
This is an electronic reprint of the original article.
This reprint may differ from the original in pagination and typographic detail.

Author(s): Aalto, L., Lappalainen, S., Salonen, H., Reijula, K.

Title: Usability evaluation (IEQ survey) in hospital buildings

Year: 2017

Version: Author accepted / Post print version

Please cite the original version:

Aalto, L., Lappalainen, S., Salonen, H., Reijula, K. (2017). Usability evaluation (IEQ survey) in hospital buildings. *International Journal of Workplace Health Management*, 10(3), 265-282. DOI: 10.1108/IJWHM-03-2016-0014

Rights: This article is © Emerald Publishing and permission has been granted for this version to appear here aaltodoc.aalto.fi. Emerald does not grant permission for this article to be further copied/distributed without the express permission of Emerald Publishing.

This publication is included in the electronic version of the article dissertation:
Aalto, Leena. Käytettävyystekijöiden huomioiminen sairaala-, perusterveys- ja vanhuspalvelurakennusten työtiloissa. Aalto University publication series DOCTORAL DISSERTATIONS, 75/2019.

All material supplied via Aaltodoc is protected by copyright and other intellectual property rights, and duplication or sale of all or part of any of the repository collections is not permitted, except that material may be duplicated by you for your research use or educational purposes in electronic or print form. You must obtain permission for any other use. Electronic or print copies may not be offered, whether for sale or otherwise to anyone who is not an authorised user.

Usability evaluation (IEQ survey) in hospital buildings

Leena Aalto and Sanna Lappalainen

Department of Healthy Workspaces,

Finnish Institute of Occupational Health, Helsinki, Finland

Heidi Salonen

Department of Civil and Structural Engineering,

Aalto University, Espoo, Finland, and

Kari Reijula

Department of Healthy Workspaces,

Finnish Institute of Occupational Health, Helsinki, Finland and

Clinicum – Department of Public Health, Helsinki University,

Helsinki, Finland

Abstract

Purpose

As hospital operations are undergoing major changes, comprehensive methods are needed for evaluating the indoor environment quality and usability of workspaces in hospital buildings. The purpose of this paper is to present a framework of the characteristics that have an impact on the usability of work environments for hospital renovations, and to use this framework to illustrate the usability evaluation process in the real environment.

Design/methodology/approach

The usability of workspaces in hospital environments was evaluated in two hospitals, as an extension of the Indoor Environmental Quality (IEQ) survey. The evaluation method was usability walk-through. The main aim was to determine the usability characteristics of hospital facility workspaces that support health, safety, good indoor air quality, and work flow.

Findings

The facilities and workspaces were evaluated by means of four main themes: 1) Orientation, 2) lay-out solution, 3) working conditions, and 4) spaces for patients. The most significant usability flaws were cramped spaces, noise/acoustic problems, faulty ergonomics, and insufficient ventilation. Due to rooms being cramped, all furnishing directly caused functionality and safety problems in these spaces.

Originality/value

The paper proposes a framework that links different design characteristics to the usability of hospital workspaces that need renovation.

Keywords usability, hospital, environment, indoor air, personnel, workspace

Article type Research paper

Introduction

The main purpose of repairing hospitals is to generate healthy, safe workplaces that also support the efficiency of work. However, as work processes are constantly changing, we must evaluate the quality of the indoor environment and the usability of workspaces regularly, especially when major changes need to be made to processes. The inevitable, rapid changes in care processes; robotics; and other new challenges that hospital spaces will face in the near future highlight the need to carefully assess workspaces in hospital environments from many different viewpoints. Thus, considering the usability of spaces is increasingly important, especially when renovating old buildings.

The present study developed a new operations model for assessing usability, as an extension of a comprehensive indoor environment quality (IEQ) survey. FIOH's (FIOH = Finnish Institute of Occupational Health) current IEQ survey consists of an Indoor Air Quality (IAQ) questionnaire and investigations into technical and structural problems in the building. However, it lacks information on user experience of the spaces as workplaces.

This paper presents a study that utilized the results of earlier IEQ studies, as well those of other studies on the usability of buildings, in order to develop a framework and method for evaluating the usability of hospital spaces in tandem with IEQ surveys. The model was tested in two hospitals in Finland.

Reason for the study

The need for good quality indoor air is undoubtedly higher in hospitals than in most other buildings. Moisture damage in hospital buildings and the resulting health risks became a public issue in Finland in the mid-1990s. In 2012, the estimated incidence of significant moisture and mold damage in Finnish hospitals was as high as 20%–26% of gross floor space (Reijula et al. 2012).

Hospital building renovations are problematic. Even without serious indoor air problems, hospital buildings are under constant repair due to their age, the functional changes in hospital organizations and the use of space. Indoor air issues are usually due to a cluster of problems. Structural problems connected to limited ventilation (e.g., moisture damage) are in turn related to symptoms and the fear of getting sick (Hellgren & Reijula 2011).

Indoor environment quality problems are not exclusive to Finnish hospitals. Several studies (inter alia Loo et al., 1996; Oren, Haddad, Finkelstein, & Rowe, 2001) suggest a link between hospital construction activities and airborne infection outbreaks. According to Rashid & Zimring (2008), indoor environments may also lead to stress by affecting individual and/or workplace needs in health care settings.

Al-Harbi (2005) stressed that IEQ in health care buildings can be improved by taking all IEQ parameters into account in the design of the buildings. These parameters include thermal comfort, acoustic comfort and indoor air quality (IAQ). Clements-Croome & Baizhan (2000) have also stated that good IEQ in hospitals is crucial not only for patient care, but also for the well-being and productivity of employees.

Hospital IEQ problems call for perceiving human factors, especially ergonomics, in the work environment of hospital staff. According to Capodaglio (2014), paying greater attention to the ergonomics of hospital spaces such as bathrooms could improve safety, usability and accessibility for any user, and could contribute to overcoming adverse situations that significantly affect daily hospital routines. Furthermore, Carayon et al. (2014) claim that knowledge of specific topics concerning human factors and ergonomics (HFE) (e.g. teamwork, usability, coordination, physical stressors and resilience), must be studied in order to improve healthcare quality and patients' safety.

Aim of the study

FIOH has recently carried out comprehensive IEQ surveys in several Finnish hospitals. These surveys examined indoor climate, the healthiness of spaces and the repair needs of the buildings. Hospital premises have been greatly in need of repairs due to indoor air problems, and now usability evaluations of these spaces have also become an important issue. As extensive renovations due to indoor air problems in the hospital buildings under study had to be carried out in any case, it made sense to determine the usability flaws of the spaces, and repair these at the same time.

The aim of this study was to develop and test a framework of characteristics that have an impact on the usability of work environments in hospitals that need renovations. The framework functions as a tool and a checklist for building inspectors and architects to detect and take account of usability requirements during renovation processes in hospital buildings.

Usability in built environments

According to Hansen et al. (2011) the study of usability was first developed in the 1950s in Human Computer Interaction and is widely known in relation to applications within User Centred Design (UCD), Usability Engineering (UE) and user experience (UX), and associated with friendliness criteria (Fenker, 2008; Gulliksen, 2006). Usability research on the built environment is associated with the International Council for Research and Innovation in Building and Construction (CIB) Task Group 51 "Usability of Buildings 2005", Workshop

W111 – “Usability of Workplaces 2-2008” and “Usability of Workplaces 3-2010” (Hansen et al. 2011).

The ISO 9241-11 (1998) standard describes three factors that determine usability. *Efficiency* means that the artefact allows users to perform with ease and little use of resources.

Effectiveness describes the ability of the artefact to deliver a certain desired effect. The third factor is *satisfaction*, which describes the users' feeling and attitudes towards the artefact and its effects (Alexander 2006). When evaluating usability, it is essential to consider which factors enhance and which hinder the effectiveness or the performance of various activities.

Usability measures quality in use, and usability evaluation is for tracking the process of quality in use (Bevan, 1995; Voordt, 2005; 2009); a process of understanding the interaction between facilities and their use, and the characteristics of this interaction. When evaluating usability, it is essential to consider which factors enhance and which inhibit the effectiveness or the performance of various activities.

Usability includes all aspects of the user's experience when interacting with the product, service, environment, or facilities (Alexander, 2007). User characteristics, knowledge, personality, age, surroundings, and culture also have an impact on the usability experience. Usability illustrates not only the accessibility of the environment but also the satisfaction of the residents. A well-designed living environment can provide a sense of security, as well as promote independence.

Different methods and tools can be used to make visible the usability elements that have an impact on the built environment. An example of such a method is Post-Occupancy Evaluation (POE), the process of systematically collecting data on occupied built environments, analyzing these data, and comparing them with performance criteria (Preiser et al. 1988). POEs assess how well buildings match users' needs, and identify ways in which to improve building design, performance and fitness for purpose. Nevertheless, as Hansen et al. (2011) stress, POE evaluation is still about the building rather than the user experience and primary process of the occupants.

Alho et al. (2008) describe a Usability Rating Tool developed for evaluating the usability of trade centers, in a method that allows managers, owners and designers to assess and develop the usability of different places. The tool analyses relevant usability attributes. These attributes are specified using different parameters that are identified during the research. They mention the following attributes in their study: image, accessibility, business mix, functionality, atmosphere, navigation and interaction.

Blakstad et al. (2010) developed another usability mapping tool, the USE tool, which is meant for use by building owners and facilities managers. Blakstad et al. (2008) also recommend *usability walk-through* as a quick, easy way of obtaining an initial overview and indications of the usability of a building, since it focuses on understanding the operations that take place in the built environment. Moreover, Hansen et al. (2011) claim it is possible to conduct a walk-through in different ways, ranging from a completely open structure with evaluation based on spontaneous, subjective, on-the-spot assessments by random participants, to predefined stops and evaluation criteria with selected participants and specific themes.

The group taking part in walk-through evaluation should not be too large; a maximum of 10 to 15 people. If necessary, the walking tour can be performed in several stages. It is important to document all the emerging issues during the walk (De Laval, 2004). Guides and checklists help ensure that the usability perspective is taken into account in planning (Nenonen et al. 2007, Nielsen 1993, Alho et al. 2008).

The goal of usability development, particularly in the hospital environment, is to enhance well-being at workplaces by comprehensively improving the healthiness and safety of the spaces and the efficiency of the work processes.

For instance, Haron et al. (2011) have used usability walk-through as a research method in order to implement usability research in hospital environments. They claim that a walk-through, together with an interview and observation methods, is a suitable method for collecting data that deals with human needs, especially when it touches on field experience and reflection of experience (Haron et al. 2011).

Beneficial environmental elements of hospital design

According to Haron et al. (2012), a good hospital design is structured through movement in the space. Therefore, spatial layout is always important in shaping the ways in which visitors explore, engage, and understand the function of the facility or space. Salonen et al. (2013) highlighted that the design elements with the most beneficial environmental effects on the health and well-being of people in health care facilities are: Single-bed patient rooms with private toilets, safe and easily cleanable surface materials, sound-absorbing ceiling tiles, adequate and sufficient ventilation, thermal comfort, control over temperature and lighting, natural daylight, views from windows, access to nature, and appropriate equipment and furniture in the patient room.

Chaudhury et al. (2009) found that certain environmental variables can contribute to errors in acute care settings. These variables are: *Noise levels, ergonomics/furniture/equipment,*

lighting, and design/layout. Thus, crowded, acoustically ineffective, and poorly designed nursing stations and other health care staff's workspaces in the hospital add to staff stress and may increase the risk of medical errors. The reduction of staff stress and medical errors by *ergonomic* interventions, as well as environmental considerations (e.g. *air quality, acoustics, lighting*) can have a significant impact on staff health (Ulrich et al. 2004, Janowitz et al. 2006, Chaudhury et al. 2009). It can also influence staff efficiency and contribute to patient safety (Ulrich et al. 2004, Rothschild et al.2005).

Good *spatial design* can reduce stress and physical effort among patients or other hospital users and increase the overall efficiency and effectiveness of the hospital design (Mollerup, 2009). *Clear signage* also creates a sense of safety and caring, and reduces the need for staff to guide patients and visitors (Hossi & Jänkälä 2008). Further, employees with *window views of natural environments* are less stressed, report better health, and have higher levels of job satisfaction than comparable groups without such views (Leather et al. 1997).

When designing hospital spaces, it is essential that patients, visitors and personnel are all taken into account. Moreover, when the spaces support effective work, patients also benefit. Workplace health protection and promotion is the strategic and systematic integration of distinct environmental, health and safety policies and programs into a continuum of activities that enhances the overall health and well-being of the workforce and prevents work-related injuries and illnesses.

Methods

A process of seven phases was used to develop the framework and to test it in a real environment. These phases are shown in Table 1.

Table 1. *Phases of developing and testing the framework*

Phases	Aim of the phases
1	To collect data: literature review, existing studies
2	Results of IAQ survey (knowledge regarding factors affecting healthiness in work environments of hospitals in question)
3	To create a framework
4	To make decisions regarding themes of walk-through and participatory groups, and to plan walk-throughs
5	To implement walk-throughs, make recordings and take clarifying photos
6	To summarize results of walk-throughs, and to make analyses
7	To draw up report with proposals of action

Figure 1 shows the whole process chart for the usability evaluation used in this study (notes P1 – P7 mean Phase 1 – Phase 7).

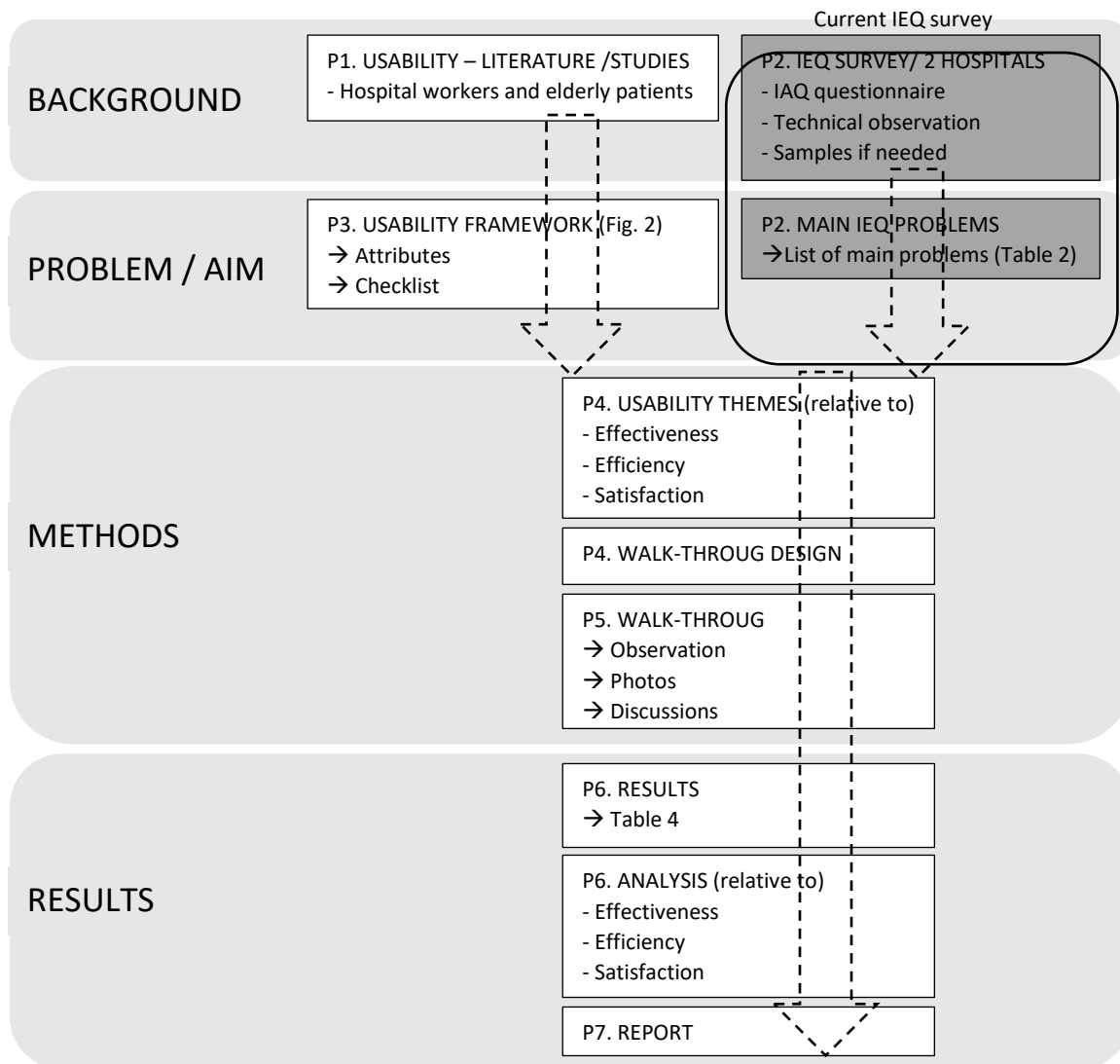


Figure 1. Process chart of usability evaluation

The IAQ questionnaire used in FIOH’s IEQ surveys is “The Indoor Air Questionnaire of FIOH” (Reijula & Sundman-Digert 2004), which is based on the Örebro indoor climate questionnaire (MM-40) (Andersson 1998). This paper does not present the inclusive results of the IAQ questionnaire in the hospitals studied, A and B. Instead, it charts the main problems (on the basis of the questionnaire) in the hospital premises via the themes of the usability walk-throughs. The main IAQ problems (value above reference values) found in Hospitals A and B, as a result of the IAQ questionnaire used in the current study, are shown in Table 2.

Table 2. Main indoor air quality problems in Hospitals A and B

Hospital A	Hospital B
Stuffy, dry air	Stuffy, dry air
Draft	Draft
Room temperature too high, too low or varying temperature	Room temperature too high, too low or varying temperature
Insufficient ventilation	Insufficient ventilation
	Unpleasant odor
	Noise
	Smell of mold

On the basis of the literature on earlier IEQ studies in Finland (Korhonen et al. 2009, Lappalainen et al. 2009, Hynynen et al. 2010, Pietarinen et al. 2012, Salonen 2009, Hellgren 2012), studies of design and usability issues in hospital environments, and the results of the IEQ surveys implemented in several hospitals in Finland, we developed a framework for usability evaluation alongside the existing IEQ survey. This framework illustrates the most essential factors that affect the usability of workspaces in hospital buildings (Fig. 2), and enables an operations model for the usability walk-through in these hospital buildings.

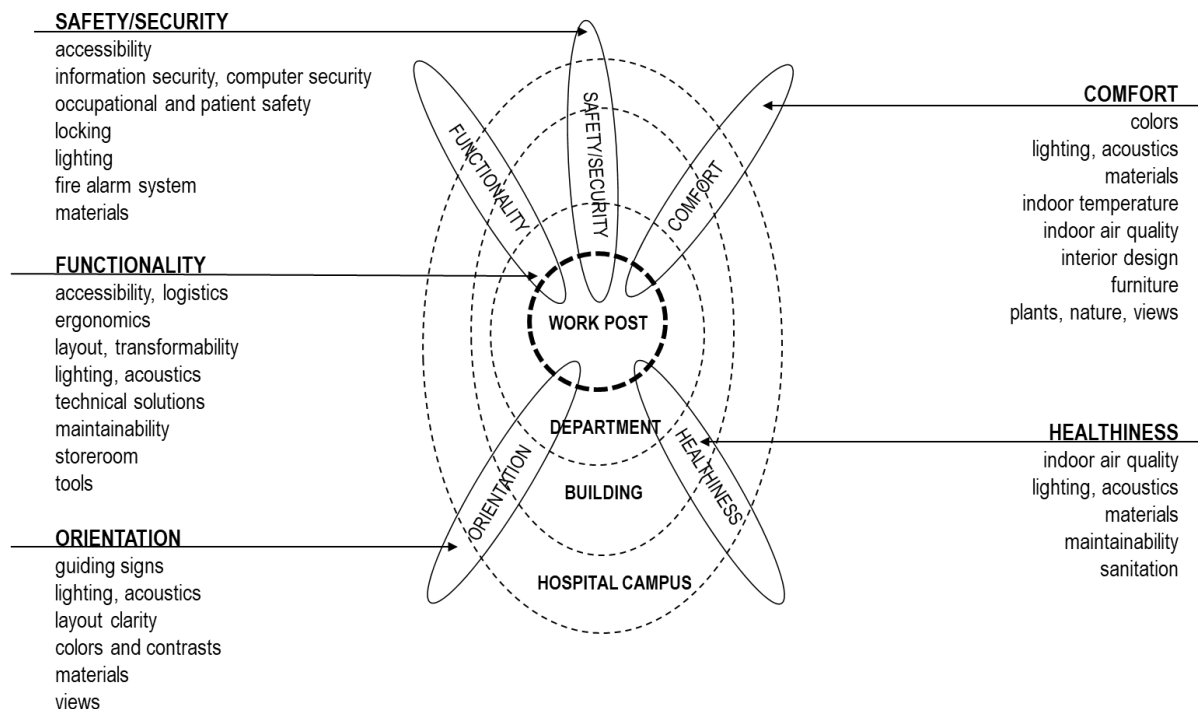


Figure 2. Usability framework of hospital buildings

In order to develop the usability evaluation method described in this paper, we used all the factors presented in the usability framework of hospital, workspaces' lay-out plans and the results of the IEQ survey.

The framework was used as a check-list by the researchers during the journey. It consists of five attributes: safety/security, functionality, orientation, comfort and healthiness, all of which have their own characteristics (Figure 2). These attributes and their characteristics can be expressed from the viewpoint of usability factors as follows:

- effectiveness: attribute – functionality and its characteristics
- efficiency: attribute – orientation and its characteristics
- satisfaction: attributes – safety/security, comfort and healthiness and their characteristics

However, in order to make the walk-through easier for the participants, the researchers compressed the most critical issues regarding hospital environments according to the literature (framework's usability factors and their characteristics) into four themes:

- 1) orientation: navigation and moving in the building (e.g. Andradea et al. 2012; Apple 2014; McCunn & Gifford 2013);
- 2) lay-out solution: clarity and functionality (e.g. Andradea et al. 2012; McCunn & Gifford 2013);
- 3) working conditions: supporting work and well-being (e.g. Andradea et al. 2012; Apple 2014; McCunn & Gifford 2013);
- 4) spaces for patients: amount, situation, comfort (e.g. Andradea et al. 2012; Apple 2014).

The four themes were discussed with the participants before the walk-through in order to help them understand what kind of work environment characteristics the researchers wanted them to think about. In addition, the researchers stressed that during the journey, the participants could discuss all kinds of flaws concerning their work environment. They also asked them questions during the tour to elaborate on the discussion.

It was important to keep in mind the three usability factors of efficiency, effectiveness and satisfaction. As a result of this kind of thinking, the researchers formulated the following four themes: orientation (with characteristics) is a factor that affects efficiency; lay-out solution (and its characteristics) is a factor that affects effectiveness, and working conditions and spaces for patients (and their characteristics), which both affect satisfaction. Table 3 shows the main themes and their more precise content.

Table 3. *Main themes of usability walk-through and content of themes*

Efficiency orientation	Effectiveness layout solution	Satisfaction work conditions	Satisfaction spaces for patients
Achievability	Functionality	Temperature, draft, IAQ	Functionality
Main entrance	Flexibility	Acoustics, lighting	Accessibility
Reception hall	Cleanliness, order	Safety	Patient privacy
Views	Ease of cleaning	Natural light	Safety
Signage	Technical solutions	Accessibility	Comfort
Colors	Maintenance	Ergonomics	Social interactions
Clarity	Clarity	Privacy	Outdoor area
		Quietude	

The operations model was tested in two hospitals, A and B, by means of a usability walk-through in 2014. Patients were not involved in this study; the personnel evaluated the spaces from the viewpoint of the patients as well as from their own.

Not all the building units in the hospital campus area were evaluated; only those that had several or serious indoor air problems. This was because the usability of these workspaces was being improved through other renovation operations.

Usability evaluations must define different user groups, and their needs and work processes in the spaces. Thus, the personnel involved in the usability walk-throughs worked in nursing, technical areas, cleaning, and occupational health and safety posts. In addition to ordinary workspaces, other spaces covered by this usability research were hallways and entrance halls, restrooms, locker rooms, meeting rooms, and storage spaces.

The usability walk-through method enables data to be collected on the quality factors and flaws in the spaces of a building. De Laval (2004) states that the group taking part in a walk-through evaluation should not be too large; a maximum of 10 to 15 people. If necessary, the walking tour can be performed in several stages, or on different days. It is important to document all the issues that emerge during the walk-through.

In Hospital A, five (5) participants took part in the entire walk-through. They represented management, nursing and technical staff, cleaning staff, and occupational health and safety personnel. In addition, the head nurse of each unit took part in the walk-through of their own unit's spaces (N=10). In total, Hospital A had fifteen (15) participants. The walk-through was conducted on four different days and covered thirteen (13) individual units of the hospital.

In Hospital B, three (3) participants took part in the entire walk-through. As in Hospital A, the head nurse of each unit took part in the walk-through of their own unit's space (N=9). Hospital B had twelve (12) participants altogether, again representing management, nursing

and technical staff, cleaning staff, and occupational health and safety personnel. Altogether twenty-three (23) units were evaluated in Hospital B, on four different days.

Before the walk-through started, the researchers explained to the participants the purpose of the study, the main themes, and the subjects that were under evaluation in the spaces.

During the usability walk-through, the operational activities of the personnel and work performance at different stages were estimated. The workers were able to verbally describe the work duties of their posts. The usability of the work environment was estimated on the grounds of conversations with the workers and observations made by researchers. All conversations during the walk-throughs were recorded and analyzed later in the office, and several photos were taken.

The recorded material was analyzed using content analysis. According to Elo and Kyngäs (2008), content analysis is a method for systematically analyzing written, visual or verbal data, which allows the researcher to test theoretical issues that might improve understanding of the data. In this approach, investigators categorize content by themes, and systematically compare cases to identify typical patterns (Elo & Kyngäs, 2008).

Results

The main purpose of this study was to create a usability framework for hospital buildings in need of renovation. Figure 2 shows the results of this development phase - Usability framework of hospital buildings.

Table 4 shows the main usability problems in Hospitals A and B, following the themes of usability shown in Table 3. The biggest usability flaws in these two hospitals can be categorized according to the four following themes:

Lay-out solution

Due to cramped rooms, furnishing workspaces practically was difficult, which directly caused functionality and safety problems in these spaces. The cramped rooms with heavy devices were also difficult to clean. As a consequence of the lack of storage rooms, extra patient beds and devices such as mobile computers had been placed in the hallways of inpatient wards, which caused safety risks and functionality problems. Mobile computers were usually recharged at nurses' working units, which increased the heat load and impracticality of these spaces.

Secretaries' rooms and restrooms were often used as meeting rooms, since there were no actual spaces for meetings, or the spaces were too small. In general, the restrooms were considered too small for resting or coffee breaks.

Space efficiency varied greatly between different hospital units. In some units, rooms were underutilized or totally unused, whereas in other units, the personnel had to work in cramped rooms. The solution to this problem, centralized space management, was lacking in both hospitals (Plates 1 and 2).



Plate 1. Crowded storeroom



Plate 2. No windows in restroom

Working conditions

Poor acoustics in workspaces interfered with duties, and compromised the privacy of patients. Ventilation problems arose from temperature, drafts, lack of fresh air, and unpleasant odors. Faulty ergonomics were also clearly visible in every ward during the walk-through (Plate 3).

Spaces for patients

The nurses reported flaws from the viewpoint of patients in the form of faulty toilets and shower rooms (Plate 5). In addition, a lack of privacy, inadequate signage (Plate 4 and Plate 6), and the lack or poor location of parking spaces were seen as shortcomings. Possibilities to

get fresh air were few, and the patients' beds had no outdoor views because the windows were too high up.

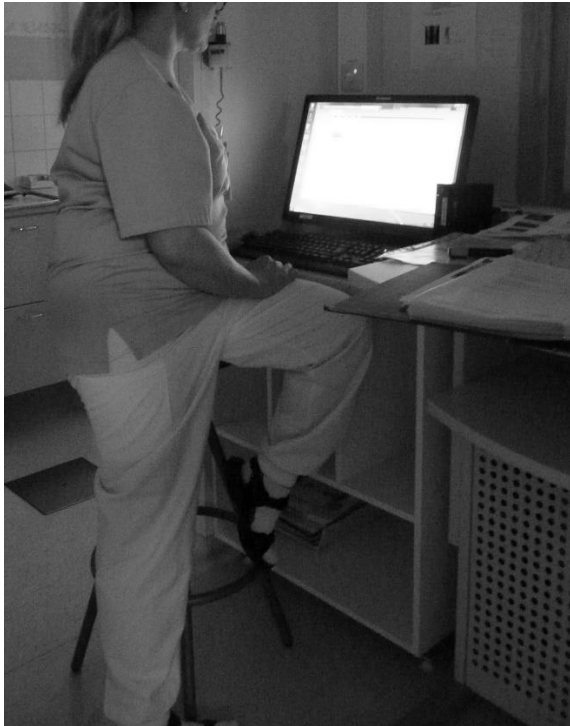


Plate 3. Poor ergonomics at work posts



Plate 4. No privacy



Plate 5. Cramped shower room



Plate 6. Poor signage

Table 4. Main usability problems in Hospitals A and B

Hospital A	Hospital B
<i>Effectiveness</i>	
Layout solution	
Lack of space > furnishing problems	Lack of space, narrow rooms
Lack of meeting rooms and storage rooms	Lack of meeting rooms and storage rooms
Open shelves that gather dust	Unequal space efficiency
Lack of occupational safety	Lack of waste room
Too small toilets	Staircases as waiting rooms
Hospital activities in old residential spaces	Furniture blocking exits
<i>Satisfaction</i>	
Working conditions	
Noise, inadequate acoustics	Noise, inadequate acoustics
Ventilation problems	Ventilation problems
Poor IAQ and unpleasant smell	Unsuitable temperature, draft
Unsuitable temperature, draft	Excessive heat in some spaces
Excessive heat in some spaces	Ergonomic flaws
Ergonomic flaws	Lack of countertops
Lack of countertops	Faulty, cramped shower rooms and toilets
Faulty and cramped shower rooms and toilets	Mobile computers in cramped workspaces
	Heavy devices that are difficult to move
<i>Satisfaction</i>	
Spaces for patients	
Accessibility problems in old buildings	Unused balconies
Cold changing rooms	Lack of outdoor recreation
Lack of privacy	Lack of day rooms
Lack of information security	Lack of hand rails
Lack of outdoor recreation	No window view
Faulty, cramped shower rooms and toilets	Faulty, cramped shower rooms and toilets
	Accessibility problems in bathrooms
<i>Efficiency</i>	
Orientation	
Poor signage (clarity and placement)	Poor signage (clarity and placement)
Lack of colors, contrast and symbols in signage	Lack of colors, contrast and symbols in signage

Orientation

During the walk-through, many patients asked the participants the right way to their destination department. Poor signage was generally fixed by extra handmade notes, which caused a very untidy general impression (Plate 6).

This study evaluated the usability of workspaces in the hospital environments of two hospitals, as an extension of the existing IEQ survey. The results were given to the hospital management groups in the form of reports (with many photos) and verbal descriptions. They were also presented to the personnel in separately arranged feedback sessions. In addition to the results of the IEQ survey, the results of the usability evaluation were utilized in renovation plans for the whole building, and in order to improve workspaces to support personnel well-being.

At the end of this section, the results of this study are summarized and compared to the main usability problems (listed in Table 4), the framework themes and the four usability factors Efficiency, Effectiveness and Satisfaction:

1. The framework worked well as a checklist for the researchers and helped them prepare for the walk-through
2. The four themes helped researchers summarize the characteristics of the framework under the three usability factors of Efficiency, Effectiveness and Satisfaction
3. The four themes helped participants understand the aim of the walk-through
4. The results of the walk-through (Table 4) show that the content of the themes covered the main usability problems in Hospitals A and B
5. The results in Table 4 express the usability flaws in Hospitals A and B, and can also be illustrated by means of the usability factors Efficiency, Effectiveness and Satisfaction.

Discussion

The aim of this study was to develop and test a framework of characteristics concerning the usability of work environments in hospital buildings that need renovations.

Although the literature mentions different methods and tools for evaluating usability in built environments, methods for investigating the usability of hospital buildings, particularly from a staff viewpoint, are rare. Studies concerning the usability of hospital buildings have mostly concentrated on patients' needs (Bishop 2008; Ibrahim 2008; Hsieh 2009; Liong 2009), design processes (Garde 2008; Ayas 2008; Hignett & Lu 2009; Voordt 2009; Behkami & David 2009) or certain difficulties in the hospital environment, for example, wayfinding (Mollerup 2009; Huelat 2007). A distinct checking tool for evaluating the usability of hospital premises is missing: The usability framework developed in this study clearly responds to this shortage.

As the central hospital buildings in Finland were for the most part built between the 1950s and 1970s, many of them are now at the end of their life cycle and are in urgent need of renovation. When these renovations are decided on, it is important to think comprehensively and far enough into the future. Planning repair operations is cost efficient when the functionality, flexibility and usability of spaces are taken into account alongside technical solutions. Usable, functional spaces support the fluency of work and the well-being of both workers and patients.

When designing hospital spaces, it is also necessary to consider the expanding number of patients, lasting effectiveness and efficiency of the design, and their flexibility to adapt to changes when required. All these are usability outcomes or solutions in the production of quality design, and serve as guidance for the management process. They also improve the health care service.

In summary, the results of this study showed that this kind of comprehensive evaluation of buildings and workspaces reveals the true needs of users. It also showed that the flaws and development needs in both hospitals were consistent, i.e. the results supported each other.

The results of this study are fairly parallel with those of other hospital design studies. The general problems in the hospital workspaces studied were noise/acoustic, ergonomic and ventilation (temperature, draft) problems. Many other studies have similarly found noise and acoustics to be problematic for hospital staff (Rashid & Zimring 2008 and Ryherd et al. 2008).

Ventilation problems (thermal and draft) (Joseph 2007, Hellgren 2008) and poor ergonomics (Hignett 2003; Hignett et al 2013) are also mentioned in many other studies. Furthermore, the problems of accessibility, and faulty patients' toilets and shower rooms are similar to those in a study by Capdaglio (2014), which evaluated hospital bathrooms.

According to the results of this study, the main flaws from the patient viewpoints were a lack of privacy, poor signage, poor opportunities to get fresh air, and no outdoor window views from patient beds. Lack of privacy was also mentioned in the studies of Ulrich et al. (2008), van de Glind, de Roode, and Goossensen (2007) and Ampt, Harris and Maxwell (2008). Studies by Sherman et al. (2005), Curtis et al. (2007) and Ulrich et al. (2008) also found restricted views of nature, and a lack of exposure and access to nature. The findings concerning poor signage and successful spatial navigation in the hospital environment in turn are in line with those of Ulrich et al. (2004) and Hossi and Jänkälä (2008).

In addition to the problems mentioned above, this study highlights usability flaws such as cramped spaces which cause furnishing and safety problems (furniture blocking exits), and a lack of storage rooms. These particular usability issues arise from a problematic situation in which personnel has to operate in old buildings: spaces are not functional or suitable for today's needs.

Outdated hospital buildings also have accessibility problems. Since the number of elderly patients is globally increasing, it is essential that hospital spaces have enough hand rails, and that accessibility is easy in all spaces; both outside and inside the buildings. The quality and placing of signs must also be improved, and colors and symbols should be clearer.

The hospital environment is a challenging workplace, since the processes in these spaces are complex, and the spaces have to serve all users and facilitate employees' work duties. Thus, in addition to the quality of indoor air, it is important to consider the work environment as a whole, also in relation to the usability of workspaces.

Conclusion

The aim of this study was to present a framework of the characteristics that have an impact on the usability of work environments for hospital renovation, and to use this framework to illustrate the usability evaluation process in the real environment. The usability framework developed in this study consists of five attributes: safety/security, functionality, orientation, comfort and healthiness. According to the results, the attributes of the framework of characteristics can be expressed from the viewpoint of usability factors as follows:

- effectiveness: attribute – functionality (and its characteristics)
- efficiency: attribute – orientation (and its characteristics)
- satisfaction: attributes – safety/security, comfort and healthiness (and their characteristics)

This kind of usability framework can be used as a checklist or a simple tool in a usability evaluation of hospital buildings which have renovation needs. The attributes with characteristics help building inspectors and architects to detect and take account of usability requirements during renovation processes in a hospital building.

Another aim of this study was to test the framework with a usability walk-through, and the method illustrated in this study proved to be suitable for this purpose.

On the basis of the results of this study, we recommend using this kind of approach when long-term maintenance plans are made for buildings with indoor air problems. When a building is in need of repair work, it is reasonable to determine the usability flaws of its spaces.

References

Alexander, K. (2006), "The application of usability concepts in the built environment", *Journal of Facilities Management*, Vol. 4 No. 4, pp. 262 – 270.

Alexander, K. (2007), "Usability: philosophy and concepts", in *Proceedings from 6th Euro FM Research Symposium. EFMC 2007. Zürich, June 26-27*.

Al-Harbi, H. A. (2005), "An Assessment Procedure for Acceptable Indoor Environmental Quality in Health Care Facilities." *King Fahd University of Petroleum & Minerals*. Dhahran.

Alho J., Nenonen S., Nissinen K. (2008), "Usability of Shopping Centres: Components of Usability Rating Tool". In Alexander (eds.) *Usability of Workplaces Phase 2*. CIB Working Commission on Usability of Workplaces. CIB W111. CIB Publication no. 316, Rotterdam, pp. 64-73.

Ampt, A., Harris, P. and Maxwell, M. (2008), "The Health Impacts of the Design of Hospital Facilities on Patient Recovery and Wellbeing, and Staff Wellbeing: A Review of the Literature", Centre for Primary Health Care and Equity, University of New South Wales, Sydney.

Andersson, K. (1998), "Epidemiological approach to indoor problems", *Indoor Air*, Vol. 8, No. S4, pp. 32-39.

Andradea, C., Limab, M. L., Fornarac, F. and Bonaiutod, M. (2012), "Users' views of hospital environmental quality: Validation of the Perceived Hospital Environment Quality Indicators (PHEQIs)", *Journal of Environmental Psychology*, Vol. 32 No. 2, pp. 97-111.

Apple, M. (2014), "A comparative evaluation of Swedish intensive care patient rooms", *Health Environments Research & Design Journal*, Vol. 7 No. 3, pp. 78-93.

Behkami. N. A. and David A. D. (2009), "User centered design in complex healthcare workflows: the case of care coordination and care management redesign", *2009 Symposium Proceeding, AMIA*, pp. 39-43.

Bevan, N. (1995), "Measuring usability as a quality of use", *Software Quality Journal*, Vol. 4 No. 2, pp. 115-130.

Bishop, K. G. (2008), "From their perspectives: children and young people's experience of a pediatric hospital environment and its relationship to their feeling of well-being", Doctoral dissertation, Faculty of Architecture, Design and Planning, The University of Sydney, Sydney.

Blakstad, S., Hansen, G. and Knudsen, W. (2008), "Methods and tools for evaluation of usability in Buildings", In Alexander, K. (ed.) *Usability of Workplaces: Phase2*, CIB W111 Research Report. CIB Publication No. 316. pp. 26-37. Rotterdam: International Council for Research and Innovation in Building and Construction CIB General Secretariat, Rotterdam, pp. 26-37.

Blakstad, SH., Olsson, N., Hansen, GK. and Knudsen, W. (2010), "Usability Mapping Tool", *CIB Publication 330, CIBW111: Usability of Workplaces-Phase 3*, pp. 17-29.

Capodaglio, E.M. (2014), "Hospital bathroom ergonomics: Safety, usability and accessibility issues." *Clinical Nursing Studies*, Vol. 2 No. 4, pp. 1-11.

Carayon, P., Werreneck, T.B., Rivera-Rodriguez, A.J., Hundt, A.S., Hoonakker, P., Holden, R. and Gurses, A.P. (2014), "Human factors systems approach to healthcare quality and patient safety", *Applied Ergonomics*, Vol. 45 No. 1, pp. 14–25.

Chaudhury, H., Mahmood, A. and Valente, M. (2009), "The effect of environmental design on reducing nursing errors and increasing efficiency in acute care settings a review and analysis of the literature", *Environment and Behavior*, Vol. 41 No. 6, pp. 755-786.

Clements-Croome, D., and L. Baizhan (2000), "Productivity and Indoor Environment", *Proceedings of Healthy Buildings, Espoo, August 6-10*.

Curtis, S., Gesler, W., Fabian, K., Francis, S. and Priebe, S. (2007), "Therapeutic Landscapes in Hospital Design: A Qualitative Assessment by Staff and Service Users of the Design of a New Mental Health Inpatient Unit", *Environment and Planning C: Government and Policy*, Vol. 25 No. 4, pp. 591–610.

De Laval, S. (2004), "Metoder för arkitekturdialog". Available at: <http://arkitekturanalys.files.wordpress.com/2013/07/metoderforarkitekturdialog.pdf> (accessed March 6 2017).

Elo, S. and Kyngäs, H. (2008), "The qualitative content analysis process", *Journal of Advanced Nursing*, Vol. 62 No. 1, pp. 107–115.

Fenker, M. (2008), "Towards a theoretical framework for usability of buildings", in *Usability of Workplaces: Phase 2, CIB Research Report 316*, CIB, Rotterdam.

Garde, J. A. (2008), "The Design of a new NICU Patient Area: Combining Design for Usability and Design for Emotion", *Design Research Society Conference, Sheffield, July 16-19*.

Gulliksen, J. (2006), "Usability professionals - Current practices and future development", *Interacting With Computers*, Vol. 18 No. 4, pp. 568-600.

Hansen, G. K., Blakstad, S. H. and Knudsen, W. (2011), "USEtool Evaluating Usability, Methods Handbook", Faculty of Architecture and Fine Art, NTNU, Trondheim.

Haron, S. N., Hamid, M. Y., Talib, A. (2011), "Exploration of Usability Issues in Malaysia Public Hospital Spatial Design: Pilot Study", *International Journal of Applied Science and Technology*, Vol. 1 No. 4, pp. 127-134.

- Haron, S. N., Hamid, M. Y., & Talib, A. (2012), "Towards healthcare service quality: An understanding of the usability concept in healthcare design", *Procedia - Social and Behavioral Sciences*, Vol. 42, pp. 63-73.
- Hellgren, U-M. (2012), "*Indoor air problems in Finnish hospitals - from the occupational health perspective*", dissertation, Helsinki University, Unigrafia oy, Helsinki.
- Hellgren, U-M. & Reijula, K. (2011), "Indoor air problems in hospitals. A challenge for occupational health care and safety", *AAOHN Journal*, Vol. 59 No. 3, pp. 111-117.
- Hellgren, U-M., Palomäki, E., Lahtinen, M., Riuttala, H. and Reijula, K. (2008), "Complaints and symptoms among hospital staff in relation to indoor air and the condition and need for repairs in hospital buildings", *Scandinavian Journal of Work, Environment & Health Supplements*, No. 4, pp. 58-63.
- Hignett, S. (2003), "Hospital Ergonomics: A Qualitative Study to Explore the Organisational and Cultural Factors", *Ergonomics*, Vol. 46 No. 9, pp. 882-903.
- Hignett, S. & Lu, J. (2009), "An Investigation Of The Use Of Health Building Notes By UK Healthcare Building Designers", *Journal Applied Ergonomics*, Vol. 40 No. 4, pp. 608-616.
- Hignett, S., Carayon, P., Buckle, P., Catchpole, K. (2013), "State of science: human factors and ergonomics in healthcare", *Ergonomics*, Vol. 56 No. 10, pp. 1491-1503.
- Hossi, P. and Jänkälä, J. (2008), "Functioning of the hospital signs from the clients' perspective". Degree Programme in Nursing. Turku University of Applied Sciences, Turku (in Finnish).
- Hsieh, Y. S. (2009), "Taking Patients' Voices Into Account Within Quality Systems: A Comparative Study", *International Journal Of Health Care Quality Assurance*, Vol. 22 No. 3, pp. 289-299.
- Huelat, B. J. (2007), "Wayfinding: Design For Understanding", A Position Paper for the Environmental Standards Council of The Center for Health Design. CA.
- Hynynen, P. and Lappalainen, S. (2010), "Priorita -A method for Health Risk Based Prioritization of Community Building Renovations", *SB10 Finland, Sustainable Community - BuildingSMART Conference Proceedings, Espoo*, pp. 62-63.
- Ibrahim, A. (2008), "*Patient satisfaction with health service of outpatient department of Indira Ghandi Memorial Hospital, Male's Maldives*", Primary Health Care Management, Faculty of Graduate studies, Master of primary Healthcare Management, Mohidol University, Salaya and Nakhon Pathom.

ISO 9241-11 (1998), *Ergonomic Requirements for Office Work with Visual Display Terminals (Vdts) Part 11: Guidance on Usability*, International Organization for Standardization, Geneva.

Janowitz, I. L., Gillen, M., Ryan, G., Rempel, D., Trupin, L., Swig, L., Mullen, K., Rugulies, R. and Blanc, P.D. (2006). "Measuring the physical demands of work in hospital settings: Design and implementation of an ergonomics assessment", *Applied Ergonomics*, Vol. 37 No.5, pp. 641-658.

Joseph, A. (2007), "Hospitals That Heal. Hospital Design for the 21st Century", *Asian Hospital and Healthcare Management*, No. 13, pp. 11–13, available at: <http://www.asianhbm.com/healthcare-management/hospitals-heal> (accessed March 6, 2017).

Korhonen, P., Lappalainen, S., Palomäki, E., Hellgren, U.-M., Holopainen, R., Autio, A., Palonen, J., Hynynen, P., Rosendahl, T. and Reijula, K. (2009), "Method for evaluating the technical quality of hospital properties", in Santanam, S., Bogucz, E.A., Zhang, J.S. and Ezzat Khalifa, H. (Eds), *Proceedings of the 9th International Healthy Buildings*, Paper No. 489, Syracuse, NY, pp. 920-924.

Lappalainen, S., Lahtinen, M., Palomäki, E., Korhonen, P., Niemelä, R. and Reijula, K. (2009), "Comprehensive procedure for solving indoor environment problems", *Proceedings of NAM 2009, 54th Nordic Work Environment Meeting*, Espoo, p. 93.

Leather, P., Pyrgas, M., Beale, D. and Lawrence, C. (1997), "Windows in the workplace: sunlight, view, and occupational stress", *Environment and Behavior*, Vol. 30 No. 6, pp. 739-762.

Liong, C-Y., Mamat, N.j.Z. and Leong, T-Y. (2009), "Satisfaction of outpatients on service quality: a case study at two specialist clinics", *Journal of Quality Measurement and Analysis*, Vol. 5 No. 1. pp. 35-44.

Loo, V. G., Bertrand, C., Dixon, C., Vitye, D., DeSalis, B., McLean, A. P., et al. (1996), "Control of construction-associated nosocomial aspergillosis in an antiquated hematology unit", *Infection Control and Hospital Epidemiology*, Vol. 17 No. 6, pp. 360-364.

McCunn, L.J. and Gifford, R. (2013), "Environmental Design in Acute Care Settings: A Case Study of a Neurological Rehabilitation Unit", *Health Environments Research & Design Journal*, Vol. 7 No. 1, pp. 102–113.

Mollerup, P. (2009), "Way showing in Hospital", *Australasian Medical Journal*, Vol. 1 No. 10, pp. 112-114.

Nenonen, S., Rasila, H., Junnonen, J.-M., Kärnä, S. (2007), "Customer Journey - a method to investigate user experience", *Proceedings from 6th EuroFM Research Symposium, EFMC, Zürich, June 26-27*.

Nielsen, J. (1993), "Non command user interfaces", *Communications of the ACM*, Vol. 36 No. 4; pp. 83-99.

Oren, I., Haddad, N., Finkelstein, R., and Rowe, J. M. (2001), "Invasive pulmonary aspergillosis in neutropenic patients during hospital construction: Before and after chemoprophylaxis and institution of HEPA filters", *American Journal of Hematology*, Vol. 66 No. 4, pp. 257-262.

Pietarinen, V.-M., Palomäki, E., Hellgren, U.-M., Hynynen, P. and Reijula, K. (2012), "Developing risk management practices in a hospital environment – a comprehensive assessment of the usability of the facilities at a one Central Hospital in Finland as an example", *IFHE 22nd Congress of the International Federation of Hospital Engineering, Bergen, April 13-17*.

Preiser, W.F.E., Rabinowits, H.Z. and White, E.T. (1988), *Post Occupancy Evaluation*, Van Nostrand Reinhold Company CRS Sirmine Houston, TX and New York, NY.

Rashid, M. and Zimring, G. (2008), "A Review of the Empirical Literature on the Relationships Between Indoor Environment and Stress in Health Care and Office Settings. Problems and Prospects of Sharing Evidence", *Environment and Behavior*, Vol. 40 No. 2, pp. 151-190.

Reijula, K. and Sundman-Digert, C. (2004), "Assessment of indoor air problems at work with a questionnaire", *Occup Environ Med*, Vol. 61 No. 1, pp. 33-38.

Reijula, K. et al. (2012), "Rakennusten kosteus- ja homeongelmat". *Eduskunnan tarkastusvaliokunnan julkaisu 1/2012*, Kopijyvä Oy, Espoo, p. 11 (in Finnish), available at: https://www.eduskunta.fi/FI/tietoeduskunnasta/julkaisut/Documents/trvj_1+2012.pdf (accessed March 6 2017).

Rothschild, J. M., Keohane, C. A., Cook, e. F., Orav, e. J., Burdick, e., Thompson, S., Hayes, J. and Bates, W. (2005). "A controlled trial of smart infusion pumps to improve medication safety in critically ill patients", *Critical Care Medicine*, Vol. 33 No. 3, pp. 533-540.

Ryherd, E.E., Persson Wayne, K. and Ljungkvist, L. (2008), "Characterizing noise and perceived work environment in a neurological intensive care unit", *The Journal of the Acoustical Society of America*, Vol. 123 No. 2, pp. 747-756.

Salonen, H. (2009), "Indoor air contaminants in office buildings", dissertation, People and Work Research Reports No. 87. Finnish Institute of Occupational Health. Yliopistopaino Oy. Tampere.

Salonen, H., Lahtinen, M., Lappalainen, S., Nevala, N., Knibbs, L.D., Morawska, L. and Reijula, K. (2013), "Design approaches for promoting beneficial indoor environments in healthcare facilities: a review", *Intelligent Buildings International*, Vol. 5 No.1, pp. 26-50.

Sherman, S.A., Varni, J.W., Ulrich, R.S. and Malcarne, V.L. (2005), "Post-Occupancy Evaluation of healing Gardens in a Pediatric Cancer Center", *Landscape and Urban Planning*, Vol.73 Nos 2/3. pp. 167–183.

Ulrich, R., Simring, C., Joseph, A., Quan, X. and Choudhury, B. (2004), *The role of the physical environment in the hospital of the 21st century: A once-in-a-lifetime opportunity*. The Center for Health Design. Robert Wood Johnson Foundation, New York, NY.

Ulrich, R. S., Zimring, C., Zhu, X., CuBose, J., Seo, H. B., Choi, Y. S., Quan, X. and Joseph. A. (2008), "A Review of the Research Literature on Evidence Based Healthcare Design", *Health Environments Research & Design Journal*, Vol. No. 3, pp. 61–125.

van de Glind, I., de Roode, S. and Goossensen, A. (2007), "Do Patients in Hospitals Benefit From Single Rooms? A Literature Review", *Health Policy*, Vol. 84 Nos 2/3, pp. 153–161.

Voordt, T. J. M. v. d. (2005), "Architecture in use", Architectural Press, Oxford.

Voordt, T. J. M. v. d. (2009), "Quality of design and usability: A Vetruvian twin", *Ambiente Construído*, Vol. 9 No. 2, pp. 17-29.