Evaluating indoor environment quality at the South Ostrobothnia central hospital

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Summary

Healthcare systems in various countries are under substantial pressure to reduce costs. Performance assessments and evaluations are an opportunity for facility management to improve spaces systematically. Many studies indicate that an improved indoor environment quality contributes positively to both the user and the economic value of the building. When workers are satisfied they usually work more effectively, increasing productivity.

In this paper, we describe results from indoor environment assessments at the South Ostrobothnia central hospital. A current main building is compared to its extension 'Y-house', which will after opening in 2012 nearly double the hospital capacity. The overall indoor environment in the extension is nearly by a third (+27%) better than in the old main building. The greatest increase in performance is related to health and comfort (+42%), mainly because of improved technical systems and guidelines. The focus in Seinäjoki towards end-user interaction has amended usability and positive stimulation (+33%). Nursing work has now better, adjustable systems supporting various nursing situations, but on the other hand, patients and personnel also visually enjoy decorative elements and colours. Safety and security are on a high level In Finland, and therefore old hospital improvements are marginal (+6%). Standard spaces enable better versatility and maintenance in 'Y-House' and upgrade adaptability and serviceability (+23%).

A transparent indicator system to monitor the indoor conditions is an interesting opportunity to monitor the quality of spaces. The framework mobilised in this research is a path opener, and should be enhanced in the future. A structured approach to evaluate indoor environment through indicators helps the owner to track differences between facilities and demonstrates to the management of facility how well they are performing.

Keywords: PERFECTION project, Seinäjoki, Hospital, Indoor environment, Performance indicators, Performance assessment

1. Introduction

At a time when the world economy is stuttering, healthcare systems in various countries are under substantial pressure to reduce costs. The effects of these reductions are not just restricted to nursing work in hospitals, but also it is evident that the annual real estate budgets are cut.

Therefore, the facility management personnel are forced to carefully consider their investments. It is important to notice that if the value of a building declines, renovation or new construction is required to maintain the required level of nursing quality in the hospital.

Performance assessments and evaluations are an opportunity for the facility management to improve spaces systematically. Many indicator-based approaches have been developed in the construction industry to benchmark building performance against defined criteria. The criteria are often economical, but recently the industry has started to put more value on end-users. Present and future needs of end-users have to be understood if supportive environments are to be created for them [1]. Understanding such needs leads to more satisfied and less critical end-users [1, 2], simultaneously improving the hospital outcomes. The performance of indoor environments is important for end-users, especially in relation to their own objectives [3]. It should be recognised that improving these objectives, worker satisfaction and productivity by providing well-performing spaces, is much more important than saving money in the design and construction phase [4].

The remainder of this paper is structured as follows. First, we explain our indicator-based approach to benchmark indoor environment quality at the South Ostrobothnia central hospital. Then, we give the results from a current main building and an on-going hospital extension, the latter of which was estimated during the design phase, and describe their differences. Finally, we present findings on how accumulated user-involvement in the design process effects design outcomes and we draw concluding remarks for the indicator-based approach.

2. Building performance evaluation

The value of buildings has been framed in a number of ways. Buildings are both functional (value in use) and economic (value for money) resources [5]. The functional value usually reflects essential attributes to facility end-users, while the economic value comprises traditional business measures. To capture the value in relation to a building performance, many indicator-based systems have been developed. One of the first industry-wide classification attempts was the CIB master list in 1964 [6]. Subsequently, several public and regulatory efforts, many times with political aims, have been established to polish the tarnish reputation of the construction industry. A fine example is the British ‘Rethinking Construction’ program that launched ‘Key Performance Indicators’ (KPIs) in the late 1990s to benchmark industry performance [7]. Later, as an extension, the same program launched ‘Design Quality Indicators’ (DQI) to capture value creation in design in relation to different user needs [7]. In 2002, after only a few years, a modified version of DQIs were utilised in healthcare buildings [8]. The public and regulatory frameworks have traditionally captured the economic value of buildings. Recent technological advancement has allowed for considerable tool development and knowledge extension, enhancing the sustainability of the built environment [9].

Rating systems are prevalent in the industry today. These systems are voluntary-based and focus on high-performance, energy-efficient, economical and environment-friendly buildings [10]. Even though numerous rating systems market themselves as ‘green building’, BREEAM and LEED for instance, they do not attempt to capture the value for users.

User satisfaction in the existing facilities is many times tracked with performance evaluations. A popular method for these evaluations is Post-Occupancy Evaluation (POE), which consists from systematic data collection, analysis, and comparison to occupied built environments [11]. The method has progressed from a one dimensional feedback process to a multidimensional process, considering also non-technical factors [12]. For building use the added value stems from facilitated activities and contributed organisational outcomes.

An improved indoor environment quality contributes positively to both the user and the economic value of the building. However, the evaluation of indoor environment is complicated. Many characteristics related to indoor conditions, for instance productivity, worker satisfaction, and wellbeing, correlate strongly with each other [13, 14]. Thus, when workers are satisfied they usually work more effectively, increasing productivity. Results from construction projects where user-contribution is strengthened are promising. When users can participate in the design, worker productivity may increase by 6% through impacts on health, comfort and work task performance [15]. One such method is ‘participatory design’, giving the people who are affected by a change in the workplace a chance to influence the design process [16]. Furthermore, end-users appreciate an opportunity to regulate indoor conditions: adjust lighting, heating and cooling; opt for personalised aesthetic appearance, prefer natural lighting in the workplace, and enjoy a view to the outside [14]. The published results reveal that an increase of 1% in productivity may already cover the additional capital expenditure made for user involvement [17, 18]. To sum, it appears that building performance is important and building owners should add user involvement to indoor environment development, especially in workspaces such as hospital.

Different categories have been used to illustrate building performance. Although buildings have become more sophisticated over the years, they may be in some ways less robust and dependent on specialised technologies [9]. Depending on the scope of evaluation, a number of categories may be used to define performance. Lützkendorf et al. (2005) identified functional, technical, environmental, economic, social, and process categories [19]. In recent years, many EU projects have developed the assessment of indoor environment, sustainability and the establishment of respective indicators [20]. These EU projects usually propose fresh categories for building performance assessment, which may provide fruitful extensions to the prevailing indicator systems in the future. One of such efforts in indoor environment quality is the PERFECTION project [21, 22].

2.1 Key performance indicators for indoor environment quality

The PERFECTION methodology describes ‘KIPI framework’ (Key Indoor Performance Indicators), which is a result from an inventory of current performance indicators, standards, regulations, guidelines, research activities and policies used in the design and construction of the built environment. The ‘KIPI framework’ consists of 31 indicators composed of four categories.

- *Health and Comfort* (10 indicators)
- *Safety and Security* (7 indicators)
- *Usability and Positive Stimulation* (7 indicators)
- *Adaptability and Serviceability* (7 indicators)

These four categories give a holistic view to the performance of indoor environment. In the first category, *Health and Comfort,* the ten indicators describe measurable air quality and issues of comfort, necessary for the wellbeing of end-users. The *Safety and Security* category draws from the seven indicators for the building structures and equipment for people, materials and knowledge. Then, the third category ‘*Usability and Positive Stimulation’* assesses the ease of building use and its adjustability to various situations. In fact, the third category differentiates the framework from the other indicator frameworks. Many studies [14] have underlined the impacts of soft issues, often related to productivity, worker satisfaction and wellbeing, but usually indicators related to these issues are not included to the indicator frameworks. The final category (*Adaptability and Serviceability*) completes the framework with adaptability to prevailing settings and maintenance.

How is the indoor environment performance evaluated? Each indicator in the framework has a rigorous description in the PERFECTION methodology and separate assessment rules are described for design and operation phases. The indicators are applied to various building types through a weighting system, which specifies the importance of each indicator. The framework specifies weights for offices, schools, hospitals, residential buildings and exhibition places [22]. When assessing indicators, a grade is given to each indicator from a five-level analogy that ranges from the lowest *class E* to the highest *class A* [23]. After each of the framework indicators is assessed, the quality of indoor environment is presented as a ‘KIPI score’. The ‘KIPI score’ summarises the indoor performance in respect of the framework [24, 25] with a number from zero to a hundred. The values near hundred indicate a high-performing indoor environment.

3. Results from indicator assessment at the South Ostrobothnia central hospital

Every fifth health care building in Finland is currently a central hospital. When compared to other building types, such as offices and schools, central hospitals are composed of many demand-intensive spaces in terms of indoor environment. For example in laboratories and surgical wards, the indoor conditions must remain stabile over long period of a time. The hospital operates around-the-clock seven days a week, and therefore, a well-performing indoor environment is critical for providing care services. Diverse trends affect healthcare organisations and facilities. Much effort has been put to care quality and safety, which are monitored with many criteria such as efficiency of work, number of accidents, medication errors and care mistakes [26]. The design of healthcare facilities is also changing. A traditional architectural design is challenged with 'evidence-based design' (EBD) - a new practice - directed to improving outcomes. The EBD ranges from clinical or medical outcomes (pain or length of stay), to patient and staff wellbeing (satisfaction, waiting times, and safety) and to economic outcomes [27, 28].

The South Ostrobothnia central hospital (*Figure 1*) is a secondary health care unit located to Seinäjoki in Western Finland, serving a population of 200,000 inhabitants [29]. We consider in this paper indoor environment quality in two sections of the central hospital, an existing main building is compared to its on-going 'Y-house' extension building.

Figure 1. The South Ostrobothnia central hospital, current main building on left and its extension 'Y-house' on right (Courtesy of the South Ostrobothnia Hospital District).

3.1 Current main hospital building

The main building of South Ostrobothnia central hospital was built in two stages between 1977 and 1983. A layout in seven floors provides spaces for nearly 2500 employees. Patient modules with 398 beds consist from two-handed multi-patient rooms. The current hospital carries out annually over 22 000 surgeries and 180 000 outpatient visits. Interestingly, the number of outpatient visits has grown by 60% since the hospital opening, and units need more spaces. The central hospital is managed by the South Ostrobothnia Hospital District. They collect annual data from the building automation system and make surveys of user satisfaction to personnel yearly, to amend the quality of care. A small number of operational units have been renovated according to current regulations. The existing central hospital building is set to grow by a third in 2012 when the extension 'Y-house' opens.

3.2 On-going extension project 'Y-house'

The extension of the central hospital (*Figure 2*), with gross floor area of 33 870 m^2 and 1309 rooms, is one of the biggest hospital projects in Finland. This 58 million euro project is due to be completed in September 2012, and will increase the central hospital's bed capacity by a third simultaneously doubling the number of annual patient visits. The extension will employ about 450 people in 20 operational units of the central hospital. In addition, half of the 'Y-house' building is determined for the use of primary health care services and Seinäjoki polytechnic. Architectural designer UKI Architects Oy has provided a unique plan in five floors, connected to the current main hospital building through a corridor. The new section includes better access for ambulances, and a helipad for urgent patient moves to other hospitals. The layout builds on four functional modules that have common elements, for example colours as a signage to ease in navigation. The inpatient wards have two-handed double-patient rooms. Each of the patient rooms has a bathroom, and the manager of the central hospital has added few spacious single-patient rooms, for testing purposes, in the layout. The focal point of design solution is a four-floor-high atrium with large windows. The atrium has cafeteria services that nurture the wellbeing of occupants of the central hospital.

The Hospital District invests greatly to develop health care. In the future, they aim to provide a more pleasant, care environment to patients and personnel and optimise the consumption of energy in their facilities [30]. The District is an active client, determined to increase interaction during the architectural design. In the 'Y-house' project they utilise virtual reality [29, 31, 32] to cross a bridge in interaction between experts and non-experts. Yet, 250 end-users have given 4600 observations about the usability of spaces.

Figure 2. Web-camera picture from the South Ostrobothnia central hospital extension 'Y-house' on 15th of April 2011 (Courtesy of the South Ostrobothnia Hospital District).

3.3 Results from indoor environment quality assessment

The assessment of indoor environment quality at the South Ostrobothnia central hospital is performed according to the PERFECTION methodology. The current main central hospital building is compared to its extension 'Y-house', which is evaluated at design phase. The data for evaluation was collected from documents and client interviews. Besides, user satisfaction survey results are used in the current central hospital building. Results indicate strengths in 'Y-house' design, but on the other hand, point out defective areas in the current main building. Since the user satisfaction surveys were available only for the current hospital building, the results are indicative. These indicative results are thoroughly explained in this chapter, with graphs from the assessments in *Figures 3* and *4.*

The ten indicators in *Health and comfort* draw attention to indoor condition differences between the existing buildings. The current hospital building with old technical systems scored 53 points, while the extension, equipped with the latest HVAC solutions meeting the national FiSIAQ guidelines for air quality and materials [33], performs 93 points. The management of hospital has service manual for their facilities. In the renovated wings old technical systems are changed to forced ventilation with presence sensors controlling the amount of air taken in. However, since a majority of units in the old building has not been renovated, air quality is adequate (class C). Accordingly, in ‘Y-house’ air quality is excellent (class A) and the building automation system controls air supplies to all rooms. When spaces are utilised, the supply of air is increased. The forced ventilation removes gases, such as carbon dioxide, and odour, efficiently. Surface materials in the extension are user-friendly and do not emit harmful components: M1 class for materials from the Finnish classification of indoor environment [33]. All central hospital buildings in Seinäjoki are non-smoking. The client develops technical solutions together with suppliers. For instance, better lighting in ‘Y-house’ helps the elderly and lighting switch locations have been discussed with the personnel. On the other hand, lighting in the old building is acceptable, but small windows reduce daylight and make rooms dark. Thus, for the extension, the client has selected extended windows to fasten the recovery of patients [27]. Acoustics in ‘Y-house’ is improved with a better noise reduction in suspended ceilings. The supplier of suspended ceilings provided two options to select from. Drinking water quality in all facilities of the central hospital is excellent.

Both buildings have a high rating in *Safety and Security*. The score for current main building is 93 points, while the extension ‘Y-house’ has 99 points. Security systems in both buildings have alarm switches and the personnel are trained for various emergency situations. In addition, the extension building has a block with cells. A part of surface materials were changed to not slippery and easy-to-clean in ‘Y-house’. Furthermore, information safety has been thoroughly considered. The central hospital has electronic customer service system for patient records and care planning. For the safety perspective, the double-patient room units in ‘Y-house’ are safer option than multi-patient rooms at the old central hospital building. The multi-patient rooms have higher space utilisation, but may jeopardize the wellbeing of personnel and patients with a high bacteria infections risk.

The strength of ‘Y-house’ is the ease of building use and a good adjustability to various situations. 92 points of the extension in the seven indicators *in usability and positive stimulation* are well ahead of 62 points in the current main building. During the architectural design process, user-friendliness has been acknowledged. Even though the old building has accessible main entrances, all entrances in ‘Y-house’ are accessible-for-all. Besides, a patient entrance is separated from an emergency entrance with helipad. The spaces in ‘Y-house’ are more attractive to end-users and there are functional improvements, such as therapy garden for patients. Windows, which were mentioned in *health and comfort* category to bring more daylight into patient rooms, bring additionally an outstanding view to nature or a lake. In the old section, the patients are able to see sky when lying in the bed, but the extended windows enable the great view in ‘Y-house’ from the bed. Artworks have been used everywhere, and there are spaces for social enhancement and physical exercises. The Hospital Districts supports local culture, for example, artworks are usually ordered from the local artists. Colours are used in signage and surfaces of the extension building. An old navigation system, floor stripes to different units, will be updated. Corridors and units are colourful; theme colours nurture patient recovery and atmosphere in patient room wards is relaxed and healing. Changes in layout contribute to physical activities. Walking of personnel during their work shift is reduced. Standardisation in ‘Y-house’ has halved the amount of different room types from the number of different room types in the old main building.

The extension of the central hospital adapts to the prevailing settings. The scores for *Adaptability and serviceability* are 69 points in the main building and 90 points for the ‘Y-house’ extension. Services are excellent in the area and at both buildings. The central hospital is located on a hill next to the lake Kyrkösjärvi, a reservoir equipped with water power station. The water power station is able to serve the whole area if disasters occur. The area has a historical value in the region, and has great recreational routes around the lake. Cleaning of the current central hospital has been awarded and is rated very good. However, part of the surface materials in the old main building are not optimal for cleaning causing additional work.

perfection KIPI building tool — **Phase 2 - indicator assessment**

Name	Perfection case 4: Seinäjoki Central Hospital				
Country	Finland	Owner	South Ostrabotnia Hospital District, http://www.epshp.fi		
Building type	hospital	Gross floor area	85000	Number of storeys	7
Life-cycle stage	operation	Construction year	1977, 1983	Renovation year	annual, next 2012

			Design							Operation							
		Indicator	-	E	D	C	B	A	Comments	-	E	D	C	B	A	Comments	Weights
Health and comfort	Health	1 Mould growth risk	X										X				3.6%
		2 Ventilation / CO2	X										X				4.2%
		3 Combustion sources / infiltration	X										X				3.2%
		4 Particulate matter	X										X				3.1%
		5 Drinking water quality	X												X		3.4%
	Comfort	6 Operative temperature / PPD	X										X				3.8%
		7 Illuminance	X										X				2.9%
		8 Daylight factor	X									X					3.6%
		9 Background noise level	X										X				3.2%
		10 Reverberation time	X										X				1.8%
Safety and security	Safety	11 Safety in use	X											X			3.7%
		12 Feeling of safety	X												X		3.3%
		13 Meeting current regulation	X												X		4.1%
		14 Building type specific	X										X				1.3%
	Security	15 Personal and material security	X												X		3.7%
		16 Security of Information	X												X		3.3%
		17 Reliability in exceptional cases	X												X		3.4%
Usability and positive stimulation	Usability	18 Access to and in the building	X											X			4.5%
		19 Wayfinding	X										X				4.0%
		20 Adjustability	X										X				3.1%
	Positive Stimulation	21 View to outside	X												X		3.8%
		22 Privacy	X										X				3.6%
		23 Feelings and sensations	X										X				3.3%
		24 Availability and quality of recreational spaces	X										X				2.4%
Adaptability and serviceability	Adaptability	25 Versatility and protection	X										X				2.7%
		26 Tecnical service life	X										X				3.3%
		27 Adaptability to climate change	X												X		2.4%
	Serviceability	28 Branding and cultural heritage	X										X				1.3%
		29 Availability of services in the building	X												X		3.4%
		30 Cleanliness	X											X			3.4%
		31 Maintanibility	X										X				3.0%

perfection

Key Indoor Performance Indicators

Total KIPI score	**67**
Health and comfort	53
Safety and security	93
Usability and positive stimulation	62
Adaptability and serviceability	69
	OPERATION
KIPI coverage	100%

Figure 3. Indoor environment quality assessment at the South Ostrobothnia central hospital's current main building (during operation stage).

perfection **KIPI building tool** — **Phase 2 - indicator assessment**

Name	Seinäjoki Central Hospital extension, Y-house				
Country	Finland	**Owner**	Kiinteistö Oy Seinäjoen Y-talo, http://www.y-talo.fi		
Building type	hospital	**Gross floor area**	33870	**Number of storeys**	6
Life-cycle stage	design	**Construction year**	2012	**Renovation year**	-

			Design							Operation							
		Indicator	-	E	D	C	B	A	Comments	-	E	D	C	B	A	Comments	Weights
Health and comfort	Health	1 Mould growth risk						X		X							3.6%
		2 Ventilation / CO2					X			X							4.2%
		3 Combustion sources / infiltration						X		X							3.2%
		4 Particulate matter					X			X							3.1%
		5 Drinking water quality						X		X							3.4%
	Comfort	6 Operative temperature / PPD						X		X							3.8%
		7 Illuminance						X		X							2.9%
		8 Daylight factor					X			X							3.6%
		9 Background noise level						X		X							3.2%
		10 Reverberation time					X			X							1.8%
Safety and security	Safety	11 Safety in use						X		X							3.7%
		12 Feeling of safety						X		X							3.3%
		13 Meeting current regulation						X		X							4.1%
		14 Building type specific					X			X							1.3%
	Security	15 Personal and material security						X		X							3.7%
		16 Security of Information						X		X							3.3%
		17 Reliability in exceptional cases						X		X							3.4%
Usability and positive stimulation	Usability	18 Access to and in the building						X		X							4.5%
		19 Wayfinding					X			X							4.0%
		20 Adjustability						X		X							3.1%
	Positive Stimulation	21 View to outside						X		X							3.8%
		22 Privacy					X			X							3.6%
		23 Feelings and sensations						X		X							3.3%
		24 Availability and quality of recreational spaces						X		X							2.4%
Adaptability and serviceability	Adaptability	25 Versatility and protection						X		X							2.7%
		26 Tecnical service life				X				X							3.3%
		27 Adaptability to climate change						X		X							2.4%
	Serviceability	28 Branding and cultural heritage					X			X							1.3%
		29 Availability of services in the building						X		X							3.4%
		30 Cleanliness						X		X							3.4%
		31 Maintanibility						X		X							3.0%

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Key Indoor Performance Indicators

Total KIPI score	**93**
Health and comfort	90
Safety and security	99
Usability and positive stimulation	92
Adaptability and serviceability	90
	DESIGN
KIPI coverage	100%

Figure 4. Indoor environment quality assessment at the South Ostrobothnia central hospital extension building 'Y-house' (indicative results from design phase).

4. Discussion

The results of the assessment give an extensive overview of the indoor environment in the South Ostrobothnia central hospital. The greatest performance increase is detected in *health and comfort*

(+42%). The rise in this category is primarily caused by improved technical systems and guidelines. The annual energy use and water consumption are fairly high in the current main building. The estimates for electricity use and water consumption in 'Y-house' per square meter are remarkably smaller. On the other hand, the unique architecture and an atrium raise the consumption of heating energy. When the extension building is opened, nursing work has better, adjustable systems for various use situations, but on the other hand, patients and personnel have more motivating indoor environment. Soft issues like decorative elements and colours are revered by end-users. As an outcome, *usability and positive stimulation* is amplified by a third (+33%). In Finland, *safety and security* indicators are typically on a high level, and therefore, the difference between the buildings was marginal (+6%). The new extension building has been designed to be adaptable to prevailing settings and versatile decreasing maintenance needs. Thus, *adaptability and serviceability* is amended by a fourth (+23%).

In the healthcare environment a number of bacteria infections are growing rapidly. How many patients should be placed to a patient room? Recent evidence-based design studies [27, 28] indicate that we should go from double-patient rooms further to single patient rooms. In single-patient rooms the average patient staying time is shorter, patients need less medication and they have a feeling of health care quality [28]. Unfortunately, due to economic reasons, hospital patient rooms are designed for multiple patients.

5. Conclusion

This paper has described positive experiences from the performance assessments in Seinäjoki central hospital. A structured, indicator-based approach to evaluate indoor environment helps the owner to track differences between facilities and demonstrates to the management of facility how well they are performing. Hence, it is important that indicators are evaluated coherently.

Since the extension is yet under construction, the indicative results elucidate differences between the buildings. Based on findings, the indoor environment quality is improved in 'Y-house' by nearly a third (+27%) from the current main building. The results corroborate that old buildings are facing a challenge to meet today's requirements. The objective in the 'Y-house' extension project has been to create a healthcare environment that improves outcomes. Therefore, the South Ostrobothnia hospital District has promoted user-contribution in architectural design phase by increasing interaction between the design professionals and end-users. As a outcome, *usability and positive stimulation* is improved by a third (+33%). However, new technical systems and improved requirements in HVAC guidelines augment *health and comfort* by 42%.

A transparent indicator system to monitor the indoor conditions is an interesting opportunity to monitor the quality of spaces. The framework mobilised in this research is a path opener, and should be enhanced in the future. If the indicators are addressed annually, the outcomes enable picking up trends from the building stock.

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7. References

[1] Pemsel, S., Widen, K. & Hansson B. (2010) "Managing the needs of end-users in the design and delivery of construction projects ", Facilities, vol. 28, no. 1/2, pp. 17-30.

[2] Kaya, S. (2004) “Relating building attributes to end user’s needs: ‘the owners-designers-end users’ equation”, Facilities, vol. 22, no 9-10, pp. 247-252.

[3] Lai, J. & Yik, F. (2007) “Perceived importance of the quality of the indoor environment in commercial buildings”, Indoor and Built Environment, Vol. 16, No. 4, pp. 311-321.

[4] Huovila P. (2005) “Organisation & Management, Performance Based Building Thematic Network (PeBBu)”. Final report 9, CIBdf, The Netherlands, 52 pages. Available at: http://www.pebbu.nl/resources/allreports/ (Accessed April 15th 2011)

[5] Douglas, J. (1996) “Building Performance ans Its Relevance to Facilities Management” Facilities, Vol 14, Issue 3, pp 23-32.

[6] CIB (1964) “CIB Master List of the properties of building materials and products”, CIB Report.

[7] Cole-Colander, C. (2003) “Designing the Customer Experience”, Building Research and Information, vol. 31, no. 5, pp. 357-366.

[8] NHS Estates (2002) “Achieving Excellence Design Evaluation Tool”, AEDET toolkit.

[9] Huovila, P., Lupišek, A., Lefebvre, P-H. & Steskens, P. (2010) “Indoor Performance and Sustainability”. In: Portugal SB10 Proceedings: Sustainable Building Affordable to all Conference, Algarve, Portugal, March 2010.

[10] Gowri, K. (2010) “Green Building Rating Systems: An Overview”, ASHRAE Journal, November 2010, pp. 56-60.

[11] Preiser, W., Rabinowitz, H. & White, E. (1988) “Post-Occupancy Evaluation”, Van Nostrand Reinhold, New York, NY.

[12] Hadjri, K. & Crozier, C. (2009) “Post-occupancy evaluation: purpose, benefits and barriers”, Facilities, vol. 27, no. 1, pp. 21-33.

[13] Leaman A. and Bordass B. (2001) “Assessing Building Performance in Use 4: the Probe Occupant Surveys and Their Implications”, Building Research & Information 29(2), pp. 129-143.

[14] Walden R. (2005) “Assessing the Performance of Offices of the Future”, In Preiser W. and Vischer J. (eds.) Assessing Building Performance, Elsevier, Burlington, U.K., pp. 118-127.

[15] Seppänen O. (2006) “Sisäympäristön Terveys- ja Tuottavuusvaikutukset Toimistorakennusten Elinkaaren Aikaisissa Taloudellisissa Laskelmissa” (in Finnish), The Finnish Association of HVAC Societies FINVAC ry, Forssa, Finland, 57 pages.

[16] Davies, R. (2004) “Adapting Virtual Reality for the Participatory Design of Work Environments”, Computer Supported Cooperative Work, Vol. 13, pp. 1–33.

[17] Fisk W. (1999) “Estimates of Potential Nationwide Productivity and Health Benefits from Better Indoor Environments: An Update”, In Spengler J., Samet J. and McCarthy J. (eds.) “Indoor Air Quality Handbook”, New York, McGrawhill, 36 pages.

[18] Clements-Croome D. (2000) “Computers and Health in the Workplace”, Proceedings of Healthy Buildings Conference, Espoo, 6-10 August, vol 1, pp. 119-124.

[19] Lützkendorf T., Speer T., Szigeti F., Davis G., Le Roux P., Kato A. and Tsunekawa K. (2005) “A Comparison of International Classifications for Performance Requirements and BuildingPerformance Categories Used in Evaluation Methods”, In proceedings: CIB 2005,

Helsinki, Finland. pp. 61 – 67.

[20] Desmyter, J. & Huovila, P. (2010) “Performance Indicators for Health, Comfort and Safety of the Indoor Environment”. In proceedings: CIB World Congress 2010, Manchester, May 2010

[21] PERFECTION project (2009-2011). “the European research project PERFECTION”. On-going FP7 coordination (Grant Number 212998) action until 2011 aiming at development of an indicator framework concerning overall quality of buildings’ indoor environment, available at: http://www.ca-perfection.eu (accessed April 15th 2011)

[22] Perfection newsletter 1. (2010). “Performance Indicators for health, comfort and safety of the indoor environment”. Volume 1, Issue 1. Newsletter published in June 2010, available at: http://www.ca-perfection.eu/media/files/Newsletter1.pdf (accessed April 15th 2011)

[23] Porkka, J., Huovila, A., Huovila, P. & Stirano, F. (2010) “Tool for assessing Indoor Performance. Case Study Examples from Perfection project”. In: SB10 Finland, pp. 204-205.

[24] Huovila, A. (2010) “Key indoor performance indicators contributing to health, comfort and safety of the indoor environment”. In: The 7th International Conference “Indoor Climate of Buildings 2010”, Strbské Pleso, Slovakia, November-December 2010. pp. 91-98.

[25] Stirano, F., Sabbatelli, R., Porkka, J. & Huovila, A. (2010). “D2.2 Indicator Toolbox”. Project report released July 2010.

[26] Kobus, R., Skaggs, R., Kliment, S., Bobrow, M., Thomas, J. & Payette, T. (2008) “Building type basics for healthcare facilities”, 2nd ed., John Wiley & Sons, Inc., Hoboken, New Jersey. 352p.

[27] Hamilton, K. & Watkins, D. (2008). “Evidence-Based Design for Multiple Building Types”. John Wiley and Sons, Inc, Hoboken, New Jersey.

[28] Ulrich, R. (2003). “The Effects of Healthcare Architecture and Art on Medical Outcomes”. In Arts Council England architecture week event, 25th June 2003. Available at: http://www.publicartonline.org.uk/resources/reports/rephealthcare/ulrich_presenta tion.php (accessed April 15th 2011)

[29] Yli-Karhu, T. & Kotilainen, H. (2011) “Virtual environment (CAVE) as a tool for end-user participation in health facility design, a case study”. In: 4th European Coference on Healthcare Engineering, Paris, May-June 2011. To be published.

[30] Hospilot (2010). Currently ongoing EU-funded project for reducing energy consumption in hospitals. Available at: http://195.83.41.221/ (accessed April 15th 2011)

[31] Hospitool (2009). “User-oriented hospital space” project website. Available at: http://hospitool.vtt.fi/ (accessed April 15th 2011)

[32] HospiCaseY (2010). Ongoing project that supports Seinäjoki central hospital extension project. Available at: http://www.hospicasey.fi/english.htm (accessed April 15th 2011)

[33] FISIAQ (2008) “Classification of Indoor Environment, Target Values, Design Guidance, and Product Requirements”. Finnish Society of Indoor Quality and Climate (FISIAQ), Helsinki, Finland.