THE INNER SPACE ELEMENTS IN SHAPING INDOOR ENVIRONMENT QUALITY PARAMETERS

1. INTRODUCTION

Realization of sustainability paradigm in the creation of built environment, understood as building as a functional and spatial entity, building with its' surroundings and its' inner spaces[1], including commercial spaces, demands the engagement of many specialists and professionals from the very early stages of design process. They work as partners and co-learners[2] on the projects on the basis of integrative design teams (IDT) in the design process characterized by its' cyclic form involving repeated revisiting of consecutive design phases[3]. This becomes a modern formula of cooperation between participants of design process. Among these participants the interior designers play a significant role as they may significantly influence the enhancement of buildings' or space systems' performance through the reduction of overall energy consumption and minimization of operational costs. They can do it through their informed design decisions regarding spatial organization, proper selection and specification of building materials and products, including questions of minimization of usage of natural resources and the reduction of amount of embodied energy (EE), methods of elements' construction and finishing, energy and water supply[4]. The reduction of negative impact on natural environment over technical life cycle of the building and its' spaces, including construction and demolition wastes production and management, is yet another issue that should be considered by the architect and interior designer.

Problems regarding the quality of indoor environment and assurance of well-being and physio-social comfort of users is becoming recognized recently as substantial in the process of environmentally responsible interior design (ERID) and essential for the creation of environmentally conscious interior[5] described as implying

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[1] E. Niezabitowska, D. Masly (ed.), 2007. Oceny jakości środowiska zbudowanego i ich znaczenie dla rozwoju koncepcji budynku zrównoważonego. Wydawnictwo Politechniki Śląskiej. Gliwice.

[2] B. Reed, 2007. *Integrated design.* [In:] P. Bonda, K. Sosnowchik, Sustainable Commercial Interiors, John Wiley & Sons, Hoboken. New Jersey, p. 28-31.

[3] R. Foque, 2010. Building Knowledge in Architecture, UPA, Brussels.

[4] Moxion Sian, 2012. Sustainability in Interior Design. Laurence King Publishing London.

[5] See: G. Pilatowicz, 1994. Eco-Interiors. A Guide to Environmentally Conscious Interior Design. Wiley New York; Moxion Sian, 2012, *op. cit*.

the interest in both sustainable and green design issues[6]. The consideration of spatial, functional and formal design solutions in this context, is seen as a valuable designers' contribution to accomplishment of sustainability imperatives in terms of endorsement of indoor environment quality. Acoustical, optical, thermal and visual characteristics of the built environment, as well as micro-climate parameters, including such problems as, for example, the monitoring of the content of toxic chemical substances in the inside air, may be stimulated and optimized by knowledgeable design solutions proposed by architects and designers. They may be optimized through the implementation into design process: (1) results of scientific researches[7]; (2) design methods based on quantitative and qualitative simulations of proposals discussed at the eco-charrettes; (3) design tools including the multicriterial environmental evaluation systems. This developed design process should assure physiologically and psychologically healthy environment, being essential for occupants' comfort and satisfaction[8] and important from economic point of view, in case of commercial building, the high productivity level.

2. ENVIRONMENTAL SUSTAINABILITY OF INTERIOR DESIGN

The effectiveness of implementation of sustainability paradigm into interior design may be possible to achieve due to certain modifications applied in the conventional design process. This modified approach to the creation of built environment should be based on the idea of multi-aspect and **comprehensive contextualization**[9] of given proposals regarding the inner space, especially its' structural as well as supplementing elements. The interior elements should not be than created by designers in a traditional way including functional, formal, and aesthetic contexts, but in a more complex[10], environmental context, considering interconnectedness of both natural and man-made settings and predicting consequences of their mutual interrelationship. The innovative and comprehensive design concept may be realized with respect to such sustainability-related issues as: (1) the rational usage of inner space with previsions of possible future modifications and adaptations; (2) proper resources-oriented selection and management of building materials and products; (3) energy effectiveness realized through the building systems enhancement and achieved with the space plan as well as space elements concept, providing occupants with high indoor environment quality. Carefully outlined and executed interior elements may indirectly address the sustainability of indoor environment issue seen through its three dimensions: economic, environmental and social.

[6] L. Jones (ed.), 2008. Environmentally Responsible Design. Green and Sustainable Design for Interior Designers, John Wiley & Sons Inc. Hoboken, New Jersey.

[7] S. Winchip, 2011. Sustainable Design for Interior Environments. 2nd Edition, Fairchild Books New York.

[8] M. Kang, D.A. Guerin, 2009. *The State of Environmentally Sustainable Interior Design Practice* American Journal of Environmental Sciences, nr 5(2), p. 179-186.

[9] M. Celadyn, 2016. *Inner space elements in environmentally responsible interior design education,* World Transactions on Engineering and Technology Education WIETE, 14(4), p. 495-499.

[10] G. Pilatowicz, 1994. *op. cit.*

Multi-functionality of interior structural elements, as well as supplementing components, along with their complex composition, are supposed to be the mostly environmentally sustainable design imperatives[11]. The structural indoor components, as proposed in the author's classification, comprise: (1) external walls determined as enclosures separating the inner space from the natural environment, actively responding to changing climate conditions[12], mostly accompanied on the inner side by various technical devices or natural finishing; (2) partitions and space dividers of various dimensions; (3) raised floors; (4) suspended ceilings. Supplementing or completing interior components include furniture, furnishings, and equipment (FF&E) enabling the proper usage of spaces. Some architecture critics assign to this category fixtures (light fittings), while others describe them as essential elements for making the inner space functional and contributing to its ambience, and therefore worth of isolation in another category[13].

The analysis of **multi-functionality of interior components,** claimed by the author, as crucial for their role in the creation of sustainable built environment, may include such issues as follows: (1) construction issues, especially methods of their execution and implementation in closed space; (2) formal integration with building construction elements; (3) materials' and products' selection; (4) impact of interior components on building systems effectiveness; (5) indoor environment quality related to components' structural proposals and specification of materials.

Construction issues, regarding indoor elements, refer mainly to the methods of their assembly and fixing to other components, which may assure greater adaptability of each element and the space as a whole. Solutions preferred, and recognized as sustainably-conscious, in a minimal way interfere with existing structural building components. Mechanical and point fixings enable reconfiguration of spatial organization, according to changing functional exigencies or partial relocation of certain elements, as well as further reuse with limited demolition wastes. Therefore environmentally responsible demand of design for change may be realized in this way.

Formal integration of interior components with construction elements may enable more economic and effective spatial organization and visible reduction in amount of used building materials and products.

Materials' selection should be oriented on their physical and chemical properties assuring the reduction in content of harmful or toxic substances, as they have impact on the health and well-being of the built environment users. The selection has to be made with prediction of possible consequences of decisions made over object's life cycle[14]. These effects, in terms of used materials, concern reuse, reclaiming or recycling of dismantled or disassembled products, leading to the extension of materials' life cycle and savings in natural resources.

The effect of the inner elements spatial and functional integration with building systems' (i.e. heating, cooling, air conditioning and artificial lighting) on the

[11] M. Celadyn, 2017. Zrównoważone środowiskowo wnętrza biurowe, Faculty of Interior Design, Academy of Fine Arts in Krakow, Kraków.

[12] M. Celadyn, 2016. *op. cit*., p. 496.

[13] See: S. Raymond, R. Cunliffe, 2000. *Tomorrow's Office. Creating Effective and Human Interiors*, E & FN Spon – Taylor & Francis Group London–New York, p. 133.

[14] Moxion Sian, 2012. *op. cit*., p. 38.

enhancement of their effectiveness may be seen as another important interior sustainability criterion. It imposes on interior designers a new approach to the research- and evidence-based design process, realized in close cooperation with traditionally involved professionals and the new ones, including building physics specialists or "green building" consultants.

3. ENVIRONMENTAL ACTIVATION OF INNER SPACE ELEMENTS

The interior design imperatives, concentrated on the shaping of indoor environment quality, and related building-performance improvements, require from designers the advanced, informed and to some extent innovative approach to the process of inner space creation. The indicated requirements, as an important part of the sustainability paradigm in architectural design, may be possible to accomplish through the complex and **environmental-responsibility-oriented activation** of interior elements' proposed by designers and then consequently realized. The environmental activation of interior elements, as the author names it, may be understood as their specific stimulation to the directed action achieved with their location in inner spaces, formal and structural forming, and functional integration with building components and building systems' equipment. Among main goals of this activation concept are: (1) passive control of indoor environment quality parameters; (2) passive methods of gaining, redistribution of daylight and solar thermal energy; (3) enhancement of building systems' effectiveness. The examination of examples of indoor components, presented in this paper, indicate the possible spatial and technical methods of execution in the areas, where interior designers' evidence- and research-based proposals may influence, and positively stimulate, the interior's quality parameters.

The analyzed cases of space components are limited to structurally and formally modified external wall zones, treated as the first components of inner spaces, separating and protecting them from the outside environment, and being *prerequisite for creating an effective interior*[15]. The examined aims and possibilities of components' activation are illustrated with the recently completed office interiors mostly certified under the Leadership in Energy and Environmental Design LEED Green Building Rating System. They have been validated in assessment category Commercial Interiors LEED-CI established in 2004 especially for the evaluation of sustainability of commercial interiors, including commercial offices.

3.1. Inner space elements and the regulation of thermal conditions

The thermal conditions (including inner air temperature and airflow) play a significant role in creating satisfactory working environment. This requirement may be assured by interior designers, in the properly conceived spatial layout, and with location of the circulation area in a way to separate workstations from usually fully glazed envelopes (Fig. 1.). The established thermal buffer zone may diminish the direct exposure of occupants to solar heat gains, permitting to avoid the necessity of the usage of expensive cooling systems. Using bright colors for ceiling, partitions and furniture finishing layers, complemented with reflective surfaces of

[15] S. Raymond, R. Cunliffe, 2000, *op. cit.*, p.121.

suspended ceilings, may compensate for the possible insufficient amount of daylighting at working areas and enable their better luminance, as required. With this outline, there is no need to complete glass panes with internally mounted, manually or electrically operated sun shading equipment.

Therefore, properly designed arrangements, in accordance with functional requirements, may provide occupants with optimal thermal conditions, and additionally enable their constant visual contact with outside views, being in fact one of the valuable well-being factors and indoor environment quality assessment criteria.

Fig. 1. Location of row of individual box workstations in a distance from external glazed facade in order to reduce direct solar thermal gains and assure equal natural lighting at workplaces in an open space office. NRDC, Chicago, USA, 2013, proj. Studio-Gang Architects (fot. S. Hall), Hedrich Blessing, certificate LEED-CI level Platinum. (source: http://www.nrdc.org/cities/building/chioffic.asp,http://www.earchitect.co.uk/chicago/natural-resources-defence-council-office (access: 12.08.2015))

3.2. Inner space elements versus visual and optical comfort

The glazed full height external walls, commonly introduced in the construction of building's envelope, are supposed to provide inner spaces, especially commercial office interiors, with required amount of natural lighting. In practice, by the conventional floor heights, only the workstations positioned along these glazed walls get a sufficient amount of daylighting, whereas the workplaces located deeper in the inner spaces remain under lighted, causing workers' physical and psychosocial discomfort. In consequence, it rises dissatisfaction or fatigue, and decreases workers productivity. These problems concerning proper daylighting distribution, along with other results of disadvantageous daylighting conditions like glare effects or lighting contrast at workplaces, both causing optical discomfort and eyesight's damaging side effects, may be diminished or avoided by different solutions. Modifications in spatial organization, installation of passive solar optical systems PSO, and sun shading devices outside the wall, may be complemented with other technical devices installed on the inside of the building envelope. These devices participate in: (1) redirecting incoming, direct sun lighting; (2) enabling its transmission into deeper-situated workstation areas and balancing its distribution; (3) protecting workers from glare effects occurring on desk-tops; (4) minimization of direct sunlight penetration; (5) assuring advantageous ambient light.

The properly conceived configuration of light-shelves, (Fig. 2.) as commonly introduced by interior designers systems of daylighting optimization, and their integration with envelopes' construction components, may therefore be seen as

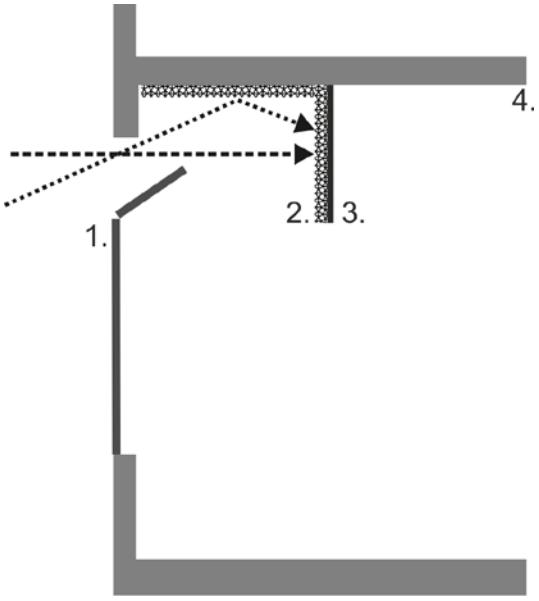

Fig. 3. The method of the enhancement of acoustic insulation of inner spaces and reduction of noise incoming from outside. (1. External glazed wall supplemented with mobile ventilation opening (potential source of noise coming into the space from outside), 2. Acoustic absorber panels mounted directly to the ceiling and parallel to the glazed wall, 3. Acoustic absorber's finishing layer adjusted to inner space spatial and formal concept, 4. Ceiling surface finishing layer adjusted to inner space spatial and formal concept) (source: author's drawing based on: S.V. Szokolay, Introduction to Architectural Science. The Basis of Sustainable Design, Architectural Press Oxford, 2010, p. 175)

a method of improvement in occupants' optical comfort through a uniform distribution of the daylight. Additionally, it may enhance the artificial lighting systems' effectiveness. With introduced optical devices and lack of necessity for introduction of other equipment protecting from glare, both direct and reflect the sunlight towards the deeper parts of interiors. These systems can replace traditional vertical louvers, blinds, fabric curtains, that obliterate views to the outdoors. Therefore, the optical comfort established with a formal and structural modification of the envelope area is accompanied by visual comfort.

3.3. Inner space elements and control of acoustic

The improvement in acoustical conditions of inner spaces, made by interior designers, begins with the reduction of the level of excessive noise coming from outside the building (e.g. heavy traffic, construction, wind, sirens) to the inside through openings in enclosures, especially in the spaces where natural ventilation systems are accompanied by manually- or electrically-operated clerestory windows or ventilation openings. Different solutions applied by designers, in order to assure the enhancement of acoustic insulation of inner spaces and elimination of distracting noise, may include a modification of the external wall structure. This goal may be achieved by a proper placement of acoustic absorbing panels situated parallel to the building shell, mounted beneath the ceiling and complemented with similar panels fixed directly to the floor slabs (Fig. 3).

The elements, used as acoustic barriers, require an additional treatment and are characterized by highly porous sound-dissipating or limp structures, as well as sound diffusing multi-faceted surfaces. Among materials used in inner commercial spaces, providing an effective acoustic absorption, are wooden fiberboards taking a shape of continuous panels finished with mineral paints. They seem to be valuable for these applications and functions. This composite waste product

of timber constructions, due to its' hygroscopic properties, may actively regulate relative humidity of inner air, thus enhancing the effectiveness of air conditioning systems.

Among other products enhancing acoustic performance of the building shell zone are sets of lightweight translucent perforated membranes or polymer foams, as composites of recycled materials, enclosed in acoustic fabrics and formed as point-wise mounted "acoustic cones" or baffles.

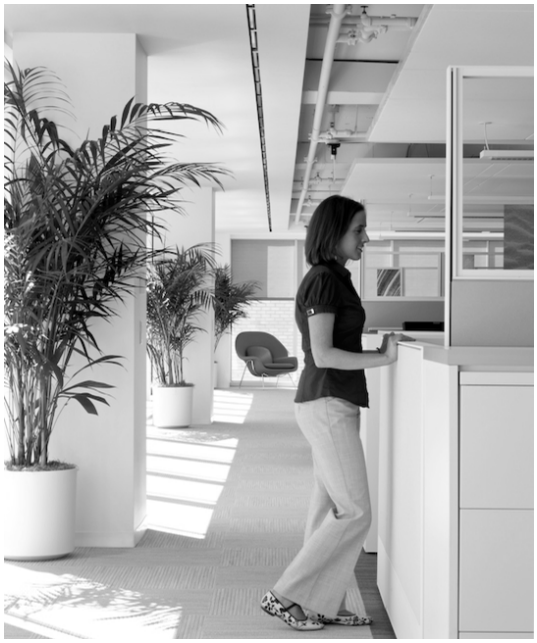

Fig. 4. "Biological corridors" in the interior climatic concept as a possible method of modification in thermal comfort, through the optimization of relative air humidity and inner temperature. USGBC headquarters, Washington, DC, USA, architect Envision Design Perkins, 2007, certificate LEED-CI, level Platinum, 2009 (fot. USGBC) (source: http://www.interiorsandsources.com/article-details/articleid/5331/title/u-s-green-building-council-headquarters-washington-d-c-.aspx (access: 02.12.2016)).

3.4. Inner space elements in the indoor environment microclimate endorsement

Microclimate in the built environment, including office environment analyzed in this paper, as defined by researchers, relates to such main characteristics as: (1) inner air temperature; (2) air relative humidity level; (3) surface temperature; (4) air flow; (5) indoor air quality (IAQ) mostly affecting occupant's health and well-being, indicating the content of hazardous chemical substances present in the inner air as the result of their evaporation from introduced products and building materials, as well as furnishings, finishes and equipment (FF&E).

Interior designers, responsible for creating healthy environment, are obliged to make knowledgeable decisions in predictions of their results implicating the users' satisfaction and well-being. Microclimate parameters, shaped by designers, are strictly connected to their design solutions including; (1) overall outline of spaces, realized in the context to building orientation and related to the spaces' sun exposure; (2) zoning of spaces in accordance to the functional exigencies and technology; (3) finishes of interior structural components, and furnishings specification with focus on the reduction in amount of contained pollutants, as well as the elimination of off-gas noxious or toxic vapors being potentially carcinogenic substances; (4) enhancement of ventilation and air conditioning systems with consequent and vast implementation of plants into spaces playing a complex role of

airborne chemicals filters, carbon dioxide absorbers and source of oxygen released in the daytime into the inner space, and elements decreasing the inner temperature.

The proposal by Envision Design Perkins made for USGBC headquarters in Washington, DC, with unusual concept of workstations away from the glazed building's shell, enables the optimization of inner air humidity and the control of air temperature, as well as the reduction in the negative effect of glare appearance and heat gains on working surfaces. The "biological corridors" (Fig.4.) developed between the external glazed walls and the row of box workstations complemented with plants, may be seen as designers' solution affecting the open space microclimate through a properly conceived office layout, and experienced in the minor-scale plant climate actively participating in the adjustment of the parameters of indoor environment quality.

4. CONCLUSION

The interior design environmental responsibility issues, as it has been referred to by many architecture critics and theorists, are still beyond interest of many interior designers, traditionally focused on aesthetic and functional aspects of created spaces[16]. As there is an increasing recognition of environmentally sustainable interior design[17], with regard to the estimation of impacts of interrelationship of natural and artificial environments, the designers have to modify their methodology and perspectives, in order to comply with the sustainability paradigm. This means a more comprehensive approach to design problems, including the creation of psychologically and physically healthy man-made environment through the optimization of indoor environment quality with the reduction in negative impact on natural environment, as well as the increase in energy effectiveness. As it was presented in this paper, these listed postulates may be realized by interior designers through the cautious selection of building materials, rationally developed and adaptable space layout in conformity with the present and prevision of possible future functions. The concepts of widely explored inner space components, multifunctionality and their multi-faceted environmental activation analyzed in this paper, seem to be substantial in view of provision of occupants with high performance of offices, natural environment-friendly and healthy indoor environment, as well as innovative methods in terms of searching for formal and functional integrity of evidence- and research-based inner spaces.

REFERENCES

[1] Attman O., 2010. *Green Architecture. Advanced Technologies and Materials*, McGraw Hill New York.

[2] Celadyn M., 2016. *Inner space elements in environmentally responsible interior design education,* World Transactions on Engineering and Technology Education WIETE 14(4), p. 495-499.

[16] M. Kang, D.A. Guerin, 2009, *op. cit*., p.180.

[17] L. Jones, (ed.), 2008. Environmentally Responsible Design. Green and Sustainable Design for Interior Designers. John Wiley & Sons Inc, Hoboken, New Jersey, p. 4.

[3] Celadyn M., 2017. *Zrównoważone środowiskowo wnętrza biurowe*, Faculty of Interior Design, Academy of Fine Arts in Krakow Kraków.
[4] Foque R., 2010. Building Knowledge in Architecture, UPA, Brussels.
[5] Hascher R., Jeska S., Klauck B. (ed.), 2002. *A Design Manual. Office Buildings.* Birkhauser Basel–Berlin–Boston.
[6] Jones L. (ed.), 2008, *Environmentally Responsible Design. Green and Sustainable Design for Interior Designers,* John Wiley & Sons Inc. Hoboken, New Jersey.
[7] Kang M., Guerin D.A., 2009. *The State of Environmentally Sustainable Interior Design Practice.* American Journal of Environmental Sciences 5(2), p. 179-186.
[8] McMullan R., 1998. *Environmental Science in Buildings.* Macmillan London.
[9] Moxion Sian, 2012. *Sustainability in Interior Design.* Laurence King Publishing London.
[10] Niezabitowska E., Masly D. (red.), 2007. *Oceny jakości środowiska zbudowanego i ich znaczenie dla rozwoju koncepcji budynku zrównoważonego.* Wydawnictwo Politechniki Śląskiej Gliwice.
[11] Nussbaumer L.L., 2009. *Evidence Based Design for Interior Designers*. Fairchild Books New York.
[12] Pilatowicz G., 1994. *Eco-Interiors. A Guide to Environmentally Conscious Interior Design.* Wiley New York.
[13] Raymond S., Cunliffe R., 2000. *Tomorrow's Office. Creating Effective and Human Interiors*, E & FN Spon – Taylor & Francis Group London–New York.
[14] Reed P., 2007. *Integrated design.* [In:] P. Bonda, K. Sosnowchik, *Sustainable Commercial Interiors.* John Wiley & Sons, Hoboken New Jersey, p. 28- 31.
[15] Smith A., Pitt M., 2011. *Sustainable workplaces and building user comfort and satisfaction.* Journal of Corporate Estate 13, p. 144-156, http://clok.uclan.ac.uk/2748/1/smith_aj_sustainable_workplaces_and_building_user_comfort_and_satisfaction.pdf [access: 18.03.2015).
[16] Śliwowski L., 1999. *Mikroklimat wnętrz i komfort cieplny ludzi w pomieszczeniach.* Oficyna Wydawnicza Politechniki Wrocławskiej Wrocław.
[17] Szokolay S.V., 2010. *Introduction to Architectural Science. The Basis of Sustainable Design.* Architectural Press Oxford.
[18] Winchip S., 2011. *Sustainable Design for Interior Environments* 2nd Edition, Fairchild Books New York.

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SUMMARY. This paper discusses problems of optimization of indoor environment quality parameters and possible methods undertaken by architects and designers in order to improve users' comfort. It is based on the analysis of recently completed commercial spaces including offices fulfilling sustainable design imperatives and implementing into design process new design tool, multi-criterial environmental evaluation being a parametric method of sustainability verification of architectural objects. The analysis addresses these components of the built environment, which passively enhance performance of building's systems and may optimize the indoor environment quality parameters, including inner air quality, and provide

occupants with expected psychological and physiological comforts combining such characteristics as thermal, visual, optical and acoustical. Evaluation of chosen examples of recently completed commercial office interiors and certified with leading rating systems, regarding their conformity with sustainability postulates, is based on the analysis of one of their structural components – external walls, as may be understood, separating spaces from natural environment. Assessment of external walls made by the author combines such criteria as structure and integration with building construction elements, technical and technological solutions, selection of building materials and primary, as well as supplementary functions of these interior components. The analysis indicates that properly conceived and modernized external wall area (treated as an inner space component), may have substantial effect on the meeting sustainability imperatives in terms of ecology, energy and shaping the indoor environment quality parameters as being mostly valuable from point of view the users of these spaces.

Key words: indoor environment quality, inner space elements, environmentally responsible interior design