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Open service innovation ecosystem for public transportation

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Abstract

Public transportation is an essential part of the urban, digital and carbon neutral future of Europe, and is thus undergoing a major transformation that needs to be supported and boosted by all stakeholders in the society. To support and facilitate open innovation in the area, we have developed an open application ecosystem for creating and deploying mobile services and testing them with real end-users. In this article, we describe the ecosystem, the motives behind it and the actions we have taken with students in software engineering and design to test and improve it. We also propose directions for future actions and research.

Keywords: OPEN INNOVATION, MOBILE SERVICES, PUBLIC TRANSPORTATION

Introduction

In European Union, public transportation is undergoing a major transformation due to digitalization, urbanization, and actions taken against climate change. In inland passenger transport, the use of passenger cars still accounts for 83% of all traffic – ranging from 90% in Portugal to 67% in Hungary [1]. To succeed in efficient, inclusive and environmentally friendly urban planning, more people need to choose public transportation over private vehicles [2]. We believe that in addition to more traditional means like vehicle, route and schedule updates, public transportation attractiveness can be increased also by offering passengers new contextual and personalized digital services that address their needs and aspirations that go beyond just transportation.

Within recent years, mobile devices have become the most important channel for digital consumer services [3]. According to Eurostat [4], in EU around 60% of people aged 16 to 74 used internet services through mobile devices outside home or workplace. In Finland, Netherlands, Luxembourg, Sweden, UK and Denmark the share was more than 75%. For example, social media and online searches are now mostly used through mobile devices. In the context of public transportation, mobile services are currently used, e.g., in route planning and ticket purchases, but also other motives apply. According to Julsrud and Denstadli [5], there are more than 150 000 applications in Google Play and Apple Store which directly relate to travelling. In Finland, many of the most popular mobile services

are different route planning or traffic monitoring applications, which are developed iteratively over time with passenger feedback by private individuals or groups. For example, the Journey Planner of Helsinki Region Transport, which now has more than 150 000 daily users, was initiated as a student project. Notably, these services utilize open data sources offered by traffic contractors or public institutions through interaction that can be described as open innovation [6]. In short, open innovation processes utilize external ideas and resources in internal innovation.

While the benefits of open innovation in public services have been receiving extensive support and success stories exist, it is a difficult activity especially in the context of public transportation. This is firstly because the initiatives involve multiple public and private stakeholders, each having their own evolving policies and regulations. Vehicle manufacturers, bus operators, road operators and different public utilities on both state and city levels are examples that can be direct or indirect stakeholders in a single service. Secondly, passengers (i.e., potential service users) are a tremendously versatile group and use contexts are various. Thirdly, since public transportation as a field is in transformation and digital services are still in many respects a new thing, there is a lack of easily usable data and context-bound information on design, best practices and workable business models. To alleviate these difficulties, we have developed an open application ecosystem (OAE) for mobile service development, distribution and testing. We want to know – in the context of public transportation – *how an open application ecosystem should be implemented so it would support open innovation in mobile services in the best way*.

Our OAE offers data, information and tools for iterative mobile service development to any interested developer or innovator. The main goals are to boost open innovation processes in public transportation by linking the makers with the (potential) users in real context already in the early development phase, and by offering unique resources to support development work. At this stage the OAE focuses on busses, but it can be easily expanded to include also other means of transportation. Main features include a downloadable toolkit for application development, exclusive APIs with data from electric busses, set of design guidelines, a distribution channel for testing and deploying the service, and a mechanism for collecting feedback from the users.

Our work is a part of a larger research and development effort called *Living Lab Bus* (LLB) – a co-operation between research organizations and companies [7]. The project aims to enable and support faster development and evaluation of mobility services through a concrete, open test environment in a real public transport context. In practice, real data are collected in electric busses in the capital area of Finland, and these data, possibly in combination with other data sources, can be utilized in the services through different APIs.

In this paper, we first present the current version of the OAE, and then discuss the ideation and development efforts conducted mainly by technology- and design-oriented university students. We conclude by summarizing the lessons learned, and discussing our views on future work.

2. Related work

Open innovation has received a considerable amount of academic and managerial attention since the

idea was first defined by Henry Chesbrough in 2003 [6]. He noted how in the 1980's and 1990's, many of the leading technology businesses had been losing market shares to new companies which were inferior on paper. In his view, this was largely because the leading companies were comfortably stuck in what he called a closed innovation model when it came to R&D. In a closed innovation model, an organization generates, develops and commercializes its own ideas. It was the leading model for gaining competitive advantage for the most part of the 20th century, and did produce numerous remarkable innovations like transistors (by Bell Labs), Kevlar (by DuPont) or the Ethernet (by Xerox), to name a few. The prevailing idea was that in order to profit from research and development (R&D) efforts, the relating activities should be conducted internally. This would give the organization the best chances to protect and control intellectual property (IP) and be the first one in the markets. The new growing companies however used (also) a different approach Chesbrough calls an open innovation model. The open innovation model is initiated by the acknowledgement that most smart people work outside of "our own" organization. Therefore, an external R&D has a great potential to bring significant value, and an organization can also profit from an IP created by others. The focus is more on the business model than it is in the IP or ability to be in the markets before the competitors. Notably, even though open and closed innovations are conceptual opposites they do not exclude each other in R&D work – closed innovation is usually always needed in some extent.

While in business world the acquisition of external resources by e.g. buying promising start-ups and their IP is sometimes also understood as means to practice open innovation, in here we focus on approaches that are per se open for anyone with a relevant set of skills. In practice, these approaches typically include competitions, communities and platforms [8]. **Competitions** have a given timeframe, a topic or a problem statement, and usually a specific set of novel tools or other resources like data. The motive is in gaining novel approaches "fast and cheap". The competitions are often referred as hackathons, even though the word originally refers to programming and many competitions are not focused or limited to software development. Europe's largest yearly hackathon Junction is an example of an open innovation competition. Junction brings together 1500 developers and tens of companies and organizations from different fields for weekend-long innovation sprint with prizes that are up to 20 000 €. **Communities** are largely unmanaged groups that work for a common cause. These groups have had a significant impact especially in software development. A notorious Finnish example is the Linux community, which developed the Linux kernel initiated by Linus Torvalds. Once the project had stabilized by version 2.2 in 2000, more than 4200 developers had worked in it since 1995 [9]. **Platforms** are hubs used for information sharing and creation. Typically, platforms offer accesses to internally developed or generated resources in a machine-readable format through application programming interfaces (APIs). Living Labs, which involve also potential end-users in real use environment, are considered as one specific type of open innovation platform [10].

Open innovation is now applied in virtually every field of business, and with all the mentioned approaches which often intertwine. The potential benefits are widely recognized. In public transportation, open innovation in principle means giving design power and resources also to actors

that are not part of the internal service design network, i.e., public officials or service providers. In the research field, observations, analysis and suggestions on how open innovation should and could be facilitated in have been made for example by [9], [11].

Lee and Cole [9] studied the community approach and contrasted it with closed innovation settings, using Linux development community as the target case. They describe the open community based development as "evolutionary process of learning driven by criticism", i.e. feedback: developers learned from their peers how to improve their next submission. According to authors, this kind of like behaviour was largely absent in closed innovation settings. In those, innovation often only develops further if it is driven and managed by somebody – an "innovation champion" as Glynn [14] puts it [15]. The Linux community might be an extreme example of open innovation in terms of scale and impact, but enabling and nurturing peer interaction is essential in all community-based innovation efforts.

Considering platform-related approaches, Albano and Reinhard [11] have studied the facilitation and motivation of open government data on the basis of e.g. [16], and their own empirical work in Brazil. For the public stakeholders, increased transparency between them and society was seen as the primary motivator, while possible economic benefits did not get much attention. This might be affected by the novelty of the activity and the low capabilities of society to use the information. Technical factors such as the format, quality and usability of information were seen as the most serious inhibitors, followed by lack clarity in legislation relating to e.g. privacy issues. In addition, lack of facilitative activity and support for the heterogeneous user group was considered as a major barrier.

To conclude, open innovation bears a great promise but is difficult to orchestrate especially in areas where there are multiple stakeholders – like in public transportation. Still, this does not hinder the value of approaches like Living Labs – on the contrary. The socioeconomic issues faced in building and utilizing them are very likely the same ones that are needed to overcome anyway for the developed innovations to succeed.

3. Open Application Ecosystem

Based on the presented rationale, we chose an iterative development approach to the implementation of our open application ecosystem (OAE). Next, we will present the current status and the key parts of it. The main actors in the OAE are the developers who create the mobile services and the end-users who use and evaluate the services.

3.1. Developer portal

The LLB Developer portal [18] is the heart of, and the entry point to, the application ecosystem from developers' point of view. It provides the tools and guidelines through which the developers can create, deploy and manage their applications, and collect valuable feedback from the end-users. Using the Developer portal, as well as all other parts of the application ecosystem, is free of charge, but requires logging in, either with a created profile or with an existing Google or Facebook account. The login/sign-up page and the entry page of the Developer portal can be seen in Fig. 1.

To start the development work, one should download an LLB-dedicated Development kit through the

Developer portal. It is a GitHub repository [19] with means and documentation for creating applications compatible with the LLB application ecosystem. The Developer kit provides, e.g., a simulated mobile experience in the browser so that the developer can check how his/her application behaves in different phone browsers. Also, events such as location events, notification events as well as context based events can be simulated, and Development kit uses "live-reload" which enhances faster development. In the GitHub page, there are also a few Angular-based example applications available. However, applications can be done in a library/framework agnostic way, and new applications can be created using also jQuery or AngularJS, for example. Graphical guidelines and inspirational material on designing the user interface itself are also available in the Developer portal.

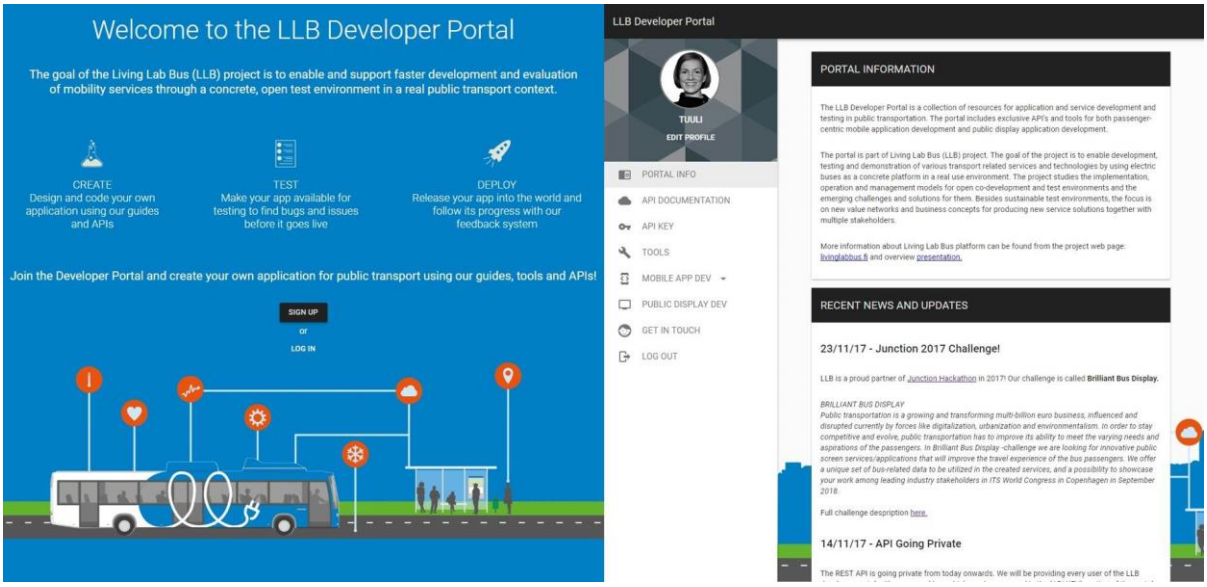

Figure 1 - The login/sign-up page (left) and the entry page (right) of the LLB Developer portal.

As the core idea of the whole project is to utilize real, diverse data collected from actual busses, these data can be accessed through the Developer portal. For example, the LLB REST API is currently managed on the Tyk Platform [20], but to access it, one gets an API key and instructions from the Developer portal to actually use the data within his/her service. The real-time REST API offers a snapshot of the current data available from each bus every second. Other APIs are also available, and more importantly, additional data sources will be made available as the project proceeds. Considering the management side, the API key is user-dependent, and thus, enables tracking and controlling the data usage.

When a developer feels like he/she is ready to share the service it can be uploaded to the Own collection [21], which is a mobile user interface for end-users (see next sub-section for details). When uploading an application, there are two options: The developer can publish it for testing and the application will appear only in "testing mode" in the Own collection, or submit it for approval after which we as the administrators will check it and publish it as an actual service as part of the Own collection application listing. Also, the developer needs to specify which permissions (location, notification and context) his/her service requires from the end-user's device. The applications are uploaded to the system as zip files. After uploading, the application can be updated, managed and

deleted through the Developer portal. One can also set up feedback collection as well as view and save the results (see the sub-section below for details about the feedback).

3.2. Own collection

The LLB Own collection [21] is the end-users' touch point to the application ecosystem. It is a web service which enables the users to create their own unique page of applications made by developers. Own collection is mainly designed for personal mobile devices, but can be used with any device having Internet access and a web browser, really. The users can search the list of uploaded applications, and by installing their favourite ones, and deleting the undesired ones, customize the content of the entry page (in addition to a set of featured applications). Each installed application will appear as a tile on the entry page, and become enlarged to full screen when selected. The entry page of the Own collection with an example set of installed applications can be seen in Fig. 2.

Figure 2 - The entry page of the LLB Own collection with a set of installed applications.

Through the speech bubble icon in the top-right corner of the entry page, end-users can provide feedback by filling in questionnaires set up by the administrators. Considering individual applications, the same icon will take the user to the questionnaire set up by the developer of that specific application, or in case no questionnaire items are defined, to a simple star rating.

Own collection does not necessarily require any kind of login from the user, but in order to keep the personalized content, i.e., the installed applications and their order, consistent across devices one needs to sign up for the service, or use a Google or Facebook account to log in. Currently, only a username, an email address and a password are required on the sign-up, but in the future, we will add basic background information questions there. This way, we will be able to investigate end-users' behaviour and experiences based on the different user characteristics without the need to inquire such information more than one time. Users logging in is highly desirable so that their application usage can be tracked, and more importantly, their usage, background information and provided feedback can be linked together. Individual-level information is not important nor interesting here, but based on the information gathered from different sources we may be ultimately able to recognize usage patterns, preferences and needs, e.g., and thus, to provide services for different groups of end-users and improve their traveller experiences.

3.3. Feedback system

One of the key features of our LLB application ecosystem is the feedback functionality. Feedback questionnaires can be set up through the Developer portal either onto the entry page of the Own collection by administrators, or for individual applications by the developers themselves. The feedback set-up in the Developer portal enables the developers to define any number of questionnaire items of their own application by application. The items can be questions or statements, and there are five answering types from which the developer can choose the best one for a specific item: 1) text, i.e., free text entry, 2) single choice, i.e., a single (radio button) choice from the defined options, 3) multiple choice, i.e., any number of (checkbox) choices from the defined options, 4) sentiment, i.e., a single choice of the given three smiley faces (sad, neutral or happy), and 5) rating, i.e., a rating with 1-5 stars. As mentioned above, if no questionnaire items are defined, the star rating will be shown as default for the user.

Through the feedback system in the Developer portal, the developer can view the application-specific feedback data, and download them as a csv file for further analysis and visualization in Microsoft Excel, or such (see Fig. 3 for an example).

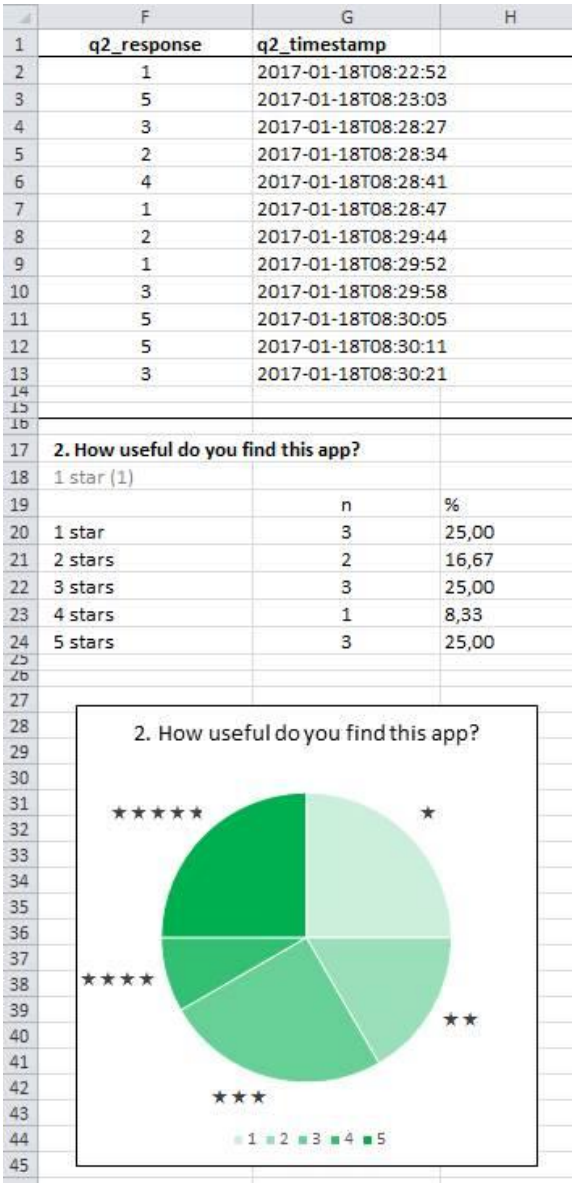

Figure 3 - An example of utilizing the feedback data gathered from the end-users through the LLB feedback system and the LLB Own collection.

4. Involving Students and Developers

We have involved university-level students around the topic on several courses related to human-technology interaction. The depth of the assignments has gradually changed from service concept ideation to actual project works and a student software competition, although for example service ideas have been collected ever since the project started in fall 2015. Also, workshop-like events and a hackathon challenge have been organized to attract service developers. As a result, we have collected several service ideas and several prototype applications have been created. By involving students, e.g., we have been able to utilize the outcomes of these activities and advance the project gradually and better – along with the design and development work by our project team, obviously.

4.1. Service concept ideation

The involvement of students started in fall 2015 with a course focusing on service concept ideation. There, the students were simply asked to design a multimodal service for bus passengers representing one user group of the students' own choice. At the time of the course there was no access to real data from the busses, which could have affected the outcomes' innovativeness, e.g. However, we received 28 designs in total. From these, 15 services are meant to be used in the bus, 5 outside the bus, and 8 services can be used both in and outside the bus. A summary of service features included in the student contributions is represented in Table 1. All in all, the contributions try to solve very practical issues related to bus traveling. In fact, only a few of the proposed services are purely of entertainment nature. A clear majority of the services (22/28) have a route information aspect to them, i.e., bus route info, time schedules, journey planner, and such. This goes well in line with the fact that many (11/28) of the services were targeted for tourists or persons unfamiliar with the city in general.

Table 1 - Service features present in the students' designs.

Service feature category	Present in n/28 designs
Buying tickets, replacing the bus card, mobile paying	5
Route info	22
Forming groups, sociality	2
Gamification	5
What services near the route – location awareness	10
Stopping the bus	3
Notification of a target approaching	5

Providing information on services, city attractions, and events near the route, e.g., are also a part of many of the services. Features to resolve payment-related issues as well as to notify of a bus stop approaching and to stop the bus are included in some of the services. A bit surprisingly, gamification or social features are included only in a few services. In addition, despite public transportation is considered as an ecological means of transport, none of the proposed services promoted this aspect in any way. It should be mentioned, though, that at the time of the course assignment, the local city did not have any electric-based public transportation means, i.e., trams or electric buses, which may have resulted in not thinking about the ecology-related features.

Perhaps boosted by the assignment's requirement of multimodality, the proposed services utilize different technological devices quite widely, as can be seen in Table 2. User's personal device is obviously an unsurprising norm in this smart phone era, but for example gestures are mentioned as an input modality regarding 26 of the services, and thus, also displays along with Microsoft Kinect or other camera-like device are present in almost half of the designs. Further, speech is used as an input modality in 21 and even gaze in 11 of the designs.

The students' multimodal service designs discussed here indicate that there are still very practical issues related to bus traveling as we did not receive more than a few entertainment-related proposals, for example. Many of the basic, practical issues related to route and time schedule information, e.g., could be resolved with quite simple technological solutions. In fact, for many of them there are already for example mobile applications available. However, the existing solutions are often very limited, i.e., they address one or few issues related to traveling at the most, although to provide added value for passengers they would probably need to resolve many issues with one application. On the other hand, if and when the basic, practical issues of bus traveling are solved, added value, and thus, better traveller experience can be gained through services providing entertainment, information beyond the traveling activity itself, and so forth.

Table 2 - Device utilization present in the students' designs.

Utilizes / includes…	**Present in n/28 designs**
User's personal device	18
Displays	17
Functionality within the seats	3
Kinect or similar, camera	15
Speakers	9
Microphone	7

4.2. Prototype application creation

In addition to the course related to service concepts described above, the theme "Applications for Public Transportation" has been a topic for a group of students on two project work courses. This course lasts for one semester, and the group is led by a student taking a course on software project management.

For the first project work group, in fall 2016, the more specific task was to create prototype applications to be shared through the Own collection. It should be noted that, still, no live data from the busses were available at the time of this project work course. The group implemented two applications, the *Upcoming* and the *City info*, both utilizing user's location information. The Upcoming informs the user about nearby events and shows them on a map. Also, an ordered list with distances to specific events is available. The original idea of the group was to tie the events, and the distances, to bus stops, and prompt the user to get off the bus on a correct stop. However, the information on which bus the user is on is not readily available, so the design was simplified to user–event distance instead. The City info, in turn, shows major sites and the user's location on a map. The user is also able to search for other places manually. Planned, but not fully implemented, features

were location-based news and the ability to save places of one's interest as well as categorization possibility for filtering the shown places.

To motivate developers to create services, and thus to enlarge the application selection in the Own collection, especially, we also organized a student software competition in spring 2017. The students from three local universities could participate in teams of 1–3 persons and the task was to design and implement a web application which would benefit bus passengers somehow. Also, it was required that the application would utilize at least one publicly available API, and it would be developed using the LLB Developer Kit as well as submitted through the LLB Developer Portal. The teams with the best applications were given monetary prizes, and the students were also able to have 1–5 ECTS given they returned a proper development report. We received five contributions, and the prize was divided between three teams with the applications *MyBus*, *Kiva Kaupunki* ("Nice city") and *Bussing*. MyBus is a kind of a reminder application. Its user can search for a route, then select a specific bus line, and set an alarm notifying how many minutes there are left until the bus arrives to the specified bus stop. Kiva Kaupunki, in turn, enables people to report both positive and negative comments about something they want to share with other citizens. The comments can vary, e.g., from "a dangerous crossing" to "a beautiful place you must visit". The application utilizes user's location information to map the comments onto the locations that are shown to others. And finally, Bussing shows the bus stops near the user's location. After selecting a bus stop from the given list, the application shows the route to the selected bus stop, the number of upcoming buses within the next half an hour as well as a timeline for reaching the bus stop, a specific bus arriving, and so forth.

As an involvement activity outside the student community, we were participating in organizing a hackathon challenge in Junction 2017 event [22] with other LLB project partners. In our challenge, the Brilliant Bus Display, we were looking for innovative services or applications for public screens, specifically, that would utilize the REST API data to improve the travel experience of bus passengers. We wanted to examine, how the developers would utilize the data and what resources they would use in the developer portal that was primarily designed for mobile development. As the outcome of this three-day event, we received eight contributions in total. Most of these were travel- and route information services. The winner, *Bussig*, is a social game application which integrates personal mobile devices and a public screen on a bus. Through a series of mini-games, the bus passengers can compete against each other, but also stay anonymous if they wish. To ensure no one misses their stop, the application utilizes sensor- and location data to, e.g., stop the game when the bus doors open and tell the players where the bus is currently at.

5. Discussion and Future Work

Innovation in multi-stakeholder environments is difficult, and it needs to be supported and facilitated in diverse ways. For many smaller, and even larger, service providers, OAE and Living Lab -type of approaches are basically the only way to gather valuable, or even essential, socioeconomic and sociotechnical information for the development.

The implementation of an open innovation platform is, and should be, an iterative process [13]. Based on our experiences on involving university students with open innovation approaches, we have decided to focus on the following four aspects in our future work.

First, we are going to improve the supporting information offered for the developers in the LLB Developer Portal. This relates both to instructional material like design guidelines and passenger profiles, and feedback information from the applications they have developed. The instructional material should be as engaging and interactive as possible to attract developers and support them in their design work. The feedback information should – in addition to subjective and direct feedback – include usage metrics (e.g., the number of users, session lengths, screen flows, retention rates) and richer information on the end-users who give the feedback; gender, age, location etc. (with end-users' consent, of course).

Second, we are going to improve the intelligibility and usability of data. While the access to real time data in the portal is a rather straight-forward process, it is evident that mere access and simple documentation is not enough. Since there are dozens of data sources using different measures, understanding the nature of the data, and its potential uses, is a time-consuming process and requires engineering expertise. This is not a desired characteristic as the developers have – and are hoped to have – diverse backgrounds. Thus, we are producing interactive and informative visualizations of the data for faster and broader insights on it.

Third, we are going to add community tools for the developers and investigate how developer experience could, and should, be supported. Developer experience is a concept defined by Fagerholm and Munch [23], and it refers to the "means for capturing how developers think and feel about their activities within their working environments" – to which the OAE belongs. The assumption is that by improving the developer experience, we improve the attractiveness of the OAE and the quality of innovation and services.

Fourth, we are going to expand the OAE to support also other digital service channels, most importantly public screens on busses and other transportation vehicles, and combinations of multiple channels like mobile devices and public screens. Public screen services are a very different design challenge from mobile services, and this is not a trivial matter.

In addition, we are going to launch the OAE, and especially the Own Collection, to a wider public in the near future to attract more developers, and further, through their new applications, attract more end-users.

6. Conclusion

In this paper, we have presented the current status of our open application ecosystem for public transportation, the actions we have taken to develop it and the future directions we are taking to improve it.

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