Smart and Individual Travel Assistance - Barrierfree Mobility for all

Smartphone application for barrierfree cross-modal transportation information in real-time

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Abstract—**Public transport operators focus on a public transport system, which is inclusive and fair to all groups of society as required in the United Nations´s Convention on the Rights of Persons with Disabilities. This requires an innovative approach reflecting both the users' and the service providers' perspective. From the passengers' point of view it becomes obvious that not only the accessibility of a single mode of transportation is relevant. Furthermore, a systemic view is required as a trip from door to door most likely includes different means of transportation. The interchanges within one transportation system as well as the change-over to other means of transportation must be improved regarding the special requirements of people with reduced mobility and/or sensory restrictions. So, in order to create a public transportation system for all, all public transport service providers and their processes have to be linked with each other. This article describes how this objective can be achieved by a holistic approach that helps developing individual and smart solution available and useable for each passenger.**

Keywords - cross-modal public transportation; barrierfree; smart solutions; customer-orientation; feedback; service application.

I. INTRODUCTION

Every mobility chain - not only in public transportation - is accompanied by an information chain. This has to be seen both from the passengers' perspective as well as from the public transport service providers' point of view. Especially passengers with reduced mobility and/or sensory restrictions have to be informed in due time. Not only when operations are affected as planned, but especially in case of unexpected events and service disruptions. In this case, existing travel itineraries have to be updated or new travel itineraries have to be generated and distributed to the relevant passengers. Updates of travel itineraries need to reflect changeover times and have to consider special needs of passengers with reduced mobility. In particular, this means that information needs to be presented in time and in an understandable way, e.g., in sign language [1]. By carrying out the demo research project aim4it (Researchproject aim4it - accessible and inclusive mobility for all with individual travel assistance. EU Funding programme Future Travelling (ENT III, Flagship Call 2013), Projectnumber: 4304059) , barrierfree mobility for all should be achieved as demanded by UN´s Convention on the Rights of Persons with Disabilities [2] as well as corresponding legislation on European [3] and national level [4].

Innovative intermodal transport information systems (ITIS) manage the challenge to provide such relevant pre-trip, on-trip and post-trip information to passengers. Precise and up to date information is the basis for travel assistance applications.

Within the travel assistance application information representation is tailored to the specific requirements of passengers with sensory restrictions, e.g., information display in sign language using an avatar on smartphones. Blind passengers benefit from audible output provided by screen readers.

The offer of travel assistance applications significantly increases service quality perceived by the passenger and can thus increase the use of public transportation. By doing this public transport can make a significant contribution towards a sustainable modal split, which helps to reduce pollution in urban areas. Furthermore, with suitable evaluation algorithms customer feedback can be systematically solicited, evaluated and interpreted by the public transport operators. Better handling of passenger feedback is a solid basis for a continuous improvement of public transport operations. For example, timetables can be adjusted or available digital maps further enhanced furthermore, service personal can be used more appropriate. Overall, this will result in a better service quality for passengers – not only the ones with reduced mobility and/or sensory restrictions. All groups of our society benefit from improved passenger information and value-added services.

In the following sections, it will be described how an innovative approach can support the development of a barrierfree public transportation system. The technical components have to fulfill the passenger´s needs as well as the public transport service provider´s needs and will be further described below. Furthermore, the chosen use case example "UC6: Passenger feedback function" will be explained in more detail to point out the innovative methodological approach, which helps to continuously improve value-added services for passengers with reduced mobility. Finally, a conclusion will sum up the most important facts and show the next steps on the way to a barrierfree public transportation system for all.

II. Innovative approach for barrierfree public transportation

The project aim4it (accessible and inclusive mobility for all with individual travel assistance) incorporates and integrates both the user's and service provider's point of view. In order to bring together both views service blueprints of the passenger processes and use cases from the public transport service provider´s point of view are linked to each other. Demands and requirements from passengers and public transport service providers are linked to the processes and sub-processes of service maps and use cases (see Figure 1) in order to gain known-ledge about all relevant requirements (for more information refer to [5]) that need to be fulfilled.

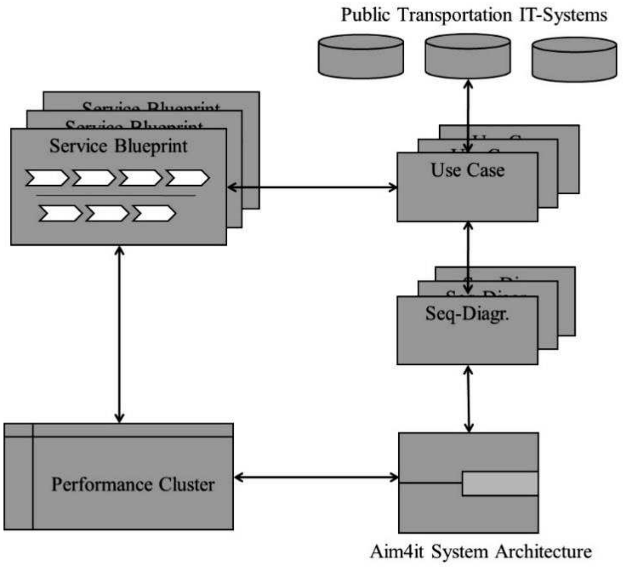

Figure 1. Innovative approach for developing barrierfree public transportation systems in accordance to [6]

Furthermore, a requirements management approach for networks is implemented to evaluate, structure, assess and monitor the process of requirement fulfillment [7] and to assure the quality of the project outcome. In order to show the way how the system is developed, based on elicited requirements and processes, a short use case example is given in the following.

When a journey is viewed from the perspective of the customer/user, it becomes clear that it is not enough to design individual transport modes and facilities for just one transport system. In order to be passenger-friendly and suitable for use by passengers with special mobility needs (in this use case visually impaired passengers as well as the deaf and hard of hearing) all transport modes and, therefore, all service providers have to be considered [8]. For a given destination to be reachable by everyone, barrierfree mobility chains for all transport modes should be set up. As every mobility chain is accompanied by an information chain passengers with reduced mobility and/or sensory restrictions have to get all relevant information about departure and arrival times as well as necessary transfer procedures at interchange stations. This information must be up-to-date, precise and understandable at important nodes before, along as well as after the journey. Significant information needs to be conveyed in optical, acoustical and/or tactile form [9].

These demands and requirements lead to several use cases (UC), which will be addressed in the aim4it project:

- UC1: Request for connection protection especially for passengers with reduced mobility who have a need for prolonged changeover times at interchange stations.
- UC2: Information about current incidents in the public transport network in sign language.
- UC3: Request for staff assistance to get on and off the vehicle to facilitate use of public transport services for passengers with reduced mobility.
- UC4: Re-Routing especially in case of incidents, but also in case of delays in public transport operations.
- UC5: In-Vehicle passenger information based on the integrated on-board information system (IBIS).
- UC6: Passenger feedback function to trigger continuous improvement activities of public transport operators.

Afterwards those use cases are transferred, based on their storyline, into Unified Modelling Language (UML) sequence diagrams in order to support the development of technical interfaces between the different information systems of the service providers. For the use case 5 "in-vehicle passenger information" such a sequence-diagram is shown as an example in Figure 2. It shows how the background system (the journey planner, which is part of the intermodal transport information system, ITIS), the travel assistance application on the passengers' smartphones, the Bluetooth-Gateway on board of the vehicle as well as the on-board unit of the intermodal transport control system (ITCS) interact with each other.

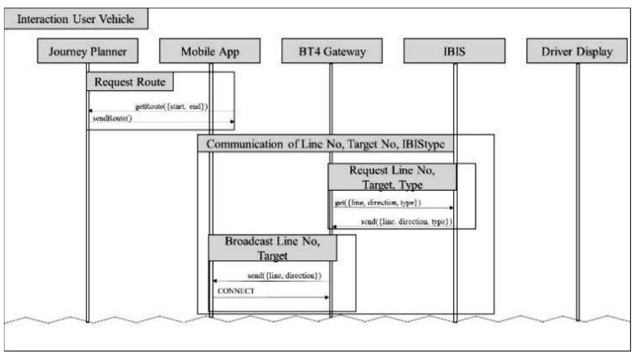

Figure 2. Detail of sequence diagram about "In-Vehicle Passenger Information" use case

Based on the defined use cases and the sequence diagrams that show, which information sources are available and how they should interact with each other, the whole system architecture with its components was set up. The following section describes those components, based on the use cases in more detail.

III. Components of the aim4it System Architecture

The intended overall aim4it system provides a benefit from the user's as well as the public transport service provider's point of view. The key idea of the aim4it system architecture is to use industry standards. This facilitates implementation of the aim4it travel assistance application as well as field integration in the test field in Vienna. Furthermore, it allows easy transfer of project results to other regions after the project.

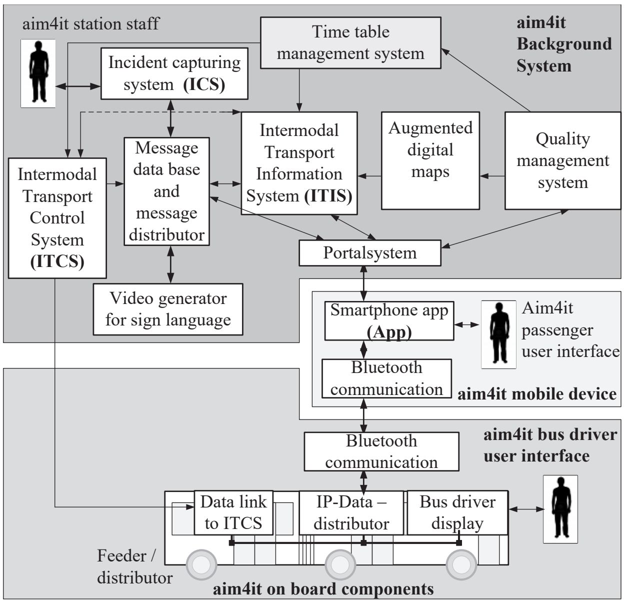

Figure 3. Aim4it system architecture [10]

Thereby the aim4it smartphone app is the key element as shown in Figure 3. The following sections will explain the aim4it sub-systems and their interactions in more detail.

A. *aim4it smartphone app*

With the aim4it smartphone app passengers with reduced mobility and/or sensory restrictions get assistance in both trip planning and execution. At home the passenger can start the planning of the trip by entering information about the start and the destination into the app. Data entry and display on the aim4it user interface are designed in a user-centered way. All information provided will be displayed as multi-sensual output to secure information for the different groups of passengers. For example, blind and visually impaired passengers receive audible output. Once all data is entered, the aim4it smartphone app sends a request for a barrierfree trip to the Intermodal Transport Information System (ITIS) [11]. This way a bi-directional communication between passengers and service providers can be established [12]. This bi-directional link will be maintained once the passenger started his journey. This means once a triggering condition for a route-update has been identified by the ITIS the passenger will receive a new itinerary on his smart phone (see Figure 4). With the app the passenger can also "book" other value-added services. If required prolonged change-over times at interchange stations can be requested as well as boarding assistance to enter or leave the public transport vehicle.

Figure 4. Push-updates for passenger´s smartphones

The passenger receives updates about current public transport operations with push-updates. Figure 4 shows a sample screen shot of the aim4it smartphone app. The example shows a trip with the subway line U2 in Vienna to the convention center. The trip from start to destination requires an interchange from subway line U2 to the bus line 82A. The connection from subway to bus is successfully booked and the bus driver is informed. The passenger receives a positive acknowledgement about this.

B. *Intermodal Transport Information (ITIS)*

Based on the start and end point of the requested trip the ITIS performs barrierfree routing from start to destination. In order to do this, the system is supplied with all relevant time table information from time table planning systems. Furthermore, the available infrastructure at stations (e.g., lifts and escalators) is part of the system. The combination of time table data and infrastructure modelling allows the execution of barrierfree routings. In addition to "just" reflecting time table data, the ITIS also reflects real-time data [13] of current public transport operations. Real-time data is provided by the Intermodal Transport Control System (ITCS). Furthermore, available information from augmented digital maps (e.g., based on crowdsourcing projects such as wheelmap) and incident from the incident capturing system (ICS, see section III, D) are considered in the routing function. For example, incident messages can be entered by local service staff at stations (e.g., defect of an escalator). The barrierfree route compiled by the ITIS is sent to the smartphone app. There it is displayed for barrierfree navigation along the planned trip chain. Besides this routing function, the ITIS also serves as a "message broker" between the passenger and the public transport operators. For the use cases "connection protection" and "staff assistance" the ITIS receives the requests, maps the requests to specific vehicle movements and forwards these requests to the intermodal transport control system (ITCS). If required by the usecase feedback from the ITCS will be forwarded to the passenger by the ITIS (e.g., acknowledgement of staff assistance request). The passenger will receive corresponding information on his/her smart phone.

C. Intermodal Transport Control Systems (ITCS)

The intermodal transport control system (ITCS) continuously monitors the current status of public transport operations (see Figure 5). Each day the current time table is loaded into the system.

Figure 5. Operations control center

Each vehicle receives information, that is relevant. Time table information is displayed to the driver who adheres to the schedule in the best possible way. Based on GPS-tracking the vehicles send updates about schedule adherence and their current position to the ITCS. Based on the available information, existing conflicts in public transport operations can be detected (or future conflicts predicted) and appropriate corrective action is triggered by the staff in the operations control center. In the operations control center previously booked connection requests are monitored. The same applies for previously booked requests for staff assistance. In case planned connections cannot be kept or planned staff assistance at a station cannot be guaranteed any more, appropriate action is taken. Connection monitoring is visualized in the screenshot in Figure 6 below. This list provides information, which connections are subject to monitoring and if these are critical due to delays especially of the feeding bus.

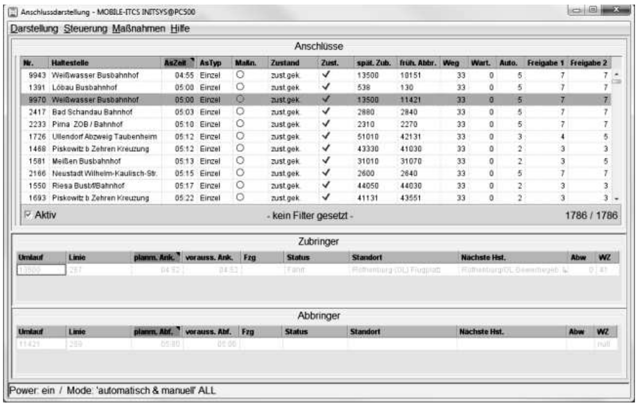

Figure 6. Display of secured connections at the operator's terminal in the operations control center

Besides this equipment in the operations control center each vehicle (bus and tram) has an ITCS on-board unit. By implementing a new bi-directional interface between the aim4it smart phone app and the onboard unit new services become available to the passengers. An example of a possible new feature is the request for bus driver assistance e.g., to board the vehicle. This request can be processed in two different ways. In a first option, the request is entered into the smart phone app and is sent to the ITIS. By the ITIS this request is passed to the ITCS where the corresponding vehicle is identified. Via the existing data link between the ITCS and the vehicle the request for bus driver assistance is sent to the bus (see Figure 7) [11]. In a second option, a direct communication link between app and vehicle (e.g., WiFi or Bluetooth) can be used.

Figure 7. Bus driver display shows requested assistance

On board of the vehicle the boarding request is displayed to the bus driver within the aim4it bus driver user interface when the vehicle approaches the proposed station. Figure 7 shows how a boarding request of a wheel chair user is displayed to the bus driver.

D. Incident Capturing System (ICS)

During operations the initial route of the passenger will be updated based on available information about timetable deviations or changes in the status of the network infrastructure (real-time data). Real-time data also includes incidents and disruption information due to their mostly shortterm nature. For this reason public transport service providers have to capture incidents in their route network [14]. For example, this can be line closures (e.g., due to an accident) or a defect of facilities at stations. With the incident capturing system the operator can enter currently existing problems. This information is made available to the ITIS. ITIS determines which line/station is affected by the entered incident message. Furthermore, ITIS has an overview, which passengers need to be informed about currently existing restrictions within the public transport network. The existing incident is reflected in the routing of passengers (see section IV.D). With the push service all passengers receive information that is relevant to them in their specific usage context. For example, a wheel chair use will get an adequate route information in case a lift is broken. In this case, he/she might be asked to use a different route or to leave the subway at another station. In case an incident has been solved the incident message is revoked. In this case, the ITIS can determine a new route.

IV. Value-added Services and their continuous improvement

With the aim4it smartphone app passengers with reduced mobility and/or sensory restrictions get on-trip assistance. This includes several services, which are based on pre-defined use cases. The implemented use cases are further described in the following sections.

A. UC 1: Request for connection protection

Most often trips in a public transportation network can only be realized with at least one transfer [10]. To provide a dependable transportation chain time tables have to be matched and transport operators have to monitor connections in order to synchronize transportation chains in case of incidents. If needed, the connecting vehicle can wait for passengers of the feeding vehicle. The request for connection protection in the aim4it system takes into account that passengers with mobility or sensual restrictions need a longer transfer time to the vehicle. Based on this service the connection is guaranteed and the passenger is informed in due time. The driver of the receiving vehicle is informed about the prolonged waiting time at the requested station. In addition, connections can also be cancelled if no longer required (e.g., due to re-routing, see Section IV.B – Incident information in sign language) to avoid delay [1, 10]. If a connection cannot be kept because of delays or incidents within the public transport network the passenger will get an automatic route update.

B. UC 2: Incident information in sign language

All passengers need to get access to detailed and reliable information regarding their trip. To provide such comprehensive information by the travel assistance application for sensory restricted passengers, this information have to be made available in an appropriate way. Whenever service irregularities (e.g., delays, cancellations, missed connections) are detected in the ITCS error information is forwarded to the passenger. In order to provide barrierfree information, this process includes several media types, which supply information for the passenger in a way suitable for his special needs.

The aim4it project pays special attention to deaf and hearing-impaired passengers. As this passenger group has difficulties in deciphering complex linguistic structures relevant information will be provided by sign language-based avatar videos. The aim4it message generator automatically transforms the text message to a video stream, *displaying error information in sign language* for deaf and hard of hearing passengers on their smartphones [1, 10]. Figure 8 shows the video avatar for displaying information in sign language.

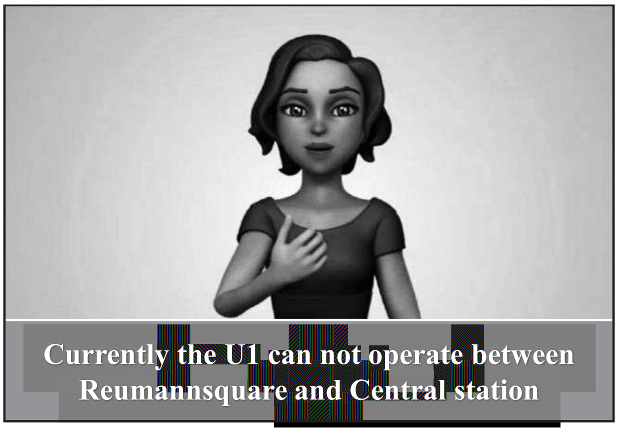

Figure 8. Video avatar for displaying information in sign language [10]

C. UC 3: Request for staff assistance

On trip the passenger can make stop requests along with requests for bus driver assistance. For instance, a blind or sensory restricted passenger can call for help to get on the vehicle (see Figure 9). It is also possible to call for help to get off the vehicle. Therefore, the bus driver can assist, e.g., a wheelchair user by a bus integrated ramp (see Figure 10).

Figure 9. Sensory restricted passenger requests via aim4it application

Figure 10. Assistance for wheelchair user

Figure 11. Recognition of approaching line via aim4it application

This service provides an easier usage of public transportation services for passengers with reduced mobility or with sensual restrictions. Information about a staff assistance request is sent by the passenger prior to the trip. The staff member awaits the passenger at the previously defined station and helps to board the vehicle. At the designated station the staff member helps again by alighting from the vehicle [1, 10].

D. UC 4: Re-routing

During the trip of a passenger, a previously defined trip may become impractical. This may be due to

a) the passenger changing his or her mind about basic parameters of the initial trip,
b) the passenger showing up to late at the start station or missing a connection or
c) irregularities of public transport operations, for example, in case of delays, cancellation or detours.

Therefore, dynamic *re-routing* is an integral part of the system. Once one of these triggering conditions is identified by the smartphone app a new trip request is initiated. Using available information in the ITIS as well as the information about the passenger´s disability profile a new route is generated considering current position of the passenger and real time data of public transport operations (including delays and incident information). If re-routing involves another use case, e.g., "Request for staff assistance" information is updated or the request is cancelled [1, 10].

E. UC 5: In-vehicle passenger information based on IBIS IP

In order to establish internet protocol (IP) based communication, wireless communication between the aim4it application and the public transportation vehicle will be implemented by means of Bluetooth 4.0-interface. This way waiting passengers can recognize, which line the approaching vehicle is assigned to (Figure 11).

Additional information is sent from the vehicle to the application on board. This contains information about the travel directions, route and stop sequences, real-time information to catch connected services, etc. Deviations from the scheduled timetable can be sent as well [1, 10].

F. UC 6: Feedback for continuous improvement

To realize a continuous improvement of the public transportation system, as well as the aim4it services, the passengers have to be surveyed. With the aim4it feedback function passengers with sensory restrictions or restricted mobility will be directly involved in this improvement process during their travel [15]. Based on these assessed performances and opinions of the passengers, the public service providers can improve performances of service quality in a precise way. The public transport operators can set up the right priorities for the adaptation of existing facilities and services or add new, gathered requirements for further design, planning and – after implementation - assessment of public transportation systems. To realize this actual state of the art customer satisfaction measurement concepts have to be enhanced and combined with the potentials of up-do date information and communication technology [16, 17].

In detail, this means that passengers, their processes and their contact points are used to implement a concept for customer- and process-oriented satisfaction measurement, which is based on real time data.

The service blueprint showing the passenger processes, their contact points and links to service providers [8] offer input for the performance cluster that is a knowledge base for survey questions and their results. Furthermore, it is used as basis for the use cases of each function that is supplemented with available information systems and standards in public transportation [15]. The execution of every journey generates data that is sent to and from the smartphone device of the passenger. This data can serve as a kind of direct performance measurement in the sense of the European standard specifying service quality for the public transport domain [15]. With this data the actual quality delivered by the public transport operator can be measured by using statistical matrices.

One possible measurement concept is the so called direct performance measures (DPM) [18]. DPM have proven to be an adequate method of monitoring the actual performance of services based on operational data records. Examples of data collected in public transportation are information indications of passengers arriving on time, indications of passengers departing early/late from the (re)routing service. This data can be used as a DPM for the service criterion "adherence to schedule" [15]. Another example is the indication of connections met, which is a result of the connection protection service in connection with the (re)routing service. This can also be used to quantify actual service performance regarding the service criterion "process data" (e.g., successful execution of service) or the request for bus driver assistance (e.g., successful execution of staff assistance) [6].

Furthermore, the aim4it smartphone app allows to conduct customer satisfaction surveys (see Figure 12).

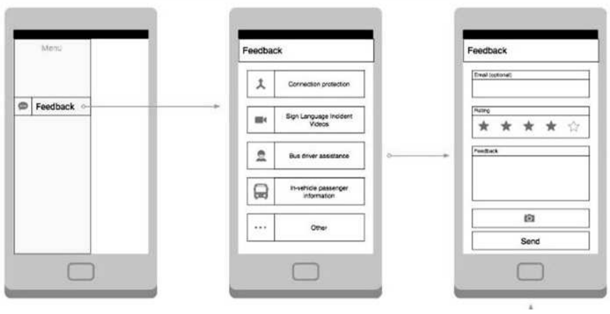

Figure 12. Mock-up of graphical user interface for customer feedback [6]

Customer satisfaction surveys shall assess the degree to, which a customer believes his or her demands with respect to public transport services have been met [15]. These levels of satisfaction with a provided service can be compared against defined scales of quality expected by the customer. With the integration of customer satisfaction surveys into the travel assistance application surveys can be conducted and reported just in time of delivering the service. By using a star-rating for different categories of service quality the customer can evaluate the service he just consumed and the assessment can be linked to the system data. This way, the actually achieved service performance is linked to the customer satisfaction, not to the planned service performance [6].

The gathered data will be analyzed with respect to different kind of criteria that are based on the passengers' service requirements. In this case, two different kind of analysis are possible. A simple one offers KPIs to get an overview about the actual performance while the complex analysis offers widespread facts to gain knowledge about correlations of service attributes [6].

Both analyses support the implementation of a continuous improvement process of service quality in different ways:

(1) existing quality levels are identified,
(2) areas for potential improvement are identified and
(3) corrective action can be taken. Corrective actions include actual improvement of performance, appropriate communication to the customers as well as corrective action in the case of unacceptable performance [6].

While KPIs are a simple analysis to achieve an overview on the actual performance, the customer satisfaction index is a more complex analysis. For this product, attributes will be defined, which have an effect on customer satisfaction. In the smartphone application questions regarding the product attributes (in this case e.g., kindness of staff during staff assistance) are presented to the passenger, when the product criteria are used.

The customer is asked to evaluate each attribute he or she just consumed [7]. The evaluation includes their perception and expectation of *performance* and *importance*. The smartphone application provides a five-point scale (but you can use x-point scale also). Where for example, for performance: 1-means very dissatisfied, 2-somewhat dissatisfied, 3-neither dissatisfied and satisfied, 4-somewhat satisfied, 5-very satisfied. For the measurement of importance a different scale applies, where 1-means is not important, 2-little importance, 3-neutral, 4-important, 5-very important [6]. As a result, a customer quality map can be set up (see Figure 13).

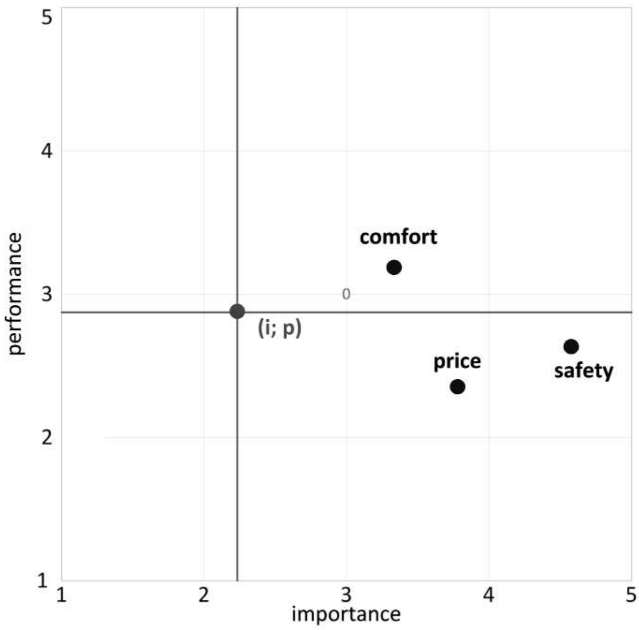

Figure 13. Importance/Performance portfolio of the CSI [6]

The customer quality map is split into four areas. The areas of this map indicate, which attributes should be kept at the current level, and, which should be improved. Section I shows quality attributes whose values should be kept. Section II shows service characteristics whose attributes should be improved first (in the short time). Section III contains insignificant attributes. Public transport operators should transfer their resources they spend on those criteria to other areas. Section IV includes characteristics for improvement, but they are rated as insignificant by the passenger [19]. For this reason, these service characteristics should be considered as last for service improvement [6].

By implementing such a feedback function into the aim4it system and carrying out the KPI and CSI analysis continuously the service providers are able to improve their services constantly while avoiding mismanagement of resources.

V. Conclusion

Currently, the demonstrator of the aim4it app is tested and implemented by the consortium members. First results of the integration in the city of Vienna (Austria) show the enhanced possibilities of such an application. A first prototype of the smart phone application has been tested with a focus group of passenger with reduced mobility in Vienna (two blind persons, three deaf persons, two persons in a wheel chair). Based on the project results and future real scenario tests the local public transport operator in Vienna evaluates if project results can be incorporated into the productive version of the travel assistance application after the end of the project. Based on the project results, further value added services for travel assistance can be developed in the future, which is facilitated by using industry standards in the project. The results of the aim4it project will be the basis for further standardization projects (further enhancement of the outcomes of the previous national standardization project IP-based communication in public transportation, IP-KOM-ÖV). In close cooperation with the VDV (German Transport Companies) aim4it project results will be integrated into the existing set of standards. Aim4it project results will be formulated as change requests and fed into the standardization process carried out by VDV. Only this way it will be possible to enable a nationwide implementation of smart applications as they need some kind of common standards so that needed data can be exchanged. Thus, domain experts will review the project's deliverables and will reflect project outcomes in an updated revision of the TRIAS standard (Travellers‘ Real-time Information and Advisory Standard).

Acknowledgment

The promotion plan 64.004/2014 of the European research program era-net transport has been funded by the German Federal Ministry of Transport and Digital Infrastructure based on an enactment of the German Parliament.

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