Usability: A Core Concept in Socio-Technical Systems Development

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Abstract. This paper restates the importance of the concept of usability in the socio-technical systems development. Usability covers the breadth and depth of the rich interaction of users and technology in the socio-technical context. By drawing parallels between the Vitruvian design principle of suitability and usefulness, and the paradigms of usability conceptualization, this paper argues that usability can act as *speculum mundi*, a lens through which the impacts of interaction at all levels of the organization and society can be identified.

Keywords: Usability, Socio-Technical Systems, Conceptualization.

1 Introduction

A *socio-technical system approach* views an organization and a society as consisting of the technical system interacting with the social system for a common goal (Bostrom & Heinen, 1977). In this conceptualization, the human has an active role in improving and contributing to his/her environment. Moreover, the *design* of new technologies implies a human influence in that the technical requirements are ideally adapted to the needs and capabilities of the human and social components. The interaction technology-human is mutual, both influence each other. Technology shapes human relations and societies, and likewise technology is shaped by social, economic, and political forces alike (Rip & Kemp, 1998).

Though the conceptualization of the socio-technical systems and landscape exists for a long time (see Bostrom & Heinen, 1977; Rip & Kemp, 1998; Mumford, 2000), the research in this field reinvigorated in recent years especially from a conceptual and theoretical approach perspective (see e.g., Geels & Schot, 2007). The actual design and implementation of technology following the assumption of socio-technical systems approach (Bostrom & Heinen, 1977) are limited because the technology usually lacks essential features for it to adapt seamlessly to users' needs. Moreover, empirical research on socio-technical landscape, culture, and future lacks breadth and scope in that findings provide only "short-distance" insights, and do not focus on broad themes, long term impacts, or influential constructs. Instead, the socio-technical systems research rather focuses on narrow problem domains and it concerns mainly the development and implementation of information technology (IT) systems (see Davis et al., 2014).

With the advancement of artificial intelligence and emerging technologies that are capable to learn about their environment including the users, there are hopes and promises that the existing limitations of technology disappear as technology becomes capable of adapting to users' contexts, needs, and values. However, new challenges appear for the *system designers* such as ethical concerns, uncertainties of users' acceptance and impacts, new needs and requirements for services, products and systems, as well as challenges to ensure the technology is part of the solution to the global challenges and not part of the problem (see Rip & Kemp, 1998). In this context, the *usability* work is crucial to ensure that the new services, products, and systems indeed meet the users' needs and expectations, while the usability construct has the role of an influential construct throughout the system life-cycle and has an established history.

In this position paper, we restate the importance of the usability concept in the socio-technical systems (STS) development approach. Usability is or should be a fundamental concept for professionals designing the systems of the future, for users as active participants in the co-creation process as well as consumers with needs, expectations, feelings and cognitive appraisals vis à vis a service, product, or system, and academics as active or passive observers of the social-technical systems life cycle. All these stakeholders need a common language and shared understanding to make sense of, contribute to, and engage in the life-cycle of and discourse about social-technical systems. Figure 1 illustrates the underlying assumption of the role of social-technical systems' usability in impacting the organization or society at large. Usability concept as *speculum mundi* or as an analysis lens can capture impacts at all levels in the organization and society (group, individual, technical, environmental, and financial).

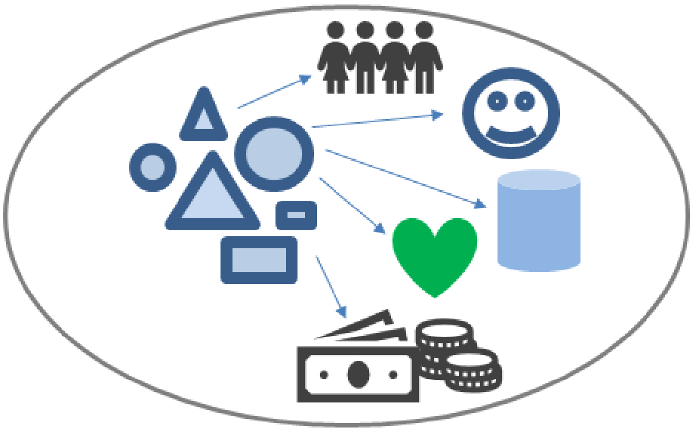

Fig. 1. Social-technical systems (geometrical shapes in the picture) influence organization at all levels: group, individual, technical, environmental, and financial through usability.

We believe that usability is a concept that can provide the breadth and depth to cover essential attributes of social-technical systems in such a way that all stakeholders involved in a system, service, or product life-cycle can employ. However, we also embrace the view that usability is like a living entity which adapts to its ecosystem; thus, the concept evolves in time to capture and hold new attributes and meanings (see e.g., Hertzum, 2010; Rajanen et al., 2017). A brief description of the usability construct and various paradigms of usability research are presented in section 2. In section 3, we position usability at the core of the STS development, and we employ the usability as lens to analyse the STS landscape by highlighting the impacts usability generates at all levels of an organization and society (group, individual, technical, environmental, and financial). The paper ends with discussion and conclusions.

2 Usability construct

Usability emerged in 1980s and 1990s as a quality concept in the human-computer interaction (HCI) community to characterize visual displays and interactive systems from the perspective of users (Bevan et al., 2015). The concept was intended to capture the attributes of interactive software products that would make them usable and that can be incorporated in design and further evaluated (Bevan et al., 2015). This user perspective was incorporated in design standards (i.e., ISO 9241-11; ISO 9241-210) and further in software quality standards (i.e., ISO 9126). Usability is currently defined in the ISO standard of human-centred design as being "*the extent to which a product, system, or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use*" (ISO 9241-210). The roots of usability and the recognition of the needs of the users in system design can be traced back to Vitruvius in 1st century BC, who introduced the principle of *utilitas* (suitability and usefulness for the intended user; Pollio, 1960) as one of his three core principles in architectural design. The other two principles, *firmitas* and *venustas* (i.e., durability and beauty, respectively) are also influential concepts in usability and system design.

One of the early paradigms in the usability research conceptualized usability as a *property of the software* or system itself, and the research focused on finding and documenting these usability properties, so that they could be taken into account in the design of the system (c.f. Grudin, 1991; Ohnemus, 1996). Technology-centred usability guidelines and inspection methods, such as heuristic evaluation and the Fitt's law, originate from this view of usability as property or innate feature of the technology. In this paradigm, bad usability is resulted when the design of the system does not follow the universal best design practices. As a Vitruvian example, a designer of staircase would make sure that all the steps are level and have equal dimensions.

At the same time, another paradigm conceptualized usability as studying and documenting the physical and cognitive *characteristic of the users* and taking them into account in the design of the system. Cognition-based usability guidelines, such as design of graphical user interface elements, originated mostly from this ergonomics paradigm (see Bevan et al., 2015). Here, the bad usability is caused by not taking into account the universal characteristics of the users in the design of the system. To continue the aforementioned example, our staircase designer would make sure that the staircase and the individual steps do not raise so steeply or shallowly that it would make climbing the staircase difficult for the user.

A third, later paradigm conceptualized usability as characterizing the *interaction* between a particular user and a particular system in a particular context of use (i.e., quality in use). In this paradigm, the usability is incorporated in the rich interaction between the user and the technology, each interaction being unique in such way that no universal best design guidelines can be made (c.f. Rogers et al., 2011; Rosson & Carroll, 2002). User-based usability evaluation methods, such as usability testing, originate from this paradigm. Our staircase designer would make sure that there is enough lighting and that the material of the stairs is non-slippery if the staircase is located outdoors, and that there should be a handrail and wheelchair ramp to assist the whole diversity of users.

3 Usability in the core of STS development

The socio-technical landscape, understood as the interaction between humans and technology in a broad scale in the organizational and societal levels, represents the conditions of solving both small local problems on individual and group level, and emerging global scale problems such as the climate change. Technology should be shaped in such a way as to provide solutions to existing problems and to enhance the capabilities of the humans to solve these problems and challenges, taking into account the rich interaction between humans and technology. The design of STS should take into account all three paradigms of usability, namely usability as a *property of technology*, usability as taking into account the physical and cognitive *characteristics of the users*, and the rich *interaction* between both users and technology. However, the main focus should be on the human-technology interaction as, at this level, both human (social) and technical systems meet and work for a common goal. At the same time, humans in organizational and societal levels should be active participants in designing and developing technology as a response to their needs and adapting the technology to the human characteristics. This is an assumption which is in the core of the Scandinavian tradition of developing IT systems (Bansler, 1998; Bjerknes & Bratteteig, 1995; Iivari & Lyytinen, 1999).

In the following, we show how usability can act as a lens of socio-technical systems landscape (*speculum mundi*) by highlighting the impacts it generates at different levels of an organization and society.

3.1 Individual impact

Usability has an impact at the individual level of STS (i.e., on users) by enabling the concept of *utilitas* in that the design is useful and suitable for the intended users. Furthermore, better usability makes the users more effective, increases the overall performance of the users, reduces errors, helps to avoid frustration and stress due to poor working conditions and tools (i.e., effectiveness, efficiency, and satisfaction of the users). This impact is best understood, encapsulated, and analysed in the *interaction* between the individual and the technology, as the properties and features of technology and the physical and cognitive characteristics of humans in general do not address the needs and expectations of a particular individual in a particular context.

3.2 Group impact

The use of technology enables groups of users to work towards a common goal through technical means. Here the usability enables the concept of *utilitas* by making the socio-technical system suitable and useful for groups of people to work together, to communicate, to share a common goal or to be parts of a larger work process. As at the individual level, the impact of usability at group level is best understood through user-user and user-technology *interactions*.

3.3 Technological impact

Better usability has an impact at the technology level by reducing the developmental failures and consequently the need for necessary changes when the technology does not meet the requirements and characteristics of the users. Therefore, the technology and socio-technical system need only to be improved, developed, and replaced when the user, organizational, and societal requirements change. This impact concerns properties and features of the technology or technical system as a result of the STS design, therefore the impact of usability at the technological level is ensured and observed as *property* of the technology, taking into account the *users' characteristics* including needs and requirements, as well as the *interaction* between users and technology. Designing with technological impact in mind enables the principles of *utilitas* and *firmitas* as the technology should be both useful and reliable.

3.4 Environmental impact

Better usability can have environmental impacts through minimizing the amount of materials required for software or service enabled printing and manufacturing of products, as well as minimizing the amount of the excess waste, the hazardous waste, and the energy. This impact concerns not only the technology itself, but the way users, groups, organizations and society at large use the technology, therefore the environmental impact of usability is best analyzed both as a *property* of the technology itself and as the *interaction* between the users and the technology. A design and product that is useful to a user, business or society has a long life-cycle, which has a positive impact on the environment through minimizing waste, thus the usability principle *utilitas* is enabled. Furthermore, the design that is built to last both in design, material, and constructional sense enables the *firmitas* principle.

3.5 Financial impact

Usability has been recognized in literature as a crucial factor for the success of interactive systems and products for both vendor organizations, customer organizations and individual users in many different contexts of use (Maguire, 2001). The following are some of the benefits with financial implications that have been identified for users and vendors: increased user productivity, reduced user errors, reduced user learning effort, reduced service and support, increased acceptance, and increased reputation (see Maguire, 2001; and Rajanen & Rajanen, 2017). These benefits are enabled through the concept of *utilitas* that ensures that the user's and organizational goals are fulfilled and therefore generate economic value. Furthermore, better usability has financial impact through minimizing the required work, the material resources and the amount of waste.

The financial impact of usability can thus be ensured and observed as *property* of the technology, physical and cognitive *characteristics* of the user, and *interaction* between the users and the technology.

4 Discussion

In this paper, usability was conceptualized through the principles of Vitruvian architectural design: *utilitas*, *firmitas*, and *venustas* (see Pollio, 1960). We showed how usability of the socio-technical systems can impact organizations and society at individual (user), group, technical, environmental, and financial levels. We argue that usability can be employed as *speculum mundi* or mirror of the world; **the degree of usability of the various socio-technical systems that exist in the world reflects the advancement of technology, socio-technical systems, organizations, society at large, and environmental responsibility**. This proposition is especially relevant in the perspective of new technological breakthroughs that are looming at the horizon. Artificial intelligence, internet of things, and new generations of communication technologies represent both the promise and challenges of designing socio-technical systems in line with their original philosophy that social and technical systems should optimally adapt to each other (see Bostrom & Heinen, 1977). Moreover, at the core of the STS philosophy lies the principle that "design is systemic" (Clegg, 2000, p. 465), meaning that one component in the system affects other components or the whole system (Davis et al., 2014).

Many authors have linked the HCI approach to the STS approach from various perspectives such as ergonomics and human factors (e.g., Carayon, 2006). Whitworth (2009) classifies the STS requirements into four categories based on different components of STS: hardware, software, human-computer interaction, and organization. Thus, introducing *usability thinking* into the STS development approach is not new and it builds upon the user-centred design approach which is a specific system development approach in HCI (see e.g., Rajanen & Rajanen, 2017). The contribution of this paper is to restate the importance of the concept of usability, and for this we referred to the classical principles of architectural design as providing an everlasting foundation for STS design. Especially *utilitas* and *firmitas* were found to be relevant, while the impact of *venustas* (beauty) remains to be demonstrated empirically (see Tuch et al., 2012).

Present empirical research on STS has often a too narrow and short-distance focus. Davis et al. (2014) proposes that to advance this field, exemplar studies demonstrating the value of STS are needed. For example, Cassano-Piché et al. (2006) used the risk management framework for complex socio-technical systems by Rasmussen (1997) in a long-term multimethod empirical study in order to have a holistic understanding of how small accidents and mistakes in food production propagated over time into a nationwide epidemic. Furthermore, AlSabbagh and Kowalski (2012, 2015) utilized in their work the socio-technical framework on IT security threats by Kowalski (1994) in their exploratory and design science studies on developing a social security metrics for modelling the individual security culture and software supply chain security with a holistic view of a socio-technical system and its interactions.

However, to demonstrate the value of STS, usability can act as *speculum mundi* or analysis lens that reflects the empirical developments of STS through these classic principles of *utilitas*, *firmitas*, and *venustas*. If we compare our concept with the other concepts which have been used to analyse or design STS, we can identify both commonalities and empirical evidence. For example, the original idea of STS development shares commonalities with our concept, as the optimization of the social and technical parts and its impact fit under the individual, group, and technological impacts in our concept. As a second example, the augmented STS matrix, which was verified, abstracted, and adapted by Bider (2017) and Bider and Klyukina (2018), presents four socio-technical quadrants of people, social structure, tasks, and technology, which also fit under the individual, group, and technological impacts in our concept. Our concept further expands these previous concepts by introducing the environmental and financial impacts.

5 Conclusions

In this position paper, we presented the concept of usability as *speculum mundi*, mirror of the world, or the lens through which the rich interaction between socio-technical systems and the levels of individual user, organizations, and society can be encapsulated and analysed. We argue that usability as a concept and development method should be in the core of the STS development to ensure that the systems adapt seamlessly to the needs of the individual users, groups of users, technological requirements, environmental concerns, and financial considerations. We hope that this position paper will further invigorate the discussion and research of the role of usability as the core concept in STS development.

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