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***Abstract*—As recent studies have shown, compared to other sectors the customers of public transportation services are unsatisfied with regard to the service quality. One mayor source of the dissatisfaction is caused by missing or inconsistent information about the duration and route of planned trips in case of disruptions. Existing possibilities to interact witht he transportation company generally does not lead to changes in the disruption management process. To overcome these limitations, we propose to use mobile communication techniques to transfer bi-directional information between the customer and the transportation company via an information platform. This allows to include on-site information from customers in operational decisions as well as fast and consistent informations in case of plan changes. Therefore, our proposed solution allows structural process changes which would increase the customer satisfaction by means.**

I. Introduction

Public transport serves the society by providing cheap and fast transportation services. Due to experiences over decades, the provided services are highly reliable and affordable. Traditionally, the routes, the interval and the vehicles were planned top down based on a priori knowledge about the traveller flows and desired interchanges. Due to the slow changing nature of traveller flows and a huge basis of domain knowledge, this planning process works well if every actor is on time. Things look different in case of short term interruptions delays or even cancellations. As the dispatcher has only a priori knowledge about the situation, it is impossible to come to an optimal dispatching decisions to work around the potential problems.

To overcome these limitation and to take better disposition decisions in case of short term plan changes, the dispatcher in charge needs more and better knowledge of the local situation in vehicles to be rescheduled. Having this knowledge, it would be possible to improve the dispatching decision in general, e.g. by minimizing the waiting time for all travellers in situ and to inform the travellers in time about plan changes. This would improve the travelling experience because it reduces the uncertainty in case of plan changes.

In former times, it was impossible to gather and process the journey informations of multiple thousands of travellers in a timely manner. But these times have changed due to the wide availability of modern communication systems like smart phones with mobile data plans and high performance servers. Having these communication and data processing capabilities as of today, it becomes possible to collect and include in situ information from the travellers in operational decision processes. A wide integration of this information does not reduce the probability of negative events but it certainly reduces their impact. Augmenting the existing operational dispatching processes with real time information about the traveller flows allows to minimize the average waiting times for all passengers. Furthermore those communication systems could be used to inform the traveller about dispatching decisions which may cause schedule changes in a timely manner. This gives the passengers the feeling of being well informed and thus increases the user experience.

Last but not least, such an integration of the traveller information in the decision making process simplifies the collection of long term, fine grained traveller flows and enables novel analysis for finding frequently breaking connections or unnecessary waiting times. Due to these reasons, a deep integration of travellers aspects in the connection planning and dispatching process is a worthwhile optimization for the transportation companies as well as for the travellers.

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In this paper we present the outcome of the IP-KOM-ÖV project funded by the German ministry of economics whose goal is to standardize an interface for data exchange in public transportations. The so created Travellers Realtime Information and Advisory Standard, TRIAS, consists of several services for information exchange. Some of these services allow to collect information directly from the travellers about their scheduled trip or planned interchanges and also permits them to passively or actively give feedback. Having these informations, it becomes possible to include the travellers in operational short- and long term decision making processes.

The goal of this publication is to show the technical and organizational feasibility of integrating travellers aspects in the connection planning process. First, in section II we show the state of the art in traveller information systems. Then in section III and section IV a brief description of operational and traveller aspects is given. Building upon that, the technical realization of such a solution is described in the following chapter. Then in section VI we discuss the effects of such a process change and it's alternatives. Last but not least, this paper is concluded in section VII.

II. Related Work

Compared to other sectors, the satisfaction of public transportation travellers in Germany is low as a survey conducted by Grigoroudis [1] shows. As this problem is not limited to Germany, many researchers conducted studies about the service quality in the public transport sector.

A good overview over important influence factors is given by Suhl [2] who divided these factors in two categories: Either hard influence factors which are measurable by the dispatcher or soft factors which are not. According to Suhl, important hard influence factors include waiting times at stations, waiting times in trains, missed connections. On the other hand soft influence factors include tidiness of cars and stations security, good service, friendly staff, comfort of journey and quality of catering.

Thompson et al [3] shows that satisfaction essentially depends on the ease of use. This includes the means to transport relevant information to the transportation company. Today, means of communication are generally only person to person (on travel) or via phone, E-Mail and, quite new, social media.

Research in the area of public transport and social media is rather focused on services to connect travellers or provide entertainment for the traveller during the different phases of the trip [4]. Actual research concerning traveller feedback to the transportation company using social media is rare. Austin [5] mentions the problem of reacting on customer input via social media. Deutsche Bahn is using social media to communicate with its clients and also reacts on feedback of the clients [6]. However, this feedback can generally not be used to influence operations. Social media as well as traditional ways of communication does not allow to transmit structured information. Information cannot be easily evaluated.

Currently, the disruption management cares about timetable adjustment, rolling stock and crew rescheduling [7]. Customer information sometimes is indirectly integrated by staff reports and then displayed towards the dispatcher [8]. The notification of customers in a timely and consistent manner, is currently not a highly prioritized aspect in disruption recovery. Taking direct feedback of customers into consideration is not part of the process at all. Suhl [2] defines a customer oriented dispatching by taking the delays of travellers into consideration. However, the data is derived from models and simulation and not directly transmitted by the traveller. Currently, also the planning phase of disruption management does not consider data of direct customer feedback [9].

III. Operational Aspects

Public transport serves our society by transporting people and therefore this sector is heavily influenced by the travellers' needs. Vice versa many operational decisions directly influence the travellers. Especially the ad-hoc dispatching in case interruptions generally has a direct influence on them. However, direct feedback of the traveller is rarely used to improve the planning or operations of public transport. Therefore, in the next few paragraphs we will first discuss possible influence factors of the travellers on dispatching decisions. Then we give a brief overview of influence factors which are included in dispatching decisions today.

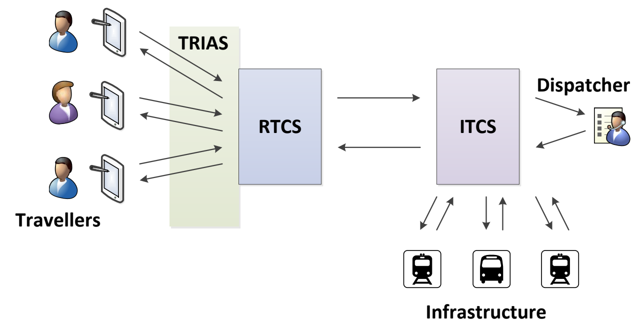

Fig. 1. Symbolic Architecture of Trias based traveller information systems.

A. Planning

In planning phase the transportation company or authority develops an offer of public transport possibilities respecting travel demands based on traffic models. With the help of customer feedback an offer can be adapted to come closer to the travellers' needs.

Customer feedback about travel chains and feedback related to interchange possibilities can give information about used travel chains and travel wishes. The transportation offer than can be improved on the basis of the collected information.

Today, the planning phase is generally based upon traffic models. The traffic models are sometimes enriched by data of ticket sales or counting of travellers. A direct integration of data sent directly from the customer is not known.

B. Dispatching

The dispatching process is highly complex and most of the times a completely human decided process. Customer feedback can efficiently support the dispatcher in his decision which dispatching action to undertake.

1) Dispatching Costs: In case of disruptions or malfunctions dispatching actions need to be undertaken to return to normal operation and to lead the traveller to his destination. Most of the dispatching action will generate costs of some sort that the dispatcher has to take into account while choosing among his dispatching possibilities.

The usage of customer feedback give the opportunity to decide more accurate on appropriate dispatching actions and also enables to evaluate costs for them.

2) Customer Satisfaction: The customer satisfaction is one of the objectives the dispatcher has to achieve. Considering customer feedback for the dispatching strategy, the travellers' wishes are met more closely than discarding any feedback (or not knowing it at all). The customer's interest is further discussed in section IV.

Today, feedback about travellers is transmitted by accompanying staff who can give only approximate information about interchangers or travel destinations. Whilst in far distance train travels, train staff often transmits the (approximate) information, it is either very unreliable or not existent in local transport where little or no staff is on the vehicles.

C. Transportation Authorities

Transportation authorities often define not only the offer of public transport but also introduce quality specifications. Customer feedback can be used to measure the quality and to evaluate if the operations meet the quality specifications.

Here, customer feedback is helpful to evaluate quality standards. Until today evaluation exists in forms of questionnaires. A usage of structured electronic data directly sent back from the customer is not known.

IV. Traveller Aspects

The EN 13816 standard defines service quality through a customer and service provider view [10]. The customers satisfaction is closely related to service quality sought and perceived by the customer [10]. In regard to the integration of customer feedback into e.g. dispatching processes, especially the quality criteria information, time, customer care and comfort are affected [10].

- Information: Introducing a feedback function, which e.g. allows customers to communicate their actual or future journey, may result in a better information service, providing information for the individual journey.
- Time: Normally, using public transport is connected to reaching a specified location within a defined time. Being able to e.g. communicate a connection demand to secure a connection is critical to meet the defined arrival times. The opportunity of being involved into this process gives customers a feeling of security.
- Customer care: Providing some sort of feedback function for customers, may serve as a new and easy way to show that the customers well-being along the journey matters to the transportation company. Feeling integrated as an individual may influence the quality perceived, if the feedback is considered and an effect is recognized.
- Comfort: Being able to have some sort of control and the opportunity to communicate feedback, which is integrated into e.g. the dispatching process, will shorten the time the passenger is worrying about his or her journey, leaving him or her more time to relax. This may result in a better experience and perceived quality as well.

Previous studies and analysis in transportation and other application areas show, that customers want to give feedback for different reasons [11], [12], [13]. Besides having the opportunity to complain to someone about lack of quality, giving some sort of relief to the actual situation [14], customers often have a connection to their community, inspiring them to give feedback to enhance the community. FixMyCity [15] and FixMyTransport [16] are an example for such involvement. In addition to the customers needs for participation by giving and getting feedback, a study in public transport revealed three basic customer requirements on information [17]: reliability, intelligibility and consistency. In order to satisfy these needs, customer feedback can provide essential information to the transport companies. At the moment customer feedback in public transport is often received through service hotlines, service personal, emails or social networks. Providing public transport companies with insight into problems within their network. Using these information in a real-time decision process, is often not possible, as the data is provided in different forms and often lacks essential information. In some cases, service personal is able to forward these information in time and report back to the customer. From a customer point of view it is worthwhile to open new ways for these kind of feedback.

V. Technical Realization

Traditionally, the communication channel between the transportation company and the traveller is uni-directional which allows the transportation company to inform the traveller. But without in situ knowledge about each traveller, it is technically impossible to integrate the travellers' requirements in operational decisions. From a technical point of view, today, a bi-directional communication between both parties is possible due to the wide availability of mobile internet and handheld devices. This allows a pervasive integration of traveller feedback in taking operational decisions.

In this section, a brief description of the technical feasibility is given. First, we describe the technical standard to exchange the required data. Then we explain important services of the interface and finally we give an outlook how these informations could be used to increase the travel experiences.

A. Standardized Interfaces

1) Information Flow: To effectively use information about the traveller in the dispatching process, or to inform the custom about dispatching decisions, relevant information must be collected at the source and transferred to the sink. Relevant information includes e.g. malfunctions of facilities and travel wishes reported by the customers but also delays or cancellations affecting the traveller.

This information flow, as shown in Figure 2, either happens from the customer to the transportation company or vice versa, each of which are totally separated processes that can exist one without the other. Nevertheless, information about dispatching decisions can depend on earlier reported customer information.

Relevant informations regarding travellers could be exchanged using commercially of the shelf available smart phones which communicate with dedicated servers operated by the transportation companies. A challenge is to transport the relevant information from one traveller to multiple dispatchers who could use this information to improve their dispatching decision. The traveller and the dispatchers might not have a direct communication link. Furthermore the traveller's privacy concerns must be taken into consideration.

2) Interfaces: To address some of the issues, the project IP-KOM-ÖV defined a standardized interface called TRIAS to transfer relevant information. As shown in Figure 1, this interface is used in conjunction with a Real Time Communication System (RTCS) which provides information services for

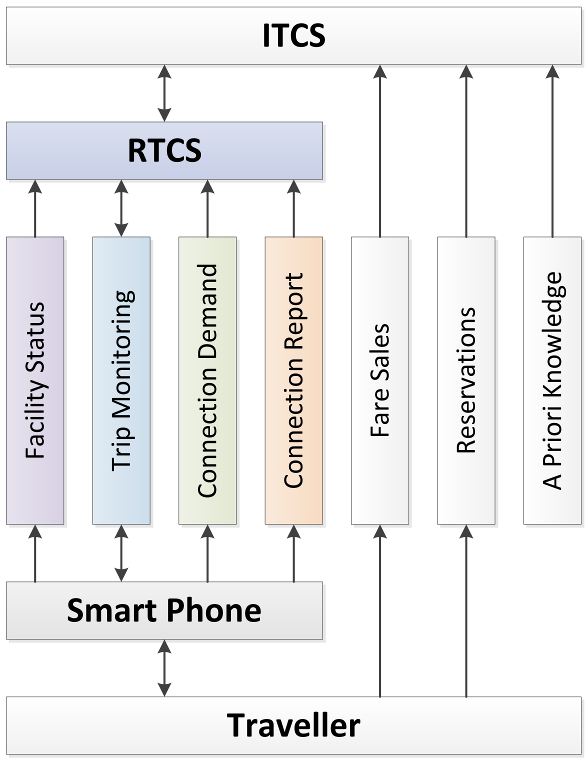

Fig. 2. Information Flow in TRIAS based information exchange systems

the travellers. This interface is mainly intended for travellers who want to be informed about their scheduled travel and the connections in between but it can be also used to inform the transportation company about the number and the route of their traveller flows.

The TRIAS interface consists of a modular set of services where each service has a well described interface. These services can be consumed either directly by the travellers mobile clients or by immediate systems which could provide additional services for its users.

The TRIAS interface fulfils all requirements to integrate travellers in operational decisions. This interface describes services to inform the dispatcher about the travellers exchange wishes and damages in operating transportation vehicles. Furthermore it allows informing the traveller about delays or cancellations. Namely, defined services which permit customer feedback are ConnectionDemand, ConnectionReport, FacilityStatusReport and TripMonitoring. A complete overview of all services can be found in [18]. The most relevant services for collecting customer feedback are shown in Figure 2.

B. Services

1) ConnectionDemand: This service is used by the traveller to request a future connection at a certain interchange point. To do so, each traveller's (handheld) terminal sends a message for each interchange on a route to be taken. With help of this service, better estimations of the passenger flow could be given to the dispatcher.

2) FacilityStatusReport: Using this service, the travellers could give feedback to the transportation company about the state of their facilities. This service is useful to collect e.g. damage reports given by passengers in a structured way. Having such a service, damages or defects could be reported in a standardized and structured way which could reduce the response times to fix the issues.

3) TripMonitoring: By subscribing to notifications related to their trip, the travellers could be informed about delays or interruptions as soon as possible. Furthermore, the transportation company could use these subscriptions to estimate the number of travellers on arbitrary routes. Similar to the connection demand service, this information could be used to estimate the passenger flow.

4) ConnectionReport: By using the Connection Report service, the passengers could report whether a (historical) interchange was successful or not. This information is worthwhile for the transportation company to perform offline reports about frequently breaking interchanges.

C. Usage of Customer Feedback

With feedback from customers, specific data about the usage of public transport can be collected. This data can be used to improve or create models about traffic demands or cost models to evaluate dispatching actions.

1) Traffic Models: To improve dispatching quality, the dispatcher requires information about the number of travellers and their travel destinations including an interchange behaviour. A mean to obtain this information is the creation of traffic models. Especially in local transport, source data to create and refine these models is rare. The TripMonitoring service and the connections services can be used to create and improve models. Based on the models the dispatching quality can be improved. Possibilities to use these services for traffic models have also been addressed in [19, chapter 5].

2) Cost Models: With the help of data collected with the ConnectionDemand service a transportation company is able to compute possible cost of a connection break. A first input is the amount of connection wishes, thus interchangers. The usage of such numbers is not new [2], nevertheless the way of retrieving it is.

Having reliable information about interchangers a transportation company can put a value on a connection. A simple way would be using the amount of interchangers. However, using this approach, connections within highly frequented networks such as commuter transportation systems, where a traveller can easily catch the next vehicle, would be of equal value to those on far distant trains, where a broken connection can lead to several hours of delay. That is why a more complex evaluation method is needed.

The travel chain of interchangers in not generally known. Nevertheless, also the travel chain can be transmitted by the customer using the TripMonitoring service. Two cases can be distinguished: a) The travel chain is known and b) The travel chain is unknown. In the first case, for each interchanger an alternative route can be calculated [20] and the difference of waiting Δt_w and travel times Δt_t can be detected. In the second case an equivalent train has to be found for which we assume the interchange will wait Δt_w. The perception of waiting time is not linear [2], [21].

Be n the number of interchangers for a specific connection. The variable $k_i := 0, 1$ defines if the travel chain is known for customer i. The customer related cost value c to the connection can then be calculated as follows:

$$c = \sum_{i=0}^{n} k_i \cdot (\Delta t_{wi} + \Delta t_{ti}) + (n - \sum_{i=0}^{n} k_i) \cdot \Delta t_w$$

A transportation company can now compute the effect of a broken connection by summing up the specific and general waiting times. Generally all approaches to connection dispatching need information about the interchangers. The collected data can thus be the basis for more sophisticated models as for example presented in [22].

In addition to that European laws grant a reimbursement for the traveller if the total travel time is prolonged [23]. From delay of 60 minutes 25 % of the ticket price can be reimbursed, from 120 minutes 50 %. Be p_a the average price of a ticket for travellers with unknown tickets. Be f the factor for calculating the potential reimbursement cost.

$$f = \begin{cases} 0,\text{, if } \Delta t_w + \Delta t_t < 60min \\ 0.25, \text{ if } 60min \leq \Delta t_w + \Delta t_t < 120min \\ 0.5, \text{ if } \Delta t_w + \Delta t_t \geq 120min \end{cases}$$

For the travellers whose tickets and their prices p_i are known, the cost can be individually calculated, and a sum for the unknown ticket prices can be added estimating the delay by again using an equivalent train as reference.

$$d = \sum_{i=0}^{n} k_i \cdot f_i \cdot p_i + (n - \sum_{i=0}^{n} k_i) \cdot f \cdot p_a$$

3) Quality Measurement of Dispatching Actions: A very new approach is to ask the customer for a feedback about a dispatching action that has already been taken. Of course, the feedback has no effect for the dispatching action already taken, but can be used for the dispatcher to reflect his action and measure the quality. Also, the dispatcher can learn about the effectiveness of his actions and improve them in the future.

With the help of the service ConnectionReport it is possible to give feedback about whether a (dispatched) interchange could be reached and used by a traveller. The traveller reports if he reached a connection or not. The connection can be planned or unplanned. It is up to the transportation company to draw conclusions about the information delivered by the traveller.

A ratio r can be determined of the amount of travellers s who reach their connection and those who do not (f) (for the same connection):

$$r = \frac{f}{s}$$

A good value of r has to be evaluated in a real environment taking into account that more travellers might report a failed connection out of anger than those who reach it as negative feedback is more likely formulated [12].

Also the feedback in this context can be used to improve the planning of connections (section III-A) as it delivers information about the connection usage and success. Waiting times can be adjusted unused connections can be withdrawn and even new (unplanned) connections can be discovered if people use it frequently.

4) Dispatching Fault Repair Using Customer Feedback: The feedback of customers can also be used to improve the dispatching process. Using the service FacilityStatusReport the customer can give feedback about problems and damages of vehicles or infrastructure.

With the help of customers damages and malfunctions can be detected faster than by staff only. Approaches of customer integration exist in a way, that for example numbers are provided on ticket machines which can be called in case of malfunction. Using standardized interfaces improves the quality of the customer feedback and also reduces the barrier of reporting problems, assuming proper and easy to use applications exist.

Damages that affect more travellers will be reported more often than those that have little affect. On the amount of feedback messages for a specific component or vehicle the dispatcher can prioritize the repair of affected parts. Again, the feedback alone is not a sufficient value to prioritize. The criticality of a damage also has to be taken into consideration. This can be done by assigning factors a_d to a damage type. A prioritization for a maintenance can be easily calculated as follows where i is the amount of identical reports:

$$p = i \cdot a_d$$

VI. Discussion

The idea of interacting electronically with the customer is not new. However, existing approaches are mainly focused on social media, e.g. [6]. Also, the focus is less on improving the operations than on the satisfaction the customer and offer an additional communication channel for him. Partially, information relevant for the operation is posted through social media channels. The information is generally unstructured, though. Furthermore the communication partner is generally not the dispatcher but a special social media team which is specialized in interacting with the customer through social media channels. Thus, the information exchanged cannot be automatically processed and will probably also not reach the dispatcher at all. This makes it impossible to use here gathered information to improve dispatching processes.

The new standard TRIAS in contrast offers possibilities to transfer information in a structured way such that IT systems of transportation companies are able to process the information automatized and present it to the dispatcher in a way it is useful for the dispatching decision.

In contrast to proprietary solutions, the TRIAS standard is universally usable. The usage of proprietary approaches, even structured data collection, will limit the application and usage of data to the distributor of the proprietary solution. Especially in intercompany or intermodal travels the usage of proprietary data is not possible beyond company borders. TRIAS prevents isolated applications that restrict the collected data to be used beyond the companies' borders. It enables the usage of customer feedback about interchange wishes or travel plans throughout the complete public transportation system.

To use this new technique, appropriate travel applications for mobile devices are needed. These applications support the traveller in sending relevant information towards the transportation company. Data protection needs to be addressed such that the user can define which data may be provided under which circumstances. The application handles the information exchange transparent such that user interacts in a convenient way and is not overwhelmed with too many functions. This requires an implicitly message exchange according to the use cases of travellers.

It can be assumed that, after releasing the standard, a certain time is needed for the market penetration such that a sufficient number of devices (applications) support the described interfaces and delivers valuable information for traffic operations. Nevertheless, as soon as the amount of users exceeds a certain threshold, the information transmitted by the customer using standardized interfaces will be of high value for operations and can contribute to improve planning and dispatching processes.

VII. Conclusion

The traveller is the target group of public transport. Providing a convenient travel and caring for their satisfaction should be one of the main objectives of a transportation company. If transportation companies don't focus on satisfying their customers, there will not only be a shortage of customers but also a higher burden for our society and the environment caused by individual motor traffic. By including the travellers into operational decisions with help of modern ICT equipment, it becomes possible to increase the customer satisfaction with little running costs. Therefore, our presented solution shows general concepts for transportation companies to focus on their main user group and integrate their needs into the operational processes.

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