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DESIGNING FOR AMBIENT UX

DESIGN FRAMEWORK FOR MANAGING USER EXPERIENCE WITHIN CYBER-PHYSICAL SYSTEMS

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DESIGNING FOR AMBIENT UX

Design Framework for Managing User Experience within Cyber-Physical Systems

Submitted by
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Abstract

Cyber-physical systems are stimulating the rise of novel design applications that can support variety of everyday human activities and chores in diverse environments as domestic, transportation, office, retail, hospital, and others. These systems are observed as connected spaces enhanced by digitized services, and their complexity imposes numerous challenges for approaching design practices from a point of view of designing for holistic user experiences. The approach for designing for user experiences (UX) within such system is observed as a suitable one, as comprehending desirable experiences could foster sustainable long-term user engagements.

Research aims to contribute the field of User Interaction and Experience Design, by providing a discussion on a potential design strategy and toolset to be applied within the emerging projects for spaces enhanced by digitized services, i.e. cyber-physical systems. Peculiar nature of the design field deals with projects of high complexity imposed towards users' experience, that appears not to be addressed accordingly with current tools employed in practices. Therefore, the research has identified a necessity for expanding current practices in the UX field by supporting them with the set of tools to be used as a backbone for structured design processes. Design tools, in this case, facilitate creation of a common language between all the parties and stakeholders involved in the design project, for identifying and communicating user values.

The research methodology consists of three extensive steps, that have as an outcome: (1) proposal for a design framework for Ambient UX, (2) verification of the Ambient UX framework, (3) identification of gaps between the proposed framework and design tools currently employed in practices, as well as identification of main upgrade issues for the design tools. The Ambient UX framework is based on the definition of Design Domains and levels of User Values within a project, and according to these aspects the design tools are analysed and discussed. Main methods employed throughout the research path are literature reviews, research-through-design within design case studies that took part, as well as qualitative analysis of gathered tools.

Two main outcomes of the research are: (1) definition of the Ambient UX design strategy, and (2) definition of contents and concepts for building up a novel design tool platform for supporting the design processes. The research provides a support for structured processes for designing cyber-physical systems focusing on users' experience, and it strives for creation of a common language within the field among designer and non-designer professionals. Future steps for the research are development of the actual software platform and its testing throughout diverse design projects of correspondent nature.

Keywords

User Experience
Ambient UX
Cyber-Physical Systems
Design Strategy
Design Tools

Abstract

I sistemi cyber-fisici (Cyber-Physical) stimolano la generazione di nuovi concetti di design a supporto di una moltitudine di attività quotidiane in diversi ambiti come, ad esempio, il contesto domestico, i trasporti, gli ambienti lavorativi e per il retail, il mondo ospedaliero e altri. Questi sistemi possono essere considerati come spazi connessi e aumentati dai servizi digitali; la loro complessità pone diverse sfide in un approccio al design olistico e focalizzato sull'esperienza utente. La progettazione orientata alla esperienza di questi sistemi è volta a generare un coinvolgimento degli utenti sostenibile e gratificante a lungo termine.

L'obiettivo della ricerca è di fornire un contributo nel campo di progetto indicato come User Interaction e User Experience (UX) Design, e propone una discussione su una strategia di design e un insieme di strumenti progettuali da applicare nel design degli spazi aumentati attraverso la realizzazione di servizi digitali, i.e. sistemi Cyber-Physical. Il focus è sul progetto di sistemi di complessità elevata dal punto di vista della esperienza utente, che non possono essere affrontati in maniera adeguata con gli strumenti attualmente disponibili. La ricerca presenta la necessità di espandere le pratiche di design esistenti nell'ambito di UX con l'introduzione di nuovi strumenti da usare come base per strutturare i processi di progettazione. Gli strumenti facilitano la creazione di un linguaggio comune tra tutte le parti coinvolte nel progetto, destinato a identificare e comunicare gli elementi di valore dal punto di vista degli utenti finali - User Values.

La metodologia di ricerca include tre fasi che presentano come risultato: (1) una proposta di schema concettuale di inquadramento: Ambient UX design framework, (2) la relazione sulla validazione dello schema concettuale, i.e. Ambient UX design framework, (3) l'analisi del divario oggi esistente tra il framework proposto e gli strumenti di design attualmente in uso nelle pratiche di design, e alcune proposte per migliorare tali strumenti. L'Ambient UX design framework è basato sulla definizione delle dimensioni in cui si articola il progetto-Design Domains, e livelli di valore visti dal punto di vista degli utenti finali - User Values attorno cui si articola il progetto. Coerentemente con questi aspetti, gli strumenti di design sono discussi e analizzati. I principali metodi di ricerca utilizzati sono: ricerca bibliografica, ricerca tramite esperienze di progettazione (research-through-design) applicato ai vari casi studio, e l'analisi qualitativa di una collezione di strumenti progettuali esistenti.

I principali risultati della ricerca possono essere identificati in due punti principali: (1) la definizione della strategia per Ambient UX Design, e (2) l'individuazione di nodi progettuali su cui costruire nuovi strumenti da utilizzare durante le fasi di progettazione. La ricerca fornisce quindi un supporto per progettare sistemi Cyber-Physical in maniera strutturata, focalizzandosi sull'esperienza utente e creando un linguaggio comune tra designer e non-designer. Possibili sviluppi futuri della ricerca possono essere identificati nella creazione della piattaforma software che raccoglie i casi di studio e nella sua validazione attraverso la progettazione di questi sistemi.

Parole chiave

Esperienza utente (User Experience)
Esperienza ambientale (Ambient UX)
Sistemi cyber-fisici (Cyber-Physical)
Strategia di Design
Strumenti di Design

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according to a timeline of activities, (c) defining elements that influence the perception and are grouped within diverse mental spaces, according to the hierarchy of perception and the timeline of sequential activities, (d) aligning with the back-end of the service system, (e) more precisely, aligning what is needed to be done to support the mental spaces and desired experiences related to the upper line part.

DOCUMENT KEYWORDS

Cyber-Physical System (CPS)

Dynamic system in which human actions and activities are enhanced by digitized services present in the physical space

Ambient UX

Conceptual approach for designing systems of enhanced spaces with a focus on user experience

Design Framework

Conceptual framework that proposes a design strategy for a structured design process

Design Domains (DDs)

All possible design outcomes that regard cyber-physical systems; these are further grouped within 3 architectures and time as a variable between them

User Values (UVs)

Motivations for making and developing a design concept in a certain way; they are the drivers of the design concept interpreted through three diverse levels, i.e. Usability, Meanings and Motivations, Social consensus

Value Alignment

Alignment within a design project between the values perceived from the side of the users and those perceived from the side of stakeholders that are developing a project; alignment is dependent on the touchpoints between the two

Introduction

Research Focus & Motivation

The doctoral thesis is developed in collaboration with TIM S.p.A., Services Innovation Department, through the Joint Open Lab Digital Life in Milan. The telecommunication company endeavours designing meaningful services supported by the new stream for a 5G network that will be guiding some of company's business application fields within the current and following years. The network promises to have significant higher speed and reliability, thus enabling with ease employment of complex connected services that rely on diversity of systems of sensors and actuators implemented within the physical space. The observation of this emerging application field helped shaping the ***needs of novel design practices*** it imposes.

Design is a fast-paced evolving field which main scope is responding to current societal needs and values. Design projects that are emerging currently are complex systems that need to take into account diverse aspects of their influence on individuals and society. This is where design responsibility takes part, implying that designers who deal with widely spread and widely used systems need to acknowledge the impact of their design interventions by acknowledging the need for facing responsibility within design processes.

This research reasons on a design strategy for projects of hybrid and complex nature, and on design tools that might support the strategy within a design process. In this context, design strategy reflects responsibilities by shaping design outcomes through research conducted on user values, perceived as such from the side of an individual and society. The research explores emerging design practices that evolve at the intersection of diverse practice fields, such as Interaction, Game and Service Design, Product Design and Architecture, Communication and Marketing, as well as Computer and Electronic Sciences, Business Development, Social and Cognitive Sciences. The intersection of fields contributes the

hybrid nature of projects and requires merging of the fields towards a unique goal and project focus.

In the design field, more and more we support the notion of designing systems rather than products, to be able to tackle imposed complexities of emergent projects and practices. The systems that this research refers to are cyber-physical by character. The proposed approach for designing such systems is the approach of designing for users' experiences (UX). Considering complexity of cyber-physical systems, designing for users' experiences should be approached in a holistic manner, with respect to diverse levels of influence a design solution might have on an individual and society.

Designing for smarter and enhanced spaces within cities imposes rethinking and ***reshaping design approaches*** from practices currently employed in the field, ***towards more hybrid*** approaches that lie at the intersection of diverse fields. This research proposes as a suitable approach designing for users' experiences, as a backbone of the design process and the focus of novel cyber-physical systems. In this context, the research discusses a conceptual framework for a possible design strategy, which stands for an Ambient UX approach. More precisely, it discusses a framework for a ***holistic UX approach***, which appears to be missing in current UX practices as a structured design process.

Outcome of the research is aimed towards UX design practitioners and strategists targeting new applications within systems of smart enhanced spaces, for supporting design processes through design tools. Here, the role of a UX practitioner and strategist is observed in translating user research into design hints, which are based on user values, providing a holistic overview in regard to the type of projects in question.

Research emphasises the communication of user inquiries and design hints, based on user values within a project, shared among all of the project stakeholders. Namely, ***establishing creation of a common language*** around the emerging applications and design practices is an important contribution to both the design theory as well as industry practices. The importance of creation of a common language reflects in the complex nature of emerging design systems that require collaboration from the side of many diverse professional backgrounds, among which are many non-designer profiles as well. Common language around issues on UX values, as the core focus of the project, is significant for gathering diverse field practitioners around the same scope and within diverse phases of project development.

The design language that should be established and nurtured within a project development can be embodied through design tools, that rely on the conceptual framework as a backbone of structured design processes. Design tools, thus, mirror their importance in relation to design strategy and guidance of a process, as well as inspiration for concept development. Furthermore, tools enable anticipation of possible users' experiences, and the consequences a designed system might bring, which is a manner of responding to design responsibility. Since the approach is the one of UX design, for defining the novel tools the research refers to examining existing UX tools; this is done in regard to which of the Ambient UX framework concepts they are containing, and to which extent and manner they could be a fit and/or good inspiration. The proposed conceptual framework ***provides a base for reasoning on a new toolkit***, and a starting point for its development.

The research shapes a discussion around building a conceptual design framework as a support for design processes and tools for emergent projects that call for merging of diverse practices around a same focus value, bridging the tangible and intangible outcomes. The way of reasoning about the development of a design strategy and framework, presented in the research, could be observed as a product itself and reutilized for other researches of similar nature. It provides a ***possibility to be repeated as a process of reasoning on a design framework and novel design tools to support it, when it comes to hybrid projects***; i.e. projects that imply contaminations and intertwining between diverse fields. In this regard, repeatable is the way of reasoning about a design framework, which looks into design domains (what can be made) and the drivers (why it should be made).

How To Read This Thesis

The thesis starts by introducing the main research area as the area of possible design applications and approaches it aims to explore. From the definition of the area and the implications imposed towards design practices, the research question and goals emerged. A research methodology has been shaped to respond to the goals and is presented as a closure for Chapter 1.

Chapter 2 describes in details manner of reasoning on a design strategy for practices related to the previously discussed focus field. The strategy leads to a proposal for a conceptual framework for Ambient UX, which is based on two main conceptual groups as Design Domains and User Values.

The following, Chapter 3, provides a verification for the proposed conceptual framework through diverse case studies. The first case study provides an initial evaluation and verification of the overall framework, while the following three discuss more in depth the dominant user values within the cases and peculiar needs that regard the design process and tools that could support it.

In Chapter 4, design tools are analysed that have potential in supporting the Ambient UX framework and the concept of value alignment within a design process. Furthermore, a confrontation between the framework and the gathered tools is discussed, followed by a discussion on emerged mismatches shaped as conceptual issues. The emerged issues are proposed to be an upgrade of existing tools for supporting projects for Ambient UX design.

Finally, within Chapter 5 an overview of the whole research is provided, and main conclusions are presented, as well as possible future steps for the research.

01

Research Area & Research Methodology

The doctoral thesis is developed in collaboration with TIM S.p.A., Services Innovation Department, through Joint Open Lab Digital Life in Milan. The telecommunication company is looking into designing meaningful services supported by the new stream for 5G network that will be guiding the company's business application fields within the current and following years. The network promises to have significant higher speed and reliability, thus enabling with ease employment of complex connected services that rely on diversity of systems of sensors and actuators implemented within the physical space. This comprehension of an emerging application field helped shaping the main research field of the doctoral thesis.

This chapter introduces the application field for design practices that the research concerns. Broadly, the field relates to Cyber-Physical Systems (CPS) and the vision of Ambient Intelligence (AmI), which are an intersection between: Artificial Intelligence (AI), Internet of Things (IoT), Pervasive and Ubiquitous Computing, and Interactive Architecture. Definitions of these fields are introduced in the chapter, as well as the perspective of the design approach, seen as designing for (user/customer) experiences. In this context, a base overview is provided for reasoning on CPS and AmI design practices, observing them on the merge between Service and Interaction Design, and AI and Spatial Design. From the identified research area of design practice, research questions emerged targeting identification of an Ambient UX approach.

Finally, the chapter discusses a methodology that was selected for responding to the shaped research objective. The methodology comprises three main research areas that are reflected in the following as chapters: Chapter 2) Design Strategy for Ambient UX, Chapter 3) Verification of the Ambient UX Framework Hypothesis, and Chapter 4) Design Tools for Ambient UX. Main research methods employed throughout the chapters are: literature reviews, gathering and comparative analysis of case studies deriving from practice, research through design employed through practical design projects that took part, analytical confrontation between the defined Ambient UX framework and practical design projects that took part, gathering and critical analysis of design tools deriving from practice, analytical confrontation between the defined Ambient UX method and gathered UX design tools.

1.1 IDENTIFYING THE RESEARCH AREA

The area of inquiry is being shaped through the collaboration with TIM S.p.A., company supporting the PhD research path. From the stream for development of meaningful application areas for connected spaces and IoT systems, the research refers to Cyber-Physical Systems (CPS) and a vision of Ambient Intelligence (AmI). This vision and the application area find their connections within diverse fields that finally merge towards same practices. The fields are Artificial Intelligence, Pervasive and Ubiquitous Computing, and Interactive Architecture.

Within the research, I approach this application field by designing for users' experiences. Furthermore, as the field represents a convergence, the design approach is observed through convergences as well, positioning itself on the merge between Service and Interaction Design, and AI and Spatial Design. Focusing on AmI design practices, specific research questions are shaped, and an objective is posed for defining an Ambient UX strategy as a possible suitable approach for responding to the focus application field.

Collaboration with TIM S.p.A. 1.1.1

The doctoral thesis is developed in collaboration with TIM S.p.A., Services Innovation Department, through the Joint Open Lab Digital Life in Milan. TIM S.p.A. (known as Telecom Italia S.p.A. until May 2016) is an Italian telecommunication company which offers services in Italy and abroad. The telecommunication company endeavours to design meaningful services supported by the new stream for a 5G network that will be guiding the company's business application fields within the current and following years (Notiziario Tecnico TIM, 2017, 2018). The network promises to have significant high speed and reliability, thus enabling with ease employment of complex connected services that rely on diversity of systems of sensors and actuators implemented within the physical space (Li et al., 2014; Gupta & Jha, 2015). This comprehension of an emerging application field helped shaping the focus of the doctoral thesis.

The company states that 5G is the new generation of mobile systems, and that its field of application is much broader than in the past, leading towards a cyber-physical revolution. The paradigms of innovation are based on continuously evolving technologies and business models, which require Telecommunication Operators to undergo a process of profound transformation (TIM Notiziario Tecnico, 2017, 2018). The articles on business and innovation streams published by the company analyse the principles of evolution of the digital age, the technologies characterizing 5G and the TIM vision, in addition to hypothesizing a deployment path that puts the combined benefits of 5G and Long-Term Evolution (LTE) technologies to value.

New scenarios have begun to emerge: the ones in which the "digital" world extends from virtual to the physical world, the software world extends to the world of "objects" that surround us, from sensors to robotics, impacting on the environments such as the house, the city, the car, etc.

The enablers of this new wave are various. One of them are the availability of sensors at competitive costs, which can translate physical information into digital, thus transforming the objects that surround us into digital data. As a consequence, based on the typical property of digital information, objects, or rather their data, have become easily copied, transferable and processed anywhere in the world. Another enabler is connectivity that is becoming increasingly widespread and available in abundance, allowing any object to transfer and receive information and data at any time. Following are the cognitive technologies and artificial intelligence technologies in general, which allow large amounts of data to be processed in a sophisticated manner. Robotics, as another enabler, allow performance of actions controlled also remotely, that are becoming systems of "implementation" of what is picked up by the sensors, transported and reworked in decisions and actions. Finally there are also 3D printers with their ability to transform digital information into physical objects, enabling new business and innovation opportunities.

Contrary to the previous phase driven by smartphones and applications, which has strongly impacted the "consumer" world, this technological wave is determining a path of profound innovation starting from the industrial context and production systems, and thus in a certain sense from the services B2B (business-to-business), to then progressively change the consumer experience in people's daily lives.

The 5G is, in this context, a disruptive transformation of the network, which introduces 10 times higher performance than today. It has been projected that, in the next decade, a mobile traffic increase on the order of 1,000 times is expected compared to what we experience today (Li et al., 2014). Some general trends related to 5G can be explained in terms of machine to machine traffic and number of machine-to-machine connections in mobile (Tikhvinskiy & Bochechka, 2016).

After Guglielmo Marconi's (Italian inventor) communication of letter "S" with the help of electromagnetic waves, wireless communications have become an important part of the nowadays society. Today with satellite communication, television and radio transmission has evolved towards mobile and wireless

communications, and as such, they have transformed lifestyle of the society. According to TIM's Notiziario Tecnico (2017, 2018), 5G technologies are likely to appear in the market in 2020. The technology is expected to significantly improve customers quality of service in the context of increasing growth of data volume in mobile networks and the growth of wireless devices with variety of services provided (Gupta & Jha, 2015). Gupta and Jha (2015) observe that it is commonly assumed that 5G cellular networks must address new challenges that are not effectively addressed by 4G, such as for e.g. higher capacity, higher data rate, massive device connectivity, and consistent quality of experiences.

For telecommunication operators the 5G represents the opportunity to look at new markets, taking advantage of the technological transition that leads to the pervasive connection and the digitalization of the physical world. To successfully face this transition, it is necessary for the Operators to know how to guide the transformation process according to a clear mission both from a business point of view and from that of technological evolution. In fact, in a technical and regulatory context increasingly oriented to the opening and sharing of assets, only the connection services will represent a partial element of the business. Therefore, desirable directions are the creation of technological and business partnerships, the definition of a new relationship with technology suppliers, and, finally, the creation of a programmable network that allows new services to be deployed, evolved continuously and at low cost. These represent guidelines of the evolution of the telecommunication operators as important players in the connected and digital society.

TIM's path towards 5G is in line with the milestones identified by the standards' representative bodies and European political institutions. The agreement is signed to build the first 5G network in Italy in the city of Turin, where the first trial will start by 2018, with numerous trial activities in TIM and on field laboratories that are preparing the availability of commercial services starting from 2019-2020.

The 5G network opens possibilities for shaping diverse use cases for smart cities, where the company recognizes suitable application fields within smart homes, agriculture, education, government, health, mobility, and retail. Furthermore, in the period of development

of this thesis, the company is developing use cases for smart city scenarios in the city of Matera (Italy) for 5G network coverage.; the scenarios relate to experimentation within the area of tourism and culture, smart port, public safety, environment monitoring, healthcare, virtual reality, mobility, safety and agriculture.

The contribution of this research, developed in collaboration with TIM S.p.A. Services Innovation Department and the Joint Open Lab Digital Life, is identification of a design strategy for developing innovative and desirable use-case scenarios for connected spaces enhanced by digitizes services, which realization is enabled by the new technological streams.

Cyber-Physical Systems 1.1.2

Cyber-Physical Systems (CPS) (Rajkumar et al. 2010) consist of mutually informing computational and physical mechanisms that operate cooperatively and continuously via a Wireless Sensor and Actuator Network (WSAN) (Yang 2014). CPS refer to environments that are sensitive and responsive to people; they integrate a variety of devices operating in concert to support human activity in an unobtrusive way, using intelligence that is hidden in the network connecting them. Bier et al. (2018) define Cyber-Physical Systems (CPS) for Architecture (Bier, 2017; Bier 2019) as the current state of development of previous similar systems known in academic research such as Ambient Intelligence, Digitally-driven or Interactive Architecture, Adaptive Environments (inter al. Fox and Kemp, 2009; Bier and Knight, 2014; Bier et al. 2017), etc.

Application field for design practices that this research concerns relates to the concept of CPS, which are broadly observed as an intersection between: Ambient Intelligence (AmI) (Aarts & Marzano, 2003; Augusto & McCullagh, 2007; Mukherjee, Aarts & Doyle, 2009; Carneiro & Novais, 2014), Artificial Intelligence (AI) (Ferber & Weiss, 1999; Russell & Norvig, 2016; Gams et al., 2019), Internet of Things (IoT) (Atzori, Iera & Morabito, 2010; Gubbi et al, 2013), Pervasive and Ubiquitous Computing (Lyytinen & Yoo, 2002; Chen et al., 2004), and Interactive Architecture (Fox, 2016; Dalton et al., 2016).

Ambient Intelligence Vision

We witness technology pervading our world by making its way towards the augmentation of objects, people, and spaces. Connected sensors and actuators are advancing our private and public environments, opening up new challenges and opportunities for the design of such spaces. Ambient Intelligence (AmI) is a vision where technology becomes invisible, embedded in our natural surroundings, adaptive

to users and context-sensitive, with high-quality information access and personalized content available to everybody, anywhere, and any time (Ducatel et al., 2001; Aarts & Marzano, 2003; Augusto & McCullagh, 2007; Carneiro & Novais, 2014).

Ambient Intelligence refers to environments that are sensitive and responsive to people. They integrate a variety of devices operating in concert to support human activity in an unobtrusive and intelligent way, using intelligence that is hidden in the network connecting them. AmI experiences can be provided by autonomous Artificial Intelligence (AI) agents or not, in response to perceived needs, or user input. Autonomous AmI agents know how and when to provide a functionality.

The original AmI vision (Zelkha & Epstein, 1998), builds upon the concepts of pervasive computing, ubiquitous computing, profiling, context awareness, and human-centric computer interaction. It is characterized by networked devices that are: embedded, integrated into the same environment; context aware, able to recognize the users and their situational context; personalized, tailored to the user needs; adaptive, able to change states in response to users' needs; and anticipatory, able to anticipate user desires without explicit user input. As AmI devices grow smaller, more connected, and more integrated into the environment, the technology will disappear and only the user interface will remain perceivable by the users. A typical context of AmI experimentation is home, but applications may also be extended to work in public spaces (with technologies such as smart streetlights), hospital environments, transportation, etc. First generation intelligent agents, like personal software assistants with a certain degree of autonomy have also been developed.

Today AmI is a futuristic vision that promises to transform the role of technology in everyday life, and to change the way people live, work, relax and use their leisure time. The AmI vision differs from earlier technology visions due to its explicit human-centred goals. Unlike other visions of technology, which can be deterministic, shaped by what a specific technology can do, the AmI vision is open-ended. To realize their full potential, AmI systems need to be sensitive to the needs and the micro-contexts of their potential users. For this purpose, sensing and communication components must be always open and receptive to user input, and other contextual

variables. Ultimately, the acceptance of AmI systems depends on demographic and personal preferences regarding privacy, security, trust, individualism, diversity, mobility and lifestyle that affect the structure of communities and the way people live and work.

AmI is defined as a specific class of information and communication technology (ICT) applications enabling physical environments to become sensitive, adaptive, and responsive to human activities (Mukherjee, Aarts & Doyle, 2009). Beyond the integration of ICT devices into the physical environment, the AmI paradigm promotes the creation of new, enhanced user experiences (Aarts & Encarnaçao, 2006). Cook et al. (2009) explain that AmI systems are sensitive, responsive, adaptive, transparent, ubiquitous, and intelligent. Building on the ideas of ubiquitous computing by Marc Weiser (1991) who envisioned a digital world in which ICT components form a distributed network, AmI systems aim to supply an enhanced physical environment that strengthens the prospect of well-being, improves productivity and creativity, and augments the enjoyment of leisure time. At the same time, AmI systems introduce new levels of complexity and new challenges. Interactions cease to be human-to-machine. They are ubiquitously distributed interactions within the living environment, where new challenges emerge regarding front-end communication and avatar interaction (Hanke et al., 2015). AmI systems can also involve AI agents (O'Grady, O'Hare & Poslad, 2013; Burr, Cristianini & Ladyman, 2018) and perform as autonomous systems (Gams et al., 2019). These AI agent-based systems are recommendation systems that interpret the user's state and habits and initiate proper responses (Rasch, 2014).

Because AmI systems must be sensitive, adaptive, and responsive to people, they must be aware of their preferences, intentions, and needs (Plötz, Kleine-Cosack & Fink, 2008). Furthermore, AmI agent systems need to be unobtrusive and easy to live with (Airaghi & Schuurmans, 2001). Their interfaces must be context aware, natural, and acceptable from an ethical point of view (Brey, 2005). Streitz (2007) argues in favour of a transition from Human–Computer Interaction to Human–Environment Interaction, which leads to responsive environments (Alves Lino, Salem & Rauterberg, 2010). Koskinen (2016) points out that recent design examples dematerialize design. Material configuration becomes a secondary issue, and social aspects become the main focus of the design process. Recent

examples in using methods of civic engagement in the design process of smart cities, support this view (Forlano, 2016; Hill, 2018). Design is focusing to configuring complex socio-technical networks involving services and human experience (Hill, 2018; Lou, 2019).

Artificial Intelligence

In his book, Principles of artificial intelligence, Nilsson (1980) observed:

"...there are some computer systems that can diagnose diseases, plan the synthesis of complex organic chemical compounds, solve differential equations in symbolic form, analyse electronic circuits, understand limited amounts of human speech and natural language text, or write small computer programs to meet formal specifications. We might say that such systems possess some degree of artificial intelligence. Most of the work on building these kinds of systems has taken place in the field called Artificial Intelligence (AI). "

In the following years, the field of AI development has been observed to embrace the larger scientific goal of constructing an information-processing theory of intelligence. Indeed, AI brought up one of the grandest of scientific problems- the nature of intelligence, in humans and in artefacts (Barr & Feigenbaum, 1982). Nilsson (1980) stated that: "if such a science of intelligence could be developed, it could guide the design of intelligent machines as well as explicate intelligent behaviour as it occurs in humans and other animals."

The history of AI is a history of possibilities and promises; Buchanan (2005) observes that humans have always imagined mechanical assistants as part of their culture and fantasies, however, only in the last half century have we been able to build experimental machines that test hypotheses about the mechanisms of thought and intelligent behaviour. It is to note that AI is not just about robots, as it may appear from the media industry, rather it is about understanding the nature of intelligent thought and action using computers as experimental devices (Buchanan, 2005). Buchanan (2005) argues that AI in its formative years was influenced by ideas from many disciplines: engineering (e.g. Norbert Wiener's work on cybernetics, which includes feedback and control), biology (e.g. W. Ross Ashby and Warren McCulloch and Walter Pitts's work on neural networks

in simple organisms), experimental psychology (e.g. Newell and Simon on human problem solving), communication theory (e.g. Claude Shannon's theoretical work), game theory (e.g. John Von Neumann and Oskar Morgenstern), mathematics and statistics (e.g. Irving J. Good), logic and philosophy (e.g. Alan Turing, Alonzo Church, and Carl Hempel), and linguistics (e.g. Noam Chomsky's work on grammar).

However, it is notable that, by identifying what lies at the core of intelligence, learning is sure to be the main attribute (Minsky, 1961). Nowadays we are witnessing the development of fast-paced artificial learning processes that manage to surpass human abilities in activities such as traditional board games. An example is Google DeepMind's AlphaGo program, which triumphed in its final game against South Korean Go grandmaster Lee Sedol to win the series 4-1. AlphaGo's win over Lee is significant because it marks the first time an artificial intelligence program has beaten a top-ranked Go professional; a victory expert had predicted was still years away (Borowiec, 2016).

Minsky (2007) further argues that there is a traditional view in which emotions add extra features to plain simple thoughts. Author underlines that there is no such thing as purely logical rational thinking, as our minds are always affected by our assumptions, values and purposes. These thoughts introduce another level of complexity of designing for and understanding (artificial) emotional Intelligence as well. Lisetti and Schiano (2000) propose a multimodal intelligent interface capable of recognizing and adapting to computer users' affective states. For this purpose, authors aimed at developing an automatic facial expression interpreter, mainly in terms of signalled emotions, relying on findings on facial expressions from cognitive science and psychology.

The AI and human-computer interaction (HCI) research communities have often been characterized as having opposing views of how humans and computers should interact; it appears that there is a contrast across the two communities in conceiving the relationship between knowledge and design (Winograd, 2006). Even though achieving total artificial intelligence remains still in the future, we should create and maintain an ongoing dialogue about design implications of AI systems. With this comes responsibility to

consider the societal implications of AI design systems and educate decision makers and the general public in planning and developing such systems.

Internet of Things, Pervasive & Ubiquitous Computing

Weiser (1993) discuses that, due to the trends of unobtrusive technology and more intrusive information, the next phase of computing technology will develop nonlinearly. He states that, in the long run, the personal computer and the workstation will become practically obsolete because computing access will be everywhere: in the walls, on one's wrist, and in 'scrap' computers (i.e., like scrap paper) lying about to be used as needed. Thus, a fundamental measure of progress in computing involves rendering it as an inseparable part of our everyday experience while simultaneously making it disappear. "The most profound technologies are those that disappear," Weiser states.

In this context, Greenfield (2010) envisions computing as even more pervasive, ever harder to perceive, a phenomenon that has leapt off the desktop and insinuated itself into everyday life. Author names ubiquitous computing an "everyware", as it is capable of appearing in many different contexts and takes a wide variety of forms, affect almost everyone, even those not aware of its existence.

"The proliferation of computing into the physical world promises more than the ubiquitous availability of computing infrastructure; it suggests new paradigms of interaction inspired by constant access to information and computational capabilities; for the past decade, application-driven research on ubiquitous computing (ubicomp) has pushed three interaction themes: natural interfaces, context-aware applications, and automated capture and access." (Abowd & Mynatt, 2000)

Authors Abowd and Mynatt (2000) further note:

"Ubicomp requires addressing notion of scale, whether in the number and type of devices, the physical space of distributed computing, or the number of people using a system. We posit a new area of applications research, everyday computing, focussed on scaling interaction with respect to time. Just as pushing the availability of computing away from the traditional desktop fundamentally changes the relationship between humans and computers, providing continuous interaction moves computing from a localized tool to a constant companion. Designing for continuous interaction requires addressing interruption and resumption of interaction, representing passages of time and providing associative storage models."

Ubiquitous computing is enabled by radical improvements in microprocessor cost-performance ratios which further contributed reducing computing-device shapes and form factors. The new compact computing devices could, thus, be embedded in many parts of the environments, supporting and mediating users' daily activities. The shift toward ubiquitous computing poses multiple novel technical, social, and organizational challenges. Lyytinen and Yoo (2002) note the movement into the ubiquitous computing realm will integrate the advances from both mobile and pervasive computing; even though the two terms are often used interchangeably, they are conceptually different and employ different ideas of organizing and managing computing services. More precisely, mobile computing represents high levels of mobility but low levels of embeddedness, while pervasive computing is the opposite (Lyytinen & Yoo, 2002).

Pervasive computing environment is the one supported by computing and communication capability, integrated with users' daily activities, and thus, their motions and dynamics. Satyanarayanan (2001) describes the research agenda of pervasive computing as one that subsumes that of mobile computing but goes much further; it incorporates four additional research thrusts into its agenda: effective use of smart spaces, invisibility, localized scalability, and masking uneven conditioning. Saha and Mukherjee (2003) observe pervasive computing as a paradigm for the 21st century, and its main difference with traditional computing in the need for perceptual information about the environment. Sensing devices distributed in the environment provide pervasive systems with information such as the locations of people and devices, where the system can use this information to interact more naturally with users, moving beyond the desktop legacy.

Interlacing with the phenomena of ubiquitous and pervasive computing, the field of Internet of Things (IoT) rises as well, referring to the growing range of everyday objects acquiring connectivity, sensing abilities, and increased computing power. IoT appears to be

still a technically driven field, calling for a need for implementing UX practices within its design processes (Rowland et al., 2015).

IoT devices come in a wide variety of form factors with varying input and output capabilities; some may have screens, such as heating controllers or washing machines, while some may have other ways of communicating with us, such as flashing LEDs (light-emitting diodes) or sounds (Rowland et al., 2015). Rowland et al. (2015) describe that "when we talk about IoT, we tend to focus on the devices, particularly those with striking or novel forms, but the behaviour of the device might be generated by a program that lives on another device on the network (i.e., a server); we call this the Internet (or "cloud") service".

The shift from desktop to mobile and ubiquitous computing means that we now use computers in a wide variety of situations, and it is now common to use one service across multiple devices with different form factors. Complex services can have many users, multiple UIs, many devices, many rules and many applications, thus, "what started out as a straightforward system has become a complex web of interrelationships "(Rowland et al., 2015). It is note, therefore, that UX for connected devices is not just about UI and interaction design, rather it requires designers to expand the reasoning and practices on other fields as industrial design, service design, conceptual models, productization, as well as the inter-usability in-between the diverse products.

Some practical design application cases of IoT/UbiComp/AmI, as representatives of cyber-physical systems are presented in the following, showing use cases in diverse environments (e.g. hospital, home, retail, automotive).

Case 1: HealWell, Signify, 2012

HealWell (Fig.1) is the lighting solution for Patient Rooms, designed to improve the healing environment, by supporting patient comfort & wellbeing and staff performance with light that adapts to individual needs. The concept aims to create a more effective healing environment using the natural power of light. HealWell aligns patient room lighting automatically with the human circadian rhythm to help hospital patients sleep better, feel happier and heal faster.

HealWell takes an evidence-based approach to lighting with ceiling modules simulating daylight rhythms with dynamic light levels and tones while providing also required visibility for medical examinations. Patients can personalize lighting from their beds while subtle LED orientation lighting helps health workers navigate quietly. Studies show HealWell helps patients sleep more quickly and deeply, improving their mood.

Figure 1.
HealWell product used within the hospital room, showing changes in dynamic lighting adaptations.

Case 2: Google Home device, Google, 2016

Google Home (Fig.2) is a brand of smart speakers developed by Google. The devices enable users to speak voice commands to interact with services through Google Assistant, the company's virtual assistant. Both in-house and third-party services are integrated, allowing users to listen to music, control playback of videos or photos, or receive news updates entirely by voice. Google Home devices also have integrated support for home automation, letting users control smart home appliances with their voice.

Hands-free help from the Google Assistant enables getting answers, playing songs, controlling smart home appliances, and other activities, with the user's voice. It is possible to listen to music, playlists, audiobooks, get personalised help with the schedule, reminders, calls, news and more. Google Home works with Chromecast, meaning that the user can also stream shows, films and music on the TV or speakers.

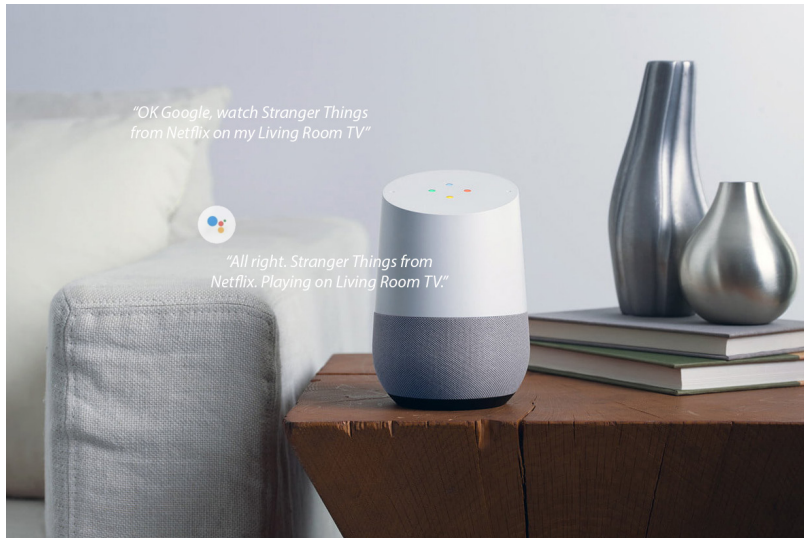


Figure 2.
Google Home product used within a home environment, providing audio feedback to the user.

Case 3: Amazon Go, Amazon, 2016

Amazon Go (Fig.3) stands for the next innovation in retail history, which is the personalized physical store (i.e. a physical experience that is different from one individual to the next, likely in this case via Amazon's mobile applications), enabled by indoor localization systems.

The concept involves three key steps: (1) The consumer downloads an app; (2) He or she scans the app's QR code on a boarding-an-airplane-like device upon entry; (3) He or she then walks into the store and takes whatever he or she wants without talking to anyone. It can be comprehended as a multi-player video game: a customer enters a store like the main player character in the game, and then via his or her voice, physical movement or interactions with a mobile phone, he or she begins to unlock experiences within a physical space that are 100% unique to him or her. Experiences, like diverse deals of online shopping or live streaming, can then be unlocked real time within the store.

Figure 3.
Amazon Go physical store without cashiers.

Case 4: Concept-i vehicle, Toyota, 2017

The Calty Design Research centre has developed a concept of automotive UX that is intelligent, friendly and helpful. Intelligent cars that continually learn, and, in turn, keep getting smarter; cars that get to know the user and its needs, and then start to anticipate them as well. Team envisioned a bond between car, driver and society that revolves around trust and loyalty. Presented as more "pal" than interface, Yui (Fig. 4), in tandem with AI, anticipates users' needs and informs the car so that Concept-i can consider and execute that next action accordingly.

Through biometric sensors present in the car, Concept-i can detect driver's feelings and states. That information then gets analysed by the car's AI. If, for example, a driver is feeling sad; the AI will analyse the emotion, make a recommendation and if necessary, take over and drive him/her safely to the final destination. So, safety and protection are presented as a major benefit of the envisioned relationship.

Figure 4.
Concept-i vehicle's interior design with dynamic adaptions.

The four presented cases show relevance of well-designed cyber-physical systems, in regard to user's experience. Designing for desirable user experiences enables planning for resiliency of a design system over a period of time in terms of user engagement. All the presented projects are complex in terms of their final product and diverse nature of touchpoints involved, and thus, in terms of influencers on the experience. Comprehending UX within cyber-physical systems, such as those of the examples shown, is a challenging quest. For that reason, it is needed to ensure a holistic overview of the impact of the design system on the experience, by addressing the systems in their full complexity. Having a good approach in design strategy oriented towards experiences could, thus, ensure sustainable design solutions on long-term bases.

The shown design cases are everyday design challenges that target everyday life activities and states. They appear to be sustainable as they are adaptable dynamic systems. The examples show how some designs enhance the activities in daily lives at home and in car, in shops and healthcare institutions. Google Home enhances activities within the house by taking care of tedious chores and acting as a personal reminder as well, while Concept-I vehicle automates in-car activities and improves the personal well-being states by anticipating user's needs. Amazon Go makes shopping more efficient and faster in physical stores, while HealWell improves moods and states of a particular group of users, such as hospital patients, and dynamically adapts the environment according to ongoing activities.

In these cases, the digitized systems enhance activities in previously static spaces, thus improving daily lives of users. The cases, as complex cyber-physical systems that are enhancing daily activities, are provoking certain behavioural changes in users as well. Among the behavioural changes user values are observable, which influence the desirability and acceptability of design solutions. In this context, entities that are project stakeholders of design systems impose the need for designing for value alignment perceived as such from the side of users, for fostering acceptability and desirability. Such a design approach can show to be sustainable for the design product, i.e. system, development over a period of time.

Interactive Architecture

In his book, City of bits: space, place, and the infobahn, Mitchell (1996) wrote:

"Once we have both a real three-dimensional world and computer constructed virtual ones, the distinction between these worlds can get fuzzed or lost.

...Places in the cyberspace of the Net are software constructions. Each piece of software running anywhere – on any machine or collection of machines in the Net – creates environments for interaction, virtual realms that you can potentially enter.

...Spatial cities, of course, are not only condensations of activity to maximize accessibility and promote face-to-face interaction but are also elaborate structures for organizing and controlling access."

"Ubiquitous computing has a vision of information embedded in the world around us, yet the built environment, while familiar, is also the subject of design; recently, architects have also seen digital elements incorporated into the fabric of buildings as a way of creating advanced spaces, and environments to meet the dynamic challenges of future habitation. " (Dalton et al., 2016)

As computing is becoming embedded in homes, streets and buildings, the demands to understand the role of space and architecture is becoming critical to HCI; the interaction spreads to a spatial level, thus requiring a larger physical scale comprehension and overview of the context. In parallel to this need, architecture as a field is becoming far more engaged with the digital experiences as well. Dalton et al. (2012) suggest that Architecture and HCI are not discordant; "while there are clearly differences, Architecture, as a design profession is hundreds of years old, while HCI is relatively new, they do offer many similarities". The bridging of physical and digital dimensions through sensors and actuators requires an interdisciplinary dialogue and explorations at the intersection of moving bodies, information technologies and architecture. Interactive architecture calls for understanding embodied interaction, a definition of interaction design for placemaking while mapping the intangible elements of the projects, such as users' activities and experience within the physical space.

Houben et al. (2017) discuss the meaningful integration of

interactive media in architecture, with the aim of informing emerging HCI research on human-building interaction from a 'building' perspective, presenting a design rationale of a permanent, sound-based media facade that will consist of the dynamic mechanical actuation of multiple wooden window frames. Authors observe that current media architecture practice demonstrates the rich potential of interactive media in the built environment for various economic, social and cultural purposes, however, the meaningful integration of interactive media with(in) architecture remains challenging.

Fox (2016) underlines that designing interactive architecture is not so much about inventing, as it is about understanding what technology exists and extrapolating from it to suit an architectural vision.

"...new architecture projects have been built at scales that both move beyond the scope of the architectural exhibit as test bed and push the boundaries of our thinking in terms of material performance, connectivity and control. Our architectural surroundings have become so inextricably tied to technological trends that the two ultimately and simultaneously respond to and define each other... interactive architectural environments are built upon the convergence of embedded computation and a physical counterpart that satisfies adaptation within the framework of interaction. "Fox (2016)

Field of interactive architecture relates also to the notion of tangible interaction, which has grown in practice in recent years.

"The Tangible Media Group at the MIT Media Laboratory moved from graphical user interfaces (GUIs) to tangible user interfaces (TUIs) in the mid-1990s. TUIs represented a new way to embody Mark Weiser's vision of ubiquitous computing by weaving digital technology into the fabric of the physical environment, rendering the technology invisible. Rather than make pixels melt into an interface, TUIs use physical forms that fit seamlessly into a user's physical environment. TUIs aim to take advantage of these haptic-interaction skills, an approach significantly different from GUIs. The key TUI idea is to give physical form to digital information, letting serve as the representation and controls for its digital counterparts. TUIs make digital information directly manipulatable with our hands and perceptible through our peripheral senses through its physical embodiment.

...The TUI builds upon our dexterity by embodying digital information in physical space. TUIs expand the affordances of physical objects, surfaces, and spaces so they can support direct engagement with the digital world." Ishii (2008)

Beyond the Tangible Bits a vision for Radical Atoms emerged:

"In 2012, Radical Atoms takes a leap beyond Tangible Bits by assuming a hypothetical generation of materials that can change form and appearance dynamically, becoming as reconfigurable as pixels on a screen. Radical Atoms is a computationally transformable and reconfigurable material that is bidirectionally coupled with an underlying digital model (bits) so that dynamic changes of physical form can be reflected in digital states in real time, and vice versa.

Radical Atoms is the future material that can transform their shape, conform to constraints, and inform the users of their affordances. Radical Atoms is a vision for the future of human-material interaction, in which all digital information has a physical manifestation so that we can interact directly with it. We no longer think of designing the interface, but rather of the interface itself as material. We may call it Material User Interface (MUI)." Ishii (2008)

Some concrete examples of projects that depict Interactive Architecture are presented in the following.

Case 1: Hylozoic Ground by Philip Beesley Architect at Venice Architecture Biennale, 2010

Hylozoic Ground (Fig. 5) project transformed the Canada Pavilion into an artificial forest made of an intricate lattice of small transparent acrylic meshwork links, covered with a network of interactive mechanical fronds, filters, and whiskers. Tens of thousands of lightweight digitally fabricated components were fitted with microprocessors and proximity sensors that reacted to human presence. This responsive environment functions like a giant lung that breathes in and out around its occupants. Arrays of touch sensors and shape-memory alloy actuators create waves of empathic motion, luring visitors into the eerie shimmering depths of a mythical landscape.

Beesley's visionary architecture affects people on an emotional and poetic level, linking the animate and the inanimate. The sophisticated technologies used in the work are also being directly translated into architectural envelopes that include manufactured filtering and shading systems.

Figure 5. Visitor interacting with the Hylozoic Ground structure presented during the exhibition.

inFORM (Fig. 6) is a Dynamic Shape Display that can render 3D content physically, so users can interact with digital information in a tangible way. inFORM can also interact with the physical world around it, for example moving objects on the table's surface. Remote participants in a video conference can be displayed physically, allowing for a strong sense of presence and the ability to interact physically at a distance. inFORM is a step toward the vision of Radical Atoms.

Case 2: inFORM, Tangible Media Lab, MIT, 2013

The authors propose to use shape displays in three different ways to mediate interaction: facilitate, providing dynamic physical affordances through shape change; restrict, guiding users through dynamic physical constraints; and manipulate, actuating passive physical objects on the interface surface. They demonstrate the concept on a new, high-resolution shape display.

Figure 6.
Researcher interacting with the inFORM prototype.

Designing for Experiences 1.1.3

CPS design is influenced by user-centric methods where the user is placed at the centre of the design activity and asked to give feedback through evaluations and tests to improve the design, or even co-create the design with a group of designers, or users. The challenge of designing and implementing a CPS is the lack of models enabling the analysis of the system requirements while designing the system, and of verification and testing methods when the system is implemented. Designing a CPS implies planning for interactions that are contextual and open-ended, triggered by the unrestricted activity of the users within the environment.

Definitions of UX, following a chronological review of academic publications:

Forlizzi & Ford (2000) reason on UX in design practices through the following:

"Experience design is a design approach which focuses on the quality of the user experience during the whole period of engagement with a product: from the first impression and the feeling of discovery, through aspects of usability, cultural relevance and durability, to the memory of the complete relationship. Also, it considers the form, content and context of communication occurring over time. The simple way to think about what influences experience is to think about the components of a user-product interaction, and what surrounds it. Users represent how people influence experience. Users bring to the moment all their prior experiences, as well as their emotions and feelings, values, and cognitive models for hearing, seeing, touching, and interpreting. Products represent how artefacts influence experience."

Forlizzi and Battarbee (2004) reasoned about a framework of user

experience for the design of interactive systems. They formulated the framework from an interaction-centred perspective, lined up with social contexts. Within this perspective, they observed three types of user-product interactions, which, in a context of use, brought three types of experience. The types of user-product interactions are Fluent, Cognitive and Expressive. The first one is automatic, the second one creates a deeper bound and comprehension of a product at hand, and the third forms an actual in-depth relationship to the product. The three types of experience are recognized as Experience, An Experience, Co-Experience. These three types are gradual in their strength of bound and comprehension of a certain product. They refer to the levels of influence and creation of meanings that certain design outcomes can provide to an individual, i.e. the end-user.

In 2003, Sanders wrote that the term "Experience Design," whose aim is to design users' experiences of things, events and places, became very popular and widespread in use. The author acknowledged that we can never really "design experience," rather experiencing is a constructive activity; if we have access to both what is being communicated and what experiences are influencing the reception of communication, then we can design for experiencing. Furthermore, the author noted that there are many ways we can learn from people about their memories, their current experiences and their ideal experiences.

According to Shedroff (2003), experiences (and, by default, products, services, events, etc.) are much richer than most design processes reflect. McCarthy et al. (2006) note that there are varieties of experiences, good and bad, and we need to characterise these varieties if we are to improve user experience, arguing that enchantment is a useful concept to facilitate closer relationships between people and technology.

In 2006, Hassenzahl and Tractinsky proposed a research agenda for UX, following their notion that, by that moment, there was no unique and clear meaning attributed to this term among practitioners and researchers. The authors aimed at providing a stimulus for further UX research, identifying the following streams in the field:

"A glance at the literature on UX, such as the 'Design and Emotion' conferences (e.g. McDonagh et al. 2003), the 'Funology' workshops

and publications (Blythe 2003, Blythe et al. 2004), Helander and Tham's (2003) special issue on 'Hedonomics', the emerging literature on 'Aesthetics' (e.g. Tractinsky in press), or the work of Pat Jordan (e.g. Jordan 2000) and – recently – Don Norman (2004a), reveals three major perspectives. One thread predominantly deals with addressing human needs beyond the instrumental; a second thread stresses affective and emotional aspects of the interaction; and a third thread deals with the nature of experience (emphasizes two aspects of technology use: its situatedness and its temporality). "

Hassenzahl and Tractinsky, however, discuss that none of the three perspectives fully captures the phenomenon of UX practices. Accordingly, they define UX as "a consequence of a user's internal state (predispositions, expectations, needs, motivation, mood, etc.), the characteristics of the designed system (e.g. complexity, purpose, usability, functionality, etc.) and the context (or the environment) within which the interaction occurs (e.g. organisational/social setting, meaningfulness of the activity, voluntariness of use, etc.)." Finally, the authors state: "From our perspective, one of HCI's main objectives in the future is to contribute to our quality of life by designing for pleasure rather than for absence of pain; UX is all about this idea."

Hassenzahl (2008), in the light of the HCI field of design practice, defines UX as a momentary, primarily evaluative feeling (good-bad) while interacting with a product or service. Therefore, the author states that "UX shifts attention from the product and materials (i.e., content, function, presentation, interaction) to humans and feelings – the subjective side of product use," where "UX becomes a temporal phenomenon. "

Tarssanen and Kylänen (2009) acknowledge that experiences are not static units like products, as they occur in a process during which interactions take place in a certain setting. For bringing meaningful experiences in a commercial setting, authors propose the assessment of experiences according to following ten characteristics: (1) One's concentration is heightened and focus more intense, involving all senses, (2) One's concept of time is altered, (3) One is touched emotionally, (4) The process is unique for the individual and has intrinsic value, (5) There is contact with the 'raw stuff', the real thing, (6) One does something or undergoes a transformation, (7) There is

a sense of playfulness, (8) One has a feeling of having control over the situation, (9) There is a balance between the challenge and one's own capabilities, (10) There is a clear goal.

Garrett (2010) argues:

"User experience is not about the inner workings of a product or service. User experience is about how it works on the outside, where a person comes into contact with it. When someone asks you what it's like to use a product or service, they're asking about the user experience. Is it hard to do simple things? Is it easy to figure out? How does it feel to interact with the product?"

It is to note, however, that designing products with the user experience as an explicit outcome means looking beyond the functional or aesthetic. For the users who do come, you must set out to provide them with an Experiences provided should be cohesive, intuitive, and maybe even pleasurable. Garrett's book (2010) is primarily about the user experience of one particular kind of product, which are the Web sites. Author states that on the Web, user experience becomes even more important than it is for other kinds of products; but the lessons we've learned from creating user experiences on the Web can be applied far beyond its boundaries.

Observed by Hassenzahl (2010), experiences emerge through situations, objects, people, their interrelationships, and their relationship to the experientor (the person who undergoes an experience).

When it comes to understanding UX within systems of ubiquitous computing, Kuniavsky (2010) stated that it goes well beyond the utility of the device. It is a pleasure that's coupled with satisfaction, and definitions from researchers and practitioners extend all the way from examining neurological phenomena to macroeconomic behaviours. "Somewhere between counting the firings of neurons and calculating profit and loss statements is a practical set of boundaries that defines what to consider in a design process. Usability, for example, is the practice of making things easy to use. It is often equated with user experience, but while bad usability can break a good product, good usability is insufficient to create a good experience." Kuniavsky (2010).

In his book, Smart things: ubiquitous computing user experience design, Kuniavsky (2010) provided his definition of UX:

"The user experience is the totality of end users' perceptions as they interact with a product or service. These perceptions include effectiveness (how good is the result?), efficiency (how fast or cheap is it?), emotional satisfaction (how good does it feel?), and the quality of the relationship with the entity that created the product or service (what expectations does it create for subsequent interactions?)."

Gegner et al. (2011) recognize a difference in assessments form "wow" moments to a long-term experience.

Pine and Gilmore (2011), on the aspects of emerging Experience Economy, argue that consumers increasingly desire neither goods nor services but sensation filled experiences that engage them in a personal and memorable way.

It is to note that the experience design field is a lot more than a trivial say "I'm a user experience designer, I design websites", or "I design apps" (Norman, 2016). Following this statement, Norman (2016), known as the inventor of the term "user experience", continues:

"…they have no clue as to what they're doing, and they think the experience is that simple device, the website, or the app, or who knows what. No! It's everything—it's the way you experience the world, it's the way you experience your life, it's the way you experience the service. Or, yeah, an app or a computer system. But it's a system that's everything."

Evans (2017) assesses user experience through "bottlenecks of attention, perception, memory, disposition, motivation, and social influence." Author states that digital innovations must survive the psychological bottlenecks of attention, perception, memory, disposition, motivation, and social-influence if they are to proliferate.

"If the bottlenecked user is our fundamental assertion, then our fundamental assumption is that there exist many good memes worth spreading that fail due to avoidable misalignments with our nervous systems. We're talking about bottlenecks as the myriad of fundamentally viable memes that, through some shortcoming or

flaw in their design, fail to pass through the bottlenecks that we use to block out the noise." Evans (2017)

Wright et al. (2018) discuss experience from a design perspective as consisting of four threads: compositional, sensory, emotional and spatial-temporal.

Sheppard et al. (2018) for the McKinsey Quarterly report on The Business Values of Design write:

"The boundaries between products and services are merging into integrated experiences." Authors advice companies to practice UX design for improving their revenue. "In practice, this often means mapping a customer journey (pain points and potential sources of delight) rather than starting with "copy and paste" technical specs from the last product. This design approach requires solid customer insights gathered first-hand by observing and—more importantly—understanding the underlying needs of potential users in their own environments."

CPS & AmI Design Practices 1.1.4

Digital technologies are employed to create new user experiences that enhance and extend the way people work, communicate and interact. This research aims at identifying processes for designing for user experience within systems of spaces enhanced by digitized services. The design of such systems is an activity that belongs to diverse fields of practices, such as: Architecture/Interior Design, Human-Computer Interaction (HCI), and Interaction/Service Design. These disciplines have different approaches and focuses, nevertheless their activities always affect the way the user perceives and experiences the space. There is a need, thus, for merging and intertwining the known fields of practices, in order to expand the design practice itself for responding to the needs of emerging projects.

Assessment of the user's experience within systems of enhanced spaces could find suitable models in both strategic planning for customer experience, i.e. Service Design, as well as planning for detailed interaction flows within design interfaces, i.e. Interaction Design. In terms of design domains, systems of enhanced spaces cover a wide span of practices from AI towards Spatial Design.

On the Merge Between Service & Interaction Design

Service Design differs from the design of products in semantical terms; products are tangible objects that exist in both time and space; services consist solely of acts or process(es) and exist in time only (Lynn Shostack, 1982). It is observable that services are rendered, while products are possessed, thus services cannot be possessed, rather they can only be experienced (Lynn Shostack, 1982). Pine and Gilmore (1998) expand further on their concept for Experience Economy, noting that, from the customer's point of view, services are equal to "time saved", while experience design equals to "time well spent".

"While it is true that designers' activities usually have focused

on material artefacts (whether industrial products, spaces, or architectures), rather than on systemic solutions including services, it also is worth remarking that product/service systems (PSS) often are marketed as products, and several aspects of the development of such systems are related to the discipline of design, from the analysis of technological potentials to the investigation of users' behaviour and attitudes with respect to new products, technologies, and services. "(Morelli, 2002)

Service organizations have long recognized the importance of the customer experience for customer satisfaction and loyalty (Zomerdijk & Voss, 2010). An experience occurs when a customer has any sensation or acquires knowledge from some level of interaction with the elements of a context created by a service provider, therefore, many service organizations are increasingly placing the customer experience at the core of the service offering (Pullman & Gross, 2004). Pullman and Gross (2004) observe then that the main characteristic of services is that they encourage customer loyalty by creating emotional connections through engaging, compelling, and consistent contexts. Morelli (2009) in this context proposes an active participation of customers to the value production process, shifting the role of industrial companies towards facilitators of a process of value co-production.

Interaction Design is seen as the design of subjective and qualitative aspects of everything that is both digital and interactive, creating designs that are useful, desirable and acceptable (Moggridge & Atkinson, 2007). Designing interactive systems is connected with developing high quality interactive systems and products that fit with people and their ways of living, where user interface is all those parts of the system which people come into contact physically, perceptually and conceptually (Moggridge & Atkinson, 2007).

Saffer (2010) argues that Interaction Design as a discipline tricky to define as it has interdisciplinary roots: in industrial and communication design, human factors, and human-computer interaction. Furthermore, the design product is invisible and functioning behind the scenes; it deals with behaviour, which is much harder to observe and understand than appearance. Furthermore, Saffer (2010) notes that interaction designers design for the possibility of interaction, while the interaction itself takes place between people,

machines, and systems, in a variety of combinations.

Other authors, such as Wigdor and Wixon (2011), opt for defining the design field through the modalities of interaction and shaping of interfaces, by proposing input and output technologies that offer the opportunity to create a more natural UI (NUI). The NUI lies in the UI and experiences we create for use with those technologies and how we leverage the potential of new technologies to better mirror human capabilities, optimize the path to expert, apply to given contexts and tasks, and fulfil our needs (Wigdor & Wixon, 2011). Authors use the word "natural" as referring to the way users interact with and feel about the product, or more precisely, what they do and how they feel while they are using it.

Service Design appears to be a responsibility of marketing and/or management profiles, as its design outcome are service blueprints for businesses development, which details the processes within a company and how each process interacts with other processes. One of the most fundamental aspects of service production is the intertwining of stakeholders—most notably, providers and clients—in exchange relations. Exchange relations establish the context for attributing particular roles to the stakeholders involved in service co-production (Secomandi & Snelders, 2011). In this context, Service Design is related to design practices for digitally enhanced spaces by supporting definitions of relations within a complex system, as well as their connections and flows across diverse touchpoints. Interaction Design, on the other side, deals with the design of all of the details of touchpoints in-between the users (i.e. customers) and other stakeholders. Design outcome from this field are definitions of details that influence and guide the interaction processes, as well as the movements, perceptions and behaviours from the side of the user.

On the Merge Between AI & Spatial Design

Besides processes that move from Service towards Interaction Design, projects for enhanced spaces, i.e. CPSes, imply designing on the merge between AI and Spatial Design as well. This can be observed through lenses of design material, which in this particular case supports the notion of designing systems of bits and bricks (Haw & Ratti, 2012). More precisely, such system calls upon definitions

of bits (software) through AI algorithms that support operations and interactions initiated by the complex system, as well as bricks (physical elements) as the shaping of spatial and tangible material forms of the system. Merging and harmonising the relation among the two builds up a unique design system.

One long-term goal of machine learning and AI research is to produce methods that are applicable to highly complex tasks, such as perception (vision, audition), reasoning, intelligent control, and other artificially intelligent behaviours (Bengio & LeCun, 2007). Authors argue that, in order to progress towards this goal, the AI community must endeavour to discover algorithms that can learn highly complex functions, with minimal need for prior knowledge, and with minimal human intervention. Refined AI which are capable of supporting complex learning processes and automating outputs according to predicted desirable outcomes are a backbone for user interaction flows within AmI systems.

On the other side, Spatial Design provides a backbone for tangible interactions and activity flows within a certain environment. Spatial design essentially deals with shaping of human shelters (Pile, 2005) through 3D volumes, structural grids and materials (Ching, & Binggeli, 2017). In regard to spatial layout, Hillier et al. (1986) tackle the question of "architectural determinism" arguing that the layout in itself generates a field of probabilistic encounter, with structural properties that vary with the syntax of the layout. Architectural determinism can be defined as the belief that architectural design affects human behaviour in some way- that is, that it acts as an independent variable in a describable process of cause and effect (Hillier et al., 1986). Considering that spaces are mechanisms for generating a potential field of probabilistic co-presence and encounter, Ulrich (1991) also points out at the effects of spatial design on wellness of inhabitants and importance of designing for states of well-being.

Considering the design of AI systems, it is observable that the "design material" are codes, algorithms, data and information. Spatial Design employs actual physical construction material. Even though the materials and design outcomes differ, the two fields inevitably merge within a holistic design process for defining a design outcome of enhanced spaces, i.e. CPSes.

RESEARCH OBJECTIVE 1.2

The research aims to contribute the field of User Interaction and Experience Design, by providing a discussion on a potential design strategy and toolset to be applied within the emerging projects for spaces enhanced by digitized services. Peculiar nature of the design field deals with projects of high complexity imposed towards users' experience, that appears not to be addressed accordingly with current tools employed in practices. Therefore, the research has identified a necessity for expanding the current practices in the UX field by supporting them with the set of tools to be used as a backbone for structured design processes for the indicated field. Design tools, in this case, facilitate creation of a common language between all the parties and stakeholders involved in the design project for identifying and communicating user values as a focus of the design activity.

1.2.1 Research Questions

From the identified area of design practice, research questions emerged targeting identification of an Ambient UX approach. The research provides a contribution to the Experience Design filed practitioners and strategists, as well as the community of HCI practitioners and interactive and smart Architecture systems.

The objective of the research is definition of a strategical method and toolset that could support the process of managing users' experiences within cyber-physical systems. The aim is to develop a framework for a design process that emphasizes user experience values, and a toolset that would support such processes within a multi-stakeholder working environment. The conceptual framework is referred to as Ambient UX.

Research questions are shaped as the following:

- What might be the suitable design strategy for Ambient UX?
- How to map user experiences and how to represent its values within cyber-physical systems?
- Are the currently practiced UX design tools enough for addressing projects of Ambient UX? Is an update needed?

Defining Ambient UX 1.2.2

Within this thesis, I am investigating the concept of Ambient User Experience (UX), by proposing an update to current UX practices, enabling them to face projects for designing systems of enhanced spaces. Ambient UX, in this view, is a conceptual strategical framework that supports the design of interactive spaces by focusing on users' experience. It refers to the evaluation of experiences beyond mere usability, considering the creation of meanings and the hedonic qualities, which seemed to be neglected by the approaches in the HCI field for a long period (Von Wilamowitz et al., 2006; Karapanos et al., 2009), as well as social and ethical implications that influence the experiences.

For initiating a proposal for an Ambient UX design strategy, it is important to reason on relations of stakeholders involved in the project and role of a UX practitioner. Considering these complexities of relations among project stakeholders, the strategic design framework for Ambient UX is shaped accordingly within the thesis. The framework consists of a definition of Design Domains (what is to be designed) and User Values (why it is designed). The framework is described in detail and discussed in the following chapter of the thesis.

Why the Need for Defining Ambient UX

Dealing with abstract and intangible concepts like experience is challenging for the practitioners in the field, as well as design educators of the same thematic area. Certainly, when it comes to designing systems of intelligent interactive spaces, another layer of complexity is added to these efforts.

A shared comprehension of the peculiar UX practices within these complex projects is required, as well as development of a common language. The importance of establishing a common language in communicating design projects is evident for the design practice

and industry related projects which require multi-stakeholder collaborations among representatives of diverse professional backgrounds. The role of a UXer is being shaped through industrial practices as a figure capable to understand and frame complexity of emerging design streams, and envision and manage the novel design challenges while ensuring that all the stakeholders, designers and non-designers, are gathered around the same project drivers, which are the users' experiences.

Therefore, defining the field of Ambient UX practices helps shaping a common language among all the parties involved in the projects of spaces enhanced by digitized services that approach them with a focus on user's experiences. Designing CPSes requires expanding current UX practices for addressing the projects' complexities accordingly, thus an Ambient UX framework is an attempt to build a shared thought around this issue. Equally, the shared design framework and common language, embodied through design tools, can be established and nurtured within the educational sector for empowering future UX design practitioners.

1.3 RESEARCH METHODOLOGY

Scheme

According to presented research questions, two main research areas are identified as: (1) design strategy for Ambient UX, and (2) recommendations for correspondent design tools. For designing the research methodology to respond to research aims, I referred to Blessing and Chakrabarti's (2009) argumentation on Design Research Methodology (DRM) schemes and nomenclature. Namely, the authors had a goal of identifying common research methodology and terminology in design, as they identified that shared view of the goals and framework for doing design research was missing.

DRM identifies few main stages that can be iterated with diverse sequencing according to a specific research project. "In some cases, the literature provides sufficient material for a particular stage; in other cases, a research project may focus on only one stage for an in-depth study, because of time restrictions or because the project is part of a larger programme" (Blessing & Chakrabarti, 2009).

Within my research methodology, I start with a ***research clarification (RC)*** which is a review-based study, further I conduct a ***descriptive study I (DS I)*** which is review-based as well, followed by the ***prescriptive study I (PS I)*** which is a comprehensive one, and these two studies are related to the design strategy for Ambient UX. Following is the research area for correspondent design tools, and it is composed of ***descriptive study II (DS II)*** which is again review-based, and the ***prescriptive study II (PS II)*** which is an initial study that opens up the argument for further research.

Figure 7 shows the scheme of tailored research methodology through two main areas of inquiry, with the research methods applied within them and main findings that derived.

RC phase within the methodology brought up the definition of a research aim as: Proposing design strategy and tools for systems of enhanced spaces. Furthermore, it brought up also a research hypothesis

as the following: Need for upgrading current UX tools in practices.

The ***DS I*** stage aims at investigating the phenomenon of design field through reviewing the literature, undertaking empirical research, and, in addition, through critical reflection. In this step I am investigating the phenomenon of design in the particular application field of spaces enhanced by digitized services (i.e. CPS). The objective of this stage is to obtain a better understanding of the existing situation by identifying and clarifying in more detail the factors that influence this design field. Namely, the literature review focused on comparative case studies for identifying Design Domains within the projects of targeted application field, as well as the UX design theories, from which derived a synthesis on User Values.

The objectives of the ***PS I*** stage is to use the understanding obtained in DS I to determine the most suitable factors to be addressed in PS (the Key Factors) in order to improve the existing situation, and in this step the framework for Ambient UX is defined. PS I develops the Intended Support, that addresses the Key Factors in a systematic way. In this step three practical design projects took part that helped the verification of the Ambient UX framework. UX research was conducted in all three projects that called for alignment of values between the users and the design outcomes. The three projects were selected as each of them represents strong influence on User Values through one of the three previously identified Design Domains. This step, PS I, developed an Impact Model, which is the verified Ambient UX framework, to be used as a starting point for the evaluation in the following DS II.

The ***DS-II*** stage focuses on identifying whether the support can be used for the task for which it is intended and has the expected effect on the Key Factors; it also identifies whether the expected impact, as represented in the Impact Model, has been realised. More precisely, in this step I analyse gathered tools for UX value alignment, which are to be correspondent to the design strategy. The gathered tools are analysed according to the Ambient UX framework and the two conceptual groups it implies, i.e. Design Domains and User Values, and a synthesis of tools' structural elements is provided accordingly.

The last step in the research methodology, ***PS II***, delivers an Initial Study which closes the research activities and prepares the results for use by others. Within this step, I confronted the Ambient UX Framework with the synthesis of structures and elements of gathered tools, and I give a proposal on the six upgrade issues that emerged as mismatches between the framework and the tools. The six issues are a recommendation for potential upgrade of the tools and, thus, an enlargement of UX design practices for satisfying the needs of CPSes. Providing the strategical design framework, discussion on suitable tools and recommendation on conceptual issues for the enlargement, the research leaves the path open for further research that might be focused on development of a software platform that could embody the conceptual outcomes and support Ambient UX practices in a more tangible manner.

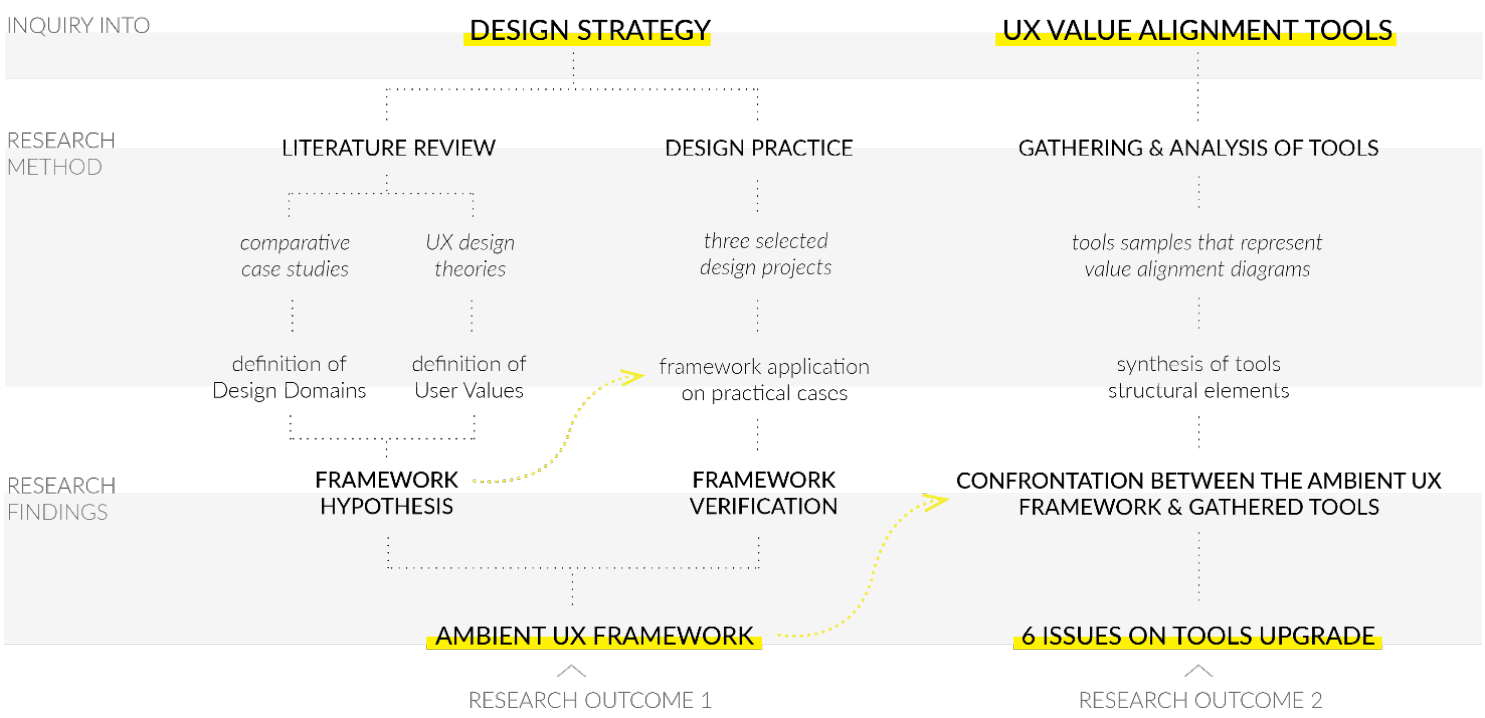


Figure 7. Scheme for the overall research methodology with areas of inquiry, applied methods and main findings.

02

Design Strategy for Ambient UX

The chapter analyses a design strategy and proposes an Ambient UX design framework hypothesis accordingly. The framework consists of a definition of Design Domains (DDs) and User Values (UVs) for Ambient UX.

Design Domains are analysed through possible outcomes of complex systems of enhanced spaces, in terms of what can a designer manipulate with and shape in a certain sense. More precisely, what are the domains and elements a designer can manipulate with in order to create enablers and constraints for certain activities, thus influencing the user's experience. The observations provide possible grouping of design outcomes as physical products, information flows and triggering of social relations. In this context, the Design Domains are interpreted through three architectures within targeted design systems: Spatial, Informational and Relational. Besides the architectures, the element of Time is also considered, presented as a variable in-between the architectures, that, with same importance, influences the activities and experience.

Defined Design Domains are in direct relation with the user's experience, and therefore, the User Values, perceived as such in regard to the interaction with a designed system. Experience is, thus, influenced on diverse levels, scaling from personal towards social perceptions and acceptability. The levels here are discussed as: Usability, Meanings and Motivations, and Social Consensus. This is to say that recognized architectures and time as a variable influence comfort and wellbeing, creation of meanings over time, and social relations of a user of the interactive system.

Finally, an overall hypothesis for an Ambient UX design framework is provided, followed by a brief discussion on the elements and framework as whole.

2.1 Observing Design Domains for Ambient UX

2.1.1 Design Process
Stages in the Process
Role of the Designer

2.1.2 Understanding the Imposed Complexity
Systemic Design principles
Different Communications with Different Stakeholders

2.1.3 Defining the Design Domains
Mapping Activities through Constraints and Enablers
Three Architectures and Time as a Variable
Spatial Architecture
Informational Architecture
Relational Architecture
Variable of Time

2.2 Observing Users' Values for Ambient UX

2.2.1 Evaluating User's Experience
UX Evaluation in Design Processes

2.2.2 Three Levels for Evaluating Ambient UX
Usability
Meanings & Motivations
Social Consensus

2.3 Ambient UX Design Framework Hypothesis

Discussion on User Values & Design Domains
Framework Scheme

2.1 OBSERVING DESIGN DOMAINS FOR AMBIENT UX

In the following, discussion on possible design outcomes of the projects focused on Ambient UX, and complex systems of spaces enhanced by digitized services (i.e. CPSes), is provided. Design outcomes are identified as Design Domains (DDs), and are described on a level of a conceptual framework for Ambient UX. The framework reflects a strategy to look up to while designing for Ambient UX.

Initially, an overview of most commonly discussed schemes for a design process is provided. Main stages of a design process are diversified according to strategical and creative phases, with loops of design and evaluation activities. An overview on role of the designer, as an interpreter and advocate, is provided as well. Furthermore, the complexity of targeted design projects is observed, and the need for tailoring different communication in regard to different project phases, design outcomes and stakeholders involved. Finally, Design Domains are described in form of three Architectures and Time as a variable among them.

Design Process 2.1.1

Stages in the Process

Design processes that have as core focus values that are based on User Experience are often swapped for models of Design Thinking (Plattner et al., 2009). Design Thinking is a term that gained popularity in business media and became a label for the awareness that any kind of business and organisation can benefit from the designers' way of thinking and working (Tschimmel, 2012), i.e. identifying essential mental strategies of designers while working on a project. Two decades before becoming a popular concept for innovation, design thinking had been defined and studied by an international research group, solely as the cognitive process of designers (Cross et al., 1992; Eastman et al., 2001). Traditionally, the method relies on designer's capacity to consider and balance at the same time: (1) human needs and behaviour, (2) technological trends and resources, and (3) constraints and opportunities of a project or business (Tschimmel, 2012).

Cross (2011) observes that visualising ideas through sketching "provides a temporary, external store for tentative ideas, and supports the 'dialogue' that the designer has between a problem and a solution." The form of drawing is seen as a convenient media of expression for intangible conceptual models. The models for Design Thinking methods describe effectively conceptual phases within design processes.

From literature review, the most commonly used and referenced design process schemes derived:

- Double Diamond defined by the Design Council,
- 3 I Model, defined by IDEO,
- Design Thinking scheme defined by the Stanford Institute of Design, with a post-intervention made by the Interaction

Design Foundation,

- 5 steps of the UX process defined by Jesse James Garrett.

Double Diamond defined by the Design Council

The Double Diamond (Fig. 8) design process model, developed at the Design Council in 2005, is graphically based on a simple diagram describing the divergent and convergent stages of the design process, which gives the model the form of a double diamond. According to the authors, every design specialism has a different approach and ways of working, but there are some commonalities to the creative process, which they mapped out within a visual scheme. The authors discuss:

"In all creative processes a number of possible ideas are created ('divergent thinking') before refining and narrowing down to the best idea ('convergent thinking'), and this can be represented by a diamond shape. But the Double Diamond indicates that this happens twice – once to confirm the problem definition and once to create the solution. One of the greatest mistakes is to omit the left-hand diamond and end up solving the wrong problem."

The Double Diamond as a visual map of the design process is divided into four distinct phases: Discover, Define, Develop and Deliver.

Discover – The first quarter of the Double Diamond model covers the start of the project. Designers try to look at the world in a fresh way, notice new things and gather insights.

Define – The second quarter represents the definition stage, in which designers try to make sense of all the possibilities identified in the Discover phase. Which matters most? Which should we act on first? What is feasible? The goal here is to develop a clear creative brief that frames the fundamental design challenge.

Develop – The third quarter marks a period of development where solutions or concepts are created, prototyped, tested and iterated. This process of trial and error helps designers to improve and refine their ideas.

Delivery – The final quarter of the double diamond model is the delivery stage, where the resulting project (a product, service or environment, for example) is finalised, produced and launched.

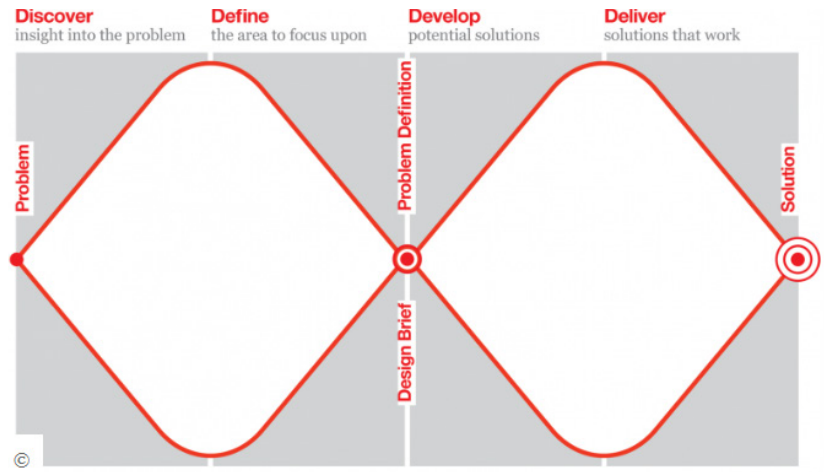


Figure 8. Double Diamond design process scheme defined by the Design Council.

3 I Model, defined by IDEO

The work of IDEO, a global innovation and design firm, was resumed in the internal design process scheme (Fig. 9), authored by Tim Brown and Jocelyn Wyatt. The scheme consists of three main steps within the process, namely: Inspiration, Ideation, and Implementation.

Inspiration is the first step towards creation of a product or service. Making user reach on real-life situations in regard to behaviours and needs is a starting point for drawing inspiration. At the end of the step, a synthesis of the results is provided.

In the Ideation phase, the authors highlight the importance of letting ideas emerge throughout brainstorming sessions. Following is the creation of prototypes and refinement of ideas.

The last phase is Implementation, which implies creation of the final product or service. In this space, prototyping and testing take part, as well as the final definition and dissemination of the design product.

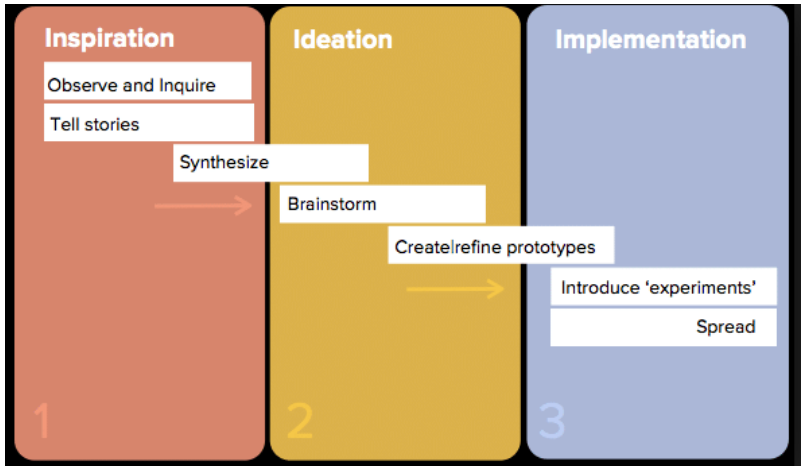


Figure 9.
3 I Model for a design process defined by IDEO.

The Design Thinking scheme defined by the Stanford Institute of Design (Fig. 10) consist of five main steps: Empathize, Define, Ideate, Prototype, and Test.

Design Thinking scheme defined by the Stanford Institute of Design

Empathize- Empathy, by definition, is the intellectual identification with or vicarious experiencing of the feelings, thoughts or attitudes of another. Three main techniques are used to gain empathy: interviewing, observation, immersion.

Define- The Define mode is seen as a 'narrowing' part of the process. After collecting volumes of user information, it is time to distil down to one specific user group, their need and the insight behind that need so as to unify and inspire a team. The goal of this mode is to come up with at least one actionable problem statement that focuses on the insights that are uncovered from real users.

Ideate- Ideation is the process of idea generation. Mentally it represents a process of "going broad" in terms of concepts and outcomes. Ideation provides the fuel for building prototypes and driving innovative solutions.

Prototype- Prototyping is the iterative development of artefacts – digital, physical, or experiential – intended to elicit qualitative or quantitative feedback. The act of prototyping implies "building", testing, and iterating and is, itself, both a flaring and a narrowing process.

Test- The test mode is another iterative mode in which we place low-resolution artefacts in the appropriate context of the user's life. Testing is the chance to refine our solutions and make them better.

Figure 10.
Design Thinking scheme defined by the Stanford Institute of Design.

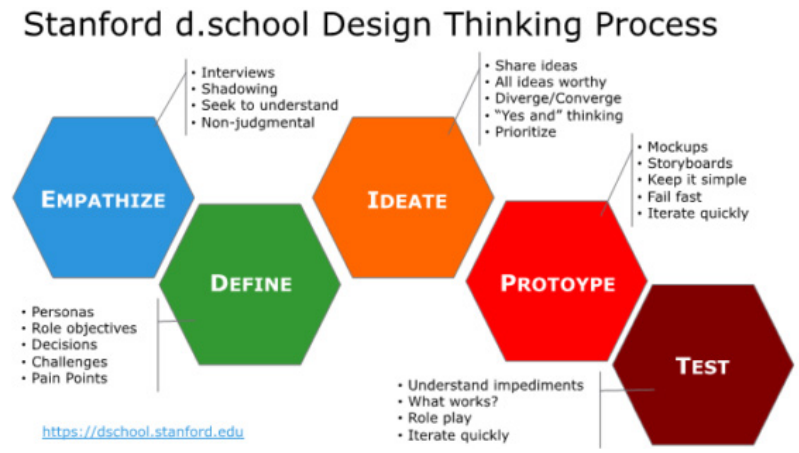
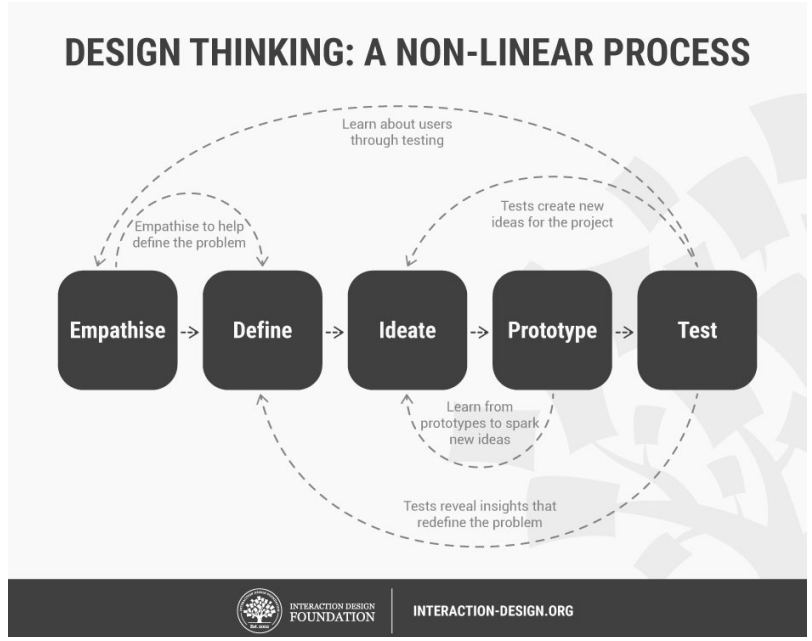


Figure 11.
A non-linear process scheme for design thinking proposed by the Interaction Design Foundation.



In regard to this scheme, the Interaction Design Foundation proposes an upgrade (Fig. 11):

"In practice, the process is carried out in a more flexible and non-linear fashion. For example, different groups within the design team may conduct more than one stage concurrently, or the designers may collect information and prototype during the entire project so as to enable them to bring their ideas to life and visualise the problem solutions... It is important to note that the five stages are not always sequential — they do not have to follow any specific order and they can often occur in parallel and be repeated iteratively. As such, the stages should be understood as different modes that contribute to a project, rather than sequential steps."

5 steps of the UX process defined by Jesse James Garrett

The Five Elements of UX (Fig. 12) derived from "The Elements of User Experience" book written by Jesse James Garrett, one of the founders of Adaptive Path, a user experience consultancy based in San Francisco. There are five dependent layers, each level builds on the level before it, and they start with abstract level towards concrete one (from bottom to top): Objectives, Scope, Structure, Skeleton, and Surface. The author discusses aspects of the reason for which the product, application or the site is created; why we create it, who are we doing this for, why people are willing to use it, why they need it. The goal here is to define the user needs and business objectives. This could be done through Strategic Research Process, where one interview users, and all stakeholders in addition to review the competing products or companies.

Functional Requirements are the requirements about the functions, or features in the product, how features work with each other, and how they interrelate with each other. These features are what user need to reach the objectives. Furthermore, Content Requirements are the information we need in order to provide the value (for e.g. text, images, audio, videos, …etc.).

Structure defines how user interacts with the product, how system behave when user interacts, how it's organized and prioritized. This level is split into two components, Interaction Design & Information Architecture. Interaction Design, given the functional requirements, defines how user can interact with the product,

and how the system behaves in response to the user interactions. Information Architecture, given the content requirements, defines the arrangement of content elements and how they are organized, to facilitate human understanding.

Skeleton determines the visual form on the screen, presentation and arrangement of all elements that make us interact with the functionality of the system that exist on the interface. Also, how the user moves through the information, and how information is presented to make it effective, clear, and obvious. So, the Skeleton should answer these questions:

- What visual form of all things that will be presented on screen?
- How interactions will be presented and arranged?
- How will users move around the site, or application?
- How content will be presented clearly?

Surface is the sum total of all the work and decisions previously made. It determines how the product will look like, choosing the right layout, typography, colours, …etc. In Surface we are dealing with visual appearance of content, controls, which gives a clue of what the user can do, and how to interact with the elements.

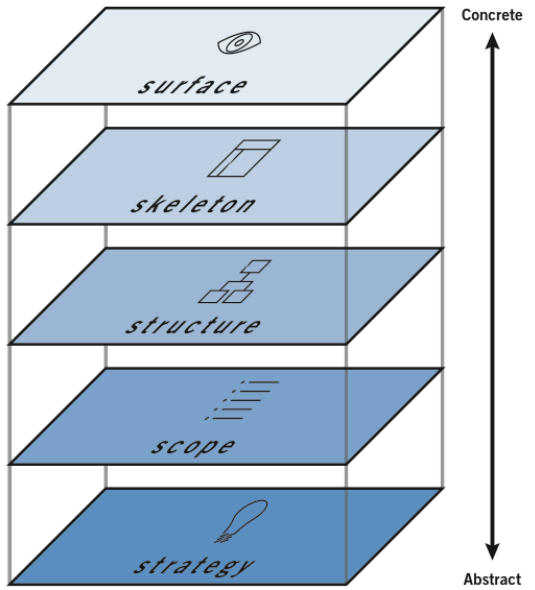


Figure 12.
Five steps within the UX design process defined by J. J. Garrett.

Even though the design process schemes presented differ between them, they all share quite similar considerations. Namely, the workflow steps for the design team are always observed as being part of the process that lead from abstraction to concrete ideation. This process is not necessarily following always the same order and there could be many iteration phases within one project. What is surely recognized in all of the processes is that there are: (1) moments of user research and concept development, and (2) moments of hands-on designing and prototyping.

The hands-on designing and prototyping are the steps of the process in which the design projects obtains shape, i.e. the product of the working phases here are tangible and concrete design outcomes seen as shaping of every possible element that a designer could influence. The user research and concept development step in the process implies that the product of this working phase is an abstract outcome of a problem-framing and problem-solving process. User research is seen as a necessary step for building empathy with potential users and customers, that is considered to be the backbone for building a novel design concept.

During all the steps within a workflow, diverse design tools can be employed for supporting the diversity of needs of the ongoing work, from ideation to prototyping and testing. It is, therefore, observable that ***ideation and evaluation*** are always present and iterate constantly within a design process.

The two phases, ideation and evaluation, respond to the questions of what is/can be designed and why it should/will be deigned in a specific manner. Following this notion, it is to conclude that a design process does not have a very strict protocol in terms of a workflow. To be more precise, the design process has main core phases that enter in diverse iteration loops regarding project needs, thus the process itself is not necessarily linear neither. Not having a strict protocol, a design process based on a UX approach still relies on a structural support in terms of core identified phases (i.e. ideation and evaluation), and this allows for sparks of creativity to emerge and take part in the process and development of designs.

Design process is usually supported by design tools, which, in the same manner, can make working phases structured by providing

a backbone support to workflows, while still leaving space for creativity and un-structured working moments to appear. In this context, it is to note that designer in his workflows is mostly confined, as well as guided and inspired, by the tools he uses for creation and development of designs.

Role of the Designer

A UX practitioner (UXer) is positioned in-between the individuals, i.e. users and customers, and the organization providing an interactive system, i.e. one or group of stakeholders involved (Fig. 13). The in-between space reflects the interactions happening between the two sides, where the UXer empathizes with the individuals and evaluates these interactions from both sides, for envisioning and/or reshaping the interaction touchpoints. For the envisioning phase, the UXer comes up with a set of guidelines and requirements that are shaped into final design outcomes with a team of diverse design profiles (from architects to UI designers), developers and makers.

Designer as Interpreter & Advocate

The term ‘user-centred design’ (UCD) originated in Donald Norman’s research laboratory at the University of California San Diego (UCSD) in the 1980s and became widely used after the publication of a co-authored book entitled User-Centred System Design: New Perspectives on Human-Computer Interaction (Norman & Draper, 1986). Norman built further on the UCD concept throughout the book The Psychology of Everyday Things (Norman, 1988). In the user-centred design process, we are focused on the thing being designed (e.g. the object, communication, space, interface, service, etc.), looking for ways to ensure that it meets the needs of the user (Sanders, 2003).

In the context of user-centred design, the role of the designer can be seen as the one who conducts research on users and interprets the findings through a set of recommendations for the design concept. The designer, thus, ‘empathizes’ with the users of the projects, and represents an advocate, i.e. the voice of the users, within the project and among all the stakeholders involved. Therefore, building and translating empathy, through the involvement of users in the design process and by conducting user research, is one of the key roles of a UX practitioner. Deep understanding of users’ needs is critical

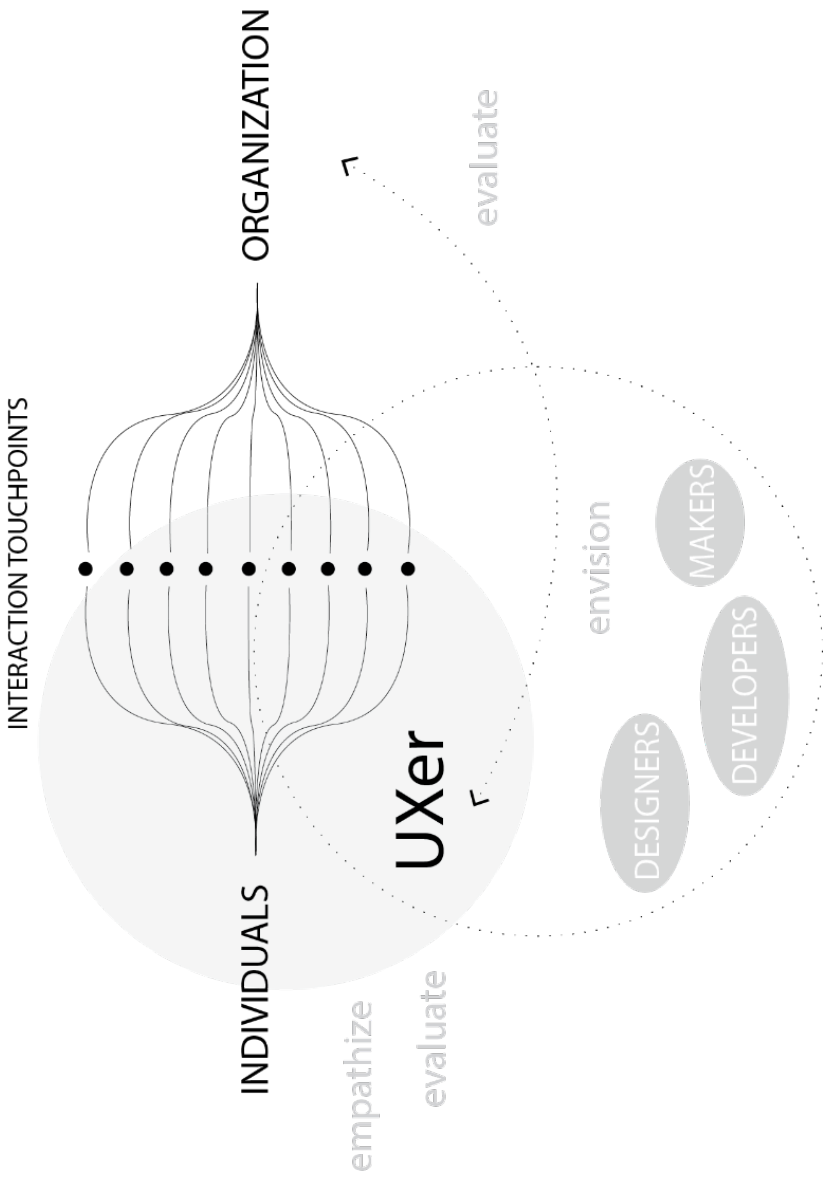


Figure 13. Scheme for positioning a UX practitioner within the design process and in regard to relations with project stakeholders.

for a designer to respond with more effective product outcomes. By employing empathic modelling strategies, designers can gain insight and shared understanding with their target users. The term 'design empathy', in fact, has been used in the field from 1990s for depicting the actual role of designers and user researchers (Battarbee & Koskinen, 2005).

Besides the communication with individuals and groups of users, a UX practitioner translates the findings from this communication to project stakeholders, i.e. organizations that hold interest in the project development. Furthermore, when developing and evaluating the design concept, the UXer communicates simultaneously with other designer profiles (e.g. product and UI designer), developers and makers, making sure that the 'voice of the user' is present in all of the project development stages. There are diverse modalities of communication that enable this presence, among which personas (Cooper, 2004) appears to be common in practices. There are as well many discussions on pros and cons of diverse communication modalities when advocating for users; as an e.g., Matthews et al. (2012), state that it is important that the personas not completely replace immersion in actual user data, and that they should not mislead or distract within the workflow.

Communication within Projects of Design for Experience

Even though designing for experiences aims at an intangible final product, it still requires some defined steps of the design process, to be established for supporting a creation of a common and shared language in this field (Buxton, 2007). Buxton (2007) approaches the discussion of such steps in analogy to sketching. He calls for distinguishing two main aspects of design: the problem solving and the problem setting, as backbones of the design process. These refer to definitions of how something is built, and what is the right thing to be built. From the problems emerging during the design process, methods should be shaped. For e.g., it is already evident that, when dealing with representation of an experience, we are dealing with a representation that contains a temporal component, therefore the drawings should be established accordingly. Buxton discusses drawings as the consequence of matching the appropriate visual language to the intended purpose, where every step within the drawing process is a refinement of the previous one. Therefore,

diverse drawings should correspond to diverse phases of the design process.

With the level of refinement of the drawing, the designer communicates the state of the final product, showing to the audience if the design solution is closed, or perhaps open for further suggestions. In case the communication should invite for further discussion, the provided visuals should enable further intervention within them, giving space to changes and proposals. In this context, Buxton is proposing five types of rendering of drawings: Sketch, Memory Drawing, Presentation Drawing, Technical Drawing, Description Drawing. Furthermore, he is identifying the abstraction of sketches and sketching, capturing the relevant attributes: Quick, Timely, Inexpensive, Disposable, Plentiful, Clear Vocabulary, Distinct gesture, Minimal detail, Appropriate degree of refinement, Suggest and explore rather than confirm, Ambiguity. Whatever rendering level of a drawing is used, it should comply with the need of ongoing negotiation within the design process and communication with diverse parties and profiles.

Designing for user's experience implies identifying use case scenarios, which are in essence presented through a story. Mapping a story indicates mapping out an intended experience of use, the same as one would do for a story - plot point by plot point (Lichaw, 2016). A user journey, thus, is a schematic way of representing in detail the elements of activities one is designing for. The whole design process we are dealing with is oriented toward the user's satisfaction and the identified needs and perception; therefore, all the previously mentioned representations reflect the alignment of values between the final users and the parties involved in the offerings related to the design solution.

Understanding the imposed complexity

2.1.2

Systemic Design Principles

The design of hybrid physical-digital experiences poses the issue of managing complexity on diverse levels. This complexity is mirrored with the issue of design ecosystems that arise when adding digital solutions to physical environments and contexts. Maurice & Collin (1962) suggest that "there are as many spaces as there are distinct spatial experiences".

Ecosystems here refer to two main points of view: 1) the multi-stakeholder environment that brings multidisciplinary contribution to the project, thus bringing diverse interests and values within the same (Tsujimoto et al., 2017); 2) the perception and meaningfulness, shaped from the side of the user, towards a posed connected system of digitized services (Levin, 2014; Rowland, 2015). The interlacing of fields and cross-discipline perspectives can lead to redundancy (or even contradictions or incongruences), in the terms of data provided and of functionalities posed to the user. Therefore, establishing a shared view upon the user experience (UX) in a holistic manner is of high importance to the successful design solution.

Defining and establishing a common language to be used for the field of UX within these complex hybrid systems, referred to as spaces enhanced by digitized services, is the objective of this research. Specifics focus is on the tools to be used for communicating a design project of such nature. In particular, I am referring to representation capabilities and mapping techniques focused on experience and on user activities. The concept of mapping helps understanding complex systems of interaction, particularly when dealing with abstract concepts such as experience.

Working as educator and designer, I recognize the importance of developing new representation tools apt to support the integrated design of physical/digital systems and of systemic sets of solutions, as an evolution of drawing techniques traditionally employed in the main disciplines converging in the management of complex systems.

Different Communication with Different Stakeholders

As mentioned previously, the complexity of user experience in the kinds of projects that deal with cyber-physical systems is higher than what is currently addressed in design projects that deal with service and interaction design, and the evaluation and strategy for users' experiences should be treated according to this complexity. The projects for Ambient UX pose communication with quite diverse stakeholders, in terms of their professional background and interest in the project outcomes. Stakeholders are seen as those groups or individuals who either have the power to affect or are affected by the design and/or planning activity.

Design itself is seen as a collaborative effort where the design process is spread among diverse participating stakeholders and competences (Bjogvinsson et al., 2012). Bjogvinsson et al., (2012) suggest that the focus of a design project should be an outcome defined as material "presenters" of the evolving object of design supporting communication or participation in the design process; this evolving object of design is potentially binding different stakeholders together.

Kimbell (2011) recognizes that the design process is a version of managerial practices, and in that context, it deals also with challenges facing organizations and diverse businesses. Therefore, within the design process it is important to comprehend the diverse profiles and interests of stakeholders. It is common practice to have mapping out of such information within a unique scheme. For e.g., MindTools association suggests an approach to plot on a graph the various stakeholders' "Power of Influence" and their "Level of Interest" to give an idea of how to manage the range of stakeholder needs. Furthermore, they suggest grouping stakeholders and mapping them according to their financial and/or emotional interest in the outcome of the work, their motivations, the information they require, their current opinion of the work and the best way to communicate a certain message to them, as well as who influences their opinion.

From the side of UX practitioners, understanding the need for different communication with different stakeholders within diverse phases of a design processes requires an analysis of present stakeholders and planning for intuitive successful communication accordingly.

Defining Design Domains 2.1.3

Mapping Activities through Constraints and Enablers

The diffusion of digital technologies imposes an upgrade of design knowledge and skills, and, between others, of drawing capabilities. The design of digital facilities for functional spaces, (as, for example, in the project of digital applications and self-service touch points for retail big stores, hospitals, university campuses, libraries, etc.), requires the integration of multiple design competences: service, communication, interaction, product and interior design. Furthermore, the design of technology-based solutions, requires the collaboration between experts of different disciplines, such as engineers and business managers, and their involvement in co-design processes. In order to manage the complexity of these physical/digital solutions, and to ensure a design result oriented towards the optimal satisfaction of users, authors such as Dalton et al. (2016) and Kalbach (2016), have proposed new design approaches and mapping techniques focused on experience and on user activities.

In a project focused on user experience, drawing activities are not only aimed at defining the physical characteristics of products and spaces, but also at representing users' physical and cognitive activities in time, and the interactive processes through the system of touchpoints. The new forms of drawing integrate the traditional representations so to manage complexity due to the integrated design of service and physical environments; besides, they support the management of the multidisciplinary contributions of different stakeholders, allowing creation of a common view. Designing for such complex interactive spatial systems poses, as relevant aim, the comprehension of the experience that the user will have in the functional environment. This comprehension has to be mapped and represented in a way to communicate clear messages to all the stakeholders and parties involved in the design project, thus establishing a shared language among them, while orienting the project efforts toward a common goal.

In this context, mapping out user's activities through a story of use-case scenarios appears as a suitable backbone for projects focused on design for users' experience. Mapping of user's activities is usually seen as the possible or existent "journey" he/she is undertaking, which helps directing a disunion within a design process towards very concrete and specific design outcomes.

As previously mentioned, dealing with experience design implies dealing with the overlapping of diverse known and practiced design fields, for e.g. service, communication, interaction, product, and interior design. The overlapping leads to a creation of holistic experiences and perception of the design delivery. However, the complexity of such projects does not mean that we have to deal with all the elements immediately within separate fields of design, as they are considered to be at the moment. Rather, we are to reason about an abstraction of a structure to be used as a base for developing design projects that deal with experiences. This is where the concept of Ambient UX comes into place and calls upon a definition of a shared language.

Mental Models are applied in design within the user-centric design approach, as they are associated to a deep understanding of people's motivations and thought-processes, along with the emotional and philosophical landscape in which they are operating (Sax & Clack, 2015). Young observes it is a visual depiction of a particular audience's behaviour, faithfully representing individual's root motivations and goals, and what procedure and philosophy the individual follows to accomplish. The research of Mental Models can be carried out as a step in the design process that follows user data collection and precedes product and interaction design concepts (Young, 2008). Considering the level of abstraction, the model holds, as well as the overview scale of the user studies, the same model can be applied for diverse projects and lead to diverse design outcomes. For this reason, measuring and representing mental models is a hard task, as there are multiple possible outcomes. Measuring, therefore, is guided by the final aim for the design application of the user research activity.

Developing design strategies in experience-centred design requires thorough understandings of the users, their goals, motivations and thought-processes, guided by emotional states and contexts. An

experience can be observed as an episode, a story within a certain time length, that emerges from the dialogue of a person with the surrounding world through actions (Hassenzahl, 2010). Designing for everyday activities from the perspective of perceived experience through emotions, rather than from the perspective of material output, opens up many possibilities for reflecting on meaningfulness in design scenarios (Hassenzahl et al., 2013). When describing meaningful episodes of experiences, Forlizzi and Ford (2000) consider "an experience" as a particular meaningful momentary construction, with a beginning and an end, that grows from the interaction between people and their environment. This is where Mental Models take part in the design field, by supporting development of empathy towards potential users and their experiences. Understanding and getting to know the potential users in their lived and felt life implies understanding what it feels like to be those people, and this calls for empathy.

What is in common for all the maps, as experience design tools, is the fact that they are activity-based designs (Dalton et al., 2016; Carvalho & Goodyear, 2017). People are always in an environment that consists of contexts and technologies, in whom they are engaged in activities (Benyon, 2014). The activities are enabled within an ecosystem seen as a network of interactions. An ecosystem essentially describes a network of interactions, among organisms, and between those organisms and their environment, which together create an ecology that is greater than the sum of its parts (Levin, 2014). Within the design ecosystems, designers should ensure the consistency and continuity of enabled activities.

Norman, in his book The Design of Everyday Things (2013), defined design as "the successive application of constraints until only a unique product is left." Norman (2013) discusses design outcomes as constraints, as they provide the user with a number of possible actions that are limited. He discusses the power of constraints and suggests using constraints so that the user feels as if there is only one possible thing to do—the right one. Author used the example of the Lego toy motorcycle, which could be correctly put together by people who had never before seen it before, as it exploits a variety of constraints. It is a good example of the power of natural mappings and constraints, constraints that reduce the number of alternative actions at each step to at most a few. In this case, logic provided the

answer: only one piece left, only one possible place to go.

Furthermore, Norman (2013) states that: “a good designer makes sure that appropriate actions are perceptible and inappropriate ones invisible.” The surest way to make something easy to use, with few errors, is to make it impossible to do otherwise, thus constraining the choices of activities. Responding to the question of how we can design the appropriate actions, Norman in his book discusses on design principles and signals:

“One important set of signals comes through the natural constraints of objects, physical constraints that limit what can be done. Another set of signals comes from the affordances of objects, which convey messages about their possible uses, actions, and functions. A flat plate affords pushing, an empty container affords filling, and so on. Affordances can signal how an object can be moved, what it will support, and whether anything will fit into its crevices, over it, or under it. Where do we grab it, which parts move, and which parts are fixed? ***Affordances suggest the range of possibilities; constraints limit the number of alternatives***.”

In this context, I observe a journey of a user as based on the foundation of touchpoints through definition of ***constraints and enablers*** of activities within it. Considering that user activities are the core of mapping of experiences, I observe the limitation and enabling points of such, as the base for developing a design project. Norman (2013) discusses design outcomes as constraints, as they provide to the user a number of possible actions that are limited. These constraining/enabling points of activities are starting points from whom the pain points and desirable experiences emerge, from the side of the user. These further correspond to the opportunities for the stakeholders that offer services and guide their modification.

Three Architectures and Time as a Variable

Within the Ambient UX concept, ***Design Domains*** (DDs) are considered to be the system of touchpoints visible to the user, and they derive from diverse design fields employed where all of the fields contribute the simulation of user journey, i.e. an experience. There is a limit to what can be designed, therefore there are certain constraints in designers’ actions. One can design tangible elements and relations. The concept of designing constraints and enablers of

activities is a take on designing (for) relations, and thus, interactions with diverse touchpoints and entities.

The Design Domains within Ambient UX systems are recognized through mapping of activities and touchpoints encountered within. Touchpoints are seen as enablers and constraints of activities, and thus, they are the active points within a certain environment which provide possibilities of interactions and communication (Fig. 14).

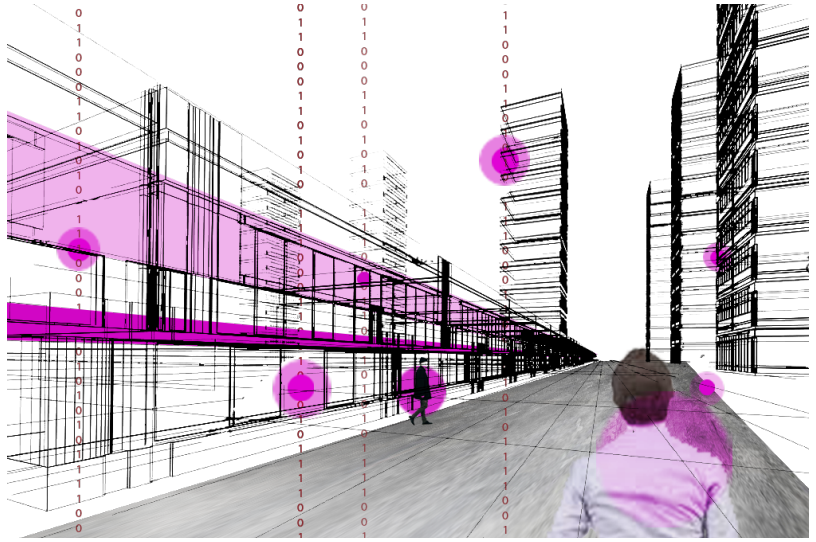


Figure 14. Representation of active points that enable communication within an environment, identified with a pink coloured area.

For identifying DDs for Ambient UX an analysis of use cases took part, selecting cases that satisfy the nature of projects for CPSes. More precisely, for this research activity samples of cases were gathered from a course on interactive architecture, that takes part within the Robotic Building Lab (formerly known as Hyperbody), at the Technical University of Delft. I was part of the teaching staff during the winter semester design studio course in 2017, named Design-to-Robotic-Production and –Operation (D2RP&O) for Interactive Urban Furniture. The examples of students’ group work presented in the following are projects from the Spring and Fall semester 2017, developed by Master students of the Robotic Building studio (uf. roboticbuilding.eu) formerly known as Hyperbody.

As digital technologies are employed to create new user experiences that enhance and extend the way people work, communicate and interact, as teachers within the course, we opted for giving visibility to experience in architecture. We observed that merging the dualist parts presented in projects for intelligent interactive architecture, i.e. physical and digital (non-physical) design, happens through perception and experience observed from the side of the users of the space.

Reasoning on the design of systems of interactive spaces, I identified Design Domains that derived from the analysis of previous works of the Lab, and that we were proposed during the teaching course.

During the course, the students were developing the project in phases: analysing the context, defining the concept, developing the project on macro, meso and micro scale, and finally arriving to a tangible prototype of a defined parametric architectural structure. From analysing and mapping activities, understanding the needs to the concept development, towards the definition of the physical form and additional devices and interactive elements that support diverse services; understanding different scales of the project and different scales of intervention was clearly observable within the design process. Task of the students, during the semester when I was present at the Lab, was to design an interactive spatial system within a designated area in the city of Rotterdam.

The initial phase of the project implied schematic design thinking through mapping of activities that take part in an existent and/or might take part in a newly designed space. Students used as reference another D2RP&O project implemented in Spring semester 2017 with students from Dessau Institute of Architecture (Fig. 15 & 16) wherein the focus was on student housing.

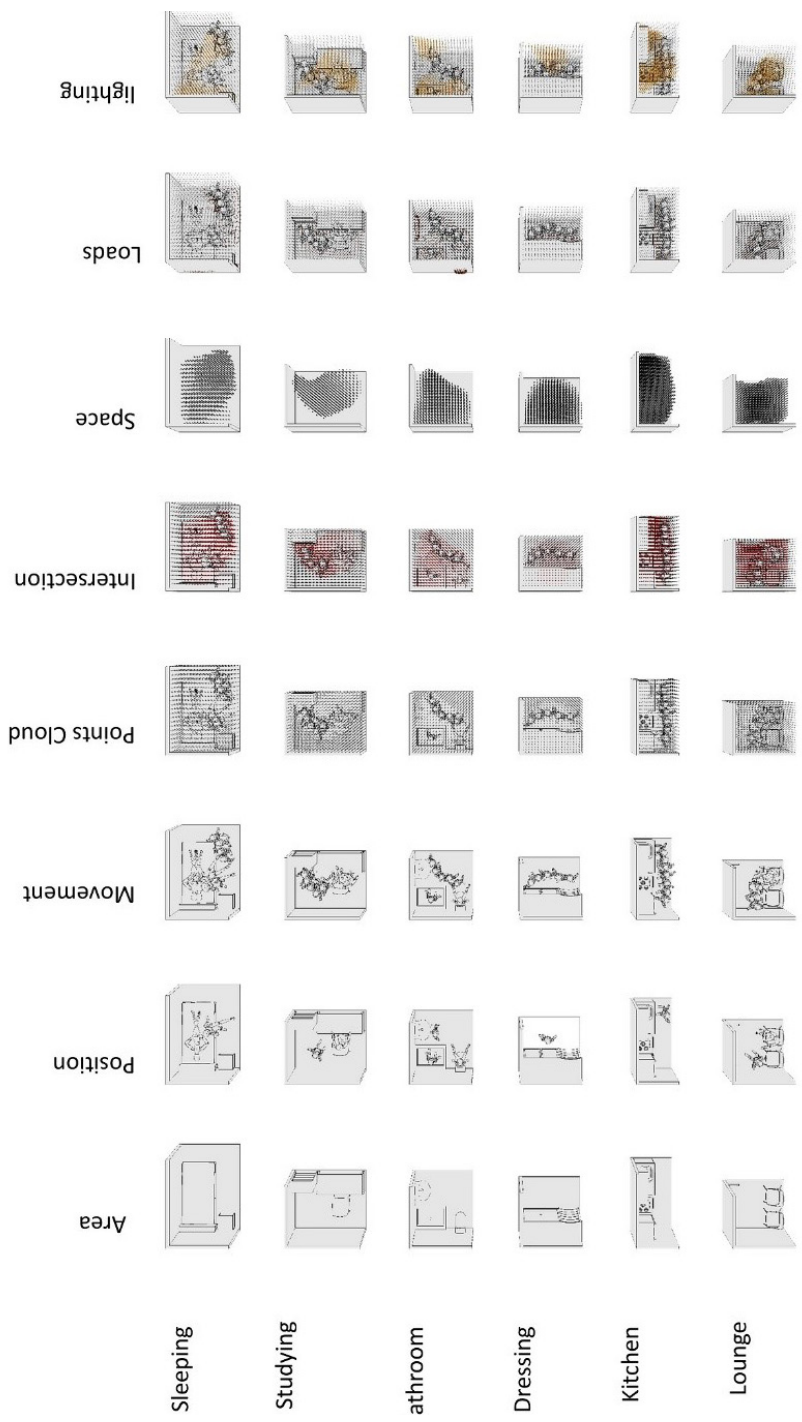


Figure 15. Mapping of activities of the users of a space, considering the body movements and positions, as well as diverse characteristics of the same space; presented example is a student's group project for the course of Robotic Building Lab.

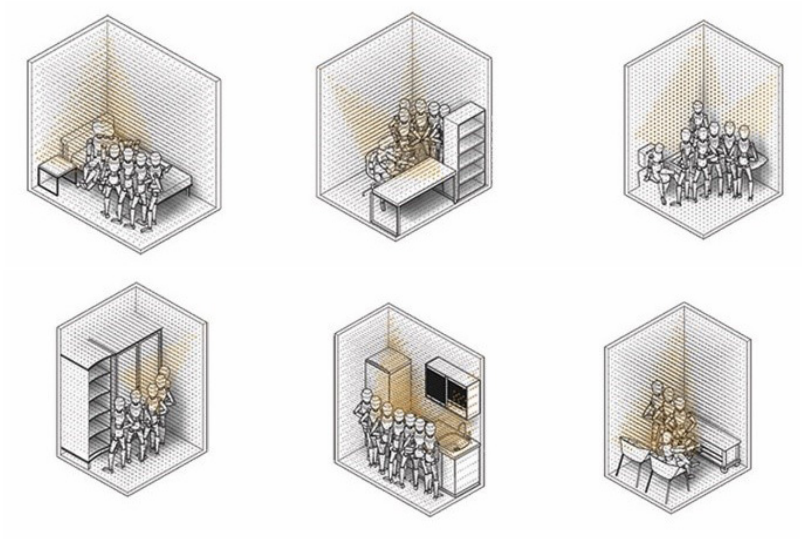


Figure 16.
Mapping of activities of the users of a space, considering the body movements and positions, as well as diverse characteristics of the same space (zoomed-in view); presented example is a student's group project for the course of Robotic Building Lab.

After defining the possible activities and mapping them within spatial parameters, students defined the scheme of zoning (Fig. 17). Zoning is related to the diversity of activities, and the defined zones are used as a starting point for a new shape that is proposed for the novel design concept of an interactive architecture piece.

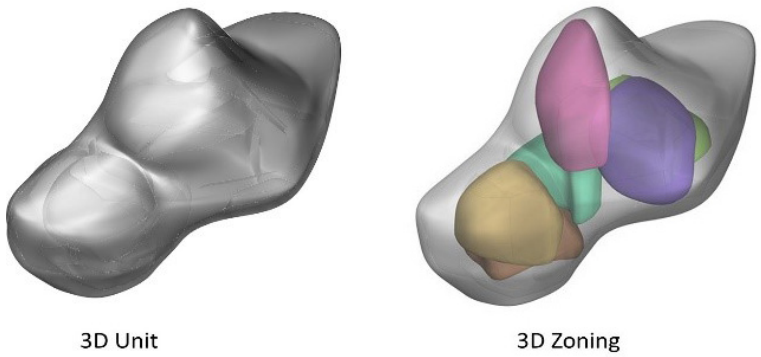
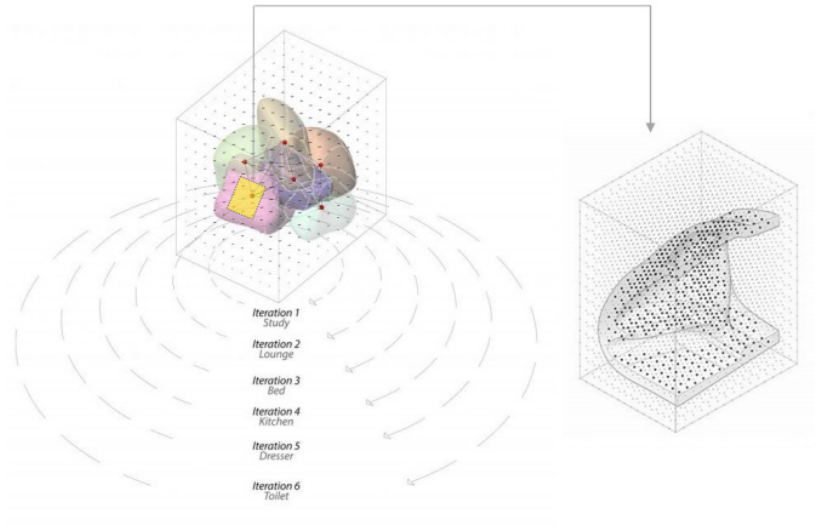


Figure 17.
Novel 3D unit based on the zoning of diverse desired activities; presented example is a student's group project for the course of Robotic Building Lab

After defining the novel 3D unit according to the zoning scheme, identification of additional digitized interactive elements takes part (Fig. 18). Students identify spatial parameters for mapping and continue with the activity of mapping active points (input and output elements and their positioning within the spatial dimensions) and information flows.

Figure 18.
Mapping of additional interactive elements (inputs and outputs and the information flows) on the defined spatial dimensions; presented example is a student's group project for the course of Robotic Building Lab.



Once defined the elements and zones of interaction, the definition of a final spatial form takes part, and the spatial model is generated according to the needed physical structure and support (Fig. 19). Definition of a physical shape implies also a definition of diverse layers that intertwine and generate a unique holistic form (Fig. 20).

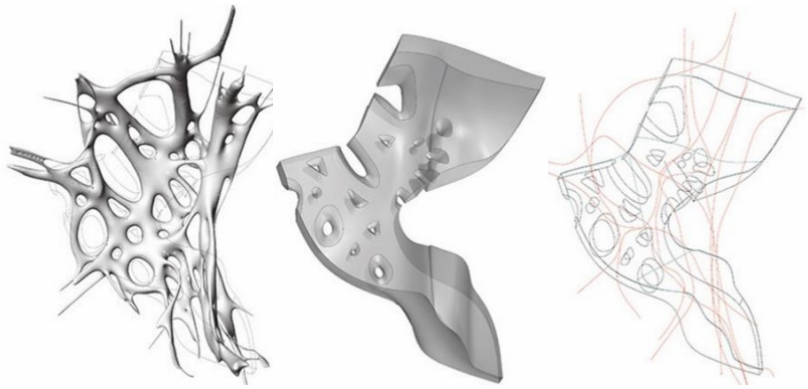


Figure 19. Definition of a final spatial model; presented example is a student's group project for the course of Robotic Building Lab.

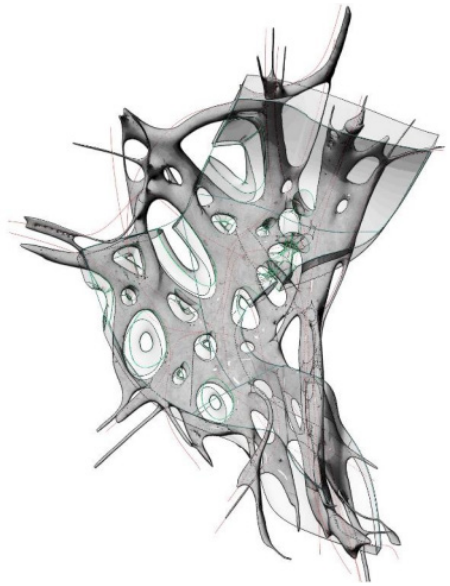
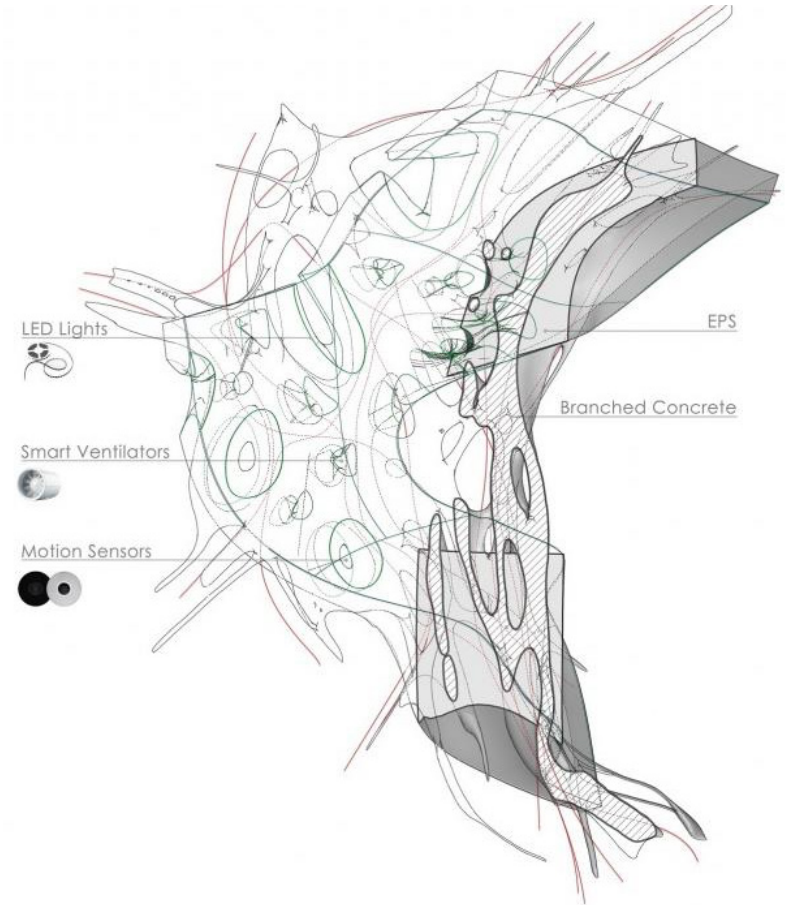


Figure 20. Representation of diverse layers present within the final spatial model; presented example is a student's group project for the course of Robotic Building Lab.

After having defined the final spatial form, i.e. the 3D physical model, definition of smart systems of sensors and actuators takes part, according to the predefined interaction flows present within the design concept (Fig. 21). Positioning of sensors and actuators, as inputs and output for the digitized information flows, is followed by selection of materials for the structure.

Figure 21. Definition and positioning of smart systems of sensors and actuators; presented example is a student's group project for the course of Robotic Building Lab.



Systems of sensors and actuators, during the course, were explained as interactive feedback loops of inputs and outputs, dependent on computer processing in back-end (Fig. 22). The feedback loops directly influence the activities and states of the users of the space. Within these loops, sensors convert information into digital signals. Sensors rely on chemical, mechanical and/or electrical properties to detect and measure changes in the physical environment. Two main possible sensing areas were defined as the Body and the Environment (Fig. 23).

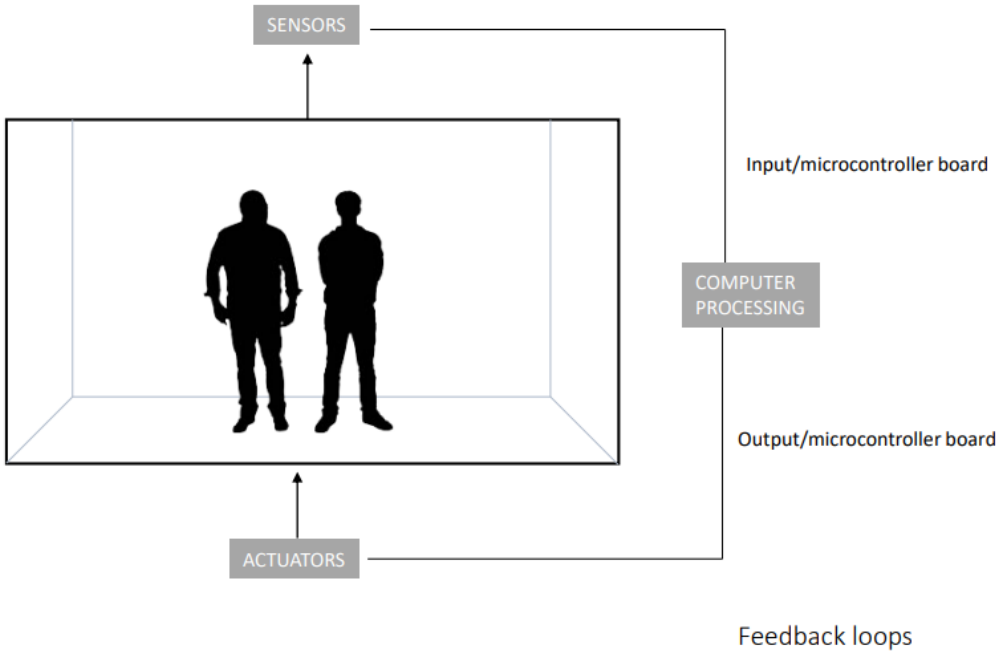


Figure 22. Representation scheme for feedback loops within systems for sensors and actuators.

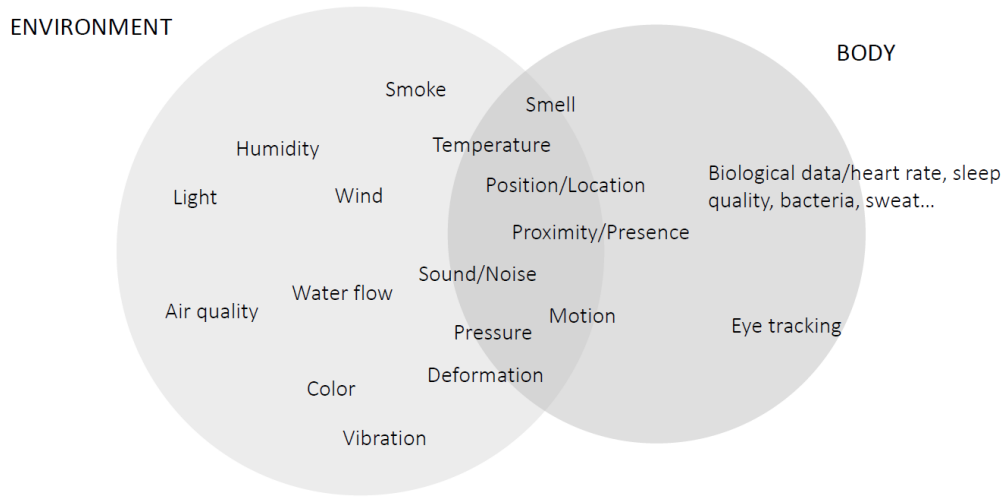


Figure 23. Scheme describing whish parameters can be gathered through sensors, in regard to two main groups as Environment and the Body.

With the provided task, students had to develop a design strategy, which manifests itself on different scales (urban/architectural/furniture). The concept had to meet user experience interests and agendas and use data from disciplines relevant to respective design. Design implementation is realized through multiple media: detailed 3D model both as deliverable and as work medium, and the set of architectural representations required for communicating spatial qualities and technical features of respective designs. The complexity of computational solutions was expected to be adequate to structural challenges for 3D parametric design. The proposed cyber-physical system is controlled or monitored by computer-based algorithms, integrated with IoT and its users. Physical and software components are, in this context, deeply intertwined.

As prior to my stay at the Lab at the course was emphasized the building of new physical forms, during my stay at the Lab, and the teaching semester that took part in that period, we tended to emphasise the user-centred approach towards interactive spatial systems. Therefore, when proposing a design concept, students were focusing on the experience of the people that would inhabit the certain space and use it daily, and the perceptions of the context of use itself. In this case, analysing daily activities of inhabitants, and designing for movements and well-being were the integrated part of the design activity for building a CPS.

When mapping the user's experience through activities, I focused on analysing the projects from the previous semester (course that took part in spring 2017) according to all the possible interactions taking part from the side of the user. By analysing the interactions points, it was possible to make a synthesis of networks of interactions in regard to their diverse nature, and group them as following (Fig. 24):

- Interactions with physical environment;
- Interactions enabled by information flows;
- Interactions referring to human relations.

Therefore, the students of the following semester course (fall of 2017) were provided with parameters for mapping activities through time, space, social relations, and information flows.

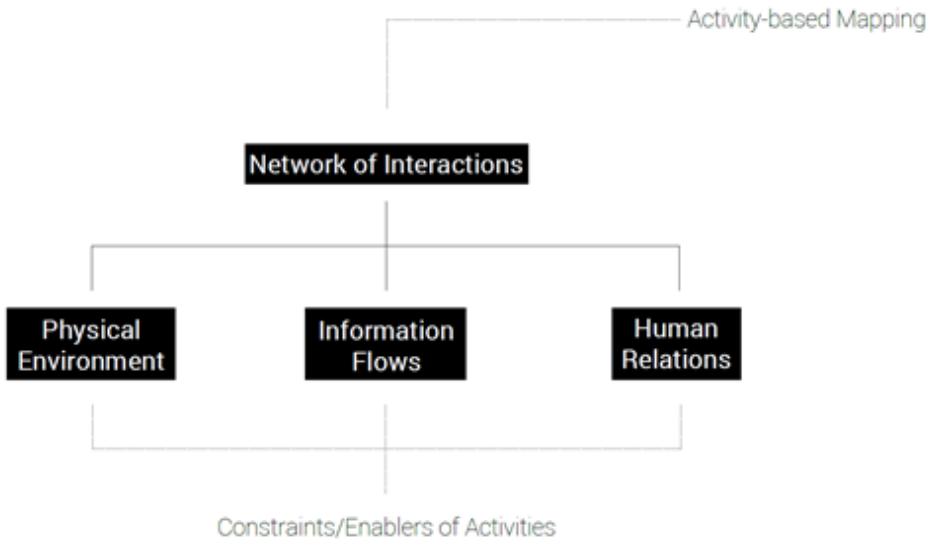


Figure 24. Ambient UX scheme for activity-based mapping according to networks of interaction, defined by constraints and enablers of activities.

Mapping of activities brought to identification of three networks of interactions with three diverse architectures, where Time is considered as a variable between these three. The architectures are: Spatial (interaction related to the physical environment), Informational (interaction related to information flows), Relational (interaction related to human/social relations) (Fig. 25).

Within the three architectures, the dimensions, i.e. Design Domains, of the project are:

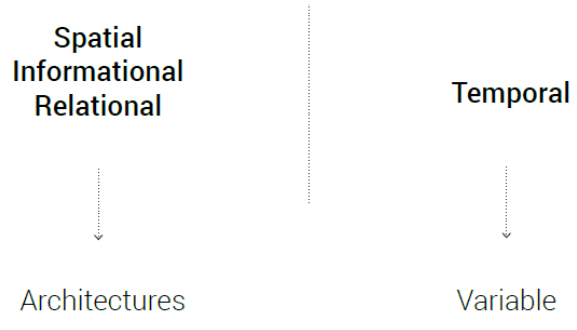


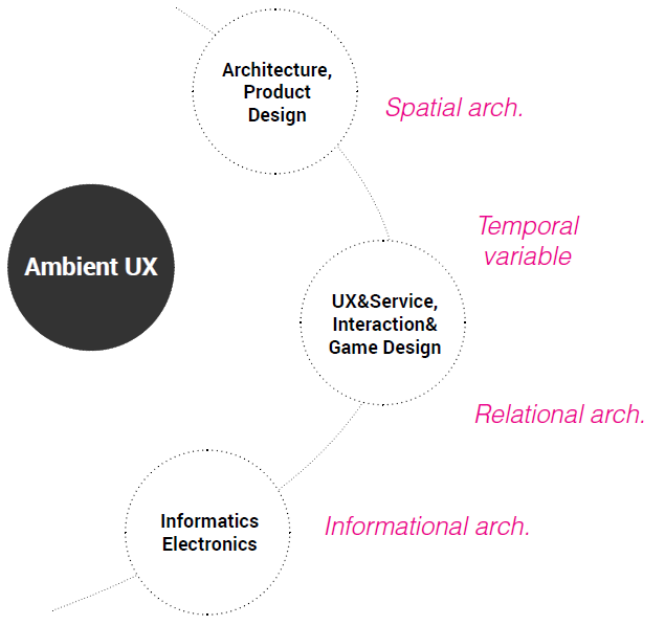
Figure 25. Identification of Design Domains for Ambient UX through three architectures and a variable.

- Physical Environment and Artefacts- considerations are spatial and material, which regards design of new elements as well as existing surrounding;
- Information Flows and Processing – considerations on the source of communication, manner of communication and data content;
- Social Relations- considerations on role and identity from the side of stakeholders and service providers, as well as other individuals involved in the interactive system.

Strategies for designing interactions, considering the three architectures, should bring attention towards creating consistent, continuous and complementary interactions in-between them.

Considering the identified Design Domains for Ambient UX, which are the three architectures and Time as a variable, it is possible to observe Ambient UX as an attempt to gather diverse design practices and domains for obtaining a holistic approach towards designing for experiences in interactive intelligent spaces. Namely, these practices cover a span from Architecture and Product, UX and Service, Interaction and Game Design, towards Informatics and Electronics (Fig. 26).

Figure 26. Representation of design practices that Ambient UX covers within its Design Domains.



Spatial Architecture

Spatial architecture, as one of the Design Domains for Ambient UX, is intended as the traditional comprehension of architecture as physical shaping and intervention (Fig. 27); in this context it is implied as intervention on diverse scales, from an environment to individual products.

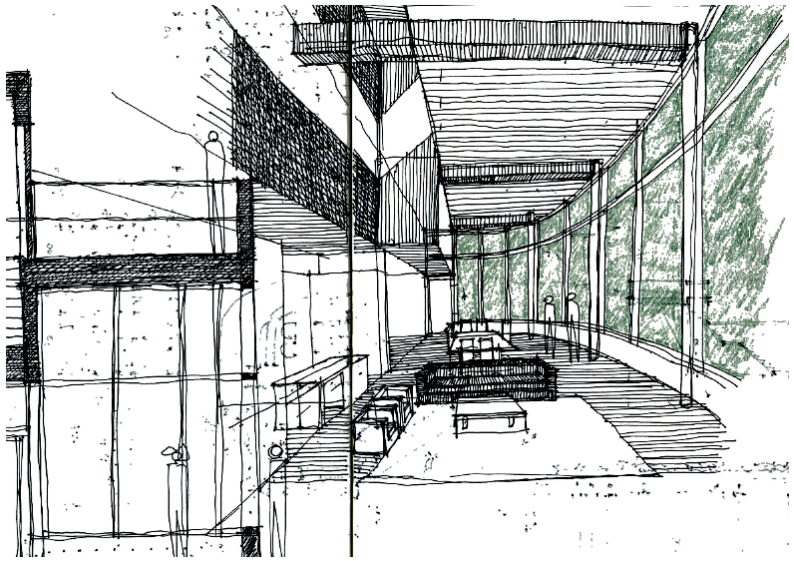


Figure 27.
Hand sketch of a 3D perspective architectural design concept; sketch made by Michael Malone (Malone Maxwell Borson Architects).

Spatial architecture in the field of digital applications can be found as often referred to as “context” in which the usage of a digitized product/gadget happens. Kim et al. (2005) have observed the importance of a context of use, where they identified Personal and Environmental context as part of the Mobile context. The environmental context is further divided into Physical and Social context, where the physical is observed to influence an experience, more precisely usability, through visual and/or auditory distraction. The authors point out that different contexts cause different kinds of usability problems.

Spatial architecture, as a Design Domain, should to be observed beyond just a context. Meaning that the spatial and physical aspects are also considered as elements of intervention when designing for experiences. Referring to the AmI vision as an example, it is observable that the design intervention goes way beyond the mere

smartphone interface. In fact, it derives that AmI vision did not get its full fulfilment because we are still carrying our digitized service in our smartphones.

Architecture as an Ambient UX Design Domain is intended as the modern comprehension of the term in design practices; it regards teaching on materials and shapes as a commonly established comprehension of design and manufacturing of physical items that are evoking bodily sensations. More precisely, the modern comprehension of the term Architecture, as Spatial and Product design, finds its roots in the practice and teaching established within the Staatliches Bauhaus, school of design, architecture, and applied arts. Bauhaus is celebrating 100 years from its establishment at the time of writing this thesis (the school was operational from 1919 to 1933); it combined crafts and fine arts and was famous for the approach to design that it publicized and taught.

Gropius, in his book The New Architecture and the Bauhaus (1965) wrote:

“The morphology of dead styles has been destroyed, and we are returning to honesty of thought and feeling... It is now becoming widely recognized that although the outward form of the New Architecture differ fundamentally in an organic sense from these of the old, they are not the personal whims of a handful of architects avid for innovation at all cost, but simply the inevitable logical product of the intellectual, social and technical conditions of our age.”

Le Corbusier (2007) defines Architecture as:

“...the masterly, correct and magnificent play of masses brought together in light. Our eyes are made to see forms in light; light and shade reveal these forms; cubes, cones, spheres, cylinders or pyramids are the great primary forms which light reveals to advantage; the image of these is distinct and tangible within us without ambiguity. It is for this reason that these are beautiful forms, the most beautiful forms.”

Furthermore, when a physical form is designed, it takes life on its own that might also differ from the initial purpose that the architect intended it for. The Architecture lives through diverse changes over time. Le Corbusier, quoted by Boudon (1972), replied upon learning

that the housing project he had designed at Pessac had been altered by its inhabitants: "You know, it is life that is right and the architect who is wrong."

Branzi (2006) proposes to analyse the innovations that the twenty-first century is introducing to the world of design, to the passage from the strong and concentrated modernity of the twentieth century to the weak and diffuse current one, and to investigate whether there is, in this passage, the possibility of imagining a future for non-figurative architecture. Branzi underlines that today's urban condition is made up of services, information technologies networks, product systems, environmental componential practice, microclimates, commercial information, and above all perceptive structures that produce systems of sensorial and intelligent tunnels that are contained within architecture but cannot be represented by architecture's figurative codes. One of the many merits of Branzi is to be one of the first to hypothesize the city of the future, intended more as a concept than as an artifice.

Ledford et al. (2014) discuss the concept of Psychology of space. According to the authors, architectural psychology can be described as a branch of environmental or ecological psychology; dealing with the psychological processes of the interaction between man and his environment, as for example spatial perception, spatial thinking, orientation behaviour, or spatial experience, territorial behaviour, living requirements and satisfaction, local identity (Lehman, 2009). Rudolph (1958) claimed that if these spaces are to be created and if we are to enrich our architecture, "it will be through better understanding of our concept of space, its effect upon and relationship to people, and the forces which dominate and plague us."

Rudolph continued to speak about the psychology of space, the psychological needs of the users of space, and the complex relationship between them (Ledford et al., 2014). Ledford et al. (2014) quoted Rudolph, who claimed: "People, if they think about architecture at all, usually think in terms of the materials. While that's important, it's not the thing that determines the psychology of the building. It's really the compression and release of space, the lighting of that space—dark to light—and the progression of one space to another." Architecture, in particular, which moves beyond mere building, strives to enhance the human condition and promote emotional well-being through the manipulation of space, light, material, and form.

Constraints and Enablers within the Spatial Architecture

Constraints and enablers of activities, in regard to Spatial architecture, can be observed through examples of student's group work that took part during the fall course in 2017, at the Robotic Building Lab (formerly known as Hyperbody) of TU Delft.

Students would start with analysing the existing physical surrounding where the new interactive installation could be placed (Fig. 28).

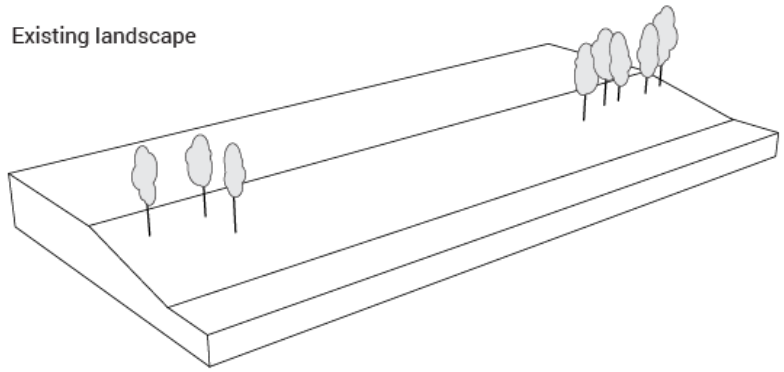


Figure 28. Analysing the existing physical surrounding; presented example is a student's group project for the course of Robotic Building Lab.

They would proceed with mapping out activities that take part in the physical area, and the new desired activities for the novel design concept, in regard to spatial disposition and occupation size (Fig. 29).

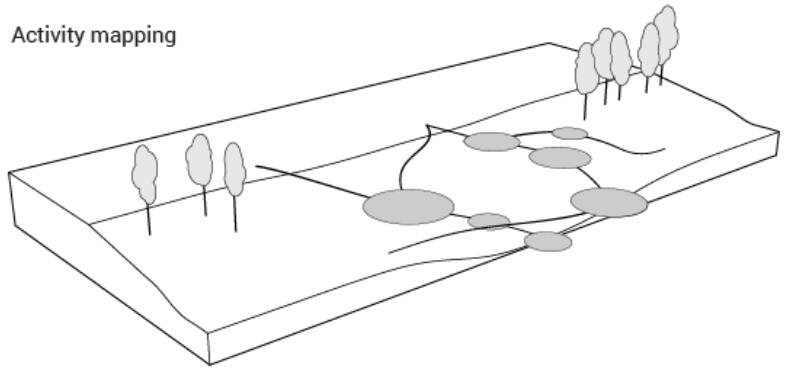


Figure 29. Mapping of activities within the physical area; presented example is a student's group project for the course of Robotic Building Lab.

Finally, students would define and place a physical shape that would enable and support certain planned activities, while at the same time building constraints for the way in which activities were happening previously in the same area (Fig. 30).

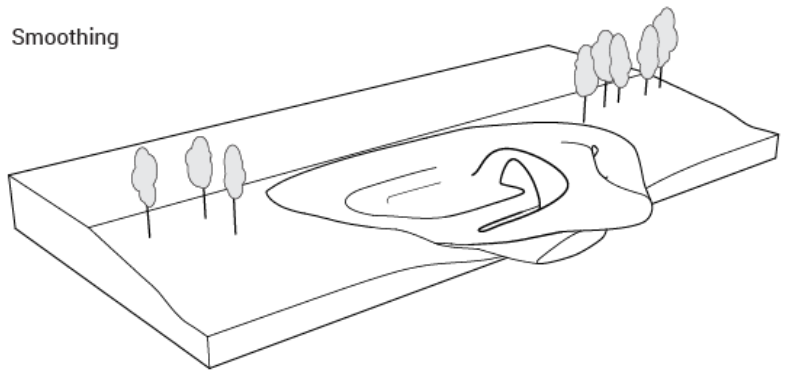


Figure 30.
Definition of physical enablers and constraints of activities; presented example is a student's group project for the course of Robotic Building Lab.

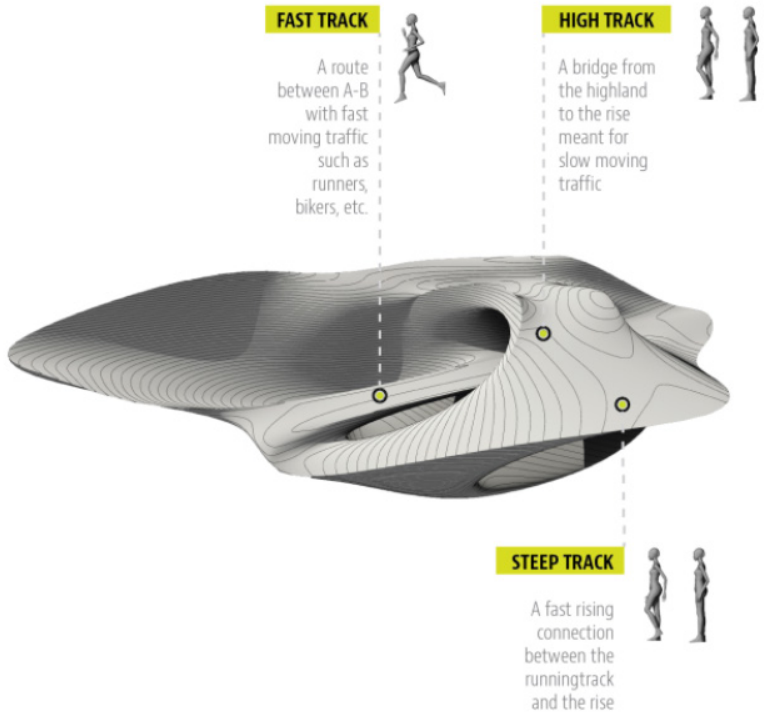


Figure 31.
Mapping out diverse types of activities and routes that the physical shape supports; presented example is a student's group project for the course of Robotic Building Lab.

Students would map on designed novel physical shape the moments and positions in which it is planned and/or predicted for certain activities to take part (Fig. 31) using simulation tools.

Design concept for Spatial Architecture could be communicated through following practiced design tools:

- Freehand Sketching,
- Mood Boards,
- Urban Mapping,
- Plan & Cross Section Drawings,
- Renders & 3D Animation,
- 3D Physical Scale Model,
- Multi-agent Simulations,
- Design-to-Robotic-Production,
- Executive Technical Drawings,
- Material Palette.

Informational Architecture

Information architecture, as one of the Design Domains for Ambient UX, is intended as the established field in the website and mobile app design (Fig. 32).

Information Architecture (IA) is a process of organizing, labelling, and designing navigation and searching, that helps people find and manage information more successfully (Rosenfeld and Morville, 2002).

Garrett in his book, Elements of user experience, the: user-centered design for the web and beyond (2010), defines:

"Interaction design and information architecture share an emphasis on defining patterns and sequences in which options will be presented to users. Information architecture deals with the options involved in conveying information to a user.

...Information architecture is a new idea, but it's an old practice—in fact, you could say it's as old as human communication itself. For

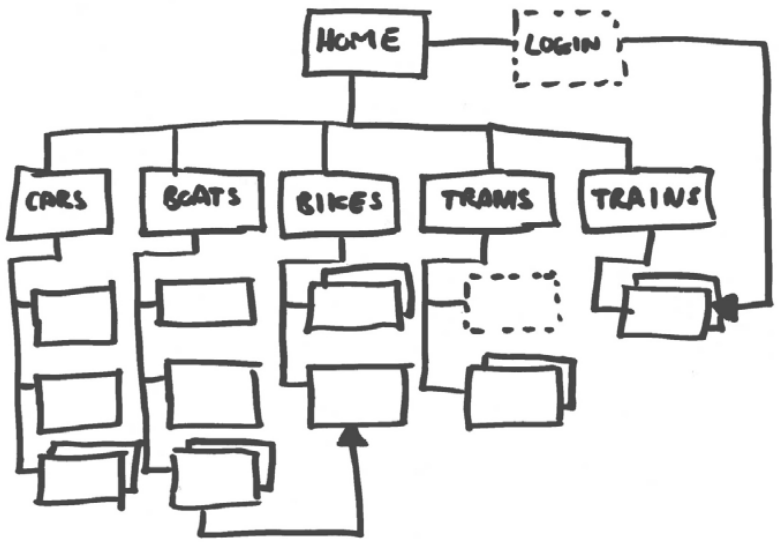


Figure 32.
Sketch of an information architecture scheme; sketch retrieved from the online article on User Interface Design of Claudia Jacques, UX designer.

as long as people have had information to convey, they have had to make choices about how they structure that information so other people can understand and use it. Because information architecture is concerned with how people cognitively process information, its considerations come up in any product that requires users to make sense of the information presented.

... On content sites, information architecture is concerned with creating organizational and navigational schemes that allow users to move through site content efficiently and effectively."

Resmini and Rosati (2012) define information architecture as "a professional practice and field of studies focused on solving the basic problems of accessing, and using, the vast amounts of information available today." IA is mostly referred to as related to the design of web sites both large and small, and in regard to wireframes, labels, and taxonomies.

Resmini and Rosati (2012) on the history of IA:

"Even though its modern use, strictly related to the design of information, goes back no farther than the mid-1970s and Richard Saul

Wurman's famous address at the American Institute of Architecture conference of 1976, use of the term information together with the term architecture. It must be remembered that Wurman wrote an article with Joel Katz entitled Beyond Graphics: The Architecture of Information, which was published by the AIA Journal in 1975. In an interview with Dirk Knemeyer in 2004, Wurman said: "The common term then was 'information design.' What got confusing was information design and interior design and industrial design, at that moment and still today in many and most people's minds, are about making something look good.

...Weitzman (1995) supports this notion that the modern inception of the term originally came from Xerox Labs3. Quoting Smith and Alexander (1988), Weitzman maintains that Xerox was among the first corporations to address this notion of information structure and use the 'elegant and inspiring phraseology, the architecture of information' to define its new corporate mission."

Constraints and Enablers within the Informational Architecture

Constraints and enablers of activities, in regard to Informational architecture, can be observed through examples of student's group work that took part during the fall course in 2017, at the Robotic Building Lab of TU Delft.

Students would define the desired interactions enabled by systems of sensors and actuators, such as for example a dynamic change of lighting through intensity and colours, according to the movement of the users within the physical structure and the social moments and settings (Fig. 33 & 34). When shaping inputs and outputs and the information flows, clear enablers are defined through triggers of pre-designed responses to them, while constraints reflect the fact that only certain triggers and pre-designed responses are selected while all the other possibilities are disabled. IA through systems of sensors and actuators can be observed as a pre-defined network of cause and effect.

Informational architecture is then a design that is developed in the back-end of the digitized dynamic system, and it is visible to the users only when being present within the designated spatial areas and when the triggers for dynamic changes are performed.

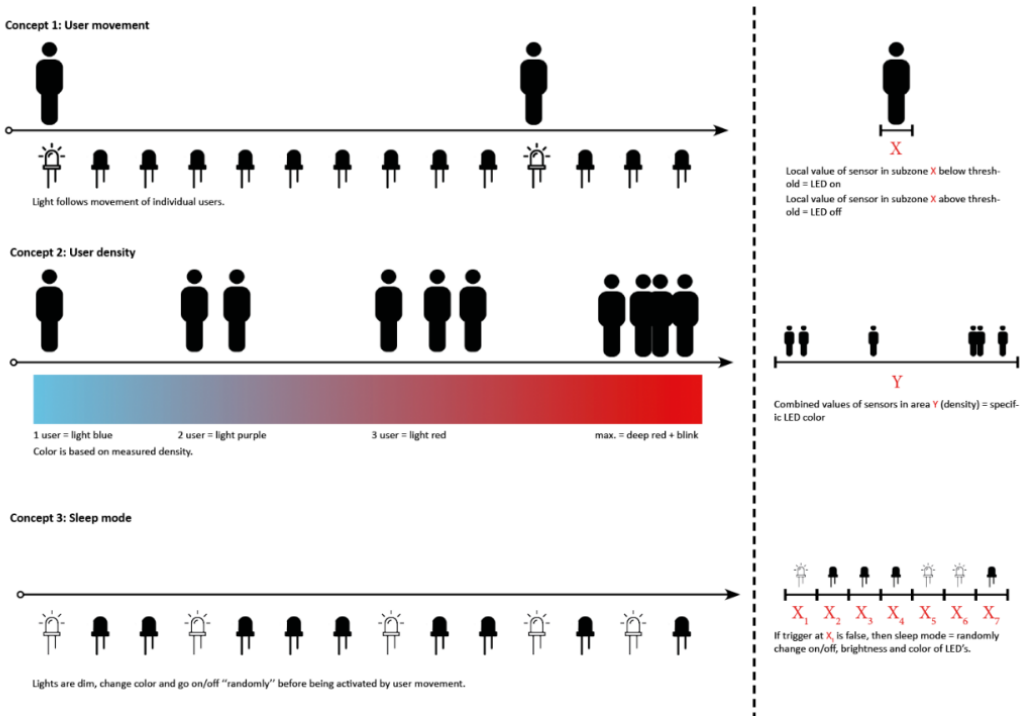


Figure 33. Design scheme for a dynamic lighting system based on automated inputs through real-time user activities; presented example is a student's group project for the course of Robotic Building Lab.

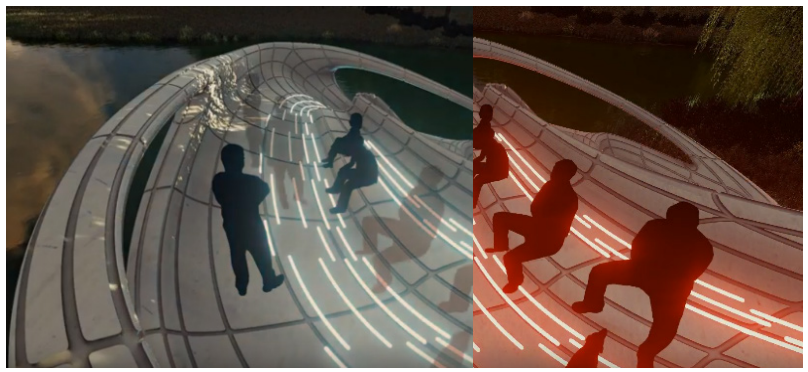


Figure 34. Perspective render of the ambient in which dynamic lighting changes are taking part; presented example is a student's group project for the course of Robotic Building Lab.

Design concept for Informational Architecture could be communicated through following practiced design tools:

- Information Architecture Diagrams,
- Mental Model Diagrams,
- Data Modelling,
- Interface Mock-ups,
- Data Visualization,
- Information Flows Interactive Maps,
- Input / Output Flowcharts.

Relational Architecture

Relational architecture, as one of the Design Domains for Ambient UX, is intended as anticipation and/or triggering of most probable interactions to happen among actors involved in a particular system/situation/circumstances/context (Fig. 35); it refers to understanding and mapping actors within a system and understanding and mapping stakeholders (it is to note that actors and stakeholders occasionally overlap).

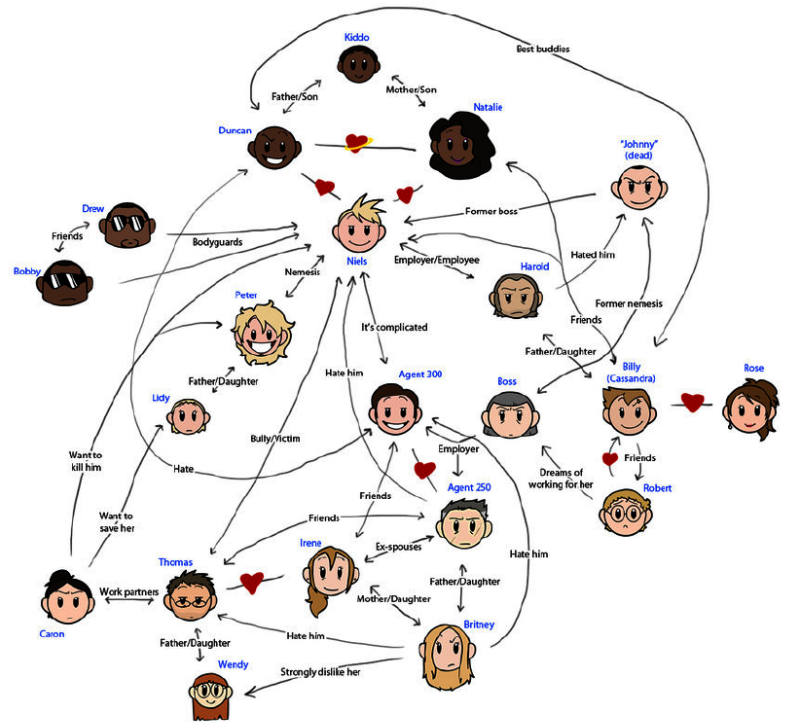


Figure 35. Sketch of a relational scheme between game actors; sketch retrieved from an online article on Character Relationships Charts by Luna Rose, designer.

Jenkins (2004) defines game design as narrative architecture, arguing that:

"The relationship between games and story remains a divisive question among ludologists and narratologists... we can observe ludologists focusing on mechanics of game play and narratologists focusing on storytelling media (seeing how a story develops); but not all games tell stories, the experience of playing games can never be simply reduced to the experience of a story... it is rather an enacting of stories."

Swain and Hauska (1977) present the basic concepts of a multistage classification strategy called the decision tree classifier within gaming design. The authors describe that "decision trees are evaluated from root to leaf, every time. For a decision tree to work properly, the child nodes of each parent must represent all possible decisions for that node. If a node can be answered "Yes, No, Maybe", there must be three children, Yes node, No node and Maybe node. This means there's always some lower node to traverse, until reaching an end node - deciding if or not to make an interaction with another actor."

Game designing, thus, relies on actors, intended almost as theatre actors; actors can be any entity that acts, even objects in games. Some computer games model real-world activities, whereas other computer games attempt to model the processes of noncomputer games. Laurel (2013) discusses on mediated collaboration in this context, i.e. interactions among interactors and players.

Tychsen et al. (2006) discuss the phenomenon of live action role-playing games (LARPs), which also share a range of characteristics with massively multiplayer online games (MMOGs): "Because these games have existed for more than 20 years, players of these games have a substantial amount of experience in handling issues pertinent to MMOGs. Survey and review of live action role-playing games, whose participant count can be in the thousands, reveal that features such as size, theme, game master-to-player ratio, and others interact to form complex systems that require several different groups of control tools to manage. The way that these games are managed offers a variety of venues for further research into how these management techniques can be applied to MMOGs."

Tychsen et al. (2006) write on LARPs:

"Pen-and-paper (or tabletop) role-playing games (PnP RPGs) have been recognized as an important source of information for the study of interactive storytelling (Louchart & Aylett, 2003; Peinado & Gervás, 2004). PnP RPGs do not form a homogeneous group of games; however, they can be roughly described as an activity where one or more players take on roles within an interactive story, usually under the guidance of one or more game masters (GMs).

...Live action role-playing games (LARPs) is a term covering a wide variety of game play, it encompasses games that share a range of features with massively multiplayer online role-playing games (MMORPGs) ... The lack of explicitly academic theoretical and empirical research within the field further hinders studies into LARPs, and most theoretical and practical knowledge is currently presented in non-academic sources. However, recently, a few academics, especially in northern Europe, have begun to study LARPs as pervasive games and, in particular, applications of IT in these games (Soderberg et al., 2004). Large-scale freeform LARPs have existed for more than 20 years (Soderberg et al., 2004).

...Efforts are currently focusing on studying LARPs in relation to mobile gaming, and the development of technological aids for pervasive gaming (Falk & Davenport, 2004). Furthermore, LARPs form a possible source of information of relevance for interactive storytelling (Louchart & Aylett, 2003)."

Brandt (2006) opts for designing exploratory design games for the purpose of participatory design. The author describes the research activities:

"In relation to participation in scenario construction we have found inspiration from Forum Theatre (Boal, 1974). Here a group of actors play a conventional piece of theatre. The audience are asked to suggest changes in the play according to their preferences, and after a debate the play with incorporated changes is performed again. When using the principles and rules of Forum Theatre in designing the users or other stakeholders can be players, audience or both. Another source of inspiration is "The magic if" technique created by Stanislavskij (1988). When creating a role, the actress has to ask herself questions like: "what if the character was in this or this

situation – how would she react?" In design projects it is easy to ask similar questions for instance focusing on user experiences or when exploring use contexts."

Exploratory design games provide a valuable framework for organising participation if one takes the dogma of participatory design seriously; designers need to involve other people actively in the design process.

Diverse authors describe the need for employing role-plays when dealing with experience prototyping in the design field (Buchenau & Suri, 2000; Svanaes & Seland, 2004). Experience prototyping, therefore, refers also to prototyping how people interact with each other (Kurvinen et al., 2008). Svanaes and Seland (2004) describe the idea as the following:

"Some actors, the sample users or the designers themselves, perform a hypothetical service experience. The implied condition is thinking that the service really exists and then building a potential journey through some of its functionalities. A possible evolution of this tool consists in the performance of the same scene several times, changing the character profiles on each scene in order to understand how different users would act in the same situation."

Bjogvinsson et al. (2012) discuss on contemporary participatory design challenges:

"In a European tradition, these challenges have been addressed as design for social innovation. Social innovations can be products or services just like any innovation, but they can also be a principle, an idea, a piece of legislation, a social movement, or an intervention—or some combination of these innovative possibilities. The key aspect is their capacity to simultaneously meet social needs and create new social relations. The Young Foundation in the United Kingdom has been a major player in developing the social innovation perspective in theory and practice. Italian designer and researcher Ezio Manzini and the international group of people around him have been primary drivers in spreading such design practices. Here, new ideas emerge from a variety of actors directly involved in the problem to be addressed: end users, grass roots designers, technicians and entrepreneurs, local institutions, and civil society organizations. "

Constraints and Enablers within the Relational Architecture

Constraints and enablers of activities, in regard to relational architecture, can be observed through examples of student's group work that took part during the fall course in 2017, at the Robotic Building Lab of TU Delft.

Students would analyse and map out the social activities and relations happening within an existing environment, considering also their causes (Fig. 36).

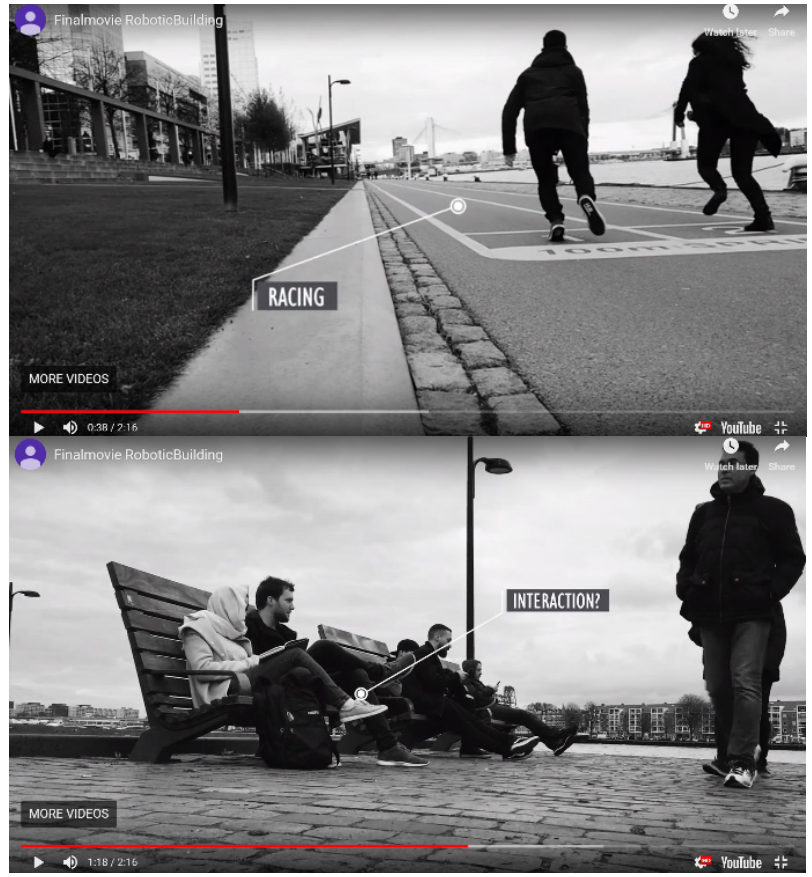


Figure 36. Analysing social activities and relations within a current encountered situation; presented example is a student's group project for the course of Robotic Building Lab.

Furthermore, within the novel design concept they would design for and propose probable interactions and encounters to happen (Fig. 73); meaning that in this manner the social relations are part of the design planning process and they are directional with certain enablers and/or constraints within the project.

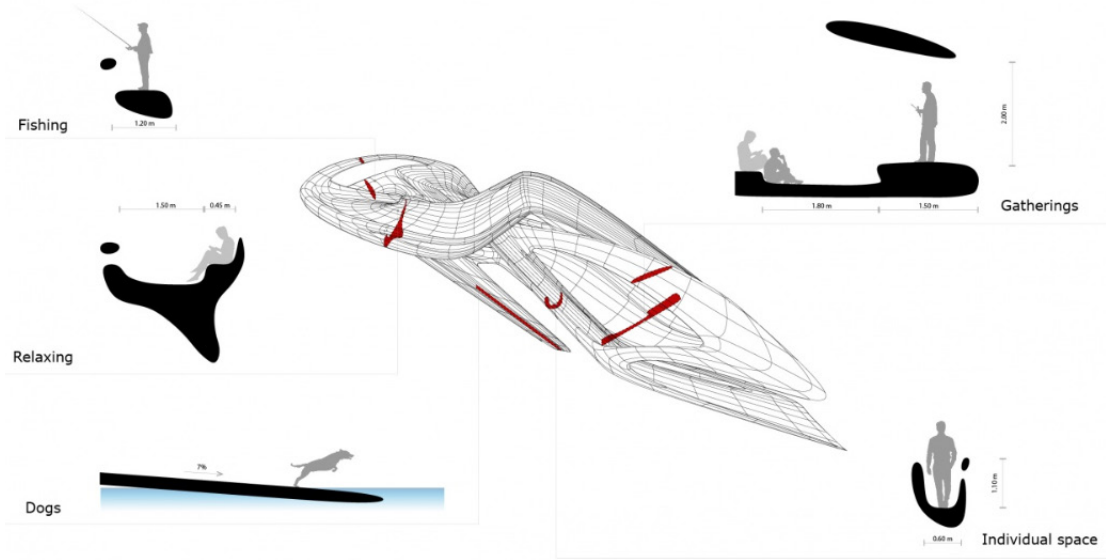


Figure 37. Planning for probable social activities within the novel design concept; presented example is a student's group project for the course of Robotic Building Lab.

Design concept for Relational Architecture could be communicated through following practiced design tools:

- Service Blueprints,
- Stakeholder Ecosystems,
- Personas,
- Touchpoint Matrix,
- Role Play,
- Game Design Plot,
- Game Design Decision Tree,
- Game Design Flow Diagrams.

Variable of Time

Variable of Time, as one of the Design Domains for Ambient UX, is the backbone that puts together all the three architectures described previously; it refers to sequential steps of an activity (Fig. 38), and it can reflect diverse time scales and length.

Figure 38. Sketch for activities displaced within sequential time frames; sketch retrieved from the online article of UX Collective (2018).

Service Design considers time as an aspect of design. Pine and Gilmore in their book The Experience Economy (2011) reason on time in a manner in which they propose that rather than thinking about time efficiency, when it comes to experience design, we should refer to planning for time well spent. This statement is one of the main differences the authors observe between Service and Experience design.

Lynn Shostack (1982) argues on the semantic difference between products and services:

"Products are tangible objects that exist in both time and space; services consist solely of acts or process(es) and exist in time only. The basic distinction between "things" and "processes" is the starting point for a focused investigation of services. Services are rendered; products are possessed. Services cannot be possessed; they can only be experienced, created or participated in.

... a service only exists during the time it is being rendered or while it is "on"… For example, the potential service of haircutting consists of a series of steps which a barber should perform in a particular order and manner to yield a particular type of haircut."

It derives, therefore, that the chronological sequence of the operations and activities is a Design Dimension for projects with a focus on experiences. Showing a time dimension is needed for describing use case scenarios around which certain experience

is being built. With this concept, when it comes to designing for experiences, storymapping comes into play (Hassenzahl, 2010; Lichaw, 2016). In fact, Quesenbery and Brooks (2010) define a story as a crafted experience, and storytelling is the craft. It is about stories whose goal is to describe or communicate some aspect of user's experience.

One of the research tools for user storymapping are longitudinal studies. Longitudinal studies are convenient for comprehending, for e.g., behavioural changes developed over long period of time of use of certain technology, considering also the adoption of the same occurring over time (Blaynee et al., 2016). Monitoring and storymapping, in this context, is used to the ends of improving the quality of user's life.

For mapping out activities over time, Patton and Economy (2014) suggest following a narrative flow, describing a story one step at a time:

"Close your eyes and think back to the moment you woke up this morning. You did wake up this morning, right? What's the first thing you recall doing? Now, open your eyes, and write it down on a sticky note. I'll write along with you. My first sticky note says, "Hit snooze." Now, peel off that sticky and put it on the table in front of you. Then, think of the next thing you did. Got it? Now, write it on the next sticky, peel it off, and place it next to the first one. Then keep going. My next couple of stickies say, "Turn off alarm" and "Stumble to the bathroom."

For considering Time as a variable as one of the Ambient UX Design Domains, user tasks are the basic building blocks for mapping out a story map that relates to particular use-case scenarios.

Constraints and Enablers within the Variable of Time

Constraints and enablers of activities, in regard to time as a variable, can be observed through examples of student's group work that took part during the fall course in 2017, at the Robotic Building Lab of TU Delft.

Students would analyse and map out time frames of their planed user journeys and activities within the interactive installation (Fig. 39). Time can be observed as an element that can be enabled or constrained by defining, for e.g., a period in which certain dynamic changes and interactions can happen.

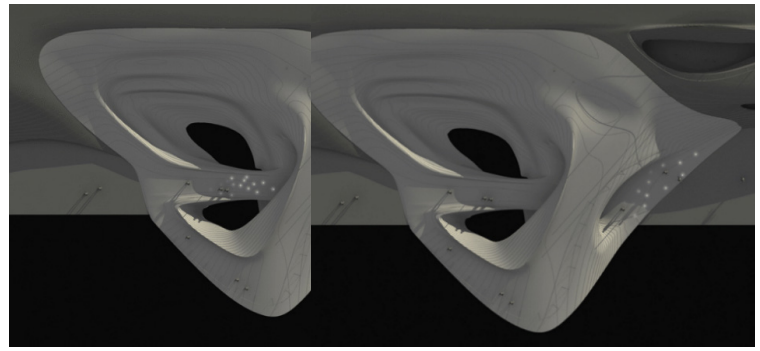


Figure 39.
Render of a design concept showing moments when dynamic changes are taking part, like for e.g. light; presented example is a student's group project for the course of Robotic Building Lab

By taking on the approach of designing for experiences, students focus on defining particular journeys which happen over a certain timespan, i.e. they anticipate possible paths and moments of interaction and encounters, as well as their sequence (Fig. 40).

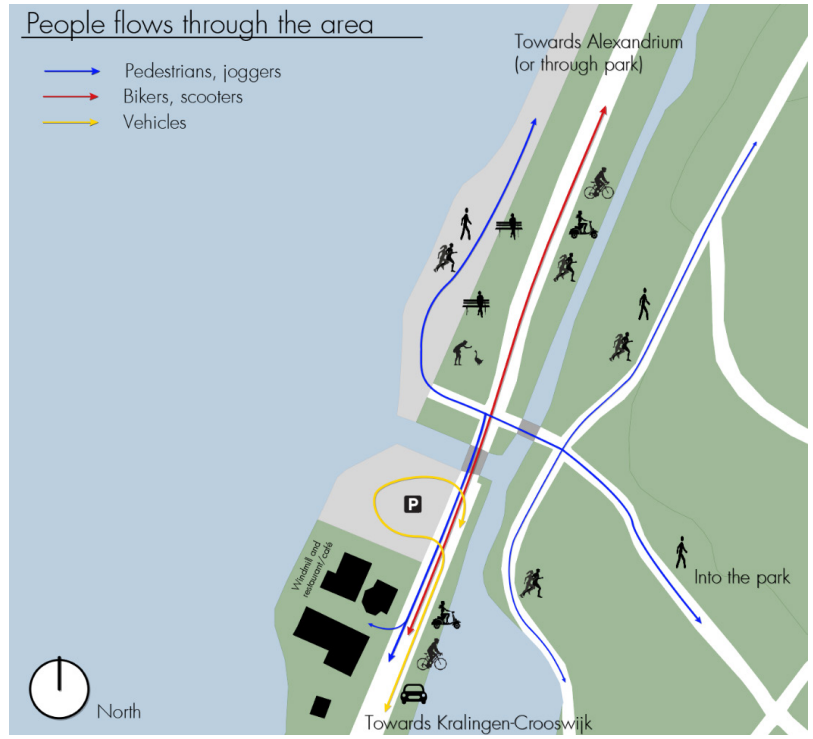


Figure 40.
Planning for probable journeys and encounters that could take part over time within a certain setting; presented example is a student's group project for the course of Robotic Building Lab.

Design concept considering Time as a Variable could be communicated through following practiced design tools:

- Storyboarding,
- Customer Journey Mapping,
- User Flow Charts,
- Musical System Time Signature,
- Movie Plots,
- Comic Books,
- Game Design Activity Gantt.

In projects of system designs that we are dealing with, we should embrace complexity of their nature (Norman, 2011). For Ambient UX, the nature of produced design outcomes is dictating the main parameters for mapping a user journey, thus reflecting the nature of constraining/enabling touchpoints. The parameters are the activity enablers through time and physical space, information flows from diverse sources, and all enabled interactions through human relations. In the ecosystem of networked interactions, we can define levels of diverse architectures of constraints/enablers that reflect the introduced parameters (Time, Space, Information, Human Relations).

All of the three architectures interlace and influence each other, and all of them contribute to coherency of fluid transitions of activities within the Ambient UX. Next to Spatial, the Information architecture emerges as an inevitable component strongly characterizing ecosystems supported by digitized platforms. Information architecture defines intangible structures that support users' needs, realized both in the digital space as apps and websites, as well as in the physical space through objects such as maps, signs or physical structures (Benyon, 2014). In this evident discipline overlap within Information architecture (Saffer, 2009), the structure of content has to be organized taking in consideration all the diverse information sources and the most suitable optimization and organization of content, avoiding information redundancy and providing clear communication. When designing for experiences, it is to consider traversing different domains (constraining/enabling touchpoints) in order to communicate successfully, complete a task, or elicit a

desired physical, mental, or emotional response (Grossman, 2006). The movement between diverse design domains an touchpoints Grossman identified as Bridge Experiences.

The three architectures (Spatial, Informational, Relational) and Time as a variable all sink into a holistic design concept when it comes to designing CPSes. The architectures derive from the already established fields, and thus, they are recognizable within design practices; they have different traditions regarding design methods and history of development and designing, as some of them, like Spatial Architecture, are known and practiced for much longer time period than Informational for example. Furthermore, as the architectures are known in design practices in terms of the final outcome of the concept and project development, design tools used in the practices are also quite known. As indicated in the description of each architecture, different design tools are known for modelling diverse three architectures according to their final design outcome, such as the physical 3D shapes and materials, information flows and communications, as well as anticipation of social encounters and actors. The already known tools, being proven as efficient for their peculiar practice, can be used as a starting point for reasoning on a toolkit or a unique tool platform for designing cyber-physical systems.

The element that connects all three architectures is the variable of Time, which provides a backbone for planning and designing for human activities and interactions. Three architectures intertwine around the element of Time and allow for planning and designing of touchpoints on three levels.

2.2 OBSERVING USERS' VALUES FOR AMBIENT UX

Complexity encountered in case studies that relate to systems of spaces enhanced by digitized services is observable within the previously defined Design Domains for such projects. However, the projects pose another level of complexity when it comes to analysing, comprehending and interpreting users experience within the systems.

For comprehending the implications of Ambient UX, a research was conducted for identifying diverse manners in which diverse authors approach the topic of user's experience and its evaluation within a project. Understanding the approaches towards evaluating users experience is crucial for the alignment of all the stakeholders on the aspects that the project should focuses on. Therefore, the User Values (UVs) are recognized as the main driver for developing design concepts for projects of Ambient UX, and thus, provide a significant stepstone within a design process.

Analysis of literature on dimensions of User Values brought up an identification of levels on which the phenomenon can be discussed. Grouping all the considerations, the following main levels of UV emerge:

- ***Usability,***
- ***Meanings & Motivations,***
- ***Social Consensus***.

Ambient UX adopts these as the levels to be considered when evaluating a project with a focus on experiences. The three levels require diverse UX research approaches, and they influence shaping of Design Domains in diverse manners. The three levels take roots from different fields, which appear to collide and overlap within the concept of designing for Ambient UX. Namely, the Usability evaluation takes roots from the HCI field, Meanings & Motivations take roots from management and business planning, while Social Consensus relates to social and philosophical studies on ethics.

Evaluating User's Experience 2.2.1

UX Evaluation in Design Processes

Friedman et al. (2002) propose Value Sensitive Design (VSD) as a theoretically grounded approach to the design of technology that accounts for human values in a principled and comprehensive manner throughout the design process. Authors describe the proposed approach in the following:

"Value Sensitive Design is arguing that in socio-technical analyses, both the social and the technical need to be taken seriously, and integrated. Toward this end, Value Sensitive Design proposes the integration and iteration of conceptual, empirical, and technical investigations – and seeks to ground them within an overarching theory with intellectual commitments from the social sciences, philosophy, and system design.

… Early interest in computer technology, values, and design emerged in the work of Norbert Wiener (1954) and others. More recently, such interest has led to such areas as Computer Ethics, Social Informatics, Participatory Design, and Computer-Supported Cooperative Work. Value Sensitive Design seeks to work both levels, the concrete and abstract, depending on the design problem at hand.

… Value Sensitive Design seeks to be proactive: to influence the design of technology early in and throughout the design process. It enlarges the scope of human values beyond those of cooperation (CSCW) and participation and democracy (Participatory Design) to include all values, especially those with moral import. Value Sensitive Design contributes a unique integrative methodology that involves conceptual, empirical, and technical investigations."

MacDonald and Atwood (2013) have acknowledged that we are now in the "User Experience phase" within the field of HCI, referring to the period starting from 2000s until now. Within this phase, UX has emerged as a "new paradigm" for design and evaluation, where we overcome the mere utilitarian aspects of use, as we are shifting from

task-based performance to user's affect and the value of interactions in everyday life (Law et al., 2009; MacDonald & Atwood, 2013). In the HCI field, it is possible to predict with ease the technical feasibility of systems, however what will be socially acceptable and meaningful brings uncertainties and calls upon further explorations of conceptual frameworks to reason on this issue (Forest et al., 2013).

Even though in the HCI research field user experience has been studied by various researchers (like for e.g. Hassenzahl & Sandweg, 2004; McCarthy & Wright, 2004; Hassenzahl & Tractinsky, 2006; Desmet & Hekkert, 2007) it appears that we are still lacking a shared conceptual framework when it comes to more holistic UX approaches (Law et al., 2009; MacDonald & Atwood, 2013; Lachner et al., 2016). Authors have, however, been proposing similar approaches towards UX through diverse reasoning on this topic, pointing out levels that go beyond usability. Norman (2004) talks about "emotional design" in terms of visceral, behavioural, and reflective experiences. In a similar manner, Hassenzahl (2003) underlines that products have hedonic attributes, besides the pragmatic ones (e.g., an ability to evoke feelings of pleasure). Desmet (2003) provides a conceptual model for emotional responses that results from the perception of consumer products. Furthermore, Forlizzi and Battarbee (2004) are differentiating "experience, an experience, and co-experience", having "an experience" as inspiring emotional and behavioural changes in the experiencer. In this context, MacDonald and Atwood (2013) suggest that the exploration of UX evaluation methods, implying both pragmatic and hedonic dimensions, is a valuable research direction for real-world interaction design projects, as it is recognized that usability is not enough (Arhippainen, 2013).

Pragmatic and hedonic dimensions can be observed as correspondent to "what" and "why", where the main aim is to understand the "why" behind the "what" (Kim et al., 2008). Kim et al. (2008) propose a system for Tracking Real-Time User Experience (TRUE), which refers to users in the gaming sector, where they emphasize the importance of contextual information for understanding complex use-case systems. Namely, context of use is an important characteristic to take into account in user experience studies (Roto et al., 2011).

Within my research, I am targeting a holistic approach towards

users' experience, and I refer to UX as dynamic, context-dependent, and subjective phenomena (Law et al., 2009) that emerge from the interaction with a designed system. As we are dealing with spatial dynamic systems, we observe that, even though there are references on 3D user interfaces that regard objects and space, still these are found in the virtual gaming environment (Arhippainen et al., 2013) rather than real use-case scenario, which we are focusing on. A measuring tool for Ambient UX in real use cases appears to be a needed approach that yet has to be established.

Experience also changes over time, as it is affected by the creation of memories that might further guide the future perceptions and behaviour of the individual (Karapanos et al., 2010; Kujala et al., 2011; Norman, 2009). Kujala et al. (2011) propose a UX Curve method for evaluating the hedonic aspects of UX over time. In this method, users are asked to recall and express significant reasons for changes in their experience by drawing a certain curve on a timeline, in regard to the use of Facebook and mobile phones. Von Wilamowitz-Moellendorff et al. (2006) propose CORPUS (Change Oriented analysis of the Relationship between Product and User), an interview technique that reconstructs changes in user experience over a period of more than one year.

Other authors, like Karapanos et al. (2009) presented a study that followed an actual purchase of the Apple iPhone, analysing early and prolonged experiences to understand when the product becomes meaningful. They were inspired by Silverstone and Haddon's (1996) study on prolonged user experiences, observing three dimensions of adoption: commodification, appropriation and conversion. From their findings, Karapanos et al. (2009) promoted three directions for HCI practice in regard to product adoption: designing for meaningful mediation (i.e. qualities of stimulation and learnability), designing for daily rituals (i.e. usefulness and long-term usability), and designing for the self (i.e. personal and social experiences). Here the temporality of experience is connected to three main forces: an increasing familiarity, functional dependency and emotional attachment.

I use the manner of reasoning about user experience over time proposed by Karapanos et al. (2009) as an inspiration for our own study. I further underline the importance of experiences that are

created together with others as well. This kind of an approach is recognized as co-experience (Battarbee & Koskinen, 2005), and it brings upon various ways of evaluating and prototyping social interactions (Kurvinen et al., 2008).

Three Levels for Evaluating Ambient UX

2.2.2

The design and development of personal services and applications based on technology ecosystems involves several different competences: from service design to technology engineering, from business planning to interaction design, UX design, communication and marketing. The design of such systems often requires the collaboration of different stakeholders and partners, each one aiming at specific goals and purposes. Indeed, the challenges of designing new digital services, very often, go way beyond rethinking interaction modalities and interfaces; as connected products and digital services evolve to produce deep modifications of individual behaviours and social organizations through the creation of new paradigms of services, (Young, 2012; Greengard, 2015) designers face questions about the definition of new values that these connected systems offer to the users (Rowland et al., 2015).

When we design a socio-technical ecosystem (Trist, 1981; Rowland et al., 2015) with an approach of design for experience, the roles and responsibilities of designers occur on multiple scales: beyond the straightforward requirements of acceptance, acceptability (Greengard, 2015; Taebi, 2017), usability, convenience and including physical, digital, individual and social issues (Winner, 1980).

Observed by Hassenzahl (2010), experiences emerge through situations, objects, people, and their interrelationships with the experientor (the person who undergoes an experience). It is to underline that dealing with abstraction of experiences and its representation is quite a complex quest for a creation of a common language within a working field.

Jensen (2014) also argues the creation of meanings and values through experiences of certain designed outcomes. This author identified three dimensions of experience: Instrumental,

User-experience, and Profound Experience. The Instrumental dimension is the physical condition of the product itself, that allows the experience to happen in a certain manner. User-experience here relates to flows and relations, by defining the actions that the user is undertaking. The third dimension is the Profound one, that shapes the meanings and motivations, and answers the question of "why" the user is accepting to be involved in the first place.

In the field of Human-Computer interaction (HCI), User Experience (UX) has emerged as a new paradigm for the generation and evaluation of designs, which shifts the focus from utility and task-based performance, to user experience and interaction value in different use contexts (MacDonald & Atwood, 2013). In the evaluation of AmI UX the pragmatic and enjoyment aspects are equally important (Hassenzahl, 2003; Forlizzi & Battarbee, 2004). MacDonald and Atwood (2013) argue that the use of UX evaluation methods involving pragmatic and enjoyment parameters, is an approach that leads to real-world design. Usability is not enough (Arhippainen et al., 2013). Furthermore, because user experience is mutable, affecting both the perception and the behaviour of the user, it should be evaluated within a specific timeframe and context (Karapanos et al., 2009).

Human-activity recognition and biofeedback analysis are common practices for evaluating UX within indicative environments (Treur, 2007). For example, applications of AmI systems focusing on Ambient Assisted Living (AAL) involve monitoring and supporting elderly and disabled people in their homes (Salvi et al., 2015; Veronese et al., 2016). In this context, Bono-Nuez et al. (2014) propose a model for evaluating the quality of life of these individuals, based on activity monitoring, while Ntoa et al. (2018) present a UX evaluation framework measuring how AmI systems anticipate and satisfy the user needs. This method employs video recording and measuring during user testing experiments. O'Grady et al. (2013) propose six quantifiable dimensions to measure software quality from the end-user's point of view, namely: efficiency, affect, helpfulness, control, learnability and global usability.

Previous methods are used in evaluating AmI systems during prototyping, while different methods apply in the evaluation of early design concepts. The assessment is based on the potential of a

system to get broadly adopted, rather than usability criteria. Video-fiction prototyping is used for this purpose (Kymäläinen et al., 2017). Gaggioli (2005) proposes an Experience Sampling Method to evaluate UX in AmI systems, focusing how user attention selects information from the environment. Gaggioli defines an "optimal experience" as a flow of psychological processes causing various states of user consciousness. Other researchers focus on the user journey and the relationship between system operations and user expectations, to assess user confidence (Corno et al., 2015). In this case, the design vision and the user's point of view are not identical. Forest et al. (2013) base the assessment of AmI concepts on this paradox. Cabitza et al. (2016) propose Event-Condition-Action rules as a novel conceptual framework for designing complex socio-technical systems and supporting users to propose trigger-action rules.

Besides the potential of system adoption, UX assessment also relies on the anticipation of social impact (Little & Briggs, 2005) and ethical norms (Colombo, 2018). Wiegerling (2015) poses the question of ethics in AmI, observing that autonomous systems incapacitate the users if they are not controlled properly. As the spatial context within which the interaction between humans and system is no longer static, single-user, and location-independent, but a dynamic multi-user, situated environment, there is a need for reconsidering the implications of novel design systems, and proposing new design methods for intelligent systems (Streitz et al., 2019). And because data is a core resource in designing AmI systems (Arslan et al., 2017) the acquisition of data requires broader social consensus.

It is evident that there are many definitions and reasoning about experience within the design field, and finally these are all conditioned by the nature of design outcomes. Referring to the literature on evaluation of users' experiences, it therefore derives that, when designing for experiences, we have to consider diverse levels of significance and impacts involved in design solutions. The ground and primary level refers to the aesthetical meaning, as well as usability of the posed elements: the direct, physical contact with the tangible elements of the designed system. This implies comprehension of functionalities and usability, and it includes ergonomics of the material solutions as well as their pleasantness in direct interaction.

The upper level of user experience attends to the creation of the service meaning: valuable utility provided by the designed solution, through convenient modalities of use and involvement, as perceived from the user end. To this regard, an important challenge is posed to the designers concerning the consequences of their solutions. The meaning perceived by the end user, within emerging socio-technical systems, can be of a diverse nature and vary from short to longer-term effects. As designers, we should be able to foresee and manage both, long and short-term consequences of design choices.

Considering the complexity and hybrid nature of the systems that influence Ambient UX, I identified three diverse levels of reasoning about user experience, and thus, ***User Values for Ambient UX: (1) Usability, (2) Meanings & Motivations, (3) Social Consensus*** (Fig. 41).

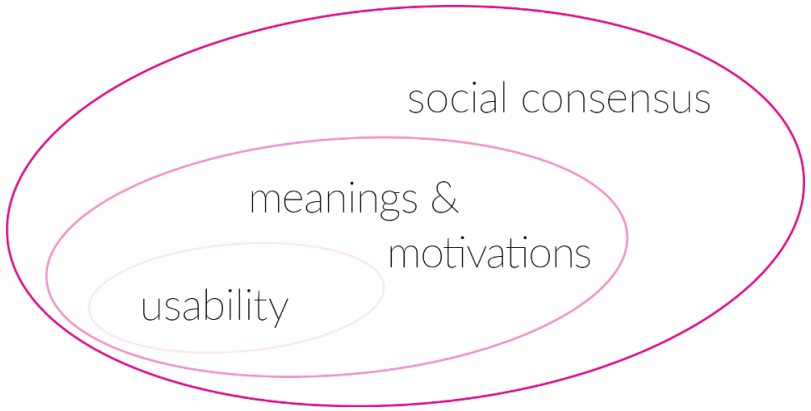


Figure 41.
Three levels of User Values for Ambient UX.

Usability concerns the modalities of user interaction, in regard to Ambient UX, that are natural and multimodal. This level of User Values implies comprehension of functionalities and cognitive processes, as well as ergonomics imposed by physical direct interaction. Gibson (1977) defined usability as the physical pleasantness and ergonomic aspects of a design outcome, as well as the ease of comprehension, in terms of affordances.

Over time, many authors have emphasised the importance of more

UX Evaluation in Design Processes

specific aspects of usability; like for e.g. Nielsen (2003) defined usability including considerations on, in addition to efficiency in normal use and satisfaction with use, also learnability in early use, memorability after a period of non-use, the fact that errors during use can be corrected, and do not lead to undesirable consequences.

ISO 9241-11 revised standard definition of Usability, provided in 2015, states that Usability is "the effectiveness, efficiency and satisfaction with which specified users achieve specified goals in particular environments."

Green et al. (2008) discuss on measurement of system usage by practitioners involved in user-centred design as being often concerned with usability evaluation. The authors argue on Usability ensuring that the products are easy and comfortable to use, safe, effective, efficient, and easy to learn how to be used. They further note that usability evaluations are made through objective (e.g., time or physiology) and subjective (e.g., perceptions, attitudes, and other scales of psychological constructs) measurement and are typically based on at least one of three dimensions outlined by ISO 9241-11, which are: Efficiency, Effectiveness, and Satisfaction.

Bevan et al. (2015) underline that there is more to usability evaluation than usability measurement. In fact, they observe it as something we learnt about usability since the old ISO definition from 1998 and implemented it in the definition provide within the revised ISO 9241-11 standard. The authors write:

"The intention was to emphasise that usability is an outcome of interaction rather than a property of a product. This is now widely accepted. However, the standard also places emphasis on usability measurement, and it is now appreciated that there is more to usability evaluation than measurement. Other developments include an increasing awareness of the importance of the individual user's emotional experience as discretionary usage of complex consumer products and use of the World Wide Web have become more widespread. From an organisational perspective, it is now appreciated that usability plays an important role in managing the potentials risks that can arise from inappropriate outcomes of interaction. The revision of ISO 9241-11 takes account of these issues and other feedback."

Meanings & Motivations

Creation of Meanings over time concerns an analysis and understanding of motivations and goals, acceptability and desirability, as well as context- aware interaction. Meaningfulness reflect the notion of Profound Experience defined by Jensen (2014), as well as the Co-Experience defined by Battarbee and Koskinen (2005). This level of User Values refers to pragmatic and hedonic dimensions (Hassenzahl, 2006; Kujala et al., 2011), previously discussed, that are observed as correspondent to "what" and "why", while emphasizing the aspects of "why", i.e. the motivations behind the "what". Using a product should be enjoyable, engaging, and appealing (Helander et al., 2001; Blythe et al., 2003).

Although the general interest of the Human-Computer Interaction (HCI) research community in pleasure and fun as a goal of software design is growing for quite a long while already (Monk & Frohlich, 1999), we are far from having a coherent understanding of what enjoyment actually is and how it can be addressed by products and processes (Hassenzahl et al., 2001). Monk et al. (2002) call for reflecting on whether designing for fun, pleasure and enjoyment is a desirable goal and whether the processes and topics involved differ in any significant way from designing for usability.

Green et al. (2008) discuss upon a product adoption framework for evaluation:

"Obviously, performance criteria related to Efficiency and Effectiveness are important for consumer products, especially in the case of safety, comfort, and learnability. Particularly for consumer products, however, it has been increasingly accepted that other requirements related to Satisfaction should also be considered."

Desmet (2002) proposes a framework for analysing emotional responses to products. Furthermore, Desmet and Hekkert (2002) propose a model for understanding product emotions, by thinking of product pleasures that go beyond usability:

"The model describes the various ways in which products can act as emotional stimuli and the matching concerns that can either correspond or collide with these stimuli. Products can act as stimuli in three different ways: the product as such, the product (or designer) as an agent, and the products as a promise for future usage or ownership. The corresponding concerns that are addressed are

respectively: attitudes, standards, and goals."

Verganti (2008) discusses the notion of design strategies based on creation of meanings and novel design languages, which he observed as an empty spot in innovation management literature. The author observed that it shows that the process of creating breakthrough innovations of meanings partially mirrors the process of creating breakthrough technological innovations. Furthermore, Verganti writes that "radical changes in meanings ask for radical changes in sociocultural models, and this is something that might be understood (and affected) only by looking at long-term phenomena with a broader perspective". Norman and Verganti (2014) further discuss the possibilities of meaning changes when it comes to designed products and systems, where meaning change is analysed in parallel with technology change for comprehending the drivers for innovation.

Newbery and Farnham (2013) reason on user experience as value creation, and on business as value exchange of something that one side has and the other desires. The authors refer to non-tangible values in terms of creation of values over time, which has to do with measuring engagement and managing customer relationships over time through diverse touchpoints.

Social Consensus

The level of Social Consensus is referred to as the level which deals with acceptability on a social scale; concerns data usage (data privacy and security), as well as behavioural changes. Social Consensus represents the upper level of acceptability and desirability of a design outcome, and it depends on a long-term period of use and the influences that a solution brings with it. This upper level is conditioned by the use of digital services and platforms, which influence might appear as unpredictable on longer terms, but nevertheless affects creation of a lifestyle, followed by behavioural changes.

Battarbee and Koskinen (2005) observe user experience through social interactions, i.e. a co-experience, arguing:

"User experience is becoming a key term in the world of interactive product design. The term itself lacks proper theoretical

definition and is used in many different, even contradictory, ways. This paper reviews various existing approaches to understanding user experience and describes three main approaches and their differences. A missing perspective is noted in all three: their focus is on only the individual having the experience and neglects the kinds of experiences that are created together with others. To address this, a new elaboration called co-experience is presented. It builds on an existing approach but borrows from symbolic interactionism to create a more inclusive interactionist framework for thinking about user experiences."

Bevan et al. (2015) bring up one critique of the previous version of ISO 9241-11 (standard definition of Usability) which is that it ignores social responsibility. Social responsibility, in fact, now has its own ISO standard numbered 26000. The authors underline that a clear distinction needs to be made between considering usability for the user's intended outcomes and diverse stakeholder's intended outcomes, since "taking account of the user's goals satisfies fundamental human needs and produces designs that respects human dignity".

ISO 26000 (2010), standard on social responsibility, provides guidance on how businesses and organizations can operate in a socially responsible way; this means acting in an ethical and transparent way that contributes to the health and welfare of society. Business and organizations do not operate in a vacuum, in fact, their relationship to the society and environment in which they operate is a critical factor in their ability to continue to operate effectively. Social responsibility is also increasingly being used as a measure of their overall performance.

Bernhaupt et al. (2011) write on security, privacy, and personalization in digitized service systems, taking as a case study a user research on acceptability of an interactive TV system:

"The results show that new forms of user interaction must support personalized access to the content on the TV, that they must support security and privacy, and that they should enable new forms of connectivity for all devices used in the living room."

Tromp et al. (2011) define design as an active attempt to change behaviour, regarding behaviour from a social perspective; namely,

when talking about designing products that influence behaviour, the authors equalize it with the behaviour that realizes desired social implications. Other authors, like Steen (2016), refer to a need for a socially responsive design with the aim of designing for wellbeing, equalizing it with (design for) social innovation, which aims to solve societal problems through innovation.

2.3 AMBIENT UX DESIGN FRAMEWORK HYPOTHESIS

Discussion on User Values & Design Domains

Ambient UX framework hypothesis refers to a conceptual framework for designing systems of spaces enhanced by digitized services, with the approach of designing for user experiences. The framework hypothesis of designing for Ambient UX is based on a definition of Design Domains and User Values. Framework is intended to provide a conceptual support for structured design processes that deal with enhanced spaces, focusing on the user experience.

Design Domains, that are previously described in detail, are corresponding to possible outcomes that a designer could manipulate with and influence in any way. Design Domains, finally, are defined through three architectures (Spatial, Informational, Relational) and Time as a variable that gathers them.

User Values, that are previously described in detail, are corresponding to possible levels on which an experience can be influenced in regard to design outcomes for systems of enhanced spaces. To this end, three levels of User Values are defined: Usability, Meanings & Motivations, Social Consensus.

Within the hypothesis for an Ambient UX framework, Design Domains are a response to what is being designed, while the User Values are a response to why it is being designed. Design Domains and User Values are conceptual groups of the framework that intertwine and are mutually dependent. The two groups are present through all the diverse and iterative phases of a design project, from abstraction to concrete realization, thus pointing out the need for implementing tailored UX research within diverse phases of the project.

Framework Scheme

In the initial part of this section, positioning of a UX practitioner inside of the design process was discussed and summarized through a visual scheme (see Fig. 13).

According to the visual for positioning a UX practitioner within a design process, the interaction touchpoints are indicated and positioned in-between the user(s) and the organization (one or a group of stakeholders). The touchpoints are all the possible moments in which there is an interaction happening, provided by the organization towards the user, and these are the ***Design Domains*** (Fig. 42). Design Domains, thus, indicate all possible interactions happening on a spatial, informational and relational levels, i.e. the identified architectures as design interventions.

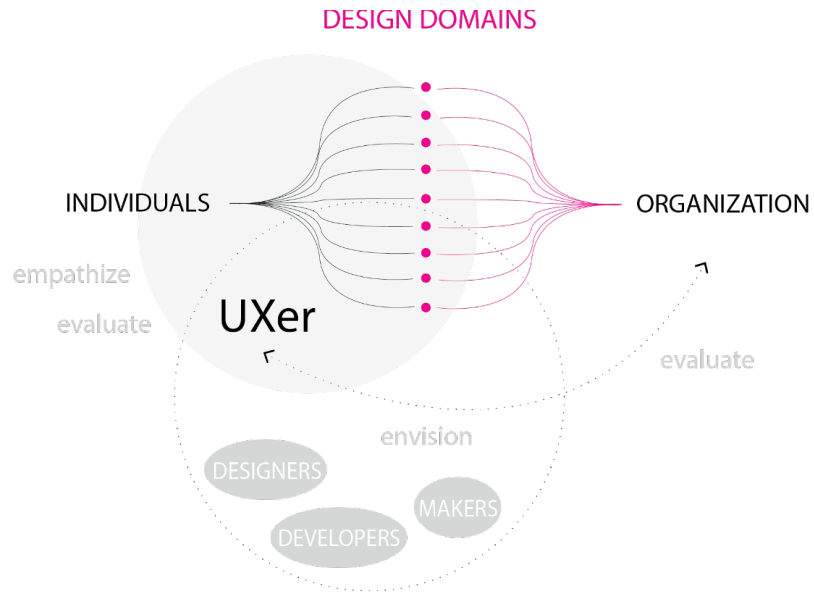


Figure 42. Scheme for positioning a UX practitioner within the design process with indicated positioning of Design Domains.

Within the scheme with indicated relations and communications from the side of the UX practitioner and other parties, the ***User Values*** of Ambient UX are comprehended as the moment of alignment. Namely, the value alignment happens between the user(s) on one side, and organization (one or a group of stakeholders) and design professionals, developers and makers on the other (Fig. 43).

UXer in this context ensures to gather valid and thorough insights by conducting user research and align these, in regard to diverse levels of User Values, accordingly with the sides that can influence them within the project. More precisely, the alignment on Usability values would happen mostly with the team of design professionals, developers and makers, while Meanings & Motivations and level of Social Consensus would be aligning mostly on a strategical level, i.e. with the organization.

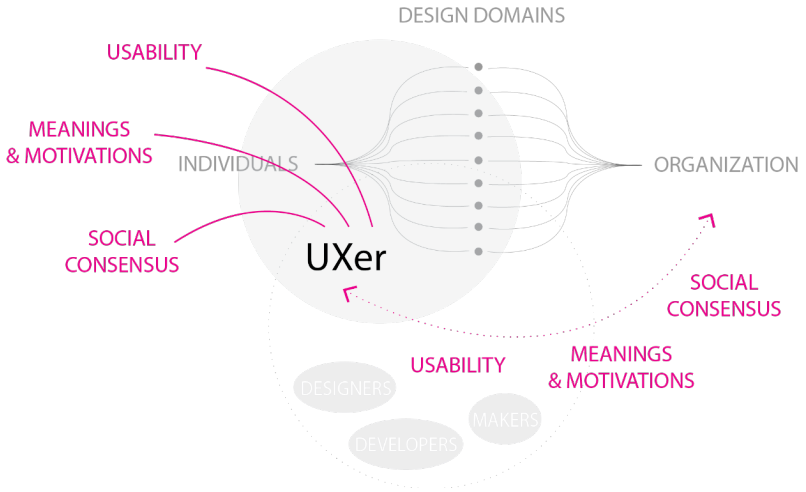
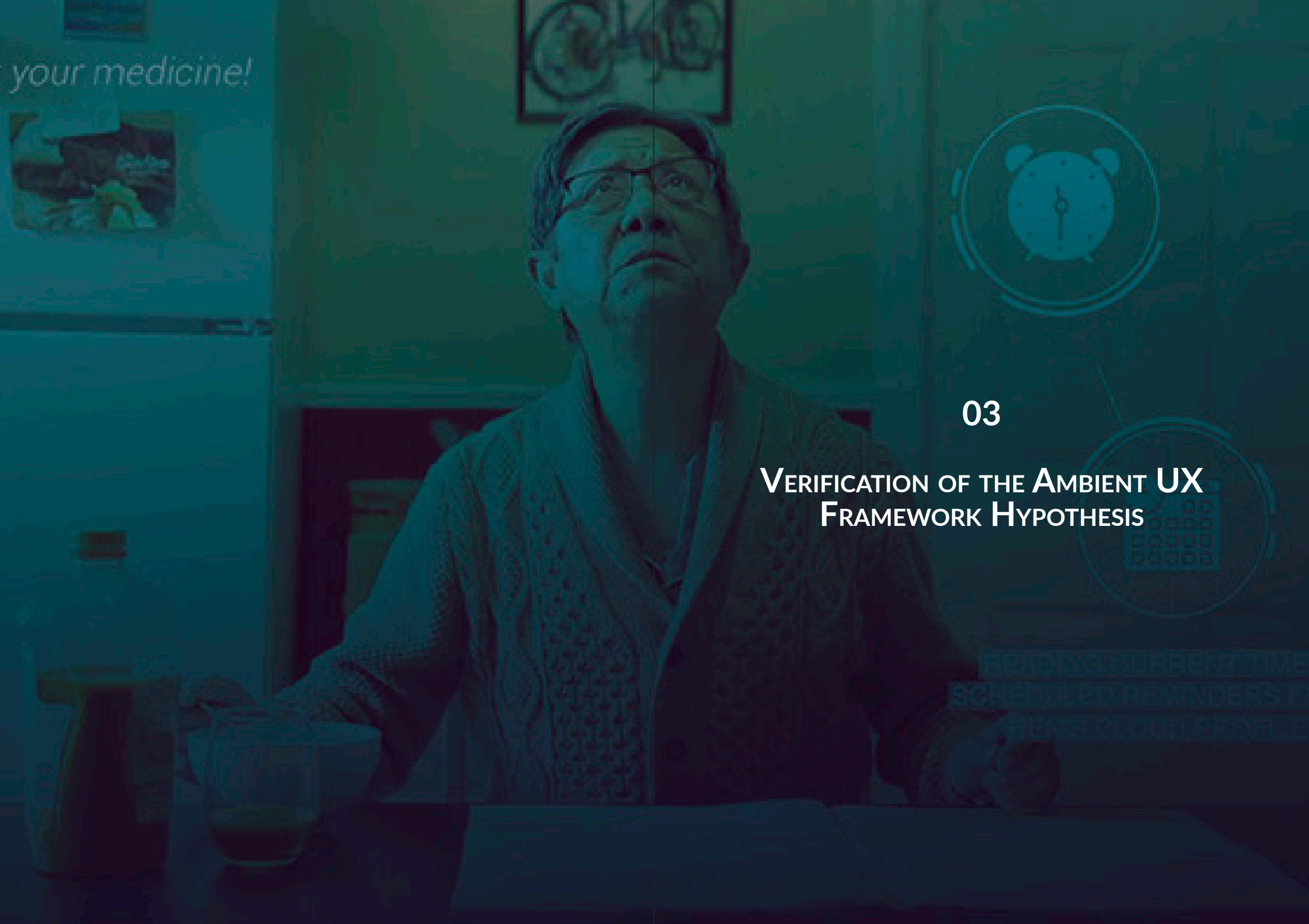


Figure 43.
Scheme for positioning a UX practitioner within the design process with indicated positioning of User Values and their alignment.



03

Verification of the Ambient UX Framework Hypothesis

Research aim for this step is verifying the framework for Ambient UX strategy as well as design tools that could support it. The verification is made by confronting the previously proposed design strategy (Chapter 2) with research projects that satisfy the Ambient UX concept and involve studies on user experience. This is done by identifying what is perceived as User Values in all of the cases and projects, and what is the relation between Design Domains (DDs) and User Values (UVs).

Initially, a first testing has been made for verifying the framework hypothesis, through a case study of a dynamic connected lighting system within an office working environment. The verification consists of identifying the Design Domains as such, as well as their influence on the hypothesized levels of User Values.

After making the first holistic verification of the framework, i.e. the existence and suitability of hypothesized Design Domains within the project and the suitability and existence of influenced User Values within the same, three research projects took part. Three projects had as scope to further verify the hypothesis and observe the connections between Design Domains and User Values, considering also their mutual influence. The three projects are selected according to their diversity in terms of having dominant architectures (even though all three are represented, one is dominant in regard to user values), diverse products complexity and nature, diverse levels of user input or automatized input (through sensors); furthermore, they are all placed in diverse environments, namely: hospital, automotive and city (outdoor and indoor) ambient. The projects are:

1. Humanitas (hospital environment),
2. MEMoSa (automotive environment),
3. Connected Lighting for a Caring City (city environment).

For each of the projects the conducted UX research is described and the User Values are discussed. Finally, overall reflections and discussion are made, and an overall Ambient UX framework verification is presented.

3.1 TESTING THE AMBIENT UX FRAMEWORK HYPOTHESIS

In order to comprehend the user experience of CPS, i.e. physical environment enhanced with digital services and interactive systems, I introduce a real use-case scenario for the study. The case study refers to a connected IoT system of interactive LED light bulbs placed in a work environment. The lighting settings have been designed according to diverse needs of the users of the space and were further assessed in regard to users' experiences. Within the study, I examined a number of aspects to take into consideration when designing CPSes while focusing on experiences evoked by the design system. The results of this user study verify the elements of the Ambient UX design framework, considering both DDs employed within the systems and perceived levels of UVs.

Case Study of a Dynamic Lighting System for a Workspace 3.1.1

The research case aims at proposing and validating a framework supporting the design for user experiences in CPSes, i.e. Ambient UX. It suggests that dynamic changes in interactive spaces should be designed focusing on their effects on three levels of the user experience: physical wellbeing and usability, creation of meanings and motivations, and social relations. Validation occurred through a field study performed in an office working environment, where a dynamic lighting system was designed and installed. Preliminary results validate the relevance of the three levels, thus laying the ground for further research and discussion.

Based on literature review on previous research within the UX field, a framework for Ambient UX is proposed as an extension of the UX approaches in design of dynamic spaces enhanced by digital elements. It is observed that the interactive elements of an environment can be abstracted on three levels, which in turn affect three different levels of users' experience (Fig. 44):

1. The dynamic physical layout, which influences comfort and wellbeing;
2. The digital information, which supports the creation and communication of meanings;
3. The social dynamics and interactions, which influence the social relations.

Presented scheme underlines, on one side, what can be designed and what a designer can manipulate with in a particular context, and on the other, what is the user perceiving and how his/her experience is changed and stimulated by the design interventions. Hypothesis is that this framework can help the design and evaluation of user experience in CPSes. In order to test this hypothesis, the framework is applied to a real case study, i.e. the design and evaluation of an interactive environment enriched by a dynamic lighting system.

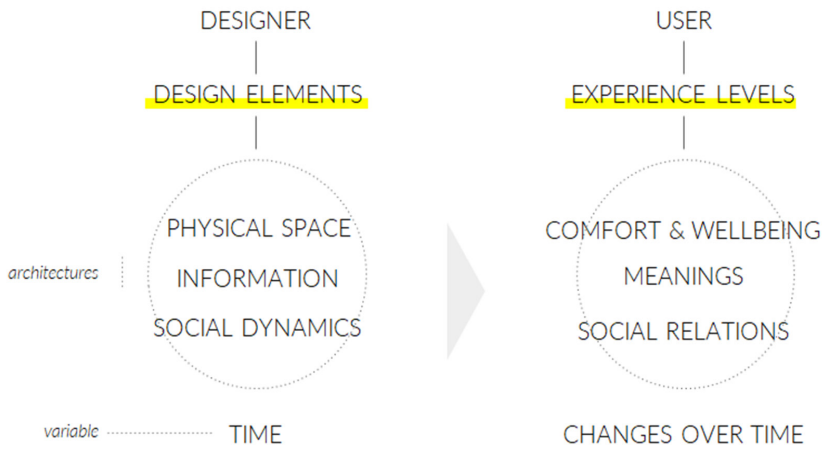


Figure 44. Scheme based on the Ambient UX framework.

Test Setting

In order to test the framework's validity, a user study in a workspace was conducted (Fig. 45). The study consisted of three main steps, where (1) initially the current lighting setting was assessed, then (2) the new interactive lighting system was designed following the needs of the users derived from the previous step, and finally (3) the new interactive lighting system was assessed and confronted with the previous experience of the ambient. Both the design and assessment phases were driven by the elements of defined Ambient UX framework.

Physical environment was augmented by deploying a dynamic lighting system, with the aim to explore how it would affect the user experience on three levels: comfort and efficiency (influenced by the dynamic physical layer), meanings (digital information layer), and social relations (social dynamics layer). A set of dynamic changes was designed as part of the lighting system intervention. Such changes were either pre-scheduled or consequent to specific triggers (e.g. information coming from an application program interface, a.k.a. API). The study was performed over a period of one month, and aimed at generating preliminary results on the application of the conceptual framework to the design and evaluation of Ambient UX.

The test was performed in the workspace of a research group at Massachusetts Institute of Technology (MIT) known as Design Lab, during my stay as a visiting research fellow. The environment consists of an open space with 13 desks and three smaller rooms (Fig. 46). The

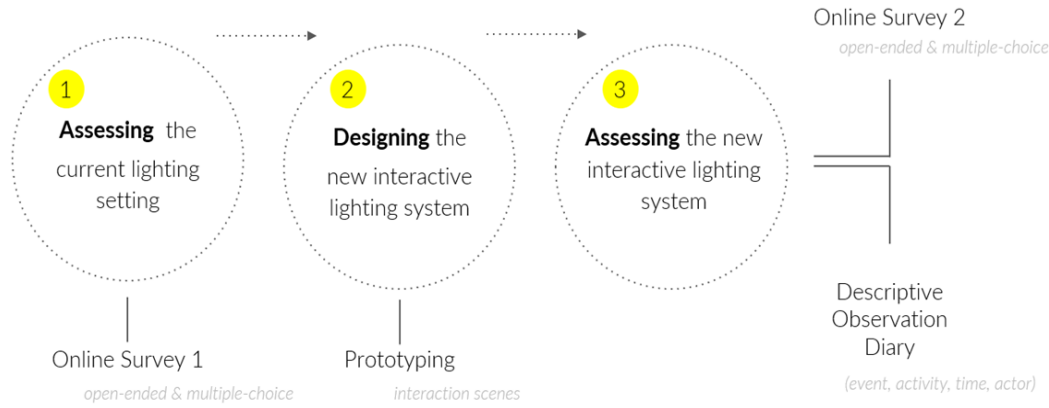


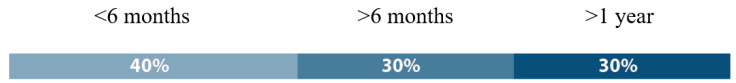
Figure 45. UX research methodology employed within the case study of a dynamic lighting system for a workplace.

workspace has no windows nor natural light sources. Four active areas with ambient light sources were originally present in the open space and were kept in the experiment to provide enough lumen. The test occurred in the main open-space area, where 13 Philips Hue colour light bulbs were installed, plus three Philips Hue colour LightStrips. The connected light sources were programmed and controlled by a mobile application, which was not accessible by the users at the time of the experiment.

The study involved 8 users, who share the workspace on a daily basis, and who were invited to join the study on a voluntary base. They are addressed as user1 - user8 and assigned with diverse roles they have in the work environment, according to time spent at the desk and the time required for interactions and meetings. In the following an overview is shown in percentages, where 8 users present 100%.

Estimated time spent in the office per week:

Timespan of being part of the Lab:



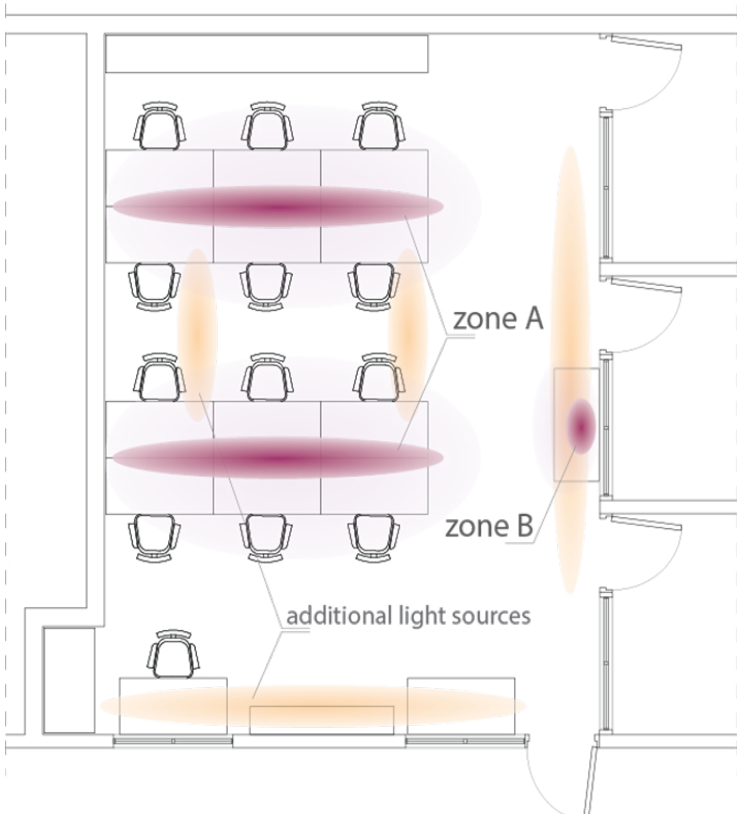
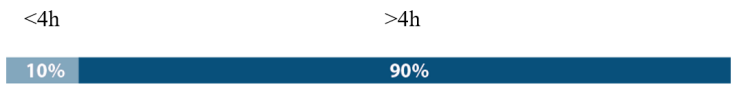
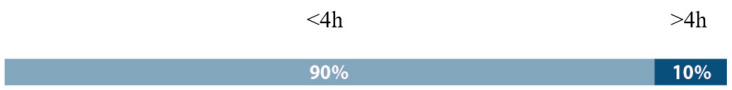


Figure 46.
Top view drawing of the office layout with distribution of new light sources and users' positioning in the space according to their working desks. Zone A and B (pink areas) are the zones of connected light sources, where zone B is separated as it is the socializing corner and differs by particular notifications.

Estimated time spent at the working desk on a daily basis:



Estimated time spent in team meetings on a daily basis:



Being it a real use-case scenario, the working environment has its own particular internal dynamics, and contains already established relations among the working team members.

Two online surveys were performed before and after the installation of the new dynamic system, together with an observation activity,

in order to identify changes on the three levels of the experience proposed in the framework (comfort and efficiency, communication of meanings, social relations).

Understanding the current user experience and designing the new lighting system following the results of the first survey, a new dynamic lighting system was designed with the intent to improve the users' experience of the space.

Comfort & efficiency. Starting from the users' desire to have natural light in the office, three light settings were designed, which follow the rhythm of daily activities:

1. *Start the Day*- The lights turn on at 8:40 AM gradually fading for 30 min towards the 100% intensity, creating a "Concentrate" scene with cool light (Fig. 47);

2. *After Lunch* - At 1:30 PM, lights gradually fade for 30 min from the "Concentration" towards the "Bright" scene, creating a warmer light that still supports concentration for work (Fig. 47);

3. *Get Ready to Go Home* - At 5:45 PM, lights gradually fade for 15 min towards "Savanna sunset" Hue scene. In this scene, a mix of strong warm shades ranging from red to yellow decreases the focus and supports socialization. At 7 PM the Hue lights turn off (Fig. 47).

Figure 47. Images of the office interior with users and diverse light settings during the day. First image from the left is "Start the Day" scene, following is the "After Lunch", and the last one on the right is "Get Ready to Go Home" scene.

Meanings communication. In order to influence the user experience on the meanings level, the idea of conveying the following messages by light changes was explored. Such messages follow users' routines and needs emerged by the survey:

1. Daily *Reminder to Make a Break* at 4 PM – the light changes for 1 min to green/blue and then comes back to the previous working setting;

2. Events notifications, referred to the following situations:

   - *Food-Cam* real-time notification, which refers to the presence of free food in a corner outside the office. This notification, usually sent via the group's Slack channel, was translated into a blinking light (Fig. 48) next to the coffee machine (Zone B in Fig. 46);

   - *Group Meeting* reminder, 5 minutes before a scheduled all-team meeting, all lights blink and change in colour (distracting from work).

Figure 48.
Image of the lamp next to the coffee machine, marked as zone B in the top view drawing of the office layout.

Social dynamics. This level leveraged the *Get Ready to Go Home* function (described previously), which intended to foster socialization at the end of the day. In addition to it, another function was designed, consisting of a weekly notification of *Social Mondays.* Following the group routine of social activities every Monday evening, on Mondays at 5:40 PM the light fades gradually for 5 min towards the "Tropical twilight" scene, which has a colour palette from pink to orange. The scene lasts for 30 minutes, to notify the team they should get ready to leave the office.

Assessing Users' Experience of the Newly Designed Interactive System

After three weeks since the introduction of the newly designed system, a second online survey was delivered to the users. The survey was structured around the framework levels and aimed at analysing the perceived changes in users' perception and experience, compared to the previous setting. Both open-ended and multiple-choice questions were asked. Axial coding was used to analyse responses to open-ended questions. The multiple-choice questions were based on a 5-point Likert scale. When applicable, the Mann-Whitney U Test calculation method was used to compare the results derived from the first and second survey on the same questions, to highlight significant differences.

In addition to the questionnaire, as a member of the research team working in the same space, I performed focused Descriptive Observations (Robson & McCartan, 2016) (i.e. event, activity, time, actor) during the experiment, by taking notes of the users' reactions to dynamic changes.

In order to validate the relevance of the three design levels of the Ambient UX framework, I investigated if the changes on the three levels were perceived by the users, if they were considered relevant, and if they affected their experience of the space. Results are presented in the following.

Comfort & efficiency. On the physical level, dynamic changes in the environment were mostly perceived as positive. The workspace was interpreted as more comfortable and inviting as a consequence of the direction, positioning, and behaviour of the new lights. The pleasantness of the workspace was assessed before and after the field test. Results show a significant difference in the perceived pleasantness, which improves with the new dynamic system (Fig. 49). Users stated they could better sense the natural flow of time while in the office. Furthermore, they noticed the "focus" morning hours with cool and high-intensity light, and they reported its effectiveness. Before the installation of the new system, 75% of users declared that the current light in the office was not supporting their usual workflow and routines. After the installation, only 37.5% of the users confirmed their previous experience.

Meanings communication. 87.5% of participants perceived all the notifications sent through light signals in the office. According

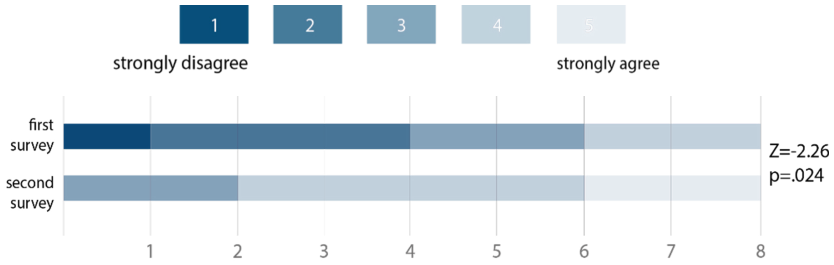


Figure 49.
Results on comparison of perceived pleasantness of space before and after the installation of the new system.

to 62.5% of respondents, light is suitable for real-time notifications in the workplace. 87.5% of respondents believe light is appropriate for subtle, non-invasive forms of communications. Light reminders were also perceived as subtle and pleasant.

Compared to traditional notifications by platforms such as Slack (frequently used among the working team), light resulted to be more interesting, intuitive, useful and subtle (Fig. 50). However, half of the users stated that communication by light lacked in clarity. Slack was observed to be suitable for: small group meetings, individual messages, personal invites and communications, specific reminders, and project team meetings. Light signals, on the other hand, were stated to be suitable for: regularly scheduled meetings, recurring events and rituals, break reminders, bringing up attention to something that is happening at the moment, more emotional forms of communication. Despite being more evident, light-based communications are not always clear in terms of content. Two main downsides of light-based forms of communications emerged by the experiment. First, certain notifications became effective only after learning their meanings, but they were not self-explaining (e.g. free food, group meetings). Second, the communication signals were perceived as annoying in some cases, i.e. when the blinking light lasted for too long. This shows that the meaning level has some influence on the comfort, as well as the aspect of time.

Social dynamics. Changes on the social level were assessed through the following question: "Do you think your workspace improves your relations with co-workers?" Results didn't show a significant difference between the two settings (Fig. 51). However, users stated that the new light triggers and initiates conversation and interaction among co-workers, thus encouraging communication and

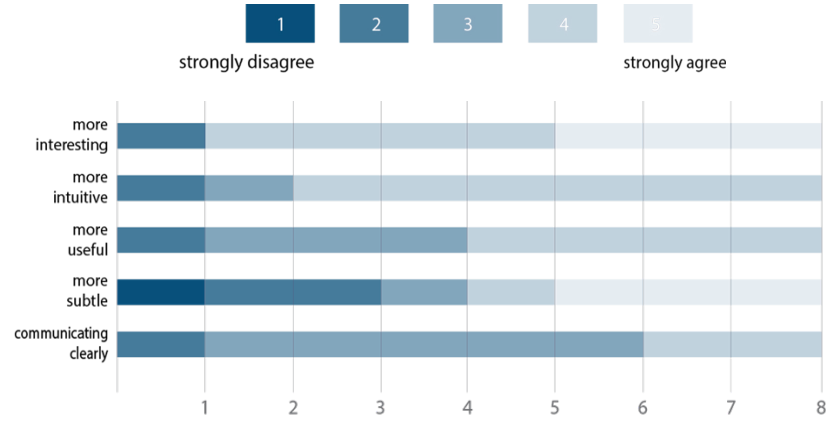


Figure 50.
Results on perception of notifications enabled through the new lighting system in comparison to notifications being communicated through a traditional screen interface, like the one of Slack platform.

bonding among colleagues in the office. 87.5% of users stated that dynamic lighting was effective in helping to build a "team spirit", and that the workplace was supporting the feeling of being part of a particular group, thanks to the use of a shared unique language.

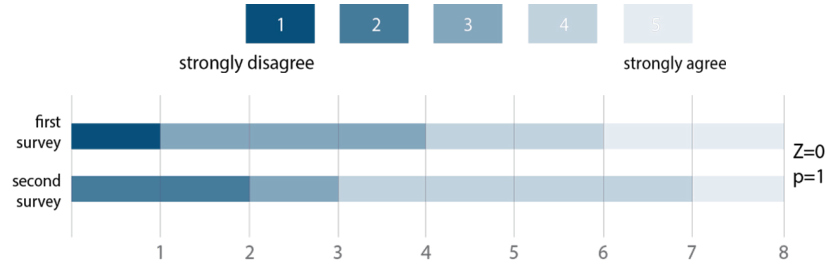


Figure 51.
Results on comparison before and after the installation of the new system in regard to the perception of the working space improving relations among co-workers.

Study Findings & Discussion

The Ambient UX framework scheme shown as effective as I could validate that the proposed design elements were provoking changes in perception and influencing the UX on defined experience levels.

In this study, I tested the proposed framework for designing and evaluating user experience in CPSes. As of yet, there is a lack of studies on this topic, and I am proposing an expansion of current UX practices to design for experience on an ambiental scale. The study aimed at providing a preliminary validation of an initial framework for Ambient UX through a field test. The initial framework's levels were confirmed as valid and effective elements to consider when

designing for Ambient UX. Some interconnections and mutual influences between the framework elements emerged, pointing out the need to consider experience in a holistic way. The impact of the meaning level on the comfort and social one, for instance, should not be overlooked, when designing new information flows in an intelligent interactive environment.

Mutual Influence Between the Framework's Elements

The two surveys enabled to comprehend how the users' experience was affected by the new lighting system. The diary of observations allowed to analyse in which manner time as a variable influenced the experience over a one-month period. For instance, in the first week I observed that users were confused by the meaning of the different light notifications, but in the third week they were able to recognize them and to react to them easily. Another example is the influence of time observed through social relations, where the feeling of "belonging to a group" appeared to be created only when the majority from the group started practicing the unique activities proposed by the light signals.

The initial framework's levels were confirmed as valid and effective elements to consider when designing for Ambient UX. The connection between design elements and experience levels was also confirmed, according to the following results:

1. Comfort and overall efficiency were influenced by the design of the physical system in terms of quality of lighting, its positioning and layout, and its physical changes over time.

2. Newly designed information flows enriched communication in the workspace and created a new level of meanings that could be transferred by the dynamic space, in a subtle and non-intrusive manner.

3. Social dynamics and inclusion were strengthened by the creation of new social moments, triggered by the dynamic environment. Moreover, their quality was influenced by both physical changes as well as the introduced information flows.

From the results analysis, it emerged that the three levels influence each other, and they are influenced by the element of time as well.

When it comes to the aspect of time, learning and creation of habits appear to be important factors in the experience of the system. It was evident that the meaning level required some time to become effective, and it took almost three weeks before the new routines were created and accepted. On the other side, the system triggered many spontaneous social interactions at the beginning of the test, as the participants took advantage of the light changes to trigger conversations. Over time, such interactions became more sporadic, but the level of social experience gained a new meaning in terms of creating a feeling of belonging to a certain group and sharing very unique rituals and language. Furthermore, on the time influence level, it is to say that the users perceived the "project meetings" function as too effortful over time, which resulted in not using this function of the system at all.

In regard to the notifications, the meaning level was much affected by the comfort and efficiency level. In particular, the physical position of the lamp for the "Food-Cam" seems to be influencing the perception of this notification, as it is placed in the socializing corner of the office, next to the coffee machine, making its meaning more intuitive. However, this notification influenced the comfort level, because the long blinking was perceived as annoying in few cases. The "Taking a break" notification could have been longer, as its duration could guide the duration of the break. At the moment it was short and just a reminder, but it could have had a stronger impact on the mood if it was longer. The "Project Meetings" notifications were not meant for everyone; therefore, they were interpreted as disturbing and distracting by people who were not involved in the ongoing meeting. This is to say that the information level here intertwines with social aspects, as well as comfort. Similar consideration refers to the user's proposal to have an individual smaller luminaire for a private lighting signal that would improve the use of lighting and its distribution, supporting the desire for private notifications and respecting the colleagues within a shared space.

Designing for a Holistic Ambient UX

Design elements influence users' experience by interlacing between them and creating values for users, as observed through the previous results and examples. Therefore, it is to point out that a ***holistic approach towards Ambient UX*** is required in order for a newly

designed CPS to be accepted in regard to users' needs and desires.

In addition to being used as support for the design process, the framework turned out to be a valid instrument also to assess the user experience of a cyber-physical system. Indeed, it provides with a structure that helped evaluate how users experienced space on the physical, informational and social levels, confronting two different settings, i.e. before and after the introduction of the dynamic interactive lighting system.

3.2 EXPERIENCES DERIVING FROM DESIGN PRACTICE

The further verification of the design method is made by applying the proposed framework for Ambient UX on design research projects that involve studies on user experience, and therefore what is perceived as user values in all of them.

Three research projects took part, which are placed in diverse ambients:

1. Humanitas (hospital environment),
2. MEMoSa (automotive environment),
3. Connected Lighting for a Caring City (city environment).

For each of the projects the conducted UX research is described and the user values are discussed.

The three projects were chosen in particular, because of their diversity in regard to the dominant architecture form Design Domains, i.e. the architecture that influences user experience values the most (see Fig. 52a). Therefore, even though all three architectures are represented in all of the projects, one appears to be dominant regarding user values. Other aspects of diversity refer to the nature of products, as well as the system inputs; namely, the diversity here is observed in regard to inputs that could be manual or fully automated (e.g. through sensors data gathering), as well as the inputs that require a GUI or other interface modalities (see Fig. 52b).

In the radar diagrams represented bellow (Fig. 52), the levelling parameters are based on a 5-point scale according to the presence and influence of the parameter within a case study.

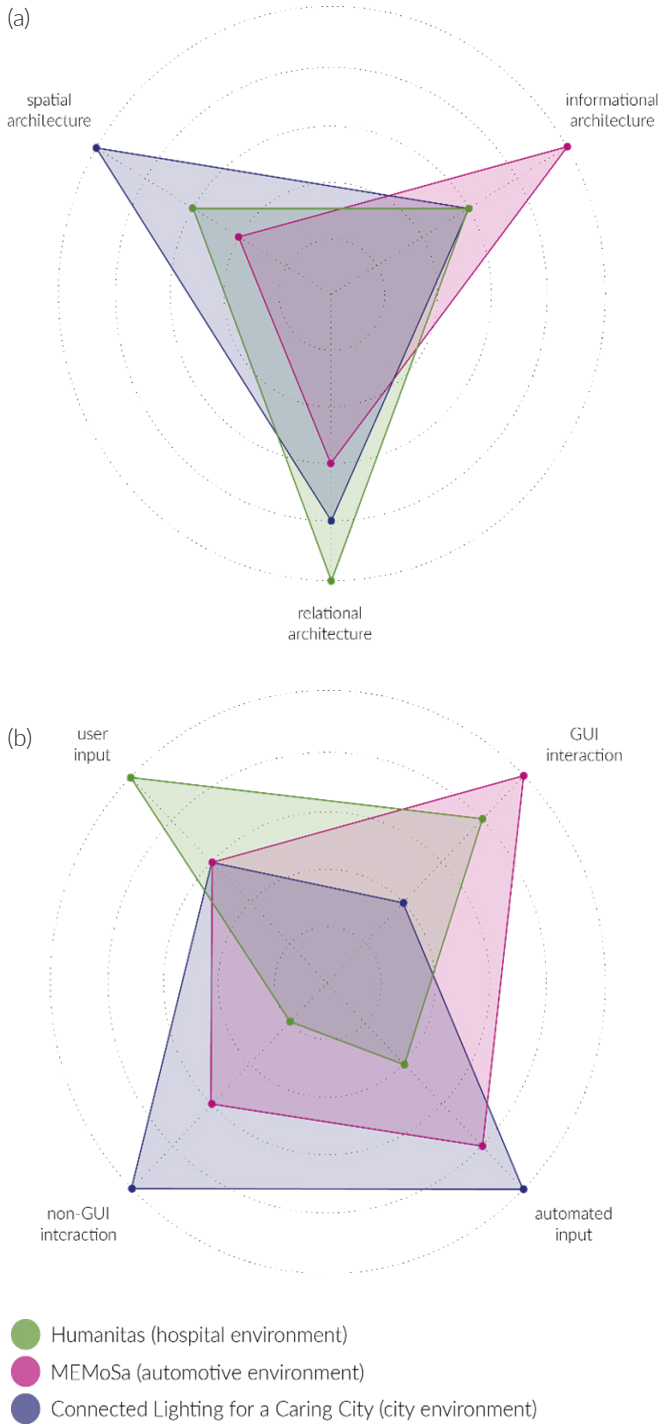


Figure 52.
Radar diagrams showing the diversity between the three projects, according to: (a) architectures as Design Domains, (b) system input modalities.

Case Study 1: Humanitas (Hospital Environment)

3.2.1

Project Description

Project Stakeholders (Fig. 53) are the hospital centre Humanitas, start-up company Artexe that produces digital kiosks, and the Interaction and Experience (IEX) Design Research Lab from Politecnico di Milano (from which side I was engaged in the project).

Figure 53.
Stakeholders of the project Humanitas: Humanitas, Artexe and IEX.

Humanitas is a case study of UX design and research within a hospital centre in Milan. At the beginning of Fall 2016, our design research group (IEX) was engaged by the company Artexe, providing technical facilities and solutions for service delivery in medical environments, to conduct a design project for the optimisation of existing hospital self-service touchpoints.

The medical institution was interested in investigating the functional characteristics of digital kiosks for administrative procedures

concerning booking, payment, check-in and collection of medical results for outpatient services, as well as a broad-spectrum analysis of the experience of users in hospital locations. Our research group was called in as a third-party observer to collect information with a view on enhancing digital services offered by the hospital and, consequently, its identity.

The project assignment can be broken down into the following main tasks:

- Analysis of users' behaviour with respect to the delivery of administrative services with traditional (operator-based) counter touchpoints and self-service kiosks, through shadowing, participant observations and interviews (Bryman & Bell, 2015; Padgett, 2016);
- Interviews with personnel assigned to various functions within administrative services in both private and public healthcare sector;
- Critical survey of the hospital environment as a whole, including ancillary facilities such as parking areas, outdoor areas of the hospital campus, entrances, waiting rooms for administration and healthcare services, and other communal spaces (Musante & DeWalt, 2010; Jorgensen, 2015); Spradley, 2016);
- Design of a solution to support self-service access to administration services within hospital spaces, consisting of a collaborative system with staff members, a totally redesigned kiosk (physical features and interface), and a coordinated system of artefacts (hostesses' desk, information artefacts).
- Reports on analysis of the user experience and a discussion of the results with administrative hospital staff.

Overall, the project provided interesting opportunities to investigate specific constraints and requirements in regard to the design of physical/digital solutions in healthcare settings, and to extend discussion of the complexity of designing for transition from traditional services towards cyber-physical environments.

Some of the results obtained are presented in the following, showing that the introduction of technology-based solutions and, in particular, touchpoints geared towards automation of in-hospital services,

is a complex process. Such process requires for the consequences of innovation to be anticipated, in regard to both user experience and back-office organisation. Furthermore, the conducted user research highlights the sensitivity of ethnographic analysis in medical environments, and the complex task of framing the variety of attitudes of patients with respect to technology-based innovation, beyond stereotyped prediction of behaviour and expectations.

Why the case study is an Ambient UX concept

The project considers an approach of designing for user's experiences within the medical centre. It does refer to a holistic overview and evaluation of UX, including also observations that regard the physical ambient itself. Users are influenced by the ambiental context in whom digitized services are placed, and the activities happening in the medical centre are surely influenced by the interaction with digitized kiosks. Therefore, the project is considered a suitable example for discussing an Ambient UX design concept.

The project has a strong influence of the relational architecture in regard to user's experience (Fig. 54a) and relies strongly on user manual input and GUI interaction (Fig. 54b).

Figure 54.
Radar diagrams showing
(a) architectures as Design Domains and
(b) system input modalities for project Humanitas.

UX Research

Methodology

In the research described here, we focused on the design of technology-based solutions for a hospital in Milan that can support the administrative procedures involved in delivering medical outpatient services (examinations and diagnostic tests) on the physical premises of the hospital. Our interest included information inquiries about organisation and services and the deployment of procedures for booking, payment, check-in activities, collection of medical exam results, and so on.

As various interactive technologies and products change people's behaviour by defining the behaviour of artefacts, environments and systems themselves (Fogg, 2009; Wright et al., 2010), we decided to conduct an in-depth analysis of users' interaction with the digital kiosks installed in the hospital to understand how users from groups with different attributes (not only in terms of age, social status and condition, gender, cultural background but also daily healthcare needs) deal with the transition from traditional, human-human interaction to a human-digital interaction. Our aim was to focus on how patients interact with new self-service solutions with intention of devising an effective way of improving the quality of non-medical interactions between patients and healthcare institutions. We sought to understand how to design the transition towards digital services in a way that is consistent with patients' journeys, by embracing the diversity of users.

This approach of applying digital technologies to the real world is strongly linked to the idea of designing experiences, which means designing not only functional elements (i.e. within the engineering realm), but also the features needed to engage users at the emotional level. We therefore focused on users' needs and set out to rethink the services considering them beyond mere product function and performance. We wanted the new system to be able to engage directly with users by understanding their needs, goals, and preferences.

We approached the project at the time when the hospital in question needed to develop a strategy for improving its digital services and make them more acceptable in everyday use. This required us to analyse current daily users' activities. The two main methods adopted to this end were (Fig. 55):

- Contextual inquiry, i.e. ethnography and shadowing of the

patients within the main building of the hospital dedicated to administrative procedures;

- Unstructured interviews with the hospital staff.

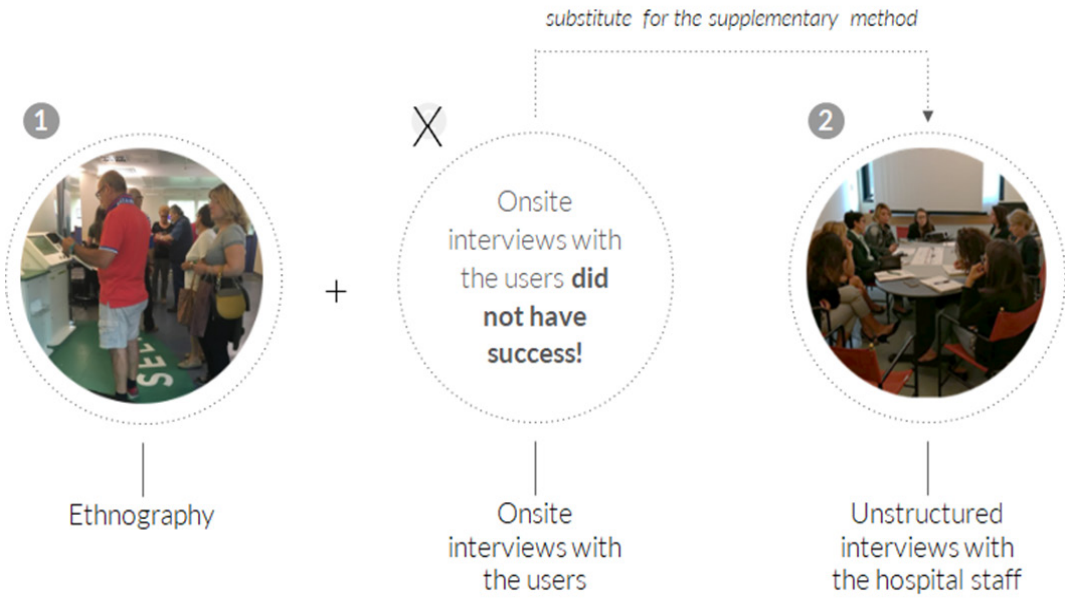


Figure 55. UX research methodology employed within the project Humanitas.

Several scholars (Rice & Ezzy, 1999; Savage, 2000; Van der Geest & Finkler, 2004) have argued for the effectiveness of ethnographic methods in hospital settings. According to Goodson and Vassar (2011), ethnography has been used in medical education for over 50 years. Indeed, the community of the hospital is often unique; through ethnography, behaviours are understood and used to treat patients and adapt to their needs. The ethnographic method can analyse patients' social and cultural backgrounds and investigate how behaviours differ across groups.

Our ethnographic research implied observing over 400 patients during their daily activities, as they used all available self-service

solutions in order to book medical examinations, admission for medical examinations and collect medical results. We were thus able to capture patients' behaviour and how they interacted with different services as a means of gaining insights into their experience, motivations, drivers and needs.

Despite the evident benefits, our shadowing activity was subject to a number of limitations. One of these was the sample size. The lengthy time requirements of participants' observation greatly limit the sample size and, in contrast to typical surveys, the collection of ethnographic data is laborious and extensive. There was no list of answers to choose from; instead, notes were made and later interpreted and categorised by research team members. Additionally, even though the shadowing process was conducted as discreetly and anonymously as possible, patients and hostesses were, nevertheless, aware of being under observation and hence unable to act freely.

We additionally planned to conduct interviews with hospital visitors to get more direct insights from their side. However, due to the very sensitive context, such as a hospital centre, many visitors were not much interested in responding to survey questions and did not want to dedicate time. Despite the problematics with this research method, we managed to come up with a supplementary inquiry method that brought us to the same results we were aiming for from one-on-one interviews. The supplementary method were unstructured interviews with the hostesses and other hospital staff.

The interviews with the hospital staff actually helped us gain valuable insights on patients' behaviours, main considerations, needs and doubts while in the hospital area. Considering the sensitive aspect of environment such as the hospital, it was hard to get someone willing to get involved into our questionnaires, particularly considering the time they were willing to dedicate and the purpose of their visit to the hospital. On the other side, the interviews with the staff actually provided us with many information on the patients and users, as they interact with them on a daily basis and had a chance to learn much about them during these interactions.

Results

The main insights gained in relation to the use of digital kiosks were the following:

- Patients are willing to use digital solutions if they make the required operation more effective and faster, thus reducing queuing times;
- Patients are highly motivated to cooperate with the medical system ensuring that procedures are performed correctly;
- The presence of several digital channels, each with different information and varying hierarchies of functions, leads patients (especially elderly patients or those lacking digital literacy) to seek information and reassurance regarding the correct use of self-service solutions (see Fig. 56);
- The presence of hostesses and volunteers is essential, not only to support patients who need information, but also to improve the quality of the experience of using digital services.

Figure 56. The presence of different digital kiosk channels and the role of hostesses.

Main insights derived from the unstructured interviews with the group of hospital hostesses (6 staff members) and their coordinator, during which we managed to observe their supporting role in the use of digital kiosks (dealing with errors, assisting users in understanding the main functions, etc.). The interviews helped us confirming the importance of their presence and emphasising their role as both facilitators and educators in the use of digital services.

The importance of the hostesses' role is emphasised by a dedicated desk (Fig. 57), which acts as a reference point for them when dialoguing with clients and/or performing actions involving the use of a portable computer.

Figure 57.
The hostess' desk and digital touchpoints.

The user analysis shows a hospital environment undergoing a full transition, a situation in which traditional and digital procedures still co-exist. The observation and unstructured interviews revealed two main aspects. First is that the current transition from the traditional human-human interaction of hospital services to digital interaction is not disorienting users to any significant degree; on the contrary, they perceive digital kiosks as natural and helpful. At the same time, there is a need for a reassuring human presence in the transition towards the use of digital services.

As emerged from our interviews, a variety of two-way information is exchanged, allowing users to acquaint themselves with the medical system and staff to learn about their needs and expectations. To meet the patients' needs to feel welcomed and to enhance the overall image of the institution in question, both medical and non-medical staff are trained to manage formal and informal interactions appropriately.

After the analysis, we concluded that in a medical context undergoing such transition, the quality of human-human interactions at all levels plays, and will continue to play, an important role in shaping patients' experiences and their perception of the quality of care provided. The peculiar situation is closely related to the specific sensitivity of healthcare purposes of the service; this means that the design of new solutions must consider the integration of digital, physical and human touchpoints.

Embracing Complexity of User Experience in Healthcare. Hospitals host many different processes. They offer emergency treatment and provide a stable point of reference for patients with chronic diseases in constant need of treatment and diagnosis and are used by outpatients for medical examinations and specialist consultations. Hospitals, therefore, are complex organisations. They treat hundreds of patients daily and process the necessary paperwork for them to access provided services, such as: queries, reservations, payments, collection of results, and so on. At the same time, hospitals are also workplaces for doctors, paramedics, researchers, administrative staff, service personnel, etc. They are, as well, places frequented by visitors, relatives and friends of patients, thus creating a variety of human flows and activities, characterised by different needs, expectations and attitudes.

Patients', i.e. users', perception of the quality of services provided by hospitals depends on several factors, such as the expertise of doctors and paramedics providing healthcare, or facilities and equipment for diagnosis and treatment. Beyond these evident factors, several others play a significant role in the quality of the overall experience of patients and their companions. Such examples are access to information about healthcare processes and the organisation of the institution, the fluidity or complexity of administrative procedures for access to medical services, the nature of human-to-human interactions between patients with medical and non-medical staff, the physical appearance and layout of interiors, and many others. In other words, in hospitals and healthcare institutions both physical environments, and medical and non-medical services, contribute significantly to patients' wellbeing and their acceptance of the treatment provided.

Our shadowing activities and meetings with staff helped us analyse patient pathways and the individual administrative steps associated with patients' experience in the hospital, such as booking medical appointments, being admitted for medical appointments or procedures, undergoing medical examinations and collecting results. During their hospital visit, patients come into contact with different, equally important touchpoints, both digital and physical. Shadowing patients enabled us also to understand how they interact with the various digital kiosks and hostesses, and we observed that users' interaction with the kiosks takes place on two levels, through digital/physical interaction.

In digital/physical interaction, the first issue that arose was users' failure to understand the functions of each specific kiosk (e.g. booking, admission, collection of results) and the basic means of interaction (e.g. for activation and use). Compared to physical interaction, the existing configuration of the digital kiosk generated various problems related to communication of self-service functions, thus restricting use as a result of wrong affordance of the individual physical elements of the product: for example, reading the magnetic health card (direction and orientation), payment (ATM and contactless), orientation of the prescription, printing, scanning and saving files to the USB device.

Problems in digital interaction were partly due to lack of digital literacy from the side of users, particularly – although not exclusively – among older users. Another problem is the relative novelty of kiosks as one of several touchpoints, which limits their use.

Problems related to physical affordance and visual communication (perceptual information) generate two different scenarios:

- Patients' fail to understand the kiosk's functions or how to use it and thus ask the hostess directly for assistance, who must then use the kiosk instead of the patient.
- Frustration among patients who attempt to use the kiosk unsuccessfully or are unable to continue, leading them to contact the hostess.

Moreover, the areas where the analysis took place were overcrowded with communications and digital kiosks of different kinds. Single-function kiosks are positioned alongside other kiosks performing different functions, making it difficult for users to identify the correct one for their purposes (e.g. booking, admission or collection of results).

After the shadowing process and interviews with the hostesses, our design research group drew up a draft design brief containing suggestions for an overall redesign of the system of kiosks and hostess desks. The analysis revealed significant opportunities to improve the physical characteristics and the graphical user interface of kiosks for enhancing their understandability, usability and accessibility.

Furthermore, observations of user behaviour in the hospital highlighted the importance of making kiosks more effective as touchpoints by positioning them more appropriately and improving communication to guide users toward the automatic self-service machines. Such improvements would increase the number of users that use digital touchpoints as opposed to traditional desks with human operators for administrative procedures, thus reducing costs. At the same time, our analysis also highlighted the importance of hostesses assisting users in their interaction with kiosks. Human-human interactions indeed provide practical support in the deployment of procedures but also information on a wide range of topics, as well as valuable emotional and psychological encouragement.

The draft of the brief was discussed in detail during a brainstorming session lasting approximately two hours with the hospital operations manager, the hospital customer experience director and the CEO of the company. Through a proactive discussion during which we shared our thoughts and the staff shared their knowledge regarding the customer experience, we were able to establish the final brief for the system as a whole. This discussion led to the development of a specific brief and generated the design concept for a design system consisting of a digital kiosk and hostess desk.

All Three Architectures Considered Simultaneously within the CPS

Main Issues Imposed by UX Research and Identified User Values

In hospital and care institutions, digital technologies play an increasingly important role in several different areas. Indeed, digital technologies support the development of innovative medical appliances, provide the means to improve medical diagnosis and treatment through the collection and analysis of data; they also help making medical organisations and services more efficient and provide more effective forms of healthcare and remote monitoring (Johnson et al., 2005; Hahn & Zimmermann, 2011; Taylor et al., 2011; Gastaldi & Corso, 2012; Kilic, 2016).

Interactions between patients and healthcare institutions are increasingly web-based, reducing the need for physical transportation of patients. The digitalization of interactions also supports the systematic and efficient conservation of data about personal health

conditions and treatment history, with evident benefits in terms of accurate knowledge about patients. However, in most cases provision of medical services requires patients to be physically present in healthcare locations. Although remotely provided digital health services are predicted to increase (Lettieri & Masella, 2009; Fichman et al., 2011; Haggerty, 2017), in private and public medical services, most activities maintain their tangible nature, which is why physical touchpoints for administration services are far from disappearing in hospitals. In the conducted research, we argue that the procedures that precede and accompany healthcare provision play, and will continue to play, a significant role in shaping the overall experience of patients.

In Italy, especially in public health services, administrative procedures can be cumbersome and take up a significant proportion of time spent in hospitals, with major effects on the overall physical and cognitive burden of accessing healthcare (Mariotti, 1999). Given the complexity of hospital organisations, human interaction compensates for the lack of information and standardisation of procedures. The support that it provides for healthcare services is unquantifiable. The automation of touchpoints for administration services, and the total or partial replacement of human operators with self-service kiosks (Nicholas et al., 2000; Nicholas et al., 2002; Jones, 2009) do, however, offer gains in terms of efficiency, increased flexibility of services and cost savings, thus freeing up resources for medical purposes. Furthermore, digitisation of processes allows data and knowledge to be collected which can subsequently be used to refine and improve services.

The digitisation of hospital touchpoints provides an alternative to traditional counter-based interactions. The digitisation process has demonstrated its feasibility and cost-effectiveness in several case studies (Nicholas et al., 2003; Mackrill et al., 2017). In the best-case scenario, the automation of administrative procedures through the introduction of kiosks does not negatively affect the institution's image, and it should not reduce the degree or quality of personalised assistance and information that patients receive.

In many hospitals today, patients can access administrative procedures not just through the traditional operator-staffed counter touchpoints and digital self-service kiosks, but also through online

services and remote communication, based on, for instance, call centres and smartphone applications. The various communication channels through which users may interact with hospitals should provide a consistent environment, in which each individual can choose how he/she accesses services and can move freely in between services offered in the physical spaces to virtual services supported by digital technologies, and vice versa.

In terms of administration services, hospitals are, therefore, complex physical/digital environments (Nicholas et al., 2003; Kilic, 2016; Ribera et al., 2016), where users can choose to transfer some of their interactions to the virtual domain of synchronous and asynchronous remote services at their convenience. This proliferation of channels and options only benefits users if each interaction process is understandable, usable and acceptable (Duarte & Guerra, 2012; Ghazali et al., 2014; Mival & Benyon, 2015). However, this is only true when the different processes are mutually consistent and compatible and do not require excessive cognitive effort to be learned, compared with procedures that have been already learned and are still currently practised by patients, staff and visitors.

In conducting the presented case study, we were able to verify that the organisation of the physical and digital touchpoints in a hospital also involves its spatial organisation. The way self-service kiosks are distributed in various locations, or how they are concentrated in dedicated areas, can determine patients' and visitors' itineraries, which raises issues related to semantic and visual appearance of spaces and the management of human flows to avoid undesirable overcrowding. The management of touchpoints for administrative procedures requires an integrated approach to the design of objects, spaces, and customer journeys. This integrated approach makes it possible to produce appropriate representations of spaces, procedures and journeys and of alternative paths produced by introducing solutions in transition; for the scope of optimising the physical/digital system both in terms of the experience for users and of cost effectiveness and sustainability for the hospital. Therefore, within this project case study, it is observable that during the design process we face a need for considering all three architectures of Ambient UX (Spatial, Informational, Relational) simultaneously, in order to enable a comprehensive holistic overview of the experience and Design Domains which shape it.

Analysis of Alternative Paths within the CPS

In the case study Humanitas, we observed and confronted user journeys following two different paths: namely, when administrative services are provided through traditional counters, i.e. a traditional path, and when they are provided via digital kiosks, i.e. a digitised path. The term "administrative services" refers to the process of booking a medical examination/consultation, admission on the day of the examination/consultation, and the collection of results when the examination/consultation is over. Our research focused on the processes encountered during these journeys and was based on on-site observations with regard to spaces, services, and user/patient behaviour.

We arranged several individual and group meetings with hospital staff in order to understand and record their point of view with regard to patients' behaviour as well as any perspectives that they could share in their capacity as individuals working at the hospital. These meetings and observations allowed us to map user journeys. It should be stressed out that, in order to optimise the processes of hospital services and thus the user journeys that shape patients' experience, it is necessary to deal with the complexity and multiplicity of communication channels currently provided by the hospital, as well as all the various touchpoints patients interact with during different stages of the treatment process.

Nowadays, services are based upon a complex mix of interactions which include human-human and online interactions (i.e. through websites, mobile applications and call centres), thus offering a wide range of alternatives. These alternatives are sometimes equivalent as types of services they offer. However, they may also be different in terms of levels of efficiency of the procedures as experienced by users. Although medical services clearly target a broad public, with different motivations and preferences in the access to digital services, it is equally clear that a growing segment of the population considers the option of accessing automated online services an advantage; such services can reduce the need to be physically present in the hospital environment and allow them to personalise their time of use.

Therefore, to encourage the use of automated processes, both in person and online, a top-down approach, which brings together

all of the various components that make these processes feasible, would seem to be the most appropriate. Such an approach makes it possible to gear every part of the system towards the rationalisation and simplification of processes in such a way that they are perceived as acceptable by patients. From the information architecture of the hospital website to mobile applications, from the centralised management of medical reports to the information and instructions contained in the ticket issued by the queue management system – in short, all elements that are connected in any way with the organisation of data and information flows – should be coordinated to facilitate the user journey through a comprehensive series of self-service touchpoints. At the same time, they should consider those users who still choose the traditional journey for whatever reason, as this segment of the user population will continue to exist in the future, although to a lesser and lesser extent. It is important to point out that in most hospitals in Italy digital services have been introduced progressively in the course of time, integrating existing solutions with the new ones. A radical, rapid transition from traditional to digital-based services is not possible in medical environments, where interruptions in service delivery must be avoided and users need to be guided through organisational changes.

Different medical services are distributed throughout hospital buildings according to various logistical constraints and needs. How these buildings are used may change over time, and there is not always a clear correspondence between the use for which they were designed and the outpatient and inpatient medical services that they host. The hospital is a place with physical flows of people, including patients, visitors, staff, suppliers, researchers and conference participants. These flows make it a "living" space but at the same time pose delicate problems of space management.

We visited spaces in several of the hospital buildings, focusing on some areas that are particularly complex for the type of functions that they host and the flows that they produce. An example is the ground-floor space of a building where all patient administration procedures take place (Fig. 58). This area sees the greatest flows, with crowds of people sometimes waiting to access counters with administrative personnel. The automatic terminals with digital kiosks at patient's disposal are located in a "self-service" area present here.

An examination of this initial configuration of the space allowed us to assess the feasibility of the digital kiosk-based automated solutions staffed by hostesses.

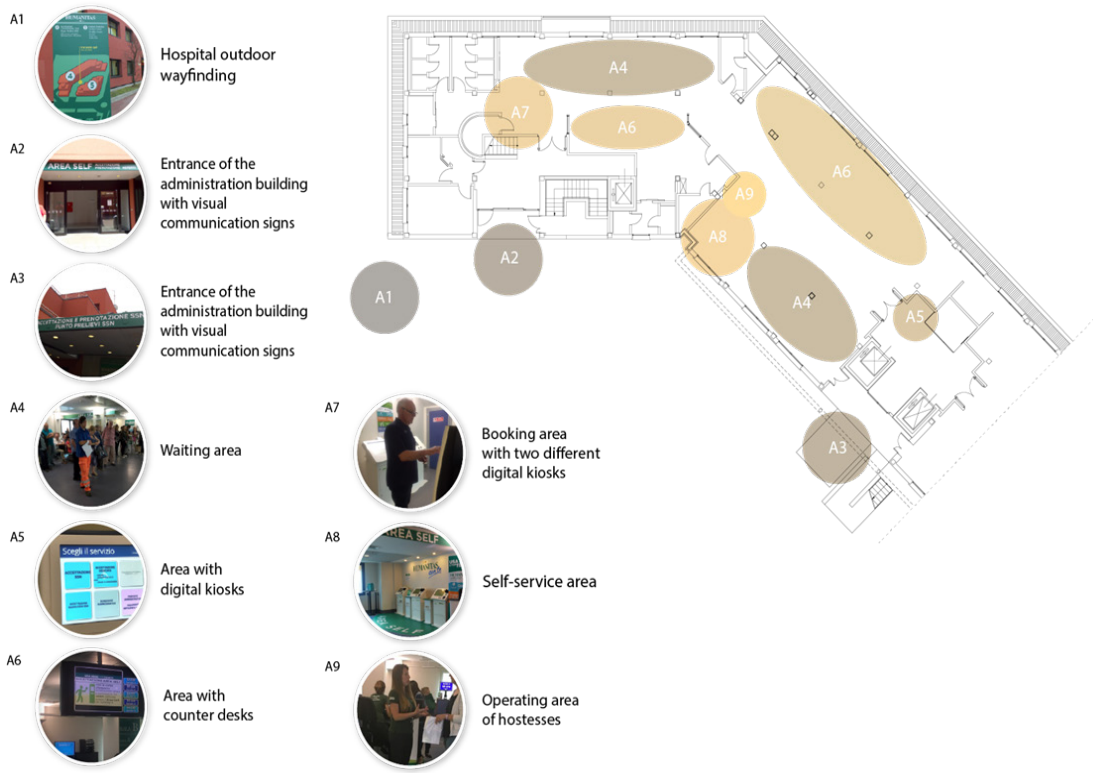


Figure 58. Zones of interaction and communication with the clients in the building for administrative services: plan view of the ground floor with marked areas of interaction.

The initial configuration encountered highlighted two key factors:

- The importance of consistent information across all alternative means of providing administrative services, particularly automated terminals, in order to encourage their use as an effective alternative to traditional counters;
- The importance of organising spaces dedicated to administrative services in such a way as to make self-service terminals highly visible compared to traditional counters.

For our on-site observations, we mapped the activities of several users (both patients and their companions) and used the results to analyse their paths within the hospital. The mapping process consisted of images, i.e. visual recording material, and diaries of observations, which together enabled us to picture the present situation.

To map users' experiences (Newbery & Farnham, 2013; Levin, 2014; Kalbach, 2016), we analysed how they engaged with the hospital centre and identified certain touchpoints, i.e. direct points of interaction between users and the hospital. We observed the difference between the conceptual journey built by users and the physical journey that they made in the centre. We mapped their activities according to a detailed breakdown of the interaction spaces and elements used to identify the touchpoints (Fig. 59).

Figure 59. Physical and digital touchpoints with which hospital users interact during their journey for having a medical examination.

Following the touchpoints, we analysed three flows related to administrative procedures (booking, admission for examinations and collection of results) and compared the two types of user journey: (1)

traditional user journey based on counter desk interactions, and (2) journey enabled by interactions with digital kiosks (Fig. 60).

We compared the two types of user journey in terms of positive sides (values) of the experience and pain points as perceived by users, considering the time and steps required to reach the desired outcome, as well as the number of documents produced (see Fig. 61).

Comparing these different paths allowed us to draw up certain design hints. More specifically, we proposed a multitask interface for digital kiosks that would optimise all the current processes and needed communication, and further reduce the amount of time and steps required to perform an action. The interface of the digital kiosk finally defines and influences flows in the overall journey.

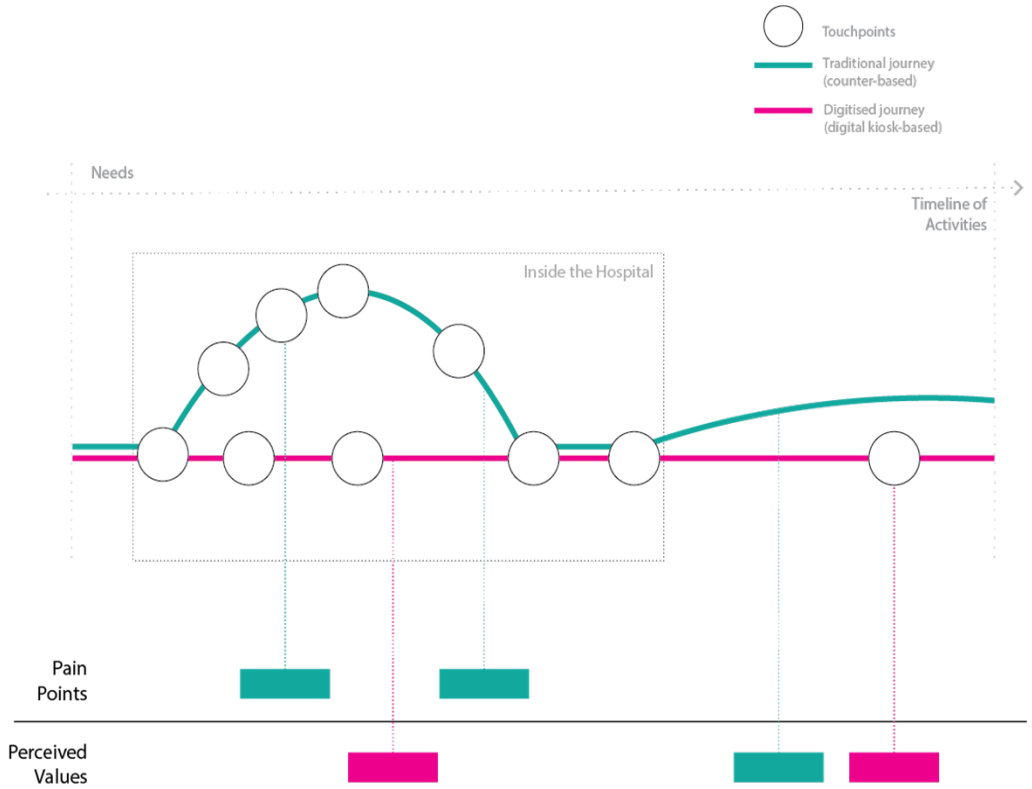


Figure 60. Structure of user journeys for medical examinations: comparison of traditional user journey based on counters/desks and digitised user journey based on use of digital kiosks.

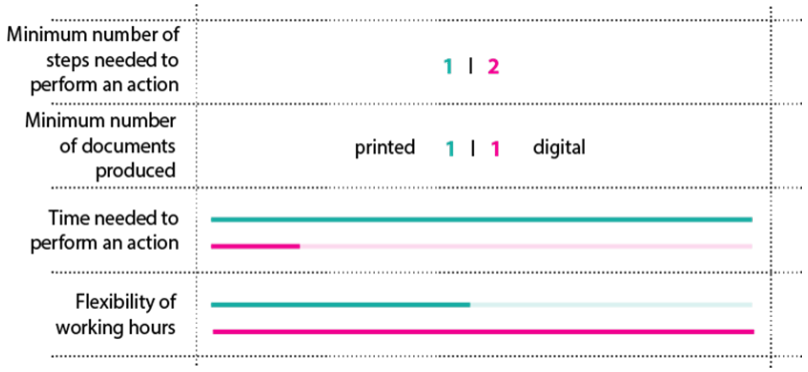


Figure 61.
An example of one activity analysis with regard to two different user journeys, i.e. traditional and digitised.

Our focus was on designing for continuity in transition, since we expect attitudes towards digital interaction to change and keep on changing in the future as medical organisations and customers' expectations and preferences evolve. Therefore, the design of novel solutions will always be a strict requirement, as will the need to create smooth transitions from existing solutions to the new ones and to keep up with changes in communication and interaction habits. In addition, to describe how the consistency – or at least, the compatibility and reversibility – of physical and digital interaction paths can be managed, we introduce the concept of designing for transition environments.

In our view, transition is created in physical/digital services by overlaying different alternative channels for communication, information, transactions, and non-physical service provision. In several application fields, such as education, retail, marketing and so on, services are increasingly delivered via web of different channels supporting blended physical and digital implementations of communication and interaction processes. This proliferation of channels for service and information delivery is, therefore, a general requirement of our times, since it meets the growing social expectation of being able to interact with everything and everyone at any time and from anywhere. On the other hand, diversifying channels for interaction with customers requires investments in back-office operations to handle and respond to queries consistently. For instance, in a medical institution, the multiplication of different channels for booking an examination requires back-office staff in charge of scheduling services to be organised in a different way for

creation of a data management system for handling queries from many different sources, and clear rules with regard to priorities and emergencies. Furthermore, replacing human operators – either totally or partially – with kiosks or automatic interfaces requires increased effort in terms of communication to compensate for the rigidity of such interfaces in order to cope with the wide variety of patients' situations.

We believe that consistency across the overall system of physical/digital touchpoints is key to the institution's reputation and to the quality of user experience in accessing healthcare services. Therefore, a need for analysing alternative user/customer paths within complex systems of Ambient UX rises and poses a necessity of enabling analysis and comparison of such alternative paths during the design process.

3.2.2 Case Study 2: MEMoSa (Automotive Environment)

Project Description

Project Stakeholders (Fig. 62) are the telecommunication company TIM S.p.A. (introduced in the initial chapter, with whom I am developing the PhD research), Politecnico di Milano University with diverse research labs, Exrade company, FBK Create-Net research center, Philips company, insurance companies Generali S.p.A. and BNP Paribas Cardif.

Fig 62.
Stakeholders of the project: TIM S.p.A., Politecnico di Milano, Exrade, FBK Create-Net, Philips, Generali S.p.A. Insurance, BNP Paribas Cardif.

Advancements in technological capabilities are enabling cross-device interactions and the creation of complex ecosystems of Internet of Things (IoTs), delivering services through personalized Artificially Intelligent (AI) Agents. Such networked systems can produce valuable solutions for both individuals and communities (Krueger, 2014; Arslan et al., 2017): efficient management of energy through lighting and heating systems, smart transportation, monitoring of physiological parameters for fitness and medical purposes by wearable devices and others; these are just some examples of progress produced by the evolution of digital technologies. In this setting, the spreading of devices able to collect and use data gathered from individuals is shaping current socio-technical systems and it induces innovations that are changing everyday scenarios and behaviours (Friedman et al., 2013; Taebi, 2017; Colombo, 2018). The design of personalized digital services requires knowledge and tools to understand the potential impact on individuals and communities such services might bring over short and long terms, thus enabling designers with stakeholder teams to make conscious design choices during the design process.

Project MEMoSa, concluded in December 2017, aims for testing and reshaping a design concept for a personalized assistive system for car drivers. Main aim of MEMoSa system is to launch an innovative system able to solve issues of road accidents attributed to distracted and drowsy driving. The design proposal is an interactive connected car solution that helps drivers to be aware of their status while driving, at the same time improving road safety and reducing overall insurance costs by lowering the possibility of car accidents.

The project refers to development of a mobile and cloud service for insurance companies (providing health and car insurance), by supporting drivers in being aware of their physical and psychological status while driving. The system, therefore, is improving road safety and reducing overall insurance costs with benefits for customers and insurance companies. The system (Fig. 63) is based on a combination of a wearable device that tracks driver's physiological conditions, an On-Board Diagnostic (OBD) unit that collects data from the car, a mobile app and cloud components for data integration and analysis. This is the MEMoSa Assistant component (i.e. Agent) that, thanks to AI algorithms, provides safety alerts and suggestions to avoid risky situations.

In addition, with the MEMoSa Marketplace cars are foreseen to become business opportunities for insurance companies and 3rd party service providers to deliver targeted offers and ad-hoc insurance packages based on car and travel contextual information, while preserving drivers' privacy. From their perspective, insurance companies are interested in reducing insurance costs and policy prices, while knowing better their customers, performing better

driver profiling, and being able to offer more personalized insurance packages and mobility services to their customers.

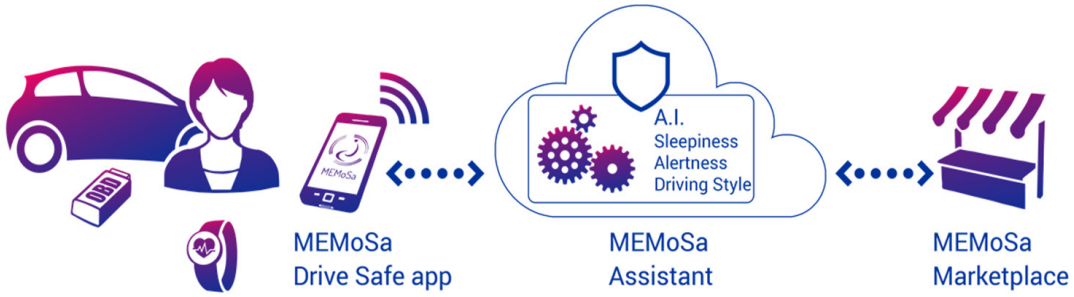


Figure 63. Elements of the MEMoSa design system.

In addition, with the MEMoSa Marketplace cars are foreseen to become business opportunities for insurance companies and 3rd party service providers to deliver targeted offers and ad-hoc insurance packages based on car and travel contextual information, while preserving drivers' privacy. From their perspective, insurance companies are interested in reducing insurance costs and policy prices, while knowing better their customers, performing better driver profiling, and being able to offer more personalized insurance packages and mobility services to their customers.

The MEMoSa project aimed at developing a mobile and cloud service to support safe driving. The final service is based on personal data about behaviours (driving and other activities) and health-states of final users; furthermore, the system also collects and uses data about the vehicle and planning of the trip for offering context-based functions. The service provides feedbacks about the convenience of driving and of the suitable driving-style in real-time and based on personal information. Insurance companies, providing health and car insurance services, have the opportunity to offer flexible low-cost solutions on-the-spot, and to collect information for building a better, more comprehensive profiling of their customers. Expected impacts are the reduction of risks connected to driving in unsafe conditions due to lifestyles, health conditions or specific circumstances. Furthermore, as it is presumed that a vehicle is used

by more than one single driver, the system provides features for creating a community of drivers of the same car for keeping track of the members' activities and vehicle performance.

For its features, MEMoSa is an innovative system concept, and its development required several iterations involving testing with final users'. During the testing activities, several critical situations emerged related to the use of personal data, and the design was progressively refined in order to sync with them. As an example, some issues concern the privacy rights of users sharing the same car: as the application reports on vehicle usage and driving styles, some participants stated that they would use the service only if they could select the exact information to be shared with each particular profile in the community. All in all, the system functions by employing personal data that widely and deeply describe personal characteristics, activities and status. This situation does encourage the creation of useful services, however, possibly accompanied by certain risks that require deep investigation.

Why the case study is an Ambient UX concept

The project considers an approach of designing for user's experiences within a car interior environment, having as a core concept an IoT system. It does refer to a holistic overview and evaluation of UX, including also the observations that regard the physical ambient itself and peculiar conditions it imposes for user's activities. Users are influenced by the ambiental context in whom digitized services are placed, and the system design should correspond to conditions of driving activities and in-car environment. Therefore, the project is considered a suitable example for discussing the Ambient UX design concept.

The project has a strong influence of the informational architecture in regard to user's experience (Fig. 64a) and relies both on user manual and automated input, while GUI interaction is the more represented one (Fig. 64b).

Figure 64.
Radar diagrams showing:
(a) architectures as Design Domains and
(b) system input modalities for project MEMoSa.

UX Research

Methodology

The design and validation of the MEMoSa AI system were driven by user experience values, and they required a collaborative approach oriented towards the alignment of these values with all involved stakeholders, i.e. project partners. The evaluation process with potential users took part in three sequential phases that simultaneously drove the reshaping of the design system (Fig. 65 & Table 1).

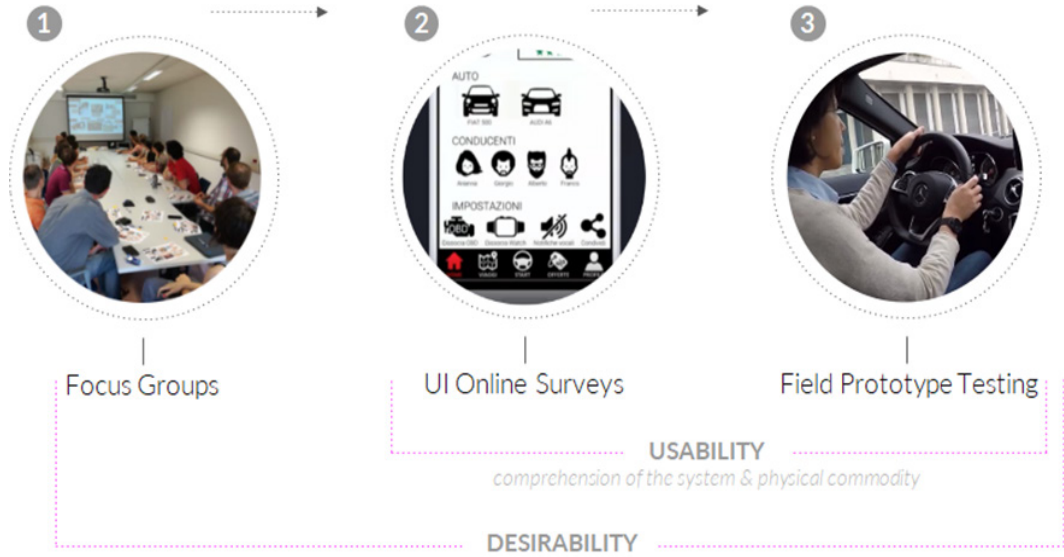


Figure 65. UX research methodology employed within the project MEMoSa.

	1st Phase	2nd Phase	3rd Phase
Aim	Validating proposed initial design use case scenarios	Validating the User Interface mock-up	Validating prototype in real-environment setting
Method	**Focus groups**	**UI video mock-ups**	**Rea-life testing**
Feedback	Online and offline surveys and open discussions	Online surveys	Surveys during and after the trial period
Participants	n=39	n=54	n=17

Table 1: Overview of the three user testing phases.

Focus groups (Fig. 66) were chosen to be a suitable approach for gathering qualitative data regarding the service proposal offers, that we were evaluating. The focus group was adopted as being a method derived from social sciences and marketing, that implies involvement of a selected group of people in a guided discussion. The group is selected according to certain targeted points that members have in common, like for example frequent car drivers with the age from 20 to 60. Focus groups lasted 3 hours each and were based on storytelling (Kankainen et al., 2012) of proposed design scenarios and had as an outcome qualitative reflection of targeted users for shaping the initial perceived values of the system. The discussion reveals and helps capture thoughts and attitudes as well as aspects that influence the experience of users. Important distinction between face-to-face interviewing and focus groups is the ability to observe interactions about a discussion topic within a group and sharing of specific attitudes and experiences (Berg & Lune, 2012).

After the focus groups, main use-case scenarios of interest were identified, and the development of the interface as the system core took part and was further tested through an online questionnaire followed by mock-up videos of interaction and main flows. This second phase relied on 5 video mock-ups of the User Interface (Fig. 67) that presented the application features and were evaluated through closed as well as open-ended survey questions.

Finally, the trial phase (Fig. 68) was organized through real-life experimentation of the MEMoSa system, providing users with the artefacts and testing version of the mobile application. In this third phase the beta version of the app was available, together with the other system components, and we found it as suitable to have real-time usage and testing over a two weeks period, with reporting through online questionnaires.

Figure 66.
Participants of a Focus Group.

Figure 67.
Video representation of the User Interface mock-up.

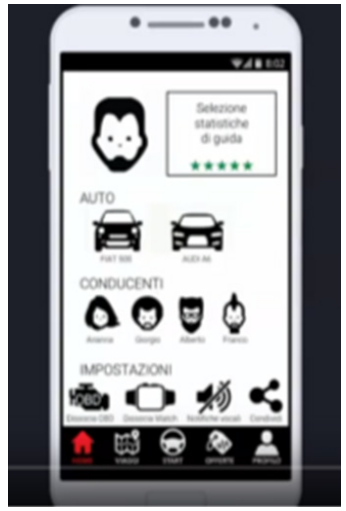


Figure 68.
User testing the system prototype in a real-life environment setting.

Results

Focus Groups. The research phase aimed to validate early assumptions and desirability with potential future users of the system. Participation followed an open call via email, selecting the candidates who met the following requirements: Italian speakers, not participating in the MEMoSa project, frequent car drivers.

This research phase followed the structure:

- Filling out the initial questionnaire before the FG gathering;
- FG introduction presentation of the MEMoSa project and the objectives of the gathering;
- FG evaluation of the four pre-defined use-case scenarios;
- FG participants' suggestions on possible novel scenarios and discussion on overall desirability of the design system;
- FG filling out the final questionnaire.

For this testing phase, participants were presented with four use-case scenarios related to the design system: 1) *On the Spot Insurance* (suggesting micro insurance products in regard to ongoing and emerging situations), 2) *Car Diagnostic* (monitoring car status and being notified about possible dangerous situations), 3) *Safe Driving* (identifying a possible dangerous situation for the driver and risk of an accident), 4) *Entertainment* (offering value added services like entertainment and contextual services to the driver).

Scenario 1: *On the Spot Insurance* (Fig. 69)

This macro area identifies business requirements oriented to the "On the spot insurance". The goal is to collect all the relevant data from the user and its environment (weather, agenda, social, geo-localization, scheduled trips, etc…) and propose ad-hoc micro Insurance products that can be purchased directly via mobile application (app).

Narrative:

White's family is going for a weekend trip to a ski resort in Trentino and Mr. White wants to have an extended insurance coverage for car thefts for this trip. He is a MEMoSa user, so the evening before the trip he searches for an extended coverage through the app and enters his travel date and destination. Mr. White negotiates and confirms the appropriate coverage for him based on the duration, exclusions and limitations, fixed/percentage excess, limit and price.

Once inserted the data of the trip, the app recognizes that there is another offer for extended customize insurance that could be added to the package. The app provides a notification for Mr. White: "please check this offer for you". The offer is for insuring all the family members from accidents during the ski weekend. He considers it and decides to accept the whole package with two diverse types of insurances. Therefore, he signs the contract in digital form on the Friday evening, with no need to be physically present in any insurance office.

Saturday morning arrives, and the family starts their trip. While approaching the ski resort, from the app they receive a notification about suitable parking places that are available: "The extended coverage policy requires that the car is parked in a covered parking, instead of parking besides the road, to minimise the risk of theft and other damages of the car." The recommended parking has a convention with the MEMoSa system, so Mr. White gets a discount for parking as an incentive of the insurance coverage. Subsequently, he gets positive points for his insurance profile that would let him save additional money as soon as he will activate an additional package with the same insurance company.

Main data exchanged in the scenario for extended coverage:

- Travel origin, destination and time (filled in by the user when he is looking for an extended coverage)
- User's current location (available from GPS)
- Micro insurance offers (proposed by insurance companies)
- Parking place locations (from external data source)

List of on-demand services/suggestions:

- Buying micro insurance:
  - Input [origin, destination, date/time, duration]
  - Output [micro insurance]
- Finding/booking a parking place:

- Input [user's current location, insurance identifier]
- Output [parking places locations]

Main data exchanged in the scenario with temporary coverage for the customer's family:

- Location information
  - Trigger questions to know about the type of activity
  - Trigger questions to know about the family info
  - Trigger questions to know about the duration of stay
- Health data (smart watch)
- Weather information (external service)
- Ski track ice condition (external service)

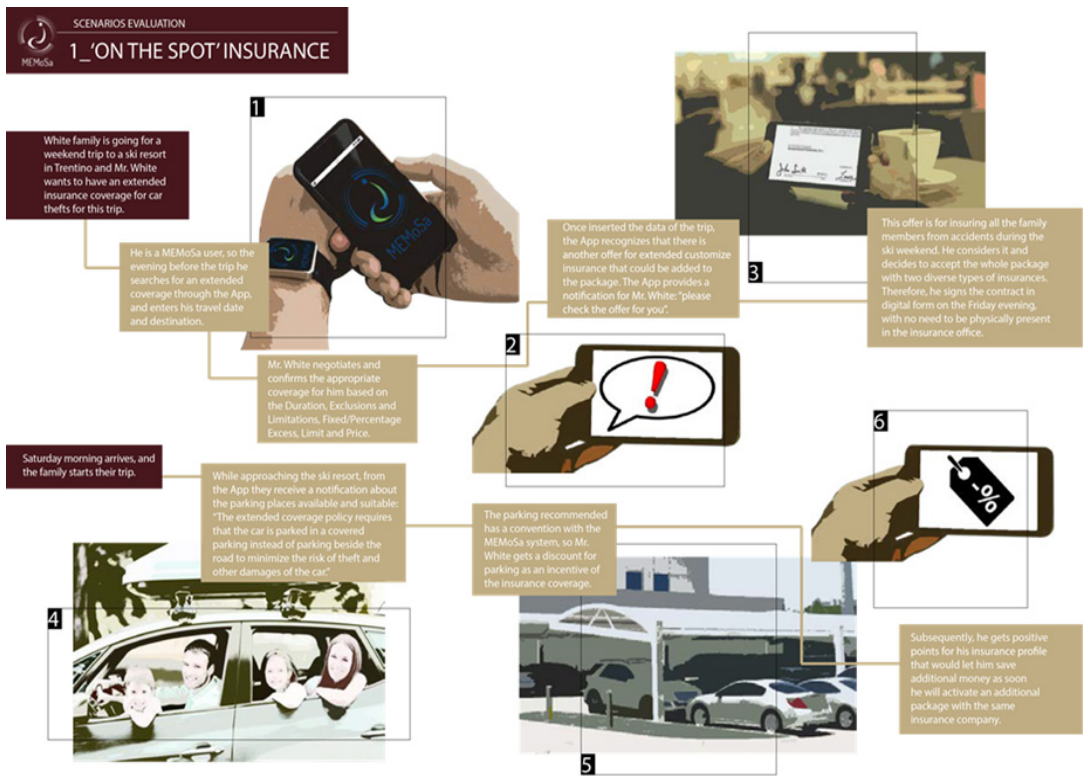


Figure 69. Focus Group: Storytelling for Scenario 1- On the Spot Insurance.

- Ski track incident information (external service)
- Activity monitoring data (external service)
- Other users' activity/schedule information

List of on-demand services/suggestions:

- Offer personalised insurance
  - Input [activity type, location, weather info, traffic info, ice condition info, incident info, family member info, physical]
  - Output [micro insurance]

Scenario 2: *Car Diagnostic* (Fig. 70)

This macro area identifies possible scenarios for active and preventive maintenance of the vehicle. MEMoSa could retrieve data and trouble codes coming from the OBD port and use them to provide information and ad-hoc services to the driver.

Narration:

It is Friday evening and Mr. Red is coming back from work. He is using the smart watch from MEMoSa system, the MEMoSa App where he sets vocal notifications on, and his car is connected with the MEMoSa system using a black box unit. While driving, the car "check engine" light turns on. The car seems fine and Mr. Red is worried because he does not understand the alert and he does not know where to go to have his car checked.

In real time, the black box unit identifies the problem and the app on the phone notifies: "injection pump issue found" trough a vocal notification. It also identifies a list of nearby mechanical repair shops where he can go to fix the problem.

Mr. Red vocally interacts with the MEMoSa app requesting to filter the list of available repair shops, by considering economical aspects and reputation. When Mr. Red agrees to do the servicing, the app creates an auction to select the most suitable mechanical repair shop where he can take his car to fix the issue, considering his preferences.

Main data exchanged in this scenario:

- User's current position (available from GPS)
- Car information (available from OBD data)
- Repair-shops locations (from external data source or predefined lists provided by insurance companies)
- Repair-shops reputation data (from external data source)
- Sleep information (from smart watch)
- Hotel information (from external data source)

List of on-demand services/suggestions:

- Finding/booking repair-shops
  - Input [location, insurance identifier]

Figure 70. Focus Group: Storytelling for Scenario 2- Car Diagnostic.

  - Output [repair-shops locations]
- Finding/booking hotel
  - Input [location, insurance identifier]
  - Output [hotel booking receipt]

Scenario 3: *Safe Driving* (Fig. 71)

This macro area identifies business requirements oriented to the health status of the insured client. The main goal is to prevent diseases and injuries, by constantly monitoring the health status of the person. Once a potential problematic is identified (lack of sleep, stress, etc…), solutions are provided to the user in order to guarantee protection and safety.

Narration:

Mrs Rossi is a MEMoSa system user, therefore she always has her smart watch on. She has been sleeping very bad in the last few days, and also this morning she woke up feeling tired. She is thinking already about her daily chores and gives input to the MEMoSa app about her travel stop points (daughter to school, supermarket, ...), in order to plan the most suitable route. Before providing a route notification, the app sends a different one: "Health parameters are below the threshold. Driving is not recommended! Would you use a contracted taxi service with 20% discount?". Mrs. Rossi considers the proposal, and finally accepts to proceed booking a taxi.

Later in the evening, Riccardo, Mrs Rossi's son, takes his mother's car for going out to a club. He arrives to the place and leaves the car in front of the club. Later in the night, Riccardo comes back to the car for going back home. The App identifies a potentially dangerous event: "Car parked near discotheque until 3am". He starts driving, but his driving style is aggressive, and the black box unit detects harsh changes in braking.

At the same time, the smart watch is detecting that his heart rate is significantly higher than usual, and that sleep has not been detected for 20 hours. The MEMoSa system then suggests a support for Riccardo in order to avoid a potential accident trough an audio notification: "The smartwatch detects a high heart rate and that you

did not sleep in the last 20 hours. Additionally, your driving style is becoming aggressive. Driving is not recommended! Get a discount for a taxi or hotel room instead?". Riccardo still decides to continue driving by taking his own risk.

The day after Mrs Rossi gets informed about the last night's situation and her son's decision through the app …

Main data exchanged in this scenario:

- Sleep quality data of one week (available from wearable device)
  - Trigger questions to know what could have affected the sleep
  - Trigger questions to know about the schedule of the day
- Travel origin & destination (available from the questions to the user)
- Weather information (external service)
- Traffic information (external service)
- Recipes suggestions (external service)
- Courses and relaxation techniques (external service)

List of on-demand services/suggestions:

- Transport booking
  - Input [origin, destination, weather info, traffic info]
  - Output [public transport ticket, taxi/Uber booking]
- Training courses booking
- Medical examination booking
  - Can be suggested possible places for medical examination or even booking an appointment

Scenario 4: *Entertainment* (Fig. 72)

This area describes possible scenarios for added value services for the MEMoSa system. The system should be able to provide to the driver personalized offers and information about places and services based on the current context. These services take advantage from the contextual data extracted from the various parts of the system and

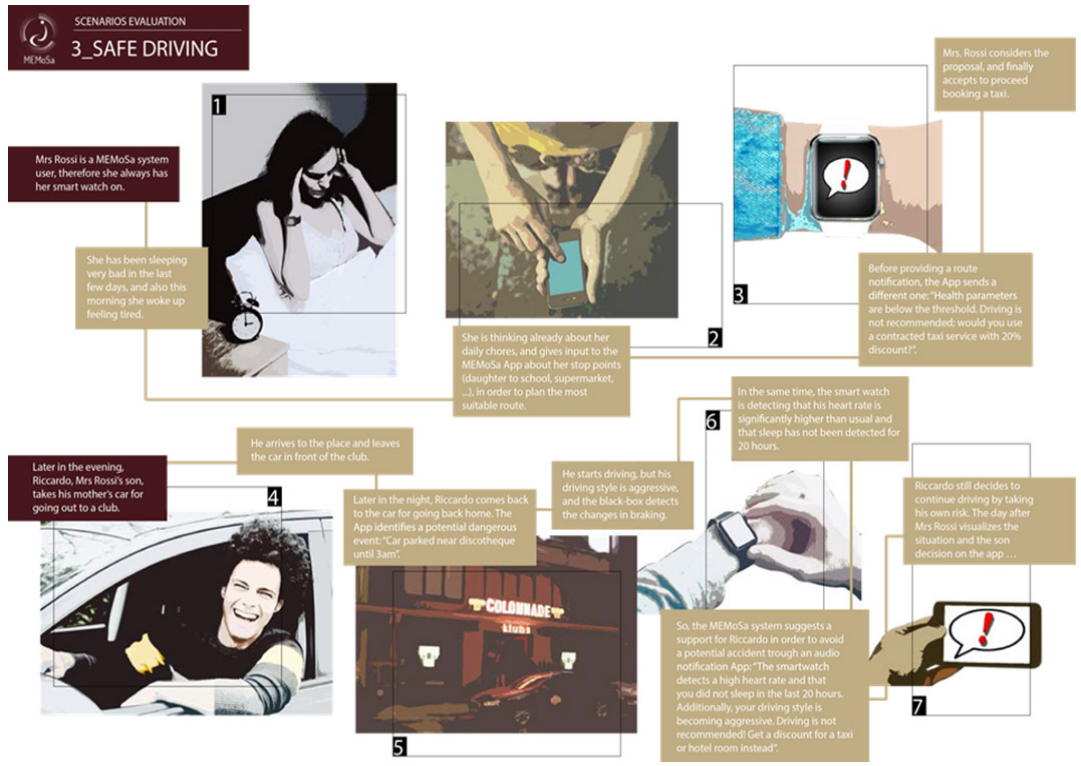


Figure 71. Focus Group: Storytelling for Scenario 3- Safe Driving.

also form the provided broadband connectivity.

Narration:

Paolo, Mario e Katia are planning their trip to the seashore. They are all MEMoSa users with already profiled preferences in terms of music and places to visit. While in car, their smartphones connect automatically to the vehicle's Wi-Fi and an ad-hoc group is created by the app.

Katia is putting the destination on the navigator and collaboratively, through their own smartphones Paolo and Mario are adding some more intermediate stops to the trip that, at the end, will be set on Katia's mobile for navigation. In this way tis how they enjoy a lot travelling together.

They would like to hear something to start off with an energized spirit, and they push "music!" on the screen. The app does a match of the preferences from the 3 people connected and provides them a list of suitable music that is played on Katia's phone.

Main data exchanged in this scenario:

- Travel origin and destination
- User's current position (available from GPS)
- User(s) preferences
- Car information (available from OBD data)
- Points of interest (POI) set (from external data source)
- Other users' activity/schedule information

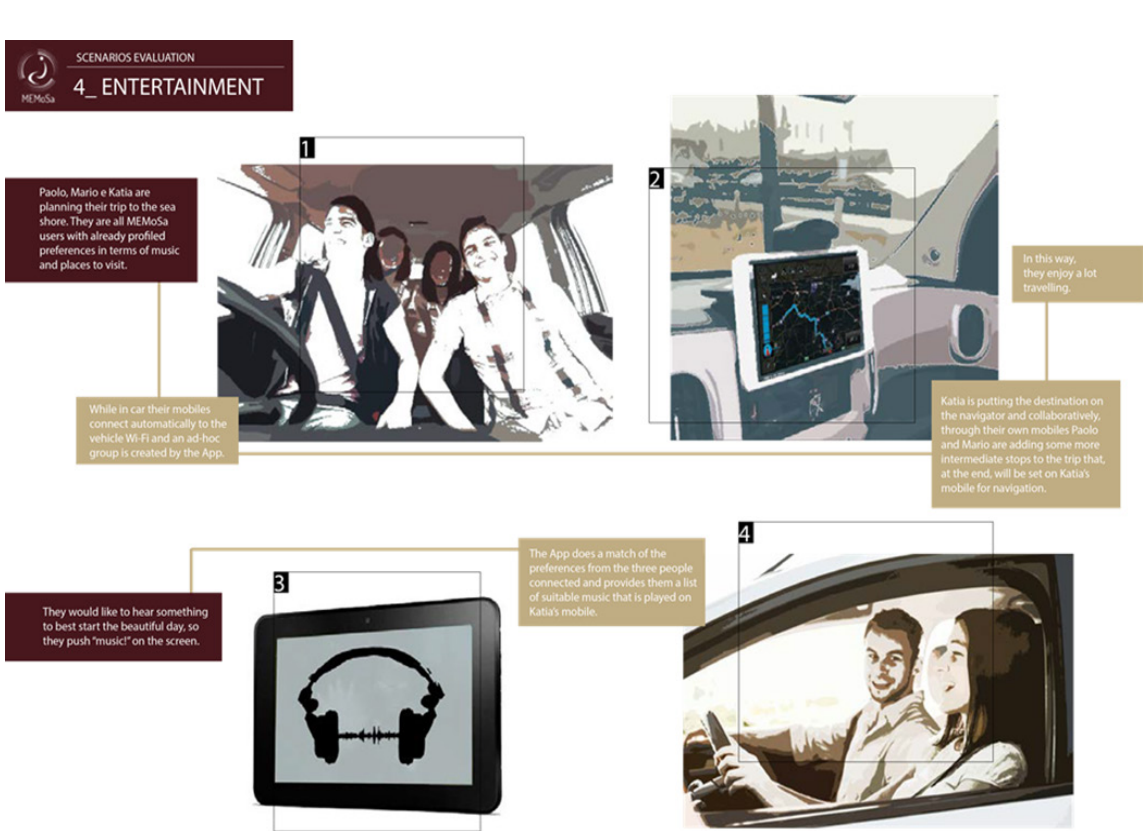


Figure 72. Focus Group: Storytelling for Scenario 4- Entertainment.

The main results derived from Focus Groups are:

- Four use-case scenarios evaluations, leading to decisions on excluding the fourth Entertainment scenario;
- A set of improvements recommendations for scenarios and MEMoSa system in general;
- A list of scenarios' ideas suggested by participants for further development of the system.

All four scenarios were rated on a scale from 0 to 4 (Fig. 73). *On the Spot Insurance* scenario was rated with medium interest (1,87 with a max scale of 4). It was observed as positive by 6 participants, who agreed that personalization of the policy, i.e. customized policies based on the needs of the customer at a certain time, are desirable. However, according to 19 participants, the negative point is that the economic side of the negotiation and some conditions may be unclear or not acceptable. Therefore, overall transparency in evaluation and back-end processes are desirable.

Even though *Car Diagnostic* scenario was rated with medium-high interest (2,39/4), it has brought up certain considerations on data usage. Namely, few participants were concerned about privacy and treatment of data deriving from the OBD, as such could be spread with subsequent issues.

Scenario *Safe Driving* rated with medium interest (1,24/4), was according to 8 participants perceived as positive in terms of monitoring psychophysical state and providing feedback to the driver, especially for long travels. Issues of one's safety as well as safety of family members are highlighted as of high interest. However, monitoring of health parameters by wearables is also touching the sensitivity of data privacy, and 7 participants reported that they might find it invasive to give such data to an insurer. Namely, they discussed that it brings a sense and feeling of presence of a "big brother".

Scenario *Entertainment* did not raise much of questions around the use of personal data, but it was also rated as very low by interest (0,66/4).

Before and after the Focus Groups open discussions on presented scenarios, participants were asked to reflect on their willingness and interest to record certain personal data via diverse artefacts in order

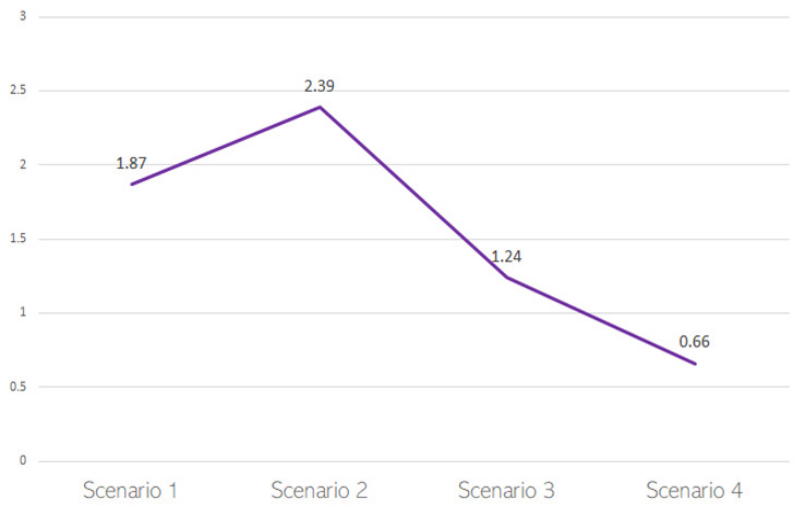


Figure 73.
Rated interest for each of the four presented scenarios, on a scale 0 - 4.

to receive an elaborated information they might find of interest in a certain context (Table 2). We observed that there is a high interest in providing certain personal data for receiving in exchange elaborated useful information and features. Before and after the storytelling of scenarios the opinions did not change drastically in numbers.

UI Mock-ups. This phase aimed to validate the first mock-up for the MEMoSa user interface, and get useful feedback in terms of interesting functionalities, preferences and user choices. It leveraged videos of diverse interaction flows of the UI mock-up (Fig. 74) incorporated within an on-line survey.

Scope	Monitoring Distraction		Measuring Stress		Receiving Support	
	Before FG	After FG	Before FG	After FG	Before FG	After FG
Yes	32	32	22	19	33	29
Maybe	6	6	8	9	5	8
No	1	1	9	11	1	2

Table 2: Participants' availability to connect wearable devices while driving, to record physiological and performance data for following scopes.

The main functionalities of the MEMoSa DriveSafe App include starting a journey, recording data during a journey, and concluding the journey. The beginning of a trip, being the trip previously planned or not, consists in the execution of the connection of OBD by retrieving the corresponding MAC ADDRESS from the shared preferences, and initiating the processing required to track position, read sensors from the smartphone and wearable devices if available, and evaluating the drivers' quality.

During a trip, the main screen shows data about the car status, such as the instantaneous velocity, and a map showing current position and direction of driving. The same screen is also a place where trip notifications land after being generated in the back-end. For example, such notifications include alerts related to harsh brakes or abrupt accelerations, possibly indicating a bad driving style, speed limit violations, or abnormal readings from the sensors on wearable device. After being displayed, the notifications are collected in a log offered to the user at the end of a trip, so the user can inspect the history of MEMoSa notifications during a journey.

It is possible to pause or restart a trip at any time. Pausing a trip is also automatically triggered in case the smartphone loses the connection to the OBD device. To plan a trip, the user is asked to fill out a number of fields including: departure point, place of arrival, departure date, departure time, and additional information about the trip, such as the number of people and the type of trip. Recurring trips may also be configured.

The selected inquiry method is an on-line survey, adopting: (a) GForm from Google, and (b) InVision, for mock-up videos. Mock-up videos show the core functionalities of MEMoSa, while the survey - which has been created with suggestions and validation of project partners – constitutes a rich ensemble of requests: satisfaction, specific choices and comments.

The survey introduction consisted of a brief introductive video with the following contents:

- What is MEMoSa: MEMoSa concept, technological requirements (car, smartphone, black box/OBD, smartwatch);
- What does it mean to evaluate a mock-up;

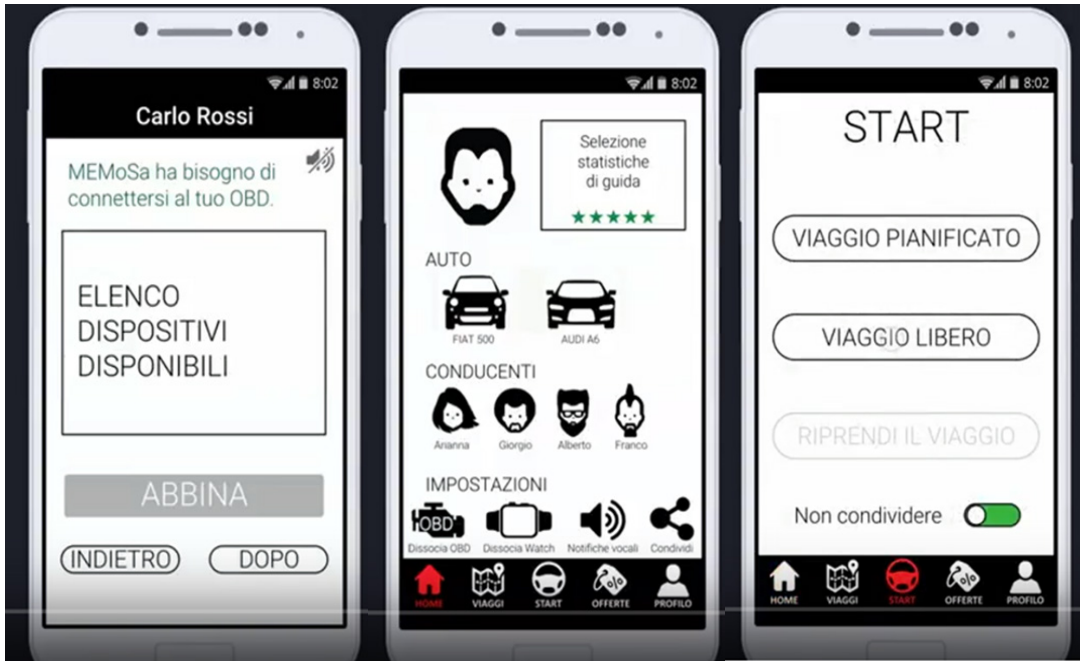


Figure 74. Preview sample of the video with the first MEMoSa UI mock-up.

- Basic functionalities: registration, dashboard, settings, in-app notifications, technology relation, the following videos' list.

The validation was based on 5 micro-videos (maximum 1-2 minutes each) explaining some core functionalities of the MEMoSa app:

1. Cars, community of drivers (https://youtu.be/ZFbieHFeIIs)
2. My Trips, offerings before the travel (https://youtu.be/IzedJ-yykdw)
3. In-car-mode I: long time driving, offerings, driving behaviour (https://youtu.be/BoLn_XVz-FU)
4. In-car-mode II: diagnostic, wellness status (https://youtu.be/FBJLtSuLlcc)
5. My profile (https://youtu.be/t1hEpBRFgXw)

After each video, the participants answered the following questions' structure:

- Overall early evaluation: 5-point scale,
- First comment: free text,
- Specific questions: regarding specific issues (negotiated with partners),
- Final comments: free text.

The main results derived from UI Mock-up evaluation are:

- Excellent evaluation of five videos explaining the core functionalities and the first version of UI of the MEMoSa DriveSafe app;
- A set of recommendations for the improvement of the overall MEMoSa system and the mobile app.

In terms of usage of personal data, the evaluation of this step referred to willingness of sharing data with different entities, such as other drivers using the same car (Table 3), insurance companies (Table 4), and MEMoSa system in general (Table 5).

Type of data	Historic Data of Individual Travels		Ongoing Travel in Real-time		Driving Statistics		Driving Behavior	
	Own	Other's	Own	Other's	Own	Other's	Own	Other's
Yes	37	33	39	36	37	37	34	36
No	17	21	15	18	17	17	20	18

Table 3: Participants' expressed willingness to share the following data with drivers with whom they share the same car, implying both the sharing of own data as well as interest in having access to other driver's data.

Majority is willing to make the data exchange in this situation as there is a certain perceived value to it. However, some stated that driving style and routes, as well as stops and positioning would share only selectively, i.e. only with certain drivers (Fig. 75).

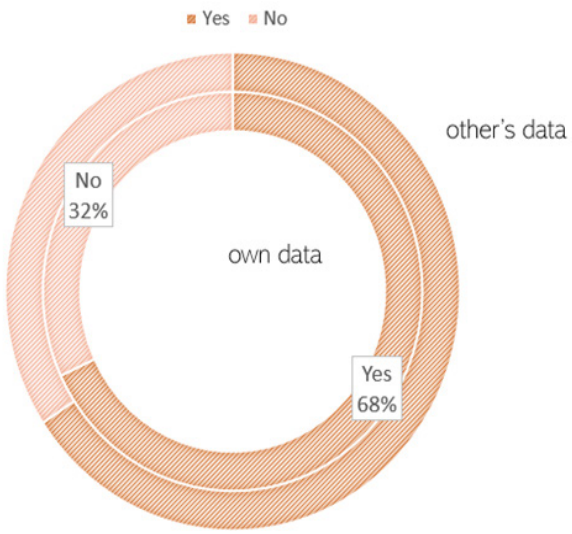


Figure 75.
Scheme showing participant's expressed willingness to share data with drivers with whom they share the same car.

Type of data	Personal Data	Age	Driving Experience	Planning of Trips	Driving Style	Ongoing Travel	Risky Drive Estimations
Yes	43	50	48	31	33	23	25
No	11	4	6	23	21	31	29

Table 4: Participants' expressed willingness to share data with an insurance company.

General personal data, age and driving experience appear to be not questionable when it comes to exchange of data with insurance companies. However, data that relate to real-time situations, ongoing trips and driver's estimations appeared to be opposite (Fig. 76).

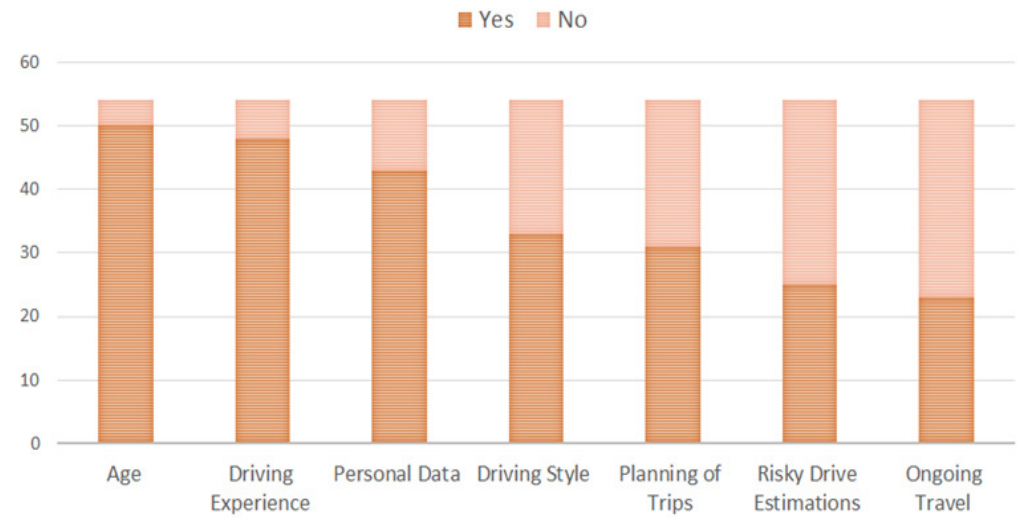


Figure 76. Scheme showing participant's expressed willingness to share data with an insurance company.

Scope	Receiving Support			Monitoring Well-being Status			
Type of data	Speed	Harsh breaks	Harsh acceleration	Anomalies detection	Heart rate	Alertness	Sleep quality
Yes	46	43	40	53	41	38	35
No	8	11	14	1	13	16	19

Table 5: Participants' expressed willingness to share data, derived from the OBD and wearable, with the MEMoSa system for the following scopes.

There is evidently an interest in having certain exchange of data for receiving support during drive (Fig. 77), as well as monitoring one's well-being (Fig. 78) (Table 5) where detection of anomalies is seen as the highest value, while alertness and sleep quality did not receive such high consent.

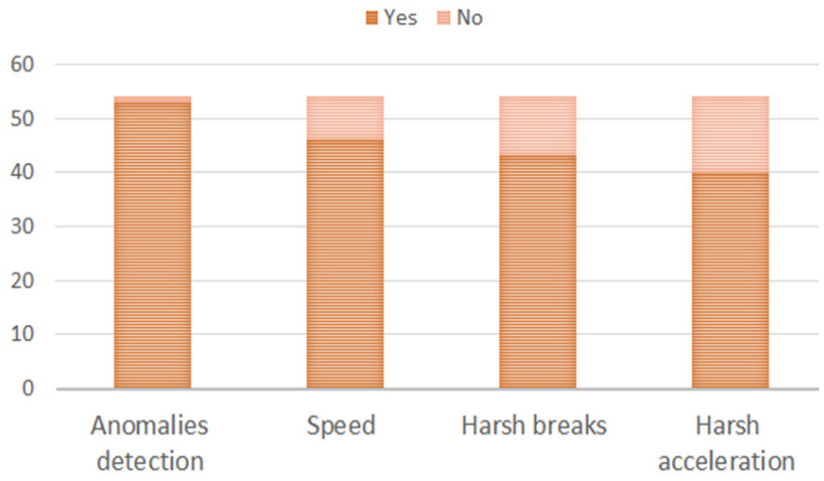


Figure 77.
Scheme showing participants' expressed willingness to share data, derived from the OBD with the MEMoSa system for receiving support.

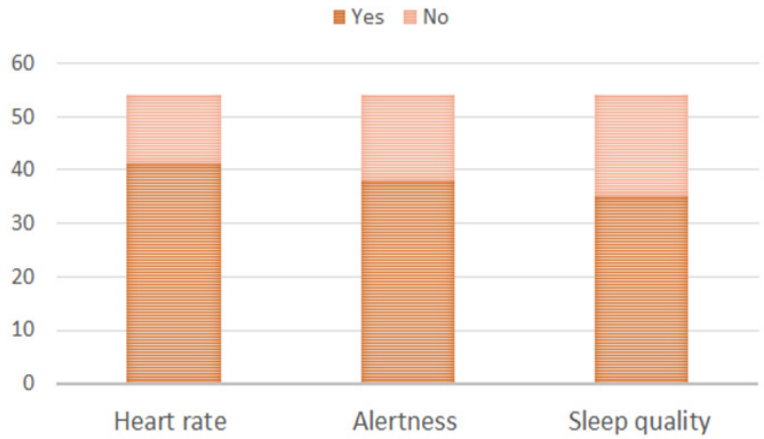


Figure 78.
Scheme showing participants' expressed willingness to share data, derived from the wearable, with the MEMoSa system for monitoring well-being status.

Doubts on privacy and data treatment emerged within the evaluation. Namely, participants did not understand "who is MEMoSa?" (an insurer, a telco, …?), and they were concerned about privacy settings and about who/how will treat/use their data. For the design system it is highly important to make a clarification on this topic, and in particular on data usage when it comes to exchange with third parties.

Real-life Testing. The trial phase aimed to validate the beta version of the MEMoSa DriveSafe app in a real environment setting.

In this phase, feedback was collected during and after the trial period through two online surveys, distributed respectively after 7 days within the two-week period. This phase was related to usability testing, as well as overall desirability now when participants had the chance to try out the actual prototype blending with their usual daily activities (Fig. 79).

Figure 79. Images extracted from the promo video, showing a driver using the MEMoSa system while on the road.

Props needed to participate to the trial were: car, Android smartphone (5.0 or higher) + data plan, OBD device, and a smartwatch. The feedback collection was enabled by two online surveys:

1. Survey 1: aim was to identify relevant first-impact issues in terms of usability and difficulties encountered by participants, to enable a quick improvement and fixes of the system app before the end of the experimentation.
2. Survey 2: aim was to gather final users' feedbacks and evaluation of the overall experience and desirability of the MEMoSa system.

Once selected, participants were invited to the first face-to-face meeting all together to start officially the trial, sign all formal agreements and privacy data treatment, receive the trial kit, the pamphlet and all needed support and assistance to configure the mobile app. In the pamphlet were listed tasks to be performed during the trial, in order to ensure validation of all the features offered by MEMoSa. The listed tasks were:

- Use the mobile app DriveSafe to plan and execute car trips,
- Do at least one trip longer than one hour and half,
- Do at least ten trips a week (some as planned trips),
- Pause/stop trip to check notifications about safety suggestions and offers,
- Plan some recurrent trips such as home-office or home-school,
- Consult "offers" tab, when not driving,
- Accept one insurance policy offer on a planned trip and simulate its subscription,
- Modify user preferences,
- Wear the smartwatch all day and during nights when sleeping.

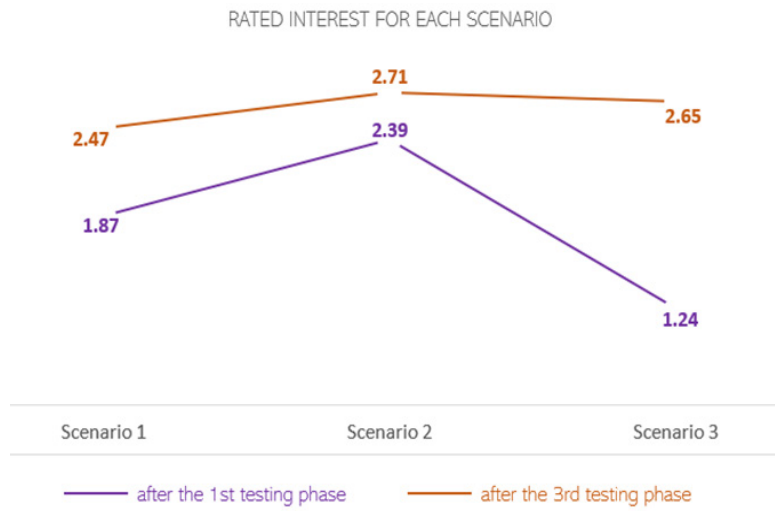
Participants were periodically assisted by email for checking the status of their trial progress and collecting eventual early feedback on issues related to functional problematics with the app. Statistical data are presented in the table below showing mileage and trips done with MEMoSa.

Experimenters [#]	Trial duration [days]	Trips done [#]	Trips planned [#]	Mileage [KM]	Duration [H]	Offers [#]
17	22	284	44	7300	137	14

Table 6: Statistical data on trips made with the MEMoSa system during the trial period.

After the real-life testing period, participants were asked to rate the three initial use-case scenarios (as mentioned, we did not proceed with the fourth one as it was ranked with low interest), in order to make a comparison with the first testing phase (Fig. 80). The values of scenarios in overall raised: On the Spot Insurance 2,47/4 as opposed to 1,87 previously rated; Car Diagnostic 2,71/4 opposed to 2,39; Safe Driving 2,65/4 opposed to 1,24.

Figure 80. Comparison of interest evaluation for same three use-case scenarios within the 1st (focus group) and 3rd (real-life trial) user testing phase.



Main results derived from the real-life testing phase are:

- Very positive evaluation of the three use-case scenarios (On the Spot Insurance, Car Diagnostic, Safe Driving), improved in regard to the first testing phase;
- MEMoSa system could be particularly appealing for transportation workers and people interested in: health issues, using the smartwatches for monitoring parameters, discounts, checking vehicle data, ensuring the family safety;
- MEMoSa system provides particular value to the users in case of long-distance travels.

After completing this trial period, 58.8% of participants declared that the use of MEMoSa system has influenced their daily life. This was perceived in two major considerations, one positive and the

other negative, that had an impact on everyday routines and habits. The first major consideration is that some participants increased their attention towards personal driving behaviour. This is seen as a positive aspect, as one of the main aims of the MEMoSa systems was exactly the stimulation of safer driving style, by making drivers become more aware of their behaviour in driving contexts. The negative influence on daily activities was perceived in redundancy of system elements/devices that the user has to take care of, for e.g. having to take care of a new device like a smartwatch that has to be charged often requires building new habits.

Overall, after the trial, the experience of the system usage was evaluated as 'medium'. The section that was evaluated as providing the most positive experience was usage of the app while traveling; the most negative experience was attributed to the subscription of a policy. From the general evaluation of the MEMoSa mobile application, it emerged that it provided added value in all main aspects of the system. One of the main desirable elements of the application is a summary view of the travels history (with routes, time spans, speeds…); it is perceived as valuable also for comparison among diverse drivers that are part of the system community.

Regarding the use of data within the MEMoSa system, it appeared as quite clear the purpose of data collection and usage. The same applies to the comprehension of the access to personal data, 88.2% declared that it was clear who are the parties that have this access. Majority of the users stated that is clear for them how their data are being handled, which is a good point in developing trust with the design system. However, the principle for calculating ones' driving behaviour is not clearly communicated, and there are certain proposals for extra parameters to be added in such calculation. The suggested parameters are, for example, side-to-side movement on the road (that was not taken in consideration at all), while the constant report of accelerations should be minimized. While using a system of this nature, drivers are actually very persistent in understanding all the parameters that influence their rating, as they want to influence the scores by acting accordingly.

For 82.4%, it seemed that the amount of personal data provided by the users and the offers provided in return (both commercial and support / security assistance) are balanced and adequate. Majority

of participants found it reasonable and acceptable to share their personal data in compensation to the information and offerings that they would receive from the system. It must be added that, due to certain technical issues during the trial period, three participants could not enjoy the full range of features that the system could offer. Therefore, these participants were not able to respond to the question about notifications of service offerings.

Main Issues Imposed by UX Research and Identified User Values

Zooming In & Out within the CPS

From the business planning side of MEMoSa project, partners agreed on offerings both Business to Busines (B2B) and Busines to Customer (B2C); as the project started already from B2B offerings, it was necessary to conduct user research for shaping B2C.

In MEMoSa we have identified two business models to follow for the go-to-market approach:

- "MEMoSa as a Service" - targeting private car drivers through a B(2B)2C business model;
- "MEMoSa as a Platform" model, a pure B2B approach, targeting insurance companies and other key stakeholders of the digitalized insurance value chain.

For overall testing of the proposed AI supported IoT system, we organized three sequential steps that followed the design process, and we reasoned about user values within the following conceptual levels:

1. Usability (physical commodity and comprehension of the system),
2. Desirability (motivations of becoming a user),
3. Acceptability (expanding on a social level, i.e. achieving social consensus).

For evaluating User Experience within the three phases, we focused on Desirability and Acceptability through all three of them, and on Usability in the last two (Fig. 81, 82 & 83).

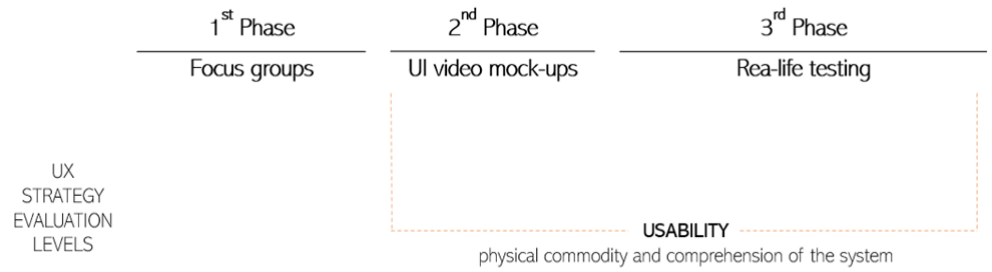


Figure 81. Research phases focusing on Usability.

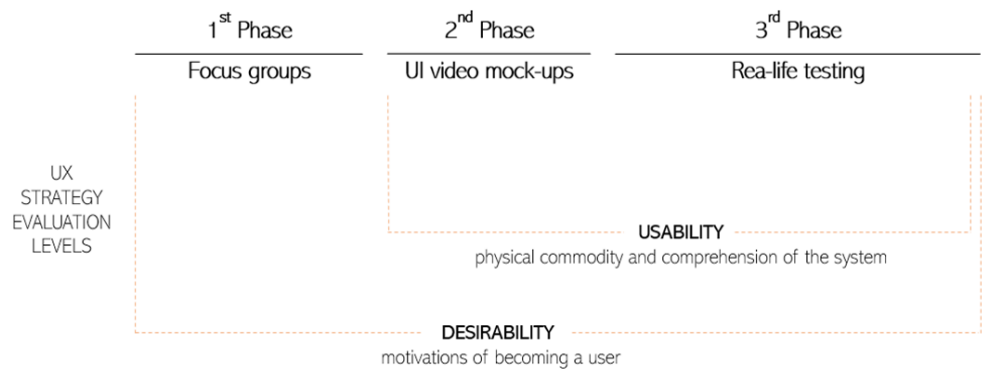


Figure 82. Adding the level of Desirability research, spread across the three phases.

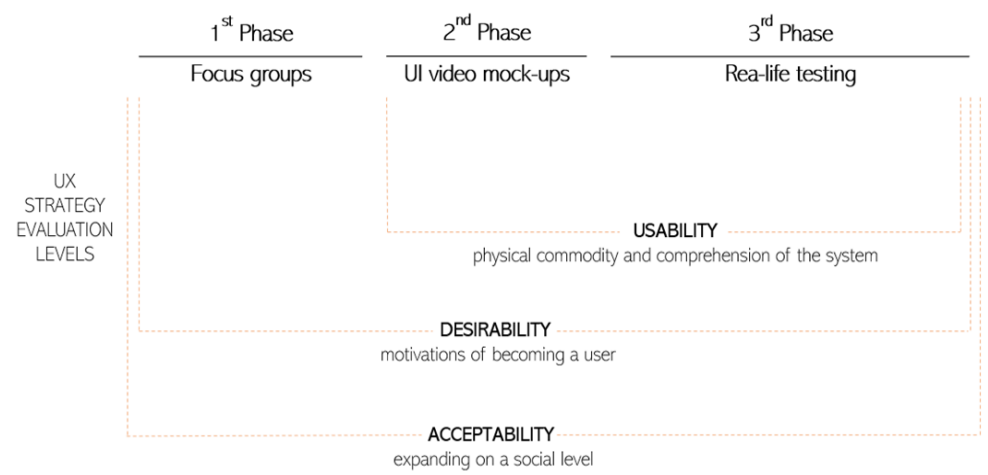


Figure 83. Adding the level of Acceptability research, spread across the three phases.

During the project development, it became evident that the UX research would be facing diverse levels in terms of evoked experience, and the testing focus had to be tailored accordingly. As we are applying a user-centric approach within the development, it is important that the research and, thus, the refinement and redesign recommendations that follow, are developed in regard to different levels of abstraction of the design concept. Therefore, projects of Ambient UX have a need for constant zooming in and out, in terms of abstraction and concretion (e.g. from broad strategy to interface elements) of the design concept and outcome, that would enable tailoring of the UX research and design refinement and iterations in diverse phases of project development. As shown in the case example, the practices for designing and developing complex systems requires zooming in and out from, for e.g., usability to acceptability (i.e. GUI design to social consensus), in diverse steps of the project.

Social Acceptability of the CPS

Within the level of usability, transparency in communication is observed as highly important when it comes to usage and interpretation of personal data. In terms of desirability, participants were willing to share their data, and also get insight into other people's data, stay informed and receive correspondent services they find as useful in regard to sensitivity of data they shared. Furthermore, they expressed willingness to be familiar with the back-end operations of the system and understand in which way gathered data is being translated into an information, and who has access to such information.

The results showed strong presence of considerations from the side of users on data usage as well as sensitivity of certain data, which consequentially translate into user values of the design concept. Privacy and data treatment transparency appear as constant considerations throughout all three conceptual evaluation levels, especially when it comes to the acceptability of the designed system itself. I emphasize the importance and need of including acceptability on a social level, i.e. achieving social consensus, within the design processes through a critical analysis of the usage of personal data in order to support the design of complex personalized services that shape emerging socio-technical systems. Fulfilling considerations

that correspond to what is established as a social consensus on a particular issue, i.e. socially acceptable, within the design process would support building trust in connected systems for personalized AIs embodied through CPSes. For e.g., for using physiological data extracted from a wearable to provide crafted information for the user, a system has to communicate clearly who are the parties that have access to such data as well in order to achieve acceptance of use.

It is to note that both in the 1st and 3rd testing phases the same three use-case scenarios were evaluated, however, in the 3rd phase the same scenarios reached higher scores in terms of desirability (see Fig. 80). This could be related to the fact that the interface itself was designed in a way that was supporting the UX research results, thus it emphasised on transparency of data usage. In the 1st phase there were many considerations in regard to this issue, and it was observed as highly negative, while in the 3rd the end of data usage and the access to data was put in evidence within the UI design, which seemed to have resulted in increasing desirability of the offered systems itself.

Following the results of this research case, it appears as a necessity addressing issues of ethical nature when it comes to treatment of data, and particularly sensitive personal data. More precisely, there is an evident need for facing social acceptability and reaching social consensus within projects of complex systems that involve much od data usage, such as those that target Ambient UX.

Case Study 3: Connected Lighting for a Caring City (City Environment)

3.2.3

Project Description

Project Stakeholders (Fig. 84) are the company Signify (former Philips Lighting) that produces luminaires and provides services for connected lighting systems, and the Massachusetts Institute of Technology (MIT) Design Lab, which I was part of during a one-year period as a visiting research fellow.

Figure 84. Stakeholders of the project Connected Lighting for a Caring City: Signify and MIT Design Lab.

Research project, *Connected Lighting for a Caring City*, is focused on the development of a design vision for an artificial lighting AI agent that would have the effect of making urban dwellers feel cared for, within the context of growing megacities. The design concept envisions a personal assistant that would accompany the users during their daily activities within diverse indoor and outdoor urban settings. Interfacing with this assistant, involves gesture-based modalities that support seamless user interactions, complementing common daily activities. Along these lines, storytelling prototypes were produced to demonstrate examples of diverse use-case scenarios, involving

the proposed AI lighting agent. The use cases were evaluated in terms of feasibility and acceptability, and a roadmap of strategic implementation for the proposed design concept was outlined. An initial concept evaluation was performed, and further evaluation steps could be conducted after a physical and digital prototype of the proposed intelligent system becomes available.

Current advancements in the field of AmI systems include sensing and actuating networks, lighting systems supporting data gathering and transmission, and light-embedded or -enabled materials. Additional topics include user-system inputs (such as sensing modalities), and interaction modalities, enabling natural user interaction (such as touch, gesture and sound). We performed secondary research, to understand the state of the art in the fields of interaction, lighting, and related technologies, and primary research, to identify what makes city dwellers feel cared for, across different generations.

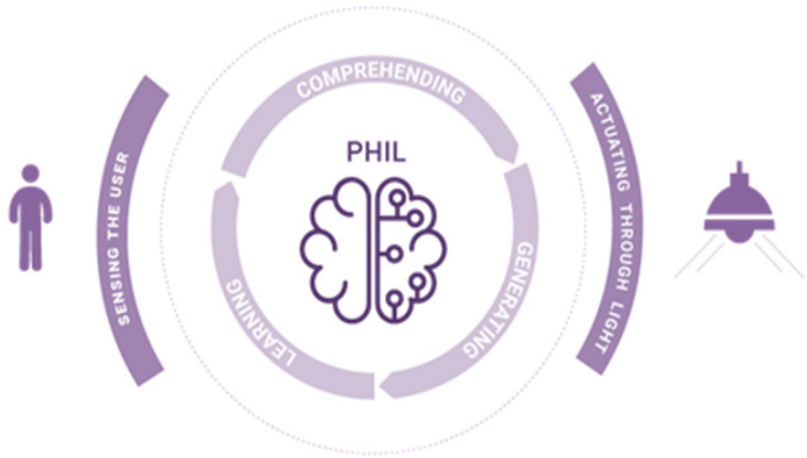
In secondary research we examined the emerging behavioural and social trends of overusing tech devices, and the isolation phenomena of urban living. We distinguished a need for human-scale service systems that could support the future shaping of "caring cities". Main characteristic of these systems would be to make urban inhabitants feel that are cared for. User values were extrapolated by observing the feelings of people in various activities and urban contexts. We distinguished the changes that the adoption of digital technologies and interactions across generations causes, with the aim to envision inclusive design alternatives for an AmI lighting agent.

Additionally, in primary research, we conducted face-to-face semi-structured interviews to identify what makes city dwellers feel cared for, across generations. The selection of participants was based on diversity in age, gender, and cultural background, as well as familiarity with urban living. Their occupations ranged from students, part-time or full-time employees, to retired elderly. The data obtained by the interviews were divided in two thematic areas: (1) what are the characteristics of various generations of urban dwellers, and (2) what makes them feel cared for. Based on the interviews we outlined four personas, corresponding to four age groups of targeted city inhabitant types. The personas incorporate common characteristics among the interviewees. They belong to different age

spans, and reflect their thoughts, daily activities, considerations, and needs.

The second thematic area of interviews yielded six key user values providing guidelines towards alternative design visions for a caring city. The design visions evolved around Phil, an intelligent lighting agent that enables citizens to feel: invited, accepted, acknowledged, accompanied, assisted, and protected. Phil senses the user activities, learns, comprehends, and generates information through AI algorithms enabling the actuation of proper light sources for each occasion (Fig. 85).

Figure 85.
Overview of the AmI agent system.



To sense the user, Phil relies on sensors that are embedded in materials for real-time activity detection. Phil also access cloud stored user profiles and preferences, as well as external APIs. Connected with the light sources Phil assists the user in outdoor and indoor environments, supporting activities at home, work, leisure, and transportation. Phil is capable to comprehend the real-time context in which the user acts by accessing their profile, the location and time of the activity, as well as the social dynamics. Phil is capable of learning people's daily routines, their needs, preferences and interests, and what they consider optimal ambiance settings. After learning, Phil caters the user needs with illumination and desired ambiance lighting, social lighting triggers, wayfinding, and event notification lighting.

We designed an interaction language for communicating with Phil, based on gestural inputs and visual outputs. The interactions would become possible through smart materials (Barrett & Omote, 2010) and electroactive fabrics (Syduzzaman, 2015), enabling capacitive touch sensitive surfaces. Such materials could be embedded in furniture, wall surfaces, and clothing, enabling seamless interactions.

AmI design is influenced by user-centric methods where the user is placed at the centre of the design activity and asked to give feedback through evaluations and tests to improve the design, or even co-create the design with a group of designers, or users. The challenge of designing and implementing an AmI system is the lack of models enabling the analysis of the system requirements while designing the system, and of verification and testing methods when the system is implemented. Designing an AmI system involving AI agents requires a different approach from traditional system design. While in traditional systems performance and interaction are determined in advance and remain fixed, in AmI agent systems interactions are contextual and open ended, triggered by the unrestricted activity of the users within the environment. This becomes possible through the integration of ICT components in the background. Furthermore, since CPS aims to build experiences that are entirely new, there is no proper model for situating and evaluating them within existing user contexts, as there is no model for aligning them to the existing production strategies of companies.

Observed holistically, the project Connected Lighting for a Caring City includes research, design, and evaluation. First, primary and secondary research on the significance of the notion of "caring" within different user contexts is used to extrapolate user values for the caring city concept, and tech research identifies emerging technology trends and possibilities. Second, a personal lighting AI agent is envisioned based on the user values. Alternative design visions are described and communicated in video storytelling format. The design vision alternatives are based on five systemic factors, namely: a) the context of interaction; b) the required system data; c) the required sensing input; d) the required user input; and e) the desired system output. Finally, third, a structured model is used for the evaluation of implementation roadmaps for each alternative design vision. Visions are evaluated by assessing three parameters: the complexity of the enabling technologies, the availability of

these technologies in the partner company, and the prospect of advantageous business partnerships.

Research deriving from this case study contributes a novel concept for the generation and evaluation of AmI systems involving AI agents, based on three distinct levels of in-built system intelligence. In the following section of the results, I provide insights and discussion on how the generation and evaluation model was used by the design team and by the partner company.

Why the case study is an Ambient UX concept

The project considers an approach of designing for user's experiences within an urban outdoor environment, following user's daily activities also within diverse indoor spaces, such as, for e.g., home and office. It does refer to a holistic overview and evaluation of UX, including also the observations that regard the physical context itself. Users are influenced by the ambiental context being enhanced by digitized services, using lights as a medium of communication and interaction. Connected and smart lighting systems are, in fact, a common design application example for systems of Ambient Intelligence. Therefore, the project is considered a suitable example for discussing the Ambient UX design concept.

The project has a strong influence of the spatial architecture in regard to user's experience (Fig. 86a) and relies mostly on automated input and non-GIU interaction (Fig. 86b).

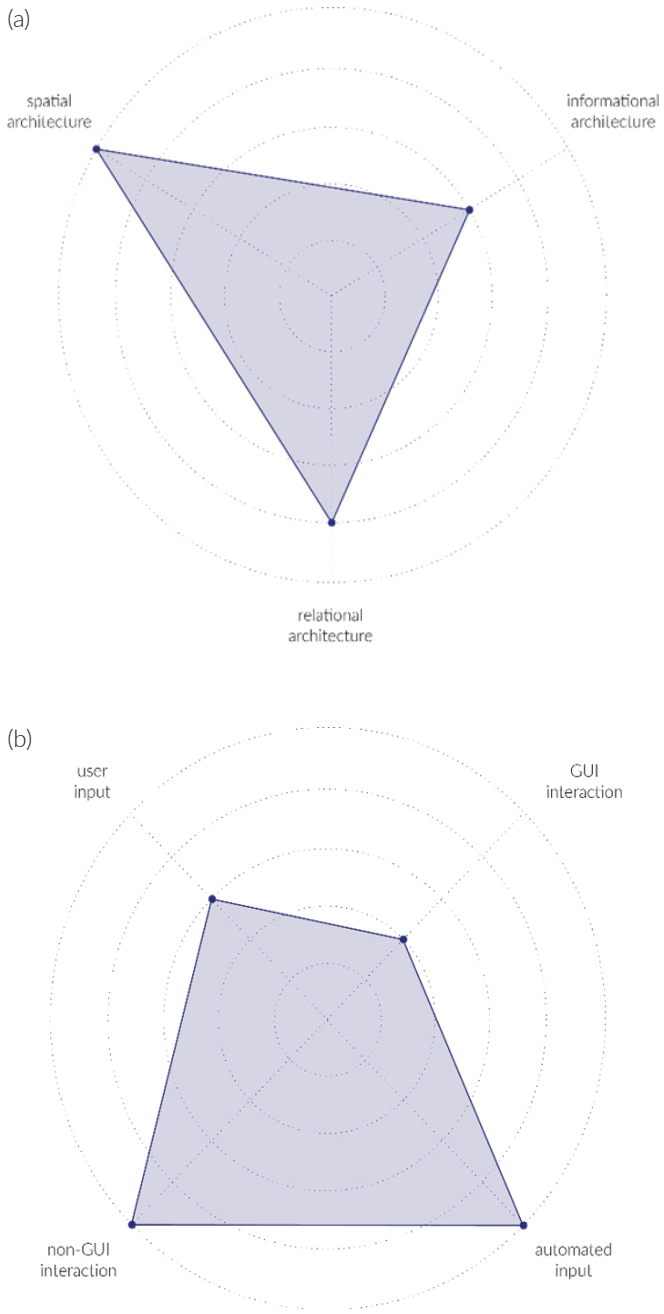


Figure 86. Radar diagrams showing (a) architectures as Design Domains and (b) system input modalities for the project Connected Lighting for a Caring City.

UX Research

Methodology

This research describes user studies through the initial secondary and primary research, that led to a definition of the design concept. However, it goes further in depth with discussing and analysing the design concept together with the representatives of the partner company (Fig. 87).

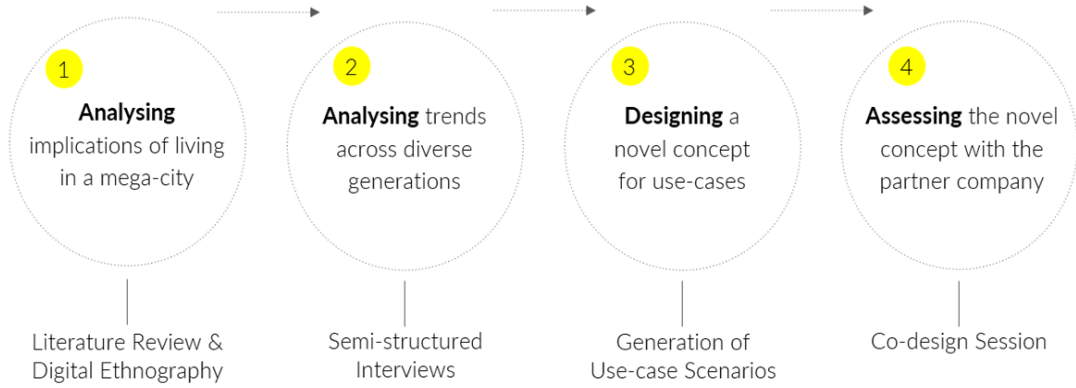


Figure 87. UX research methodology employed within the project Connected Lighting for a Caring City.

The following will focus mostly on the last step of the research methodology, i.e. the co-design session with the partner company.

The overall design process included two phases: concept generation and concept evaluation. In both phases we followed appropriate techniques that supported the design practice. In the evaluation phase we used a model that we developed for the needs of the AmI agent evaluation. The evaluation was based on a three-stage analysis, corresponding to three levels of in-built system intelligence. Specific tools were employed to support this analysis, namely: (1) use cases videos, (2) scene-analysis cards, (3) scene-evaluation diagram (matrix), (4) scene-implementation roadmap. The videos and analysis cards were developed by our design team. The evaluation and implementation roadmap were produced in collaboration with the partner company, during the workshop session. These tools supported the design process and provided a platform of communication between the design team and the company. They also served the process of alignment between user and business values.

In order to validate our tools, we set up a survey to enable the collection of feedback from the partner company. The survey was delivered online, in three sections. The first section of the survey validates the adequacy of video storytelling as a tool of description of the design vision, and its underlying user values. The second section of the survey validates the adequacy of the scene-analysis cards as a tool of analysis of the design vision. The third section of the survey validates the adequacy of the evaluation matrix and the implementation roadmap as business value demonstrations of the design vision.

We produced video storytelling prototypes based on use cases. More specifically, we envisioned the performance of the system in daily contexts and activities by determining:

1. The potential users through personas (i.e. their personal goals, needs, and issues across generations),
2. The user values (6 values for feeling cared-for),
3. The contexts of use (spatial-temporal),
4. The data input and props
5. The interaction modalities.

At the end of the design process, we conducted a workshop with the partner company, to evaluate the use cases of the system and to explore potential business strategies for implementation (Fig. 88).

Figure 88.
Workshop material and layout of the working area.

To evaluate the use-case scenarios, which were presented in video form, we analysed specific moments of interaction. This analysis focused on points such as:

1. The spatial context within which the scene was enacted,
2. The data needed for the functionality of the system,
3. The inputs deriving from the user or through various sensors.

Specific moments of interaction, called scenes, were documented with the aid of analysis cards (Fig. 89). To evaluate a scene, we evaluated with the partner company the perceived feasibility of the interaction, and the user acceptability this interaction could entail. Feasibility is what the company is capable of producing, and in what timeframe. Acceptability is the potential for familiarity and trust that the users may feel while interacting with the AI agent. A two-axis diagram was constructed with X axis representing acceptability, and Y axis representing feasibility metrics. Analysis cards were

Figure 89.
Example of a scene analysis card that was used in the workshop.

numbered, and numbers were placed on the two-axis diagram (matrix) indicating the outcome of the feasibility/acceptability evaluation (Fig. 90).

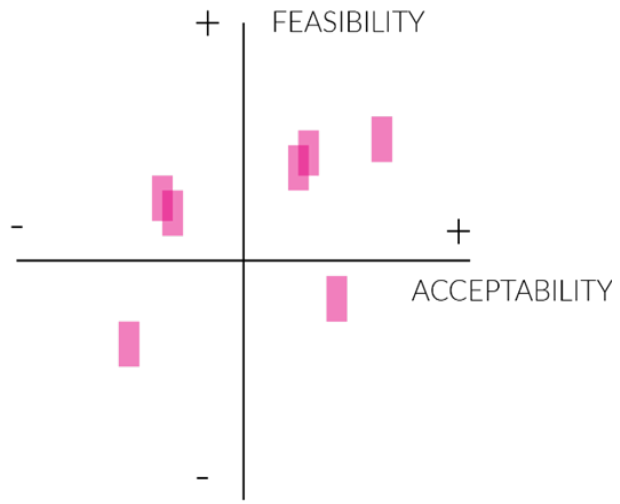


Figure 90.
Scene evaluation matrix with examples of cards placement, as it was used in the workshop.

Results

We validated the evaluation model through a survey that was distributed within the partner company. More specifically the tools that we employed: video storytelling, scene-analysis cards, scene-evaluation diagram, and scene-implementation roadmap, were validated by the company representatives, and received overall positive ratings. Four participants replied to the online survey: Head of Research (24 years in the company); a Principal Scientist (18 years in the company); an Industrial Designer (17 years in the company); and the Head of Design (3 years in the company).

All respondents agreed that video storytelling offers sufficient means to communicate the design vision and specifically, the user values, the concepts, the enabling technologies, and the interaction modalities. One participant claimed that "video storytelling is efficient to convey a vision within the organization". However, other respondents argued that the videos do not adequately represent the design vision as whole, because each time they capture only a part of the story. All respondents agreed that video storytelling is sufficient to convey the user values. They also appreciated that the videos were

"well anchored in research" allowing the company team to "see the impact of the system on people".

We also collected feedback on the adequacy of the parameters in the scene-analysis cards. The cards make the vision concrete by analysing the technologies, the criticalities and the feasibility of the design scenarios. We considered parameters such as, the context of interaction, the required data, the input deriving from sensors and from the user, and the system output. All respondents agreed that the scene-analysis cards were useful in making the vision concrete and understandable. However, only two respondents agreed that the parameters were useful in determining the feasibility and the criticalities of the design vision.

All the respondents agreed that the 2x2 matrix of the scene-evaluation diagram was useful to assess the feasibility of the design concepts, based on the current technological capabilities of the company. The respondents observed that the strengths of the scene-evaluation diagram are the simplicity in communication, the intuitiveness, and the simplification of the decision-making process. However, some respondents have pointed two shortfalls: the openness of the matrix to personal interpretation, and the fact that the matrix could "oversimplify the decisions without mapping an inclusive set of implications". These respondents claimed that introducing additional matrices to the already proposed one, could strengthen the validity of the tool. A participant suggested that it is important to acknowledge "the people's role in the company" when capturing their evaluations on the 2x2 matrix.

Three of the respondents claimed that the scene-evaluation diagram was useful in determining the scene-implementation roadmap in association to the strategic model of the company. The roadmap was based on three parameters: 1) the complexity of the enabling technology, (2) the availability of the technology within the company, (3) the potential for productive partnerships. Three of the respondents have found these parameters useful. However, not all the respondents agreed that the three parameters are sufficient. One suggestion was to add more parameters such as: "internal strategic direction, annual operating plans, external highest demand, and piloting opportunities".

This research contributes a novel model for the generation and evaluation of AmI systems involving AI agents, based on three distinct levels of in-built system intelligence. The first level corresponds to one-step notifications and simple system outputs, requiring simple data input (i.e. reading a scheduled event in the user's calendar). The second level corresponds to the hardware requirements for the sensing and processing routines of the system. The third level corresponds to emotional intelligence (Picard, 2003), the higher state that an AI agent can reach, where the system acts as a personal assistant. The three levels of in-built intelligence in combination, reflect the feasibility and acceptability metrics of the system. Feasibility is what a specific company is capable of producing, and in what timeframe. Acceptability is the potential of familiarity and trust that the users can feel while interacting with the AI system.

Main Issues Imposed by UX Research and Identified User Values

Usage Time Spans of the CPS

Based on the evaluation results, we produced development and implementation recommendations in a strategic roadmap. This approach is based on the premise of introducing the AmI agent gradually, to foster user acceptance and reduce the risk of disruption. The evaluation results emphasize the importance of enforcing trust, to ensure acceptability. Trust includes both the sense of privacy and the sense of familiarity. A system that relates to familiar services or products is more likely to be trusted. The implementation of the design concept was envisioned to progress based on the pace of technological progress. The system would start with existing solutions and services, and would incorporate new ones, when more sophisticated software would become available to run in the back-end. The use scenes were grouped, evaluated and placed on a timeline, based on three stages that determine three distinct levels of system intelligence (Fig. 91).

The proposed roadmap helped realize the need for implementing diverse time span perspectives of the impact of the design concept, while developing the concept itself. The design process requires an ability to have an overview of the impact and influence of the design concept, in regard to the users, over a larger timeframe,

Figure 91. Three incremental stages of the concept implementation roadmap, as emerged from the evaluation of use-case scenarios.

like for e.g. immediate, in the period of few month after use, few years and so on. This would contribute a sustainable planning and development of a design concept, in particular those that bring certain complexities, such as the projects that target Ambient UX. Precise planning for different time spans could foster acceptability according to familiarity of the system proposals and interactions. Besides the user impact and acceptability and/or desirability, diverse time spans overview support sustainable and incremental planning for the systems implementation and development of its components, as observed through the case study.

Intelligence Levels of the CPS

Implementation roadmap for the design concept shows three incremental stages (Fig. 91), which are equal to three distinct levels of intelligence, as it emerged from the project.

First stage of the roadmap is one-step notification. It uses off-the-shelf technology including luminaires linked to an API that trigger a notification at the right moment. Scenes in this group rely on a simple, reactive system, where lighting is the primary medium of notification. One-step notification infrastructure can also apply to settings in which in addition to API, simple gestural inputs may also serve as triggers.

The second stage of the roadmap is context aware interaction. It requires that additional hardware, containing appropriate sensors, is embedded in the outdoor and indoor environments. We examined the idea of designing "clip-on" items to be added to the existing

infrastructure. This would enable the context awareness of the system (space, time, movement, activity) based on sensory input. In comparison to the first stage, this second stage incorporates additional elements of remote interaction and awareness, which beyond the reaction to single events, synthesize the notion of a living context for each user.

Finally, the third stage of the roadmap is personalized assistant. In this stage the system obtains the complete set of features and the scenes are tailored to unique user experiences. The AI agent becomes a personal assistant understanding the physiological states as well as the lifestyle, habits, needs, and desires of the user, and acting accordingly. At this third stage, the system incorporates machine learning and is capable of emotional empathy, thus reaching the top level of emotional intelligence.

Following the above mentioned, it appears as a necessity to understand and identify intelligence levels within systems that target Ambient UX, as these systems are dependent on data processing that, in some cases, deals with learning processes. Comprehending and identifying diversity of intelligence levels supports the planning process by anticipating user acceptability of novel interactions and responses deriving from an AI system. Furthermore, it supports the planning from the development side of the project, that involves data gathering and processing. This is to say that, in complex projects powered by AI systems where Ambient UX is one of the target areas, the design process should be supported with suitable reflections on the intelligence levels involved in system operations.

3.3 DISCUSSION ON ENCOUNTERED ISSUES IN DESIGN PRACTICES

For all three projects related to design practice for systems that employ an Ambient UX design approach (Humanitas, MEMoSa, Connected Lighting for a Caring City), starting point for design are always an analysis and planning based on use-case scenarios.

All of the projects confirmed the presence and importance of defined Design Domains (three architectures and time a s a variable) of Ambient UX within the practice. Having the Ambient UX conceptual framework helped out in comprehending and dealing with complexity of design outcomes and design processes.

For the three projects, it was evident that diverse architectures were the main influencers of the user's experiences, and thus, User Values. The conducted UX research brought up considerations in regard to User Values and expanded on particular issues of importance for each of the projects and diverse levels of User Values. In regard to User Values, the following issues were identified of importance for the design process and the design concept development:

- All Three Architectures Considered Simultaneously within the CPS,
- Analysis of Alternative Paths within the CPS,
- Zooming In & Out within the CPS,
- Social Acceptability of the CPS,
- Usage Time Spans of the CPS,
- Intelligence Levels of the CPS.

The issues are proposed to be expanded considerations for projects of Ambient UX, as they are very significant in practices both for the development of Design Domains, as well as the influence on User Values.

3.3.1 Main Observations

HUMANITAS

Design goal was to improve the experience of users for hospital administration services. The chosen solution was a system integrating human and technological touchpoints. This case study was an opportunity to focus on the importance of designing digital solutions by considering contexts undergoing a transitional phase from traditional organisations to innovative smart systems. While digitising services can provide value by increasing the flexibility and efficiency of services, specific critical aspects of treatment systems require a holistic approach to the variety of human needs, and the capability of predicting and managing the consequences that the changes introduce into the procedures. Project concludes that UX Design should provide tools to support the management of alternative processes for service delivery, it illustrates the role of envisioning in co-design processes with hospital staff and introduces the concept of transition in physical/digital systems.

Mapping existing processes to illustrate patients' journeys as they interact with different physical and digital touchpoints, during the different stages of their administrative and care pathways, is essential to managing complexity in systems that regard relations with users. In our case, the mapping process has permitted a focus on knowledge of the system that is distributed among different staff members. Furthermore, it has helped us build a foundation for dialogue not only between our research team and hospital staff but also among staff members themselves, whose different roles imply they have different perspectives on the processes and problematics they face.

Maps we have produced during the project have different content and functions. In addition to representing physical spaces of the hospital, which form the basis for evaluating the different physical

pathways of patients as they move between the buildings, they also represent the physical and digital touchpoints that patients encounter in their journey. These conceptual maps illustrate the interactions at different stages of the journey as well as different physical and cognitive efforts required, linked to waiting times experienced by users. We also developed customer journey maps with different levels of detail to facilitate discussion and dialogue between staff representatives.

In overall, staff members were keen to get involved, share their points of view and identify proposals and solutions together. From the co-design process emerged the need to analyse different user profiling methods in order to establish a range of parameters for evaluating the fluidity, efficiency and effectiveness of the processes concerned, and to identify any critical issues in how services are currently organised in relation to different customer requirements, priorities, merit factors, access and evaluation models. Furthermore, we observed the importance of having shared representations of systems and processes, enabling a discussion of systemic solutions, which evidently moves beyond an approach based on occasional interventions delivered "just in time".

Our research has led us to conclude that optimisation of all factors that influence administrative services is – and will be – an important goal for improving of the overall experience of patients as they interact with medical institutions. The quality of environments dedicated to providing administrative services smoothly and efficiently, together with interactions with dedicated non-medical staff, positively influences the image of the institution and its ability to respond to customers' needs and expectations. Although administrative services may appear to be mechanical at first sight, they are much more complex and significant. Introducing digitised services and automating administrative processes does add value in terms of efficiency. However, the added values as perceived by customers – patients, in this case – are much broader and more specific than our investigated case study.

Organisations that strive for efficiency through innovation and digitisation of processes need to take an innovation management approach based on observed user journey experiences, in order to ensure the successful implementation and acceptance of innovative

aspects. Here, user experience design tools for multiple-path digital/physical services play a significant role in supporting and guiding design processes for driving such innovation based on holistic approaches to user experiences. The role of designers in extending and developing design tools, that support management of alternative processes for service delivery and their implementation in co-design processes with organisations, is set to grow in the future.

This case study underlined the importance of including and analysing all three architectures together and identifying user alternative paths for the projects based on Ambient UX.

MEMOSA

When the study participants were asked if they perceive MEMoSa as a personal assistant for safe driving, the opinions were divided to almost equally half-half. However, it is notable that 76.5% of the participants find the concept of a personal assistant supporting driving activities and generating contextualized services very interesting, therefore desirable. This is where MEMoSa seeks potential for upgrading its value offerings to potential users.

Within the project we wanted to identify profiles of users that potentially find interest in MEMoSa, and we focused a part of the survey around this issue. The participants stated that, according to their opinion, the profiles that find interest in such a system might be people with particular concerns around health problems, who usually use wearables for tracking personal performances on a daily basis, as well as people interested in economic aspects (discounts) and the thorough check of vehicle data (also for prevention), finally also people who aim to ensure the safety of their family. Furthermore, they suggested it would be quite of value for transport workers, and it would be better if such a system was to be implemented within the vehicle dashboard.

MEMoSa system seems to be providing value to the users in case of long-distance travels by monitoring real-time the trip and the elements that might influence it and providing safety notifications accordingly. Particularly, the value is added to the users to whom driving is a working position (drivers who spend a significant amount

of time behind the wheel). Familiarity with the environment in which the driving activities are happening plays a crucial role, namely, the system is perceived as worthier if used in unknown surroundings. Other perceived values are deriving from the economical point of view, considering the discount offerings. The system itself is more likely to be accepted from the people who are curious about technological advancements and interested in monitoring of diverse aspects, considering both personal and data provided by other people with whom they share certain interests (driving community members).

The project underlines the importance of data flows for building desirable services. Within the design system of radical innovation in terms of user interaction and experience, such as the one supported by an AI agent, trust plays a significant role. In the conducted case study, we confirmed that such systems that rely on the use of personal sensitive data are desirable, but acceptable under certain conditions. There is a need for a social consensus to be considered and directly employed during the design and evaluation process, in order to target and support the area of user values that deal with data and information exchange. With this notion, we want to provide an initial contribution to design methods that regard evaluation of complex IoT systems embodied through AI agents.

This case study underlined the importance of including and analysing social acceptability and enabling constant and simultaneous zooming in and out within the design concept for projects based on Ambient UX.

CONNECTED LIGHTING FOR A CARING CITY

In the case study, we determined and tested a model for the generation and evaluation of AmI system designs, based on user experience and business criteria. This research activity was driven by an observation of absence of a clearly defined working criteria, which appeared to be a conspicuous obstacle to the advancement of AmI agent system designs. The process of designing a personal lighting AI agent in collaboration with a leading lighting design company, is used as a case study to determine and test a model for the generation of AmI system designs, and for the evaluation of their

implementation roadmap, based on feasibility and acceptability.

This research contributes a novel model for the generation and evaluation of AmI systems with AI agents, based on three distinct levels of in-built system intelligence. Although evaluation based on parameters is a common method, defining the implementation roadmap based on specific levels of in-built intelligence is a new approach. The first level corresponds to one-step notifications and simple system outputs, requiring simple data input. The second level corresponds to the hardware requirements for the sensing and processing routines of the system. The third level corresponds to emotional intelligence, which is the higher state that an AI agent can reach, and the system acts as a personal assistant. The three levels of in-built intelligence in combination, reflect the feasibility and acceptability metrics of the system. Feasibility is what a specific company is capable of producing, and in what timeframe. Acceptability is the potential of familiarity and trust that the users may develop while interacting with the AI agent. There are no existing assessment methods for AmI agent systems that are based on parallel account of intelligence levels and user interaction modalities.

The process of generation and evaluation of AmI agent system designs, emphasizes that the transition from general human-centred considerations towards specific user-centred results is never a simple, straightforward process. It reflects the diverse character of the creative and analytical considerations. In the generation phase, the design team considers the human values related to the daily activities of people, in different urban contexts, and the design alternatives are shaped accordingly. In the evaluation phase the use cases depict city dwellers as system users. Collaborating with the specific partner company directs this analysis to focus on certain favourable user values and company requirements.

The potential of this evaluation model lies in the necessity to understand the role of different intelligence levels of AmI systems. We claim that the different levels of in-built intelligence can be a significant aid in generating and evaluating AmI system designs. Furthermore, we argue that understanding the role of different intelligence levels is significant both for envisioning new user interactions, and from a business point of view. This research contributes new means of evaluation and communication, which can

be equally useful to designers and to companies.

This case study underlined the importance of including and analysing diverse time spans of the influence and incremental implementation of the design concept, as well as enabling comprehension and planning for diverse levels of intelligence employed within the design concept for projects based on Ambient UX.

3.3.2 UX Practices and Ambient UX Design Framework

Main Observations

The Ambient UX framework is based on a definition of Design Domains, that a designer might manipulate with, and user's experience levels that are being influenced by the same, i.e. User Values. Initially, an experimental case study research was conducted, that verified the concept of the Ambient UX framework strategy. More precisely, both the Design Domains and User Values were identified as existent and significant for the design and evaluation process of the Ambient UX concept, and they proved to be a suitable backbone support to the design process.

In the following, three case studies of real design projects took part as research samples for comprehending the relations between the Design domains and User Values, and for underlining the needs of the design process accordingly. The three projects are Humanitas, MEMoSa, and Connected Lighting for a Caring City, in which user experience was shaped within diverse environments (hospital, automotive and city), for enabling observations based on a broad range of Ambient UX applications. Within all the three projects the Design Domains were discussed and confirmed.

User Values, that emerged during the research phases in the three case studies, confirmed the importance of having the Ambient UX framework strategy as a backbone for structured design processes when dealing with complex systems of enhanced spaces. Throughout the practical cases, design process supported by structured and defined levels of User Values appeared as desirable. The three cases confirmed the Design Domains from the framework as valid and provided further insights for the values derived from the user research. Namely, following the User Values derived from the case studies, thematic groups emerged, that shown to be quite significant for the practices and design development.

These significant considerations for designing for User Values for

Ambient UX systems are observed in the following thematic groups:

- ***All three architectures considered simultaneously within the CPS*** implies having an overview of all the Design Domains, i.e. architectures, during the design process in order to reason on which of those an intervention could be applied; three architectures (Spatial, Informational, Relational) are gathered around the variable of Time.
- ***Analysis of alternative paths within the CPS*** implies having an overview of all possible paths that are enabled by a design system, in order to analyse those and channel the system according to desirable journeys and activities.
- ***Zooming in & out within the CPS*** implies having an ability to zoom in and out within the design content, where zooming out implies working on the strategical level of the concept development, while zooming in implies working on very detailed tangible design elements that provide direct interaction with the user.
- ***Social acceptability of the CPS*** implies having to consider the aspects of ethical nature, that require achieving a social consensus when it comes to defining a design concept.
- ***Usage time spans of the CPS*** implies having an overview of influence of the design concept over different time spans of usage, for analysing the resilience of the concept as well as its impact on individual users and society.
- ***Intelligence levels of the CPS*** implies having a comprehension of the complexity of data flows and its elaboration through machine learning algorithms, which are employed within the design system; comprehending intelligence levels has an influence on defining both the system's back-end operations as well as the front end interactions through touchpoints with the user.

Research, therefore, validates the Ambient UX strategical design framework, and underlines the importance of including the indicated issues within the design process for supporting the emerging design practices and their complexities accordingly. The research stresses out the significance of dealing with cyber-physical systems according to their complexity and including the strategical approach for this

purpose within design processes. The Ambient UX framework is confirmed throughout the design and envisioning phases of the system development, relying on identified Design Domains and User Values. In all of the three project cases, certain Design Domains and certain User Values shown to be the dominant ones in regard to project development.

Besides verifying the framework elements, from three case studies emerged the six thematic issues that shown to be quite relevant from the point of view of the user-centric design approach and in regard to designing cyber-physical systems. The issues derived from novel design practice and appear not to be treated in a holistic manner and within a unique approach when it comes to designing for users' experiences in current practices, which are defined by currently available design tools. A holistic UX approach for designing cyber-physical systems is required for facing the complex nature of such projects, as well as establishing a common language among the diverse stakeholders involved in the project around common objectives of designing desirable experiences.

The three projects were developed with diverse stakeholders and this allowed to observe different communication manners among internal working teams. Each of the projects did address a design of a cyber-physical system, however the focus on dominant DDs and UVs differed. The design practice confirmed the framework and a need for a structured design process when it comes to managing UX. Furthermore, the design practice revealed implications for UX design tools to be used during the design process. In regard to design tools, each of the three projects imposed needs towards novel and/or modified UX design tools. This is to say that the UX tools currently employed and available in practices were not sufficient for addressing UX issues within the three case studies presented here. Following the project development within the three cases, I was developing diverse hybrid modalities for communicating user values and their relations with design outcomes, thus advocating for the importance of addressing complexity of UX in CPSes.

04

Design Tools for Ambient UX

This section aims to identify design tools that could support a design process driven by Ambient UX strategy. For responding to this aim, the research methodology is shaped according to two macro steps: 1) Overall analysis of current UX tools employed in practice for understanding User Values and Design Domains they refer to, 2) Comparative analysis of the tools with the proposed framework for Ambient UX defined Design Domains and User Values.

Within the first research step, tools samples are collected, with majority of them deriving from practices in industry as well as design consultancies, and the search focuses on tools that support design processes targeting value alignment (Kalbach, 2016). Such tools are: Customer Journey Maps, Experience Maps, Mental Model Diagrams, Service Blueprints, Spatial Maps, Ecosystem Models, Stakeholder Maps, Storyboards, Touchpoint Matrix, Business Model Canvases, Value Proposition Canvases, and Empathy Maps. Through the analysis, structures for each of the tools are discussed, for identifying Design Domains and User Values. Finally, a confrontation among all the tools is made, and possible emerging common patterns are observed.

Within the second research step, tools' samples are confronted with the proposed framework for Ambient UX, in terms of Design Domains and User Values they consider. The framework is based on a design strategy deriving from literature review; therefore, this confrontation can be observed as confrontation between the theory methods presented in literature and tools employed in design practices. Discussion is shaped according to encountered mismatches between the gathered tools and the method, and proposals for upgrading the tools, that could support a process for designing for Ambient UX, are made accordingly.

A database of all the gathered tools samples is available for exploration as an attachment to this document.

4.1. Analysis of Current UX Tools Employed in Practice

4.1.1. Overview on Gathered UX Value Alignment Tools

4.1.2. Analysis for Each of the UX Value Alignment Tools

Customer Journey Maps
Experience Maps
Mental Model Diagrams
Service Blueprints
Spatial Maps
Ecosystem Models
Stakeholder Maps
Storyboards
Touchpoint Matrix
Business Model Canvases
Value Proposition Canvases
Empathy Maps

4.1.3. Confrontation Between the Tools Structural Elements

Main Aim and Structure of the Tools
User Values Emphasized within the Tools

4.1.4. Discussion

4.2. Confrontation with the Ambient UX Design Framework

Recap of the Design Framework

4.2.1. Comparative Analysis for Each of the Tools

Customer Journey Maps
Experience Maps
Mental Model Diagrams
Service Blueprints
Spatial Maps
Ecosystem Models
Stakeholder Maps
Storyboards
Touchpoint Matrix
Business Model Canvases
Value Proposition Canvases
Empathy Maps

4.2.2. Overall Results

4.3. Discussion on Encountered Issues in Design Practice

4.3.1. Main Observations

4.3.2. Lacking Conceptual Considerations within UX Design Tools

All 3 Architectures Considered Simultaneously
Analysis of Alternative Paths
Zooming In & Out
Social Acceptability
Different Time Spans
Intelligence Levels

4.3.3. Discussion on Tools Upgrade

Focus on the Ambient UX Framework
Six Conceptual Issues

4.1 ANALYSIS OF CURRENT UX TOOLS EMPLOYED IN PRACTICE

In order to manage the complexity of physical/digital system solutions, and to ensure a design result oriented towards the optimal satisfaction of users, authors such as Dalton et al. (2016) and Kalbach (2016), have proposed new design approaches and mapping techniques focused on experience and on user activities.

Drawing has always been the main tool for expression within design projects, where it is employed as a communication of reasoning and analysis on a design issue. In a project focused on user experience, drawing activities are not only aimed at defining the physical characteristics of products and spaces, but also representing users' physical and cognitive activities in time, and the interactive processes through the system of touchpoints. New forms of drawings, employing traditional representations, are used for managing complexity emerged due to the integrated design of digitized services and physical environments. Furthermore, the drawings support also the complexity from the point of view of management of multidisciplinary contributions from different stakeholders, thus allowing creation of a common point of view. The interlacing of fields and cross-discipline perspective can lead to redundancy in terms of data provided and of functionalities posed to the user, which brings experience design to a quite challenging quest to deal with.

Designing for such systems poses, as relevant aim, the comprehension of the experience that the user has/will have in the functional environment. This comprehension has to be mapped and represented in a way that it communicates clear messages to all the stakeholders and parties involved in the design project, thus establishing a shared language among them, while orienting the project efforts toward a common goal. Within the project, the tools are used to sequence, track, and analyse progress (Patton, 2014).

Even though designing for experiences aims for an intangible final product, it still requires some defined steps of the design process to be established for supporting a creation of a shared language in this field (Buxton, 2007; Richardson, 2010). Buxton (2007) approaches the discussion of such steps in analogy to sketching. He pleads for distinguishing two main aspects of design: the problem setting and the problem solving, as backbones of the design process. These refer to definitions of how something is built, and what is the right thing to be built. From the problems emerging during the design process, methods should be shaped. For e.g., it is already evident that, when dealing with representation of an experience, we are dealing with a representation that contains a temporal component, therefore the drawings should be established accordingly. Buxton discusses drawings as the consequence of matching the appropriate visual language to the intended purpose, where every step within the drawing process is a refinement of the previous one. Therefore, diverse drawings should correspond to diverse phases of the design process.

With the level of refinement of the drawing, the designer communicates the state of the final product, suggesting to the audience if the design solution is closed, or perhaps open for further explorations. In case the communication should invite for further discussion, the provided visuals should enable further intervention within them, giving space to changes and proposals.

This research relates to experience mapping aimed at the creation of a shared language for the design of physical/digital environments, i.e. CPSes; the discussion is supported by studies of tools suitable for a conversation of drawing principles in design for experience. These tools are discussed as a base for establishment of an emergent design language.

This chapter aims to respond to the following questions:

- How do we identify user experience values with the UX tools currently employed in practice?
- Are these UX tools enough for supporting the Ambient UX design framework?

To do so, the conducted research is based on gathering of UX tools currently employed in practice. An analysis of current UX tools

employed in practices was conducted for defining how UX values are observed and treated throughout the tools, as well as the elements that influence the experience. As a sequential step in the overall research, confrontation of the analysis of tools and the proposed Ambient UX framework is provided and discussed.

Outcome of this research step is a classification of a library of existent tools that deal with evaluation of User Experience. More precisely, an analysis of the elements of the evaluation of UX in these tools is provided and discussed. Finally, a need for an upgrade of UX design tools is recognized, and proposals are made accordingly.

Overview of Gathered UX Value Alignment Tools

4.1.1

Examples of existent available tools deriving from UX practices have been gathered and analysed. The representations reflect the alignment of values between the final users and the parties involved in the offerings related to a design solution. It is to note that the tools are all based on use-case scenarios essentially, however, the manner in which the scenarios are analysed in terms of user's experience differs across the gathered samples. Total number of collected and analysed tools is 176.

The tools were analysed and categorized by:

1. General overview of collected samples:

- Source,
- Author/s,
- Field/Industry of application,
- Type of the tool/diagram,
- Time of publishing.

2. Considerations regarding the values of UX:

- Main aim of the representation?
- What was evaluated?
- How/in which manner was evaluated?
- How was the evaluation represented?
- From which perspective/approach was the evaluation made?

Tools were collected through (Fig. 92):

1. Literature reviews (specific cases and overviews of tools),
2. Web sources (specific cases and overviews of tools),
3. Automatic generation platforms (online generation with predefined tool structures).

General overview of collected samples

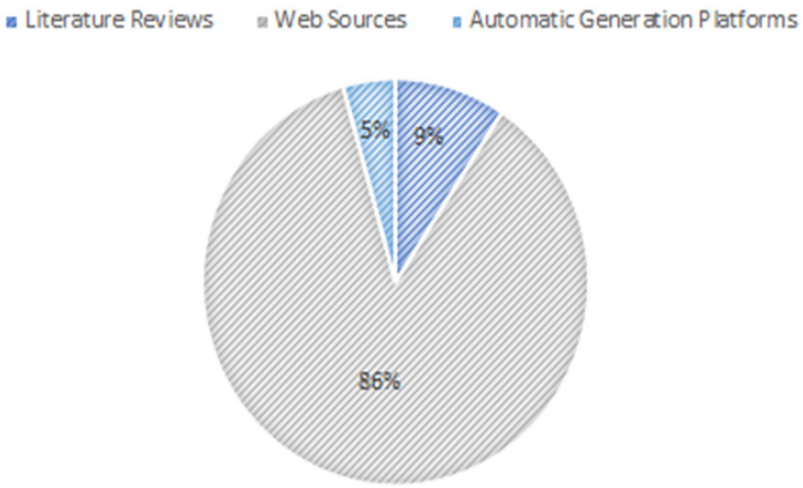


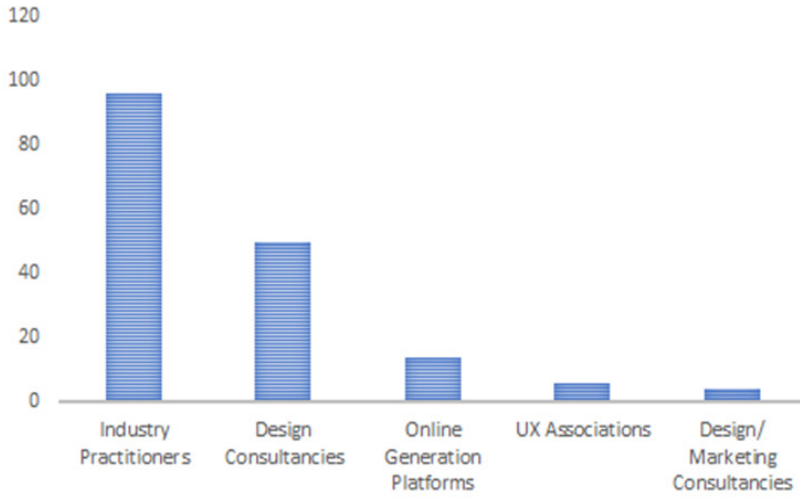
Figure 92. Search methods and sources used for gathering the tools, presented in percentages.

Keywords used in the research were:

- UX tools
- Customer Journey Maps
- User Journey Map
- Experience Maps
- Mental Model Diagrams
- Service Blueprints
- Spatial Maps
- Business Model Canvases
- Ecosystem Models
- Stakeholder Maps
- Storyboards
- Scenarios
- Storytelling Canvas
- Touchpoint Matrix
- Value Proposition Canvas
- Storylines
- Vision Canvas
- Context Canvas
- Validation Canvas
- Design Method Cards
- Card Sorting
- Affinity Diagrams
- Behavioural Mapping
- Experience Drawing

Authors fof the gathered tools, as well as the field/industry of application the tools refer to are presentd in Figures 93 and 94.

Figure 93. Authors categories of the gathered tools presented in regard to the number of samples.



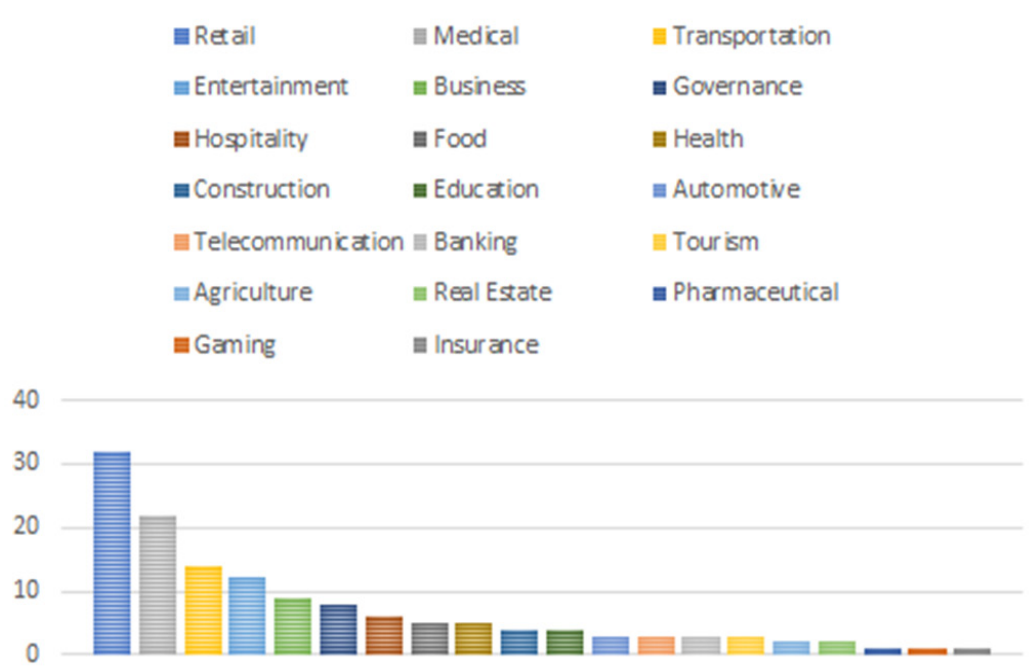


Figure 94. Industrial field in which tools were used, presented in regard to the number of samples.

Starting reference for the types of tools was Kalbach's book on Mapping Experiences (2016), and all the collected samples of diagrams focus on value alignment represented through the following known grouping of tools (Fig. 95):

- Customer Journey Maps
- Experience Maps
- Mental Model Diagrams
- Service Blueprints
- Spatial Maps
- Ecosystem Models
- Stakeholder Maps
- Storyboards
- Touchpoint Matrix
- Business Model Canvases
- Value Proposition Canvases
- Empathy Maps

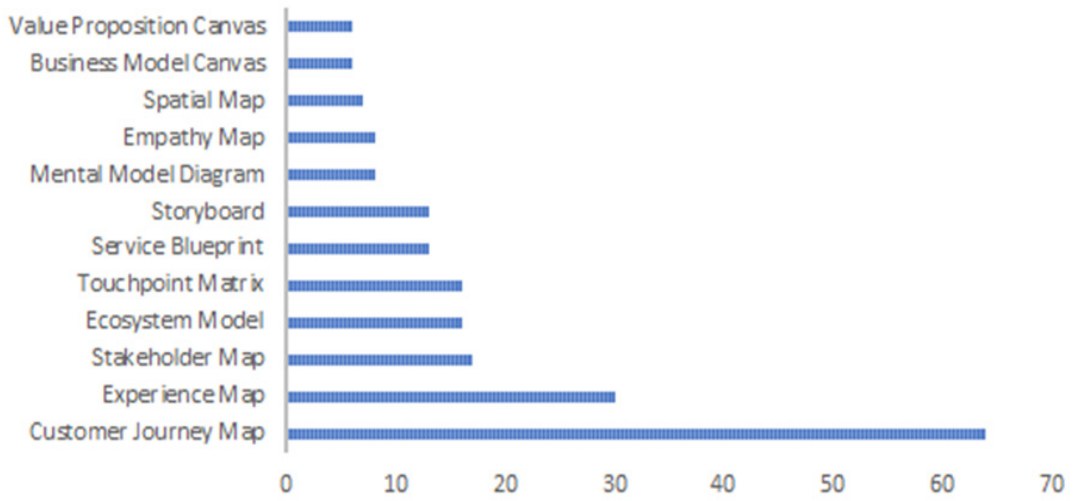


Figure 95. Numbers and categories of analysed tools.

The following Figure 96 represents years in which the gathered tools have been published.

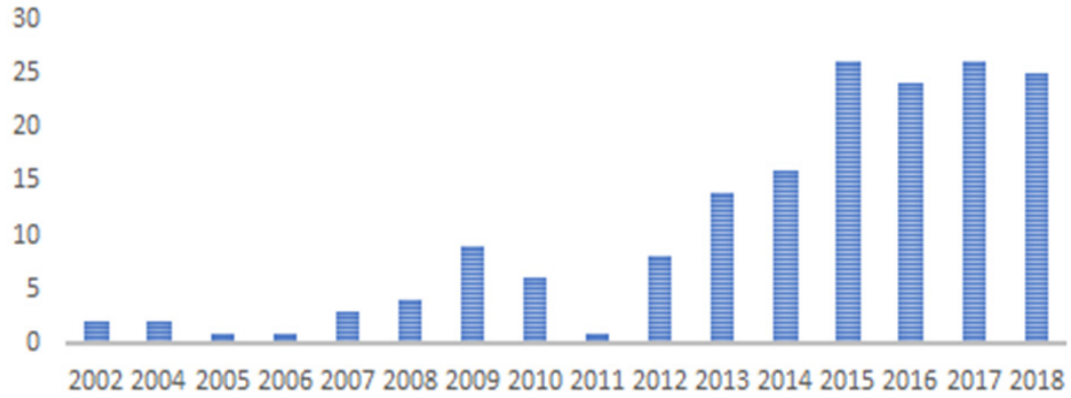


Figure 96. The number of tools found in each correspondent year of publishing.

4.1.2 Analysis for Each of the UX Value Alignment Tools

More and more, people select products and services based on the total experience they have. We discuss empathy as an ability to grasp what others are experiencing. In the process of developing empathy, there is a need for creating visualizations as shared references, a.k.a. design tools.

Kalbach (2016) calls these shared references ***alignment diagrams*** - an umbrella term for any map that seeks to align how individuals in a system engage with that system and its provider. The term alignment diagram refers to any map, diagram, or visualization that reveals both sides of value creation in a single overview. Value creation is bidirectional, it connects the dots between human-centred design and business objectives.

The concept of mapping helps us understand complex systems of interaction, particularly when we're dealing with abstract concepts like experience. Creating a diagram is not the ultimate goal, rather, it is a means to engage others in a discourse.

In the following, diverse alignment diagrams are presented and analysed. Gathered samples are expected to be based on user research, however, some of them might be based on hypothesis of users' experiences, if the map was used for rapid prototyping. When reading the visuals for abstracted structures for each of the tools, the pink elements in the representation are the ones that refer to values which vary in regard to the content, while the black ones are the usual structural elements that repeat across the representatives of the same group.

Customer Journey Maps

Definition:

"Customer journey maps illustrate the experiences of an individual as a customer of an organization.

The exact origin of the term customer journey map (CJM) is unclear. The basic idea of looking across touchpoints seems to have its roots in Jan Carlzon's concept of moments of truth. Carlzon advocated an ecological view of the customer experience, but he never explicitly talked about a map of the customer journey as such. It wasn't until the field of customer experience management came into focus just before the turn of the century that journey mapping emerged.

In 2002, customer experience expert Colin Shaw introduced the concept of what he calls moment mapping—recalling Carlzon. The resulting diagram uses an arrow to map the phases of the customer experience; from this, analysis of opportunities for creating a positive customer experience can derive. As a type of diagram, CJMs are similar to service blue-printing, particularly in structure (i.e., chronological) but there are also differences in point of view, scope, focus, and use.

The contemporary style of CJMs seems to have come about in the mid-2000s. Bruce Temkin, a leading customer experience expert, is one of the early advocates for CJMs and greatly promoted their use in the USA. In a Forrester report entitled "Mapping the Customer Journey," Temkin defines CJMs as "documents that visually illustrate customers' processes, needs, and perceptions throughout their relationships with a company." "

(Kalbach, 2016)

Main aim of the tool according to gathered samples is described in Figure 97.

Were personas and customer segments considered

38 of the visuals were considering personas, which is just a bit more than half (total was 67) of the analysed CJMs.

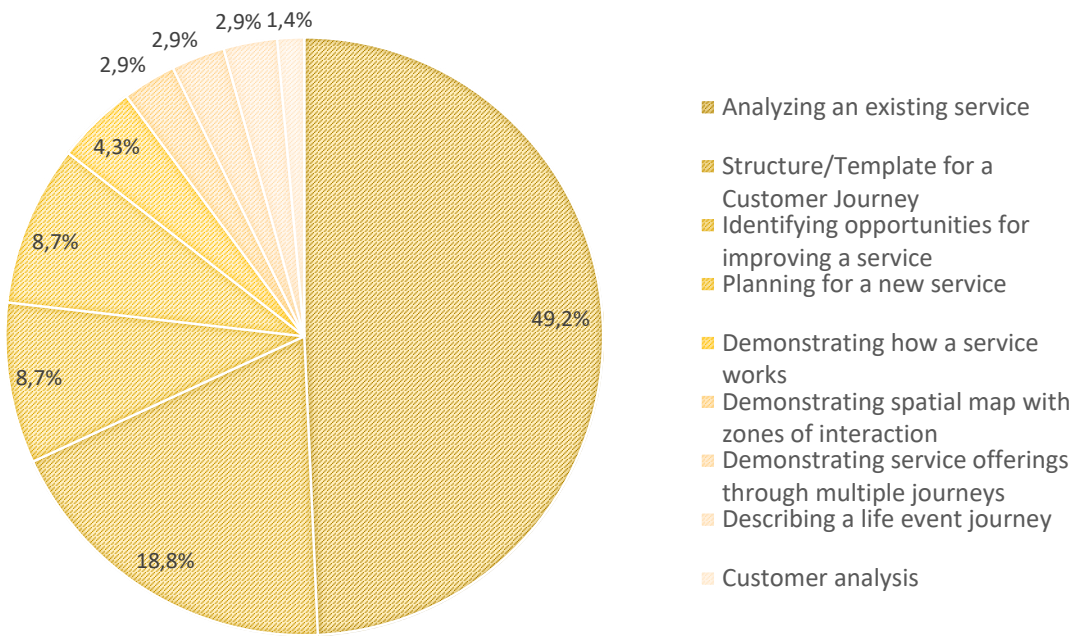


Figure 97. Main aim of the tool according to gathered samples of Customer Journey Maps.

What was evaluated in terms of UX

In terms of user experience, the aspects that were mostly considered in gathered diagrams are emotions and feelings, thoughts, satisfaction and expectations. User goals are considered in a smaller amount, as well as needs and desires. There is also a presence of negative aspects such as possible doubts, fears and efforts a user needs to make wile engaging with a service system, which are in some maps named all together as pain points. In certain maps what was considered as an overall of an experience are the user's states, which is a wide parameter and is mostly related to evoked emotions. Just very few of the maps refer to perceived content relevance and monetary value of the service system, as well as clear understanding of the content and offerings. From this analysis, it is observable that it is hard to shape a general notion of experience, as diverse maps show quite a diversity of parameters that were used for evaluating an experience within represented journeys.

How in which manner was UX evaluated

A very significant amount of gathered sample maps refers to a hypothesis on internal thoughts (monologue) mapped on levels of emotions shown as highs and lows (positives and negatives). Namely, levels of highs and lows of positive and negative feelings are the main means of evaluating a user experience within CJMs, which are mapped to particular activities and interactions with touchpoints. This relates to levels of satisfaction with touchpoints, confronted with levels of importance, as well as levels of actual and expected effort the user needs to put while being engaged. Positive feelings are: being confident, optimistic, curious, interested, pleased, satisfied, excited, impressed, relieved, accomplished. Negative feelings are: being uncertain, doubtful, sceptical, confused, unsure, upset, frustrated, impatient, angry, scared, anxious. Neutral feelings are: being apprehensive, hopeful. In some maps the evaluation of positive and negative feelings has a more physicals scale and relates to senses. An example is the journey in a Starbucks coffee shop, where positives are considered to be enriched experiences through aroma of the coffee, comfort of the chair, while negatives are the poached experiences like the lack of personal space and the loudness of the environment. In overall, when an overlap with user's goals, needs, and desired happens, that moment is considered to be positive in the timeline.

Hypothesis on internal thoughts, written in a form of a monologue, for each of the activity is a very common means of representing states in a very particular moment of interaction and activity mapped within a timeline. Considered to be understood through common sense and capability of the individual reading the map to empathize with the state, this form of explaining an experience is adopted through a significant amount of gathered sample maps. In certain moments, however, what is represented as common sense is very arguable as the parameter that is being assessed is very subjective. For example, one diagram shows the assumption that spending time meeting new people is equal to having fun, therefore these moments are assessed as a positive experience. One might argue that such an experience can be quite negative as well, in respect to the context in whom the activities are happening.

Furthermore, there is a hypothesis on possible pain points in regard to interaction with the actors influencing an experience, or timing, correctness of the content, clearance in communication, and

similar. Through pain points certain representations considered a moment of friction as a moment when the engagements from the side of the user decreases. This is a point that needs to be resolved in order to gain back the engagement and interest of the user, and in certain representations it is named as "the moment of truth". The opposite of pain point are the WOW moments, considered to be the moments of highest excitement and satisfaction.

Some representations relate to future desired outcomes for each of the activity, like for e.g. maximizing effectiveness, minimizing effort, maintaining image of the brand, etc.

How was the evaluation represented

Having to deal with the representation of positive and negative levels, most of the customer journey maps use continuous lines with highs and lows as visual references. The ones that relate to evaluation of emotional states employ the "emotional line" with levels of highs and lows, which, in some cases, contain also emoticons to underline the states through facial expressions; emoticons rely on common sense for their interpretation (Fig. 98). For representing the diversity of levelling, besides the lines of highs and lows, some maps use representations in forms scales and column heights.

Almost all of the maps are following a chronological timeline of activities, and they all contain short text boxes for descriptions like, for e.g., internal thoughts of the user. All of them identify touchpoints of interactions, while only a smaller number points out the diversity of actors. As visual references, paint points and friction points are always strongly highlighted when positioned on the mapped timeline.

In just a few examples, there are multiple lines of user's states mapped on top of each other within the same journey timeline, showing and evaluating possible diverse journeys for providing confrontation and analysis between them. It is to note that a smaller number of representations does not follow the horizontal timeline and rectangular boxes field, rather they take a different shape such as a circular one for example. Besides the main shape and visual hierarchy of representations, colours are also used for intuition on positive as negatives, where, for examples, green is used for positive aspects while red is used for the negative ones.

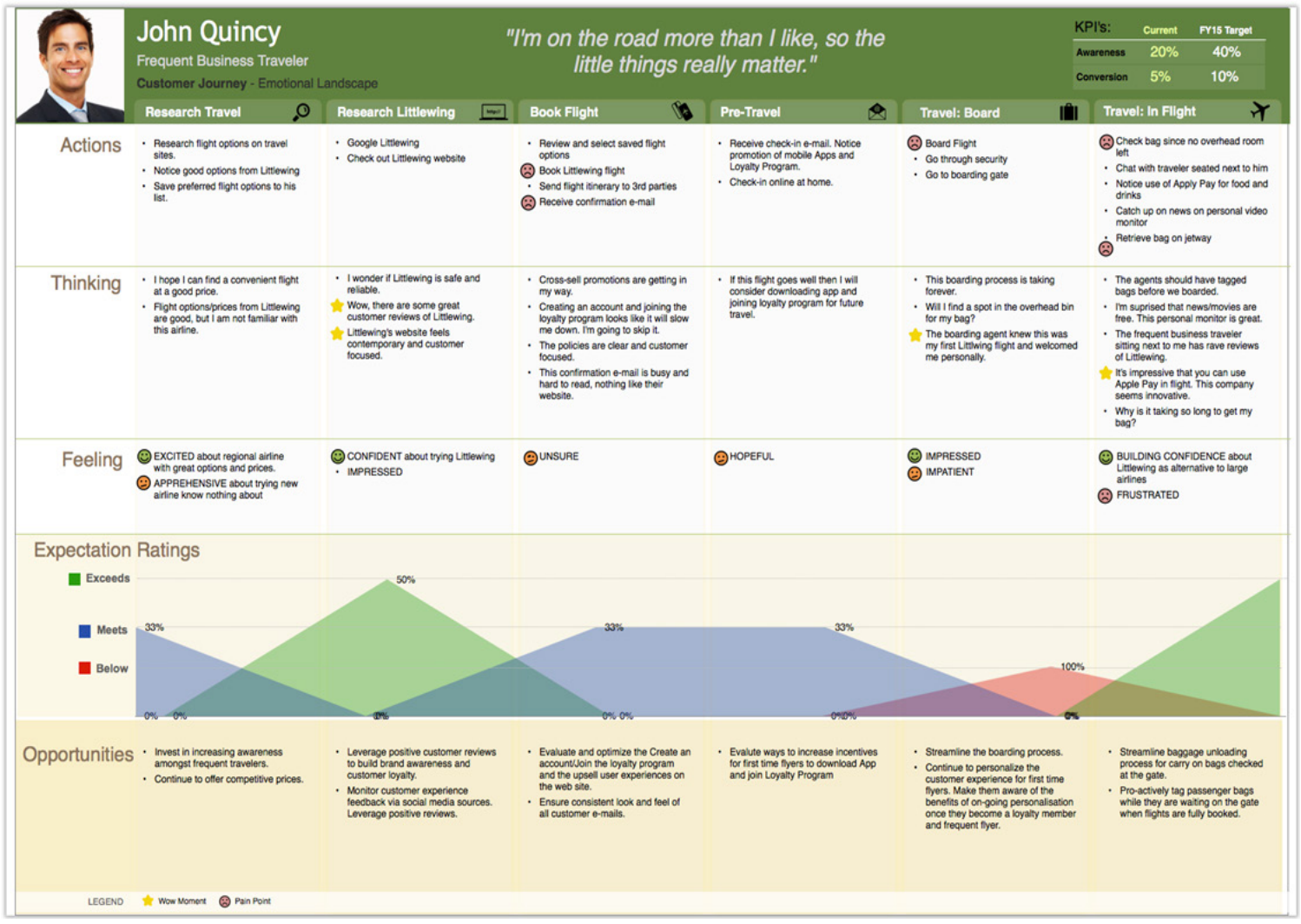


Figure 98. Sample of a Customer Journey Map for a frequent business traveller.

For majority:

- Analysis of the service according to estimation of experience being positive or negative and identifying opportunities for improvement (through moments of truth).

Others:

- Analysis during the use of the service (which can be online, like for e.g. a purchase journey, and offline, like for e.g. a medical appointment);
- Analysis of emotions in a certain life path/ emotional levels / Analysis of the patient journey according to customer's engagement / Analysis of main characteristics/ usual phases of interaction with a product/service for providing a base for acceptance prediction;
- Mapping the activities needed for reaching a final goal (e.g. organizing a new event);
- Vision of the journey process going wrong and it being resolved positively / Confrontation of current negative and desired future positive perceptions;
- Analysis of the moments of interaction that support the achievement of main goals long term/ Mapping all the activities before, during and after the service usage;
- Analysis of the journey according to the clearness of processes, and/or satisfaction with the touchpoints / Rating satisfaction according to diverse touchpoints;
- Analysis of alternative journeys/ Analysis of possible negative situations during a journey;
- Mapping the activities in all possible stages of interaction with the organization/ Mapping possible risks for bad service/ Mapping possible needs and activities in regard to organization departments in charge/ Mapping the experience states on business goals and responsible organization departments;
- Analysis of service success according to communication between actors.

From which perspective / approach was UX evaluated

Tool Structure

The following Figure 99 represents drawing steps following the main structural elements of the tool.

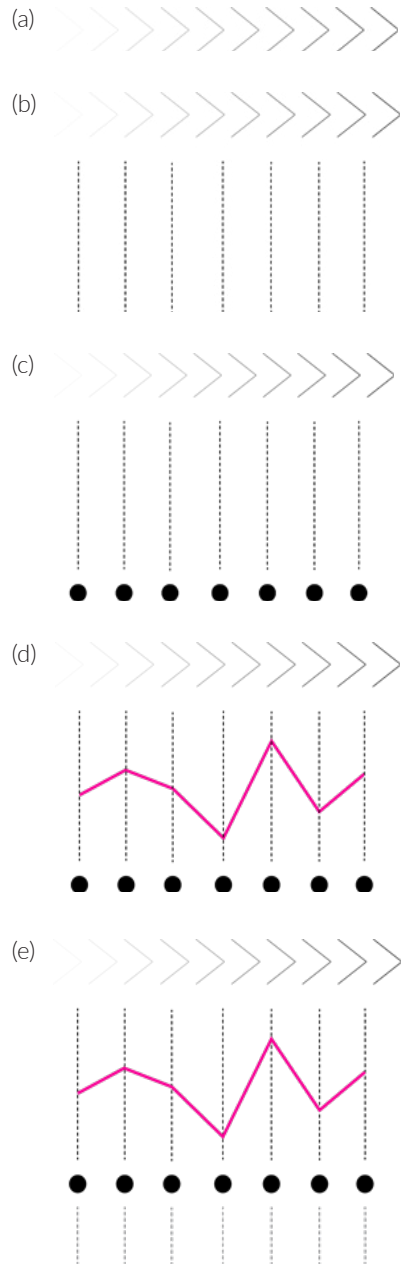


Figure 99. Drawing steps and elements contained within a structure of the tool Customer Journey Map: a) time, (b) timeline with sequential activities, (c) adding interaction touchpoints within the activities between the user and organization, (d) adding the emotional line (with highs and lows) for the evaluation of users'/ customer's experience, (e) aligning with the back-end of the service system through touchpoints.

Experience Maps

Definition:

"Experience maps are relatively new. They illustrate experiences people have within a given domain.

By some definitions and uses, experience maps overlap completely with customer journey maps. Experience maps typically focus on a general human activity within a given domain. The company or organization may not even be explicitly stated in the map, or there may be many organizations involved. Customer journey maps, on the other hand, tend to view the individual as a consumer of the products and services.

Experience maps fundamentally recognize that people interact with many products and services from a multitude of providers in many situations. Examining this broader context will become increasingly crucial as products and service become connected with each other."

(Kalbach, 2016)

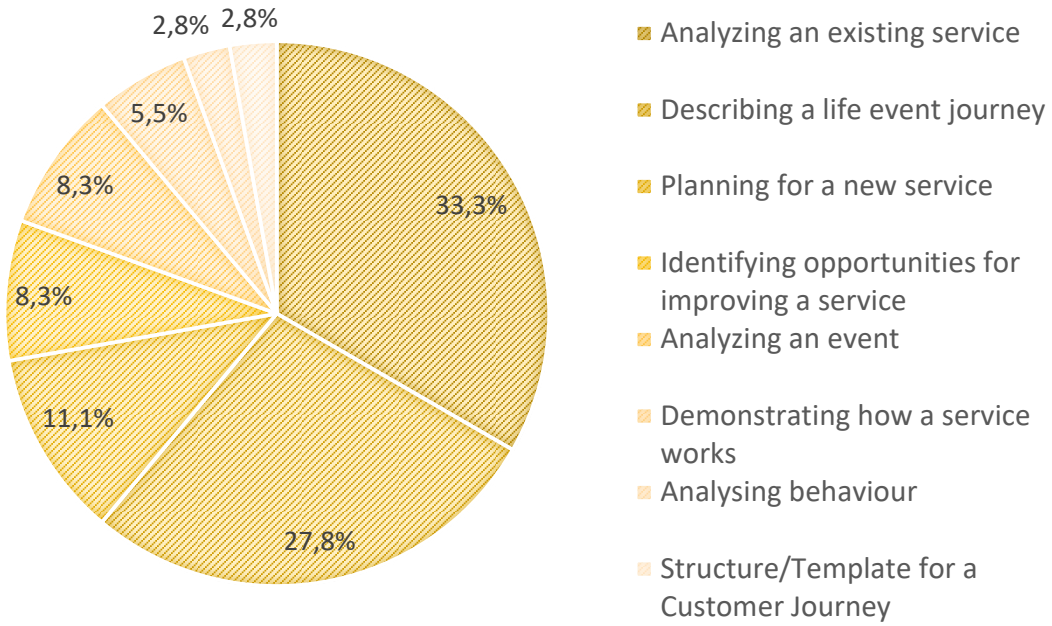


Figure 100. Main aim of the tool according to gathered samples of Experience Maps.

Main aim of the tool according to gathered samples is described in Figure 100.

Were personas and customer segments considered

Only 14 considered personas within the representations, which is less than half of the whole number of gathered samples.

What was evaluated in terms of UX

In terms of what was evaluated from the side of user's experience in Experience Maps that were gathered, the most represented ones are emotions, feelings, and satisfaction. Besides these, less represented are user's thoughts, efforts, engagement and enjoyability. In a very small amount, as experience evaluation parameters were considered behaviours, doubts, desired outcomes, context, excitement, energy needed to undertake an activity and human support. In some maps pain points were represented and negative states such as anxiety, tiredness, discomfort, dislikes, uncertainty, threats, as well as lack of time or encountering technical difficulties. Certain maps represent changes in states from the side of an individual, like for example physical body changes as weight, shown in the visualization of a Pregnancy Experience.

Experience maps not necessarily refer to an interaction with a designed service system. They analyse a journey that is a life event, and serve pure analysis of activities and perceptions, rather than performance of system elements.

How in which manner was UX evaluated

Most of the maps rely on a hypothesis on internal thoughts as a manner of evaluating experiences, presenting them in a form of a monologue. These reflect internal drivers' states of mind and thoughts. Furthermore, most of the maps, the same as Customer Journey Maps, in describing experiences rely on levels of highs and lows as positive and negative experiences, mapped on journey

activities. The highs and lows usually relate to feelings and emotions. Positive feelings are: being proud, intrigued, empowered, creative, excited, focused. Negative feelings are: being disinterested, distracted, frustrated, tired, indecisive, in panic. Usually the internal thoughts and levels of highs and lows are mapped together within the activity timeline. Within this representation important moments are underlined, such as pain points or friction points, which call for attention and intervention within the journey.

Mapping of states in some diagrams appears as overlap between diverse states for allowing for their comparison, like for example in mapping a journey for making a dinner order, one's mood and hunger levels can be compared in diverse moments. These levels further directly influence the levels of enjoyment and satisfaction considering the time frames. Another example is overlapping and confronting levels of satisfaction with touchpoint and levels of importance of the same. Besides diverse parameters, some maps show a confrontation considering the same parameter but understanding the expected and the actual state, like for e.g. expected and actual effort for undertaking a certain activity. In one example of a diagram, a context in whom an activity is happening was analysed as having to influence the experience. Namely, a journey of a patient was analysed considering context of diverse activities, like for e.g. being at home, driving a car, watching TV, exercising, being in the clinic, being outdoors, and adding also the diversity of actors' description in these environments. The maps are used to analyse and plan which levels of highs and lows can be increased or decreased for arriving to a desired experience.

How was the evaluation represented

The evaluation of experiences in the gathered maps is usually presented through a chronological timeline of activities. Most of them use continuous lines for underlining levels of highs and lows, together with brief text boxes for recalling internal thoughts of the persona in the map (Fig. 101). Some of the visuals use also rating scale columns for evaluating certain elements within the journey. Such an example are two columns for satisfaction and importance confronted by height and numbers on a scale of 0 - 10 max, or text and numbers defined as: 1- about the effort I expected, 2- far more effort than I expected, 3- slightly more effort than I expected, 4- far less effort than I expected.

In certain visuals colours were used to diversify the parameters under evaluation, like for example diverse lines of highs and lows overlapping for enabling their confrontation. Colours are also used for recalling intuition for positive and negative moments, using green and red pallets. Symbols and emoticons are used for evoking emotion recognition based on common facial expressions, using for e.g. a happy smile facial expression to point at positive moments of experience within a journey.

From which perspective / approach was UX evaluated

Some journeys approach the analysis according to all experienced states and emotions and an estimation of the experience being positive or negative. Others focus only on understanding possible negative situations, risks and problematics, and visions of the journey process going wrong and/or not as planned. These both approaches bring towards identifying moments for improvement of an experience, which is in most cases the main aim of Experience Maps. Some journeys are presented from the perspective of self-reflection and observation on current situation, while the others have a third observer's perspective.

Furthermore, it is to underline the diversity of timelines employed, as some maps refer to a journey no longer then a daily sequence of activities, while others refer to a longer-term period starching from weeks to month, even years. Timeline seems to be directly dependent on the interaction with a service system, when this is the case of a final aim of the Experience Map. Namely, such maps are a synthesis of grouping of behaviours in particular phases of interaction with the service system, and are dependent on the moment or identified longer periods of interaction and/or use.

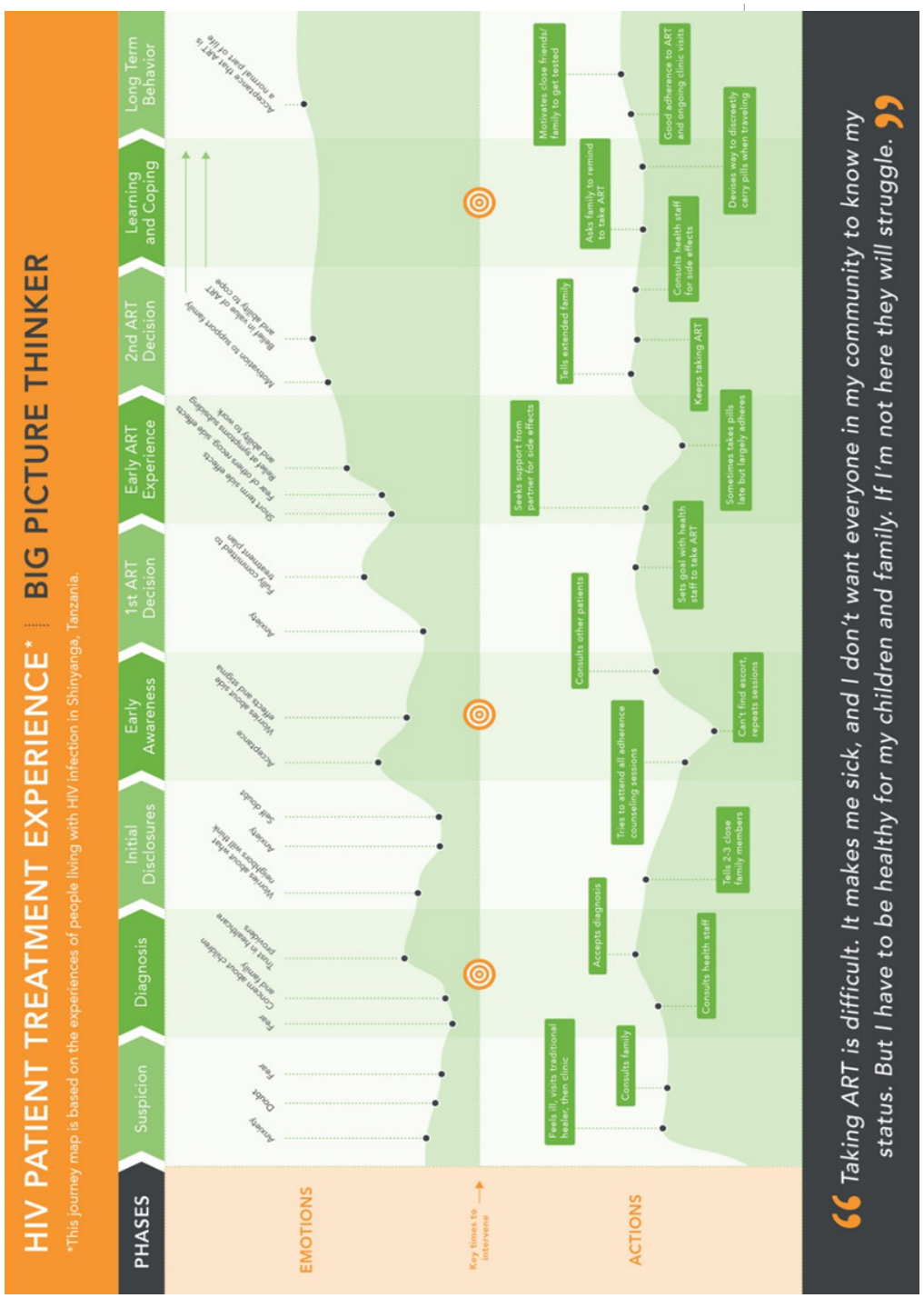


Figure 101. Sample of an Experience Map for HIV patient treatment.

Tool Structure

The following Figure 102 represents drawing steps following main structural elements of the tool. The tool has the same structure as the Customer Journey Map, except that the alignment with the back-end of the service is not quite usual in Experience Maps.

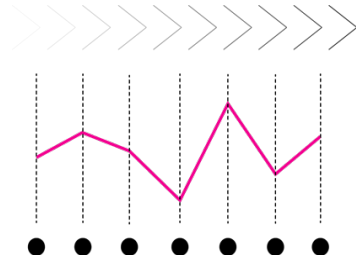


Figure 102. Drawing steps and elements contained within a structure of the tool Experience Map.

Mental Model Diagrams

Definition:

"A mental model diagram is the broad exploration of human behaviours, feelings, and motivations. The term mental model has its roots in psychology. It refers to someone's thought process about how the world works— their frame of reality. Mental models allow us to predict how things work. They are cognitive constructs built on beliefs, assumptions, and past experiences. But a person's mental model is a perception of a how a system functions, not necessarily how it actually may work.

The goal of design is to understand the mental model of the people you are designing for. The mental model the user has of the system is framed by that system. If you explore the mental model of a person, rather than a user, who is trying to achieve a purpose, then you can break out of the system frame. You can discover aspects of how a person thinks that have nothing to do with the system, but everything to do with how that person accomplishes their intent. In practice, mapping experiences is effectively mapping someone's mental model. Understanding a state of mind."

(Kalbach, 2016)

The difference in mental models is a key point Don Norman (1990) makes in his landmark book, showing three different models at play: the model the designer has of the system, the actual system

model, and the mental model the user has of the system.

Mental Models are applied in design within the user-centric design approach, as they are associated with a deep understanding of people's motivations and thought-processes, along with the emotional and philosophical landscape in which they are operating (Sax & Clack, 2015). Young (2008) observes them as a visual depiction of a particular audience's behaviour, faithfully representing individual's root motivations and goals, and what procedure and philosophy the individual follows to accomplish.

Mental Model Diagrams relate to GOMS, an HCI task analysis method that reduces a user's interaction to its most basic actions (Raskin, 2000). Operators (steps that a user performs) combine to form Methods, which are used to achieve Goals.

Main aim of the tool according to gathered samples is described in Figure 103.

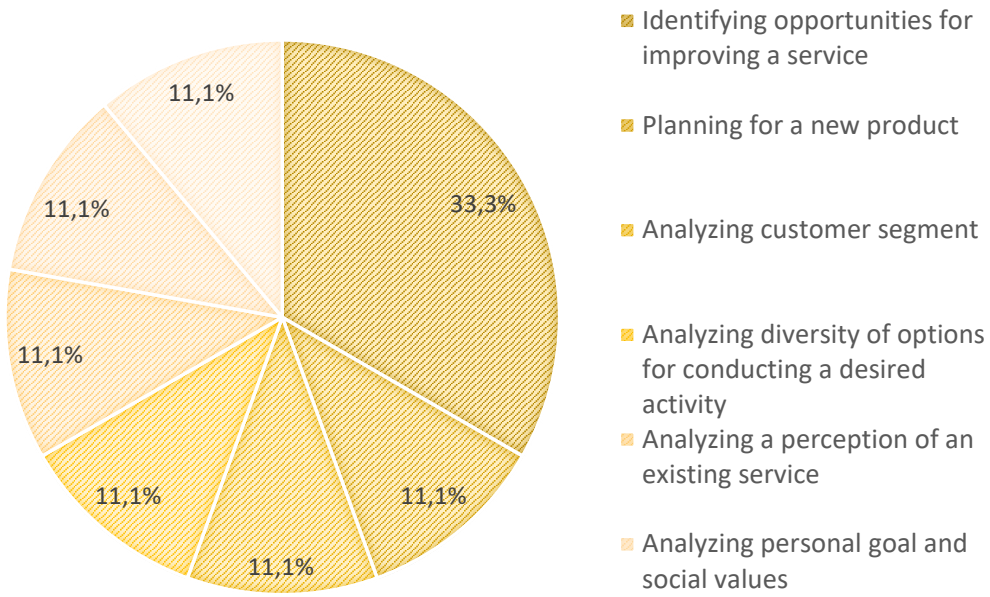


Figure 103. Main aim of the tool according to gathered samples of Mental Model Diagrams.

Were personas and customer segments considered

Only 2 personas were actually considered in the gathered visuals.

What was evaluated in terms of UX

When evaluating UX, gathered Mental Model Diagrams consider user's perception, goals, actions and decisions. They are mostly represented as hierarchy of thoughts, and they underline one's way of reasoning as well as the encountered needs within a certain situation. Drivers, motivations and means are employed to a lesser extent.

How in which manner was UX evaluated

The manner in which an experience is evaluated here is a hypothesis on perceived options when inside of a certain context and situation and grouping of the perceived elements into mental spaces. A hypothesis on internal drivers can be made, as well as the social and personal factors and means that influence a state. Usually the mental spaces of a persona are mapped on the activities required or present from the side of the service provider, for understanding what is needed to support desired positive activities.

How was the evaluation represented

The evaluation, in the gathered samples, is usually represented through text description with a visual hierarchy of levels and sub-groups (Fig. 104). Hierarchical clustering relates to identified mental spaces and their abstraction in terms of goals and needed activities that would satisfy the goals. In some examples the clustering happens through text box description where the boxes are places according to their level of abstraction, while in other cases the text boxes are clustered within a spread network scheme.

From which perspective / approach was UX evaluated

The approach for UX evaluation in these diagrams is diverse in regard to the perspective of final goals. Namely, some point out the analysis of a hierarchy and relation of personal and social goals, while other point out the analysis of company's needs and goals that follow them, and then align these with actions needed to influence the experience. Even though the approaches and goals are different, in overall, the main aim is based on the analysis of possibilities of activities for reaching a certain goal. One diagram visualizes also a confrontation of mental models of all actors involved and the service supporting the needs of all of them.

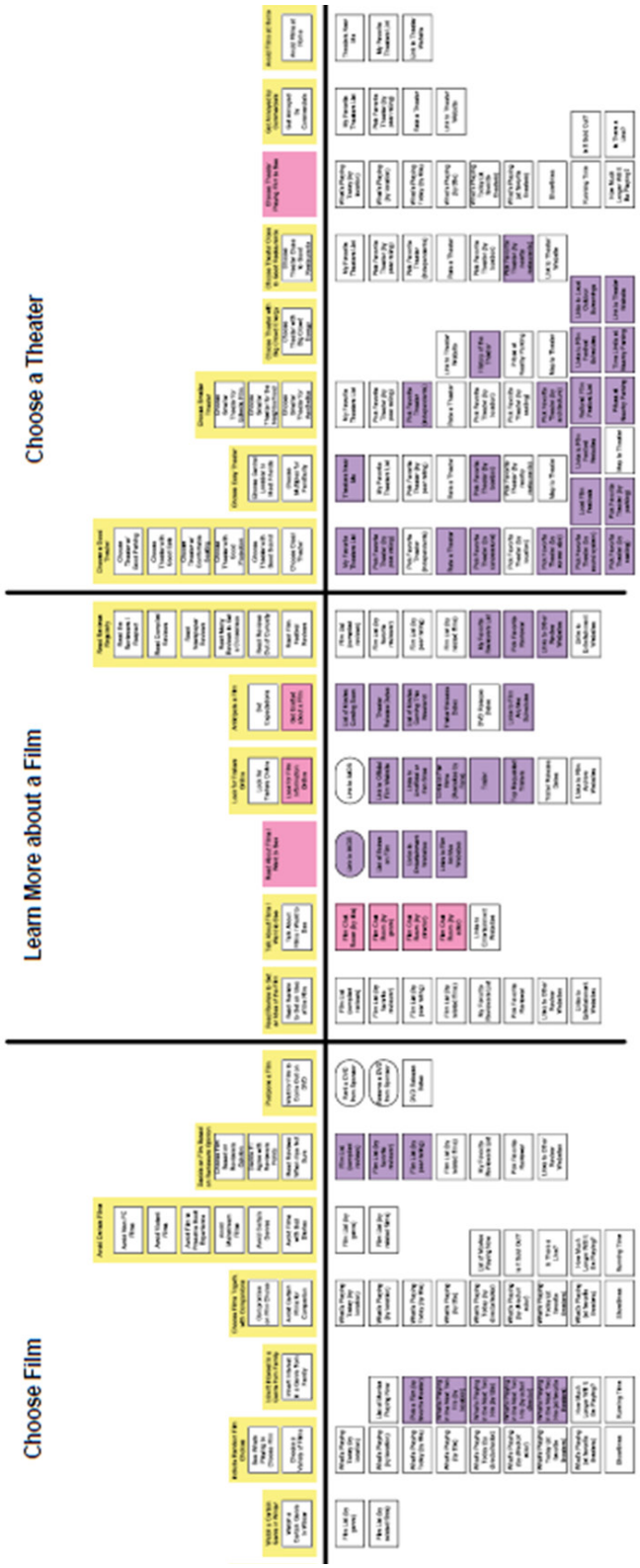


Figure 104. Sample of a Mental Model Diagram for watching a movie.

Tool Structure

The following Figure 105 represents drawing steps following main structural elements of the tool.

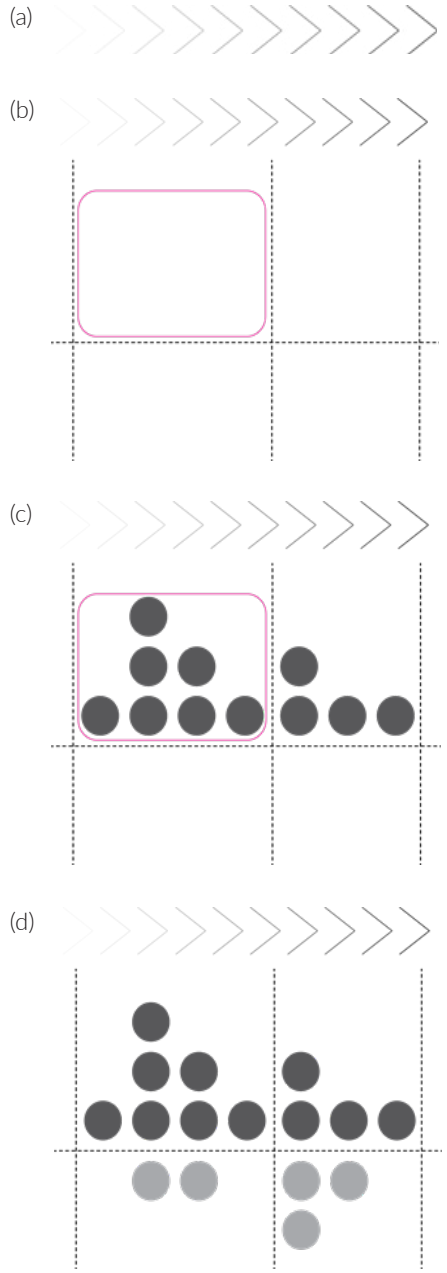
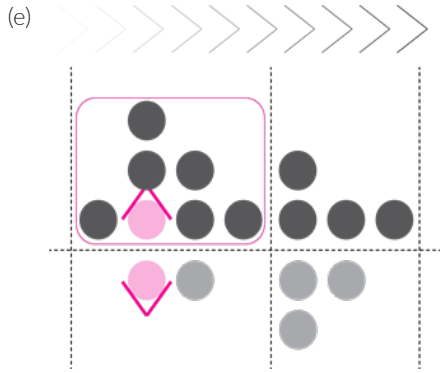


Figure 105. Drawing steps and elements contained within a structure of the tool Mental Model Diagram: (a) time, (b) defining mental spaces according to a timeline of activities, (c) defining elements that influence the perception and are grouped within diverse mental spaces, according to the hierarchy of perception and the timeline of sequential activities, (d) aligning with the back-end of the service system, (e) more precisely, aligning what is needed to be done to support the mental spaces and desired experiences related to the upper line part.



Service Blueprints

Definition:

"Service blueprints diagram a service offering. Service blueprints focus on the backstage processes."

(Kalbach, 2016)

"Service blueprinting shares similarities with other process modelling approaches: it is a visual notation for depicting business processes via symbols that represent actors and activities; it can be used to represent high-level overviews of conceptual processes or details of particular support or sub-processes; and it will accommodate links to parallel and sub-process documents and diagrams via other more internally focused process modelling tools and languages such as Business Process Modelling Notation (BPMN) and Unified Modelling Language (UML). However, service blueprinting is not as complex or as formal as some business process modelling tools such as UML.

Service blueprints are relatively simple, and their graphical representations are easy for all stakeholders involved—customers, managers, and frontline employees—to learn, use, and even modify to meet a particular innovation's requirements. Service blueprinting upholds the focus of a service innovation on the human-to-human and human-to-technology interfaces at the firm boundaries, rather than at the software engine level, allowing service designers to drill down into the firm without losing the connection to customer actions and process."

(Bitner, Ostrom & Morgan, 2008)

Main aim of the tool according to gathered samples is described in Figure 106.

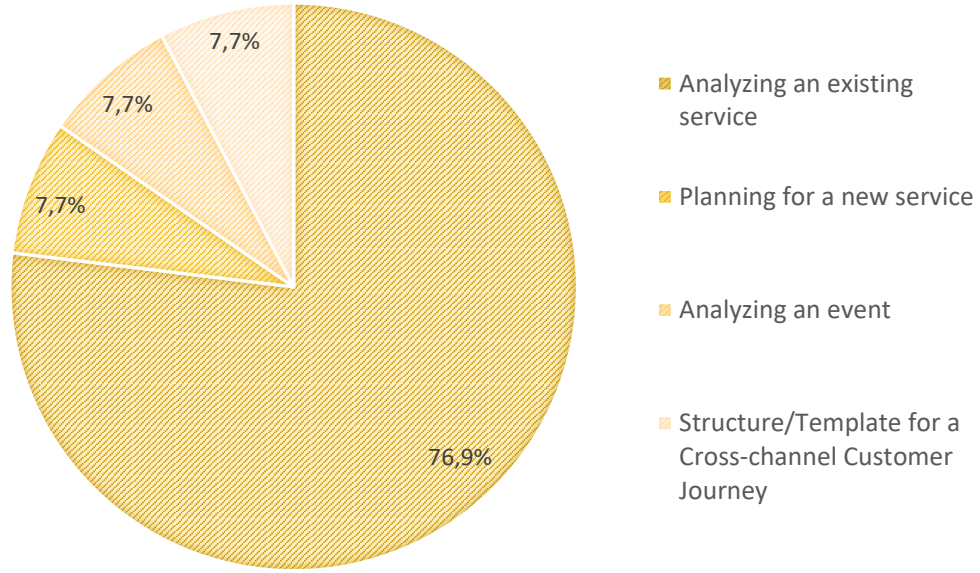


Figure 106. Main aim of the tool according to gathered samples of Service Blueprints.

Were personas and customer segments considered

Only 2 gathered samples considered such representation

What was evaluated in terms of UX

Service Blueprints do not necessarily focus on evaluating user experience itself within the representation. Among the gathered visuals samples, only three had underlined elements of experiences that were considered, which are emotions, waiting time, distraction and anxiety.

The emotions were evaluated through an analysis of interrelations between all the actors and its influence on the customer. Waiting time was considered through an analysis of journey steps and all the moments when waiting time occurs and repeats; therefore, the amount of moments when it appears and interval within the journey. Distraction and anxiety are evaluated through the levels of highs and lows and a hypothesis on internal thoughts (monologue) for each of the activity.

How in which manner was UX evaluated

Evaluation was represented as (Fig. 107):

- Emotional line with highs and lows with a baseline in-between, symbols as + and - are used for positive and negative emotion level zones,
- Textbox description in-between journey steps,
- Continuous lines of highs and lows followed by a text description.

How was the evaluation represented

The following approaches were considered:

- Analysis of service success according to communication between actors,
- Analysis of steps of the journey while considering the in-between waiting moments as important parts of the journey,
- Analysis of back-stage operations and perception of front-stage from the side of the customer.

From which perspective / approach was UX evaluated

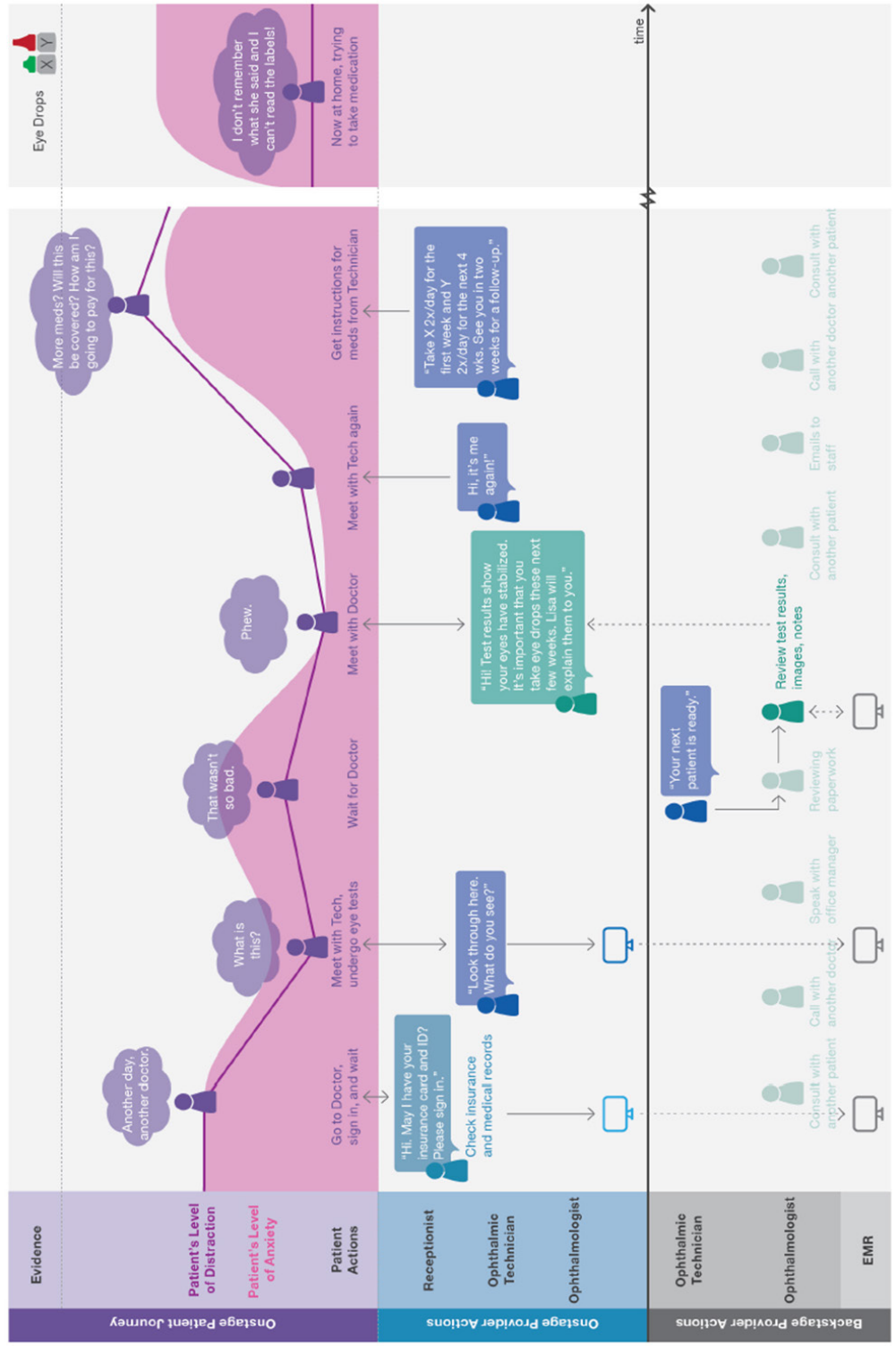


Figure 107. Sample of a Service Blueprint for a medical appointment.

The following Figure 108 represents drawing steps following main structural elements of the tool.

Tool Structure

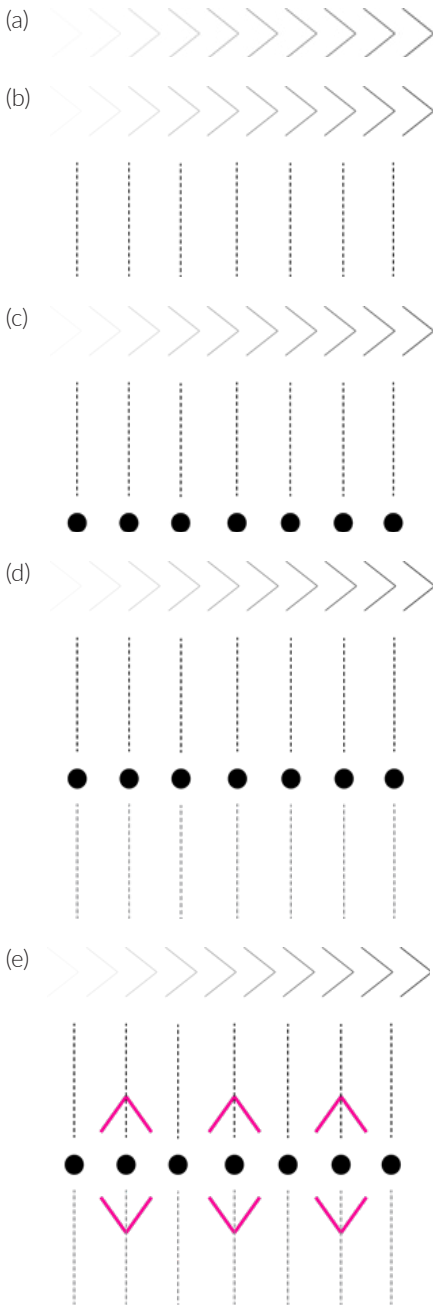


Figure 108. Drawing steps and elements contained within a structure of the tool Service Blueprint: (a) time, (b) mapping the user's activities within the phases of the defined timeline, (c) adding the touchpoints that correspond to the activities, (d) aligning the front-end of the service with the back-end, (e) evaluating the alignment between the user's experience and back-end operation and organization departments' activities interacting through diverse touchpoints.

Spatial Maps

Definition:

"These diagrams map out aspects of an experience spatially. As the name implies, spatial maps are neither chronological nor hierarchical. The three-dimensional aspect of this example makes it unique from the previous examples.

Spatial Maps offer new insight in regard to mapping. It starts with an investigation and illustration of the human condition and then works out ways to support people's needs.

Maps show interrelationships in an ecosystem."

(Kalbach, 2016)

Main aim of the tool according to gathered samples is described in Figure 109.

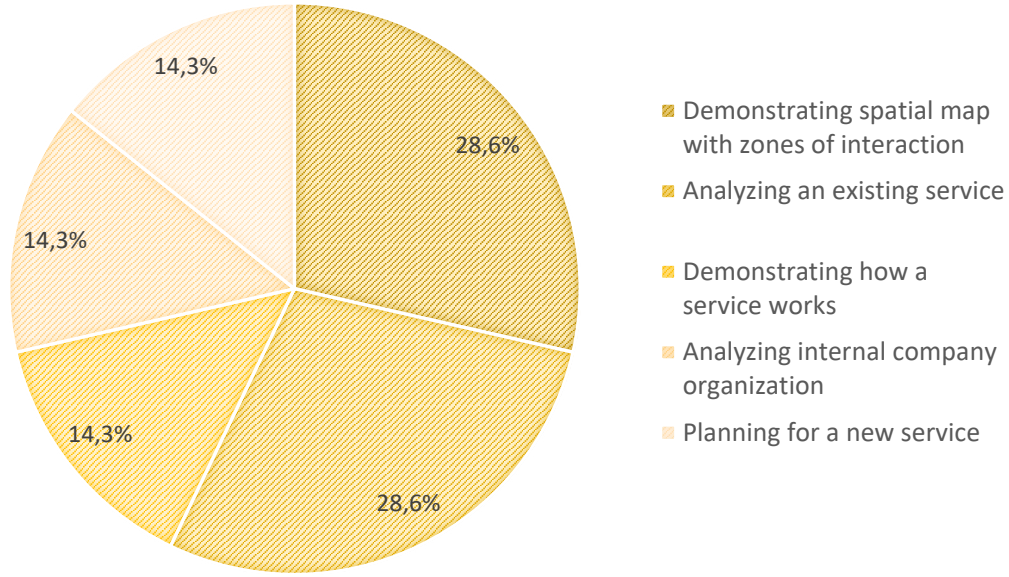


Figure 109. Main aim of the tool according to gathered samples of Spatial Maps.

None of the maps actually considered personas

Were personas and customer segments considered

Spatial maps appeared not to be considering the experience evaluation, all besides one representation, that refers to needs and goals.

What was evaluated in terms of UX

For needs and goals, an analysis based on primary research about document sharing and other organizational issues was conducted.

How in which manner was UX evaluated

Evaluation was represented through a textbox description clustered hierarchically (Fig. 110).

How was the evaluation represented

Analysing needs and goals in interaction between co-workers.

From which perspective / approach was UX evaluated

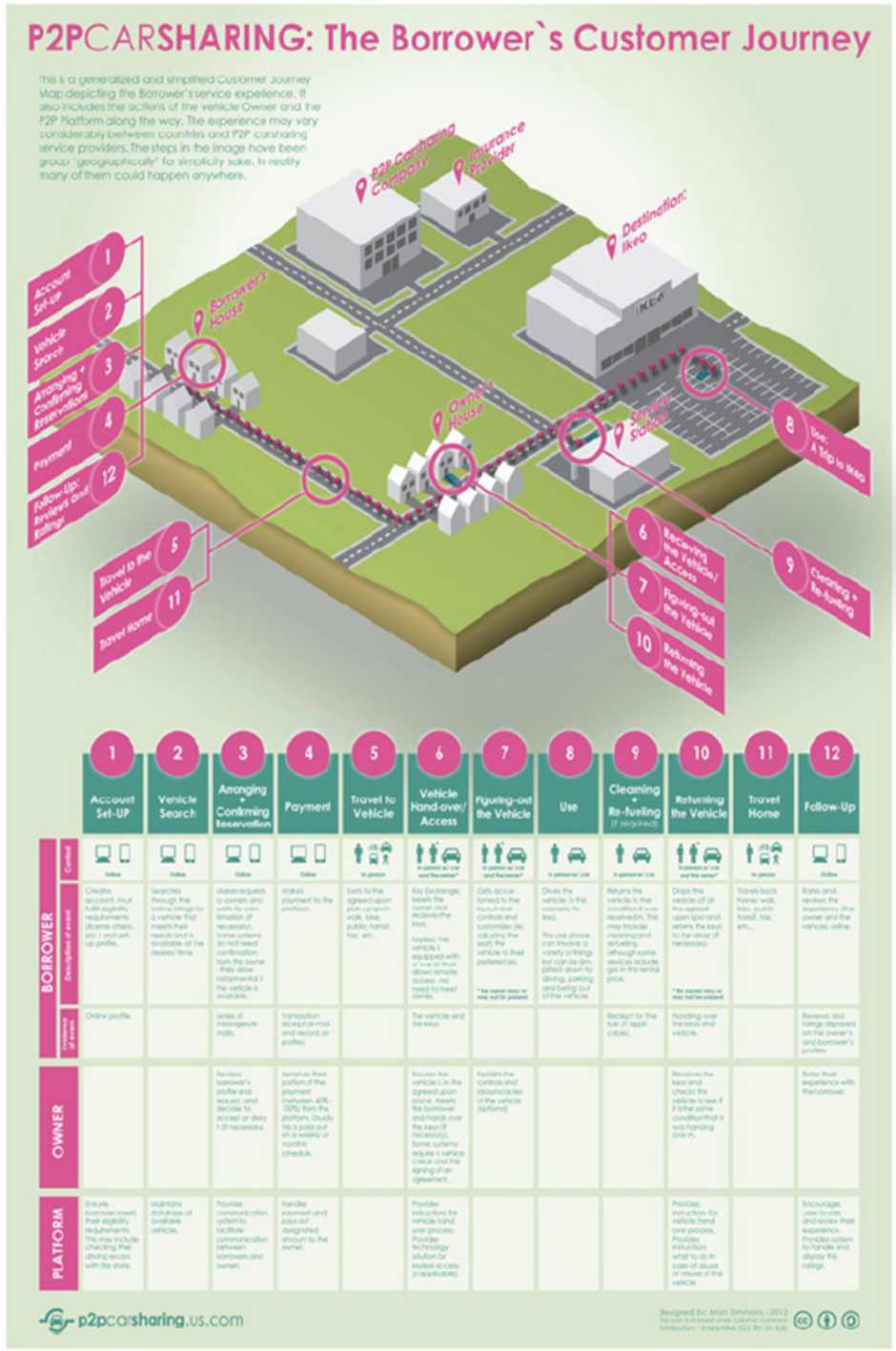


Figure 110. Sample of a Spatial Map for person-to-person car sharing service system.

The following Figure 111 represents drawing steps following main structural elements of the tool.

Tool Structure

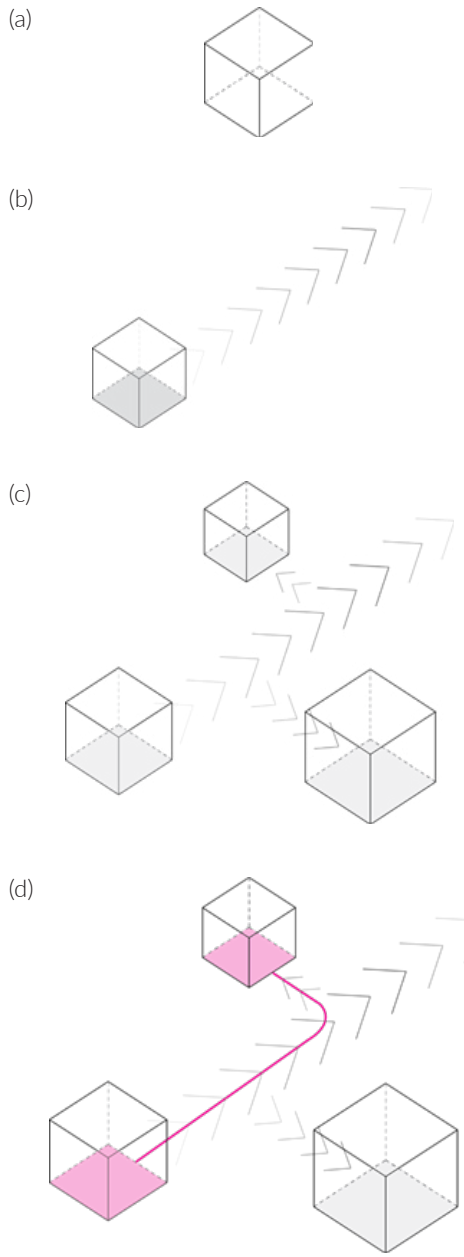


Figure 111. Drawing steps and elements contained within a structure of the tool Spatial Map: (a) starting from a 3D representation, (b) adding a path within the 3D spatial representations, (c) grouping of spatial elements, (d) defining a certain path of the user.

Ecosystem Models

Definition:

"Alignment diagrams represent these types of models. The maps look at the broader context of human activity, beyond the offerings of just one organization. They show the connections between people, places, and things, and they aid in the design of ecosystems.

As Spatial Maps, Ecosystem Models also offers new insights into mapping. It starts with an investigation and illustration of the human condition and then works out ways to support people's needs."

(Kalbach, 2016)

Main aim of the tool according to gathered samples is described in Figure 112.

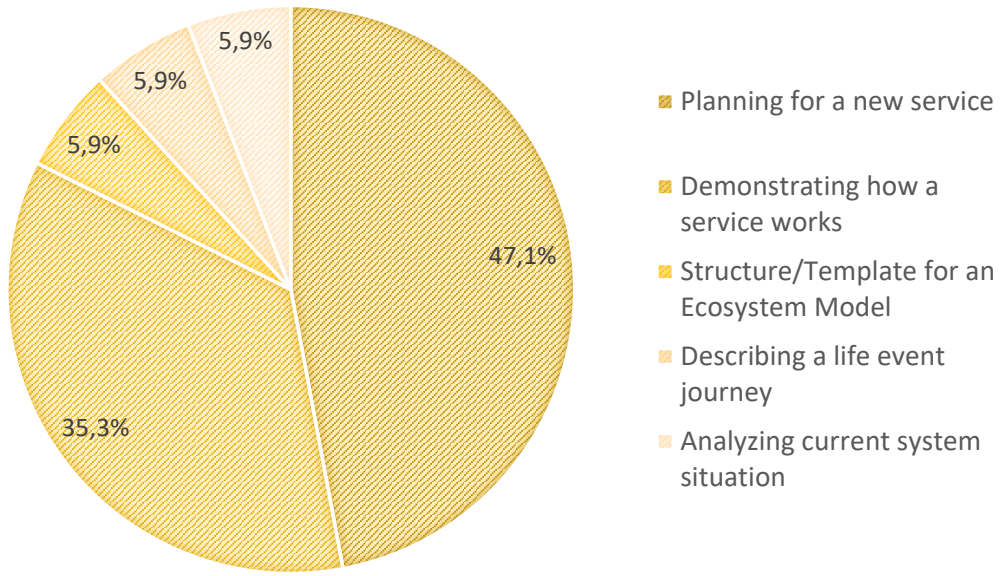


Figure 112. Main aim of the tool according to gathered samples of Ecosystem Models.

Were personas and customer segments considered

Only 1 diagram have considered a persona

What was evaluated in terms of UX

Most of the gathered Ecosystem Models do not consider directly the evaluation of experience. However, the ones that do so, refer to emotions, behaviour, being informed, needs, attitude, happiness, satisfaction, comfort, involvement, awareness, privacy issues, as well as identification of potential pain points.

A particular element of evaluation in these models is the context of activities and social settings. One of the representations focused on what is perceived as social good, while the other focused on identifying diverse contexts as: personal, environmental, social and cultural, temporal, business and technological.

How in which manner was UX evaluated

UX was evaluated through:

- Highlighting the selected aspects for consideration,
- Hypothesis on possible pain points in regard to interaction with the actors.
- Social good by confronting stakeholders' values and experience of contexts,
- Analysis of all the relevant aspects of the contexts for a use-case.

How was the evaluation represented

Evaluation was represented through (Fig. 113):

- Text description,
- Table with timeline of activities and actors,
- Icons and text for issues placed on a diagram in the field of "WHY",
- Mapping of issues by a tree diagram according to hierarchy.

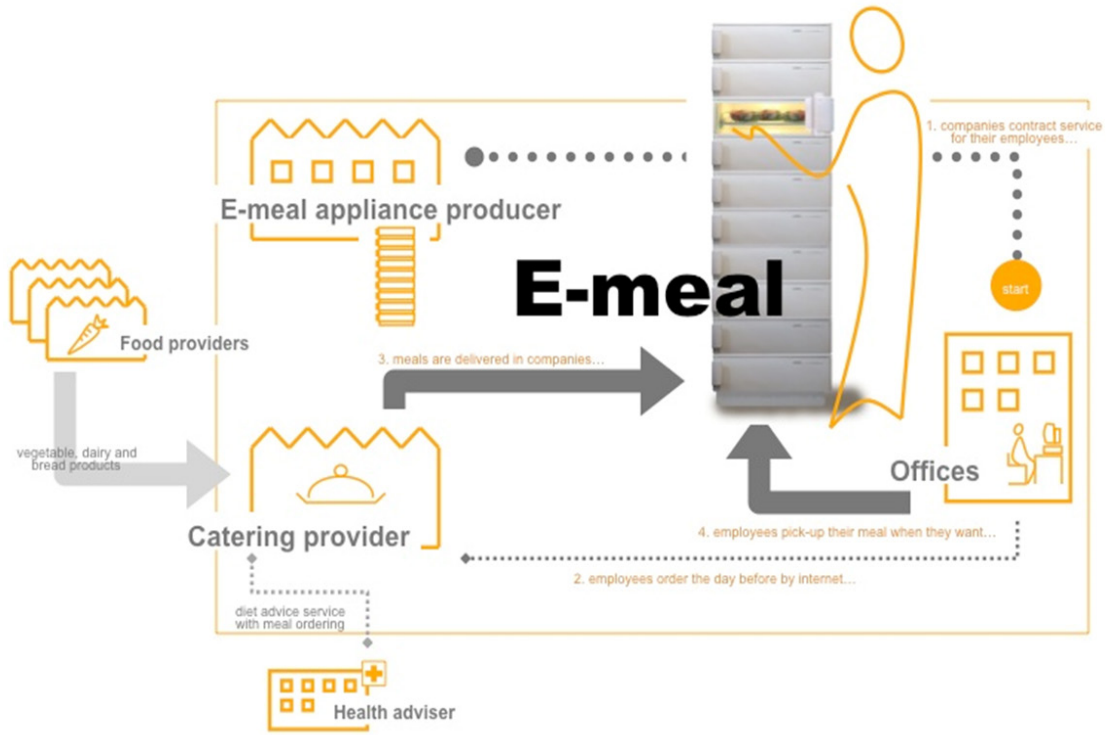


Figure 113. Sample of an Ecosystem Model for a catering service system.

From which perspective / approach was UX evaluated

UX was evaluated through following approaches:

- Confronting patients and hospitals values and communication and experience of diverse contexts,
- Mapping the activities needed for reaching a final goal (organizing a new event),
- Observing social good by analysing a service responding to questions: why, how, who, when, what, where,
- Analysing all the factors of a context that influence a creation of a particular use-case.

The following Figure 114 represents drawing steps following main structural elements of the tool.

Tool Structure

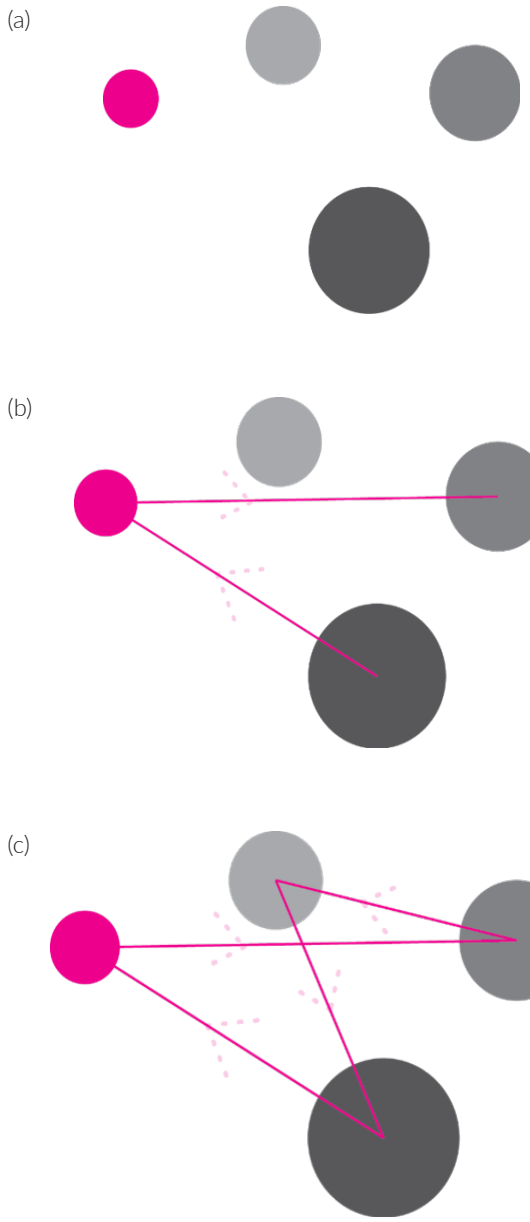


Figure 114.
Drawing steps and elements contained within a structure of the tool Ecosystem Model:
(a) identifying all the stakeholders, including the user/customer,
(b) the flows- what is the user getting form the service system and what is it giving in return, in respect to present stakeholders of the system,
(c) defining the value flows and connections between all the stakeholders of the system.

Stakeholder Maps

Definition:

"Stakeholder analysis or stakeholder mapping has evolved in recent years as a technique for analysing the likely interests and actions of stakeholders." (Johnson & Scholes, 2002)

"We have already defined stakeholders as groups or individuals who have a stake in or an expectation of the project's performance and indicated that this would include people inside the project, e.g. designers and contractors, and people outside the project, e.g. users and the community. A powerful individual stakeholder may have a significant influence on project decisions, but it is usually groups of stakeholders who combine to form temporary coalitions, who are most influential in shaping the strategy of the project. These groups have expectations which the project is under pressure to fulfil; this may not be a problem were it not for the fact that different groups of stakeholders often have conflicting expectations... Assessing the importance of stakeholder expectations is a key part of any project strategy analysis." (Newcombe, 2003)

"Opportunities have been offered to integrate two independent but complementary concepts that can be combined: (1) to facilitate identification of key stakeholders and mapping and measurement of their impact and influence, (2) to provide a useful metaphor for a visualization tool. The combination is useful because it enables stakeholders attempting to manage their relationships with others in a project management team to better appreciate political and engagement aspects of their relationship, thus helping them to respond practically and appropriately... The Stakeholder Circle has demonstrated strength in identifying key stakeholders and the nature of their impact using an engaging visualization tool." (Walker et al., 2008)

Main aim of the tool according to gathered samples is described in Figure 115.

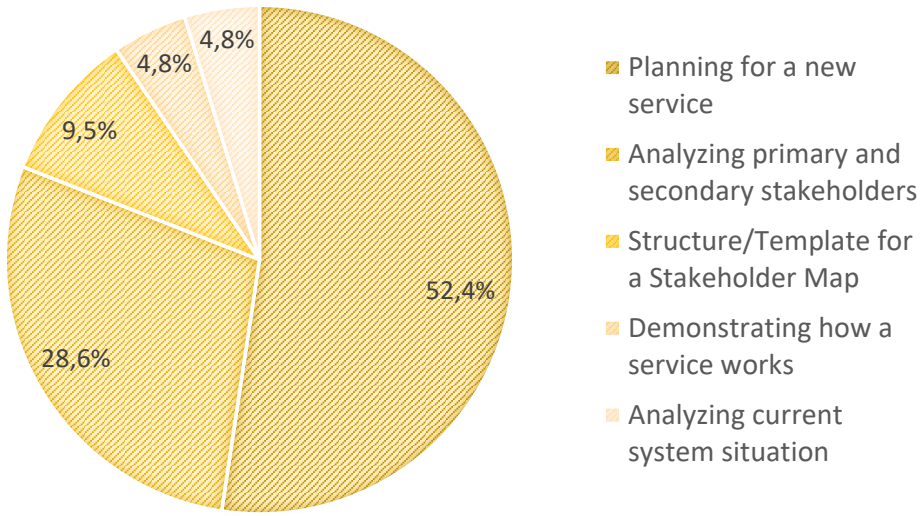


Figure 115. Main aim of the tool according to gathered samples of Stakeholder Maps.

Were personas and customer segments considered

Only 2 representations have considered a persona within the mapping process.

What was evaluated in terms of UX

Most of the gathered Stakeholder Maps do not consider directly the evaluation of experience. Only two did, in terms of influence, and contexts around the user: people, places and other factors.

How in which manner was UX evaluated

UX was evaluated through:

- Degree of interaction with others and influence,
- Analysis of all the relevant aspects of these contexts for the user.

How was the evaluation represented

Evaluation was represented through (Fig. 116):

- Positioning by circular levels where the main user is in the centre and degree of influence is shown accordingly,
- Mapping of issues by groups and expanding fields according to hierarchy.

From which perspective / approach was UX evaluated

UX was evaluated through following approaches:

- Analysing all the actors and strength of their influence and relations towards the user,
- Analysing all the factors that influence a creation of a particular use-case.

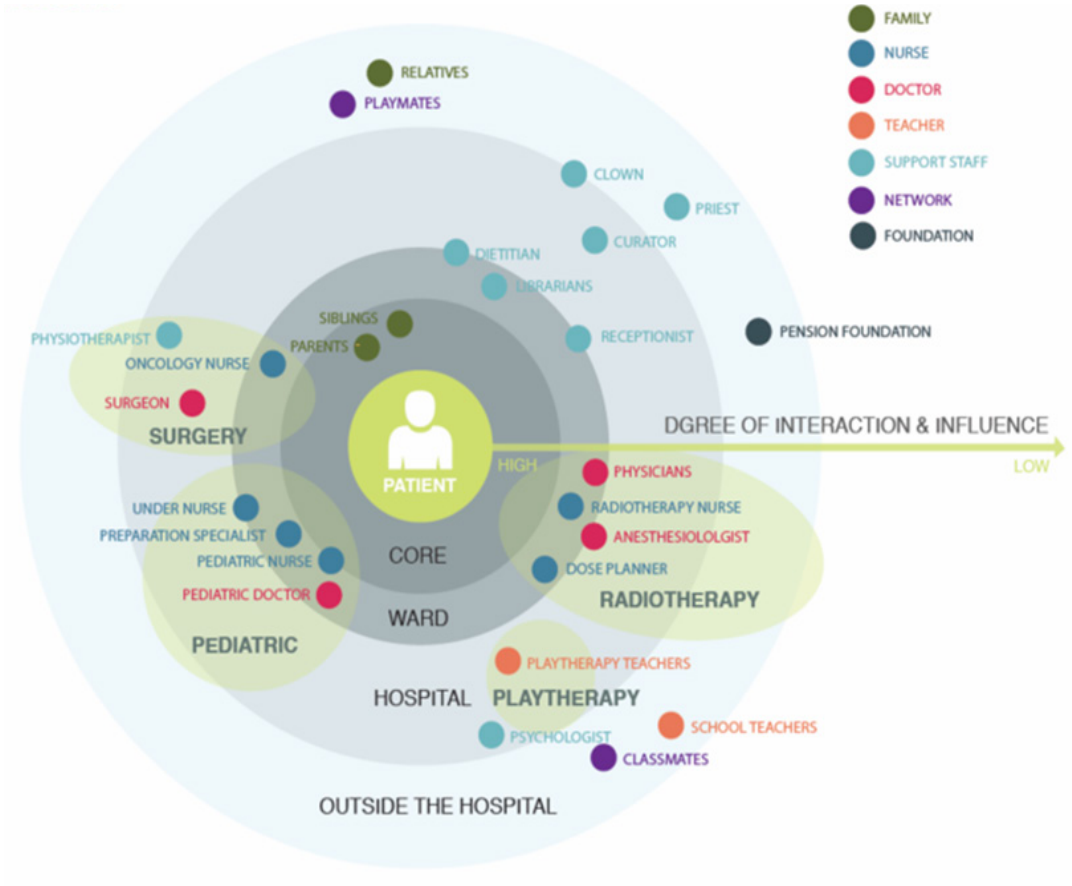


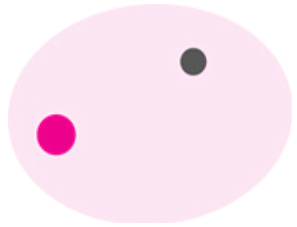
Figure 116. Sample of a Stakeholder Map for a patient.

The following Figure 117 represents drawing steps following main structural elements of the tool.

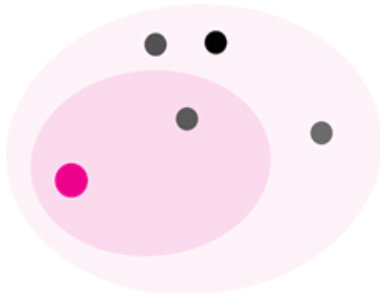
Tool Structure

(a)

(b)



(c)



(d)

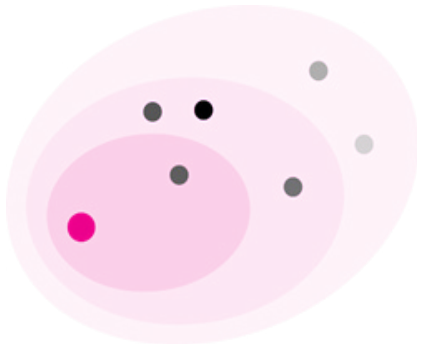


Figure 117. Drawing steps and elements contained within a structure of the tool Stakeholder Map:
(a) defining the user and hierarchy of stakeholders, starting from the very close circular field to the user,
(b) identifying the stakeholder representatives in this circle,
(c) identifying the stakeholder representatives in the new added circle,
(d) finalizing the definition of all the stakeholders and levels of influence they have on the user, positioning them in regard to the user.

Storyboards

Definition:

"Stories include fleshed-out characters and settings, dramatic elements, well-formed plotlines, and enough detail to understand the people who will use a system and the value it will bring to their lives." (Gruen et al., 2002)

"A user story describes functionality that will be valuable to either a user or purchaser of a system or software. "(Cohn, 2004)

"Mapping a story indicates mapping out an intended experience of use, the same as one would do for a story - plot point by plot point." (Lichaw, 2016)

"Storytelling is our way to put things into context, to process what we've experienced and learnt and to test that which we've not yet come across, or which we may fear." (Dahlström, 2016)

Main aim of the tool according to gathered samples is described in Figure 118.

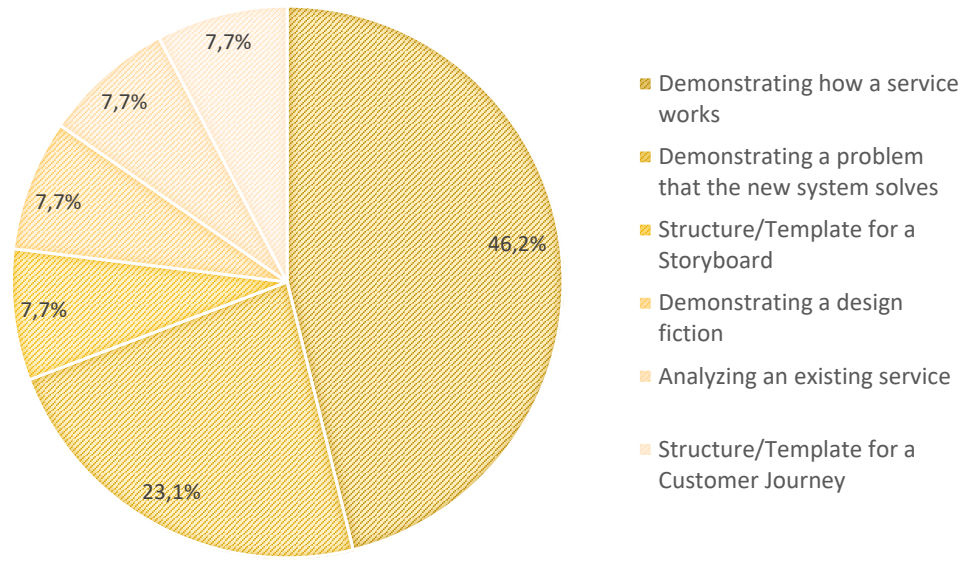


Figure 118. Main aim of the tool according to gathered samples of Storyboards.

9 representations have considered personas, which is more than the one who did not

Were personas and customer segments considered

To larger extent: problems, satisfaction and needs. To a lesser extent: intentions, emotion states, considerations, goals, expectations.

What was evaluated in terms of UX

UX was evaluated through:

How in which manner was UX evaluated

- Demonstrating a problematic daily situation,
- Storylines and flow,
- Emotional states of the character in the story/ Facial expressions for emotions that are positive, negative and neutral,
- Highs and lows for experience- when a storyboard is incorporated into a Customer Journey Map,
- Telling a story of a hypothetical need and showing how the service corresponds to it,
- Hypothesis on internal thoughts (monologue) for each of the activity / Hypothesis on goals in each activity and hypothesis on expectations in each activity.

Evaluation was represented through (Fig. 119):

How was the evaluation represented

- Drawing a situation setting with all the required elements to satisfy the story objective,
- Narration monologue text, or general story narration, form a side of an observer storyteller,
- Facial expressions,
- Continuous line with highs and lows with a Customer Journey.

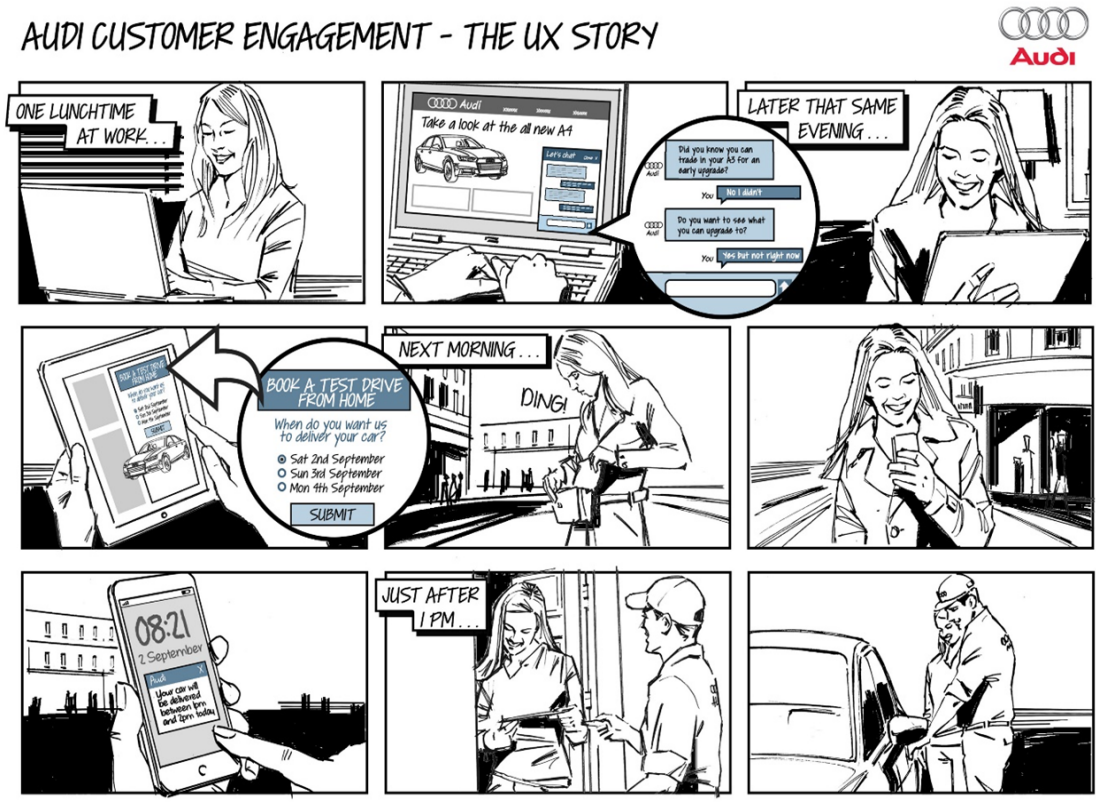


Figure 119. Sample of a Storyboard for Audi customer engagement.

From which perspective / approach was UX evaluated

UX was evaluated through following approaches:

- Setting a story with the user as main character to support a new system solution,
- Demonstration of a perfect fit of the service with the customers daily intentions and needs,
- Storyboard with emotional states during the journey process,
- Analysis of the service according to estimation of experience being positive or negative and identifying opportunities for improvement.

The following Figure 120 represents drawing steps following main structural elements of the tool.

Tool Structure

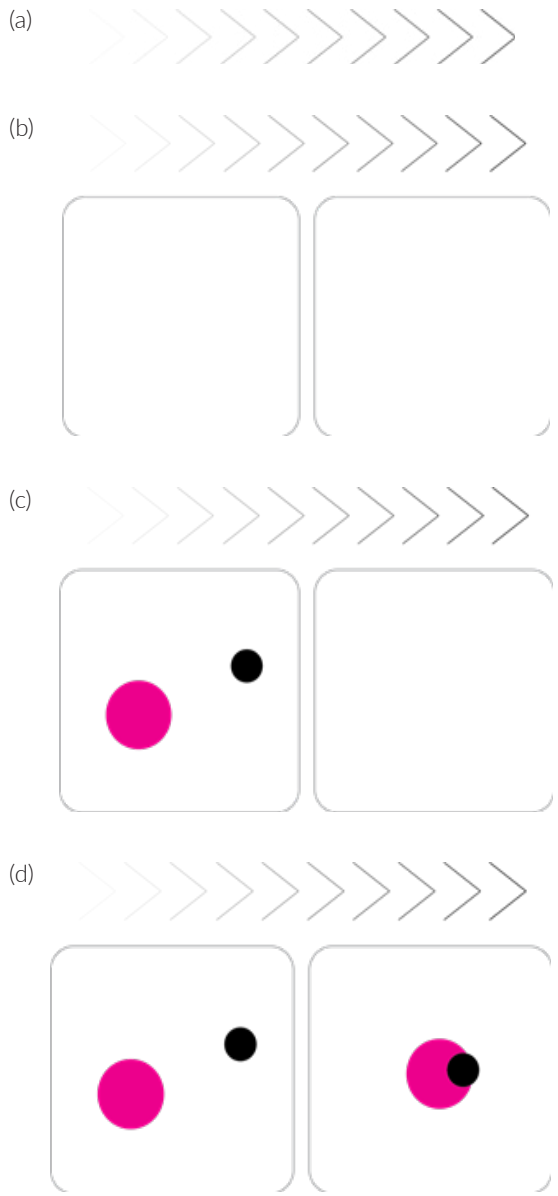


Figure 120.
Drawing steps and elements contained within a structure of the tool Storyboard:
(a) time,
(b) mapping the storytelling form through defined scene within a timeline,
(c) defining the protagonist of the story, which is the user, and the touchpoints of the system with whom he interacts, as well as the context in which the interaction is happening,
(d) further shaping the scenes according to the interaction flows.

Touchpoint Matrix

Definition:

Touchpoint Matrixes are also known as cross-channel user journeys and/or omni-channel journeys.

“Once the system and its components are defined, it becomes possible to outline the scenarios in which the user puts together available parts to achieve their goals. Connecting the dots of the matrix, it becomes possible to outline the different configurations of the user experience for each persona in the various scenarios. The sequence is based on different entry points, user goals, and data and action flows.

Establishing a system. Such systems have some interesting characteristics. The most important is the lack of a rigid structure and of a predefined hierarchy between the parts. They are open platforms for user experience, a network of opportunities, exploited practically, and occasionally, case by case. Many entry points are possible in these platforms. The user can start the interaction on a touchpoint or another following context, situation, or based on other needs or goals. There is no single or best form of user interaction.

The challenge that logically follows is to design connections. In the system scenario, design should be mainly focused on finding the right connections within the network and its parts.

For a positive and fulfilling user experience, the whole is more important than the parts. In consequence, the ‘intelligence’ of the platform is more important than the ‘intelligence’ of the single device, which could be replaced or completed by other parts, applications and other services available within the network.”

(Brugnoli, 2009)

Main aim of the tool according to gathered samples is described in Figure 121.

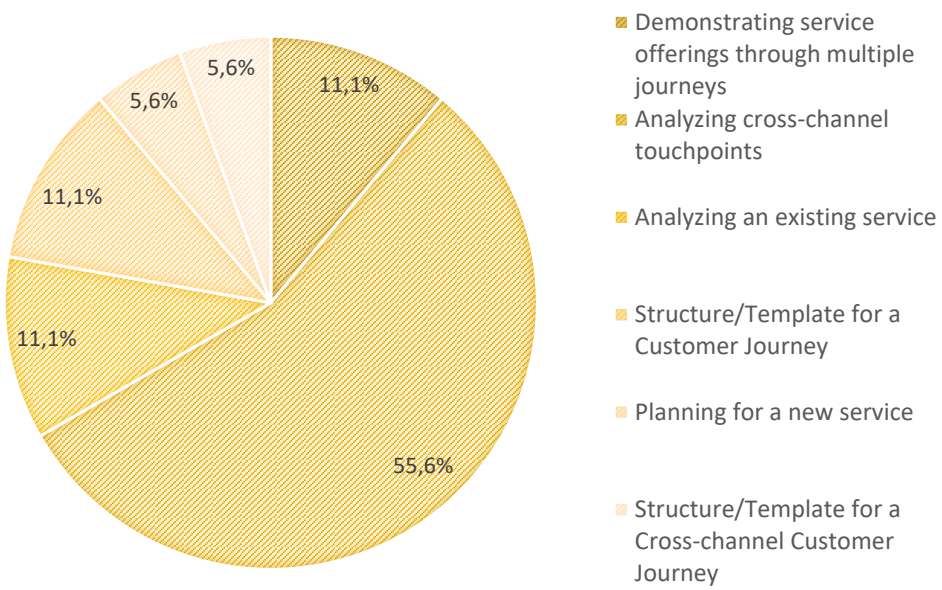


Figure 121. Main aim of the tool according to gathered samples of Touchpoint Matrix.

Were personas and customer segments considered

Only 4 visuals did consider personas

What was evaluated in terms of UX

Majority of these representations did not show an explicit evaluation of user's experience. Ones that did, however, focused on: broken journey points (pain points), emotional experience, user's intentions and posed waiting time within the journey. Others consider the evaluation of a business in terms of marketing influence and/or monetary value, mapped on the journey goals.

How in which manner was UX evaluated

UX was evaluated through:

- Pointing at the touchpoints that are problematic in the journey,
- Positive and negative states/ Rating of levels of positive and negative emotions,

- Analysing diverse channels that enable the user's intentions,
- Analysis of journey steps and all the moment when waiting time occurs and repeats,
- Levels of marketing influence on cross-channels of touchpoints,
- Description, Numbering proposal.

How was the evaluation represented

Evaluation was represented through (Fig. 122):

- Red colour with a "crash" effect form,
- Green and red colour fields/ colour palette scale (10 fields) for emotions from red (negative) to green (positive),
- Textbox description in-between journey steps,
- Connecting the dots across channels in one journey line,
- Continuous lines with highs and lows,
- Text description.

From which perspective / approach was UX evaluated

UX was evaluated through following approaches:

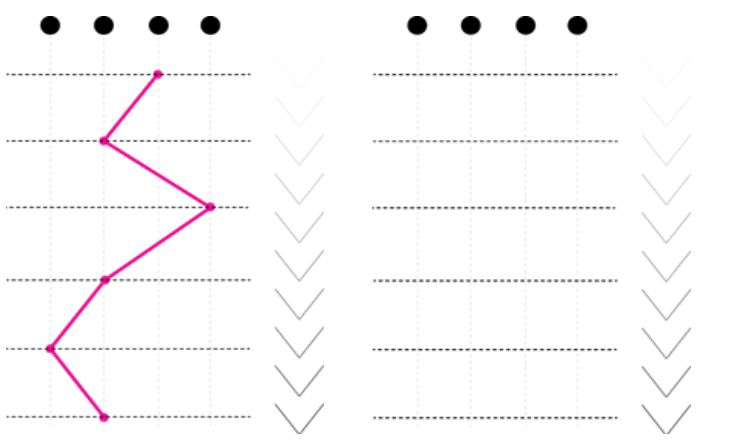
- Analysing the points where the journey appears as broken,
- Analysing multiple path- intentions and states,
- Analysing tool for mapping out customer experience according to touchpoints and emotional levels,
- Analysing steps of the journey while considering the in-between waiting moments as important parts of the journey,
- Analysing marketing success,
- Analysing and planning for new product launch marketing strategy and budget estimation.

Figure 122. Sample of a Touchpoint Matrix for a purchase journey.

Tool Structure

Figure 123. Drawing steps and elements contained within a structure of the tool Touchpoint Matrix: (a) time, (b) activities within the timeline phases, (c) diverse touchpoints added to the timeline, (d) definition of the journey path connecting diverse touchpoints.

The following Figure 123 represents drawing steps following main structural elements of the tool.



Business Model Canvases

Definition:

A business model describes the rationale of how an organization creates, develops and captures value (Osterwalder & Pigneur, 2010).

"Firms can use one or a selection of business model archetypes for shaping their own transformation, which are envisaged to provide assistance in exploring new ways to create and deliver sustainable value and developing the business model structure by providing guidance to realise the new opportunities" (Bocken et al., 2014, p.13).

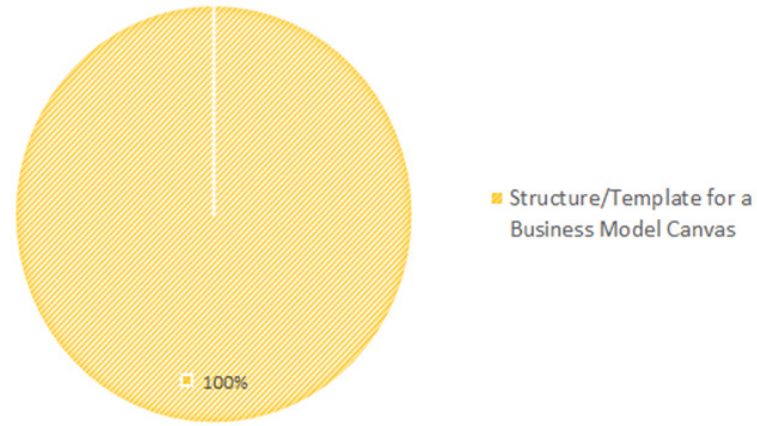
In particular, it is a conceptualization of an organization which includes 3 key aspects (Chesbrough, 2010): (1) How key components and functions, or parts, are integrated to deliver value to the customer; (2) How those parts are interconnected within the organization and throughout its supply chain and stakeholder networks; and (3) How the organization generates value, or creates profit, through those interconnections.

A business model canvas (BMC), such as that developed by Osterwalder and Pigneur (2010) tool can be quite effective in helping users understand an organization's business model. The BMC can help users visually represent the elements of a business model and the potential interconnections and impacts on value creation. As a visual tool, the BMC can facilitate discussion, debate, and exploration of potential innovations to the underlying business model itself; with users developing a more systemic perspective of an organization and highlighting its value creating impacts (Wallin et al., 2013).

Main aim of the tool according to gathered samples is described in Figure 124.

Structure/Template for a Business Model Canvas is what I encountered among the gathered samples; however, main aim of the tool is supporting a system design process based on business values and the ecosystem elements and relations.

Figure 124.
Main aim of the tool according to gathered samples of Business Model Canvases.



Were personas and customer segments considered

All of them did consider personas.

What was evaluated in terms of UX

All of the canvases considered Value Propositions and Customer Relationships.

How in which manner was UX evaluated

UX was evaluated through:

- Market analysis,
- Hypothesis on user values; as for e.g. easiest way around, low cost luxury, various levels of service, monetary value.

How was the evaluation represented

Evaluation was represented through text description in suitable canvas fields (Fig. 125).

From which perspective / approach was UX evaluated

Setting up a business plan and strategy/ Customer segmentation.

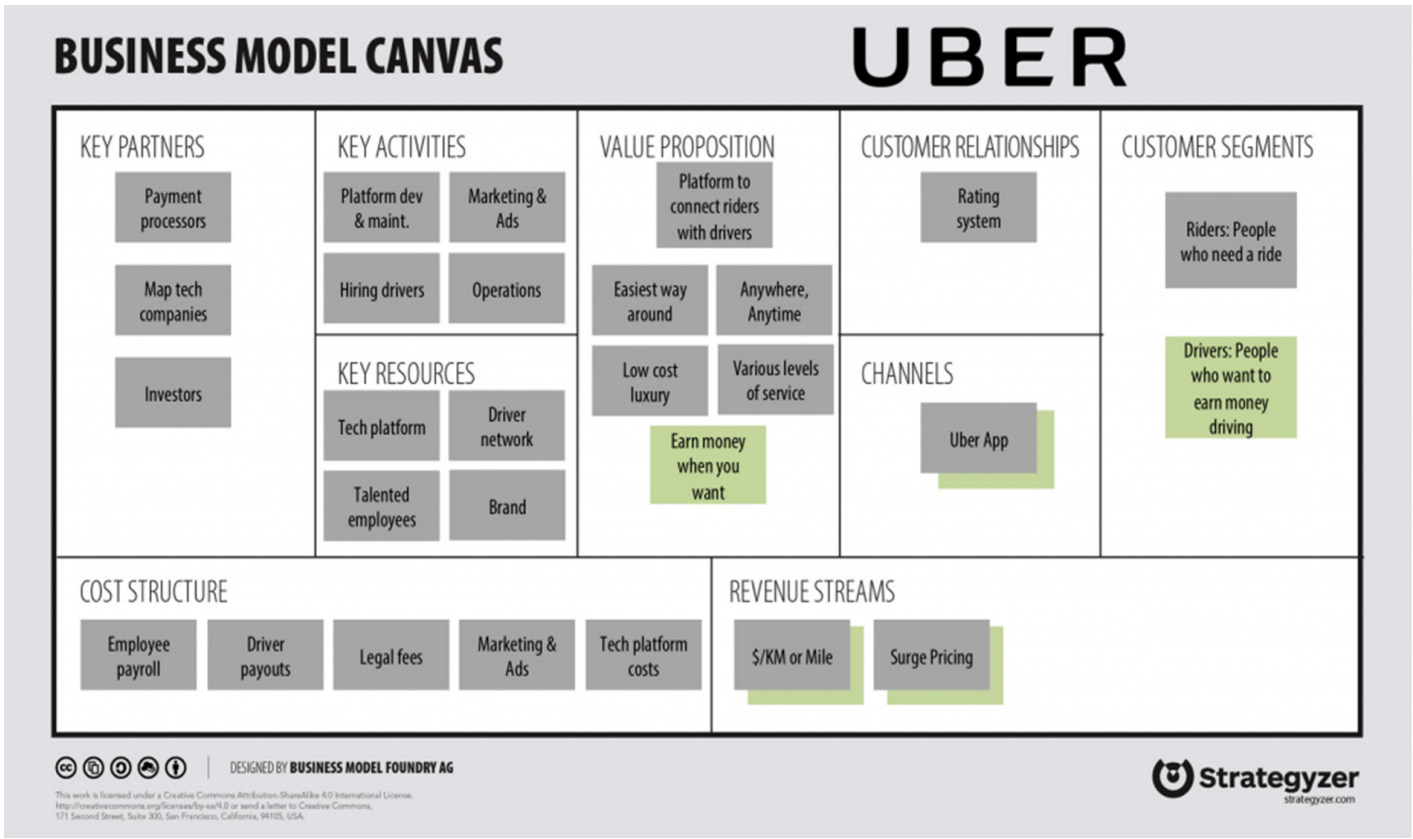
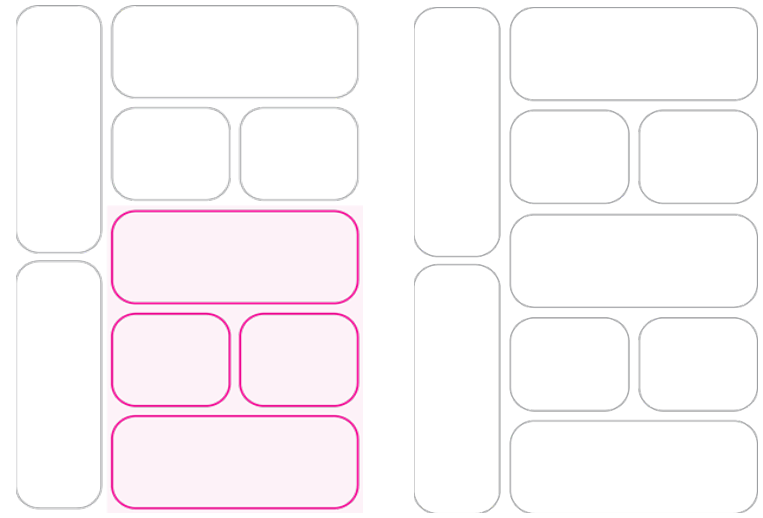


Figure 125. Sample of a Business Model Canvas for a car-pool service system (Uber).

Tool Structure

Figure 126. Drawing steps and elements contained within a structure of the tool Business Model Canvas: (a) standard format of the canvas divided by main fields, (b) identification of values according to the parts that regard customer engagement and relations analysis.

The following Figure 126 represents drawing steps following main structural elements of the tool.



Value Proposition Canvases

Definition:

Value Proposition Canvases are similar to Vision and Validation Canvases.

"Value proposition design will help you successfully understand the patterns of value creation and leverage the experience and skills of your team.

The value proposition canvas has two sides. With the customer profile you clarify your customer understanding. With the value map you describe how you intend to create value for that customer. You

achieve a fit between the two when one meets the other.

Value proposition describes benefits the customer can expect from your products and services. “

(Osterwalder et al., 2014)

Main aim of the tool according to gathered samples is described in Figure 127.

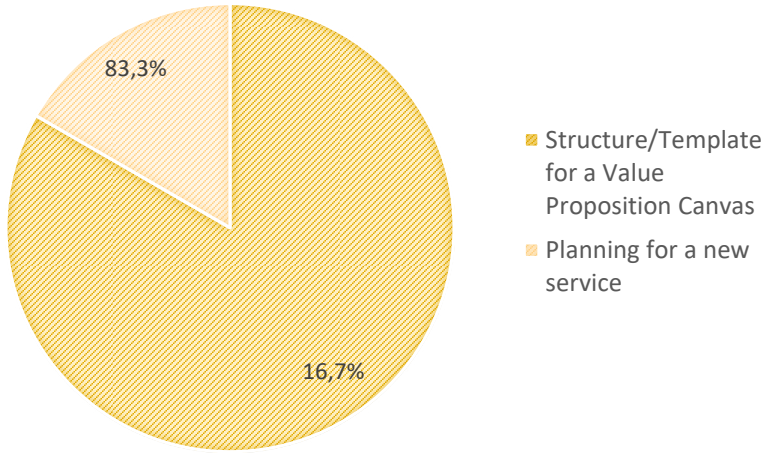


Figure 127.
Main aim of the tool according to gathered samples of Value Proposition Canvases.

All of them did consider personas.

Were personas and customer segments considered

All of the canvases considered Customer Segment and Value Proposition (e.g. Experience, Benefits, Features).

What was evaluated in terms of UX

UX was evaluated through:

How in which manner was UX evaluated

Gains (positive sides; like easy to use, increase quality time, fulfilment and dignity, enhance income...), and Pains (negative sides- all the opposites of described gains), according to Customer Jobs/Activities. An example of a service for elderly: Gains (feel loved, contribute to conversation, stay alert, stay in the know on what everyone is doing), Pains (be forgotten, get bored, feel lonely, be put aside).

Furthermore, in relation to the previously mentioned, Gain Creators and Pain Relievers are defined as well.

How was the evaluation represented

Evaluation was represented through (Fig. 128):

- Emoticons - sad and happy for negative and positive states,
- Text description,
- Symbols.

From which perspective / approach was UX evaluated

Confrontation and overlapping between the two diagrams/ Customer segmentation.

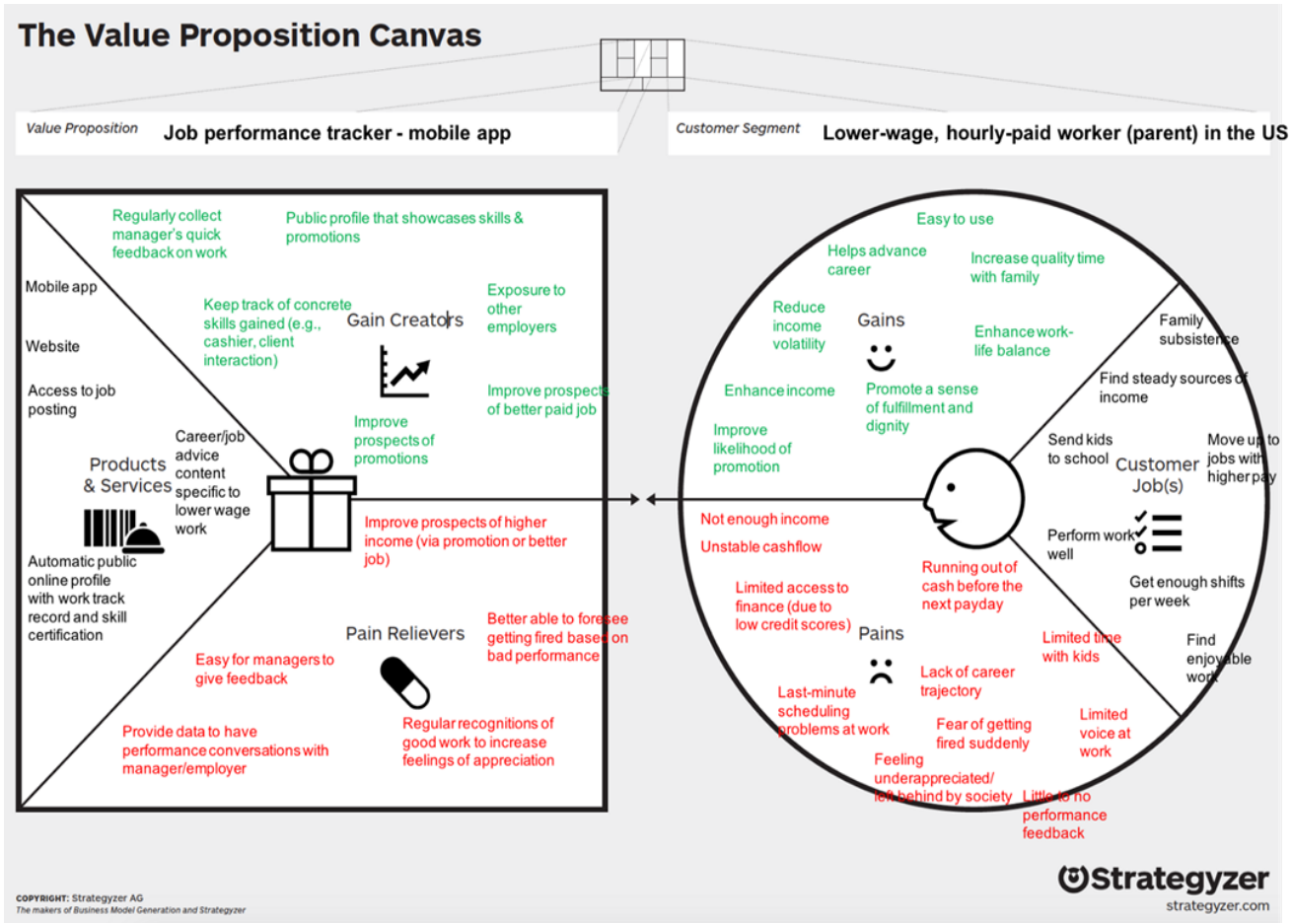


Figure 128. Sample of a Value Proposition Canvas for a job performance tracker service.

Tool Structure

The following Figure 128 represents drawing steps following main structural elements of the tool.

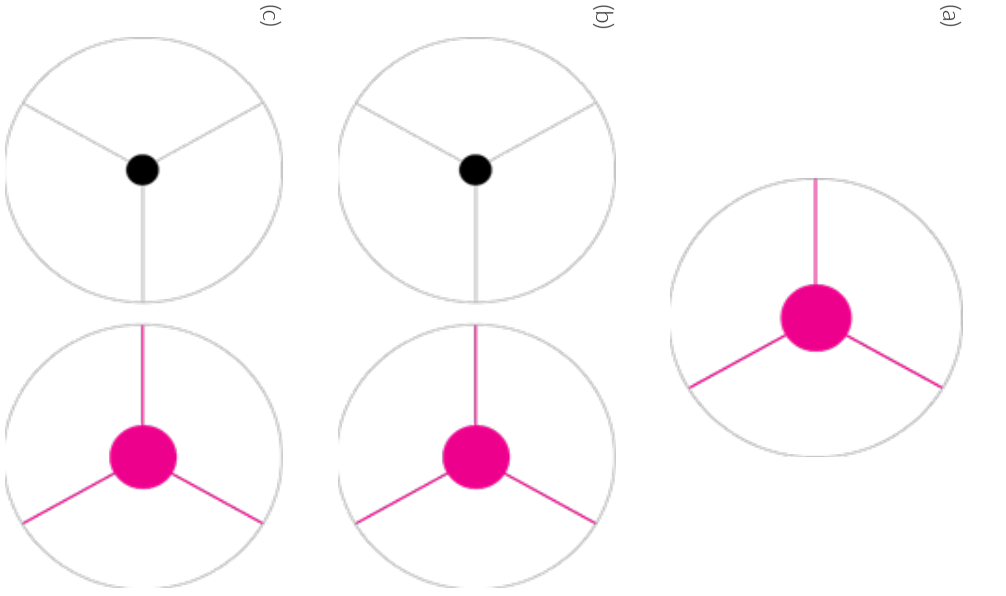


Figure 129. Drawing steps and elements contained within a structure of the tool Value Proposition Canvas: (a) defining the persona, and customer jobs, with pains and gains, (b) defining a system product responding to the identified needs, (c) aligning pains and gains with pain relievers and gain creators.

Empathy Maps

Definition:

Empathy Map is a technique that assists in designing business models according to customers' perspectives. It goes beyond demographic characteristics and develops a better understanding

of a customer's environment, behaviour, aspirations and concerns (Osterwalder & Pigneur, 2013). The Empathy Map goal is to create a degree of empathy for a specific person (or group of people) (Gray et al., 2010). An empathy map reveals the rationale underlying users' actions, decisions and choices; therefore, it helps in designing for users' real needs (Adikari et al., 2013).

Main aim of the tool according to gathered samples is described in Figure 129.

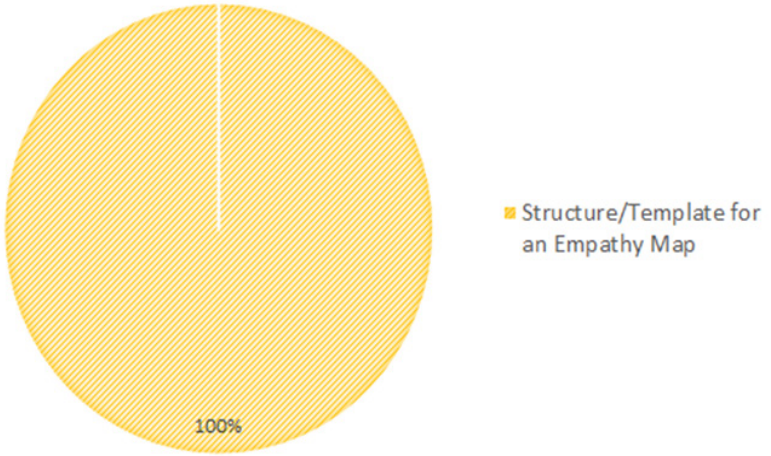


Figure 130.
Main aim of the tool according to gathered samples of Empathy Maps.

The gathered samples all refer to a structure/template for an Empathy Map, however, the main aim of these tools is to analyse a target group.

Were personas and customer segments considered

All of them did consider personas.

What was evaluated in terms of UX

Thinks & Feels, See's, Hear's, Say's, Do's, Pains & Gains, Goals

Example from NN Group:

- Says (I want something reliable, where should I start?)
- Thinks (too hard? what's the best? wasting time? I want something awesome)
- Does (asks friends, makes decisions, compares products...)
- Feels (excited, anxious, overwhelmed...)

How in which manner was UX evaluated

UX was evaluated through:

- All the points before are gathered around the user in the centre, and the Pains and Gains are mapped to them in a higher level/ Hypothesis on the points,
- Example from NN Group: Hypothesis on the points (also monologues) and Goals box has a higher level considered an overall.

How was the evaluation represented

Evaluation waas represented through text description and hierarchical grouping (Fig. 130).

From which perspective / approach was UX evaluated

Synthesizing research to better understand the users/ Persona.

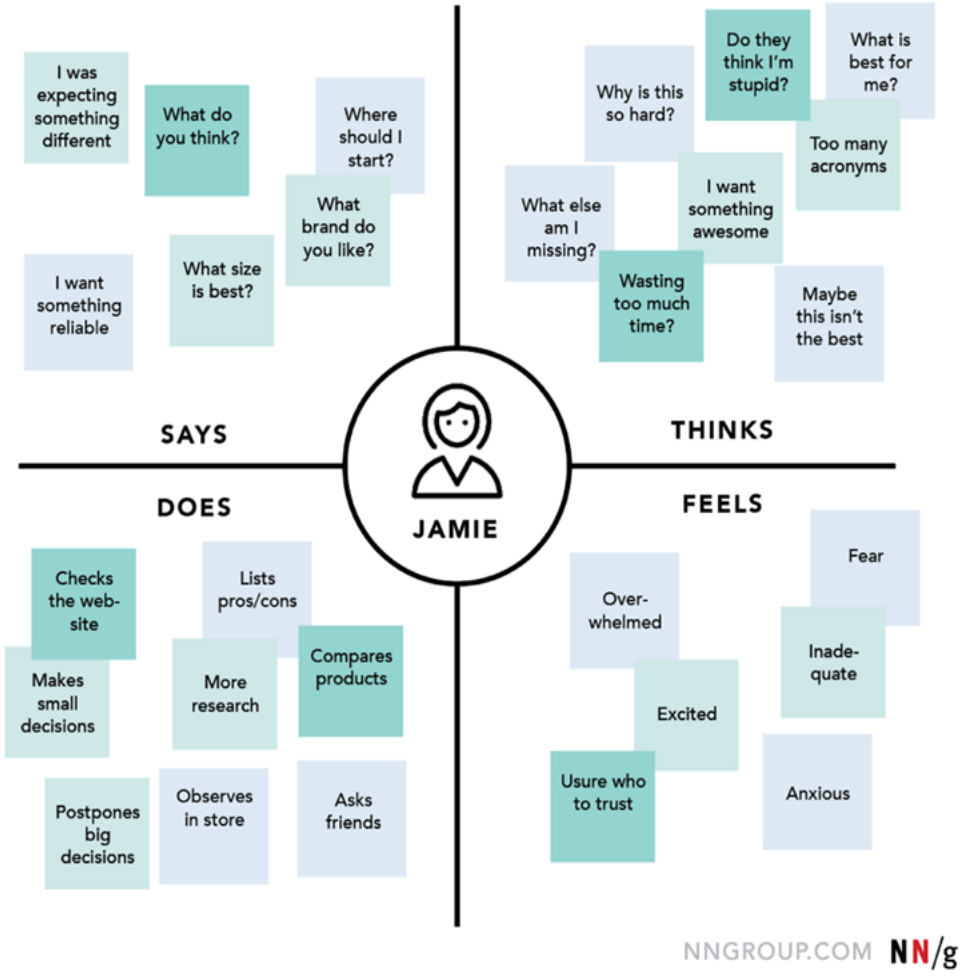


Figure 131. Sample of an Empathy Map for buying a TV.

Tool Structure

The following Figure 131 represents drawing steps following main structural elements of the tool.

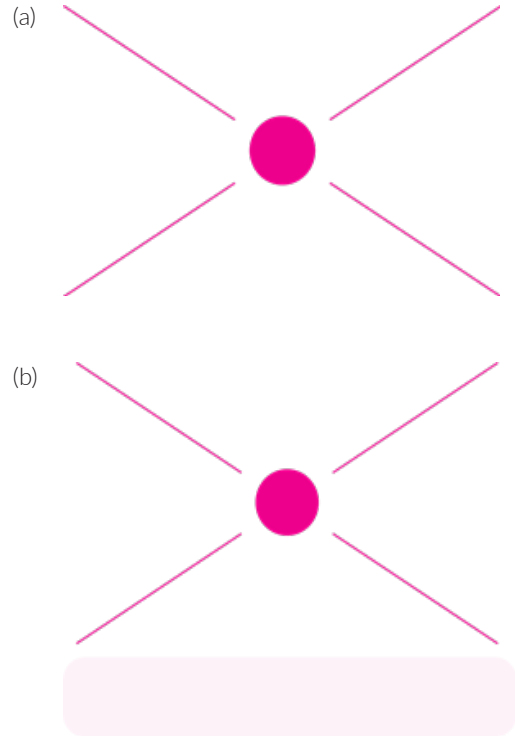


Figure 132. rawing steps and elements contained within a structure of the tool Empathy Map: (a) identifying a persona, and what she/he thinks and feels, hears and sees, says and does, in regard to the interactions within the system, (b) mapping the previously identified parameters with a higher levels' goals, or what can be read as pains and gains.

4.1.3 Confrontation Between Tools Structural Elements

Focus of the analysis is on two main groups, which features are discussed through:

- Understanding the main scope and structure of tools' representations;
- Understanding what is taken into consideration in terms of user values, and in which manner and from which perspective did the evaluation happen.

In the following the discussion is based on the conducted analysis and confrontation of the diagrams.

Main Aim and Structure of the Tools

When grouping the results of all the analysed tools, the following showed as main aims of the tools' representations:

- Analysing an existing service system,
- Providing a general template for the particular diagram,
- Planning for a new service system,
- Demonstrating how a service system works,
- Identifying opportunities for improving a service system.

Besides these, to a lesser extent, the following scopes have also been observed:

- Analysing primary and secondary stakeholders,
- Describing a life event journey,
- Analysing cross-channel touchpoints.

Finally, to a very small extent the aims were related to a very peculiar focus of the diagram, such as:

- Demonstrating spatial map with zones of interaction,
- Demonstrating how an interface works,
- Analysing an internal company organization.

Some diagrams between them show to have diverse aims, and yet the diverse diagrams sometimes satisfy same aims. For example, both Mental Model Diagrams and Stakeholder Maps as tools have a scope of planning for a new service, however, only Stakeholder Maps, from the two, deal with identification of stakeholders involved in the system design.

Confrontation of diverse structures of analysed tools brought to an observation of certain patterns that are repeating, hence allowing for grouping of tools according to these patterns. Namely, tools such as Customer Journey Maps, Experience Maps, Mental Model Diagrams, Service Blueprints, Storyboards and Touchpoint Matrixes all have in common the structure mapped on a ***timeline of sequential activities*** (Fig. 132), i.e. a journey path. The backbone of the structure are chronological phases that support the activities of the customer/user representative. While Spatial Maps could rely on a sequence of activities within a certain journey, other diagrams do not consider the aspect of time at all. Representations as Ecosystem Models, Stakeholder Maps, Business Model Canvases, Value Proposition Canvases and Empathy Maps, have as a backbone of the structure a ***network of relational elements*** (Fig. 133) that do not merge through the aspect of time.

Although it would have been expected that all the maps have a defined persona and/or customer segment, surprisingly this is not always the case with the gathered examples. Namely, only 38 from 67 Customer Journeys has a clearly shaped persona, while Spatial Maps, Service Blueprints and Ecosystem Models almost never consider a persona. Business Model and Value Proposition Canvases, as well as Empathy Maps, on the other side, always refer to a customer segment.

What is in common to all the representations' structures are the

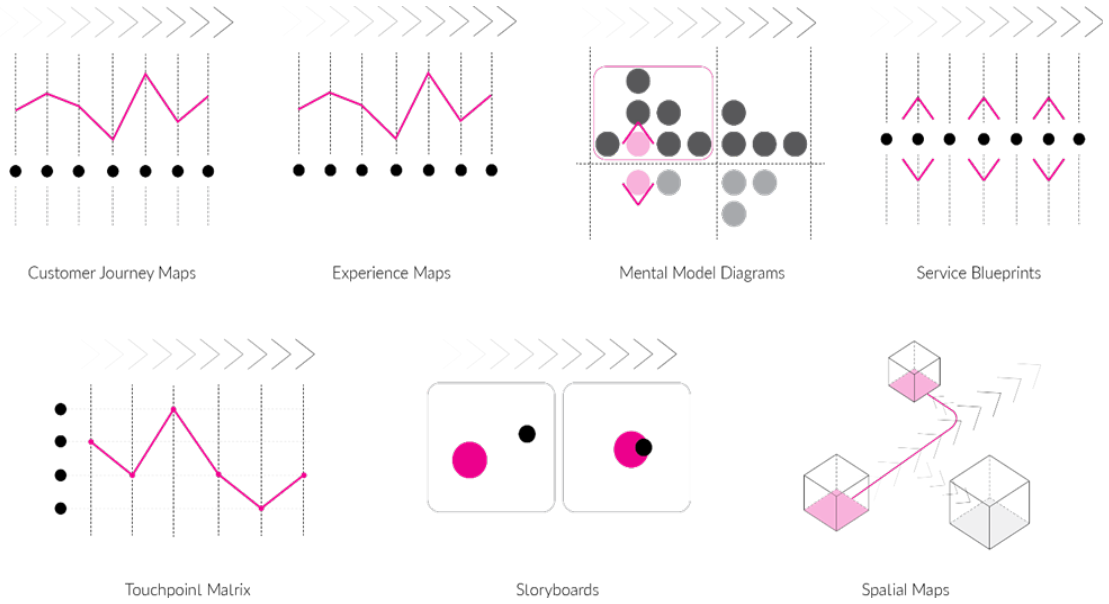


Figure 133. All the collected tools' structures mapped on a timeline of sequential activities.

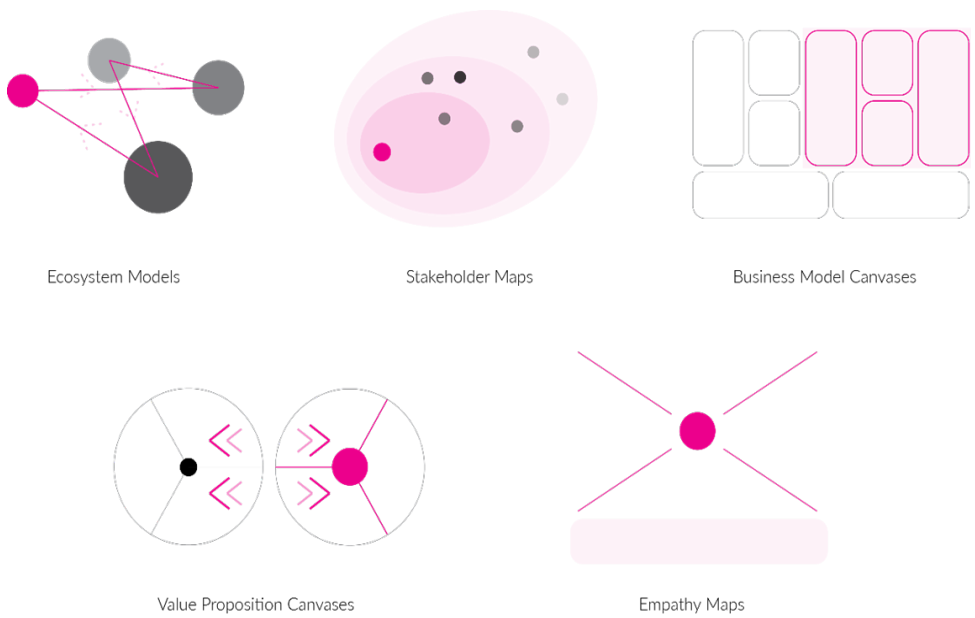


Figure 134. All the collected tools' structures mapped through a network of relational elements.

touchpoints, more precisely, the elements of interaction between the customer/user and the service system. The touchpoints are represented in different manners; however, they are always present no matter what the final aim of the diagram is. It could be observed that the touchpoints are the actual backbone for all the user case scenarios from which the mapping and analysis derived. In some diagrams they are very explicit as physical and digital elements (e.g. Customer Journeys), while in the others they are recognizable within the network of actors, i.e. stakeholders (e.g. Stakeholder Maps).

Even though all the diagrams are based on use-case scenarios and interaction moments, the considerations around user values differ significantly.

User Values Emphasized within the Tools

In terms of what was evaluated in regard to user's experience in sample diagrams, coding of focus issues through keywords was made, and the issues are grouped accordingly (Table 7).

Table 7: Grouping of User Values represented within the gathered tools according to emerged keywords from the analysis.

FOCUS ISSUES	KEYWORDS
User's Perceptions	Hear's & See's
	Clearness of steps in the process
	Doubts
	Uncertainty
	Opinion
	Means
	Considerations
	Decisions
	Threats
	Thoughts
	Distraction
	Effort
	Problems
	Use of free time / Waiting time

FOCUS ISSUES	KEYWORDS
User's States	Feelings
	Emotions
	Satisfaction
	Fears
	Energy
	Discomfort
	Body changes
	Anxiety
	Tiredness
User's Requirements	Needs
	Habits
	Goals
	Desired Outcomes/ Desires
	Trust
	Being pleased
	Price/ Value Ratio
	Demands
	Drivers
	Intentions
	Expectations
	Inspiration
User's Service Experience	Pain Points
	Enjoyability
	Engagement
	Relevance of service provider

FOCUS ISSUES	KEYWORDS
User's Service Experience	Helpfulness of the service provider
	Content Relevance
	Motivations
	Behaviour
	Marketing influence
User's Interaction Context	Context of use
	Personal
	Environmental
	Social & Cultural
	Temporal
	Business
	Technological
	Contexts around the user
	People
	Places
	Perceived social good
	Relationships

User's Perceptions group relates to ***cognitive perceptions and reasoning*** on diverse situations and activities that the user is undertaking. For example, in this group authors of the diagrams analyse what the user sees and hears, and how does he perceive the situation (e.g. clearness of steps in the process or use of waiting time) and reason upon this perception (shapes an opinion). Here the user would have particular thoughts, doubts and have perceived certain degrees of effort, problematics, and distraction. User's Perception group can be seen as almost equal to understanding usability of a certain service system. Among the analysed diagrams, this group mostly had as main aim of representation the analysis for planning a new journey and/or analysis of an existent journey.

User's States group relates to ***emotions and body states*** within diverse situations and activities that the user is undertaking. More precisely, user values are seen within the feelings he is developing, like for e.g. satisfaction, fears and anxiety. States are related to body conditions such as discomfort, energy, tiredness and diverse changes. This group of diagrams have as one of main aims the analysis of a journey according to experienced emotions. It does not relate to just usability but expands also on creation of meanings and motivations over a certain time of use.

User's Requirements group deals with identifying ***needs and desires,*** and therefore user's ***goals***, that might correspond to existing offerings, or can be used for planning for a new design system. Here the focus of the analysis of the experience are habits, drivers and demands deriving from targeted groups. In relation to a service system a user can build certain expectations and trust, be pleased if the offerings match his posed requirements. Requirements are linked to price - value ratio as well. The scope of the diagrams that enter this group are mostly planning for a new service system and the analysis of existing ones, considering an alignment with the business aspects as well. From the user point of view, this group mostly relates to satisfaction on the level of utility and the creation of meanings and motivations over time.

User's Service Experience is a group that focuses in particular on the ***relation with the offered service***, evaluating implicitly the service offerings. More precisely, it relates to the enjoyability of the service system, and analysis of what can be seen as pain points (weaknesses of the system). Furthermore, the behaviour of the user in relation to the system is being evaluated, and therefore his engagement and motivations of becoming a user. Content relevance, as well as the relevance and helpfulness of the service provider, are other parameters that enter the evaluation framework here. The evaluation within this group is in tight relation with the back-end activities and organization of the system.

User's Interaction Context group relates to the ***context of use around the user***, considering also the relations with all the diverse actors involved. Within the sample diagrams, context of use can be personal, environmental, social and cultural, temporal, technological and business related. In some of the representations, context around

the user is observed in macro lines through identification of people and spaces playing a role within use-case scenarios. In an even more abstract level, context is understood through social relations and what is perceived as social good. This group of diagrams usually deals with analysing all the factors that influence a creation of a particular use-case. From the user's point of view, it influences the levels of social acceptance, i.e. the ethics that a proposed design system interferes with.

From the five emerged groups, it is observable that diverse diagrams can have same objectives in terms of users' values. It is also observable, however, that same diagrams can have diverse objectives of evaluation as well. Customer Journey Maps, Experience Maps, Mental Model Diagrams, Storyboards, Touchpoint Matrix and Empathy Maps can be suitable for all the five groups of user values. Examples of these maps were touching diverse evaluations of experiences form perceptions, states to contexts. Spatial Maps, Service Blueprints, Ecosystem Models, Stakeholder Maps, Business Model Canvases and Value Proposition Canvases, on the other side, shown not to be so versatile in covering all the values, and these are focusing more on values such as user's requirements, overall service experience, and contexts of interaction.

For all the maps, the perspective of evaluation is the one of the user/customers, except the ones that share this focus also with confrontation with the back-end processes and relations among stakeholders, like Service Blueprints, Ecosystem Models, Stakeholder Maps, Business and Value Proposition Canvases.

For certain maps, like Customer Journeys and Experience Maps, the evaluation was performed in a manner of defining levels of highs and lows in the experience. These were usually represented through a continuous line and/or the emotional line with added facial expressions as well, for positive and negative feelings and states. Mental Model Diagrams and Service Blueprints focus on evaluating the experience of the journey through constant mapping of causes of states and their mutual analysis. Touchpoint Matrix and Spatial Maps are close to this intention as they do focus on journey analysed through touchpoints, but they do not necessarily evaluate the quality

of experience, rather they focus on the manner of representation and reasoning about elements that influence the experience. Storyboards contain a very extensive description of the elements that influence an experience placed within a context, and they evaluate the quality of experience usually through facial expression and monologues of protagonists. Storyboards provide an overall description of the use-case scenario and the contents of all the maps mentioned before, as they contain a chronological timeline, all the touchpoints and context of interaction, the actors as well as the representation of the quality of experience. However, they do not provide a clear analysis of the aspects separately.

Furthermore, Ecosystem Models and Stakeholder Maps focus on the evaluation that is on a higher, more abstracted level of the user case scenario. They do not go in depth with particular moments of interaction, rather they evaluate relations among the actors and stakeholders of the system, and the value exchanges happening between them. Empathy Maps, Value Proposition and Business Model Canvases appear to be all related between them by following the process of scaling the focus from user's self-observer experience towards the third-person observer seeing a macro picture of the service system offerings together with the back-end required activities. Empathy Maps define what users perceive in a certain context as pains and gains, Value Proposition Canvases respond to these needs by defining pain relievers and gain creators, and Business Model Canvases define other elements of the formed design system concept in order for it to be implemented in practices ensuring sustainable development.

Discussion

4.1.4

Confronting the analysed diagrams, both in terms of their structural elements and the user values they refer to, some main considerations emerged observed through differences in approaches within the design process:

1. From Human-Centred to Customer-Centred,
2. From Personal to Social,
3. From Current Scenarios to Future Scenarios.

From Human-Centred to Customer-Centred

When analysing the gathered sample of diagrams, it emerged that the focus of all of the samples was shifting in regard to how a target group was approached. More precisely, the final target appeared to be observed through the lenses that were shifting from general human aspects towards customer features. Human-centred in this case relates to the maps that were analysing ***life events*** and situations, thus having as an aim an understanding of usual daily activities or responses to situations that are not initiated by a designed system. An example is the map "Pregnancy Experience Map" that analyses states during this particular life event (Fig. 134).

Customer-centred approach, on the other hand, relates to a notion of "why the person is our customer", as well as how to make the person become a customer, and keep the person as the customer. This approach relates to an analysis of customer loyalty and influences a design of an overall ***brand image*** of a certain company. Newbery and Farnham (2013) propose a framework for integrating brand, experience, and value, which shows the alignment between customer goals and business goals, on a timeline from becoming a customer and using a product, with the evaluation of experience through engagement. For anticipating success of a product and/or service, authors propose a model for perceived value equal to "(what

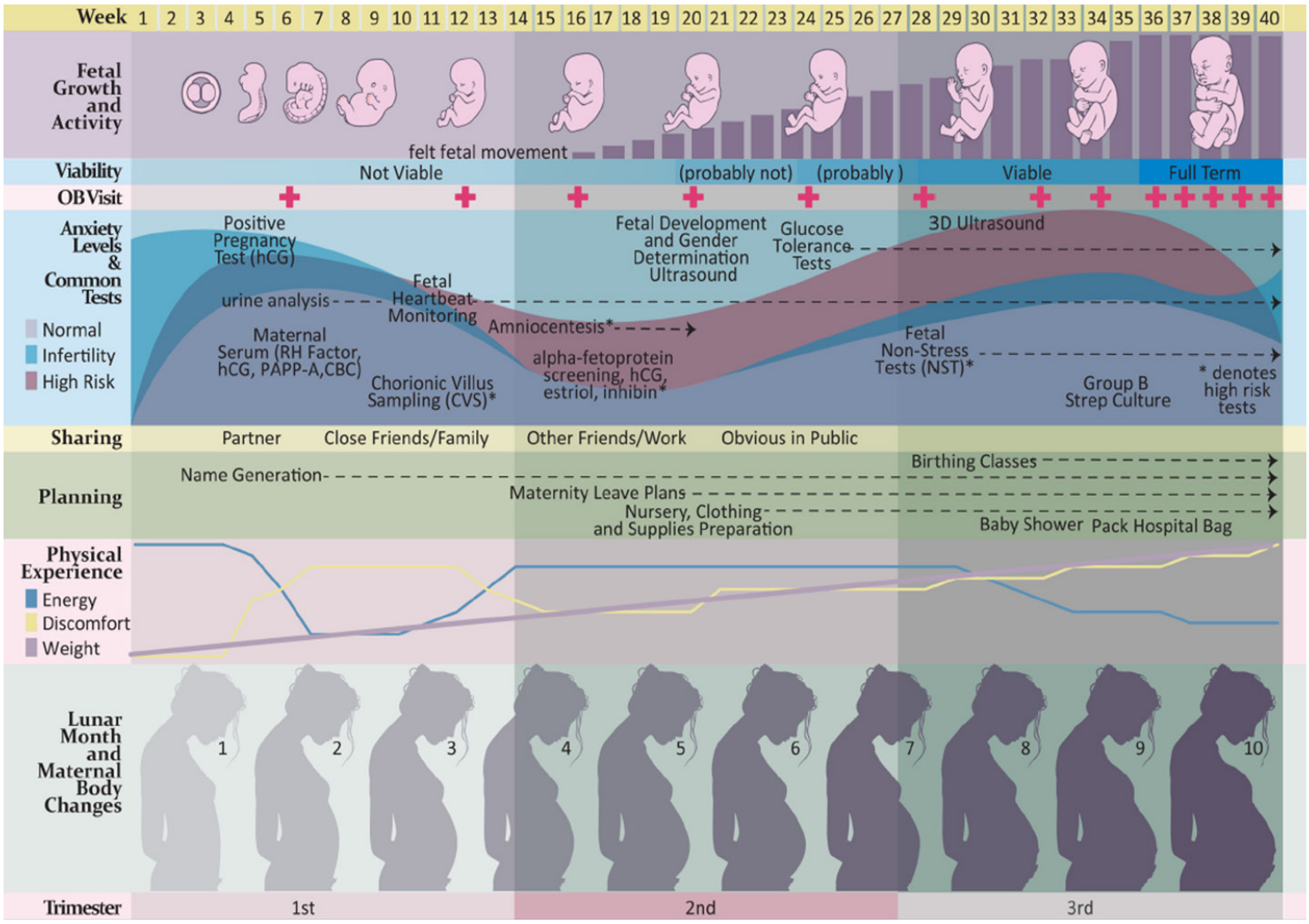


Figure 135. Sample of an Experience Map for a pregnancy journey, showing a human-centric approach while mapping a life event.

Dish Customer Journey Map

This blueprint represents all of the customer facing and behind the scenes interactions involved in setting up satelite TV service.

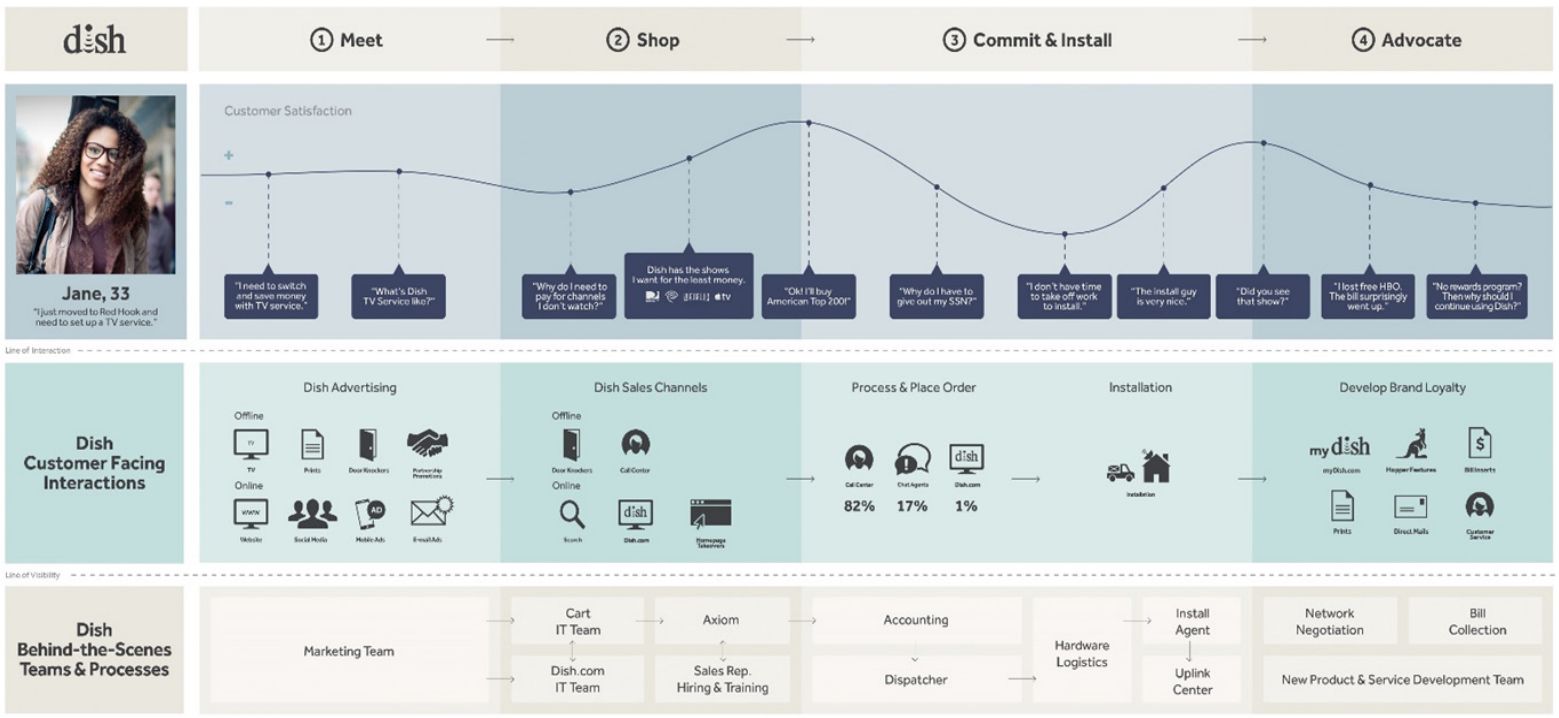


Figure 136. Sample of a Customer Journey Map for setting up a satellite TV service, showing a customer-centric approach while mapping engagement steps within the service.

has been done or provided by a business) - [(customer needs) x (customer expectations)] / customer context". An example for a map focused on customer analysis is represented in the following figure for television provider brand Dish, analysing what customers face when setting up a satellite TV service (Fig. 135).

Customer-centred maps analyse "value" as perceived through customers eyes, as it relates to a brand image. In-between the human and customer focused approaches, there is, however, another group that consults different peculiarity of values. This group refers to target categories as users. Users become a focus when a design system is not strictly related to building a particular brand communication, rather it is an outcome of a multi-stakeholder environment. The user-centred approach does imply having the evaluation confronted in relation with a particular design system, so it is not human-centred neither, considering the previous description of this group. An example of a user-centred journey is presented in the following visual, where the focus of the journey is on the ***interactions with a design system*** showing values of the system perceived as such from the side of the user. Namely, the visual represents the use of a newly designed connected device showing advantages of having a flexible wallet management for a new manner of transferring funds during purchase in-store, as well as supporting social transactions (Fig. 136).

From Personal to Social

Analysing the gathered tools, another observation that emerged is that their focus is shifting from personal to social scales. This can be understood as a method of zooming-in and zooming-out the perspective of evaluation of an experience. Personal perspective is the one that represents ***first-person observations***, analysing particular perceptions in regard to the surrounding that are commonly represented through hypothesis on internal thoughts. Examples of these tools are Empathy Maps (Fig.137), that in essence synthesize user research to better understand target groups.

Social perspective, on the opposite side, considers values that might concern a society, rather than just a target group, and/or a particular persona. This is usually represented as a ***third-observer point of a view.*** In the following example (Fig. 138) a car-sharing

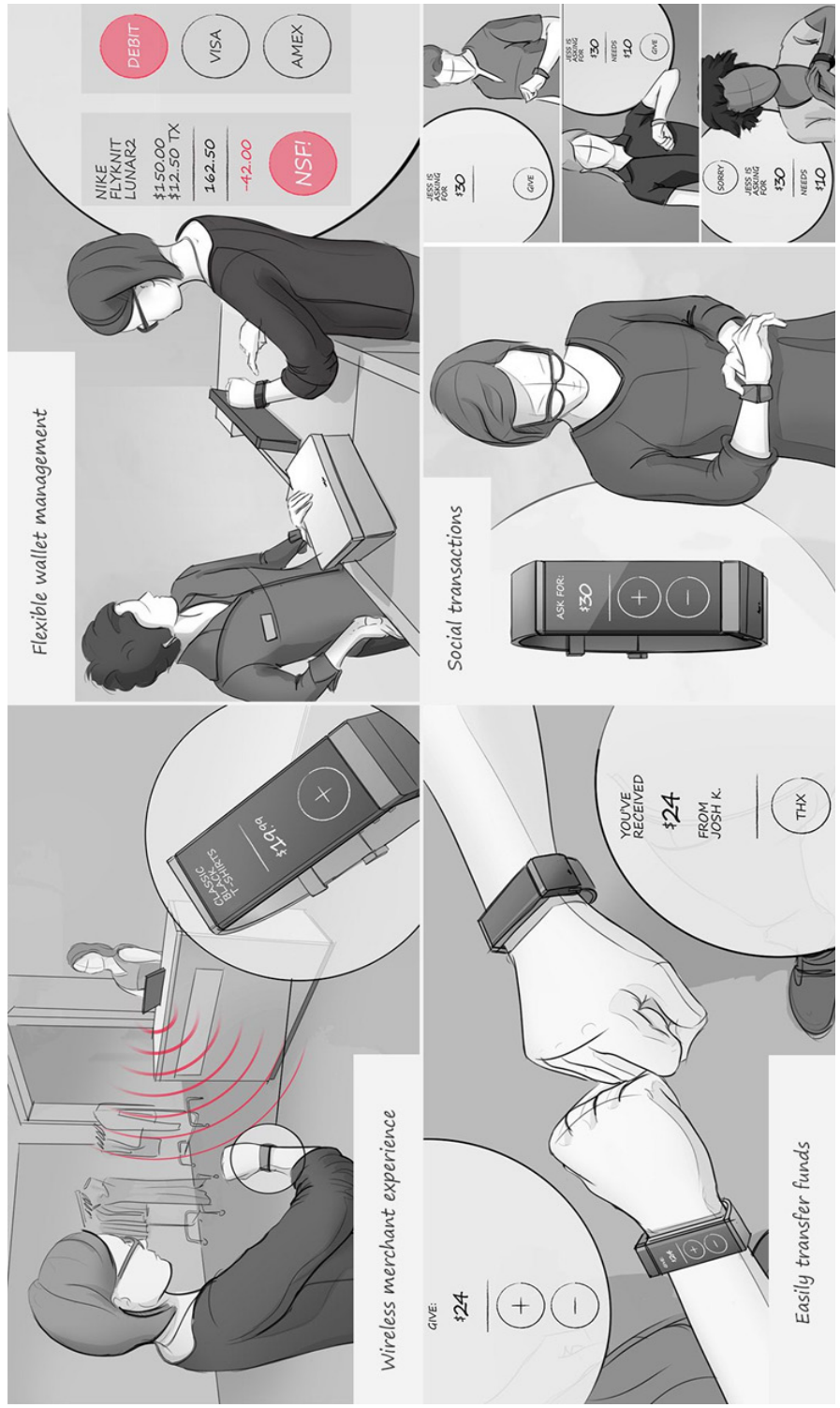


Figure 137. Sample of a Storyboard for a flexible wallet management service, showing a user-centric approach while mapping an interaction with a novel device through a purchase journey.

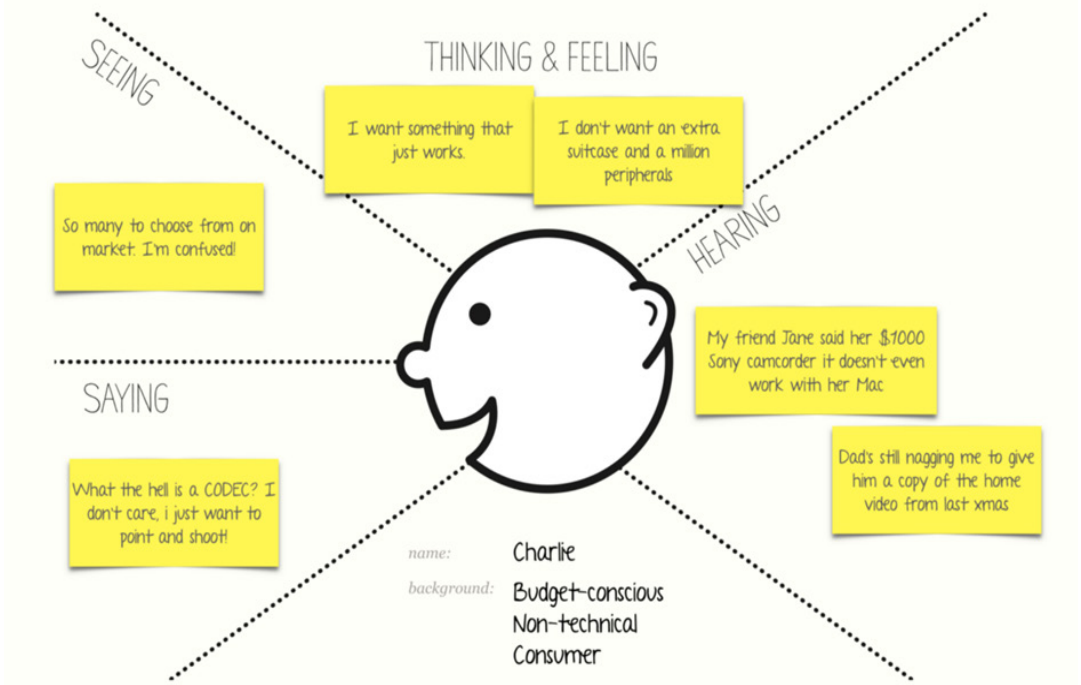


Figure 138. Sample of an Empathy Map for a purchase journey, showing a first-person perspective.

service system was analysed, which mapped motivations for implementing the service as benefits on societal level, like for e.g. employing shared journeys for reducing pollution (deriving from exhaust gasses of vehicles) in the environment. It is to underline, however, that these kinds of maps are quite rare in the gathered sample and can be found only among those that, in a certain way, consider a context around the interaction.

From Current Scenarios to Future Scenarios

The third, last, group that comprises a shifting of focuses is the one that deals with the shift from existing to potential new experiences. Namely, the tool here are observed as the ones might address the mapping of current states of experiences in confrontation to the ones that are being planned for and would be provoke intentionally. Current scenarios refer to current perceptions, states, and contexts of an experience that can be analysed though a research conducted

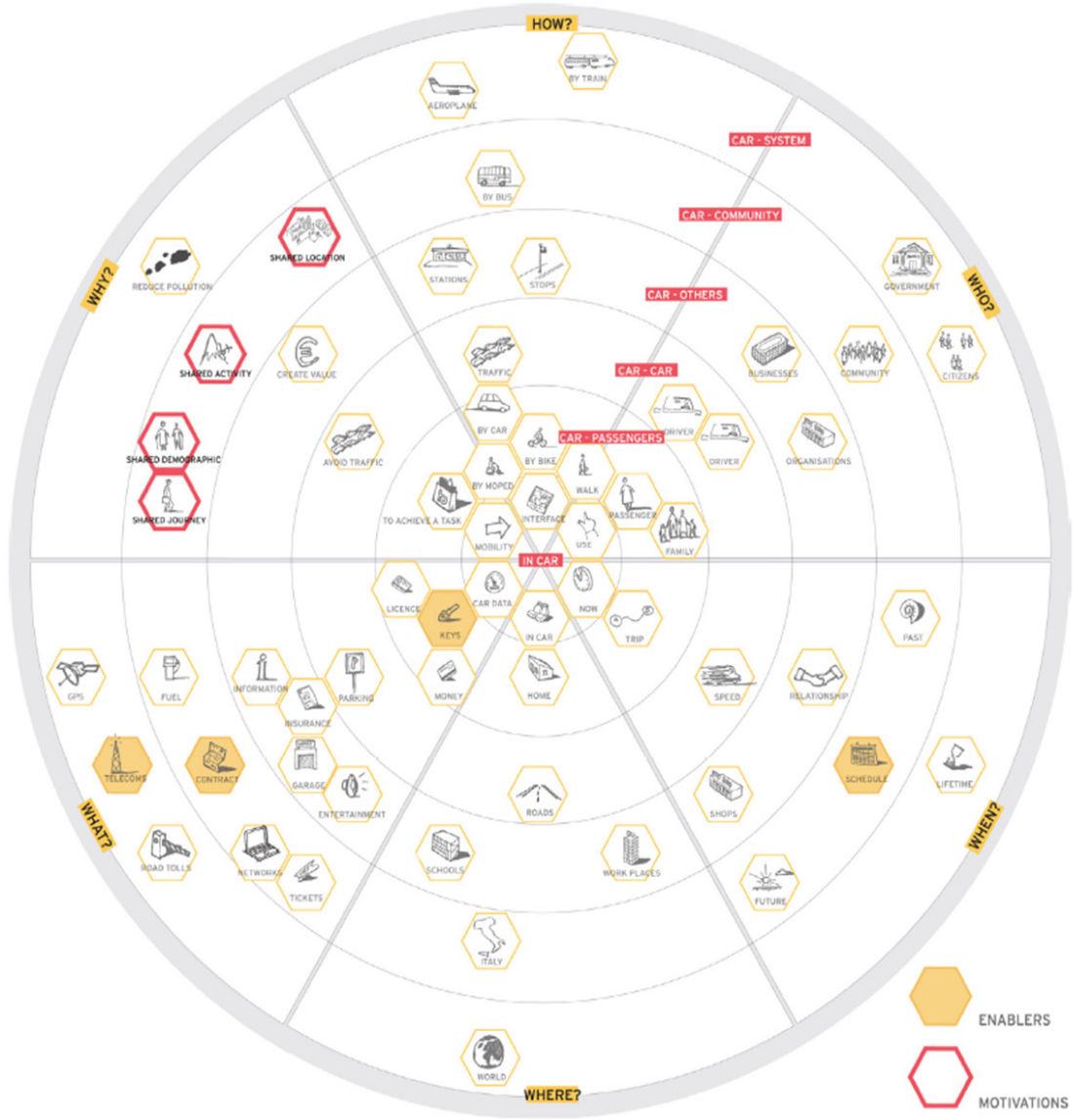


Figure 139. Sample of an Ecosystem Model for a car-sharing service system, showing a third-observer perspective.

within an existing scenario. Besides life events, current scenarios relate to an ***analysis of existent design systems***. An example is shown in the following visual (Fig. 139), where existent experience

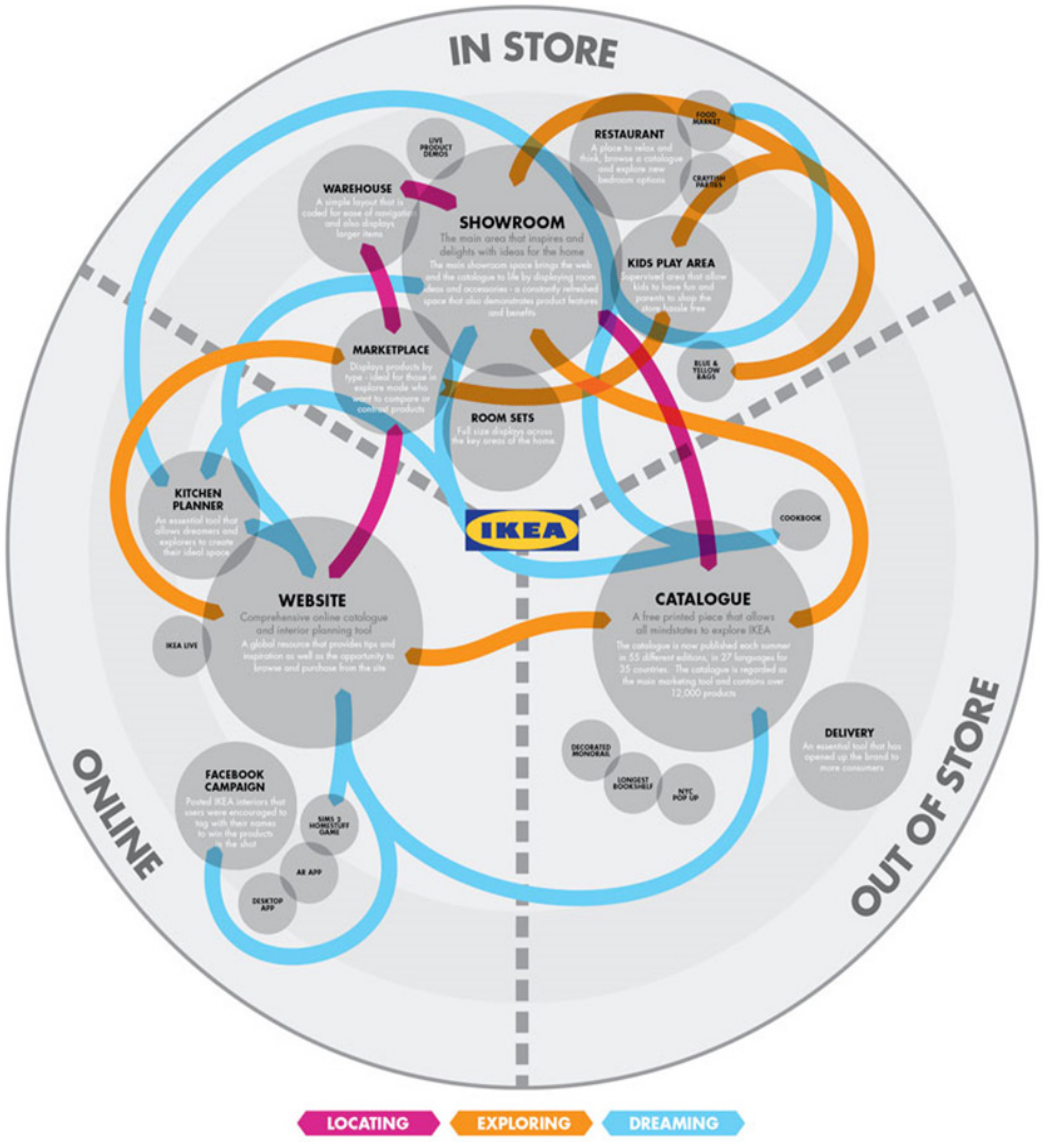


Figure 140. Sample of a Touchpoint Matrix for Ikea purchase journeys, showing an analysis of an existent design system.

journeys related to purchases online, in store and out of store of Ikea brand are analysed as all the possible activities one can exercise being a customer of this brand.

Maps that focus on future scenarios emphasize the alignment between design systems and desirable future experiences. More precisely, they deal with ***planning for a new***, non-existent, ***design system*** according to identified values. Usual examples of such maps are Value Proposition (Fig. 140) and Business Model Canvases.

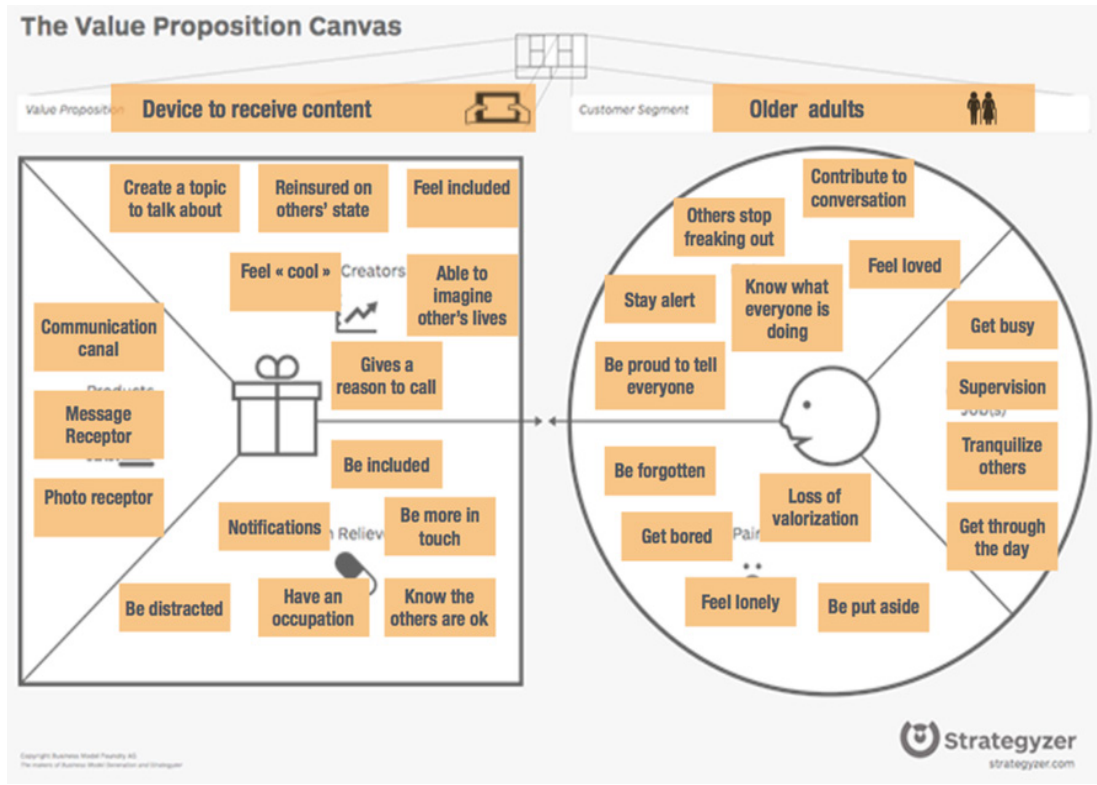


Figure 141. Sample of a Value Proposition Canvas for an entertainment service for elderly, supporting planning for a new design system.

FOCUS ISSUES	*Human-Centred*	*Customer-Centred*	*Personal*	*Social*	*Current Scenario*	*Future Scenario*
Perceptions	X		X		X	
States	X		X		X	
Requirements	X	X	X			X
Service Experience		X	X		X	
Interaction Context		X	X	X	X	X

Table 8: Previously identified focus issues for user values among the sample tools are placed within these overall considerations on focuses.

Summarized:

- User's Perceptions - Human-Centred, Personal, Current Scenarios,
- User's States - Human-Centred, Personal, Current Scenarios,
- User's Requirements - Human-Centred & Customer-Centred, Personal, Future Scenarios,
- User's Service Experience - Customer-Centred, Personal, Current Scenarios,
- User's Interaction Context - Customer-Centred, Personal & Social, Current Scenarios & Future Scenarios.

In terms of user values, all the gathered tools can be categorized among the focus issues (Perceptions, States, Requirements, Service Experience, Interaction Context) and the shifts in perspective of the focus (Human to Customer-centred, Personal to Social, Current to Future Scenarios). One tool does not cover all of these aspects, while certain tools in-between them have a lot of similarities and can be grouped. An example are Customer Journey Maps and Experience Maps that have almost the same structure and their focus in the approach differs, from human-centred to customer-centred. Furthermore, Touchpoint Matrix, Spatial Maps, and Mental Model Diagrams seem to be suitable to enter in the same group with the previous two tools, as the structure based on timeline and touchpoints overlaps, as well as the idea of an evaluation from a personal, rather than social, journey perspective. Service Blueprints, Ecosystem Model and Stakeholder Maps are a group of tools that furthers the back-end side of the system aligned with the experience journey, having Business Model Canvases as a tool that provides a very larger overview on business considerations. As mentioned previously, Empathy Maps, Value Proposition and Business Model Canvases are related and providing an analysis perspective based on zooming-in and out of the first-person experiences.

It is to note that the gathered tools that analyse user values surely allow for and require merging into groups, that might follow sequences within a design process, main focuses and approaches. This might help establishing design processes based on same frameworks and ease the utility of tools during the process. They further need more clearance, as some tools have established structures (e.g. Value Proposition and Business Model Canvases), while others still vary a lot in terms of parameters they consider (e.g. Customer Journey and Experience Maps).

4.2 CONFRONTATION WITH THE AMBIENT UX DESIGN FRAMEWORK

In this section, a confrontation between the conceptual Ambient UX framework, established previously (Chapter 2), and the gathered design tools is analysed and discussed. Analysis is made according to Design Domains and User Values deriving from the conceptual framework.

Recap of the Design Framework

Design Domains are defined as:

- Three Architectures
  - Spatial,
  - Informational,
  - Relational,
- Time as a variable.

User Values are defined as:

- Usability,
- Meanings & Motivations,
- Social Consensus.

Comparison Scheme for Each of the Tools 4.2.1

Design Domains

Representation of three architectures (Spatial-S, Informational-I, Relational-R) and Time as a variable are analyzed within the tools. The architectures are compared through Touchpoints rapresented in the tools, where also multi-paths are observable. In terms of Time, gathered tools are analysed according to:

- Long-term use (pre-service, service, post-service period; day to weeks, months to years),
- One-day use (by hours almost),
- / (no time frame considered).

User Values

Here tools are compared through a discussion based on the findings from the previous analysis on user values; namely, referring to evaluation of experiences in terms of Usability, Meanings & Motivations, and Social consensus.

Customer Journey Maps

Considered experience values

As some of the diagrams refer to an evaluation of an existing service system, they enter the levels of usability and mostly, the utility of the same. For understanding usability, the actual prototype needs to be evaluated, which is not usually the case with the gathered diagrams. On the other side, the ones that refer to planning of a new service system are entering the level of creation of meanings and motivations over time. The aspect of social context and acceptability are almost not considered, as all of the maps are strongly focused on a

personal journey that explains very detailed elements of interaction, rather that broader consequences of the same.

Considered type of Architecture occurred across how many samples

I - 58

R - 57

S - 40

/ - 5

Considered possibility for observing alternative routes occurred across how many samples

No - 27

Yes - 40

The representations leave the possibility to consider another path, but they are not explicitly visualized nor analysed.

Considered time spans (Fig. 141)

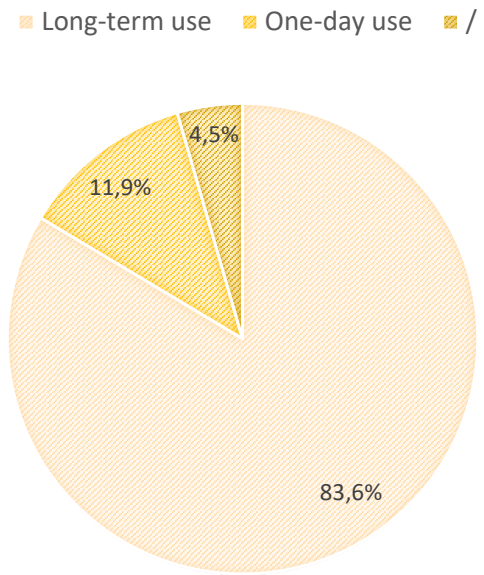


Figure 142.
Timeline scales considered within the gathered samples of Customer Journey Maps.

Experience Maps

Considered experience values

The diagrams focus on a general human activity within a given domain, and they analyse behaviour within a particular life event and allow for planning of a new service or identifying opportunities for improving a service. As such, the diagrams enter the levels of usability and perceived utility. Most of all, they cover the level of creation of meanings as they analyse behaviour and states for planning for new service systems. The aspect of social context and acceptability is hardly considered since the journeys that are presented are very personal and relate mostly to perceptions, states and requirements within an event.

Considered type of Architecture occurred across how many samples

I - 30

R - 29

S - 26

/ - 1

Considered possibility for observing alternative routes occurred across how many samples

No - 15

Yes - 17

Considered time spans (Fig. 142)

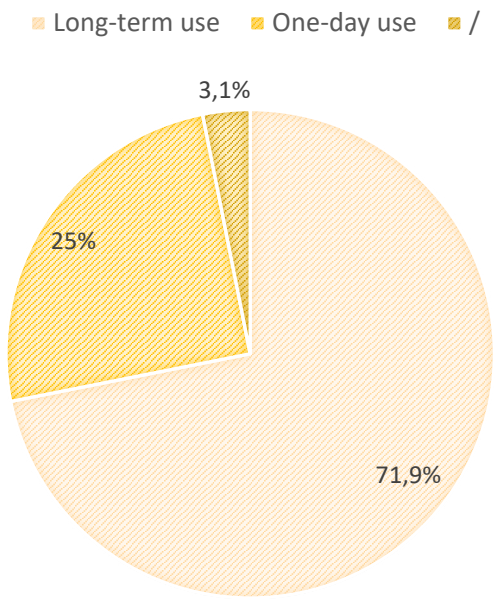


Figure 143.
Timeline scales considered within the gathered samples of Experience Maps.

Mental Model Diagrams

Considered experience values

The diagrams are mostly identifying opportunities for improving a service and/or planning for a new service. They are based on an analysis of personal goals and the activities that respond to a dilemma of how to reach the goals. In these terms, the diagrams comply with personal means, hierarchy and relation of personal needs, goals and activities which enter the value level of creation of meanings and motivations. They reflect creation of a particular mental model when analysing diversity of options for conducting a desired activity, and this enables shaping and comprehension of a customer segment according to the built mental model. The mapping presents confrontation of motivation and actions analysis of possibilities needed to respond to a higher action and goal, as such they can respond to perceived utility and usability as well. The aspect of social context and acceptability, the same as in Customer Journey and Experience Maps, are not considered.

Considered type of Architecture occurred across how many samples

I - 5

R - 6

S - 5

/ - 2

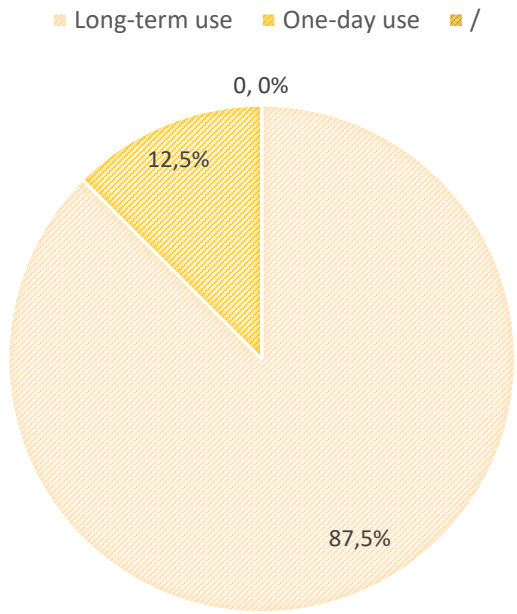
Considered possibility for observing alternative routes occurred across how many samples

No - 2

Yes - 6

Considered time spans (Fig. 143)

Figure 144.
Timeline scales considered within the gathered samples of Mental Model Diagrams.



Service Blueprints

Considered experience values

Gathered maps from this group usually do not support the mapping activity for evaluating users' experience. They are mostly analysing an existing service and/or planning for a new service system by representing the back-stage operations and aligning them with users'/customers' activities on the front-stage. User's values, however, are not represented in the majority of the cases, and where they are present, they reflect, for e.g., analysis of service success according to communication between actors, or analysing steps of the journey while considering the in-between waiting moments as important parts of the journey. Consequently, the gathered maps from this group are entering the levels of creation of meanings and motivations, while usability and socio-ethical elements are not considered.

Considered type of Architecture occurred across how many samples

I - 11

R - 12

S - 13

/ - 0

For the Spatial architecture, in the analysis I refer to physical/ spatial elements, which is something that appears in Service Blueprints as "Physical Evidence".

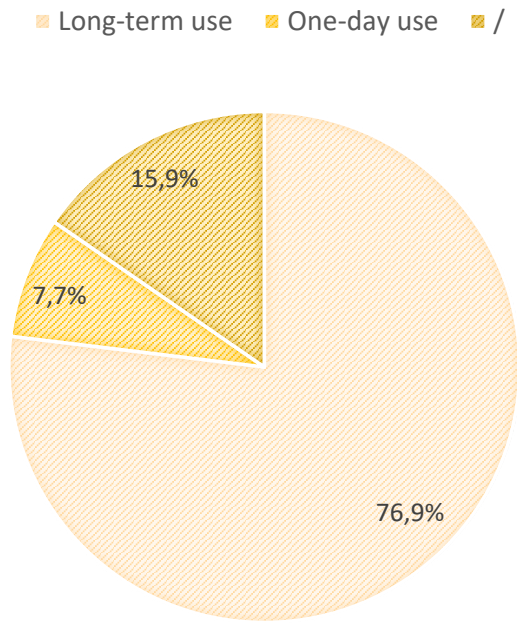
Considered possibility for observing alternative routes occurred across how many samples

No - 11

Yes - 2

Considered time spans (Fig. 144)

Figure 145. Timeline scales considered within the gathered samples of Service Blueprints.



Spatial Maps

Considered experience values

The maps mostly deal with analysing an existing service and demonstrating how a service works, while one of them targets also an analysis of internal company organization. Almost none of them consider direct evaluation of users' values, rather they rely on the representation of the system and the relation between elements, like for e.g. analysing needs and goals in interaction between co-workers (example from one of the maps). Gathered Spatial Maps do not actually evaluate interactions with spatial elements, they are a visual representation of a system that relies on spatial manner of visualising and organizing information. Correspondingly, the maps do not deal with usability, neither the social acceptability nor meanings.

Considered type of Architecture occurred across how many samples

I - 5

R - 4

S - 4

/ - 1

Considered possibility for observing alternative routes occurred across how many samples

No - 1

Yes - 6

Considered time spans (Fig. 145)

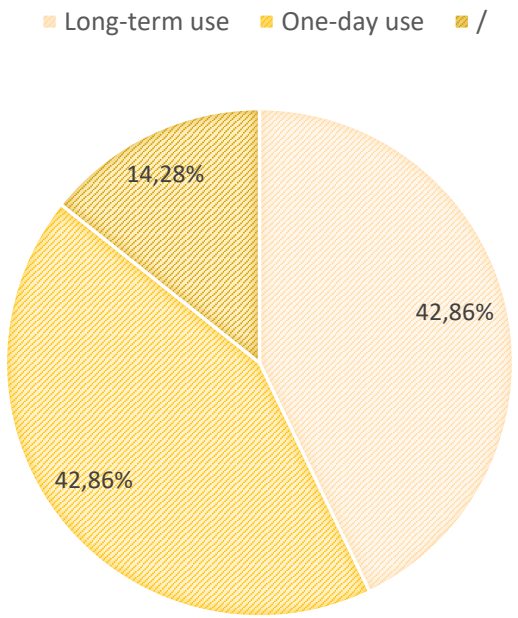


Figure 146.
Timeline scales considered within the gathered samples of Spatial Maps.

Considered experience values

Main aims for the gathered diagrams are planning for a new service and demonstrating how a service works. Similar to Spatial Maps, most of these diagrams do not consider direct evaluation of

Ecosystem Models

users' values, rather they rely on the representation of the system and relation between elements, as well as the assumption of having users' values read in the relations of the ecosystem's elements. They deal with, for e.g., an analysis of all the factors that influence a creation of a particular use case, or confrontation of customer's and providers' gains within an ecosystem. In this context, main flows between the representatives of the ecosystem are presented, such as the material, information and financial flow. These are considered to be the gains that should be balanced among all the parties for ensuring a successful functioning of the ecosystem. Diagrams do not deal with evaluation of usability, rather they expand on a more abstract level of system evaluation, that touches the creation of meanings and motivations, and, in some diagrams also the social context. Namely, some of the maps do consider contexts within the visuals, as the abstraction level that an ecosystem overview provides allows for zooming out from a personal to a broader perspective.

Considered type of Architecture occurred across how many samples

I - 13

R - 10

S - 9

/ - 2

Considered possibility for observing alternative routes occurred across how many samples

No - 4

Yes - 12

Considered time spans (Fig. 146)

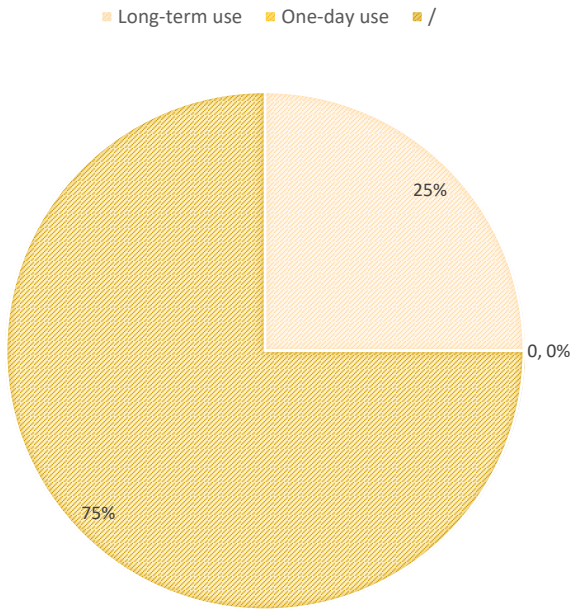


Figure 147.
Timeline scales considered within the gathered samples of Ecosystem Models.

Considered experience values

The maps aim for planning for a new service and/or analysing primary and secondary stakeholders within the service system. Almost none of them considers directly the evaluation of users'/ customer's experience. The ones that do so, aim for, for e.g., an analysis of all the actors and strength of their influence and relations towards the user, or analysis of all the factors that influence a creation of a particular use case. Stakeholder Maps can be grouped with Ecosystem Models and Spatial Maps in this case, as they also do not consider usability, but eventually the creation of meanings and motivations among the relations established within the system. They could potentially enter the level of social contexts because of the abstracted system overview they provide, however, they do not provide a direct discussion on user's/customer's values within a social context, as the gathered examples so far only demonstrate the connections between the actors.

Considered type of Architecture occurred across how many samples

Stakeholder Maps

I - 6

R - 8

S - 8

/ - 8

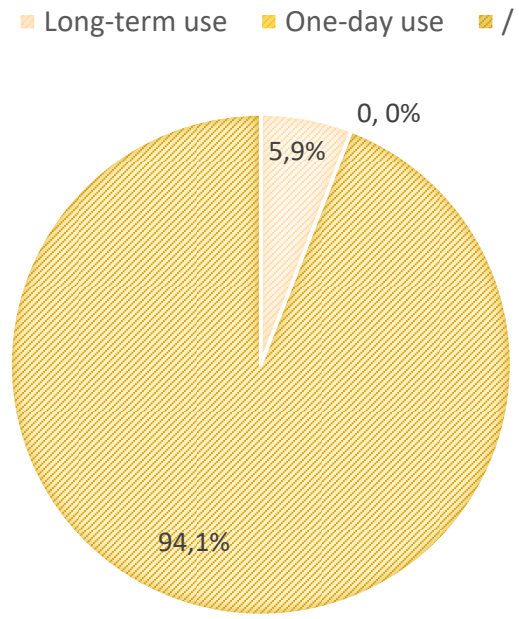
Considered possibility for observing alternative routes occurred across how many samples

No - 13

Yes - 4

Considered time spans (Fig. 147)

Figure 148.
Timeline scales considered within the gathered samples of Stakeholder Maps.



Storyboards

Considered experience values

The aim of gathered Storyboards is mostly demonstrating how a service works and/or demonstrating a problem that the new design system solves. The approach for pointing out user's values is setting a story with the user as main character (protagonist) to support a new system solution. Demonstration of a perfect fit of the service with the customer's daily intentions and needs is a usual practice, as well as analysis of the service according to estimation of experience being positive or negative for identifying opportunities for improvement. Storyboards as tools for mapping user journey experiences are convenient for pointing out values of usability. They are convenient for discussing experiences from a first-person perspective as they allow for evaluation of a particular moment of interaction with particular touchpoint elements. An overall of the storytelling brings to an evaluation of the level of meanings in relation to a particular design system, which is sometimes not said explicitly, but it is imposed and understood from the context of the story. Because of the first-person perspective, social acceptability is not represented within these maps.

Considered type of Architecture occurred across how many samples

I - 13

R - 8

S - 12

/ - 0

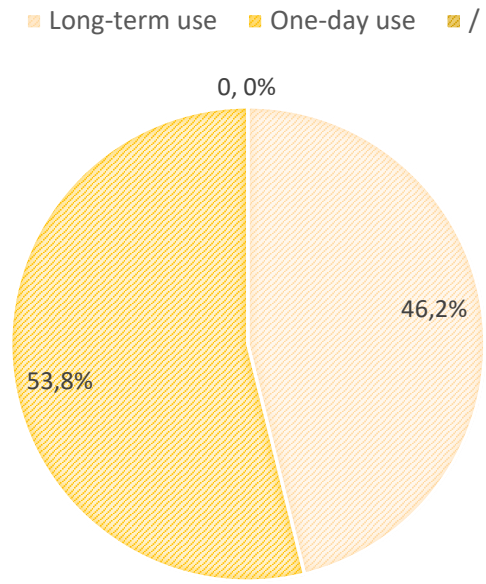
Considered possibility for observing alternative routes occurred across how many samples

No - 13

Yes - 0

Considered time spans (Fig. 148)

Figure 149. Timeline scales considered within the gathered samples of Storyboards.



Touchpoint Matrix

Considered experience values

The gathered diagrams are often demonstrating service offerings through multiple journeys, analysing cross-channel touchpoints, and thus, analysing an existing service system. Majority of the diagrams does not consider direct evaluation of user's experience, rather they serve as representation of the journey across various elements. From some of them it is understood that a shorter journey, for e.g., would imply that the optimal experience has been reached. The ones that have an aim to underline user's values, do so by, for e.g., analysing the points where the journey appears as broken in the moments of encountered pain points. Certain maps focus on analysing marketing success by identifying marketing influence throughout the journey, while others focus on analysing multiple paths and intentions a user/customer has for choosing a particular path over another. One diagram example had as a main aim evaluation of customer's goals and monetary value, for analysing and planning for new product launch marketing strategy and budget estimation. Touchpoint Matrixes are convenient for strategical planning, therefore they enter the level of creation of meanings and motivations, as well as utility of a proposed design system. They might be convenient for usability values as well, as they underline interaction with every touchpoint.

However, the gathered maps do not show detailed evaluation of usability, rather they focus on observing a journey flow. By focusing on journey flows the maps do not consider social acceptability as user values.

Considered type of Architecture occurred across how many samples

I - 17

R - 16

S - 16

/ - 0

Considered possibility for observing alternative routes occurred across how many samples

No - 3

Yes - 15

Considered time spans (Fig. 149)

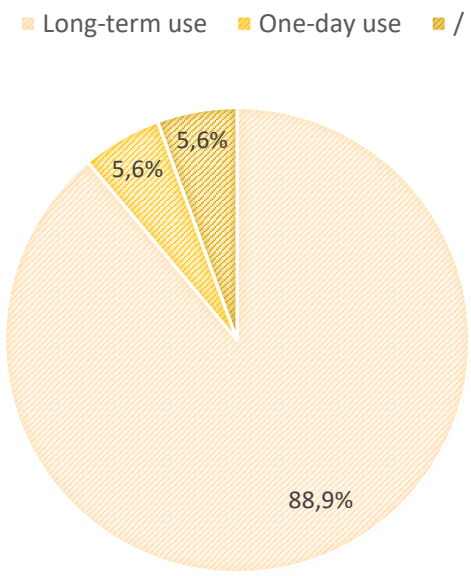


Figure 150.
Timeline scales considered within the gathered samples of Touchpoint Matrix.

Business Model Canvases

Considered experience values

The canvases aim for setting up a business plan and strategy, and, by doing so, they always have a defined customer segmentation. In the field of the canvas that regards the customers, the evaluation of a service system is based upon value propositions for customers for creating, enabling and maintaining customer relationships. Planning for a new service system though business model canvases happens through market analysis and hypothesis on user values. User values in this context are seen as needs and requirements that should be satisfied, but they are also tightly related to perceived monetary values. This brings to a conclusion that the canvases do not consider usability and social acceptability, while utility and creation of meanings and motivations might enter the field of value proposition.

Considered type of Architecture occurred across how many samples

I - 0

R - 0

S - 0

/ - 6

Considered possibility for observing alternative routes occurred across how many samples

No - 6

Yes - 0

Considered time spans (Fig. 150)

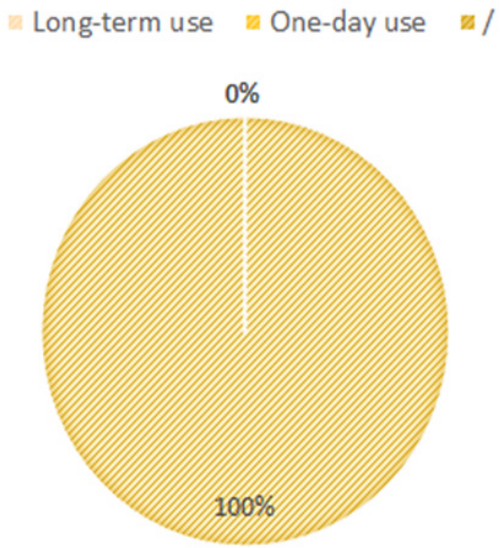


Figure 151.
Timeline scales considered within the gathered samples of Business Model Canvases.

Value Proposition Canvases

Considered experience values

These diagrams aim for planning for a new service design system. By doing so, they are in the same group of Business Model Canvases, as they consider customer segment and value proposition for target groups. These diagrams are based on confrontation and overlapping between the two diagrams where one relates to the customer segment and other to value proposition. First group relates to customer jobs and perceived pains and gains, while the second relates to pain relievers and gain creators upon which the design system solution is built. Gains are the positive and pains the negative sides of user's/ customer's activities and they are in tight relation with the target groups' wants, needs and fears, intended experiences and benefits. User values in these diagrams are within the levels of creation of meanings and motivations, while usability and social acceptability are again not being considered.

Considered type of Architecture occurred across how many samples

I - 0

R - 0

S - 0

/ - 6

Considered possibility for observing alternative routes occurred across how many samples

No - 6

Yes - 0

Considered time spans (Fig. 151)

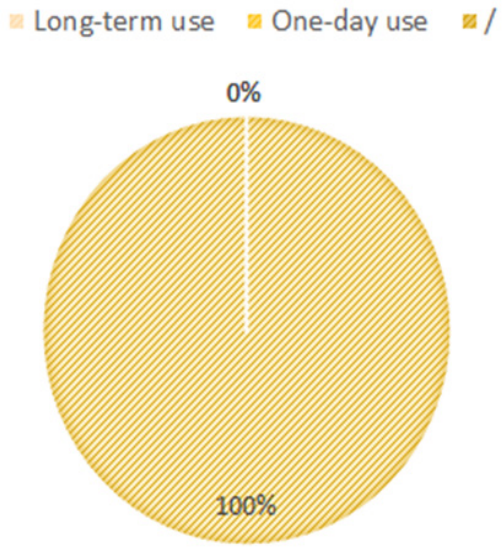


Figure 152.
Timeline scales considered within the gathered samples of Value Proposition Canvases.

Empathy Maps

Considered experience values

The gathered maps show as a way to synthesize research for better understanding the users/customers. They aim for mapping out how does a user feel, what does he/she see, hear and do, what does he/she feel consequentially, and how does all of this relate to his/her overall

goals. In this context, pains and gains are identified describing user's/ customer's requirements that will further guide shaping of a new design system. The same as Business Model and Value Proposition Canvases, the Empathy Maps consider user values within the levels of creation of meanings and motivations, while usability and social acceptability are not being considered.

Considered type of Architecture occurred across how many samples

I - 0

R - 0

S - 0

/ - 8

Considered possibility for observing alternative routes occurred across how many samples

No - 8

Yes - 0

Considered time spans (Fig. 152)

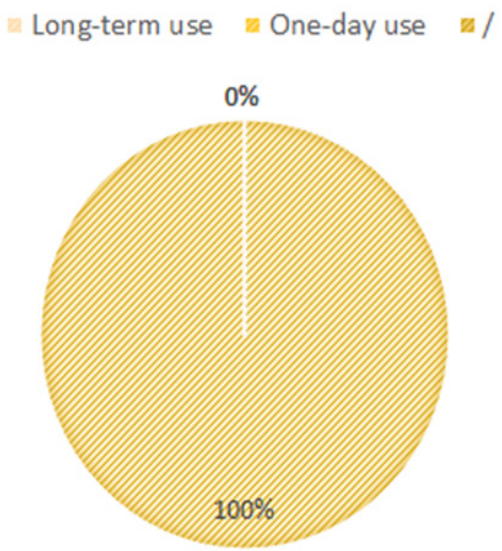


Figure 153.
Timeline scales considered within the gathered samples of Empathy Maps.

Overall Results

4.2.2

The conducted analysis reflects the correlation between the gathered samples of design tools and the conceptual Ambient UX framework. More precisely, it provides insights on points that overlap as well as the mismatches between the two.

About Design Domains

For confronting defined Ambient UX Design Domains and the ones represented trough the gathered visuals, the analysis focused on two main groups, putting the three architectures (spatial, informational, relational) into one and the element of time in the other group. Besides these, the analysis also contains observations on possibility of having multiple path journeys within the sample visual, as well as the defined structure elements of the tool.

Touchpoint Inventory

Relational architecture was observed through "Actors": customer's friend, administrator, group members, non-group members, administrator, restaurant staff, medical staff, sales representative, service staff, other unknown passenger, sales and technician staff, scheduler, nurse, doctor, other drivers, waitress, cook, manager, car borrower, car owner, tourist, working staff, parents, children, community people, office colleagues, family

grouped: working staff is most common ... e.g. for an exhibition group "diverse working staff, visitors, researchers, tourists, donors, curators, designers", or in a medical context "family, friends, medical staff, teachers, supporting staff, insurance staff"

Informational architecture was observed through "Platform channels" for communication and exchange of information: websites, emails, phone calls, sms, social networks, calendar, marketing/adds,

app/game, app, paper note orders, spatial displays, catalogue, game, wayfinding, infographics, ticket machine, digital kiosk interface

grouped: most common are website, app, email, phone call

Informational architecture is not well defined in these maps. The channels of communication are defined and provide an overall idea on the network of information exchange, while the content of the communication is hardly touched in a detailed scale.

Spatial architecture is actually represented through physical elements of any kind, it does not refer to a space as an ambient, but a physical element like a device. Spatial architecture in terms of an ambient would be rather a representation of a context within the maps, which appeared in just few maps in overall. When considering a spatial context, the architecture was observed through "Physical/ Spatial elements": car parking, hospital centre, reception, waiting room, in store, airport, samples, waiting room, appointment room, check-in desk, concert hall, car, train station, restaurant, urban outdoor, tourist agency, children centre, urban farm, bikes, bike repair shops, office space, gaming console, home, exhibition space, bar, train, branch ATM, school, conference venue, front desk, waiting room, hallway, exam room, check-out room, hotel reception, room, lobby

grouped: by journeys, like for e.g. hotel reception, room, lobby... connection between particular places brings value like for e.g. hotel, library journey for a tourist

The platform channels are quite standard, while the actors and places vary depending on the context and case. Furthermore, platform channels are always defined and underlined, while the spatial architectures taken from the context and is usually not consider in the evaluation, rather it is there to complete the storytelling. Touchpoint Matrixes consider all the standard platform channels and occasionally spatial context as well, like for e.g. in-store journeys mapped together with online channels for purchases. Actors are well defined only in particular mapping systems like Ecosystem Models and Stakeholder Maps. In the following the sum for all the architectures within all the tools are presented (Fig. 153). It appears that three architectures are represented in almost similar amount, but these amounts vary a lot depending on the tool.

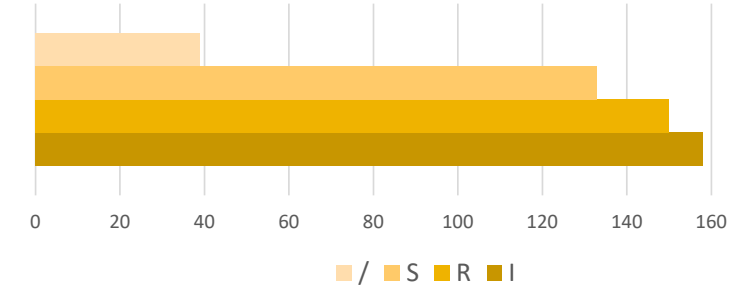


Figure 154. Representation of all the architectures in all of the gathered tools, shown through numbers of tools: Spatial (S), Informational (I), Relational (R), no architecture represented (/).

In the following, all the tools are confronted together for understanding which of the architectures each of the tools supports in representation (Fig. 154).

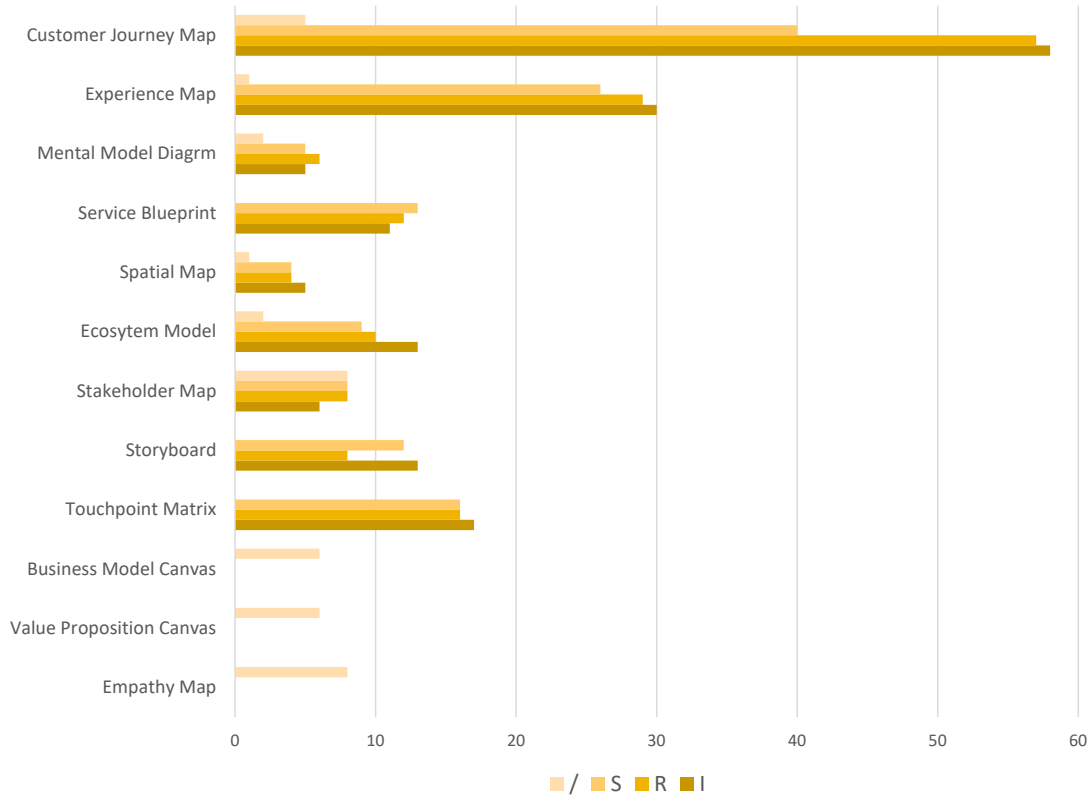


Figure 155. Representation of all the architectures in each of the gathered tools thematic groups, shown in number of tools: Spatial (S), Informational (I), Relational (R), no architecture represented (/).

Tools like Empathy Map, Value Proposition and Business Model Canvas essentially do not refer to the three architectures. In most of other tools the informational architecture appears to be the dominant one.

Furthermore, all of the gathered tools are analysed according to time scales of user engagement that they employ (Fig. 155 & 156).

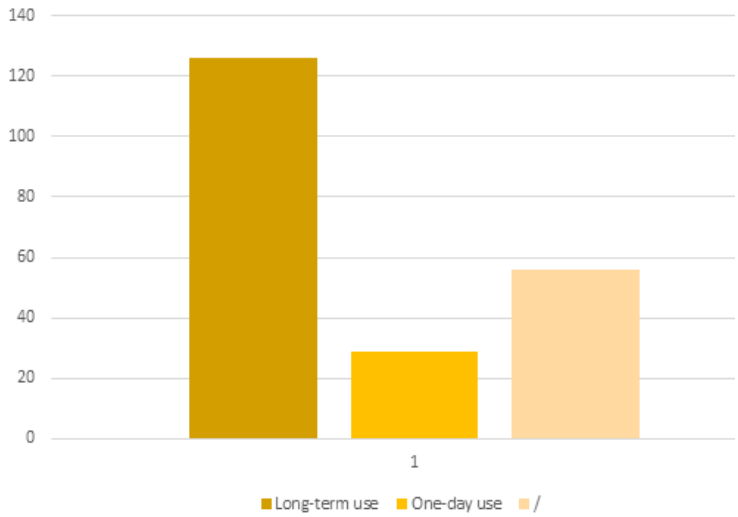


Figure 156. Representation of diverse timeline scales in all of the gathered tools, shown through numbers of tools: Long-term use, One-day use, No time scale represented (/).

Tools like Empathy Map, Value Proposition and Business Model Canvas do not consider any timeline. In addition, Ecosystem Models and Stakeholder Maps provide an element of a timeline in just very few cases. Customer Journey, Experience Map, Service Blueprint and Touchpoint Matrix tend in overall to discuss a long-term usage and user engagement. The one-day usage is a dominant representation method in tools such as Storyboards.

Allowing for multiple-path journeys/ moments of truth/ phases with alternative routes are analysed across the gathered tools as well (Fig. 157 & 158).

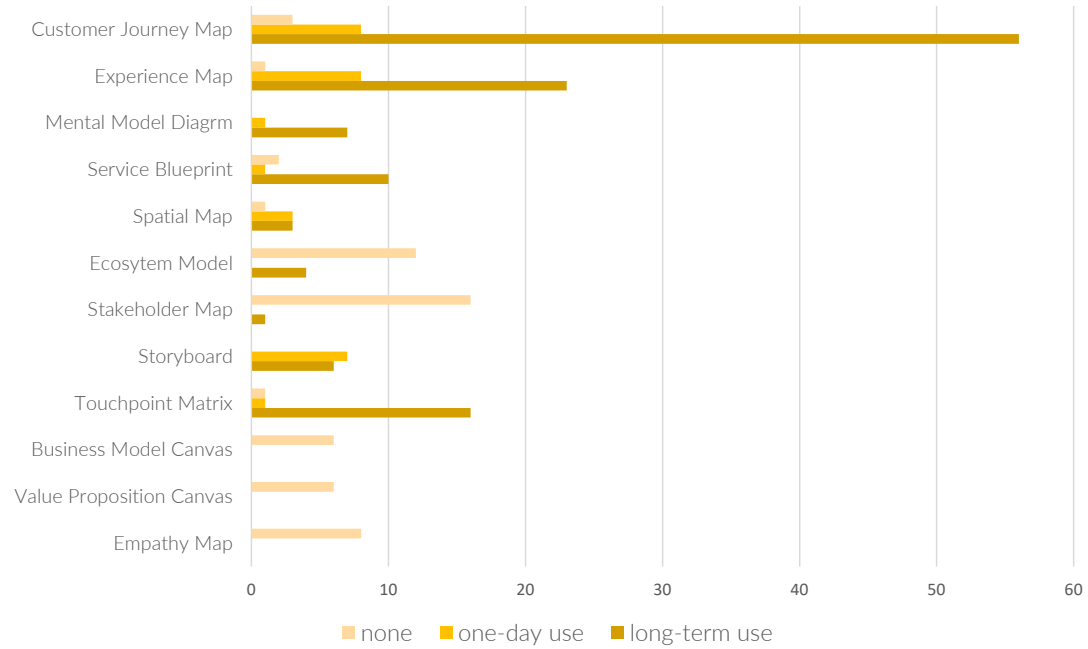
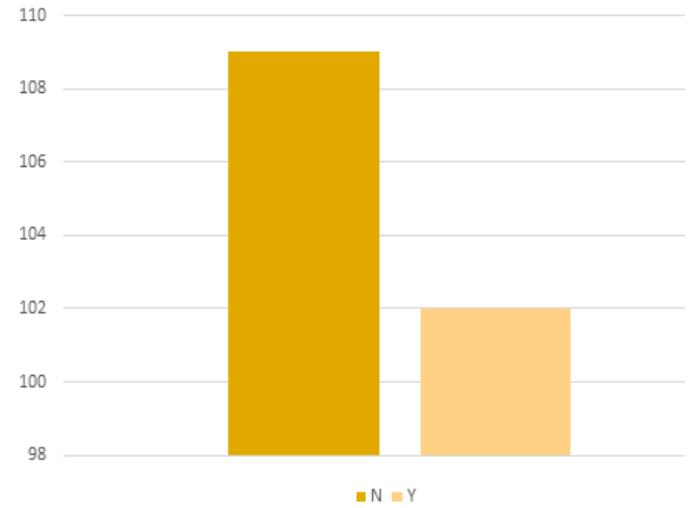


Figure 157. Representation of diverse timeline scales in each of the gathered tools thematic groups, shown through numbers of tools: Long-term use, One-day use, No time scale represented (/).

Figure 158. Possibility of representing alternative paths in all of the gathered tools, shown through numbers of tools: There is a possibility to read alterative paths (Y), There is no possibility to read alterative paths (N).



The results vary a lot in regard to the particular tool. It appears that the tools that are most likely to enable a process of considering and analysing alternative paths, in regard to the same use-case scenario, are Customer Journey Maps, Experience Maps, Ecosystem Model and Touchpoint Matrix.

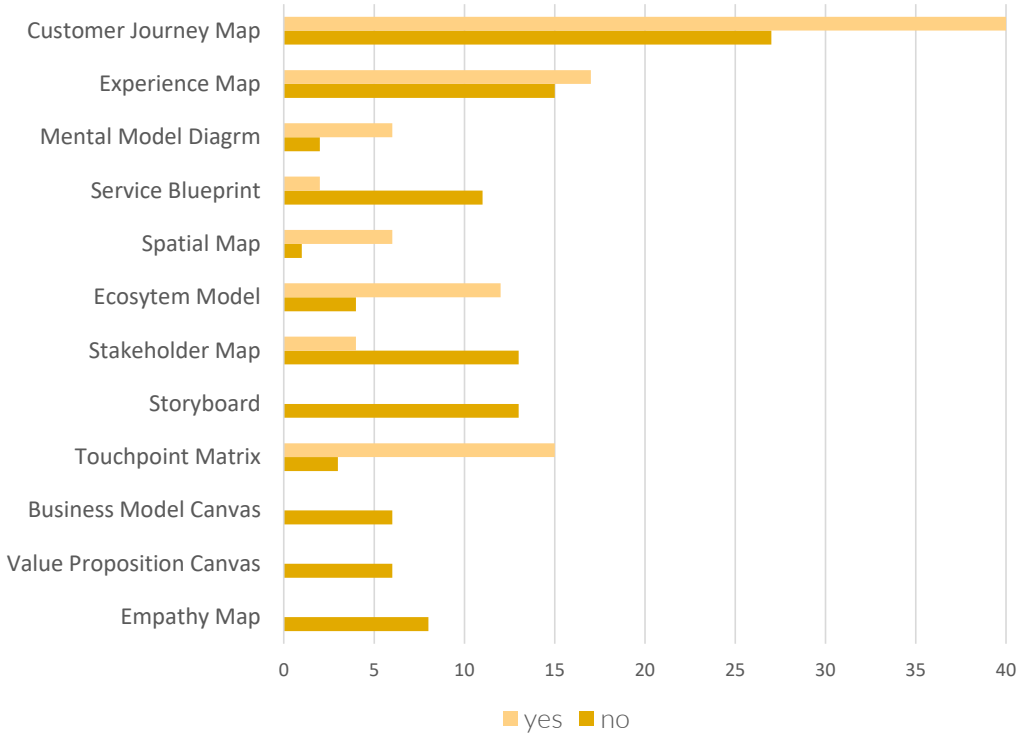


Figure 159. Possibility of representing alternative paths in each of the gathered tools thematic groups, shown through numbers of tools: There is a possibility to read alterative paths (Y), There is no possibility to read alterative paths (N).

It is to say that some maps allow for representations of multiple journeys according to their structure; however, just very few really represent and discuss diversity of journeys, and they do it in diverse manners. A good example and a starting point for having to analyse alternative paths are the Touchpoint Matrixes (Fig. 159). These tools essentially provide an overview of all the possible touchpoints within a system and then, in regard to a timeline of activities, provide

an overview of possible patterns of journeys that switch from diverse touchpoints; such an approach is further mapped within the departments and groups in charge of back-end processes that support particular touchpoints and activities.

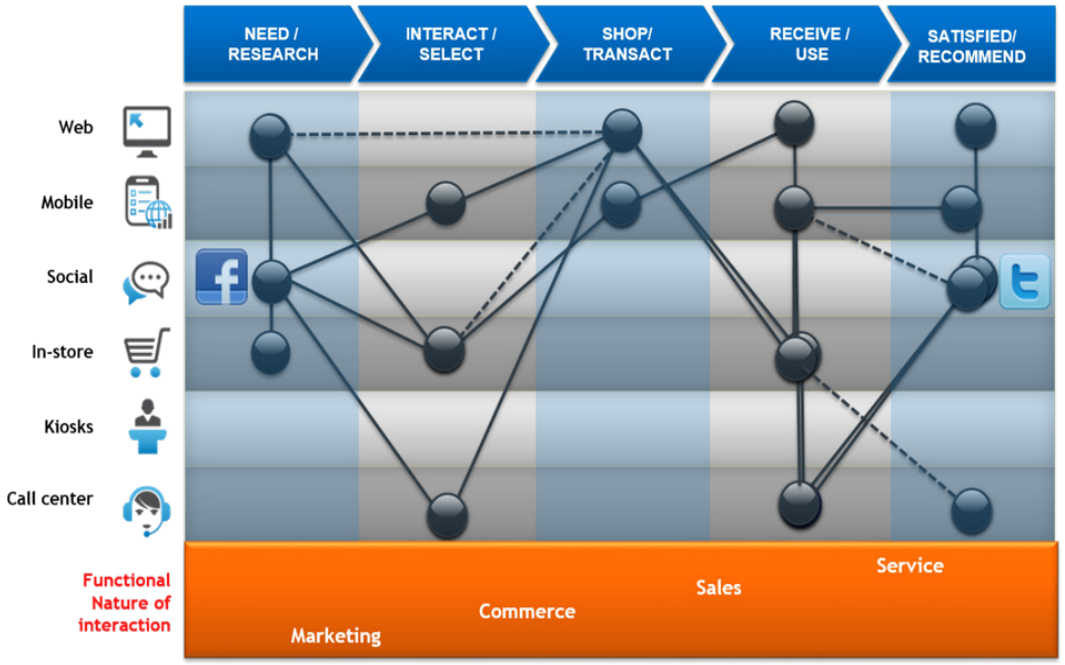


Figure 160. Sample of a Touchpoint Matrix tool showing a possibility to draw multiple diverse journey across diverse touchpoints.

About User Values

For confronting defined Ambient UX User Values and the ones represented trough gathered visuals, the analysis focused on suitability for each of the tool to represent one of the three value groups.

In terms of user's/customer's values, most of the tools are within the meanings and motivations level. This is to say that most of them are suitable for, and do consider within their evaluation, creation of meanings and motivations over time. Usability is a level that is not considered within all the diagrams, and the ones that

appear to be most suitable for this evaluation level are Storyboards, Touchpoint Matrixes, Mental Model Diagrams, Customer Journey and Experience Maps, because of the first-person perspective they provide and their ability to analyse touchpoints separately when constructing a journey. Among these maps, it is mostly utility that can be discussed as a value, while usability requires ever more complex structures. Social acceptability level, on the other hand, is not represented and discussed with these tools, eventually Stakeholder Maps and Ecosystem Models appear as potential starting point for such a discussion, considering the levels of abstraction and third-person perspective they employ.

4.3 DISCUSSION ON ENCOUNTERED ISSUES IN PRACTICED TOOLS

The following describes the main observation derived in regard to the Ambient UX framework elements analysed within the gathered tools. Namely, main observations on Design Domains and User Values are described, and six issues on mismatches between the framework and gathered tools are underlined. The six issues are proposed to be an upgrade for tools currently employed in practice for adapting them for the complexity of the projects that target Ambient UX and reflect the need for an Ambient UX strategical framework as a backbone of the design process.

4.3.1 Main Observations

The confrontation of gathered tools was made according to the two main targeted issues, namely the Design Domains and User Values.

For ***Design Domains***, three architectures (Spatial, Informational, Relational) and Time as a variable were considered, and the tools were analysed according to what leads toward these domains within the tool compositions. All three architectures were recognized among the touchpoint fields within certain tools; however, they were never considered all together within a same visual, and therefore never taken into consideration for providing a holistic analysis.

Relational architecture was observed within certain maps through the touchpoint line, while in others this network can be observed as relational connections among actors of a designed system (examples are Ecosystem Models and Stakeholder Maps). Informational architecture is present mostly through description of activities related to particular platform channels, like for e.g. website, mobile application, email, etc. In this context, the informational architecture does not relate always to the content of communication, but rather the channels and touchpoints that deliver the communication. The content is important as it influences creation of user values, and maps that have potential to communicate this level of architecture, information flows, are Customer Journey and Experience Maps, as well as Mental Model Diagrams and Service Blueprints, as they all have a potential to follow the activity flow that might be influenced by provided information. Spatial architecture can be mostly observed through a description of a context, rather than touchpoint since they mostly relate to products and devices in physical terms. Maps that consider contexts and have potential to support the spatial architecture are Spatial Maps and Ecosystem Models. None of them, however, consider a detailed analysis of the context in terms of user's values, neither the design nor manipulation of spatial elements, as they just merely introduce the context in whom activities are taking part.

The element of time is considered in the maps that follow a structure based on chronology of activities (e.g. Customer Journey and Experience Maps, Mental Model Diagrams, Service Blueprint, Touchpoint Matrix, Storyboards, Spatial Maps), while in the others it is not represented in any other manner (e.g. Ecosystem Model, Stakeholder Maps, Business Model and Value Proposition Canvas, Empathy Maps). Within certain tools that do consider a timeline structure, time spans can vary from very long journeys, in terms of years and month, to one-day journey of activities.

From the analysis of Design Domains, certain considerations emerged that regard mismatches between the proposed framework and gathered design tools' samples. The considerations are presented in the following, in form of proposals for expanding the UX tools' structures currently employed in practices:

- Within the interaction line with touchpoints, all three architectures should be considered and analysed together within the same tool, enabling evaluation of flows for al three of them simultaneously;
- Spatial architecture should be represented in a manner that enables its evaluation also in terms of spatial disposition and attributes of elements, rather than just the context;
- Informational architecture should consider clear content representation and user's values that are influenced by all of the data sources and information flows involved in the system;
- Timelines should be always observed, and should allow for including zooming in and out from long term engagement towards particular moments of interaction, so to consider diverse time spans together;
- Analysis of alternative paths should always be present and should regard all the architectures and temporal variables together, while supporting the analysis of values provoked by different paths and their confrontation.

For ***User Values***, usability, creation of meanings and motivations over time and social acceptability were considered, and the tools were analysed according to what was considered of these value

levels within the tools' content. The first two levels of values are mostly present in the tools, while the third one is not actually being considered.

First level of user values for usability is present in certain maps. Usability can be evaluated when a particular prototype is present. Maps that are gathered do not necessarily relate to an evaluation of a design system that is already prototyped, therefore they hardly consider such evaluation. Maps that have potential, however, for including this value are Mental Model Diagrams, Experience Maps and Storyboards, as they refer to an analysis of a particular moment of interaction through a first-person perspective. Level of creation of meanings and motivations, also over certain time span of use, is the level that is mostly represented within the tools. Designing for meanings appears to be a common targeted field for user values within the maps, and in fact, mostly this is the concept of a value that is directly described as such within the visuals. An example are moments of identification of values of the design system offerings through Empathy Maps, Value Proposition and Business Model Canvases. Level of social acceptability is not represented in terms of evaluating socio-ethical issues in none of the gathered tools' samples. The tools that might eventually have potential in discussing such issues are the ones that have a broad overview of system planning and evaluation, like for e.g. Ecosystem Models and Stakeholder Maps.

From the analysis of User Values, certain considerations emerged that regard mismatches between the proposed framework and gathered design tools' samples. The considerations are presented in the following, in form of proposals for expanding the UX tools' contents currently employed in practices:

- Tools should enable relative overall zooming in and out for the same project between the three levels of UVs, this would help having an overview of diversity and complexity of values and avoid focusing on one level in particular;
- Each of the levels should be provided with enough space for in-depth analysis and its own representation of highs and lows;
- Tools should enable adding the level of values that regards social acceptability, i.e. evaluation of socio-ethical issues, which influences acceptability on individual/personal levels as well.

Presented considerations and proposals for expanding the UX tools' contents and structures can be observed as an identified need for upgrading tools that support current design processes which are becoming ever more complex. Recognized mismatch between the framework and tools can be observed as the needed add-on to current tool's structures. Ideally, the tools would eventually be merged/grouped between them and expanded according to the mismatches, thus providing a more structured and unified support for designing CPSes.

4.3.2 Lacking Conceptual Considerations within UX Design Tools

Three case studies that took part (see Chapter 3) showed that user values vary depending on the context and design outcome, and, in some projects particular values appear to be more dominant than the others. Confronting emerging needs of the design process and tools within the three projects, it is observable that they are matching with gaps identified in current UX design tools, described in this chapter. Namely, the UX design tools currently employed in practices are lacking conceptual considerations that were identified as very significant within the projects based on Ambient UX. Main observations relate to following thematic elements:

- All three architectures should be considered simultaneously within the tools,
- Tools should enable an analysis of alternative user journey paths,
- Tools should enable a zooming in and out perspectives in regard to design outcomes,
- Tools should support analysis and discussion on social acceptability of the design outcome,
- Tools should enable observations on different time spans of user engagement and their analysis,
- System intelligence levels should be taken into consideration within the tools.

All Three Architectures Considered Simultaneously

The first case study, project Humanitas, pointed out at the importance of having to plan for all the three architectures from the framework simultaneously, as all three of them holistically influence the experience of users. Physical space, information flows and social relations within a particular design context and design system

intertwine and overlap over a same timeline corresponding to the period of user engagement.

In the case study presented, the physical layout of the hospital and spatial organization, the information flows supported by the digital kiosks and the relation with the hospital staff, all influence a holistic experience that refers to this particular ambient enhanced by digitized services. Designing such a system calls for design tools that would enable considerations of the diversity of three architectures within a same timeline, thus supporting an analysis of their influence on experience. Tools that enable observations within all the architectures and time as a variable simultaneously would allow for planning and analysis of changes in the architectures, and therefore, the user values within the holistic experience journey. For example, in the particular case of the hospital centre, facilitating human relations with the staff would contribute significantly changes in perception and user values because of the very peculiar sensitive context of use in which the interactions are placed.

Finally, all of the presented projects do contain the recognized Design Domains, i.e. architectures, where in certain projects some architectures are more dominant than the other, they all still require a holistic comprehension of the design system.

Analysis of Alternative Paths

Within the same project, another consideration was observed through the thematic of alternative path. Namely, there is a need for enabling a confrontation and analysis of potential diverse paths within a same user journey. This is to support the planning process of desirable journeys by anticipating possible diversities in paths that might emerge. The diversity is related to the three architectures and time variable, and possible paths they might support.

In the case study presented, two main journeys were observed in terms of diversity. Namely, a traditional and digitized path were observed, based on the interaction with the counter-desk staff and/or interaction with the digital kiosk. Two paths relate to a same journey in terms of the scope of the activities and have a same final aimed outcome, however, the touchpoints of interaction make a difference in the experience. Having to observe these differences in an analytical way supports the process for rationalization of the desired

path and thus planning for the desired design outcome. Differences emerged between the two paths deal with efficiency of the journey, as well as commodity and comfort, and user's feeling of trust and security in the system operations. This is to say that different levels of experience are touched by the diversity observed in-between the alternative paths.

All of the projects presented have possible alternative paths. It is hardly possible to have only one determined path within a design system. Paths depend on many design domains and variables, and thus should be faced as such. Confronting and analysing alternative paths helps identifying desirable ones as well as anticipating potential problematics that a design system might provoke.

Zooming In & Out

The second case study, project MEMoSa, helped observing a need for diverse lenses within the design process. More precisely, during the project development, there was an evident need for changing perspective views in regard to design aspects and roles of stakeholders involved in a particular moment of the process. This is comprehended as a constant need for zooming in and out from different perspectives during the design process.

Taking as an example the presented case study, the UX research methodology followed diverse perspectives and levels of zooming in and out in regard to the proposed design system. Zooming with different lenses was need for scaling from an abstract level of business planning and user values, towards the very detailed planning and design brief for an interface. In the initial phase the research aim was identifying user values perceived within diverse use-case scenario proposed. Building up on a journey from this level brought to a clearer and more concrete idea of potential paths, and thus, also the potential interaction requirements in terms of touchpoints happening within diverse architectures. Having to observe this level it was possible to go in detail with defining interaction flows and the interface requirements. Finally, the last research phase dealt with the validation of the built porotype with the interface as the core of the design system. It is to say, however, that even through the prototype helped verifying very particular detailed issue of the interface itself, it also helped evaluating the design system as a whole once again,

gathering feedback on overall desirability and acceptability.

Changing perspective lenses and scales is a need in all of the observed projects, as design process is a constant iteration facing refinements of the concept and outcome in diverse moments. UX design process supported by research is never a linear process, rather it requires having an ability for constant zooming in and out from business considerations and social impact of the design solution towards interface features and usability issues. Therefore, design tools should respond to this need enabling change of perceptive in any moment, providing a holistic overview of the system with scaling form very broad abstract levels and impact to very small detailed considerations for a final design artefact.

Social Acceptability

Within the same case study, project MEMoSa, another consideration was observed that lacks support in current UX design tools. Namely, the project identified a need for having tools that would support discussion of the impact of the design solution in terms of ethics and social acceptability.

Within the presented case study, the UX research methodology initially focused on evaluation of experience levels that were related to personal perceptions of the system through usability and desirability. However, from the first research phase (i.e. conducted focus groups), another aspect of considerations emerged that was not necessarily related to personal perceptions, rather it was expanding on a level of group considerations, which was interpreted as social acceptability. Acceptability, in this particular case, was related to the usage of personal data and overall data interpretation and information flows. As an example, the study participants were concerned about what happens with personal data extracted from the wearable (smartwatch) and to what end such data is interpreted and who has access to them. From the study, it resulted as highly desirable to have an ability to always customize the features for data access, i.e. the user should always be able to select with whom he wants to share what kind of information at which moment. Furthermore, the user should always be informed about the manner in which data is interpreted, most of all data that are very sensitive such as personal bio-signals, and aspects taken into consideration

for calculating a “driving behaviour” and/or tailoring an insurance policy. Consequently, the last research phase resulted in increase of acceptability of the system, when having implemented additional features in the mobile application that were providing insight into which parties have access to which data and for which purpose the data are being gathered.

Having to deal with design concepts that shape user values through complex data flows, involving also sensitive personal data, raises many considerations in terms of data treatment, privacy and transparency. This consideration is observed as a need for establishing a social consensus for data treatment, which touches one’s experience levels beyond personal perceptions and expands on ethical levels of a society. Having this particular consideration intertwine with the design process, an evident need for shaping design tools that would support its implementation arises.

Different Time Spans

Across gathered UX design tools it is observable that the element of time is mostly present. However, diverse representations deal with this element in diverse scales. Some of them consider a very abstract years-long term of user engagement while others consider very short indications that happen in a manner of minutes and/or seconds. Besides those scales, some representations describe past user engagement, while others describe planning for a future, non-existent, engagement.

In the case study for Caring Lights, the aspect of time scales was observed and discussed within the design process. Here time spans showed importance in the planning process, as they were observed as being in strict relation with possible acceptability from the side of the users. When it comes to designing systems of radical innovation, like the ones that are based on interaction with a personalized AI agent, strategical planning appears as required. The strategy would reason on breaking down the radical thought into steps for incremental innovation, assuming that as such it would foster more acceptability. This is based on the hypothesis that acceptability is dependent on familiarity with the new offerings, hence the presented case study discussed a definition of levels based on introduction of the agent through diverse phases, starting from current existent IoT

systems with whom users are familiar as they are already present on the market. Besides acceptability from the side of the users, time spans are observed also in the context of feasibility of development of the new system. The case study reasoned on this argument through a proposal that would simultaneously follow up the acceptability phases and growth of the potential of the software and installation of additional hardware in diverse planned contexts of use.

Considering diversity of time spans is a necessary for planning for design system implementation within a timeline, as well as analysis of possible impacts the system might have on users within diverse timelines of use. As mentioned, gathered design tools do consider diversity of time spans, but usually only one of the possible scales, without reflecting on shorter and longer-terms of use together within one holistic representation. Design tools should enable planning and analysis across diverse time spans for envisioning and developing design concepts, in regard to changes over time they might provoke in users’ perceptions and creation of meanings and motivations.

Intelligence Levels

Within the same case study, project Caring Lights, a new thematic element emerged, that was not observed previously through the confrontation between the design framework and design tools. Namely, the aspect of system intelligence arises as a significant argument within design processes for complex connected systems supported by AI running in the back-end.

Within the case study, intelligence levels were observed through a necessity for planning for acceptability and feasibility of a system development. This is related to the previous thematic element of time spans as well, but here the argumentation is different. In terms of feasibility of system development, intelligence reflects levels of data complexity involved in the system in diverse phases. This is to say that the initial, basic intelligence level, are the operation with “if-this-than-that” triggers. The basic level is equal to one-step notifications, while additional hardware and sensors would add more data flows, and therefore require more data processing according to desired actuation. Over time, the system would be reaching the final level, which is emotional intelligence, supported by learning processes derived from the previous step. Learning about daily life

of a particular user, his habits and needs, helps tailoring personalized actuation and unique responses according to user's read emotional states. Intelligence levels, in terms of responses and personalized relations towards the user, influence on a certain extent also the acceptability from the side of the user. Confronting the user with a system that can provide interaction triggered by higher levels of intelligence than experienced before, requires good comprehension of the changes in user's perception that such an interaction can bring, and thus also a corresponding strategical planning.

Having to deal with emerging systems of AI applied in design practices, it is observable that the design field for these applications is still young even though AI is surely not a novel research area at all. Novel systems that are supported by AI require reasoning on intelligence levels that influence user's experience, and therefore, the novel design processes require design tools to be shaped accordingly.

Discussion on Tools Upgrade 4.3.3

The six issues discussed above reflect the mismatches encountered between the Ambient UX framework and UX tools currently employed in practice that deal with value alignment. The issues are proposed to be an update of the UX tools currently employed in practices, for supporting design processes for Ambient UX.

The gathered tools correspond to the concept of value alignment between the users and the stakeholders developing the design concept and, thus, the interaction touchpoints. The interaction touchpoints within the Ambient UX framework are defined as Design Domains, and in regard to those, the above discussed issues suggest having all three architectures from Design Domains considered simultaneously. Furthermore, the tools should also enable an analysis of alternative paths that could happen in-between different architectures. For the side of the User Values of the Ambient UX framework, it is proposed to always take into account the aspects of social consensus when evaluating a concept. In regard to diverse levels of User Values, it was observed that the projects have a constant need for zooming in and out, in terms of abstraction of the design concept and intervention; i.e. from strategy to the tangible product, for analysing User Values and refining the design accordingly. In regard to the design process and values related to experiences, observing different time spans appears as a need when designing for Ambient UX, which relates to different time spans of usage and influence of the design outcome on longer and shorter terms towards the users. Finally, the intelligence levels were also imposed as required to analyse when designing for Ambient UX, as they as well influence the design process itself, and most of all the perception from the side of the users and the User Values.

It is to note that the first five issues can, to some extent, be recognized within some of the tools. The last one, intelligence levels, however, is never been considered by far within the tools for

value alignment. This is to say that the base for building the toolset to address the Ambient UX strategical design process can be found in some of the gathered existing tools to some extent, and a certain update could be made for facing the new needs of design practices. The gathered tools are available for exploration as an attachment to this document.

This thesis provides a basis for planning for upgrading the UX strategical tools, which can be a starting point for developing a software platform to be used during targeted design processes. A software platform could unite the tools that are nowadays rather diverse and sparse and provide an overall structured support for designing cyber-physical systems with an approach based on user experience. In this context, the platform can be seen as an upgraded toolset that finds roots in the UX tools samples currently employed in practices.

As the starting point are tools currently employed in practices, it is possible to give an overview on which of the tools could correspond to which elements of the Ambient UX framework and to which extent they might represent the starting point for some of the indicated six conceptual issues.

Focus on the Ambient UX Framework

Design Domains

Design Domains are defined by three architectures, namely Spatial, Informational and Relational, having Time as a variable as the backbone for all the journeys. In this context, the tools that can show as convenient for addressing the needs of the design process are those deriving from the known practices already. For e.g., designing Spatial architecture can be supported by tools that are used within the field of architecture, as sketches, modelling of the 3D mesh, renders with materials, technical drawings for making of the concept. Informational architecture is designed by defining information flows through schemes of inputs and outputs and decisional trees. Third, Relational architecture finds its roots for design tools from the field of gaming design, as definitions of actors and decision trees that regard probabilities of interacting with diverse actors. From the gathered tools that are analysed, Service Blueprints and Ecosystem Models are also touching the area of defining the

actors within a system and connections within a system, which could be taken as a starting point on reasoning on a novel tool platform in terms of Relational architecture. Furthermore, Time as a variable is an aspect that appears in various of the tools analysed, considering that certain groups are based on a structure of a timeline of user/customer activities such as: Customer Journey Maps, Experience Maps, Mental Model Diagrams, Service Blueprints, Storyboards, Touchpoint Matrix.

User Values

When it comes to tools for supporting communication on user values, there are not many examples among the design practices that could be comprehended as an accepted standard. From the gathered tools it derived that the representation on values are quite diverse, and what is observable is the difference between a personal perspective on experience and, in just very few of them, there are perspectives that expand on a social scale as well. Across some of the diagrams, the evaluation of the experience is presented through highs and lows over a time period.

In this context, communicating user values that enter the level of Usability is not represented in the gathered tools, and what might appear as convenient is to link these values to particular Design Domains that might influence it, on a very zoomed-in scale of the design concept. It might appear as convenient to have a representation of highs and lows as an overall abstraction of the evaluation; however, the evaluation and the experience are much more complex, and thus, require to be addressed through this complexity accordingly.

Communicating the level of Meanings and Motivations brings an even higher level of complexity. These aspects were communicated in some of the tools, mostly through emotions that can be perceived as positive and negative, by describing them or even showing them through visuals. In some cases, this level of User Values is presented through storyboards that are not explicit but intuitive from the story and activities, as well as the reactions of the protagonist and actors involved. Meanings and Motivations, thus, can be presented again through the complexity they bring in regard to diverse Design Domains, but also in terms of design strategy for which the main concept idea is being tested and verified.

The level of Social Consensus is not present among the gathered tools, and it can eventually only be recognized among the tools such as the Ecosystem Model, where the perspective on user experience expands on a social scale discussing potential values that are observed on a level of a group rather than individual. The level of Social Consensus is a novel concept that is proposed for being introduced within the design process with this thesis, and the tools that it requires should be based on definition of desirable use-case scenarios that are a result of an achieved consensus about potential future users. This calls for an analysis of anticipated design use-case scenarios from the side of collaborative agreements, and collective anticipation of possible consequences the scenarios might bring in regard to behavioural changes and influence on society and/or societal groups.

Six Conceptual Issues

The six conceptual issues that emerged represent the mismatches between the conceptual Ambient UX framework and the structures of analysed gathered tools. This is to say that the issues are a proposed upgrade on existing tools for enabling them to comply with the novel framework, thus supporting the design process for cyber-physical systems.

The issue that refers to having all three architectures considered simultaneously, reflects the notion that the analysed tools do not consider in a detailed manner treatment of all the identified three architectures of the framework within a representation. Potential inspiration for the representation that this issue imposes are the already practiced tools from the three fields of Architecture (Spatial, Informational and Relational), which are discussed previously. The element that puts together the three architectures is the Time flow of activities, where the architectures can be observed as diverse fields in which touchpoints are being shaped.

The analysis of alternative paths is an issue that recognizes the need to comprehend and analyse all the main possible paths a user might take within a set of imposed architectures and within a certain timeline. Identifying the alternative paths supports evaluation of experiences and anticipation of desirable ones, thus enables a planning process based on an overview of possible paths and confrontation

between them. Some of the gathered tools for value alignment did consider communicating an opportunity for an alternative path to happen, like the Touchpoint Matrix; however, most of them do not explicitly analyse all the possible paths across touchpoints and, thus, do not evaluate the experiences the diverse paths might impose. With this request, a novel tool platform could be shaped in a manner that enables anticipation of diverse paths across all the architectures and timeline, as well as giving spaces for an analysis and comparison of the hypothesized paths.

Another issue imposed by the research is named zooming in & out, and it refers to changing zooming perspectives in regard to the final design product. More precisely, this issue requires having a toolset that enables communication and overview scaling within the design process, where the zoomed-out level is the one of overall design strategy while zoomed-in is the level of detailed design tangible elements such as, for e.g., the interface. To have a platform that allows constant change of perspective considering the design product, the platform itself should be thought through as a container that allows layering from the overall journey towards details of each of the Design Domains that are being shaped. Such a platform, thus, allows for planning on strategical as well as the level of modelling of Design Domains, and it enables changes and refinement by allowing the change of perspectives and scales, and in regard to the levels of defined User Values.

One of the emerged issues refer to the necessity of inserting social acceptability within design processes. This concept is one of the levels of User Values which are described within the Ambient UX framework. The issue imposes achieving a social consensus around a design proposal for comprehending potential acceptability of the same. This issue touches to a certain extent ethical debates and comprehension of perception of a design system on a social scale and observed through social lenses. When it comes to identifying suitable tools to support this issue, it is evident that among the gathered tools none of them actually do touch the peculiar nature of this issue. Suitable tools would support a process of shaping a discussion around potential critical issues and their further analysis, by gathering data on group opinions and attitudes and further clustering them. In this context, the tools might enable an anticipation of critical issues in regard to Design Domains, and thus, propose modifications of the

Domains accordingly.

The issue on different time spans implies observing the impact of the design proposal towards the user on short and long terms. Having the ability to analyse and comprehend interactions with a design system within diverse time scales helps building a design concept that could be resilient, and thus, adaptable towards users over diverse time spans of usage. Some of the gathered tools do have timelines as backbones of the analysis of user activities, such as Customer Journey Maps, Experience Maps, Mental Model Diagrams, Service Blueprints, Storyboards and Touchpoint Matrix. However, these tools mostly consider one type of a time scale, rather than providing an overview on more and diverse scales. This is to say that for this issue, some of the named tools could be used as an inspiration and starting point, considering that they do support an analysis of use cases within a timeline defined by main activities and interactions with the design system. In addition, the novel tool platform should incorporate diverse time spans and provide a larger overview on impacts across diverse timespans, which could enable an analysis and planning for the design concept accordingly.

The last among the six issues is defined through comprehension of intelligence levels of a cyber-physical system powered by an AI in the back-end of the processes. Comprehending the diverse levels of intelligence embedded within a system helps the planning process for required data acquisition and data flows, as well as the interface with which the user has direct contact. This issue derives from specific needs and nature of cyber-physical systems, and, as such, is not present within the gathered and analysed tools. This issue would be presented through the Design Domain of Informational Architecture and would further influence User Values on all three levels. Intelligence levels reflect the complexity of data flows within the Informational Architecture and impose requirements for data acquisition and processing. However, from the side of the user, such levels impose the complexity of defining interactions accordingly, in order for the user to comprehend how the system functions while having still the direct interactions simplified and intuitive.

These six conceptual issues have to be observed as different levels of intervention and activity inside of the design process. They cover different topics and concepts, and thus, they cover a wide variety of

approaches towards tools and representations as well. However, even though they represent diverse concepts, they all contribute building of a holistic unique platform as a tool to support the design process for cyber-physical systems. Here the tools of value alignment are just a base of a novel platform, as they are comprised within the framework concept of defining Design Domains and User Values, and the proposed conceptual issues are an upgrade that contributes building of the holistic platform.

The future steps of this research are the tangible design and development of the novel tool platform, that would take these discussion and conclusions as a starting point for the activities to come. The content of the platform is defined through this thesis, while the embodiment and the actual communication aspects of the tool platform are yet to be defined and designed.

05

Conclusions

The chapter summarizes research findings and provides an overview of the contribution to the design field. A brief discussion is provided on needs that new design practices impose, expanding towards complex interactions, services and intelligent systems through a holistic UX approach. Overview of the Ambient UX framework is presented as a suitable one for managing user experiences within spatial systems enhanced by digitized services, i.e. cyber-physical systems. Additionally, limits of the research are underlined, as well as recommendations for new research opportunities that emerge from the findings.

5.1. Interpretation of Research Results

Addressing the Needs of Novel Design Practices
Ambient UX Framework
Six Issues on Tools Upgrade
Summary and Conclusions

5.2. Limits of the Research & Future Steps

Overall Limitations
Future Research Opportunities

5.1 INTERPRETATION OF RESEARCH RESULTS

Addressing the Needs of Novel Design Practices

The area of inquiry is being shaped through the collaboration with TIM S.p.A., company supporting the PhD research path. The telecommunication company is looking into designing meaningful services supported by the new stream for a 5G network that will be guiding the company's service application fields within the current and following years. The network promises to have significant higher speed and reliability, thus enabling with ease employment of complex connected services that rely on diversity of systems of sensors and actuators implemented within the physical space. The research aims for responding to observed emerging needs of novel design systems, which are becoming ever more complex in terms of connected physical devices supported by AI algorithms.

From the stream for development of meaningful application areas for connected spaces and IoT systems, the research refers to a vision of Ambient Intelligence and Cyber-Physical Systems. This vision and the application area find their connections within diverse fields that finally merge towards same practices. The fields are Artificial Intelligence, Pervasive and Ubiquitous Computing, and Interactive Architecture. Within the research, I address this application field with an approach of designing for users' experiences, as such an approach looks into sustainability and durability of design systems in terms of user engagement over time. Furthermore, as the application field represents a convergence, the design approach is observed through convergences as well, positioning itself on the merge between Service and Interaction Design, and AI and Spatial Design.

Specific research questions are shaped, and an objective is posed for defining an Ambient UX strategy as a possible suitable approach for responding to the focus application field. The aim is to develop a framework for a design process that emphasizes user experience values, and a toolset that would support such processes within a multi-stakeholder working environment.

Research questions are shaped as the following:

- What might be the suitable design strategy for Ambient UX?
- How to map user experience and how to represent its values within Cyber-Physical Systems?
- Are the currently practiced UX design tools enough for addressing projects of Ambient UX? Is an update needed?

From the identified design practice, research considerations emerged targeting identification of an Ambient UX approach. The selected research methodology comprised three main research areas: (1) hypothesis of a design strategy for Ambient UX, (2) verification of the Ambient UX framework hypothesis, (3) investigation on design tools for the Ambient UX framework.

The needs of novel design practices are shaped around the imposed complexity of Cyber-Physical Systems, where a holistic UX approach is a necessity. Facing the imposed complexity, as well as the implications it has on user's experience, is a challenging quest. In this context the research aims to propose a strategy for a holistic UX approach, while building up a common language among practitioners in the field. Common language for novel design practices would bridge the communication gaps between the diversity of professional backgrounds regarding stakeholders gathered around a project of cyber-physical nature with a focus on UX.

The research contributes in translating the very fuzzy moments of moving from user research to design hints within a design process, by proposing a conceptual framework for a design strategy and design tools that help implementing the framework within a process in a tangible manner. Research contribution provides the industry practitioners with a solid comprehension of designing for a holistic UX in CPSes through the proposed conceptual framework, and with design tools it provides a tangible manner of introducing the framework in practices while nurturing development of a common language. Industry practitioners here range from companies offering diversity of digitized services, as well as hardware product development, towards architects and governing organizations and institutions. Establishing a strategical design framework based on user values can support building sustainable systems with a conscious societal impact on long terms.

Ambient UX Framework

Ambient UX is a conceptual framework that provides a strategy for structured design processes that target Cyber-Physical Systems. Dealing with abstract and intangible concepts like experience is challenging for the practitioners in the field, as well as design educators within the same thematic area. Certainly, when it comes to designing systems of intelligent interactive spaces, another layer of complexity is added to these efforts. A shared comprehension of peculiar UX practices within these complex projects is required, as well as development and establishment of a common language.

The Ambient UX framework consists of a definition of Design Domains (what is to be designed) and User Values (why it is designed) observed within Ambient UX and CPSes.

Design Domains are analysed through possible outcomes of complex systems of enhanced spaces, in terms of what can a designer manipulate with and shape in a certain sense. More precisely, what are the domains and elements a designer can manipulate with in order to create enablers and constraints for certain activities, thus influencing the user's experience. The observations provide possible grouping of design outcomes as physical products, information flows and triggering of social relations. In this context, Design Domains are interpreted through three architectures within targeted design systems: Spatial, Informational and Relational. Besides the architectures, the element of Time is also considered, presented as a variable between the architectures which impact on activities and experience has the same significance.

Defined Design Domains are in direct relation with the user's experience, and therefore, the User Values, perceived as such in regard to the interaction with a designed system. Experience is, thus, influenced on diverse levels, scaling from personal towards social perceptions and acceptability. The levels here are discussed as: Usability, Meanings & Motivations, and Social Consensus. This is to say that recognized architectures and time as a variable influence comfort and wellbeing, creation of meanings and motivations over time, and social relations within the interactive system.

The verification of the Ambient UX framework hypothesis is made by confronting the proposed design strategy with research projects that satisfy the Ambient UX concept and involve studies

on user experience. This is done by identifying what is perceived as User Values in all of the projects, and what is the relation between Design Domains and User Values. Initially, a first testing has been made for verifying the framework hypothesis, through a case study of a dynamic connected lighting system within an office working environment. The verification consists of identifying the Design Domains as such, as well as their influence on the hypothesized levels of User Values.

After making the first holistic verification of the framework, i.e. the existence and suitability of hypothesized Design Domains and User Values, three additional research projects took part, with the scope of further verifying the hypothesis and observe the connections between DDs and UVs, considering also their mutual influence. The three projects are selected according to their diversity in terms of dominant architectures, diverse products' complexity and nature, diverse levels of manual or automatized input (through sensors), and they are all placed in diverse environments (hospital, automotive, city outdoor and indoor ambient).

For each of the projects the conducted UX research is described and the User Values are discussed. Finally, overall reflections and discussion are made, and an overall Ambient UX framework verification is presented. The three project case studies also brought up an observation that currently available UX design tools had to be modified and adapted towards the complexity of UX and CPSes.

Six Issues on Tools Upgrade

Research relates to experience mapping in order to create a common language for physical/digital ambient design. The discussion is supported by case studies of tools that are suitable for a conversation on drawing principles for experience design. These tools are discussed as the foundation to establish an emergent design language.

This section of the research aims to identify design tools that could support a design process for an Ambient UX strategy. For responding to this aim, the research methodology was shaped according to two macro steps: 1) Overall analysis of current UX tools employed in practice for understanding User Values and Design Domains they refer to, 2) Comparative analysis of tools with the proposed framework for Ambient UX, according to its defined

Design Domains and User Values.

Within the first research step, tools samples are collected with majority deriving from practices in industry and design consultancies. A database of all the gathered tools samples is available for exploration as an attachment to this document. The search focused on tools that support design processes targeting value alignment. Such tools are: Customer Journey Maps, Experience Maps, Mental Model Diagrams, Service Blueprints, Spatial Maps, Ecosystem Models, Stakeholder Maps, Storyboards, Touchpoint Matrix, Business Model Canvases, Value Proposition Canvases, and Empathy Maps. Through the analysis, structure for each of the tools is discussed for identifying Design Domains and User Values they consider. Finally, a confrontation among all the tools is made, and possible emerging grouping patterns are observed.

Within the second research step, gathered tools are confronted with the proposed framework for Ambient UX, in terms of its Design Domains and User Values. The framework is based on a design strategy deriving from literature review; therefore, this confrontation can be observed as confrontation between the theory methods presented in literature and tools employed in design practices. Discussion is shaped according to encountered mismatches between the gathered tools and the Ambient UX strategy, identifying them as a needed upgrade of the tools.

Outcome of this research activity is a classification of a library of existent tools that deal with evaluation of user's experience. More precisely, an analysis of elements that refer to the evaluation of UX in these tools is provided and discussed. Finally, a need for an upgrade of UX design tools is recognized, and proposals are made accordingly.

UX design tools currently employed in practices are lacking conceptual considerations that were identified as very significant within the described case studies based on Ambient UX. Main observations relate to following thematic issues:

- All three architectures should be considered simultaneously within the tools,
- Tools should enable an analysis of alternative user journey paths,
- Tools should enable a zooming in and out perspectives in regard to design outcomes,
- Tools should support analysis and discussion on social acceptability of the design outcome,
- Tools should enable observations on different time spans of user engagement and their analysis,
- System intelligence levels should be taken into consideration within the tools.

All of the presented project case studies do contain the recognized Design Domains, i.e. architectures, where in certain projects some architectures are more dominant than the other, they all still require a holistic comprehension of the design system. Furthermore, all of the projects presented have possible alternative paths. It is hardly possible to have only one determined path within a design system. Paths depend on many design domains and variables, and thus should be faced as such. Confronting and analysing alternative paths helps identifying desirable ones as well as anticipating potential problematics that a design system might provoke.

Changing perspective lenses and scales is needed in all of the analysed projects, as design process is a constant iteration facing refinements of the concept and tangible outcome in diverse moments. UX design process supported by research is never a linear process, rather it requires having an ability for constantly zooming in and out from business considerations and social impact of the design solution towards interface features and usability issues. Therefore, design tools should respond to this need enabling change of perspective in any moment, providing a holistic overview of the system with scaling form very broad abstract levels and impacts to very small detailed considerations for a final design artefact.

Having to deal with design concepts that shape user values through complex data flows, involving also sensitive personal data, raises many considerations in terms of data treatment, privacy and transparency. This consideration is observed as a need for establishing a social consensus for data treatment, which touches one's experience levels beyond personal perceptions and expands on ethical levels of a society. Having this particular consideration

intertwine with the design process, an evident need for shaping design tools that would support its implementation arises.

Considering diversity of time spans is necessary for planning for design system implementation within a timeline, as well as analysis of possible impacts the system might have on users within diverse timelines of use. As mentioned, gathered design tools do consider diversity of time spans, but usually only one of the possible scales, without reflecting on shorter and longer-terms of use together within one holistic representation. Design tools should enable planning and analysis across diverse time spans for envisioning and developing design concepts, in regard to changes over time they might provoke in users' perceptions and creation of meanings.

Having to deal with emerging systems of AI applied in design practices, it is observable that the design field for these applications is still young even though AI is surely not a novel research area at all. CPSes that are supported by AI require reasoning on intelligence levels that influence user's experience, and therefore, the novel design processes require design tools to be shaped accordingly.

The previously described conceptual issues represent a proposal for an update and enlargement of tools currently employed in UX practices, for supporting embodiment of the Ambient UX framework in design practices.

Summary and Conclusions

The research proposes an Ambient UX framework for expanding UX practices on the field of cyber-physical systems. A discussion on needs that new design practices impose is provided, expanding towards complexity of interactive spaces and intelligent systems. Additionally, design tools with potential for responding to the Ambient UX strategy are analysed and discussed. The framework is based on definition of Design Domains, that a designer might manipulate with (three architectures and time as a variable), and User Values that are being influenced by the Design Domains. As such, Design Domains and User Values within the gathered design tools are represented in diverse manners, without providing a holistic approach towards designing for UX, and, furthermore, showing lacks in certain aspects that proved to be significant for Ambient UX.

An initial case study of a dynamic lighting system for a workspace is presented for verifying the overall Ambient UX framework, by confirming the Design Domains and User Values during the designing process. Furthermore, three case studies of design projects that took part were taken as research sample for verifying the framework through an analysis of dominant User Values and their relations with Design Domains (Humanitas, MEMoSa, and Connected Lighting for a Caring City). Namely, in these projects, user experience was shaped within diverse environments (hospital, automotive, city) for enabling observations based on a broad range of Ambient UX applications. Three projects reflect on one of the three architectures (i.e. Design Domains) that appear as the dominant one in each of them. UX values that emerged during the research phases in case studies showed the importance of identified levels of UVs, and thus confirmed their importance for the Ambient UX framework. During the design practices developed through three case studies, UX design tools had to be modified according to the needs of the CPS and adapted towards the complexity encountered within UX.

Facing the complexity that CPSes impose, the research proposes a holistic approach towards UX. This approach is embodied through an additional proposal for design tools to be used during a design process. Tools represent also a backbone for building a common language among all the stakeholders involved in a project who represent professionals from diverse backgrounds. The common language, therefore, can be observed as common understanding of the process of translation and interpretation from user research to design hints.

For shaping a tangible embodiment of the Ambient UX framework the research explores design tools that might provide a backbone for the design strategy. Currently employed design tools are analysed, that focus on value alignment between user values and stakeholders developing the project. Gathered tools are confronted with the Ambient UX framework and encountered mismatches are underlined through six thematic issues. The issues are proposed to be an upgrade of currently employed tools in the UX field for addressing the complexity of CPS design projects. The analysis of tools and the conceptual framework are a base and a starting point for development of a novel design toolkit.

The UX tools currently employed in practices appear as not sufficient for covering all the aspects of the Ambient UX framework; for this reason, the research proposes an update of tools and a development of a novel toolkit in correspondence to the framework. The main six conceptual issues were identified as mismatches between the framework and the gathered tools, and as such are proposed as issues for an upgrade to a novel toolkit. The recommendations on including novel conceptual issues within a novel toolkit imply having: (1) All three architectures considered simultaneously, (2) Analysis of alternative user paths, (3) Zooming in and out within the aspects of the design system, (4) Inquiry on social acceptability in regard to the design concept, (5) Overview of different time spans of engagement, (6) Analysis and planning according intelligence levels within the design system.

The research provides a strategic support for bridging the fuzzy phase from user research to design hints. This strategy is translated into a conceptual framework for designing for Ambient UX, while targeting design of Cyber-Physical Systems. The framework can be used both for analysis and planning of novel design systems supporting the design process. In this context, the contribution of the research is in providing a base for supporting design processes focused on user experiences which enable building CPSes that are sustainable from the point of view of user values and, thus, acceptability, over a certain time period of use and engagement.

Contribution of the research is directed towards both design practices and design education filed. The originality of this contribution lies in its tight relation to fast-paced changes in design practices, and its translation into a proposal for an upgrade of a shared common language through design tools.

Being deeply grounded within a design practice, the research provides contribution on two levels, which are the academic theoretical research on design and the emerging design practices within industry. The contribution for academic design research community is reflected in the manner of reasoning about the conceptual hybrid framework, as it could be repeatable for similar research scenarios in which there is a need for establishing a strategy for supporting design processes in regard to Design Domains and User Values. The contribution for design practices within industry

is the concrete strategy proposed that can be re-used during design processes for CPSess, while rendering more tangible the strategy design tools are also another research outcome.

5.2 LIMITS OF THE RESEARCH & FUTURE STEPS

Overall Limitations

The research has followed the methodology defined at the beginning of the doctoral path, aimed for replying to the posed questions. The methodology is based on literature reviews, analysis of case studies, a research-trough-design method applied within design projects, and analysis of design tools used in practices. Limitation of this research can be observed in a restricted area of diversity of case studies used for final verification and for design explorations. As the concept of Cyber-Physical Systems reflects a wide variety of design environments, from homes to public spaces, hospitals, offices, transportation, and others, verification of a strategical design framework for Ambient UX might be strengthen by having it applied to all the many diverse environments it might touch. To this point, future studies might consider more diverse case studies for the verification of the Ambient UX framework, adding on the strengths and weaknesses of its definition, as well as the exploration of the needs of design tools. Further verification of the framework could be strengthened with additional collaboration and testing among a wider span of diverse professional backgrounds of project stakeholders as well. This might contribute having a more comprehensive overview on the utility and effectiveness of the proposed framework within diverse practice fields, as well as the usage of design tools.

During the development of the doctoral research, that took part over a time span of three years, there were new examples of analysed tools emerging constantly considering the rising request for UX practices, thus, to this date this research could be amplified with a broader sample of tools. The thesis clearly states which tools samples are gathered, among which majority of them is available through online sources. Limitation of the analysis of tools can be observed through restricted number of gathered samples available during the period of their collection.

Future Research Opportunities

Future steps look into a proposal for a potential development of a software platform that would support embodiment of the Ambient UX framework and its deployment within design practices. As the analysed tools currently employed in practices contain diverse tool formats, a novel software platform could potentially gather the diverse perspectives and considerations contained within current tools. The platform would rely on the Ambient UX as a backbone in terms of its elements, giving support for an analysis and planning for Design Domains and User Values. In this context, the novel software tool, i.e. platform, could support a structured design process, enabling all of the stakeholders to follow the development and build up same conceptual ideas on project values oriented towards users within CPSes.

Gathered tools demonstrate diverse possible structures currently employed in practices based on use-case scenarios. The novel tool platform should add to the existing tools in terms of analysing the use-case scenario through defined Design Domains and User Values. The enlargement of the analysed tools, according to the framework, can take inspiration from other tools deriving from diversity of other design fields (e.g. Architecture, Service, Interaction and Gaming Design) that are related to Design Domains, as presented in Chapter 2 on framework development. The backbone of the software platform should be a timeline of user activities, further supported by a representation for designing the three architectures that intertwine, while the investigation on user values should be added layers for creating a base for discussion, analysis and design process.

Novel software tool would be a support for the discussion during the design process and development of CPSes driven by a human-centred approach. Development of the software platform tool for Ambient UX, that provides a holistic UX approach and manages design domains of complex systems, is the following step of this research which would enable the tangible application of the framework within design processes, as well as its further testing.

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Apendix

Note:

Samples of gathered tools are available for exploration within the folder attached to this document