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Usability as Speculum Mundi: A Core Concept in Socio-technical Systems Development

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Abstract. Usability covers the breadth and depth of the rich interaction of users and technology in the socio-technical context. Though the concept of usability is well established, the integration of usability thinking in system development is challenging, partly due to the difficulty in understanding the importance of usability and justifying the costs incurred by usability work. This article aims to bring forth three fundamental attributes of usability that originate in classical architecture design, namely, *utilitas*, *firmitas*, and *venustas*. We provide a model of conceptualizing usability as *speculum mundi*, a lens through which the impacts of interaction at all levels of the organization and society can be identified by drawing parallels between the Vitruvian design principles and the paradigms of usability conceptualization. We restate the importance of the concept of usability in the context of socio-technical systems.
Keywords: Usability, Socio-technical Systems, Conceptualization, Vitruvius.

1 Introduction

A *socio-technical system (STS) approach* views an organization and a society as consisting of the technical system interacting with the social system for a common goal [1]. 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 between technology and human is mutual, as both of them influence each other. Technology shapes human relations and societies, and likewise, technology is shaped by social, economic, and political forces alike [2]. In this line of thought, the Scandinavian information systems (IS) tradition has advocated an ideal, human-centered adaptation of technology and an inclusive design process in which all stakeholders are represented during technical system development for organizations and society [3].

Though the conceptualization of the socio-technical systems and landscape have existed for a long time (see [1], [2], [4]), the research in this field has been reinvigorated in recent years,

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especially from a conceptual and theoretical approach perspective (see, e.g. [5]). The actual design and implementation of technology, following the assumption of a socio-technical systems approach [1], are limited because the technology usually lacks essential features necessary for it to adapt seamlessly to users' needs. Moreover, empirical research on socio-technical landscape, culture, and future lacks breadth; it provides only “short-distance” insights, and does 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 [6]).

With the advancement of artificial intelligence and emerging technologies that are capable of learning about and adapting to their environments, including the users, there are hopes and promises that the existing limitations of technology will disappear as technology becomes capable of adapting to users' contexts, needs, and values. However, new challenges appear for the *system designers* of socio-technical complex systems: such as ethical concerns, uncertainties of acceptance by and impacts on users, new needs and requirements for services, products and systems, as well as challenges to ensure that the technology is part of the solution to global challenges, not part of the problem (see [2]). In this context, *usability work* is crucial to ensure that the new services, products, and systems do indeed meet the users' needs and expectations, while *usability as a construct* fulfills the role of an influential construct throughout the system life-cycle and develops an established history.

Practical usability work must also advance through new methods, technologies, and processes from research to keep up with emerging challenges and developments in socio-technical contexts. Similarly, usability researchers update and adapt the *concept of usability* to develop these new methods, technologies, and processes for the practice of usability. Usability thus covers the breadth and depth of the rich interaction of users and technology in the socio-technical context. Though the concept of usability is well established, the integration of usability thinking in system development is challenging, partly due to the difficulty for stakeholders, other than the designers, to understand the importance of usability and justify the costs incurred by usability work in a business or organizational context (see, e.g. [7]).

This position article aims to bring forth three fundamental attributes of usability that originate in classical architecture design and to 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 and developing the systems of the future. Similarly, the meaning of usability should be understood by 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. Moreover, the usability concept should be clear also to academics as active or passive observers of the socio-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 socio-technical systems and the concept of usability.

Thus, we provide a model of conceptualizing usability as *speculum mundi*, a lens through which the impacts of interaction at all levels of the organization and society can be identified by drawing parallels between the Vitruvian design principles [8] and the paradigms of usability conceptualization. By this, we highlight the impacts that usability generates at all levels of an organization and society (group, individual, technical, environmental, and financial) and we support these propositions with literature. Along with this description, we identify the roles of the three Vitruvian design principles (*utilitas, firmitas,* and *venustas* or usefulness, durability, and aesthetics) in socio-technical system design and development in order to achieve the desired impacts.

The article is organized as follows. A brief description of the usability construct and various paradigms of usability research are presented in Section 2. In Section 3, the three Vitruvian design principles are introduced and paralleled with the concept of usability. In Section 4, we position usability at the core of STS development, and provide a model where usability is employed as a lens to analyze the STS landscape. The article ends with discussion and conclusions.

2 Usability

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 [9], though the concept of usability itself had been identified long before and was integrated into practical use in design of software, information systems and services through usability testing, usability engineering, and user-centred design. 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 [9]. This user perspective was incorporated in design standards (e.g. [10], [11]) and, further, in software quality standards (e.g. [12]).

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*" [11]. Furthermore, the usability standards identify the satisfaction of use as one of the characteristics of usability. This concept of satisfaction of use was further conceptualized in the late 1990s in the form of user experience (UX), which characterizes the overall emotions and attitudes of users resulting from using a particular product, system, or service. However, while the HCI practitioners share a consensus on the definition of usability, they have not reached a consensus on the definition of UX [13].

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. [14], [15]). Technology-centred usability guidelines and inspection methods, such as heuristic evaluation [16] and the Fitt's law [17], originate from this view of usability as a property or innate feature of the technology. In this paradigm, bad usability results from design of the system that does not follow the universal best design practices. As an example, a designer of a staircase would make sure that all the steps in the staircase are level and have equal dimensions.

At the same time, another paradigm conceptualized usability as studying and documenting the physical and cognitive *characteristics 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 [9]). Here, 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 rise so steeply or shallowly that it would make climbing the staircase difficult for the user.

The 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 a way that no universal best design guidelines can be made (c.f. [18], [19]). 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 and the Vitruvian Design Principles

The roots of usability and the recognition of the needs of the users in system design can be traced back to Vitruvius in the 1st century BC, who introduced the principle of *utilitas* (suitability, convenience and usefulness for the intended user; [8]) 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.

The first Vitruvian principle, *utilitas*, means that the design must have a practical use and be suitable and useful for its intended use by the intended user [8]. For instance, the designer of a staircase would take utilitas into account by designing the staircase so that it allows its users to traverse a vertical distance by dividing it into smaller vertical distances, or steps. In the context of socio-technical system, software, and service development, utilitas corresponds to the concept of usability in its original form: the design must allow the intended users to achieve their goals.

The second principle, *firmitas*, means that the design must be strong and built to last. For instance, a staircase designer would take firmitas into account by ensuring that the staircase is made of appropriate materials and that all the components are properly fitted together. In the context of usability, firmitas maps to the best practices of using existing designs that have been proven in practice, as well as existing mental models of the users, as the basis of a new design.

The third, and often overlooked, principle in the design of socio-technical systems, *venustas*, or beauty, is closely related to *aesthetics*, which is a concept of beauty in art and nature. In the context of socio-technical systems, venustas relates to the subjective user experience. Following the examples above, a staircase designer would take venustas into account by making the staircase aesthetically pleasing and easy on the eye. There have been calls to apply aesthetics to technological development and technology to aesthetics, or aesthetic cybernetics, to achieve a balance between cognitive and material aesthetics [20]. In the context of usability, designing for user experience links to venustas. Some studies have used aesthetics and the emotions produced by aesthetic experiences to explain why people may prefer some designs over others, and the results from these studies showed that the overall appraisal of technology by a user is influenced by the aesthetic aspects of the design [21].

In addition to adapting to emerging needs and challenges, the construct of usability has also evolved with regards to the conceptual paradigms of the nature of usability.

4 Usability in the Core of Socio-technical Systems 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 an 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 humans to solve these problems and meet 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 users and technology. However, the main focus should be on the human-technology interaction as, on STS level, both human (social) and technical systems meet and work for a common goal. At the same time, humans on organizational and societal levels, should be active participants in designing and developing technology as a response to their needs and in adapting the technology to human characteristics. This is an assumption which is in the core of the Scandinavian tradition of developing IT systems [22], [23], [24].

We believe that usability is a concept that can provide the breadth and depth to cover essential attributes of socio-technical systems in a way that makes usability to be relevant to all stakeholders involved in a system, service, or product life-cycle. 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. [13], [25]).

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

Figure 1 illustrates the underlying assumption of the role of socio-technical systems' usability in impacting the organization or society at large and is our proposed model of usability as *speculum mundi*. The usability concept as *speculum mundi* or as an analysis lens can capture impacts at different levels in the organization and society (group, individual, technical, environmental, and financial).

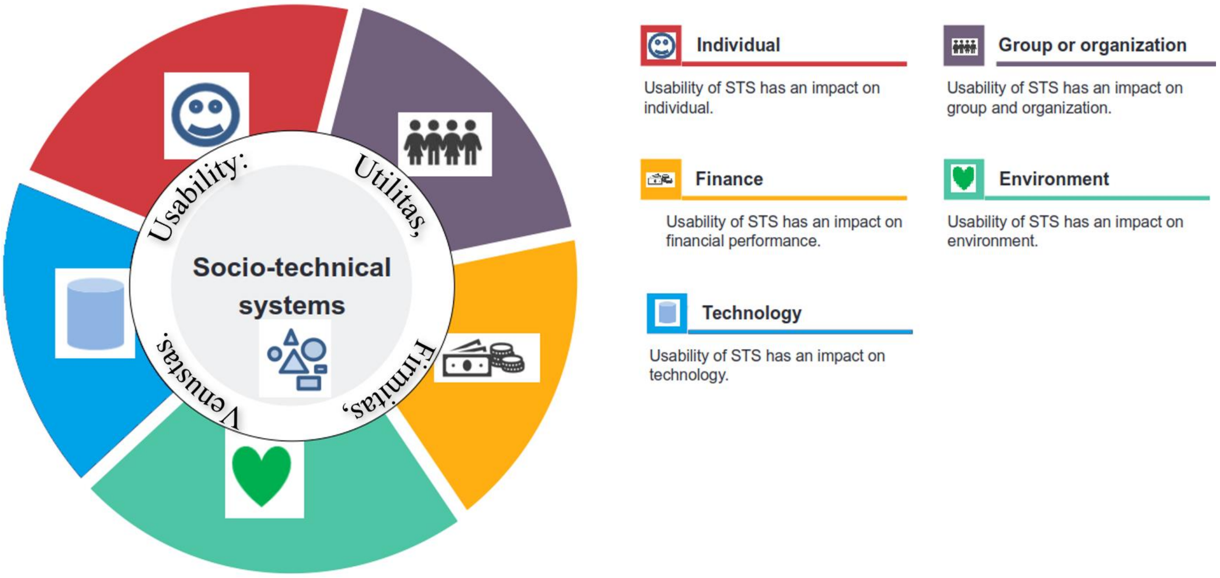

Figure 1. Usability as speculum mundi. Socio-technical systems (shown in the center of the diagram) influence an organization and society at large at different levels through usability: individual, group, financial, environmental and technical.

4.1 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 (effectiveness). 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). Subjective user experience, or the degree of satisfaction in a specific context of use of a system, also has an impact on perceived ease of use and willingness to learn to use the new system, which can also be enabled by *venustas*, in that a design that is simple and pleasant to the eye is perceived as being more attractive, and less effortful to use, by generating positive emotions (see, e.g. [21], [26], [27]). This impact is best understood, encapsulated, and analyzed in the *interaction* between the individual and the technology. Moreover, the *properties and features of technology* and the physical and cognitive *characteristics of users* are also important to be studied and to ensure the desired impact at the individual level; for instance, by incorporating the principles of *venustas* and *firmitas* in the design. The impact of STS at the individual level has been the core of HCI research and practice (see e.g., [28], [29]).

4.2 Group or Organizational Impact

The use of technology enables groups of users to work towards a common goal through technical means [30]. 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. If the communication in the group is facilitated through an interface or interactive systems that are intuitive to use, familiar and aesthetically pleasant, designed by taking into account the principles of aesthetics (*venustas*), the participants will find the interaction trustful, easy, useful and satisfactory (see, e.g. [30], [31]). Moreover, it was also shown that product aesthetics have a positive influence on professionals at the organization level (see [33], [34]). As at the individual level, the impact of usability at group level is best understood through user-user and user-technology *interactions* as well as through understanding, and incorporating in the design, the *users' characteristics*. The impact of STS at the group and organizational level has been the core of the research field of computer-supported collaborative work and also IS research, including management and organizational perspectives of IS [28], [29].

4.3 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 a *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. Moreover, designing with users in mind and making technology more attractive enables the principle of *venustas* and thus the technology, such as an interactive robot, is more likeable and trustable (see, e.g. [35]).

4.4 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 excess waste, hazardous waste, and energy. This impact concerns not only the technology itself, but the way users, groups, organizations and society at large use the technology, especially with large and complex systems. 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 the design, material, and constructional sense, enables the *firmitas* principle. Moreover, one can argue that designing using the principle of *venustas* will result in systems that create positive emotions and thus are more attractive, trustable, and familiar to consumers (see, e.g. [26]), which, in turn, may result in a longer system life cycle. Thus, the environmental impact can be analyzed and ensured to be acceptable through also taking into account *users' characteristics*.

4.5 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 [36], [37]. 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 [36], [38]). These benefits are enabled through the principle of *utilitas* that ensures that the user's and organizational goals are fulfilled and therefore generate economic value. Furthermore, better usability has a financial impact through minimizing the required work, the material resources and the amount of waste. Moreover, marketing research has long shown that product aesthetics designed with the principle of *venustas* in mind are directly linked to higher sales and thus have a positive financial impact (see, e.g. [33]). The financial impact of usability can thus be ensured and observed as a *property of the technology*, physical and cognitive *characteristics of the user*, and *interaction* between the users and the technology.

5 Discussion

In this article, usability was conceptualized through the principles of Vitruvian architectural design: *utilitas*, *firmitas*, and *venustas* (where *utilitas* refers to usefulness, suitability or convenience, *firmitas* − to strength and durability, and *venustas* − to beauty and aesthetics, see [8], [39]). We showed how usability of socio-technical systems can impact organizations and society at individual (user), group, technical, environmental, and financial levels. Though usability is a concept that evolves in time, we argue that these three design principles act as anchors for understanding the concept of usability in different contexts and areas. Further, 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 and the concept of usability itself reflects the advancement of technology, socio-technical systems, organizations, society at large, and environmental responsibility**. This proposition is especially relevant from the perspective of new technological breakthroughs that are looming on the horizon. Artificial intelligence, 5G and 6G enabled technologies, internet of things, and new generations of communication technologies face 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 [1]). Moreover, at the core of the STS philosophy lies the principle that “design is systemic” [40, p. 465], meaning that one component in the system affects other components or the whole system [6].

Many authors have linked the HCI approach to the STS approach from various perspectives such as ergonomics and human factors (e.g. [41]). Whitworth [42] 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-centered design approach which is a specific system development approach in HCI (see, e.g. [38], [43]).

However, the focus of present empirical research on STS is often too narrow and short-term. Davis et al. [6] propose that to advance this field, exemplary studies demonstrating the value of STS are needed. For instance, Cassano-Piché et al. [44] used the risk management framework for complex socio-technical systems by Rasmussen [45] in a long-term multimethod empirical study, in order to gain a holistic understanding of how small accidents and mistakes in food production, propagated over time into a nationwide epidemic. Furthermore, AlSabbagh and Kowalski [46], [47] utilized, in their work, the socio-technical framework on IT security threats by Kowalski [48] in their exploratory and design science studies on developing 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.

Therefore, we argue that 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 analyze or design STS, we can identify both commonalities and empirical evidence. For instance, the original idea of STS development shares commonalities with our concept, as the optimization of the social and technical parts, and its impact, are a good fit with 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 [49] and Bider and Klyukina [50], presents four socio-technical quadrants of people, social structure, tasks, and technology, which also fit with the individual, group, and technological impacts in our concept. Our concept further expands these previous concepts by introducing the environmental and financial impacts.

The contribution of this article is to restate the importance of the concept of usability in the STS context, and, for this, we referred to the classical principles of architectural design as providing an everlasting foundation for STS design. We indicated that designing with these three principles in mind: *utilitas*, *firmitas*, and *venustas*, the resulting systems will have positive impacts on different levels in a society: individual, group or organizational, technological, environmental and financial. We have also identified works that link aesthetics, or some specific dimensions of it, to various impacts, such as financial, individual, organizational and technological. We observed that the mapping, between the three design principles and the types of impacts, is not well balanced in the literature. On the one hand, some relationships are more studied, such as the link between aesthetics and financial impact or the link between usability and individual impact; other relationships are overlooked. On the other hand, there are various empirical and theoretical studies that link different sub-dimensions, such as aesthetics, to usability or interactivity (see, e.g. [51], [52], [53], [54]). Thus, we suggest that future research addresses both empirically and theoretically the link from lower-level constructs such as attributes of aesthetics, usefulness, and durability to higher-order constructs such as environmental impact (see also [55]). This would also advance the perspective of sustainable development of STS.

6 Conclusions

In this position article, 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 analyzed. We argue that usability as a concept and development method should be in the core of socio-technical systems 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. This article contributes to the research and practice by drawing parallels between the Vitruvian design principles and the paradigms of usability conceptualization, as well as by presenting a model that allows the researchers to further conceptualize, encapsulate and analyze the role of usability in socio-technical systems. Furthermore, the practitioners can adopt and utilize this concept to develop new socio-technical systems which fit the needs of users and organizations and have holistically good usability across different levels. Further empirical and theoretical research is still necessary, as the concept of usability as mirror of the world should be refined further and empirically tested. We hope that this position article will further invigorate the discussion and research of the role of usability as the core concept in socio-technical systems development.

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