Interaction in Mobility: The Evaluation of Interactive Systems Used by Travellers in Transportation Contexts

Christophe Kolski[1], Guillaume Uster[2], Jean-Marc Robert[3], Kathia Oliveira[1], and Bertrand David[4]

[1] LAMIH, Univ. Lille Nord de France, Univ.Valenciennes & Hainaut-Cambrésis, Le Mont-Houy, F-59313 Valenciennes Cedex 9, France
{firstname.name}@univ-valenciennes.fr
[2] Univ. Lille Nord de France, IFSTTAR, 20 rue Elisée Reclus, BP317, F-59666 Villeneuve d'Ascq Cedex, France
guillaume.uster@ifsttar.fr
[3]Ecole Polytechnique de Montréal, C.P. 6079, succ. Centre-ville, Montréal, Québec H3C 3A7
jean-marc.robert@polymtl.ca
[4]LIESP, Ecole Centrale de Lyon
36 avenue Guy de Collongue, F-69134 Ecully Cedex, France
Bertrand.David@ec-lyon.fr

Abstract. Transportation is a rich and complex domain for studying the use of interactive systems because of the diversity of travellers, activities, systems, and contexts of use, and the challenges that mobility represents for evaluation. In this paper we examine some new perspectives on transport and mobility and their impacts on evaluation. We propose to go beyond the evaluation of system utility, compatibility, accessibility and usability, and adopt the inclusive concept of User Experience. Finally we propose the use of a model-based engineering approach to take into account the variety of interactive systems, computing platforms, and media used in transport.

Keywords: Human-computer interaction, Mobility, Evaluation, transportation.

1 Introduction

This paper is about the evaluation of interactive systems used by travellers in transportation contexts. These contexts are heterogeneous since they include all means of transport (airplanes, ferries, trains, buses, subways, cars, bicycles, walk) and their respective home bases (airports, river ports, train/bus/subway/bicycle stations). What is striking here is the diversity of travellers, activities, interactive systems, and contexts of interaction, the diversity of situations that result from the combination of these elements, and the challenges that travellers' mobility represents for evaluation. This makes transportation a rich and complex domain for studying interaction [1].

The paper is structured as follows. We present some new perspectives on transport and mobility. Then we describe the sources of diversity in transport and we propose to

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evaluate the User Experience (UX) of travellers. We examine two activities which often occur in transport: learning and playing. Finally we describe some new perspectives offered by a model-based engineering approach.

2 Some New Perspectives on Transport and Mobility

Over the last years, there has been a diversification of forms of travels. Commuting is not anymore the most frequent form of travel, it has been replaced by occasional journeys. The planning of these journeys requires a lot of information and often comprises a part of uncertainty. For these journeys, private cars are still the principal mean of transport. Augmenting public transport and other green alternatives to private vehicles is the objective of sustainable mobility. But a major weakness of public transport is the lack of information. Indeed, several inquiries about occasional users of public transport mentioned this problem, for example, regarding bus routes and timetables, and the perception that the bus system is difficult to use and that information is difficult to access [2]. Furthermore, interchange of means of transport is perceived negatively by users and has also been identified as an area of public transport that should be improved [3]. Traveller information is a complex and vast research area; ATIS (Advanced Traveller Information Systems) is the common acronym to designate information systems in the area [4]. There are two main concerns in these systems: technology and user needs.

Technology can make the information accessible through a large diversity of media. For instance, during their trip, travellers can use an onboard information system through embedded screens (for instance, in a bus, a train) as well as they can use their own terminals.

User needs can be investigated through different data collection methods, including panels of travellers. Panels allow researchers to use several methods such as direct interviews, phone interviews, and focus groups to collect data [5].

Results of studies on different travellers indicate that they adapt their behaviors to travel contexts at each step, and tend to focus their attention on only a few pieces of critical information at a time. They need the right information at the right time, and relevant information should be provided in advance, before it is time to decide. Therefore, it is necessary to provide a coherent and efficient spatio-temporal system to meet travellers' needs at all stages of the journey [5]. Ergonomic studies can provide design specifications for the user interface (UI) of such a system [6], and accurate information can be delivered by the personalization of user content [7].

A travel is not only an itinerary from point A to point B, it is also the moment for travelers to do different activities such as sleeping, reading, listening to music, playing games, sending text messages, making phone calls, working, talking to other passengers, gazing out of the window, watching people, etc. [8]. Furthermore, during their trips, travellers pass through several transit spots where there is a continuous flow of information on transport, commercials, services, etc.

The principal success factor for sustainable mobility is to provide good quality interactive services to citizens and customers. This can be achieved on the base of careful observations of travellers at different times and different locations, for example onboard a train or a bus (Fig. 1). A Living Lab offers a good environment for making such observations and testing new equipments and services. It is a user-centred open innovation ecosystem, often operating on a specific territory, which allows one to do research and innovation through exploration, experimentation, and evaluation of innovative ideas, services, and equipments, in real life use cases and with numerous travellers. Furthermore, it allows one to collect data on delays, traffic, destinations, locations of the vehicles, infotainments, local news, touristic or cultural information, etc.

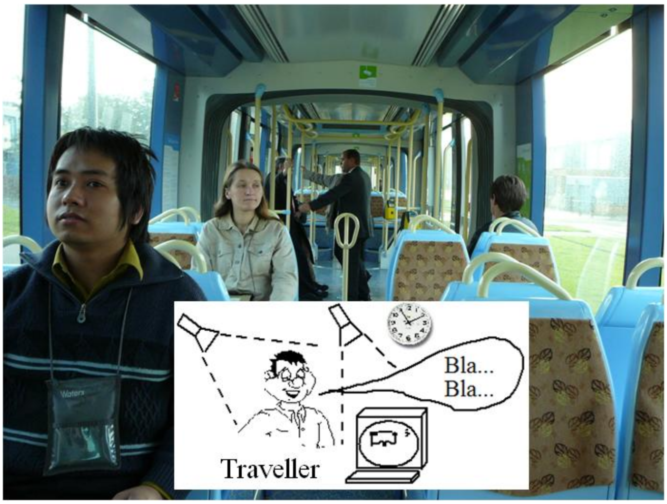

Fig. 1. Living Labs as new evaluation means in transportation contexts

3 Diversity of Usage Conditions in Transport and Evaluation of UX

Here we analyze the diversity of usage conditions in transportation contexts and its impacts on the evaluation of interactive systems, and we plead for the opportunity to evaluate the User Experience (UX) of travellers. Let's start with diversity which comes from the interaction of four categories of elements:

- Diversity of travellers. This is remarkable, be it in an airplane, a ferry, a bus, a train, a metro, or in the street. Travellers reflect the entire population and include those with specific needs such as the handicapped, elderly, illiterate, colour-blind, people from different languages and cultures, with low technical abilities, with no or little knowledge about the system (because they use it for the first time or occasionally), with their own interactive systems that they expect to be able to use in conjunction with those of carriers. There are impacts on evaluation: in accordance with the objective of universal design, accessibility of systems should be guaranteed to almost all travellers (this is more and more imposed by regulations), usability of interactive systems should be tested with representatives of each category of travellers to make sure that these systems are easy to use, and systems compatibility should be ensured for the benefit of travellers who carry their own systems and expect to be able to use them in conjunction with those of different carriers

- Diversity of activities. This was mentioned above. Travellers will perform different activities when using systems of different carriers and their own systems. These activities could be related to the planning and organization of the trip itself, and to work or leisure done during transport or transit. They can be very diversified as shown in these examples: search for information (e.g., on costs, trajectories, arrivals and departures, connections), read dynamic displays, make reservations, register, buy tickets, make electronic payments, show a reservation, valid a ticket, get, renew or recharge a payment card, read and send emails, get a receipt, write texts, play with video games, listen to music, etc. Some activities are connected to others when they have prerequisites and successors, and will be perceived as such by the travellers. Similar activities, with minor differences, will be done on different interactive systems and in different contexts: they can be called generic and correspond to activity patterns. These observations have impacts on evaluation: adequate functionalities should be available in systems of carriers to perform these activities, the procedures imposed by these systems should be short, easy to follow, and consistent, similar (or generic) activities done on different systems and in different contexts should have similar procedures, and UIs that support these functionalities and procedures should be transparent, consistent, and provide adequate guidance to travellers.
- Diversity of systems. Travellers will use systems of different carriers as well as their own interactive systems to perform their activities. Here are several examples of such systems, some being interactive and others not: ticket dispenser, information terminal, registration terminal, dynamic visual information displays, automatic teller to refill a payment card or pay parking fees, bank teller, personal computer, smart phone, etc. These systems could be used by the same traveller in a short period of time and in different locations; their rate of use will differ widely depending on the category of travellers (occasional, average, frequent). These observations have impacts on evaluation: these systems should be evaluated as parts of a global technological ecosystem, i.e. as if they were in relation with each other. To compensate the lack of standardization, their external consistency should be emphasized in order to reduce travellers' cognitive load, minimize learning, prevent errors, and improve human performance and satisfaction. This means that the task scenarios behind the usability tests should include different activities, interrelated or not, done successively by a same traveller on different systems.
- Diversity of contexts. Travellers will be using systems in very different contexts. They could be in a city or a country where the language and culture are different from theirs and represent a barrier for the interaction with systems; when using these systems, they could be sitting, standing, or walking; in a hurry because of an imminent departure, or under pressure because of people waiting behind them; in a state of great fatigue because it is late or after a long trip; in a crowded and noisy place; they can be performing an activity for which security is important (e.g., payment); they could be using a system with one or two hands, and be manipulating objects during the interaction (e.g., a travel card, a credit card) while watching their suitcases; they could be alone, in couple, or in family; they could

be using one of their systems in conjunction with those of carriers (e.g., show the reservation code on their mobile phone at the booking desk). This reality has impact on evaluation: interactive systems should be tested in the field, not only in a laboratory, with real travellers doing real activities in conditions that represent the diversity and richness of use contexts.

Given the diversity of conditions that can be found in transportation contexts and the challenge it represents for the design of good interactive systems, it is important to adopt a user-centered design approach [10] and thus put emphasis on usability of interactive systems. This will help designers to realize systems that are more effective and efficient, easier to learn and use, and more satisfying for the users; these advantages are at the core of the definition of usability [11]. Despite the necessity of usability (and other qualities such as utility, compatibility, accessibility) of interactive systems in transportation contexts, we argue that it is not sufficient. It is an instrumental quality in a system that helps users to perform tasks and achieve goals. To a large extent it is simply a hygiene factor, i.e. a factor that has to be taken into consideration in order not to create dissatisfaction among users, and not a motivational factor, which is much more positive and attractive for users.

In a context of competition, where carriers aim to attract new travellers and establish their loyalty through good pricing and high quality services, and where travellers spend much time in transport and are critical towards the products and services they use in this domain, it is important to put emphasis on the global satisfaction of travellers. As a consequence, we propose to go beyond usability with its focus of UIs, and adopt UX with its focus of users (or travellers). It is not in the scope of this paper to present UX at length, we will rather present a few highlights that show the relevance of this concept in transport.

ISO 9241-210 (20101, clause 2.15) defines UX as: « A person's perceptions and responses that result from the use and/or anticipated use of a product, system or service ». Another definition is given by [12]: « UX is a multidimensional construct that defines the overall effect over time on the user of interacting with a system or service in a specific context ». The main features of the UX are the following: multidimensional, holistic, subjective, connected to the overall impression on the user, resulting from his/her interactions with the product and from a combination of anticipation and actual experience, dynamic (it changes over time at each point of user's contact with the product or service), situated in context (depending on location, time, other human interactions, opportunities and constraints, incidents, issues), and it can be studied at different levels of granularity [13,14]. UX is global and takes into account non-instrumental qualities of system, such as aesthetics, sense-making, the capacity to generate pleasure and emotions that were not considered in usability. It has been rapidly adopted by the communities of design, HCI and human factors, at the beginning of the years 2000. It is the object of an abundant literature and it represents some major challenges for researchers, namely understand the process and evolution of UX in time, and develop methods and tools for the evaluation of UX [15]. The global approach of UX seems essential for a more complete evaluation of interactive systems in transportation domain.

4 Learning and Playing in Mobility

In this section we examine two activities which occur often in transportation contexts: learning and playing. They appear in different terms and involve different people (Table 1). They can occur during travels done individually or in group by car, bus, train, plane, boat, etc. Two categories of people are involved: active or passive actors. Active actors are drivers or crews who will be interested in training as it is related to their work and allows them to improve their knowledge of the task (e.g., rules of operations, procedures about incidents or accidents) and of the equipments they control. Here we talk either of vocational training (for learning techniques or skills), just-in-time learning (for learning things when we just need them for performing an activity), contextual learning (related to a particular space, situation, period of time), or a combination of these. Passive actors are the passengers; let's consider two groups: adults and teenagers. All of them are looking for the best way to spend the transportation time, be it through entertainment (e.g., watch a video, play a video game, listen to music) or some structured learning activities, especially in a context of learning all-along the life. Both groups could be involved in vocational training or contextual learning. On the other hand, only teenagers (and young schoolchildren) will be associated to "anti uproar activities" (to be busy during a long trip in group) and "to do or to finish homework".

Table 1. Learning and playing activities

		Passengers	
Learning and playing activities	**Carriers**	**Adults**	**Teenagers**
Use appropriately transportation time		X	X
Anti uproar activity			X
Entertainment		X	X
Vocational training	X	X	X
Just in time learning	X		
Contextual learning	X	X	X
Contextual & just in time learning	X		
Do or finish homework			X

Figure 2 shows several examples of interactive devices embedded in planes, cars and buses, and of devices carried out by travellers (e.g., laptop, tablet, Smartphone, DVD reader, portable gamer, view goggle). They support individual or collaborative learning and playing activities through a connection to a net. They are often located on the back of a seat of a plane, a car or a bus, and they use a tactile screen or command panel. They use a WIMP or post WIMP interface with gestural, vocal, or multimodal interactions. New forms of interactions provided on new mobile or wearable devices, such as the portable Kinect and WII joysticks, started to appear and should be available in the near future. It is important to evaluate their efficiency and usability, the degree of comfort for users, and their impact on neighbors in transportation context.

Fig. 2. Learning and playing devices

5 New Perspectives Offered by a Model-Based Design Approach

In this section we propose the use of a model-based design approach in transport because of the variety of interactive systems, computing platforms, and medias (e.g., audio, video, image, text) in use. Here is an example. Let's consider the scenario of a person planning a trip by train at home with a PC. Then, while going to the train station s/he gets stuck in a traffic jam. S/he checks train schedules to find another departure, using a PDA, and changes the reservation. When arriving at the train station, s/he goes to the kiosk and uses a terminal to get the ticket. Here, three kinds of platforms were used and different contexts of use have to be taken into account. They represent new challenges for the design of interactive systems: produce systems that can be customized or adapted to all types of platforms, and respect the characteristics and location of the user when interacting with the system.

Model-Driven Architecture (MDA) [23] has gained importance as a paradigm that advocates the design of systems at a high level of abstraction. In MDA, models play a more direct role in software production, being amenable to manipulation and transformation by machine with the goal of final code generation. In general, this is done by the definition of three types of models corresponding to three abstraction levels: the computation independent model (CIM) which focuses on the system requirements; the platform independent model (PIM) which specifies the degree of platform independence that is appropriate with different platforms; and, the platform specific model (PSM) which combines the specifications in the PIM with the details that specify how that system uses a particular type of platform. Transformations are used to convert a model into another model (from CIM to PIM, and from PIM to

PSM) of the same system, up to the code generation. MDA has also being applied to UI design (see examples in [22, 24, 25]). UI design is done independently of the platform and then implemented. Models in the three levels and transformations of models should be done considering the context of use of the system, including the user, the platform and the environment [17]. Even though MDA seems to be an appropriate technology for the design of interactive systems in the transportation domain, two important questions come out: (1) How to consider the particularities of transportation systems with this paradigm? (2) How to evaluate the quality of the user interaction given the high level design model?

The first question is related to the worry of making the transport system usable by everyone and in different contexts. So, for instance, if the traveller is disabled, the system should propose direct itineraries with short walking distances for connections. It should also propose seats that consider his/her disability. In the same vein, if the user informs the system that s/he would like to do personal activities (such as pay bills, do shopping), the system should propose itineraries where services are offered at the connection points. To develop systems that consider all this particularities, we should include explicit models to capture domain knowledge and context information (about use, platform and environment). How to define these models? Which information to consider? Some propositions of context modeling can be found in the literature [20, 21]. The use of domain ontologies to organize the knowledge about transportation system has also been proposed [18]. Once these models are included in the design phase, it is essential to perform quality assessments to make sure that the particularities of this domain were really taken into account.

For the second question: since in MDA we talk about models and independence (at some level) or particularities of platform, we consider that the quality models can be generic at some point and should be specified when getting to the final UI (PSM level and final code). Besides, quality is considered multidimensional and depends on the product to evaluate and the perspective of evaluation. Therefore, we should think about what to evaluate for each model and by whom (end users, designers, experts, etc.). For example since the transportation system should be developed to be used by everybody, we should not only focus on *usability* but on *accessibility*. Usually, quality models are organized in a hierarchy view (tree view) of quality characteristics, from more general to more specific ones (for example, standards like ISO 9126 [19] have characteristics, sub-characteristics and metrics). The problem is when we go to more details in this hierarchy, it is difficult to keep the generality but it is richer about what we should really evaluate. Therefore we should consider top characteristics that can be evaluated for all MDA levels (e.g., usability) and that can be refined in sub-characteristics/attributes appropriate to each model. For example, in the PSM level specific metrics should be defined for the platform or a family of platforms that use one or several interaction modes (such as only speech or graphical and text integrated). Finally, we should analyze which methods to use for the evaluation of each quality characteristic of a model. This is a well-known problem in HCI, and with the MDA paradigm we should also think that we will evaluate generic models that will be used to produce systems for different platforms using different interaction models (speech system or basic textual system). This generality aspect must therefore be taken into account while defining evaluation procedures.

6 Conclusion and Perspectives

The evaluation of interactive systems in transportation contexts represents a great challenge for researchers and practitioners due to the diversity and complexity of aspects to be taken into account, and the rapid increase of technology. Indeed, this evaluation should cover technical factors such as systems capacity, compatibility, rapidity, security, reliability, robustness, integration, and technological modernity as well as human factors such as utility, accessibility, usability that have a direct impact on travellers' performance and satisfaction. Furthermore, we proposed that the evaluation go beyond these classical factors and cover the more global and inclusive travellers' User Experience.

We propose some ideas for supporting and boosting the evaluation of interactive systems in transport : adopt a global and integrated approach in order to evaluate each system as a component of a larger ecological system; promote the use of facilities such as the Living Lab described above in order to test rapidly and continuously new systems and equipments with real travellers in an environment very close to reality; and finally use the techniques of Web analytics (or equivalent when not on the Web) to collect data on the use of interactive systems, make diagnoses, and continuously improve the user interfaces.

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