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Postprint

This is the accepted version of a paper presented at *7th International Conference, UAHCI 2013, Held as Part of HCI International 2013, Las Vegas, NV, USA, July 21-26, 2013.*

Citation for the original published paper:

Mustaquim, M., Nyström, T. (2013)

Designing Sustainable IT System – From the Perspective of Universal Design Principles.

In: Stephandis, C. and Antona, M. (ed.), *Universal Access in Human-Computer Interaction. Design Methods, Tools, and Interaction Techniques for eInclusion: Proceedings, Part I* (pp. 77-86). Berlin

Heidelberg: Springer

Lecture Notes in Computer Science

http://dx.doi.org/10.1007/978-3-642-39188-0_9

N.B. When citing this work, cite the original published paper.

Permanent link to this version:

<http://urn.kb.se/resolve?urn=urn:nbn:se:uu:diva-206924>

Designing Sustainable IT System- From the Perspective of Universal Design Principles

Moyen Mohammad Mustaquim, Tobias Nyström
Department of Informatics and Media
Uppsala University
Box 513, 75120 Uppsala, Sweden
{Moyen.Mustaquim, Tobias.Nystrom}@im.uu.se

Abstract. Since the concept of universal design is already extending the boundary of disabilities, it is significant to include different aspects of information technology where universal design enabled efforts can contribute towards better designed systems, products and services. Sustainability is an important and growing public concern in today's world. Nevertheless, attempts of designing IT system that can be called sustainable in nature are not so evident at present. In this paper we propose a framework originating from sustainable IT system design principles (also described in the paper). The universal design principles are used as a foundation upon which the resultant sustainable IT system design principles were derived. The concept of 'sustainable IT system' addressed in this research paper is beyond the common phenomenon of sustainability like green IT, CO₂ emission etc. Rather, the framework proposed in this paper incorporates more user inclusion and increased user satisfaction together towards higher usability. And an IT system designed in this manner is a sustainable IT system according to the argument of this paper which can therefore be designed by following the proposed design principles and framework.

Keywords: Universal design, Sustainability, Sustainable design principles, Design for all

1 Introduction

Different concerns for the betterment of our future life on earth are one of the major issues that motivated a lot of people to use the word, "sustainable" [2]. However, frequent use of the adjective "sustainable" is not the only thing that is needed to create a sustainable system or society, although such belief tends to be noticeable [2]. "Sustainability" has become an important topic and more academics and professionals are using this adjective for promoting their research [2], without in fact serving the real purpose of sustainability. The terms "sustainable" and "sustainability" burst into the global lexicon in the 1980s as the electronic news media made people increasingly aware of the growing global problems of overpopulation, drought, famine, and environmental degradation that had been the subject of Limits to Growth in the early 1970s [10]. A great increase of awareness came with the publication of the report by

the United Nations World Commission on Environment and Development, the Brundtland Report, which is available in bookstores under the title 'Our Common Future' [3].

For many years, studies had been conducted on ways of improving the energy efficiency in our society. These studies have been given renewed impact by referring to them now as studies in the "sustainable use of energy" [2]. Often the very first impression about sustainable system or sustainable design reflects something to be environment-friendly, ecological and green. Information technology has also been influenced by sustainability. How to create green IT system, how to promote sustainable action through designing IT system are some of the hot topic of research and practice in recent time.

While universal design is based on the pillar of design with accessibility issues, the actual concept is far beyond only accessibility. Universal design has a lot more to offer rather than being limited accessibility issues. Whether something that is universally designed should also be sustainable or not and vice versa, is an interesting question to ask. Considerable amount of research has been conducted in different aspects of sustainability and within the accessibility domain of universal design. However a combinatorial approach of considering universal design beyond accessibility together with designing IT system sustainability has not yet been addressed in the research community, as of authors' knowledge. In this paper we analyze universal design principles together with general sustainable design principles and derive sustainable IT system design principles. The proposed design principles were then mapped into a framework, following which; sustainable IT system design can be accomplished. The paper has four major sections. The background section presents a thorough outline about sustainability, sustainable system design principles followed by universal design principles. The next section proposes the design principles for designing sustainable IT system. We then showed the theoretical framework and discuss it in the next section. Finally the paper is concluded by a discussion and the possibility towards further research.

2 Background

2.1 Sustainability

With an increased awareness of the importance of sustainability, the definition of sustainability diverges depending on context and authors; therefore no universal definition exists (for a detailed review of sustainability terms; see [7]). Sustainability acknowledges that human activities could have a negative impact on our environment, including ecological, social, and economic aspects. The Brundtland's Commission defined sustainable development as "... development that meets the needs of the present without compromising the ability of future generations to meet their own needs." [13]. The aim is to improve our life without draining the resources for future generations or more preferably to minimize, reduce or reverse negative sustainable impact of current and future processes. Elkington's [6] triple bottom line (TBL) perspective considers organizational sustainability where the organization is an actor

in a social context. TBL defines sustainability to include three components: society, economic performance, and the natural environment. The organization is thus accountable for their actions in terms of social and environmental responsibilities, adding to their financial goal of profit maximization. Sustainable design is fundamentally a subset of good design. The description of good design can be a home design for the creation of a healthy and safe environment or energy efficiency that promotes sustainable goals like less transportation of physical products and the need of traveling. Unique and innovative solutions will increasingly become the objective of such design. For instance one eventual outcome of this integrated or sustainable design practice will be the development of buildings that produce more energy than they consume.

Sustainability in the field of information technology research has mostly been focused on reducing carbon dioxide emission from IT hardware [5] i.e. a resolution that is mainly focused on technical solutions. We think that the role of IT in a larger context including ecologic, economic and social attentions must be considered to achieve sustainable goals. If the design of an IT system includes these factors then the final artifact would lead towards sustainability.

2.2 Sustainable IT System- WHY?

IT systems are important for organizations since it is integrated into the organization structure and direct and restrict how business process can be done and the alignment between IT and business is important. Since organizations are more aware of the importance of a sustainability strategy the alignment between sustainable IT and business is significant. The design of the sustainable IT system is therefore important and must be done properly and should include as many stakeholders as possible this will also strengthen the equality of people.

Porter and Millar wrote that information technology would transforming the value chain [12] and it has proven that IT has a huge impact on organizations competitive advantage e.g. the change of business model on the distribution of music to customers from physical product the Compact Disc (CD) to digital files and streaming. A sustained competitive advantage is achieved when an organization have implemented a value creating strategy inimitable by others [1]. Technology per se is imitable but a sustainable IT system that supports the organizational strategy (including sustainability goals) could distinguish one organization from others and improve the chances of reaching sustained competitive advantage. The business value of a sustainable IT system is consequently high and could be crucial for an organizations strategy and future.

Sustainable IT system should focus on strategies that spur innovation, create new markets, and redefine processes [8]. Our definition of sustainable IT system is an IT system that unites user inclusion, increases user satisfaction, and gives higher usability. We assume that, if the specified design principles suggested in this paper is followed, the sustainable IT systems will have a larger chance of reaching the organizations goals for sustainability (the organizational sustainability strategy).

3 Sustainable System Design Principles

While we design something, we simply do not just design for the sake of design itself; rather we have a purpose for the design. By purpose we often mean that the design should meet a particular need or that the design achieves a set of goals. This understanding is important whether the design is for something small or even a large industry. Following the definition of sustainability we can say that, if a system is designed by including the considerations for sustainability goals, the result can be a system which is sustainable. By this we mean that, a sustainable system will be used to improve the life of the users of the system, will make sure to meet the need of the users of that system. And these two things should happen without any compromise with human culture and the living world.

Sustainability, corporate social responsibility and related trends are part of the business agenda for an increasing number of companies worldwide largely due to media attention, customers' awareness, and society's demand on business. Understanding how to integrate these concepts into business planning can be an important part of a successful business. Pressure to integrate sustainability requirements will come from government, business partners, non-governmental organizations and citizen groups. Motivation (or pressure) to implement design for sustainability can come from two different directions: from within the business itself (internal drivers) or from outside the company (external drivers). Although there are overlaps amongst the people, planet and profit aspects of sustainability, usually a driver is connected to one of them. The following design principles of sustainable design are drawn from McLennan [9].

- Learning from natural systems (Bio-mimicry Principle): Nature is considered as a model, a measure and as a mentor. For instance in an ecosystem nature recycles everything and nature can show us its limits.
- Respect for Energy & Natural Resources (Conservation Principle): Learn from nature's example of energy concentration and storage. There are several processes like physical, chemical and biological involved in these examples.
- Respect for people (Human Vitality Principle): Houses, factories and buildings are characterized utilitarian and they are unfriendly and unsafe in different manner. An aim of this principle is to create a healthy place and to do that honoring diversity and giving back control to people for their personal comfort and safety is the goal of this principle.
- Respect for place (Ecosystem Principle): How to use places optimally and how can we contribute to the local environment easily, is the goal of this principle.
- Respect for future: Whatever is consumed by human today is not available for us tomorrow. And it is impossible to ignore the influence that happens over time. As stated by great law of the Iroquois Confederacy what we do today, we should consider the consequences on the next seven generations is the reflection of this principle.

- Systems thinking (Holistic Principle): The fact that things tend to create problems over time since they are connected to each other is evident but difficult to understand completely in order to overcome it.

The bottom-line of these design principles is that, while we talk about sustainable design, it is not only important to talk about the impacts of environments, but we should also give priority to consider the impacts on peoples which reflect equality and concurrently business prospects which reflects economy. This consideration of equality and economic prospects brings the idea of inclusiveness or universal design into the deliberation within sustainable design; that is, we can include more factors into the concept of sustainable design and call this universal design in nature where inclusion or universality has nothing to do with physical accessibility. Also combination of such concept is going to generate new sustainable design conception which is more than environmental issues.

4 Universal Design Principles

The set of universal design principles were developed by a group of U.S. designers and design educators from five organizations in 1997[4]. The seven design principles' key terms are equitable use, flexibility in use, simple and intuitive use, perceptible information, tolerance of error, low physical effort and size & space for approach and use. A design should not stigmatize or disadvantage a certain group of people or group and should provide equal mean of use for all possible users. The design should accommodate a wide range of individual likings and capabilities by enabling different choices in the method of use of a system. By simple and intuitive use it is assumed that a design should be easy enough to understand and this should not depend on the past experiences of the user along with knowledge or any other special requirements like level of concentration and knowledge of language. Also information to the user should be arranged so it is consistent according to their importance [11]. Perceptible information design principles promises that the design should transfer information to the user in an effective manner and should not depend on any ambient condition of the user's sensory abilities [11]. Error tolerance principles states that hazards should be minimized and that any adverse consequences of accidental or unintended actions can be taken care of. This can be done by providing awareness and warnings of hazards and error for instance. Low Physical Effort: Universal design principle also states that the design should be used efficiently and comfortably, and with a minimum of fatigue [4]. This principle is titled as low physical effort also argues that the design should be in such way so that the user's body position remains natural with reasonable operating force required to perform a task. The final design principle is called size and space for approach and use. This principles states that appropriate size and space should be provided for approach, reach, manipulation, and use, regardless of the user's body size, posture, or mobility. A clear line of sight is also important for the user while they are dealing with several elements on a system for instance.

As the emphasis on environmentalism, safety and conservation continues to grow, it is becoming more essential than ever for the design and construction of new facilities to not only meet requirements for providing access for all individuals, but also to embrace this "green" philosophy. Relating universal design with sustainability

in terms of accessibility, one example can be given like this. A healthy, sustainable home is a home that is designed for instance for all members of the family. Also the home will serve as an inviting home to family and friends, no matter what their physical ability is. Some factors impacting physical abilities can be invisible or silent (psychological problems or allergies) or visible (physical problems cause by stroke). However the truly sustainable home will “sustain” and thereby support that homeowner and their friends and family, usually as long as they wish to remain in the home. So one could say that a universal home is not only sustainable but also gives the homeowner a sense of independence no matter what physical challenges may occur. Since universal and green (sustainable) designs are not technically design styles but simply points of reference, they often can influence the design (building construction process for example). When integrated together, they have the ability to drive the design process by creating facilities that are more user friendly and environmentally conscience as well. Rosemarie Rossetti in her statement during keynote speech at INTERIORS 2008 in New Orleans stated “ If it is not universally designed, it is not sustainable.” Following this we argue that the idea of using universal design principles in this article is, to integrate them with the sustainable design’s characteristics and thereby derive some new, better design principles; which will have positive impacts on creating IT system.

5 Proposed Design Principles

Since we argued that universal design is meant to reflect better design if we combine the characteristics from sustainable design principles together with universal design principles, a general matrix of sustainable IT system design principles can be established. Table 1 shows the keywords as design principles properties of sustainability and universal design principles. These key words are necessary to narrate the new design principles of sustainable IT system which are also shown in this section.

Table 1. Sustainability, universal design and their corresponding characteristic matrix

Sustainability	Universal Design	Design Principle Properties
Reduce gap between natural system model and practice	Equitability	Doing design following nature as a mentor guideline
Being conservative in using resources	Error Tolerance	Condense the use of resource in system design
Expand towards diversity	Approachability	Design for majority of users
Optimal use of local environment	Flexibility and Simplicity	Simple and flexible system that is customizable
Influence over time	Reduced Effort	Reducing adverse effects over time and enabling easy alternation of

		design
Systems thinking	Transparency	Understand synergies and emergent properties

The properties described in column one on the Table 1, maps over with the properties in column two. The resultant matrix from these two columns is shown in the column three as an aggregated form of previous two columns. These are the foundation upon which the following derived sustainable IT system design principles are based on.

Principle one: Practice IT system design following nature as a mentor

IT system design should be in a manner that uses fewer components in design phase and execution phase. Also following the nature's way of doing things, trying to produce a scalable system at once should be an aim for designing sustainable IT system.

Principle two: Reduce the use of resources in IT system design

Use of resources should be considered while IT system is designed. This includes planning from the beginning to the outcome of the system's effect during use and also effects after use. If a reduced amount of resources are used then it is better for the sustainability of the system. While executing the IT system, reduction of the use of resources are also necessary and safety consideration must be considered.

Principle three: Design IT system by respecting people

Designing several systems for different focused user group is a bad idea. This is not going to sustain over time since more resources will be used for each IT system. So designing IT system that supports the need of many different users should be the goal of the design. This reflects the concept of inclusive design beyond accessibility issues. Design should not exclude particular group of people because of their inability to use the system for different reasons apart from physical or mental accessibilities.

Principle four: IT system's design should be simple and flexible so that it can be customizable if needed

Designed system should be customizable for different circumstances where different users may feel challenge to use the system. That way, it will be more design towards people and for the people. A system that is appropriate and functioning in a certain situation with a certain group of users might not be useful for some other situations or for other group of users. Designing a complete new system is not an optimal solution for such circumstances. Customization for optimization is therefore important.

Principle five: Design IT system in such way that, any negative effects initiated by design gets reduced over time and to reduce these effects the design can be altered

We do not know what the negative influences are of an IT system, unless we use it. Any system tends to show its effects (positive or negative) over time. This should be considered during the design of an IT system. If any negative effects are initiated by the use of the system over time, then it should be designed such way so that it can reduce those effects without spending too much effort on the re-design of the system. That is, the system should be easily alterable to reduce or remove negative effects while in use for a longer period.

Principle six: Understand synergies and emergent properties of the designed IT system before, during and after design is in practice

The design of IT system should consider that negative synergies should be avoided while positive synergies should be accepted. Also any emerging properties that can arise during the practice of the design should be taken care of properly. It is important to remember for creating a sustainable IT system that, these effects will be connected to create problems over time since they are connected to each other. Practicing to create an IT system for reducing these effects or trying to use the positive use of these effects will therefore result in a sustainable system.

6 Proposed Framework

The proposed design principles from the previous section are considered to generate a framework for designing sustainable IT system which is shown in figure 1. The framework is a recurring process which starts from the concept of doing design by following nature's principle. If we follow the nature's practice in our design then it should reduce the use of the resources during the design. It will also reduce the resources while we use the system or do further design to update it. Minimal use of resources means it will give the designer time to think about the design from different perspective. In this case it will be to design for the majority. Low use of resource opens the opportunity to enhance design in different manner and in this case it is practicing design for the people. While design is focused for people it should be simple and flexible so that it can be easily customizable in required circumstances. Without the opportunity of simple and flexible customization, an IT system cannot be meant to be designed for majority. A system which is meant for majority with reduced resource is the outcome of following nature's example but the system also needs to be designed in a way so that it can handle any adverse effect that might arise over time. Easy alternation should be a property of the designed IT system so it can reduce negative effects if necessary. This will go back to the nature's example of how to do sustainable design and then the whole process can iterate. The concept of systems thinking is in the middle of the circle in figure 1 which is connected bi-directionally with five other circles. This means that any of these phases of the design will have effect on the synergies and emerging properties generated by the IT system and vice

versa. That is, proper use of the five phases will have positive effect towards the systems thinking of the IT system. At the same time compromise of using any of the phases will also have negative effect towards the systems thinking of the IT system. The optimal use of five different phases leave an impact on the sixth phase and this sixth phase in return has effect on each of the phases. The result of following this framework is a simple, flexible to use sustainable IT system that is useful for majority user groups. The system also uses reduced resources while in practice. The properties of such IT system is that, it will have reduced negative synergies and builds up over time with positive synergies and emerging properties of the system.

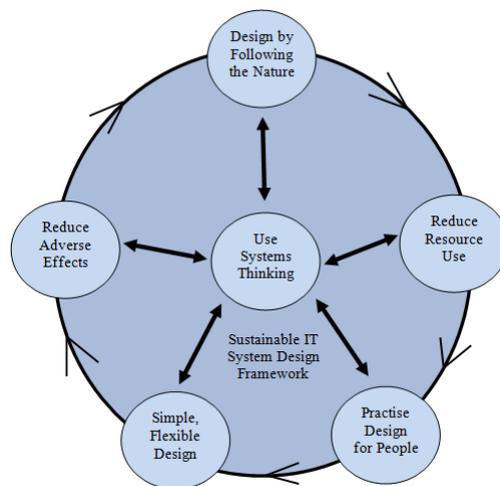


Fig.1. Proposed framework for designing sustainable IT system

7 Discussion and Conclusion

The proposed design principles support the trend suggested in the literature by McLennan [9], in terms of consistency. McLennan suggested that learning from nature will affect the sustainability goal in a positive manner. The existing universal design principles are mapped with the sustainable design principles to come up with the new principles which reflect that by following nature's way it is possible to design IT system to be more sustainable. The framework presented in this paper is theoretical in nature and we did not have any empirical evidence until now. Further research is needed to find out the reliability of the proposed framework. Quantitative data analysis from an experimental setup to design an IT system is the next step of the research that is initiated from the result of this paper. Finding statistical significance in different phases of the framework will give us further insights about enhancing the framework. Once the framework is statistically significant, it can also be used as a tool for an organization to measure the chance of achieving a sustainable IT system.

The framework could also be used to benchmark different IT systems against each other to find out how well they reach sustainability in a comparison.

Use of existing universal design principles to come up with sustainable IT system design principles is a new concept which takes the argument of considering universal design beyond accessibility, one step further. Present trend of doing research in information technology with the concept of green IT, energy consumption etc. takes a new turn in terms of sustainable IT system design concept by relating with the universal design. Two major transfers are initiated in this paper which is worth mentioning. Psychosomatic accessibility is not the only restriction to consider while talking about universal design, is the first shift to consider. The second point to note is that, sustainability in IT system does not necessarily mean the consideration of ecological factors rather there are other different dimensions to deliberate and understand sustainability in the field of information technology.

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