criteria considered very important by users is presented in Table 1. The table shows that the "Time4bus" application meets all the criteria from this most important group. It should be noted that although some applications dominate in terms of the number of fulfillment of evaluation criteria that are very important from the users' point of view, this does not mean that they are the most frequently chosen. An example would be the inability to calculate a route. In this case, we are talking about users who know the connection network or use fixed routes. These people usually expect information about the actual departure time and location of the vehicles. If they use transfers, they control it themselves. Examples of such applications are "Czynaczas", "Gdzie ta bimba", "Kiedy pojadę", which do not include the option of calculating a route. The inability to calculate a route also affects the fulfillment of other criteria for searching for alternative connections and information about the total travel time. Despite this, these applications are eagerly chosen, and the "Czynaczas" application is particularly praised for its interface and ease of use, as well as easy indication of stops and vehicles on the map. However, the highest-rated application in this group, "Time4bus", was assessed in interviews as less legible and with a map that was not very clear.

Table 1.
Verification of meeting the needs of urban public transport users by selected mobile applications in terms of criteria considered very important

Criterion	Jak dojadę	Google Maps	Czyna-czas	Gdzie ta bimba	Kiedy pojadę	Mobile MPK	moovit	Trans-portoid	Time4-bus
Calculating a route between stops	+	+	-	-	-	+	-	+	+
Calculating a route based on the entered location	+	+	-	-	-	+	+	+	+
Departure times and position based on GPS	+	+	+	/[1]	+	/[1]	/[1]	-	+
Stop map	+	+	+	+	+	+	+	-	+
Information for people with physical disabilities	/[2]	-	+	-	+	/[2]	-	/[2]	+
Stop and line timetable	+	/[3]	+	-	-	+	+	+	+
Messages about transport disruptions	-	-	+	-	-	-	-	-	+

[1] – The vehicle's location is not indicated in the application
[2] – Only on a linear timetable
[3] – Timetable for stops only

Source: own study.

It is worth noting that some applications, although they take into account the position of vehicles when estimating the departure time from a stop, the vehicle's location is not indicated on the map. This applies to three applications: "Gdzie ta bimba", "MobileMPK" and "moovit".

Information about facilities for people with mobility disabilities is available only in some of the applications. However, the "Jak dojadę", "MobileMPK" and "transportoid" applications provide this information only on a linear timetable, which makes it difficult to find it. Please note that the information regarding accessibility for people with mobility disabilities is only an example of the possible information provided by the application. For example, the "Czynaczas" application, after selecting a vehicle on the map, provides information whether it is a low-floor vehicle and whether it has a ramp, but also provides information about air conditioning, permitted bicycle transport, ticket machine on board, the possibility of purchasing a ticket from the driver and other vehicle data. The integration of the shared data with the city system is confirmed by the fact that the set of this information is different in different cities.

Table 2.
Verification of meeting the needs of urban public transport users by selected mobile applications in terms of criteria considered important

Criterion	Jak dojadę	Google Maps	Czyna-czas	Gdzie ta bimba	Kiedy pojadę	Mobile MPK	moovit	Trans-portoid	Time4-bus
Multi-city service	+	+	+	-	+	+	+	+	+
Search for alternative connections	+	+	-	-	-	+	+	+	+
Travel time information	+	+	-	-	-	+	+	+	+
Possibility to purchase a ticket	+	-	-	-	-	-	-	-	-
Offline timetable	-	-	-	-	-	+	+	+	-
Multi-system (Android, iOS)	+	+	+	/[1]	+	/[2]	+	/[2]	/[2]
Favorite stops and lines	/[3]	/[3]	+	+	+	+	+	+	+
No ads or no intrusive ads	+	+	+	+	+	-	-	-	+

[1] – iOS only
[2] – Android only
[3] – Only favorite stops

Source: own study.

Verification of the fulfillment of the "important" criteria is presented in Table 2. The search for alternative connections and information on the total travel time, as related to the inability to calculate a route with transfers, have been discussed earlier. Some information contained in the tables is clear and does not require comment, but in other cases the true/false answer is insufficient. This is the case when considering whether it is possible to use the same application in many cities. It needs to be underlined that the list of cities should be verified each time as it is subject to frequent changes. In most cases, such applications take into consideration largest Polish cities, but there are few examples that serve information about cities outside Poland. One example of an application that is not limited only to most popular cities is "mobileMPK" which is available in over 60 Polish municipalities. It needs to be noted however, that the

application offered real-time information for only 18 of them. Such information may be the basis for assessing the spread of real-time tracking service in Poland. The availability of the offline timetable also requires comment. Those applications that are marked as providing offline maps offer this option only for selected cities.

Table 3.
Verification of meeting the needs of urban public transport users by selected mobile applications in terms of criteria considered less important

Criterion	Jak dojadę	Google Maps	Czyna-czas	Gdzie ta bimba	Kiedy pojadę	Mobile MPK	moovit	Trans-portoid	Time4-bus
Different language versions of the application	+	+	+	-	+	-	+	-	+
Minimizing the number of transfers	+	+	-	-	-	+	+	+	+
Functioning without a map	+	-	+	+	+	+	-	+	+

Source: own study.

Verification of whether the criteria from the "less important" group are met is presented in Table 3. It can be suspected that users have added functions to this group that they do not need themselves, but believe that someone else may need them. On the other hand, the fact that the creators included such functions in their applications proves a very broad analysis of the needs of potential users. It needs to be noted that the ability to not load a map on slow internet connections may be useful more often than users expect.

5. Conclusion

Carrying out research and analyzes based on interviews is an underestimated and disliked research method. On the one hand, this is due to the difficulty of conducting interviews, which determines the small research sample, and on the other hand, the lack of spectacular statistics that can be obtained using other methods. However, with this method it is easier to notice the nuances of the examined issue and take advantage of the knowledge and experience of the respondents.

Analysis of the features of mobile applications to support public transport users seems to be crucial to their improvement. This series of studies managed to collect user expectations regarding the functionality of mobile applications for urban transport. Additionally, the degree of importance of each of them was taken into account, dividing them into three groups. It should be noted that the needs of each person differ and depend on the context of use. Therefore, not only do they change over time, but they may also be different when we want to use the application in a city that we do not know as well as our place of residence. Verification of the fulfillment of selected criteria for 9 public transport applications that are popular in

Poland is crucial in the process of adapting the application to a specific context of use and allows users to make more informed decisions. The practical application of the results obtained therefore concerns both the possibility of using them in the process of improving mobile applications and when selecting an application appropriate for a given user, including an elderly and disabled person.

To sum up, it can be said that although it is difficult to compare all the features useful for public transport users, it is certainly possible to distinguish a set of key importance. The results obtained indicated the strengths and weaknesses of applications for mobile devices, which may be an indication for their further improvement.

It is expected that the number of mobile applications users will increase. There will also be an increasing number of older users and users with disabilities, for whom minor imperfections may be a significant barrier to using such applications. For these reasons, it is necessary to conduct further research taking into account people of different ages and with different dysfunctions.

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