Application of collaborative information exchange in urban public transport: the Seamless Mobility solution

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Abstract

Contemporary urban transportation networks are facing challenges to address the growing needs of mobility, all the while improving their economic gains and environmental sustainability. Several studies demonstrate that competitive alternatives to individual private transport are able to address these challenges, such as public transportation services. Thus, the need for optimising their operational efficiency and offer user-centric service delivery arises, with a range of challenges related to the inherent complexity of urban transportation networks as well as the range of dynamic elements involved in such systems.

An innovative approach to this problem leverages personal mobile devices in combination with collaborative exchange of information. In this study a system was developed to combine information provided by travellers with data from public transport operators. The result is a rich model of the transportation network that enables the distribution of information in a personalized way and in real-time: the Seamless Mobility solution. Large-scale and expensive infrastructures, such as existing ticketing systems, constitute a threat to such flexibility and traveller access to services. As a result, a distributed architecture was targeted with the goal of integrating personal mobile devices in the infrastructure, with benefits for travellers and transport operators.

The proposed solution integrates a broad scope of challenges, including application of secure mobile payments methods, data aggregation from different components and distribution based on relevance techniques. With the implementation of this solution we expect to positively impact the way travellers and transport operators interact, and contribute towards mobility services that are more agile and adequate, taking into account that mobility patterns vary from person to person, seasonally, and even throughout a day.

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1. Introduction

In the last decades, serious mobility problems have been recorded daily, related to efficiency and social equity, with high economic and environmental impact in urban areas (e.g. EEA, 2013). However, several approaches have tried to address these issues with little success.

Recently, collaborative exchange concepts have been used to solve inefficiency problems of transportation, especially in urban areas. Thomphoson and Hassal (2012) and Gonzalez-Feliu and Salanova (2012) have applied collaborative concepts to urban freight transportation. Companies such as Nestlé and United Biscuits have already developed collaborative relationships to implement some of those ideas (IGD, 2009). The same trend occurs in other transportation sectors. Cruickshank et al. (2013) have analysed collaborative school travel. The primary focus of these studies has been in the optimisation of routes as well as collaboration for mutual benefit, for example sharing resources to distribute goods in a more efficient way (Thomphoson and Hassal, 2012).

In public transport, however, collaborative information exchange can be applied in a different scope, involving not only operators but also travellers. The widespread adoption of mobile devices combined with the growing popularity of social media provides a context of opportunity both for communication and collaboration in the public transport domain. Being aware of this potential, several public transport providers have been actively present in social networks, such as Twitter and Facebook (Austin 2010). Research has shown that the perceived benefits of this participation are the ability to provide customers with real-time travel updates and service information, the potential for engagement with the general public, the entertainment of passengers, and the ability to praise and recruit human resources (Bregman, 2012). In addition to the official communities that are managed by public transport providers, there are numerous independent user groups for sharing information, typically about a specific provider or route. However, the most popular social networking platforms are not designed to address the specificities of public transport. In fact, in those social networks the information that is shared cannot be filtered or organized straightforwardly in spatial or temporal terms. Therefore, passengers need to find and subscribe relevant groups and feeds, and all subscribers are bound to receive the same information despite having unique travel profiles.

In order to analyse the knowledge of collaborative travel, Dickinson et al. (2015) developed a set of apps and then synthesized some fundamental challenges to better designing a collaborative travel app. According to these authors, transport practitioners, policy makers and app developers need to better understand the challenges associated with attracting users, the use of incentives and the types of communities most appropriate to implement collaborative travel concepts using such approaches. Additionally, to investigate how the users’ sense of time pressure and the issues around reciprocal information exchange can impact long-term success and wider adoption. Thus, this project has two main goals: the integration of travelling-related services; and providing relevant information for the users of public transport. Firstly, the integration of a set of travelling-related services in a unified package, including ticket payment, journey planning and information access aims at incentivising adoption and increase public transport usage, through simplified access via personal mobile devices. The second aspect of this work focuses on providing relevant information to users and aims at leveraging travellers as both information producers and consumers: prosumers. As a result, information is readily available and may be targeted on an individual basis according to the mobility profile characteristics of a traveller and the occurring journey.

The integration of information exchange features is based on previous research (e.g. Journata) in addition to existing applications (e.g. Moovit, Waze). Furthermore, these ideas were explored in coordination with industry partners, including transport operators and infrastructure providers, aiming at incentivising user participation and benefit all the parties involved. The work is organized as follows. Section 2 presents a description of the Seamless Mobility platform while in Section 3 an analysis of the application of the main concepts of collaborative information exchange are fully presented. The experimental field trial based on the findings is then described in Section 4. Finally, Section 5 presents some final remarks of the paper.
2. The Seamless Mobility platform

The Seamless Mobility platform is the implementation of an innovative integrated solution that takes advantage of the existence of large-scale personal mobile devices connected to ubiquitous networks communication. The design and development of the platform in such a pervasive environment follows previous research (Ferreira, 2014; Amador, 2014; Costa, 2015b) and it implements a mobile application that was designed, implemented and tested in a real urban public transport environment in Porto, Portugal.

Fig. 1. Main components of the Seamless Mobility project.

The platform integrates three main components: (i) route planner, (ii) mobile payments, and (iii) information networks. Figure 1 displays an overview of the system functionalities. The route planner combines information from published schedules with real-time information to identify the nearest stops, the next departures in a stop, or the best route for a scheduled trip. Mobile payments comprise the purchasing and validation of travel tickets, supported by a centralized management platform. This real-time centralized platform integrates the different components and enables the application of interdependent advanced commercial policies capable of attracting and retaining customers, as well as improving the overall efficiency of the system by reducing operational and maintenance costs. In addition, the user-centric mobile application enables ubiquitous access to transportation services without requiring pre-planning, including journey tariffs and route discovery. This integrated approach allows the identification of unique travel patterns in real-time. Thus, dynamic and circumstantial information networks are generated based on spatiotemporal travel patterns. The combination of such individual travel patterns with readily available information enables the delivery of relevant services, which in turn, support individual traveling decisions during and even before a journey starts. The information sources, however, are not limited to transport operators and authorities, but rely heavily on traveller participation. As a result, incentive mechanisms are considered to encourage active participation of users, combined with validation methods to safeguard information reliability (e.g. crowding levels, skilfulness of drivers).
In the development of the application, a strong focus was given to user experience and interaction. This was one of the major challenges of the mobile application, particularly the usability regarding the main stages of the journey: offer information (stops, schedules, fares), availability (next departures in real-time), trip planning (suggested routes and modes of transport), ticketing (acquisition and consumption of services) and trip monitoring (destination, transfers). The performance of the communication systems as a whole is also crucial. Thus, the perceived time response experienced by the passenger, between service request and the expected result, is optimised for a more fruitful interaction.

With the implementation of systems based on mobile payments, ticket inspection becomes an integral component, particularly related with the online verification of the authenticity of the transactions and their validity. Thus, the development of this solution focuses on addressing this concerns, not only be developing a technical solution but also involving the different actors, for example, enabling bus drivers to quickly check passenger fares and conductors to carry out fare inspections during a journey. In order to develop a flexible and robust system architecture, several important requirements were defined, namely: scalability, interoperability, flexibility, and confidentiality.

The capacity to process transactions will evolve from a start-up stage, with an expected load of a few hundreds of transactions per month, to several million in a more mature stage. Moreover, the compatibility between different mobile systems was also taken into account. Dynamic data models (e.g. based on XML metadata) were used to develop a robust system able to adapt and implement new business rules. Due to sensitive travelling and personal information present in the system, additional rules were also defined to protect individual data records.

With the goal of providing an overall vision of the business to operators, the solution coexists with other traditional systems through extension points. Nevertheless, taken into account the global ambition of the project, the design and basic architecture of the solution incorporates several configurable features of the platform, such as language, currency, laws, tax provisions, products (mobility services), communications, and payment methods. More details about the Seamless Mobility solution can be found elsewhere (Costa et al. 2015a).

3. Application of collaborative information exchange in the Seamless Mobility project

The collaborative component of Seamless Mobility is based on a social networking platform that enables collaborative exchanges of information between travellers. It leverages both explicit and implicit data generated by travellers while using the mobile application on their personal devices, which is able to record travel patterns and reveal unique travelling profiles. Analysis of these travel patterns allows for the dynamic creation of circumstantial social networks in real-time to aggregate passengers whose travel patterns are geographically and temporally relevant. The primary goal is to significantly increase the relevance of information received by each traveller and assist their travel choices in real-time. Moreover, this exchange of information aims to facilitate the provision of feedback from passengers to the public transport provider in a timely and structured way. The social component is based on previous work describing the concept of a social networking service for public transport (Nunes et al. 2011) that resulted in the implementation and testing of an initial prototype (Nunes et al. 2013).

A public transport traveller often has information that may be of interest for other travellers as well as for public transport providers. That includes information about a particular vehicle (such as crowding levels, temperature, and noise); incidents or other events that affect a specific service; or even about the skilfulness and courtesy of public transport drivers and other staff. Similarly, public transport providers may have operational information that is difficult to distribute in real-time, and which only affects a set of travellers. Examples include service delays, incidents and other faults, and occasional changes to the schedules or travel destinations.

The introduction of collaborative information exchange in the context of urban public transport takes shape as a social component in the Seamless Mobility project. This component aims at collecting different types of information in a structured way, as previously described. Subsequently, the generation of circumstantial social networks enables the identification of clusters of traveller who are potential targets for information, being delivered via own personal mobile devices. In other words, each user of the Seamless Mobility application may receive information personalised according to their unique travel profile in order to ease their journeys and improve travel experience. This approach overcomes the main limitation of typical social networks, by replacing direct connections between travellers with temporary connections based on journey routes. Moreover, the system has the ability to
learn individual travel patterns over time, to ensure that a user starts receiving relevant information to support travel choices prior to the beginning of a journey (Costa, 2015c).

This social component includes both incentive and validation mechanisms to encourage active participation from users and safeguard the reliability of information. The incentive mechanisms considered for Seamless Mobility consist of a scoring feature, closely related to other gamification techniques (Deterding et al, 2011). Similarly, the validation mechanism consists of a rating feature (e.g., upvoting and downvoting) that gives travellers the possibility to evaluate information provided by others. These interactions are rewarded with points, which are accumulated in a personal profile. Information perceived by others to be of highly useful and correct is worth additional points. While at a first stage the scoring feature is expected to work as an incentive for participation in itself, by providing a gaming character to the application, there is room to further extend and integrate with other components of the platform. For example, allowing travellers to trade-in points for benefits, such as ticket discounts and even vouchers with external partners.

3.1. Mobile application

The Seamless Mobility project takes shape as a mobile application for travellers to use on their personal mobile devices. The features available include journey planning, mobile payments and social features (Costa, 2015a). The collaborative exchange of information is primarily related to the social features, as they facilitate and incentivise sharing of information and allow communication between passengers. However, these features are integral to Seamless Mobility and, as such, they are integral to different components. For example, planning a journey includes a brief overview of social feedback in addition to routes and departures; and ticket validation acts as a signpost for providing contextual timely information. Some of the features implemented in the mobile application are shown in the prototype screens in Figure 2.

Fig. 2. Seamless Mobility prototype screens: (a) view journey info; (b) submit rating; (c) planner integration.
Figure 2 shows some of the most relevant features present in the prototype of the mobile application. These features are related to the collaborative exchange of information and focus on the integration with different components of the application. As a result, the features available are not limited to sharing and accessing public transport information within a social module, but they spread to different contexts of interaction and usage scenarios, such as comparing planned routes or checking in to a journey. Figure 2 (a) shows an overview of the social information related to the current journey. In this screen, travellers are provided with aggregated information that is relevant for them. As an example, this allows travellers to dynamically adapt their route to reach a final destination according to the current state of the transportation network, including disruptions and personal preferences. One of the main challenges in presenting this type of information is the aggregation of subjective feedback. Aspects of the same journey affect travellers differently, raising difficulties in reaching a unified solution. Thus, further research is needed in order to assess these effects as well as to investigate the delivery of such personal and directed information.

The feedback submission in Figure 2 (b) partially addresses the problems related to information aggregation. This screen allows passengers to share information within pre-defined categories, with the main benefits of facilitating and speeding up input, and limiting the complexity with lesser number of items. This solution resulted not only from the need to simplify feedback but also from the concerns raised by the industry partners. In fact, the parties involved see these new features both as an opportunity for close interaction with passengers, and simultaneously as a threat to their own service and how it is perceived. Thus, written comments require more advanced presentation strategies in addition to an added layer of complexity for managing comments and suggestions (e.g. respond to recommendations or reporting abuse).

Finally, the journey-planning screen in Figure 2 (c) is augmented with information shared by other travellers. Each of the different alternatives is integrated with social feedback obtained from other travellers currently in the network, which allows for a more subjective assessment of that particular route. Journey planning becomes more informative and targets mobility needs as well as providing for an enhanced experience. The amount of information, however, is limited to a sub-set of the categories available in the mobile application, relevant for each individual traveller.

3.2. Usage scenarios

While in a first stage, only travellers are able to share information in the form of limited comments and reports, there is value in expanding the information network towards more flexible feedback as well as integrating other collaborative information sources, such as public transport staff and other citizens. At this point, however, due to the experimental nature of the collaborative information exchange open to the wide public, some partners raised concerns regarding abuse and lack of preventive mechanisms associated with an institutional product. As a result, the feedback was limited to a sub-set of use cases. Table 1 describes some of the scenarios where collaborative information can help different actors of a public urban network.
Table 1. Use cases associated with Seamless Mobility.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Shared information</th>
<th>Passive actors</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic accident</td>
<td>Negative traveller feedback identifying the location of a traffic accident.</td>
<td>Travellers affected, i.e. who are currently or planning a journey through the affected route.</td>
<td>Decrease the congestion and the environmental impacts. Allow travellers to plan their journeys accordingly, either by changing their current commute or re-plan in advance.</td>
</tr>
<tr>
<td>Scenic route</td>
<td>Positive reports about the scenery of a route.</td>
<td>Occasional travellers, e.g. tourists.</td>
<td>Generate a route profile for targeted service delivery, such as scenic routes that are not necessarily the fastest or cheapest ones.</td>
</tr>
<tr>
<td>Theft</td>
<td>Ratings by theft targets or witnesses in the network.</td>
<td>Potential travellers, private security of transport providers and local authorities.</td>
<td>Decrease the levels of crime through raising awareness of travellers and aiding authorities in pursuing criminal activities.</td>
</tr>
<tr>
<td>Helpful driver</td>
<td>Positive reports about an identifiable staff member.</td>
<td>All potential travellers.</td>
<td>Appraisal of staff members and reinforcement of confidence in the system.</td>
</tr>
<tr>
<td>Vehicle cleanliness</td>
<td>Positive comments regarding public transport staff.</td>
<td>Current and potential travellers.</td>
<td>Contribution to improve the users satisfaction about specific vehicles and trending routes or time frames.</td>
</tr>
<tr>
<td>Low occupancy</td>
<td>Positive reports about the number of seats available in the vehicle.</td>
<td>Potential travellers and transport providers.</td>
<td>May lead to an increase in the usage efficiency of a vehicle or line.</td>
</tr>
<tr>
<td>Crowded vehicle</td>
<td>Negative report about the environment conditions in a particular vehicle.</td>
<td>Potential travellers and local authorities.</td>
<td>Leveraging negative reports about the specific environment in a vehicle to manage traveller expectations and appropriate coping mechanisms.</td>
</tr>
</tbody>
</table>

3.3. Guiding principles

The development of Seamless Mobility was based on a set of guidelines, informed from previous work as well as own research, which incorporate a set of collaborative information exchange concepts in the project. Thus, the guiding principles behind the implementation of the mobile application are divided into Component Integration, User Experience and Security & Privacy:

- **Component Integration** refers primarily to the need for different systems to systemically integrate in order to provide an innovative service (Costa, 2015a). Specifically for Seamless Mobility, the journey planning, mobile payments and information sharing components are orchestrated to provide a value added service that would otherwise not be possible;

- **User Experience** refers to the interaction of the application with the traveller, and how it may affect their participation. Seamless Mobility depends upon user participation for timely contextual information. Previous work, such as the Journata (Amador, 2014) and the Superhub projects (Jylhä, 2013), were particularly inspiring for progressing towards facilitating access to information and incentivizing participation;

- **Security & Privacy** are significant aspects of the system. Security not only ensures personal information remains private but also protects the system from unauthorized or malicious interference. On the other hand, maintaining reasonable levels of privacy enhances travellers’ trust on the system and prevents undesired access without negatively impact functionality (Cavoukian, 2009).

Table 2 presents a summary of the main guiding principles and characteristics implemented in the Seamless Mobility application.
Table 2. Guiding principles and main characteristics of the application (greyed cells identify primary relationships).

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Component Integration</th>
<th>User Experience</th>
<th>Security &amp; Privacy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relevant Social Networks</td>
<td>Social network based on relevance between relies on access to other systems for analysing past and current journeys intentions.</td>
<td>The network is implicit, and protected from access.</td>
<td>Though connections are automatically generated, profiles should remain private.</td>
</tr>
<tr>
<td>Anticipate Information Consumption</td>
<td>Historic data combined from different components allows for the learning of travelling patterns and predict service delivery.</td>
<td>Deliver notifications and other proactive information only when strictly necessary.</td>
<td>Allow users to limit the functionality within their personal preferences.</td>
</tr>
<tr>
<td>Integrate Systemically</td>
<td>Achieving the innovative features presented requires a deep and systemic orchestration between different systems and partners.</td>
<td>Present a seamless solution, where the different components are presented as a whole.</td>
<td>Maintain personal and sensitive data segregated within each component of the system.</td>
</tr>
<tr>
<td>Incentivise Participation</td>
<td>Allow incentives to extend to other components of the platform.</td>
<td>Information exchange relies heavily on traveller provided information, who should have a direct benefit from the platform.</td>
<td>Secure against tampering with the incentive mechanism, or any other components.</td>
</tr>
<tr>
<td>Optimise Information Exchange</td>
<td>Leverage contextual information to support feedback input.</td>
<td>In a dynamic environment providing feedback should be as easy and fast as possible, as any barriers will discourage input.</td>
<td>Publish user feedback without establishing a connection with an identifiable source.</td>
</tr>
<tr>
<td>Prioritise Quality Sources</td>
<td>Take advantage of different information sources to support travellers.</td>
<td>Validate quality sources and prioritise them, so as to increase the value to travellers and filter irrelevant or unwanted entries.</td>
<td>Perform validation anonymously and protected.</td>
</tr>
<tr>
<td>Secure Infrastructures</td>
<td>Limit data storage to what’s necessary for each component.</td>
<td>Provide access mechanisms that are contextually appropriate.</td>
<td>It is absolutely essential to maintain sensitive data, including personal and payment details, from unauthorised access.</td>
</tr>
<tr>
<td>User Privacy</td>
<td>Enable each component to access profile details that are absolutely necessary.</td>
<td>Provide a simple interface for managing personal data and privacy settings.</td>
<td>Travellers profiles and interactions in the system should be private, to avoid making location and journeys publicly available.</td>
</tr>
</tbody>
</table>

4. Experimental field trial: OneRide

The OneRide mobile application brings to fruition some of the main ideas behind Seamless Mobility to a real-world environment. This application combines research work presented in this paper in cooperation with industry partners, to investigate and explore the envisioned mobility platform with everyday travellers. Figure 3 demonstrates some of the screens that allow users to plan their journeys, such as in Figure 3 (a), as well as exchange relevant trip information, in Figure 3 (b) and (c).

OneRide implements some of the functionality described and may be installed directly into travellers’ mobile devices, to be used during the experimental field trial. In addition, a social network community was created on Facebook to provide support during the trial. The goal of this community is twofold: on the one hand, provide support throughout the usage of the application, including questions and other issues that may arise; on the other hand, as a way to gather feedback and relevant information regarding the field trial focused on the OneRide application as well as the overall conceptual Seamless Mobility platform.
5. Final remarks

The Seamless Mobility project aims at designing and developing an integrated approach to mobility, focused on urban public transport. The resulting platform leverages pervasive environments to integrate journey planning, mobile payments and ticketing, as well as collaborative information exchange, with benefits for both travellers and transport providers. On one hand, travellers have direct access to mobility services and up-to-date information with the potential to improve their travelling experience. On the other hand, the less demanding infrastructure allows transport providers to improve operational efficiency and service flexibility.

The Seamless Mobility application is an exploration of different features and scenarios that are relevant to urban mobility. The set of features and use cases were inspired from previous work to target travellers’ needs inasmuch as industry partners’ expectations. As a result, a mobile application was develop to implement the combination of innovative research work, as well as business relevant functionality, for the next generation of public transport.

The work presented in this paper describes the main results of Seamless Mobility, including a set of guiding principles in three main areas: Component Integration, User Experience and Security & Privacy. These principles provide guidance for the design, development and implementation of collaborative information exchange in the context of urban mobility. Finally, the OneRide mobile application brings to fruition some of the most relevant and innovative aspects of the Seamless Mobility platform to a real-world environment.

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