Importance and procedure of building life cycle assessment

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Abstract. Basic pillars of sustainable development, among others, are safety and health. One major area of the security of buildings is fire protection, which is – in a complex way – an integral part of the life cycle of buildings. In almost every country of the world architectural fire protection is based on laws. We are aware of fire safety estimation methods, technical procedures, risk assessments in the science of fire protection, but they do not comprise the entire life cycle of a building in terms of building – human – fire triple interaction, nor take account of fire prevention, fire intervention, or fire investigation. Authors used building life cycle assessment (LCA) in order to create a sustainable future, to the model of which engineering methods (building diagnostics, simulation, fire test, etc.) can be used to investigate the development of fire safety status of the built environment. Analyzing the activity of all participants involved in the fire protection of buildings in terms of usage throughout the entire life cycle of the building is also possible. In this article authors analyze the implementation of complex fire protection across the full life cycle of buildings. Integrated in investigation of fires, which were generated in critical times, in critical places, and situations, authors introduced the potential development opportunities lying in complex fire protection based on engineering methods, and also in fire safety lifecycle analysis of buildings.
Key Words: life cycle assessment (LCA), complex fire protection system, engineering methods, safety.

Introduction. The basic pillars of sustainable development, among others, are security and health. We spend a significant part our lives (30-50% in the countryside, 85-95% in cities) (Wittstock et al 2009), in built environment, in buildings, therefore their long-term sustainability and safe design has become a fundamental need. The provision of healthy human habitat quality is greatly served and influenced by the built environment (Aktas & Bilec 2012). Built quality is multi-factorial, from which sustainable security will play a key role in the future. One of the main areas of the safety of buildings along with stability protection (Balázs & Lublóy 2010a), health protection, security, etc. is fire protection, which in a complex way is an integral part of the full life cycle of buildings, therefore is a cornerstone of built quality and healthy human habitat.

Nowadays we plan our buildings for a life cycle of 50-100 years (Kellenberger & Althaus 2009). This time interval is short enough that a disproportionately high quality fire safety is made up with our building, but long enough to not to be a comprehensive fire protection safety net, spanning throughout the entire time period. Forty percent of the European Union's energy consumption can be linked to buildings, which is proportional to the normal domestic pollutant emissions (Kellenberger & Althaus 2009). This load is significantly increased by emissions released from building materials and components during a possible fire (Restás 2014).

Building Life Cycle Assessment (LCA). Building LCA is one of the foundations of sustainable development (Figure 1). In the case of building materials flammability components, questions of fire protection classification, fire-resistance limit parameters are intrinsically linked to the narrowly defined architectural building life-cycle analysis. However, from fire-protecting aspects a building's life cycle analysis goes beyond the analysis and evaluation of environmental impacts to the environment.

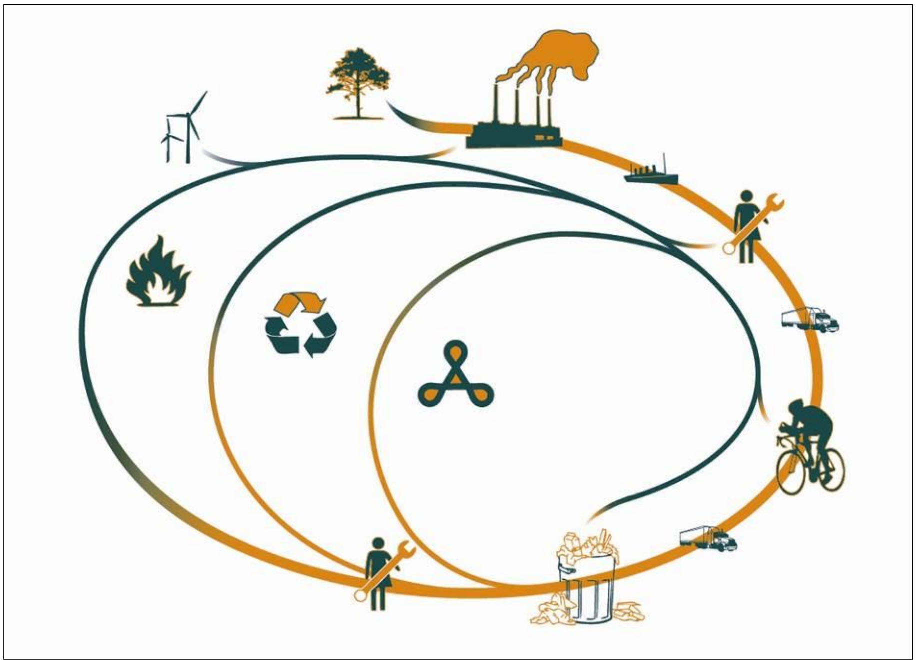

Figure 1. LCA (www.miljogiraff.se/vara-tjanster/life-cycle-assesment/?lang=en).

By the end of the 20th century environmental issues, such as resource depletion, climate change, ozone depletion, eutrophication, etc. were problems that mankind had to face with which also required engineer answers. In the case of built environment architectural life cycle analysis is one of the most effective methods which direct use plays a significant role in the development of construction products, production systems, architectural design, structural design, etc. It provides exact and engineering-based solutions (Aktas & Bilec 2012).

In the 21st century, in addition to the environmental problems, life-long implementation of the security of buildings has become of great importance. This security is complex for several reasons. On the one hand it serves the security of the built environment; on the other hand it serves the security of property values, the integrity of our health, and the safety of our lives. The life cycle of some buildings are becoming similar to human life cycle. Practically we design buildings for a lifetime that today can provide safety for 1-2 lifetimes (Fiorucci 2011).

Architectural fire protection is based on laws, policies and standards in almost every country in the world (Beda 2004). Fire safety estimation methods, technical procedures, risk analyzes are known in the science of fire protection, but they do not embrace the complete life cycle of a building in terms of the building - man - fire triple interaction, and in terms of complex fire protection: fire prevention, fire intervention, fire investigation. Due to fact that fire protection is not complex, "white spots", critical spots, and periods of time are formed in the case of buildings.

Building – Man – Fire. In terms of safety the building-fire-man triple relation plays the most important role (Beda 1999). Individually we know the parameters that define the fire protection safety for given measurable factors. The problem is hiding there that in many cases their real impact on each other results in uncertain modifying factors, typically destructive factors. If during a cleaning, a basically automatic fire door with a closing mechanism is trussed with a tidy up cart, it is not able to fill the role, so the fire is able to spread to several fire sections (human factor). During a prolonged architectural transformation the lack of demolished, but in the meantime not built back fireproof structures (walls, floors, etc.) can also lead to the rapid spread of fire (building factor). During the use of the building combustible equipment, installations, objects, materials are accumulated, which upon burning release combustion toxic gases and combustion products, also negatively affecting the fire protection status of the building (Beda &

Kerekes 2006). This, among other things, affects the evacuation ability of the people staying in the building, which could not be, or was not taken into account when designing the building (fire factor).

It can be seen from the simple examples that during the use of a building the human factor is the most uncertain, to which exact engineering solutions cannot be given. The only realistic solution is people's conscious and continuous training of fire protection, education, already from early childhood until old age. Thus, an automatism is formed, which would be favorable to prevent unintended negligent actions. In terms of engineering solutions the management of building and the fire factors is an easier problem, because there are exact solutions. The problem for these factors is caused by lack of proper analysis and evaluation of interactions that is typically a result of heterogeneous and long life cycles, as well as the different spatial and temporal location of fire protection actors.

Members of the complex fire protection. The composition of the participants is also heterogeneous. Basically it can be divided into professional and civic fire protection professionals. Two categories of the professional's team are distinguished: the assessment-analytical and operational teams which can be divided into further subgroups of three main areas of expertise: fire prevention, firefighting and fire investigation specialist area. The civilian fire protection sector is divided into four groups: fire protection planners, experts, fire protection lecturers, main lecturers; contractors, maintenance, inspectors; developers, manufacturers, distributors; and the group of volunteer firefighters (Figure 2).

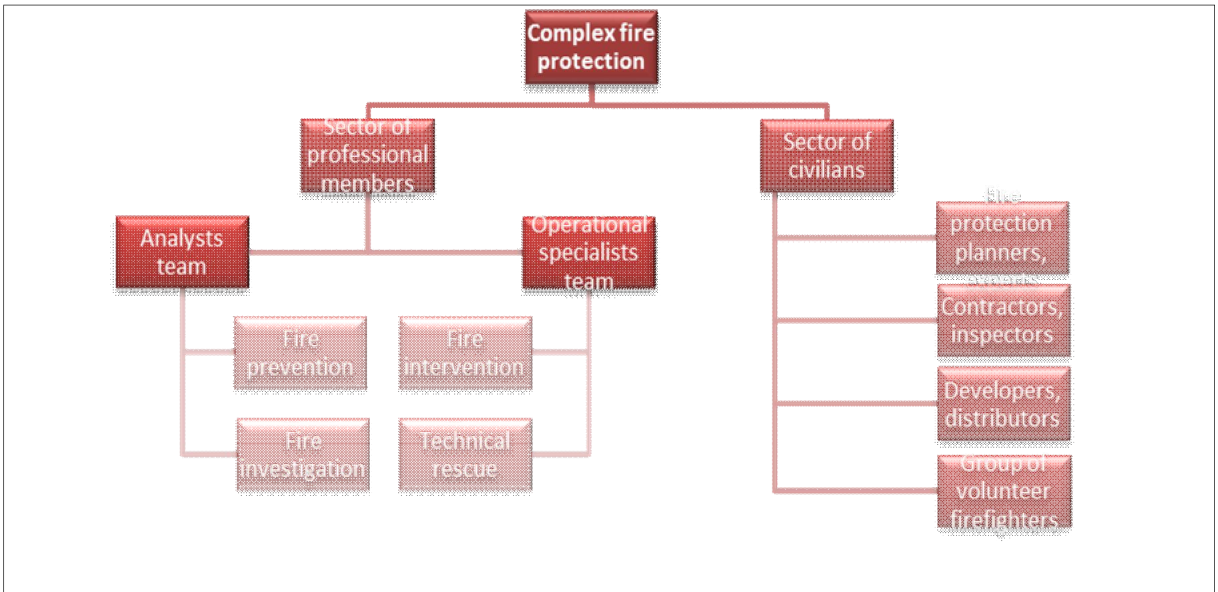

Figure 2. Members of the complex fire protection (by the author).

In each group, further specialization within subgroups can be observed, which will further strengthen the implementation of heterogeneous fire protection. Automatic, built-in fire protection equipment appear in the already complex fire protection planning, which may play a role in protection against the spread of fires, so that their operation is controlled by an automatic fire alarm system installed. This means that to a fundamental building fire protection issue, such as the protection against fire spread, three participants should provide a coordinated response: fire protection designer, built-in automatic extinguishing equipment (anti-fire spread unit) designer, built-in automatic fire detection system designer. Since all systems are considered to be construction products, their fire protection performance and rating, defined and validated by the developers and manufacturers, already plays a significant role at the selection of the products. The whole process is supervised by the professional sector in at least two respects: official (within: licensing, market surveillance) and trade official form. When only observing this fire spread problem it can be clearly seen how complicated and complex today the implementation of fire safety is. The participants listed above are not in the same space at the same, and typically involves a number of different professionals within a variety of actors, which results in the lack of homogeneity of the flow of information, so defects are formed. One of the actors do not know exactly what the other is doing, so important details are lost, and ultimately protection against a seemingly simple fire spread will not be able to perform its duties properly. In this example, we will not continue to dissect what happens with the fire spreading retardant device during use, which hides a lot more uncertainty (Balázs et al 2010). All in all, the problem in even such a simple case is that we tend to believe that by spending a lot of money and involving many professionals we certainly have built up an adequate protection and thus we create a false sense of security (Dorn 2007). The problem today is that there is hardly a time when the actors are in the same space and deal with this issue in a complex way. It is now virtually alone the date when the building is being put into use, but it is not inevitable. The solution should be leading in the direction of more homogeneous activity of participants, the development of a larger number and more active points of contact, making and setting up a well-functioning control system, the formation of a continuous back and forth linking between all professionals. The results of the specific disciplines are really starting to have an effect on each other. The way to achieve this system is digital and electronic, for which Information and Communication Technology (ICT) infrastructure is fully available in today's world. Info-communication allows operators to be present in the same "space", namely in cyberspace in real time, as well as the convenient access to the capacity of electronic databases (Haig & Várhegyi 2015). Thus, loss of information does not happen because of expert staff turnover, anyone can connect to the system.

Critical places and time intervals. Comparing the solution given fire protection problems with legal requirements is an accepted and operating method all around the world (Beda 2004). Thus, in many cases, it can be stated if the known fire protection parameter meets the requirement of the known value or not.

However, this method with the character of a dictionary knows responses only to the identified problems and also the complexity of the problems may be limited. It is far from covering the complex nature of architectural fire protection, and cannot follow the technical development of contemporary architecture. In many cases, the development of an available technology - either in the case of software or a technical product - is more advanced than inflexible legislation. The development of the above method is based on an engineering approach, by which the compliance with the technical requirements is provided by the use of the technical directives and standards. In this manner there is a significant increase in the freedom of margin, design, realization, but still there is a framework in which the user of the method is allowed to move in. Today this method is the most common and can be used the most optimally. This method is used in several European countries (use of harmonized standards), including Germany (DIN, VDS system) or Hungary (use of fire protection technical guidelines on harmonized standards), and the United States also has a similar system (the use of NFPA, FM standards) (SFPE Handbokk 2016). There are so-called complex fire-protection ratings, which are also based on engineering principles and treat fire protection problems with a technical approach and in a complex way as well, but not handle them throughout the full life cycle of a building. The future is in methods based on and regulated by engineering approaches, with the combined use of which the best individual solution can be ensured to every single problem in a manner so that we can obtain a comprehensive picture for the complete life cycle of the building's fire protection situation, taking the critical sites and potentially risky periods into account.

In determining critical time intervals the observations of fire investigation are considered to be the pole (Figure 3). In the new trend of engineering methods, in innovative engineering methods, means fire investigation one of the most significant role. During the life cycle of a building, starting from designing or redesigning and ending in demolition, different critical phases are formed, which appear as white spots in fire protection. Three critical phases are shown as an example in various international fires.

In the first case a fire occurred during an ongoing renovation of the Ritz Hotel in Paris, on 19 January 2016. The hotel facing re-opening was almost ready from an architectural point of view, but it was in an unfavorable, critical state in terms of fire protection. The fire protection system has not operated according to its intended purpose, because ongoing work took place in the building. The usage was not proper as well, since there was a construction in progress. Yet the building and fire parameters almost showed values that are true of a properly functioning building (The Telegraph 2016).

In the second case a building under restructuring, which was not affected by execution, and which was an abandoned construction site caught fire in Budapest, along Andrassy Boulevard, on 15 July 2014. The internal walls and ceilings were removed from within the upper floors of the palace building, therefore a huge air space, a huge fire sector has emerged, which persisted for a long time. The massive fire, the spread to an especially large area were due to the lack of fire retardant structures. The prevailing status of the exploded, restructured, single closed air space resulted in the building parameter which played a role in the critical space and the development of a long and potentially flammable period (XpatLoop 2014).

In the third case, the fire parameter determined the fire. The fire started on January 1, 2016 in Dubai, in The Address Downtown Hotel. During the New Year's Eve fireworks a pyrotechnic product caused the fire. In the critical time the various parameters are re-evaluated in several places as a result of different usage (BBC 2016). On New Year's Eve the concentrated increase in the number of pyrotechnic products in use is causing a potential fire hazard. The fire parameter in this example took such critical parameter values that it was able to cause a fire.

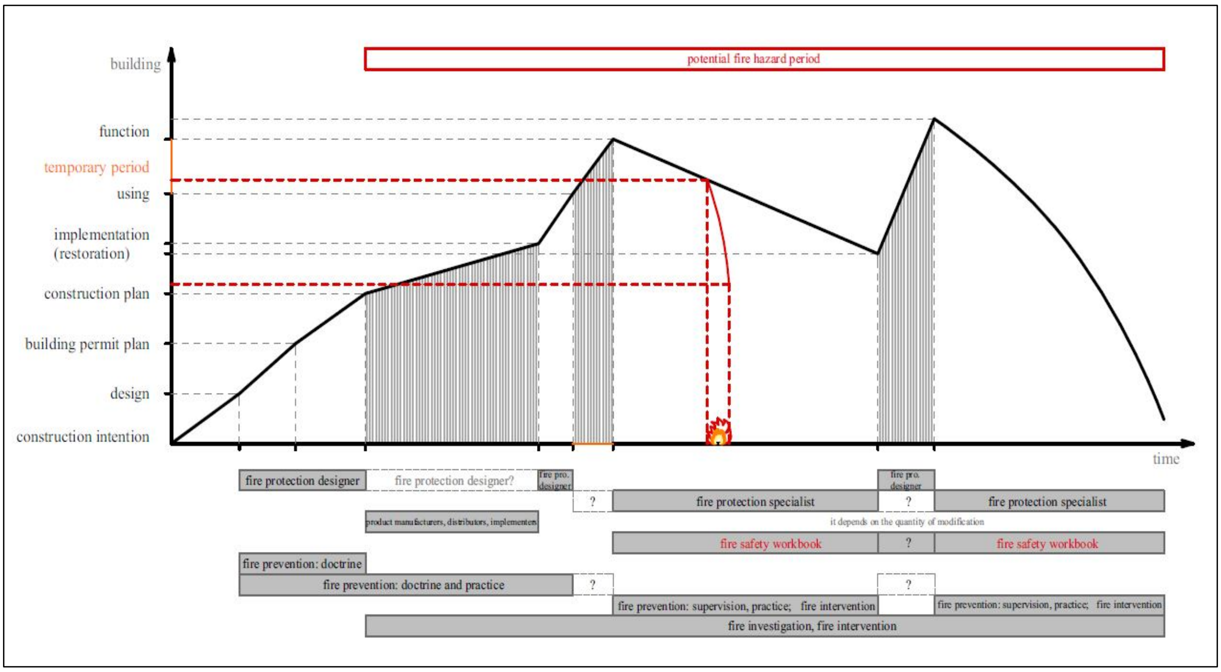

Figure 3. Critical places and periods function of time (by the author).

The examples show that all three fires occurred at a critical time from a fire protection point of view, with a shift of a fire interaction parameters (building-man-fire) towards an extreme value. We can establish exact the consequence of the fire effect on the structures with engineering based fire investigation (Pántya 2014; Lublóy et al 2016). From the perspective of traditional arrangements or administrative procedures of trade all of them were treated problems, but fire safety during critical periods has not been examined in depths of time, so the appropriate fire safety has not been worked out, thus fire started (Martin 2015). The fire protection actors were not, or were only partially present in the process, so the continuous fire protection net was interrupted in some places.

Innovative engineering methods. The real impact of the building-man-fire factors on each other can be designed with engineering methods (Zellei 2013; Badonszki et al 2013), with which we can form a clear picture of our building's fire protection lifecycle. Such methods include real fire tests and simulation examinations, calculations, analysis, evaluation, and building diagnostics, with which we can establish the evolution of our building's life cycle in advance (Balázs & Lublóy 2010b, 2013). The methods alone, however, may lead to erroneous and misleading results. The mixed use of different methods, the relative valuation of different results gives the essence of the engineering method. By themselves, the different methods provide only partial results, only in a partial system, in which they came under particular examination. A real fire test conducted in a specified manner (e.g. facade insulation fire propagation testing) manages the specific spatial design problems, but to every unique building the same system in different mounting positions, three-dimensional design can only be evaluated in approximately the same way (Kerekes 2008). Using the results of the real fire test and the spatial information of Building Information Modeling (BIM) based engineering, and with the available and rapidly developing simulation software of today the ability to plan the solution to the above problem is already in our hands. This, of course covers unique solutions in the case of each individual design, requires the proper application of several engineering methods and takes a final shape in an evaluating-analyzing summary, with which meeting with fire protection requirements can be justified. The conscious and innovative use of engineering methods requires a group of professionals with a unified approach and with almost the same level of knowledge, both from professional and civil operators. This can be achieved by a very thorough and targeted professional training. Innovative engineering approach is therefore a context in which a unique solution is being provided to the specific fire protection problem in a way it that it mixes the necessary engineering methods to the required extent, analyzes and compares the impact they have on each other, summarizes it by comparing them with experimental measured results, and evaluates the critical point in the building in a given critical time or interval.

With the use of innovative engineering methods the determination of critical areas and potentially inflammable periods is possible in the life cycle of a building, thereby creating an appropriate security. This security solves the safety of the fire intervention in special locales (Bérczi 2015; Pántya 2013). With the determination of critical areas a new type of usage, proven by engineering methods can be planned to potentially risky time intervals. Instead of static (regulation dependent only on legislative changes), legislation based rules a dynamic usage regulation can be created, with a new approach.

Fire Protection network. The information revolution allows nowadays widespread use of ICT. This includes public administration too. From the perspective of security fire protection is one of the basic pillars in the framework of digital state. Thanks to the infrastructure of the digital state, through the internet we can create a fire protection network (Figure 4).

The reality of fire protection network is tangible. The cloud-based, and in the near future, the fog-based systems give us a great possibility in safety. Architects and other engineers are planning with computers, and are using BIM systems. With this method comprise plans informations about the 3D virtual buildings. A wall is not only a line on the paper, or on the screen of the computer. It includes a lot of information: high, length, color, material, fire protection parameters, etc. Building permit processes befall digital, through the internet. So the authorities and also the sector of civilians can take place in the virtual reality of the digital state.

All of the members of fire protection can use uniformly this informations through the fire protection network. This means that all of the members of fire protection are not in different places and different time any more. In the virtual world of ICT gives fire protection a new quality of safety. The use of complex fire protection, and innovative engineering methods, fire protection will not be heterogeneous any more.

Figure 4. Fire protection network (by the author).

Conclusions. In summary, in our research so far we found that complex fire protection is the high level of heterogeneity in the case of participants, and that dynamic change of building-man-fire parameters in time results in white spots of a critical risk in the complete life cycle of a building, which significantly reduce the building's fire safety. We found that using a combination of innovative engineering methods - in addition to the solution of specific fire safety issues - on the basis of the results and experience of the fire test engineering critical periods and places can be established, to which an exact manner of use can be designed.

In this way basically a new type of dynamic operating framework is being developed, which continuously provides security throughout the full life cycle of a building. Members of the complex fire protection can work in the virtual world of digital state's system. So a new type of fire protection net, based on engineering methods, provides security from the first step of design, through the fire intervention, to the final demolition. To implement a new innovative fire protection, which can follow the accelerated tempo of the world, we should convert the fire protection education, and we should create a new education based on engineering methods.

References

Aktas C. B., Bilec M. M., 2012 Impact of lifetime on US residental building LCA results. The International Journal of Life Cycle Assessment 17(3):337-349.

Badonszki C., Szikra C., Szilágyi C., 2013 Tűzvédelmi mérnöki módszerek a világban – a szomszéd rétje. Katasztrófavédelmi Szemle 20(4):31-34.

Balázs L. G., Lublóy É., 2010a Tűzhatás a betonra. Beton 3:3-8.

Balázs L. G., Lublóy É., 2010b Tűzhatásra való méretezési lehetőségek áttekintése vasbetonszerkezetek esetén. Vasbetonépítés: A FIB Magyar Tagozat Lapja: Műszaki Folyóirat 12(1):14-22.

Balázs L. G., Lublóy É., 2013 Fire behaviour of concrete structures. In: Advanced in cementious materials and structure design. Prisco M. (ed). Konferencia helye, ideje: Milánó, Olaszország, 2013. 09. 10-2013. 09-11. Milano: pp. 110-116.

Balázs L. G., Horváth L., Kulcsár B., Lublóy É., Maros J., Mészöly T., Sas V., Takács L., Vígh L. G., 2010 Szerkezetek tervezése tűzteherre az MSZ EN szerint (beton, vasbeton, acél, fa). Oktatási segédlet ISBN 978-615-5093-02-9, pp. 5-24.

Beda L., 1999 Tűzmodellezés, tűzkockázat elemzés. Szent István Egyetem YMMFK, pp. 10-36.

Beda L., 2004 Épületek tűzbiztonságának műszaki értékelése. Doktori értekezés, ZMNE, KMDI, pp. 2-28.

Beda L., Kerekes Z., 2006 Égés - és oltáselmélet II. Budapest, Szent István Egyetem YMMFK, pp. 118.

Bérczi L., 2015 A tűzoltói beavatkozás biztonsága – helyszínen beépítve. Available at: www.vedelem.hu/letoltes/tanulmany/tan428.pdf. Accessed: September, 2015.

Dorn A. W., 2007 Tools of the trade? Monitoring and surveillance technologies in UN peacekeeping. United Nations, 98 pp.

Fiorucci P., 2011 RISICO: a decision support system (DSS) for dynamic wildfire risk evaluation in Italy. Wildfire 2011 Conference, Sun City, South Africa.

Haig Z., Várhegyi I., 2015 A cybertér és a cyberhadviselés értelmezése. Available at: http://mhtt.eu/hadtudomany/2008/2008elektronikus/2008e2.pdf. Accessed: November, 2015.

Kellenberger D., Althaus H. J., 2009 Relevance of simplifications in LCA of building components. Building and Environment 44(4):818-825.

Kerekes Z., 2008 Az építőanyagok új „Euroclass" szerinti tűzveszélyességi minősítése és hazai bevezetése. Tudományos Közlemények, Szent István Egyetem YMMFK 5(1):47-57.

Lublóy É., Czoboly O., Hlavička V., Oros Z., Balázs L. G., 2016 Testnevelési Egyetem atlétikai csarnok Budapest, tűzeset 2015. október 15. – következmények. Vasbetonépítés 17(3):50-55.

Martin U., 2015 Health after disaster: a perspective of psychological/health reactions to disaster. Cogent Psychology 2(1):1053741.

Pántya P., 2013 Füsttel telített, zárt terekben történő tűzoltói beavatkozások vizsgálata a biztonság szempontjából. Bolyai Szemle 22(3):47-58.

Pántya P., 2014 A tűzoltói beavatkozás veszélyes üzem? Bolyai Szemle 23(3):36-42.

Restás Á., 2014 Égés-és oltáselmélet. Nemzeti Közszolgálati Egyetem, Egyetemi Jegyzet, pp. 6-24.

SFPE Handbook of Fire Protection Engineering, 5th ed., National Fire Protection Association, Quincy, MA, 2016.

Wittstock B., Albrecht S., Colodel C. M., Lindner J. P., 2009 Gebäude aus Lebenszyklusperspektive – Ökobilanzen im Bauwesen. Bauphysik, pp. 17-21.

Zellei J., 2013 Mérnöki módszerek – a tűzszimuláció alkalmazásának módszerei. Katasztrófavédelmi Szemle 20(1):23-24.

*** www.miljogiraff.se/vara-tjanster/life-cycle-assesment/?lang=en.

*** The Telegraph, 2016. Available at: http://www.telegraph.co.uk/news/worldnews/europe/france/12107234/fire-engulfs-top-floor-of-the-Ritz-hotel-in-Paris.html. Accessed: December, 2016.

*** XpatLoop, 2014 http://www.xpatloop.com/news/77638.

*** BBC 2016, www.bbc.com/news/world-middle-east-35208484.

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