Usability engineering of an information model simulating emergency scenarios at construction facilities

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Abstract. The transition to the construction facilities design, that involves the application of information models, strengthens the requirements for the comfortable perception of such models by their users and consumers. The presented research work has a description of an information model that accompanies a construction facility at each stage of its lifecycle. The article addresses the usability notion in the context of the emergency scenarios' information modelling at construction facilities. The co-authors offer an infographic model of a building information model lifecycle. The information model lifecycle analysis has given an opportunity to identify the production and consumption stages of an information model. Positions of the stakeholders, involved in the usability engineering of an information model, have been determined.

1 Introduction

The construction industry has always been considered one of the most complex and significant branches of economic development. Recently, versatile strengthening requirements, applied to construction projects in the areas of safety, energy efficiency, cost management, etc., have encouraged the industry to employ new instruments and methods, including more efficient application of digital technologies. Building information modelling (BIM) is one of the fastest developing approaches in use [1-7].

The transition to the design of construction facilities, that involves the application of information models, strengthens the requirements for the comfortable perception of such models by their users and consumers. The assurance of comfortable perception and comprehension of the substance (functionality) of models can be described by "usability", the notion borrowed from ergonomics. The term "usability" is generally used in the context of interaction between a consumer, on the one hand, and pictorial/semantic information, on the other hand, that "pops up" in the course of work with a specific image on the screen and that is traditionally called "the content". The definition of "usability" is provided in the ISO 9241 standard. This document explains how to interpret each component in the definition of usability: "the extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use". Pursuant to this definition, usability means compatibility between a product and its

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consumer. And skillful usability engineering ensures comfortable and target-oriented use of a product.

The presented research work offers a description of an information model that accompanies a construction facility at each stage of its lifecycle. Besides, we assume that the requirements applicable to the usability engineering of an information model of a construction facility will take account of the features of each of its lifecycle stages.

This article will place special emphasis on the operation stage of a facility, when information models are highly popular among the maximal number of consumers. It is noteworthy that the building operation stage is now determined by the assimilation of new technologies that require tighter safety requirements in the process of the building operation.

Indeed, high-quality assessment of fire risks, as well as the results of monitoring of emergencies arising in the process of building functioning, become a relevant aspect of safety assurance [8-12]. This aspect is particularly important for the maintenance of high-rise buildings, that are subject to safe maintenance regulations and to the methodology used to identify fire risk design values inside buildings that have different fire danger classes [13].

2 Materials and Methods

A considerable number of software programmes are currently used to simulate emergencies. This research is focused on Sigma PB software.

This software package is designated for the dangerous fire factors' escalation analysis, the simulation of evacuation processes from multistorey buildings, structures, and constructions that have different classes of functional fire danger, as well as evacuation probability assessment and identification of fire risk design values.

Sigma PB software has a number of advantages over similar Russian and foreign systems:

- it uses an integrated development environment with an integrated field of information resources and the data format needed to solve the task of analyzing the persons' movement and the escalation of dangerous fire factors;
- it has an in-built constructor of graphic objects;
- it ensures the 3D visualization of evacuation and escalation of dangerous fire factors in the virtual 3D environment of a facility with an option to reposition the observer;
- it has a calculation analysis module designated for computer-aided evacuation timing, blocking of evacuation routes, and evacuation probability evaluation;
- implements an automated reporting system that encompasses input data and calculation results;

The software has a visualization and calculation analysis module (see Fig. 1), which allows to visualize any changes in the emergency situation caused by the escalation of fire inside it. It is noteworthy that the escalation pattern is determined by the features of structural design; therefore, a designer of an integrated building security system is to solve the problem of big data processing in order to fill the information model with computational data.

The analysis of various emergency scenarios also involves the additional calculations and boosts the volume of numerical results, which, in its turn, requires the use of new data presentation technologies, typical for developments made within the BIG DATA digitalization trend. However, as for the construction facilities built to standard designs, this data volume can be substantially reduced, and its reduction can simplify the information model of the indoor environment in the course of an emergency situation, provided that the

regularities of these changes are preserved. Besides, it is easier to consider standard scenarios of emergency situations inside the facilities built to standard designs.

Fig. 1. Visualization and calculation analysis module.

However, the problem of an information model visual image comfortable presentation to a consumer remains unresolved. The study of its solutions is the subject of this research.

The solution is to increase the number of the software consumers that simulates emergency scenarios in each stage of an information model lifecycle by identifying all stakeholders willing to promote this model. The outcome of this solution is the focus of an information model on user-friendliness and the understanding of its substance by consumers.

We present the lifecycle of an information model as an infographic model [14], shown in Fig. 2, to illustrate the problem solving approach.

Fig. 2. The lifecycle of an information model

The image, shown in Fig. 2, demonstrates that production and consumption phases of an information model are implemented by the following persons who have different visions for an information model as a vehicle used to attain the objective, that is, the development of this product. We can identify several persons (stakeholders) interested in promoting the information model.

Firstly, it is a developer (producer) of an information model, represented in Fig. 2 as a transparent image of a person. According to a consumer, the emergency response service is the developer authorized by the state to ensure the safety of citizens in cases of occurrence and liquidation of emergencies. This emergency response service acts as the customer that places the orders for an information model development; it is responsible for its conceptual development, implementation and assimilation by a consumer in the course of educational activities and practical classes. In the case considered in this article, these responsibilities are assumed by the emergency response service.

Secondly, these are the users of an information model, represented by a group of individuals who perform the work within the framework of the information model production at different stages of its creation by the developer (producer). Users of an information model are represented in Fig. 2 as the human images whose top is unpainted, since it symbolizes the vision of the information model concept shared with developers of a particular information model (stages 2, 3 ,4, 7). The painted bottom of their images symbolizes their having instruments needed to transform the components of an information model, in other words, the instruments that allow to change the conditions of their application. The figure next to the human image stands for the number of the stage in the lifecycle of an information model, that is, the stage in which an independent element of an information model is generated.

The calculations, performed for an information model project, as well as their visualization, can be considered as an example of the work performed in the second stage of the lifecycle of an information model. Indeed, the dangerous fire factors’ escalation visualization is shown in Fig. 3.

Fig. 3. A chart of control over the analysis of the dangerous fire factors escalation.

Therefore, the calculation results are visualized, and their visualization may be used by the experts in their fire risk assessment and evacuation modelling. It is important for our research that, despite the fact that calculation results depend on the input data, that represent a situational component, a model for the swift data transformation into the calculation result has been identified, that is, an evacuation model. The majority of universal evacuation modelling methods are discreet-continuous flow models that allow to simulate the movement of each person with regard to the surroundings (other people,

hindrances) inside buildings that have a variably complex internal infrastructure irrespective of any local density. The models of this type have recently been most widely spread worldwide.

Taking into account the availability of such data transformation models, it is possible to use a set of descriptions of changing initial data to design an information model, capable of registering the changes' visualization, and this evacuation model is optimal from the viewpoint of an information model developer.

Therefore, the co-use of the software package at stage 2 "Designing an information model" facilitates the development of a joint viewpoint by the designers of an information model and software developers on the basis of the visibility of the results of the work performed, described in the graphic language which is comprehensible by each representative in the stage.

The activity, performed by a person 3 in stage 3, included the software development for the information model. Note that presently stage 3 of the model lifecycle "Development of information modelling software" is focused on the execution of the mission that encompasses the development of "a friendly interface" for all other stages in the information model lifecycle. This interface, allowing the contributors to stages 2 and 3 to develop a joint viewpoint, was considered above. The example has proven the ability of information model designers to assimilate ready-made software in the context of the deficit of in-house programmes.

For stage 4 "Preparation and development of information modelling hardware", "a friendly interface" is designed in the form of a computer and the software, developed during stage 3. This computer allows to use the input data, that encompass versatile emergency scenarios, in order to obtain recommendations for the generation of evacuation and emergency liquidation models, etc.

Therefore, the works, performed in stage 4, are focused on the "material" execution of an information model, and, in this case, such an "execution" of an emergency scenario at construction facilities built to standard designs, represents a simulator, used to train emergency response workers employed with the emergency response service. Simulators have decision making drill machines that ensure proper evacuation decisions made in case of emergency.

The finalization of an information model before its handover to a consumer is an example of the work performed during stage 7. In this stage, a consumer can visualize and evaluate the usability of the prepared model.

Presently, an information model, ready for the end consumer, has the following components:

- an evacuation map, that has a floor plan, including all evacuation routes;
- acoustic signals that accompany the commencement and the course of an emergency situation;
- activation of emergency lighting and "exit" signs above the doors leading to the exit from the premise and/or emergency exits;
- information about the specialist responsible for the fire safety assurance on the premises;
- information about the specialist responsible for the evacuation from a building.

Usually a specialist, responsible for the evacuation from a building, knows the fundamentals of fire safety; this person is to assume responsibility for the life and health of persons evacuated from the area under his control. This specialist provides guidance on the evacuation procedure: he chooses the routing, informs evacuees about the hazard level, the direction of the fire spread, etc. Thus, it might be possible to think that he performs the function of a "friendly interface" in the course of his communication with the information model consumers.

3 Results

The performance review of an information model, devised for an emergency scenario in standard houses and designated for the end user within the framework of the “smart city” concept, shows that the ability of construction systems to make a contribution to the usability of an information model has not been employed. It is deemed necessary to improve the existing information model, including the software, since the changes monitoring organization in the indoor environment of a building or a structure can be easily implemented in case of emergency, and the input data, needed for the calculations, can be obtained in the real-time mode.

In order to bring the information model into compliance with the most recent requirements applied to its hardware and to ensure the usability engineering within the framework of the model lifecycle, shown in Fig. 2, position 10 is used. It stands for the activity of a person, engaged in the implementation of stage 10 (“Information model mastering and operational rebuilding”). This activity is focused on a consumer, as evidenced by the painted top part of the human image. In the operation stage, a person is involved to correct the functionality of an information model in accordance with the tasks set by the consumer. The unpainted bottom part of the human image denotes the application at the consumption phase of the model modification instruments, characteristic of the production phase of the lifecycle. The mastering by the model consumer of the earlier developed software becomes possible in the process of the software upgrade, independently performed by the consumer in the course of improving the user friendliness of this software.

This is how the information model usability will be engineered, and the problem, formulated in this research project, will be solved.

4 Conclusion

The existing information model of an emergency scenario for standard houses requires usability engineering, or the assurance of its comfortable perception. The practical problem, solved using the above-mentioned method, consists in providing a consumer with an information model that allows him to make a fast decision to choose a safe evacuation route in case of emergency.

The analysis of an information model lifecycle has identified the stages of its production and consumption phases. Positions of the stakeholders, involved in the usability engineering for the information model, have been identified.

Reference

1. M. Salis, B. Arca, L. Del Giudice, P. Palaiologou, F. Alcasena-Urdiroz, A. Ager, M. Fiori, G. Pellizzaro, C. Scarpa, M. Schirru, A. Ventura, M. Casula, P. Duce, *International Journal of Disaster Risk Reduction* **58**, 102189 (2021) DOI: 10.1016/j.ijdrr.2021.102189
2. H. Yang, W. Song, *Yuanzineng Kexue Jishu/Atomic Energy Science and Technology* **54 (11)**, 2113-2119 (2020) DOI: 10.7538/yzk.2019.youxian.0918
3. V. Charalampous, J. Besharat, C. Stylios, *ACM International Conference Proceeding Series*, 237-240 (2020) DOI: 10.1145/3437120.3437315
4. C.H. Wijkmark, I. Heldal, S. Fankvist, M.-M. Metallinou, *Remote virtual simulation for incident commanders: Opportunities and possibilities*, 11th IEEE International

- Conference on Cognitive Infocommunications, CogInfoCom 2020 - Proceedings, **9237830**, 445-452 (2020) DOI: 10.1109/CogInfoCom50765.2020.9237830
5. E.M., Bourhim, A., Cherkaoui, International Journal of Human Computer Studies **142**, 102484, (2020) DOI: 10.1016/j.ijhcs.2020.102484
 6. A. Sidani, Matoseiro Dinis F., Duarte J., Sanhudo L., Calvetti D., Santos Baptista J., Poças Martins J., Soeiro A., Journal of Building Engineering **42**, 102500 (2021) DOI: 10.1016/j.jobbe.2021.102500
 7. A. Doroshenko, E3S Web of Conferences **143**, 01029 (2020) DOI: 10.1051/e3sconf/202014301029
 8. E. Ronchi, Fire Safety Journal **120**, 103020 (2021) DOI: 10.1016/j.firesaf.2020.103020
 9. L.I. Dashuai, S. Ruifang, IOP Conference Series: Materials Science and Engineering **792 (1)**, 012017 (2020) DOI: 10.1088/1757-899X/792/1/012017
 10. D. Korolchenko, D. Minaylov, IOP Conference Series: Materials Science and Engineering **1001 (1)**, 012075 (2020) DOI: 10.1088/1757-899X/1001/1/012075
 11. M.N. Uddin, Q. Wang, H.H. Wei, H.L. Chi, M. Ni, Ain Shams Engineering Journal, (2021) DOI: 10.1016/j.asej.2021.04.015
 12. A.I. Mokhov, Bulletin of the Russian Academy of Natural Sciences **1**, 25-30 (2015)
 13. V.I. Shcherbina, Integrated security systems for high-rise and multifunctional buildings. Educational and methodical reference manual (Edited by UKSB IO, Moscow, 2006)
 14. Infographics T.I. Multilevel infographic modeling Modular course of lectures. Series "Infographic bases of functional systems" (IOFS) (Edited by V.O. Chulkova, SvR-ARGUS, Moscow, 2007)