Human computer interaction in transport, a systematic literature review

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Abstract. To enhance the performance of transportation systems a wide range of computer applications and computer software have been developed, which help users into the decision-making process. This paper intends to go into the field of human-computer interaction and transportation, by carrying out a literature review in order to recognize the usefulness of human-computer interaction and the way that it is used in the topic of transportation. Human-computer interaction perspectives are applicable to describe, to analyze, to improve issues as user experience, user security, urban development, business model and so for. Understanding the way, a system is utilized is crucial to achieve the purpose of its design.

1. Introduction

A variety of stakeholders and variables make up transportation systems, in the sense that they are described as complex systems. To enhance the performance of transportation systems, a wide range of computer applications and computer software has been developed, which help users with the decision-making process. Human-computer interaction (HCI) is a body of knowledge that shows a significant increase over time, especially in latest years since computers facilitate daily human activities[1]. The interaction between human and machine has progressed in recent times. It is defined as the manipulation of graphic objects in an interface using artefacts such as a keyboard or a mouse [2] that makes the interaction possible [3].

Object recognition, human dynamics [4], user experience[5], among others, have focused the attention of researchers on the development of methodologies aimed towards the improvement of HCI in a natural way, with intuitive communication being the premise to follow. From the HCI perspective, there are opportunities to evaluate and to participate in the development of transportation initiatives based on sustainability as well as user’s needs and thus following worldwide trends concerning the intelligent and efficient use of resources.

This paper intends to analyze the field of HCI and transportation, by carrying out a literature review in order to abstract the usefulness of HCI as well as the way that it is used as a part of the topic of
transportation. For that purpose, a systematic literature review approach, is going to be conducted to interpret and evaluate the relevance of the available information to this question [6].

2. Methodology
A systematic literature review is conducted to manage, filter and select, based on its application, the diversity of knowledge found in the academic world [7]. An appropriate literature review should follow a structured strategy, with fair exclusion or inclusion methods, to underpin its scientific character. A well-defined methodology helps to limit information bias as well as to provide information regarding the effects of the phenomena that are covered by different scientific methods. The review process is constituted by three main stages: Planning, conducting and reporting the review. The first of these consists of the identification of the necessity as well as the development of the review protocol. The conducting phase includes the identification of research, selection of primary studies, data extraction, and data synthesis. The last stage uses the extracted data and transforms it into the previously mentioned report.

3. Identification of the necessity
This review aims to summarize the available literature related to HCI and transport, highlighting the necessity to recognize the usefulness of HCI in transport. According to the problem statement, the literature review should respond the next two questions.

- Q1: What is the use of HCI in transport?
- Q2: What are the HCI approaches to transportation?

4. Review protocol
The search for the sample of articles is conducted in the database Web of Science (WOS), due to the wide range of resources contained within this source of information. This being said, WOS is a platform that includes more than 20,000 journals reviewed by experts, more than 190,000 conference documents and more than 90,000 books of relevant publishers, which are published worldwide. Boolean and truncation operators were used to extend the search to the entire lexical family; the operators were used simultaneously to refine the search sentence. Additionally, the search has been conducted in the period from 2004 to 2018. Search sentence:

- TOPIC: ("human-computer interaction") AND TOPIC: (transport*)

The found articles from the search are organized in decreasing order according to the number of citations calculated by the Journal Citation Report (JCR). A detailed reading of the summary is conducted to discard the articles not included within the subject matter. Also, as another selection criterion of the selected articles the availability of access to the complete document is checked, and a critical reading of each document of the final sample is carried out. Finally, information is extracted from the selected articles to answer the proposed research questions.

5. Identification of research and selection of primary studies
The search using the sentence as described above showed 33 resulting articles that meets the above-mentioned criteria, however only 24 of them are related to transport in the sense of movement of goods or people. Therefore, it is found that transport is not exclusively used in that context. From the original sample, studies related to movement of other items (electrodes transport, cellular transport, data transport) as well as the transportation theory from the psychology field, etc., are excluded. The research sample covers different scientific areas such as computer science, engineering, psychology, behavioral sciences geography, operations research management, transportation, environmental sciences, automation control and information science. The journal citation report shows that this body of knowledge has been increasing over time. According to the timespan from 2004 to 2011 the number of
citations rose from 1 to 15 and from 2011 to 2017 the amount of citations tripled up to a value of 51. By the year 2018 it raised to 63.

The years with larger number of publications are 2013 and 2014, with 4 of them each year, followed by 2016 with 3 publications. These numbers likely point out that this field of research has received special interest in the latest years, nonetheless the sample is too small to draw precise conclusions. Figure 1 depicts the manner that publications are spread in the mentioned timespan.

![Figure 1. Publication years.](image)

21 out of 24 of the documents are articles, with the other 3 corresponding to each an editorial, a meeting and a review. The country with the largest number of publications as a part of the sample is the U.S.A. Out of all articles, ten of them originate from the U.S.A., equaling to 41.66% of all publications. This is followed by France with five publications, Australia with three and Tunisia with 2 publications.

Considering the participation of institutions, the Université de Valenciennes et du Hainaut-Cambrésis and Université Lille Nord de France Comue, with 5 records each, represent the institutions with the largest number of publications in the timespan. The California State University System, Centre National de la Recherche Scientifique (CNRS), Fondation I Site Ulne, Universite de Lille and University of Melbourne have published three papers each one.

6. Data extraction, analysis and reporting review
Information extracted from the sample can be organized by a variety of types in order to examine the usefulness of HCI as a part of the transportation field. The first way to segment the group of documents is by the means of transportation (Table 1). Herein, means of transportation are described as: any vehicle that you can travel or carry goods in.

| Table 1. Mean of transport/document. |
|--------------------------------------|
| Mean of transport | Documents |
| Car                  | [8], [9], [10], [11], [12], [13] |
| Plane                | [14], [15] |
| Truck                | [16] |
| Transportation tools | [17], [18], [19], [20] |
| Multimodal           | [21], [22], [23], [24], [25], [26], [27], [28] |
| Other                | [29], [30], [31] |

Cars: The documents that appear as search results in this group represent a diverse mix of approaches. Papers cover topics such as: The readiness to trust in a specific type of technology by giving anthropomorphistic characteristics to a vehicle [8], understanding unmet needs and the potential of new policies to land use for transport system as well as environmental impacts by using an UrbanSim systems [9], bringing new opportunities to develop a context sensitive model based on rules and decision trees [10], implementing linguistic reports of vehicle’s driving activity to contribute to the automatic evaluation of on-board devices[11], providing evidence to test historical data regarding the relation between distraction and impairments on driving [12] testing the performance of drivers by using artefacts that provide optical corrections [13].

Planes: Articles that mention planes as the mean of transport are cover the following topics: using a simulator in the context of aerial transportation to explore whether a relationship between the way that people act inside a simulated environment and a real one exists [14], measuring the performance and
awareness of pilots by exchanging factors such as responsibilities between them and air traffic controllers [15].

Trucks: The search resulted in just a single document that specifically focusses on trucks. The topic of this study is focused on oversize/overweight trucks and their interaction with road surfaces and bridge performance as well as the way in which engineers and transportation professionals perceive data management system designs to cope with problems that arise [16].

Transportation Tools: This item exhibits a several documents that respond to a collection of issues. The first one does not directly constitute a transportation tool, instead it is focused on tackling the restricted availability of trucks within a fleet. Here approaches examine the outsourcing of deliveries (3pl) based on an open market platform that facilitates the real time auctioning of transportation services [17]. The second document as a part of transportation tools debates the manner in which automated systems cause accidents to operators as a result of their complexity. The problem arises from the exceeding of capabilities of non-trained personnel [18]. Other papers focus on topics such as voice recognition as well as speech warning [19] or mouth tracking to move tools using robots to enable greater degrees of accessibility for disabled people [20].

Multimodal: Multimodal transport, defined as the movement of material or people from an origin point to a destination point by using at least two modes of transport [32], is present in a wide range of situations. These cover: the necessity to design personalized models that help developers to construct interactive transport systems [21], evaluation of agent based systems [22] as well as agent based generic reconfigurable environments used to supervise a urban transport network [23]. Further articles discuss the assessing of information assistance systems that provide information to passengers in urban transport systems [24], understanding the relationship between user interfaces and mobile system users as well as their context [25], defining frameworks to activity modelling [26], understanding the interaction patterns in the public participation transportation planning context [27] and finally evaluating user interactions by using a web based group decision support system [28].

Other articles that cannot be grouped into specific vehicle groups are also present. These instead discuss high speed bridges, trains and ridesharing. It has to be taken into consideration that trains and ridesharing somehow are included into the multimodal mean of transport, it is however not possible to treat them as such due to the fact that they are studied as a unique mean of transport in this context. High speed bridges and their drivers as well as their condition and capacity to handle sophisticated technical systems [29], trains and voice operated information system in Slovakia [30] and the exploration of the ridesharing potential make up this last category [31].

From an HCI perspective, the documents can be organized by usefulness or the objective that each document pursues. Table 2 summarize this information.

| Technique        | Objective          | Document |
|------------------|--------------------|----------|
| Simulation       | User Security      | [8,13,14]|
| Simulation       | Urban development  | [9]      |
| Interface design | User experience    | [10,18,29]|
| Interface design | Business Model     | [16,17,26,31]|
| Interface design | Security           | [11,19,30]|
| Interface design | Urban Development  | [21]     |
| Simulation       | User experience    | [15]     |
| Evaluation       | Urban development  | [22,23]  |
| Data analysis    | User Security      | [12]     |
| Evaluation       | User experience    | [24,25]  |
| User interaction | Business model     | [20,27,28]|

Simulation/user security: Simulation as a technique to provide an experience to users is utilized as a way to improve the security by using virtual worlds where users are immersed. Users are invited to drive a car with three different settings: Normal, agentic and anthropomorphic. Based on their experience with
the vehicle, their trust in the system is rated [8]. Other simulations with user security as its objective cover topics such as: How cars are treated as a human agent the more humanlike their characteristics are built. This displays other dimensions than purely the psychological one such as the technological design. Also inner uncertainties from aero mobility are analyzed and used as anticipation tools that deliberately simulate emergencies, which based on pilot’s experiences open up opportunities to test their mental resilience and the ability to cope with virtual futures in order to train them for real-life situations [14]. Also, sickness caused from using a driving environment simulation tool and a proposed method that corrects it through an optical correction device are subject of the search results. This presents positive results that express how the continuous use of driving simulation helps to reduce the discomfort usually arises from the use of this tool. These results could be obtained and used to enhance the performance of the sample of 56 students as a part of the study. The later paper and the others described in this section have in common that the user security on real situations is tested by using virtual worlds on simulated environments.

Simulation with urban development as an objective describes the application of a system called UrbanSim in the metropolitan area of Salt Lake City. It facilitates the examination of the progress of the city by the local government and brings perspective towards urban developments by uncovering unintended results caused by new policies and unmet necessities that are not easily understood [9]. This approach evaluates alternatives that are proved by users’ interactions between each other and the virtual world, this powerful tool has a previous HCI evaluation to validate the proximity from a real world to the virtual one from the design perspective.

Interface design/user experience: Details that motivate the design of interfaces to validate the user experience is a broadly used approach. The use of model driven engineering (MDE) on the domain of personalized transport information by applying geographical and temporal context is the topic that [10] is addressed with the development of conceptual models that brings rules to a web application. The design of technical support governed by usability, relevant information and the interaction with final users is studied to accomplish the objective to improve the conditions of high-speed bridges drivers [29]. That objective is only achieved by understanding the human interaction with the available devices and the design of new ones, area that involves without a doubt the use of HCI perspectives. Operator errors related to automation activities that overpass their capabilities and the consequences that this issue trigger, such as accidents, are debriefed by the design of sociotechnical systems that consider expertise, training, HCI and interface design that help operators to effectively maneuver these automated systems [18]. User experience is a factor that is improved by the design of a sensible and reliable interaction between human and machine.

Interface design/business model. Doing business and the related issues that surround this field is also studied by HCI. The case of demonstrating the feasibility of an agent mediated electronic auction system [17] to deal with the day to day outsourcing of transportation activities and the design of an interactive interface to achieve this goal is a clear example of the usefulness of HCI in business models. Potential of ridesharing [31] based on the design of Dijkstra’s algorithm and an interface that represents vehicle availability to meet client’s demand, and a platform that brings information related to oversize/overweight trucks [16] are some examples that describe the design of platforms based on HCI perspectives that support business model activities.

Interface design/security: Linguistic reporting driving activities used as an assessment to measure the driving quality, voice messages that alerts driver impairments [11] and speech warnings designed to improve driver safety providing information about upcoming hazards [19] are milestones to further understand the design focused on the security.

Interface design/urban development. Challenges to deal with transportation systems in an urban environments are key-issues that are addressed by the design of approaches that connect interactive systems to user interfaces based on personalized models [21]. Once more, design allows for the achievement of challenging topics such as urban development from a generic point of view in this specific case, as it is concentrated in a conceptual model.
Simulation/user experience. Simulation techniques unveil hidden behaviors that are only visible by living experiences, in this case in a virtual environment. Different roles and a change of parameters that consequently change elements such as responsibilities in the user’s environment and therefore their way of acting as well as appropriate synergies between HCI user experience perspectives and simulations demonstrate its usefulness and are also described in this application of simulations.

Evaluation/urban development. These evaluate the performance of systems based on HCI perspectives and make up another application that researchers have been applying. This is the case for the evaluation of an agent based interactive system [18,19] that supervises the development of a urban transport system through a configurable electronic informer. This analyzes and evaluates the outcomes of the system and provides solutions.

Evaluation/user experience. Evaluation by measuring scenarios and according to the user experience as well as feedback update an interface that is conceptualized to improve transportation systems[27] The evaluation of systems from the abstract level to the guarantee of knowledge transfer is explicitly regulated in this category [25].

User interaction/Business model. Understanding the manner that a system is utilized is crucial to achieve the purpose of its design, this is especially true in the case that evaluates the user interaction initially by understanding the patterns of interaction between users and the interface [27]. Later, web based applications in a public participation transportation planning context can be evaluated [28]. It can be said that HCI plays an important role on both stages as the interaction is mediated and evaluated by its principles.

7. Conclusions
HCI is a field that has many applications. Regarding transportation, there are many ways to prove its usefulness. As it is described in this paper, HCI perspectives are applicable to describe, analyze and improve issues such as user experience, user security, urban development, business models, etc.

Interfaces design, simulation, data analysis, information are techniques that are well supported by HCI perspectives. User experience is a factor that is improved by the design of a sensible and reliable interaction between human and machine. Design makes the achievement of challenging topics as transportation systems possible.

Synergies between HCI user experience perspectives and simulations demonstrate its usefulness not only in design but also in the use of tools in an appropriate manner, resulting in the obtaining of expected performance and results.

This review provides relevant information regarding the use of HCI in transportation, which has not been sufficiently explored as is reflected in the limited availability of documents in this particular area.

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