BDC

Università degli Studi di Napoli Federico II

19

numero 1 anno 2019

BDC
Università degli Studi di Napoli Federico II

19
numero 1 anno 2019

The Circular Economy Model: from the Building Functional Reuse to the Urban System Regeneration

BDC Università degli Studi di Napoli Federico II

Via Toledo, 402
80134 Napoli
tel. + 39 081 2538659
fax + 39 081 2538649
e-mail info.bdc@unina.it
www.bdc.unina.it

Direttore responsabile: Luigi Fusco Girard
BDC - Bollettino del Centro Calza Bini - Università degli Studi di Napoli Federico II
Registrazione: Cancelleria del Tribunale di Napoli, n. 5144, 06.09.2000
BDC è pubblicato da FedOAPress (Federico II Open Access Press) e realizzato con Open Journal System

Print ISSN 1121-2918, electronic ISSN 2284-4732

Indice/Index

ADAPTIVE REUSE AND REHABILITATION OF CULTURAL HERITAGE. A PERFORMANCE-BASED APPROACH FOR FIRE SAFETY

Stefania De Medici, Martina Bellomia, Carla Senia

Abstract

The international debate on sustainable development and the growing need to find new directions for the closure of loops includes architectural issues. The countless abandoned building resources as well as buildings in advanced state of decay highlight the urgent need to extend the life cycle of the building heritage, helping the trade-off between users' needs and past performance. The use of tools and methodologies for the simulation of different intervention scenarios allows reducing the resources needed to design and perform adaptations of existing buildings to new needs. The paper introduces an example of Fire Safety Engineering (FSE) performance-based approach applied to the rehabilitation of abandoned listed heritage buildings, of the *Teatro della Concordia* in Ragusa, Sicily. The findings are easy to put into practice, allowing the FSE performance approach to be used at an early stage of the design process.

Keywords: Adaptive Reuse, Performance-Based Design, Fire Safety Engineering

RIUSO ADATTIVO E RECUPERO DEL PATRIMONIO CULTURALE. UN APPROCCIO PRESTAZIONALE PER LA SICUREZZA ANTINCENDIO

Sommario

Il dibattito internazionale sullo sviluppo sostenibile e la crescente necessità di trovare nuovi indirizzi per la "chiusura del cerchio" include questioni relative all'architettura. L'esteso patrimonio dismesso o in avanzato stato di degrado costituisce una risorsa da riutilizzare, per la quale risulta indispensabile attuare misure in grado di estenderne il ciclo di vita, operando una mediazione tra le esigenze d'uso e le prestazioni residue. L'uso di strumenti e metodologie per la simulazione di scenari di intervento alternativi permette di ridurre le risorse necessarie per adeguare gli edifici esistenti a nuove esigenze. Il contributo presenta un esempio di applicazione dell'approccio prestazionale alla prevenzione incendi (FSE) al recupero di un edificio di interesse culturale abbandonato, Teatro della Concordia di Ragusa. I risultati conseguiti costituiscono un esempio di applicazione di un nuovo approccio progettuale, che consente di limitare le trasformazioni della preesistenza nell'ottica di un bilanciamento tra benefici reali ed alterazioni prodotte.

Parole chiave: riuso adattivo, approccio prestazionale alla progettazione, approccio prestazionale alla prevenzione incendi

.

1. Introduction

The massive fire at Notre Dame Cathedral in Paris strengthened the concern for safety of the architectural heritage and, notably, of the UNESCO World Heritage Sites. Even in Italy, in the last 30 years, fires have destroyed buildings with great cultural value: the Opera House La Fenice in Venice in 1996 and the Petruzzelli Theatre in Bari in 1991, both of which were rebuilt, and the Baroque Chapel of the Holy Shroud in Turin in 1997, restored and opened for visitors in 2018.

It is an inalienable right for the community to enjoy architectural heritage as well as its cultural value. And yet, what guarantees this right is building preservation, which is often in contrast with the need of ensuring people safety. Therefore, adaptations of cultural sites look indispensable to establish safety measures and, more generally, adaptive reuse and rehabilitation choices.

The adaptation of buildings to new needs, as a result of change in human activities, has been a common and widespread practice throughout the history of construction. Continuous processes of building rehabilitation affect the urbanized areas, according to the changing needs of the community and individuals. Such needs are constantly evolving, consistently with cultural, scientific and technological progress, which changes our ways of living, introduces new activities, and increases comfort and safety requirements according to the evolution of knowledge and the experiences.

In the 1960s and 1970s, the scientific community started to discuss the issue of building rehabilitation due to the growing concern for the environment; starting from this debate, rehabilitation has been widely regarded as a sustainable strategy, able to reduce the use and transportation of material, the energy consumption and the pollution, by increasing buildings' life-cycle (Cantell, 2005; Van der Voordt, 2004; Velthius and Spennemann, 2007; Abu Samah *et al*., 2012; Kurul, 2007; Conejos *et al*., 2013).

Building rehabilitation is consistent with a sustainable approach to urban and landscape management, according to a "circular economy" model able to «turn goods that are at the end of their service life into resources for others, closing loops in industrial ecosystems and minimizing waste […]. [Circular economy, ed.] would change economic logic because it replaces production with sufficiency: reuse what you can, recycle what cannot be reused, repair what is broken, remanufacture what cannot be repaired» (Stahel, 2016, p. 435).

Besides the reduction in the consumption of resources (soil, raw materials, energy, labour, etc.), there are further reasons for building rehabilitation, since any existing building may have economic, social, cultural, functional, environmental values that makes it worth using (Pinto *et al*., 2017). For example, when we choose to use an existing building rather than construct a new one, we might benefit from its location in a central area of an urban district, just as we can reduce construction costs and planning fees.

Many pre-industrial buildings, due to multiple reasons (e.g. socio-economic transformations of the settlement context, functional and technological obsolescence, etc.), have been adapted to new functions or have been abandoned. The abandonment of a building leads to the evolution of its decay status, which over time extend to the context, causing a progressive loss of urban quality. A study carried out by Xavier Greffe shows that the value attributed to cultural heritage is a function of its state of conservation. There is a minimum quality threshold for buildings, below which the local population's lack of interest in the cultural heritage grows (Greffe, 2004).

Building rehabilitation includes a range of actions (maintenance, redevelopment or reuse) in accordance with the obsolescence degree of the building to be adapted. The rehabilitation project should be based on a complex evaluation of the building system; the decision criteria and the consequent design choices should be inspired by the building's characteristics and by its physical, cultural, social and economic environment.
The reasons that lead to building rehabilitation are strengthened if the buildings under renovation and the sites in which they are located have a cultural value. Indeed, cultural heritage is considered as key resource for sustainable development, in terms of economic growth, employment and social cohesion (European Commission, 2014; European Commission, 2015; European Parliament, 2017; UNESCO, 2015). It is a non-renewable resource (Cameron, 1994; Holtorf, 2001), that cannot be replaced or effectually reproduced. Technological development has partially dispelled the air of uniqueness, originality and unrepeatability of historical and artistic works - defined "aura" by Walter Benjamin - and has made possible to duplicate such works (Benjamin, 1969). Nevertheless, the preservation of the authentic material substance of the cultural heritage buildings safeguards the unrepeatable uniqueness of the creative act. The outcome of a technical action leading to the production of the work of art or artifact and bearing witness to the history and traditions of a social group is characterized by something original, which cannot be totally duplicated. Such characteristic guarantees its authenticity. Indirect enjoyment reduces the benefits that direct access to the original resource provides for the community. Indeed, in duplication, part of the information held in the work is lost; this reduces the knowledge process, by weakening perception and understanding.
In the case of heritage buildings, beyond the symbolic value arising from originality, we must consider technical factors that often entail their uniqueness, such as difficulty in finding materials that once were widely available, problems in applying obsolete technologies, loss of ability of workers in traditional construction techniques, etc. Therefore, the unrepeatability of the heritage building is closely related to its cultural value, which leads us to consider it a tangible evidence of the construction culture of an era.
The Faro Convention on the Value of Cultural Heritage for Society (Council of Europe, 2005) reaffirms the need of a sustainable use of the cultural heritage, «by ensuring that decisions about change include an understanding of the cultural values involved» and «that all general technical regulations take account of the specific conservation requirements of cultural heritage» (Article 9).
The UNESCO Operational Guidelines for the Implementation of the World Heritage Convention (2008) highlight that sustainability goals should not threaten heritage preservation; Article 119 declare that «World Heritage properties may support a variety of ongoing and proposed uses that are ecologically and culturally sustainable. The State Party and partners must ensure that such sustainable use does not adversely impact the outstanding universal value, integrity and/or authenticity of the property. Furthermore, any uses should be ecologically and culturally sustainable. For some properties, human use would not be appropriate». According to Luigi Fusco Girard, cultural heritage has a *complex value* (Fusco Girard, 2014; Fusco Girard, 1987), which includes use-value and an independent-of-use value, linked to its cultural significance. The need to preserve this heritage without compromising its complex value, requires a careful evaluation of the alternatives of building rehabilitation; such evaluation aims to find a balance between

.

conservation and adaptation, through a project capable of protecting and enhancing values and potential of the building.
Sciences, local and EU policies, as well as public opinion widely agree with the aims of protection and enhancement of heritage buildings. The main concern of the scientific literature is the preservation of their cultural significance (Mısırlısoy and Günçe, 2016), through the search for a balance between conservation goals and the needs of alteration. In the words of Philippe Robert, «working on an existing building means coming to terms with it; such work involves juggling constraints additional to those arising from the program and from building regulations» (Robert, 1989, p.4).

2. Research aim

The rehabilitation design choices are driven by rules which do not always consider cultural value and uniqueness of the heritage building or of its environment. In the words of Christian Ost we can identify the main causes of this problem. «The economic crisis has taken its toll the world over, with budget cuts, reduced cultural expenditures and public debt financing. There will be fewer financial resources for culture if there are no recognized economic values for projects, and there will be no recognized economic values if cultural impacts are not measured in a more systematic and holistic way, and shared and disseminated among all interested parties» (Ost, 2016, p. 229).
However, in Italy the scarcity of financial resources is not the only cause of the poor quality of building rehabilitation projects. Often building regulations for usability, comfort and safety of public buildings are not compatible with the needs of preserving the heritage buildings, because such regulations comply with a prescriptive approach. Indeed, the laws establish mandatory parameters, which must be respected both in the project of a new building and in the rehabilitation of an existing building. This approach has been adopted, for example, in the case of the Italian laws for fire-fighting design that came into force in the late eighties of the last century. Building regulations for fire-safety required minimum safety levels to be respected through prescribed measures (for example, an escape route must not be longer than 30 metres). The advantages of this approach are given by the uniformity of application of the standards at national level and by the ease of implementation for the design and control of new buildings. In the case of building rehabilitation, the prescriptive regulations impose adaptations that cannot always be implemented in compliance with the morphological, dimensional and construction characteristics of pre-industrial buildings. For example, the aim of preserving the construction criteria in buildings in which masonry plays the role of structure, partition and building envelope imposes several constraints on the alterations required for fire-fighting adaptation. In the same way, the need to preserve valuable materials and decorations is a constraint to the adaptations required by the prescriptive regulation model (Bernardini *et al.*, 2016).
It was only in the early 2000s that the performance approach to fire regulations was introduced internationally. In Italy it was implemented with the guideline for the evaluation, in exception from the laws in force, of projects for listed buildings according to Legislative Decree no. 42/2004, opened for public use and to be reused for activities listed in Annex 1 to the Presidential Decree no. 151/2011 (Circular Letter no. 3181/2016), with the Ministerial Decree of 9 May 2007 and thereafter with the provisions of the Fire Prevention Code (Ministerial Decree of 3 August 2015). This approach takes into account

the international recommendations concerning Fire Safety Engineering (FSE), i.e. on engineering principles, rules and judgements based on the scientific evaluation of the combustion phenomenon, the effects of fire and human behaviour in the event of fire. Nigro et al. define the FSE as «the application of engineering principles, rules and expert judgement based on a scientific appreciation of the fire phenomena, the effects of fire and the reaction and behaviour of people, in order to: save life, protect property and preserve the environment and heritage; quantify the hazards and risk of fire and its effects; evaluate analytically the optimum protective and prevention measures necessary to limit, within prescribed levels, the consequences of fire» (Nigro *et al.*, 2010b; p. 255).

A survey carried out in 2016 by the Italian National Council of Engineers (CNI), concerning the implementation of the Fire Prevention Code in design, shows that engineers are willing to make the best use of the Code but, at the same time, do not often use it (CNI, 2016). More than 62% of Italian designers, despite having attended training courses focused on the implementation of the Code, did not try to use it or gave up after a single attempt; only few of those who have adopted it have implemented to the so-called "alternative solutions". Probably because of the perceived complexity of the law and the increased responsibility it attributes to the designer, the Code is often ignored, and the prescriptive method is still applied today.

In order to facilitate the work of designers committed to reducing the risks in case of fire in historic buildings, in 2016 the Central Technical-Scientific Committee for Fire Prevention (C.C.T.S.) of the Italian Fire Department and the Ministry of Cultural Heritage (MIBACT) issued a joint document containing guidelines for the evaluation of fire protection projects for listed public buildings, which require exceptions to the fire laws in force in Italy. This document, which is not mandatory, confirms the established practice of making exceptions to the mandatory standards. The Guideline proposes two alternative routes that the designer can follow when he needs to derogate from the legal requirements. He may apply either fire safety engineering, according to the Ministerial Decree of 9 May 2007, or technical solutions and additional measures proposed in the same Guidelines. The technical solutions proposed compensate for the increased risk of fire – arising from non-compliance with the regulatory standards of the fire sector – with the synergistic and complementary effect of the solutions in accordance with the Code of Fire Prevention (Ministerial Decree August 3, 2015) and additional compensatory measures – including managerial measures – to protect the people and the assets to be preserved. The Guideline requires a preliminary assessment of the fire risk (for persons and assets) and, on the basis of such assessment, the identification of an overall fire strategy, consisting of technical solutions covering all fire-fighting measures, not just those required by the exemption. The aim of this strategy is to ensure a level of safety equivalent to that of the derogated technical regulation. For example, if the exemption concerns only the fire protection measure concerning the reaction to fire, when we apply the Guideline, the fire risk must be reassessed and the technical solution provided for each fire protection measure (reaction to fire, resistance to fire, partitioning, exodus, etc.) checked in relation to the current level of risk.

The proposed methodology represents a model of integration of Fire Safety Engineering in the decision-making process, allowing to identify – in the preliminary stage – design solutions able to guarantee both the preservation and the usability of the building, in compliance with the *constraints to transformation* (De Medici and Senia, 2014). These are conditions to be met so that the design solutions do not compromise the values system of

.

the building. In particular, the methodology allows evaluating – in accordance with the constraints to transformation – different layout options of the emergency escape route. For example, the purpose of escape route control is to ensure that users can reach a safe place within a reasonable time or stay in it. The shape of the spaces and the layout of the protected buildings, usually constrained by the load-bearing masonry construction system, are often an obstacle to meeting the requirements imposed by the prescriptive regulations for escape routes. The improvement of the escape routes requires alterations that can compromise the preservation of the morphological, dimensional and constructive characteristics – and therefore the identity – of the pre-industrial buildings.
The application of calculation models based on the FSE criteria improves the work of the designer by aiding in the early stages of the decision-making process. This procedure gives a competitive advantage in operational practice, since the new calculation models are able to simulate with a high degree of reliability the effects of fire, by quantifying the safety levels through the scientific evaluation of the combustion phenomenon, the effects of fire and human behaviour.

3. Background

Fire Safety Engineering

In recent decades, the fire safety design has changed significantly; prescriptive requirements are being replaced or complemented by an approach based on Performance Based Building Design (PBBD) (Gibson, 1982; Averill, 1998). More and more countries are moving towards the implementation of performance-based fire safety design regulations (Lo *et al*., 2002; Meacham, 2010; Merci et *al.*, 2013).
Borg and Njå illustrate this point when they state, "while fire safety has been addressed by the construction industry for a long time through prescriptive fire safety codes, performance-based fire safety engineering (FSE) is relatively new and has only existed for the last 15-20 years" (Borg and Njå, 2013, p. 57). Performance-based design approach has been adopted in the field of fire safety design in the 1990s. The implementation of the FSE has been aimed at ensuring a level of safety that is not quantified, but "equivalent" to what is established by the Code, rather than a real performance evaluation (Lay, 2007). However, although there are examples of FSE-based design, the prescriptive regulatory framework for design is still the main reference in most situations (Woodrow *et al.*, 2013).
Östman et *al.* explain Fire Safety Engineering as «a performance-based approach to fire safety design relies on the use of fire engineering principles, calculations and/or appropriate modelling tools to satisfy building regulations. Instead of prescribing exactly which protective measures are required, it is the required performance of the overall system that is presented against a specified set of design objectives» (Östman et *al.*, 2017, p. 13).
The design of building egress routes and the estimation of smoke and toxin propagation frequently use the performance-based design approach (Meacham, 2014; Spinardi 2016). Nowadays, significant improvements in methods, computing facilities and knowledge allow performance-based design to be used to estimate temperatures in fire compartments and load-bearing structures, and thus to calculate the fire-resistance of structures (Heinisuo *et al.*, 2010).
The computational tools for FSE have significantly developed over the last two decades. The increasing reliability of cost-effective computing and the improvement of graphical

.

user interfaces have encouraged the widespread application of computational fluid dynamics (CFD) for fire effects modelling, human fire behaviour and evacuation models (Borg and Njå, 2013).

European and national codes

Over the last 30 years, as Meacham points out, «research has become more focused on addressing the needs of FSE practice, the essential elements of a framework and vocabulary have been developed, and many practitioners appreciate where and how the current methodologies can address their problems» (Meacham, 2014, p. 8). In an international framework, this has led to the issuing of guidelines (FRC, IRCC, SFPE, SFPE, Vdbf) and standards, which are constantly updated and integrated to solve the most complex issues in the field of fire safety (Zang, 2016).

Since 1988, Subcommittee SC4 of ISO TC 92 has developed a draft of the international standards of the FSE, based on the results of the most advanced research in the field of fire-fighting. Only in 1999 ISO published the TR (Technical Report) 13387 “Fire Safety Engineering” divided into eight parts, which were subsequently updated to the 2008 version.

European countries have also introduced EN standards for fire design. In recent years, EN standards have addressed the issue of structural safety assessment in fire conditions. In the past, European technical standards for structural safety were separated from those for fire safety. Today, these standards are integrated into a single standard system, the EN 1991 series, which defines both fire and mechanical loads (Heinisuo *et al*., 2010).

In the current European codes, the performance-based approach coexists with the prescriptive approach, without replacing it (Del Prete *et al.*, 2016; Nigro *et al.*, 2010a). The technical solutions imposed by the prescriptive approach are only one of the possible choices given to the designer in the structural fire design (Nigro *et al*., 2010b).

In Europe, the Directive 89/106/CEE introduced the definition of the minimum requirements of “safety in case of fire”; such Directive has been updated as Regulation on construction products no. 305/2011. These minimum requirements of fire-safety have been transposed by the National Codes of the Member States of the European Union and refer to the following objectives:

1. to guarantee the stability of the construction for a certain period of time;
2. to limit the generation and spread of fire and smoke;
3. to limit the spread of fire to nearby buildings;
4. to ensure that occupants can leave the building;
5. to promote the safety of rescuers.

The effects of applying the performance approach to ensuring fire safety should be assessed in terms of the achievement of those objectives (Nigro *et al.,* 2010b).

The current Italian codes for fire safety design allow both prescriptive and performance-based analysis approaches. If the prescriptive upgrade is incompatible with the constraints imposed by the building, the performance approach may be used.

The performance approach of fire safety engineering (FSE), introduced in the Italian regulatory framework with DM 09/05/2007, follows principles of science and engineering to verify – through simulations based on validated mathematical models – the ability of each alternative measure in reducing the risk factors. This allows demonstrating the actual level of safety achieved by the compensatory measures adopted by the designer.

.

Fire Safety Engineering and listed buildings

According to Arborea *et al.* «fire protection of historic buildings is able to find appropriate solutions under prescriptive rules only in rare cases. In this situation, performance-based techniques seem to be the only approach that guarantees both heritage safety and preservation» (Arborea *et al.*, 2015, p. 1).

In recent decades, as argued by Naziris *et al*., «fire protection of historic buildings became an important discipline for fire engineers and researchers. In particular, NFPA 914 is the first code that describes the principles and practices of fire safety for historic structures and for those who operate, use, or visit them» (Naziris *et al*., 2016, p. 293). The U.S. National Fire Protection Association's NFPA 101 "Life Safety Code" technical standard provides eight fire design scenarios based on the performance approach in historic buildings (NFPA 101, 2000), as well as the NFPA 914 standard (NFPA 909, 2001) for this class of buildings provides requirements for fire protection, fire safety and safety (Biao *et al*., 2012).

In March 2016, in Italy, a Guideline was issued in order to assess, as an exception to the provisions of the law, rehabilitation projects for listed buildings. The document, issued by the National Fire Brigade and the Ministry of Cultural Heritage and Activities, analyses the most frequent cases of exceptions for listed buildings, referring to the regulations of the Fire Prevention Code (Ministerial Decree of 3 August 2015). The application of the Guideline is not mandatory, but it is to be considered as an aid for the designer. Often the morphological and structural characteristics of listed buildings hinder the application of the regulations, which would require alterations to the building that are incompatible with the cultural heritage preservation requirements. In most cases, the designer designs solutions which derogate from mandatory requirements and applies fire safety engineering methods.

Fire risk is one of the most important emergency issues for heritage buildings preservation (Bernardini, 2017; Marrion, 2016; Naziris *et al*., 2016; D'Orazio *et al*., 2016; Watts Jr *et al*., 2002; Watts Jr, 2001; Watts Jr *et al*., 2001). In the words of Bernardini *et al.*, «building heritage is affected by significant risk levels because of intrinsic features (structures vulnerability), presence of different hazards (e.g. fire sources; localization in earthquake or flood prone areas), high exposure (mainly due to occupants' density and characteristics; cultural and architectural value). Fire emergency represents a significant topic, especially […] when occupants are unfamiliar with the building layout (e.g. historical theatres). In these conditions, "correctly" evacuating the building (in a short time, by using the proper path) widely depends on individuals' spaces perception, architectural layout and presence of adequate wayfinding systems» (Bernardini *et al*., 2016, p. 1007).

In the case of cultural heritage, current regulatory standards are often at odds with the preservation needs; indeed, alterations made to ensure the safety of people inside historical buildings can cause the loss of historical, socio-economic and architectural information that heritage buildings can convey to us, in other words, their cultural value (Pinto *et al.*, 2017). The use of simulation software helps to control the quality of the project, especially in building rehabilitation. Indeed, such software allows to compare alternative design solutions and to evaluate their effects, in terms of building conservation.

3. The case study

The methodology proposed for the application of the FSE to cultural heritage has been tested in order to verify, at an early stage, the redevelopment project of the Concordia Theatre of Ragusa, abandoned in the seventies of the last century (Fig. 1).

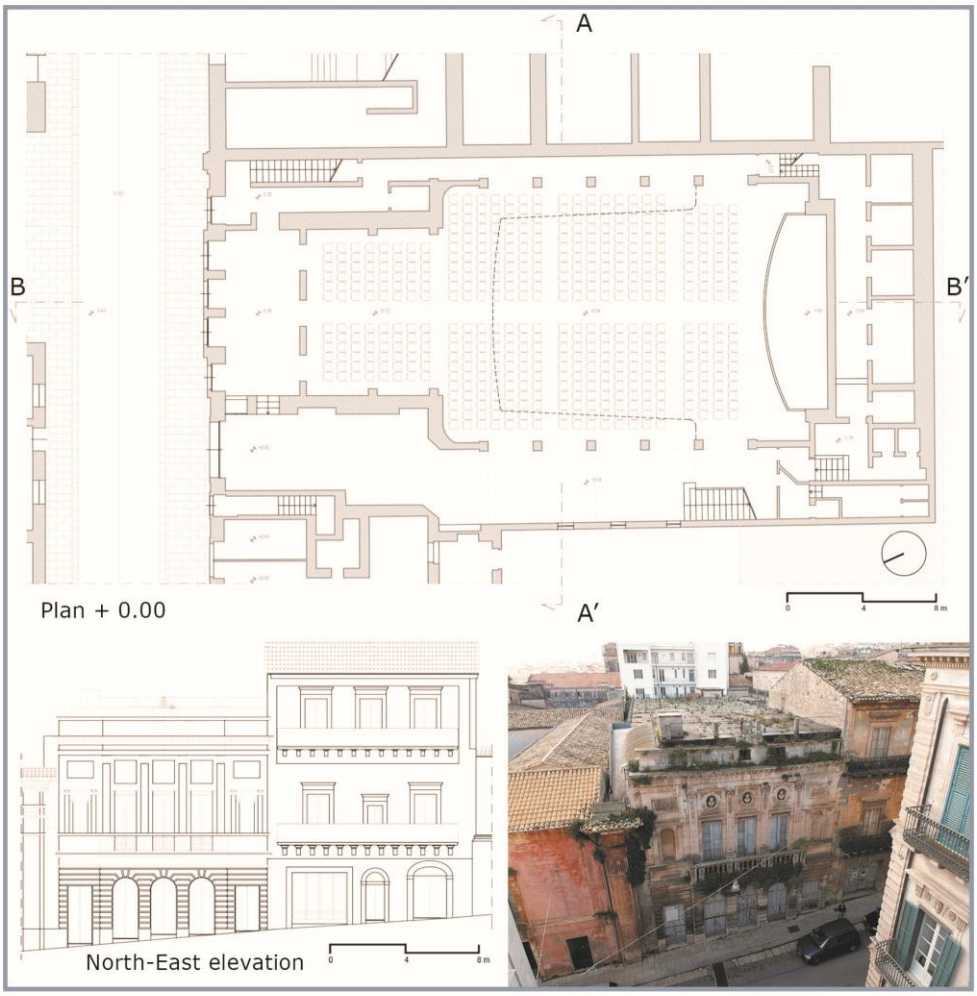
.

The Concordia Theatre in Ragusa was built between 1839 and 1843 with private funding from the richest families in Ragusa. The name recalls the agreement reached between those families who subsidised its construction. Granted as a concession by the Municipality until 1938, it was then assigned in perpetual emphyteusis to a private individual, who used it not only as a theatre, but also as a conference hall and cinema. After several changes of ownership, in the mid-seventies the building was definitively abandoned. At the turn of the twentieth century and two thousand the theater was purchased by the City of Ragusa. Currently the building is abandoned.
The building consists of two separate blocks, adjacent on Via Ecce Homo, which have different construction, dimensional and decorative characteristics (Figs. 2-3).

Fig. 1 - The Concordia Theatre in Ragusa

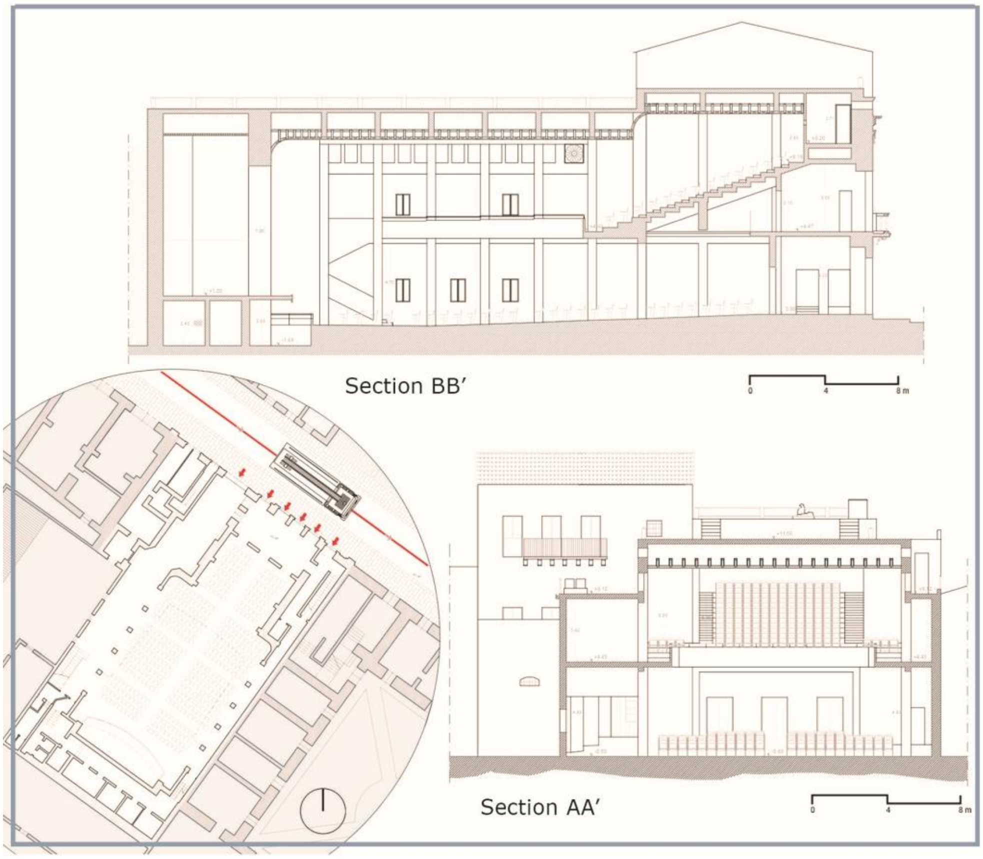
.

Fig. 2 – Concordia Theatre, Ragusa. Plan of the ground floor and North-East façade elevation



.

Fig. 3 – Concordia Theatre, Ragusa. Plan of the ground floor with entrances and sections



The oldest block has a façade with five openings in the ground floor and a large balcony, with three openings and two large side recesses, on the upper floor. Each of the three openings on the first floor is topped by three half-busts of Vincenzo Bellini, Carlo Goldoni and Vittorio Alfieri. On the top of the façade there is a stone sculpture showing the coat of arms of the City of Ragusa. The theatre was built in load-bearing masonry. The transformations in the early decades of the twentieth century, needed to adapt the building to cinema, led to the preservation of only the perimeter bearing masonry, with the construction of a shell in reinforced concrete for the structures that support the roof of the stalls.

A similar skeleton structure supports the grandstand. The adjacent block, originally used as a residence, was annexed to the theatre to extend the spaces for services: offices on the first and second floors and reception areas for the public on the ground floor.

.

4. Methodology

The first phase of the proposed methodology is aimed at collecting information on the Concordia Theatre, through analyses focused on checking building behaviour according to the use requirements (residual performance requirements). The following requirements, as prescribed by fire regulations for places of entertainment (DM 19/08/1996), have been considered: accessibility to the building, accessibility to the outside or to safe areas, capacity, practicability and internal accessibility. The analyses provide an overview of the residual performance requirements of the Theatre and the identity characteristics of the building, which are required to understand its values. As a result of this analysis a system of constraints to alteration has been defined, to guide the building's redevelopment choices (Tab. 1).

The comparison between the performance requirements of the Theatre and the requirements of fire regulations for entertainment activities allows defining solutions for the adaptation project. The need to comply with the constraints to the alteration, in order to safeguard building's identity, requires compensatory solutions to be identified through the application of the FSE. The intervention alternatives that passed the performance-based test are checked in relation to the constraints to the alteration. The final project will be developed only for the design solution with the highest compatibility with the constraints to the alteration. The integration of the FSE in the early design phase allows to reduce risks and uncertainty in the subsequent detailed design phase and to safeguard building's values.

Tab. 1 – Constraints to alteration and project purposes

Categories of constraints	Goals to be pursued in the redevelopment project
Perceptive-cultural constraints	Preservation of the historical and psychological characteristics involved in defining the image of the Theatre perceived by the people; recognisability and acceptability of alterations
Morphological-dimensional constraints	Preservation of the geometric and stereometric characteristics of the building
Material-constructive constraints	Preservation of the structural concept, of the materials and of the construction techniques of the building

For example, this method can be used to avoid building alterations which, although required to comply with statutory requirements, do not lead to a significant increase in security and, at the same time, unreasonably compromise the identity of the heritage building.

Building knowledge and definition of constraints to the alteration

The following analyses of the building have been carried out on the Concordia Theatre in Ragusa: the architectural survey, the analysis of the construction system and the analysis of the conservation status. The architectural survey allowed analysing the design of the elevation and its meanings, the complex layout of the building's spaces and the dimensional

.

relationships between its parts. The performance analysis has identified the behaviour of the building in use, compared to the requirements of accessibility to the building, internal accessibility and practicability and capacity. The analysis of the building system involved the study of the technical elements and their relationships, the analysis of the materials and the construction techniques. Finally, the cracking pattern and degradation status was mapped, in order to identify the causes of the current alterations and the dynamics of future evolution.

The knowledge phase allowed to identify the constraints to alteration, which are conditions that ought to be respected so as to ensure that the redevelopment project will not compromise the cultural value of the building (Robert, 1996). The constraints are grouped into three categories, for each of which the goals to be pursued in the redevelopment project have been identified (Tab.1).

The role of the building within the history of the site, the evolution of the local customs and traditions and the implications on the induced social transformations in the area are all immaterial components to preserve for the recognisability of the building and the traces of its function. These intangible components are reflected in tangible elements of the building, which are the sign of them, and are perceived as cultural constraints aimed at safeguarding the historical, aesthetic and psychological values of sites. Therefore, the redevelopment project aims to maintain the architectural features of the building but, at the same time, works for the recognition and acceptance of the alterations.

The shape of the building, its proportions and the geometric relationships between its parts refer to the architectural canons typical of entertainment buildings. The morphological-dimensional constraints therefore depend on these canons, in order to preserve the geometric characteristics of the building. In accordance with this objective, the redevelopment project should preserve dimensions, shapes and proportions of the antique building and its parts.

The building’s construction techniques, typical of the Sicilian building tradition, are based on local construction knowledge and on the availability of materials, which are very difficult to find today. The material-construction constraints derive from the need to preserve the physical characteristics of the building, the logic of the structural system and its image. These objectives require the use of materials and technologies compatible with the construction characteristics for the alterations of the building. Furthermore, the alterations must be reversible, durable and maintainable.

Fire Safety Engineering in the design process

The fire regulations that the building is not able to meet concern the system of escape routes and, in particular, the requirements of accessibility to the outside or to a safe area, practicability and accessibility inside. In the words of Bernardini, «wayfinding is ones of the most significant issues during a fire evacuation in Historical Buildings, mainly because of possible building layout complexity, level of occupants’ familiarity with the architectural spaces, and potential environmental modifications due to fire effects» (Bernardini, 2017, p. 45).

The requirements not met concern the number of exits required for the grandstand, the length of the exit routes to a safe area (both for the ground floor and for the grandstand), the dimensions and shape of the staircases to the grandstand and the internal accessibility to the actors’ dressing rooms. The following compensatory measures have been defined: two new

.

openings to a safe area (regarding the accessibility to the outside); two new staircases serving the grandstand and an access ramp to the dressing rooms, to ensure the requirements of practicability and internal accessibility. These measures have been verified through the application of the FSE simulation models.
When assessing the consequences of a fire for human life, we need to ensure that the time available for escape is greater than the time required (Gwynne *et al.*, 2017; D'Orazio *et al.*, 2015). The FSE performance method involves the calculation of two separate time periods as defined as follows:

- ΔT_{ASET} (ASET Available Safe Egress Time) - time interval that elapses between the time when the fire is started and the time when the environmental conditions do not allow people to be rescued;
- ΔT_{RSET} (RSET Required Safe Egress Time) - time interval between the time when the fire is started and the time when people reach a safe area (Babrauskas *et al*., 2010).

According to Poon, «The basic concept in the assessment of occupant safety in a building under fire conditions is the determination of the time when occupants are able to safely escape before hazardous conditions sets in. The Available Safe Egress Time/Required Safe Egress Time (ASET/RSET) concept of fire safety assessment in performance based fire safety engineering design has become widely used amongst fire safety engineering practitioners, since its inception more than thirty years ago» (Poon, 2014, p. 173).
The two models used for the FSE are related to the field fire simulation (the software used for the simulation is Fire Dynamics Simulator, FDS 6.2; to visualize the output of FDS the freeware 3D graphic software Smokeview, distributed by the National Institute of Science and Technology, has been used), and to the exodus simulation (using PathFinder). The Fire Dynamics Simulator is a computational fluid dynamics (CFD) calculation model for the simulation of smoke and temperature propagation used to define the ASET. The PathFinder is a calculation model for the egress simulation which considers simultaneously the movements of the occupants and their behaviour. The software allowed to define the RSET for each design alternative (the alternative solutions are characterized by a different organization of the internal routes of the building), which meets the compensation measures adopted.
In order to guarantee the safe exodus of the occupants, we must verify that the ASET is greater than the RSET according to the following equation (M.3.2.2 D.M. 03/08/2015): T_{MARG}=ASET-RSET ≥10% · RSET; nevertheless, the value of T_{MARG} may never be less than 30 seconds.

5. Discussion and results

ASET calculation

To define the time available for egress (ASET), the Fire Dynamics Simulator (FDS) calculation model was used, according to the simulation of smoke and temperature spread by applying the "zero exposure" performance limits (M.3.2.2 D.M. 03/08/2015 and ISO/TR 16738). These limits of non-exposure of the occupants refer to conditions considered dangerous with regard to the height of the fumes from the floor, which must be over 2 m, and the temperature of the layer of hot gases, which must not exceed 200°C.
All possible fire scenarios which represent the events that can reasonably occur have been identified. In identifying scenarios, the fires that have affected similar buildings or activities

.

have been considered. In particular, the fire at the *Cinema Statuto* in Turin has been analysed. Although being the most severe, the fire of seats started with flammable liquid has not been analysed, since it has been considered unrealistic; in fact, in Italy the furniture installed in public entertainment buildings must have a certified fire reaction.

The selected scenario consists of an accidental fire of scenic material αT^2 type of 1 MW with gaseous phase chemical reaction of polyurethane to maximize smoke production. The planned fire involves the ignition and propagation in the stage over an area of 1.0 m^2 (1.0 m x 1.0 m) from which a fire is generated with HRR 1000 kW/m^2 with a total heat output of 1000 kW (1.0 m x 1.0 m x 1000 kW/m^2 = 1000 kW). The fire growth curve adopted is quadratic in the first phase of the αT^2 type and quadratic growth rate in 75 s of the Ultra-Fast type. For theatres, Eurocode 1 (UNI EN 1991-1-2 – Tab. E.5) assumes an initial quadratic growth rate of the Fast type in 150 s; nevertheless, the speed of growth of the Ultra-Fast type has been considered in favour of safety. In order to maximize smoke production within the simulation room, the gaseous phase chemical reaction of the Polyurethane has been chosen.

The Fire Scenarios are based on the accidental fire risk analysis on the theatre stage. The simulation has been performed on three fire scenarios, characterized by three different fire-fighting systems (Figs. 4, 5, 6). In the first and second scenarios, smoke immediately invades the room. In the third scenario, instead, during the egress of the occupants and for much more time, the smoke is mainly confined to the area of the stage. The smoke that spreads in the room is sucked in by the forced smoke and heat extraction system, the radiation and temperatures at the level of the pathways, for the examined period, are very limited. It is therefore possible to assume the ASET of 400 sec.

RSET calculation

The time required for egress (RSET) consists of four stages, as defined in BS PD 7974-6 2004, $RSET = \Delta T_{det} + \Delta T_a + \Delta T_{pre} + \Delta T_{trav}$

ΔT_{det}: *detection time.* Time elapsing between the start of the combustion process and its detection by automatic or manual system. Its value varies according to the characteristics of the systems, if available, or the ability of people to detect the fire and warn.

ΔT_a: *alarm time.* The time between the onset of a fire and its warning by an alarm system.

ΔT_{pre}: *pre-movement time.* Time elapsing from alarm reception until the first person starts moving to the exit.

ΔT_{trav}: *travel time.* Time needed to move people from their place to a safe place.

Fig. 4 – Fire scenario 1

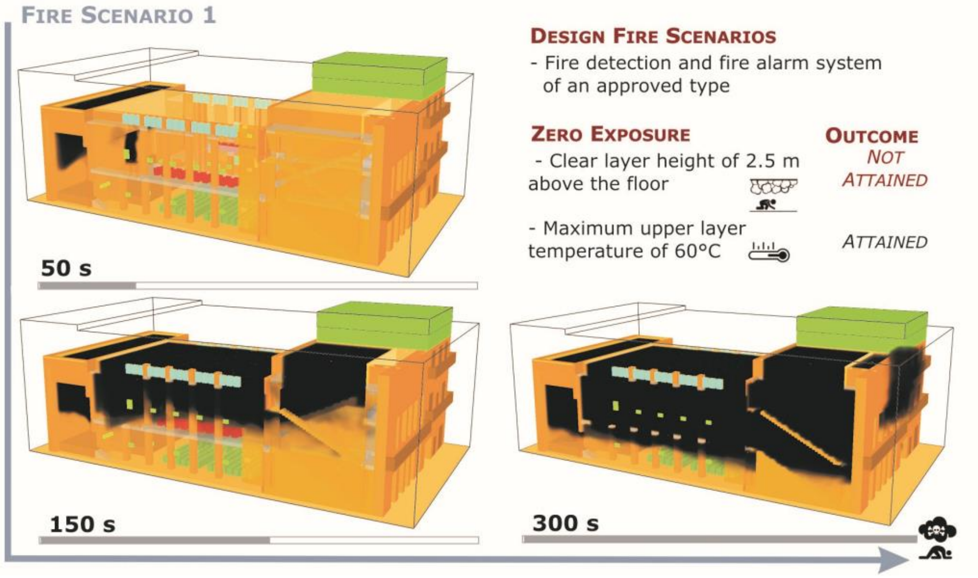


Fig. 5 – Fire scenario 2

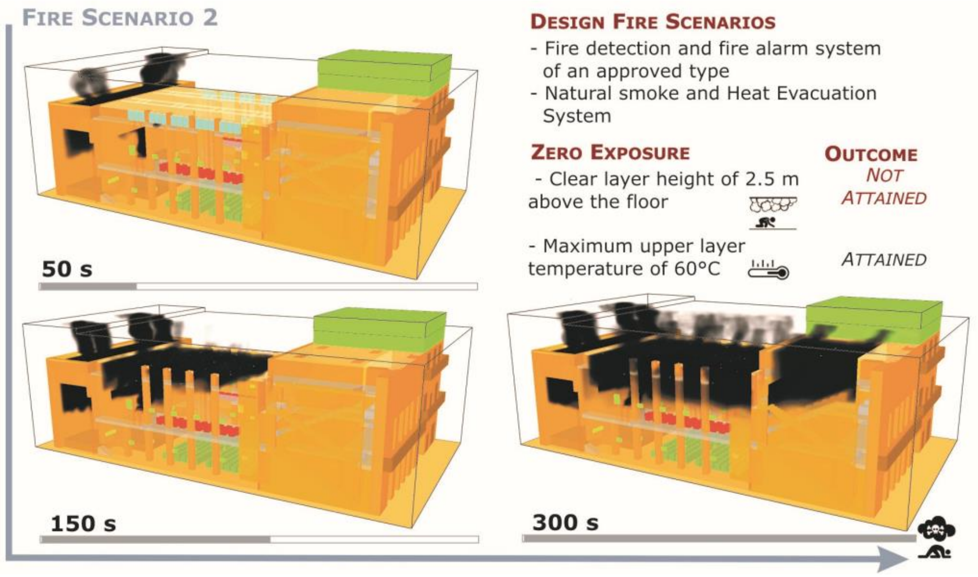
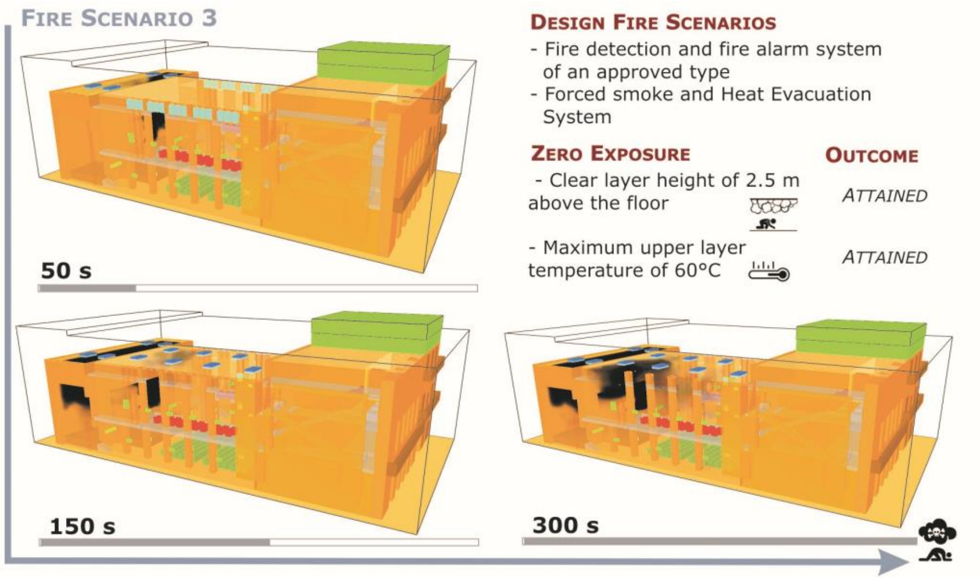


Fig. 6 – Fire scenario 3



A mixed methodology has been used to calculate the RSET:

– the detection time was calculated using the FDS simulation model:
  $\Delta T_{det} = 16$ sec
– the alarm and pre-movement time were estimated in accordance with BS 7974-6:2004:
  $\Delta T_a = 0$ sec (the alarm system inside the theater is connected to the detection system therefore the alarm is immediate)
  $\Delta T_{pre} = 60$ sec (the time has been estimated using Table C.1. Annex C of BS 7974-6:2004)
– the travel time has been calculated with the simulation software PathFinder 2015.

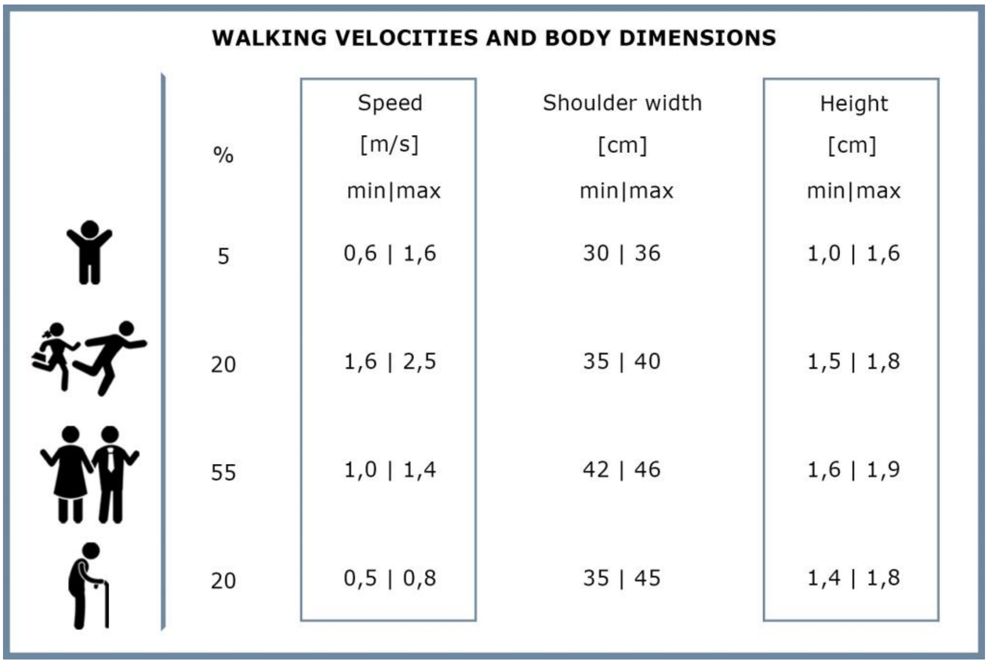
The PathFinder software is an exodus simulation model that includes a 3D viewer of the building, allowing to design rooms, corridors, ramps and elevators. The model can be populated with people of different ages, abilities, physique and behaviour. In the words of Kobes *et al*., “it appears that the measures currently required by law do not always provide the support that people in burning buildings need. Consequently, understanding how individuals behave in the case of fire and fire evacuation is essential if we are to bring fire safety measures into line with occupants’ needs during an incident” (Kobes *et al.*, 2010, p. 1). The modeling of the *Teatro della Concordia* allowed to develop four layout hypotheses with different paths as shown in Table 2.

Tab. 2 – Four layout hypotheses with different paths

		Compensatory measures
layout hypotheses	1	Ramp to the dressing rooms
	2	Ramp to the dressing rooms; 2 emergency exits - 1.20 m wide - to a safe area (inner courtyard)
	3	Ramp to the dressing rooms; 2 protected staircases for access to the grandstand
	4	Ramp to the dressing rooms; 2 protected staircases for access to the grandstand; 2 emergency exits - 1.20 m wide - to a safe area (inner courtyard)

The most crowded state of the theatre has been simulated, with a maximum number of 427 people. The users included children, young people, adults and elderly people. Their characteristics (percentage of persons for each age group, speed, width and height) are shown in Fig. 7.

Fig. 7 – Characteristics of the users



WALKING VELOCITIES AND BODY DIMENSIONS

%	Speed [m/s] min|max	Shoulder width [cm] min|max	Height [cm] min|max
5	0,6 | 1,6	30 | 36	1,0 | 1,6
20	1,6 | 2,5	35 | 40	1,5 | 1,8
55	1,0 | 1,4	42 | 46	1,6 | 1,9
20	0,5 | 0,8	35 | 45	1,4 | 1,8

The software allows setting the behaviour of the occupants as a fixed parameter or using a statistical distribution (constant, uniform, standard, log normal). In the case of the

.

Concordia Theatre, a standard distribution has been used, so that all individuals have different behaviours.
The egress simulations, based on fire scenario 3, highlighted that the safety time (Tmarg = ASET- RSET > 10% RSET with a minimum time of 30 seconds) is satisfied for all of the four layout hypotheses (Figs. 8, 9, 10, 11). This confirms the effectiveness of the compensatory measures adopted as an exception to the prescriptions on fire prevention.
Out of the four hypotheses tested, the second one allows to achieve the optimal balance between the need to improve the performance of egress routes in case of fire and the need to define design solutions compatible with the constraints of the alteration. The possibility of creating two emergency exits on an internal facade of the theatre, without affecting the openings in place, allows preserving the nineteenth-century facade of the building.

Fig. 8 – Egress simulation - Layout 1

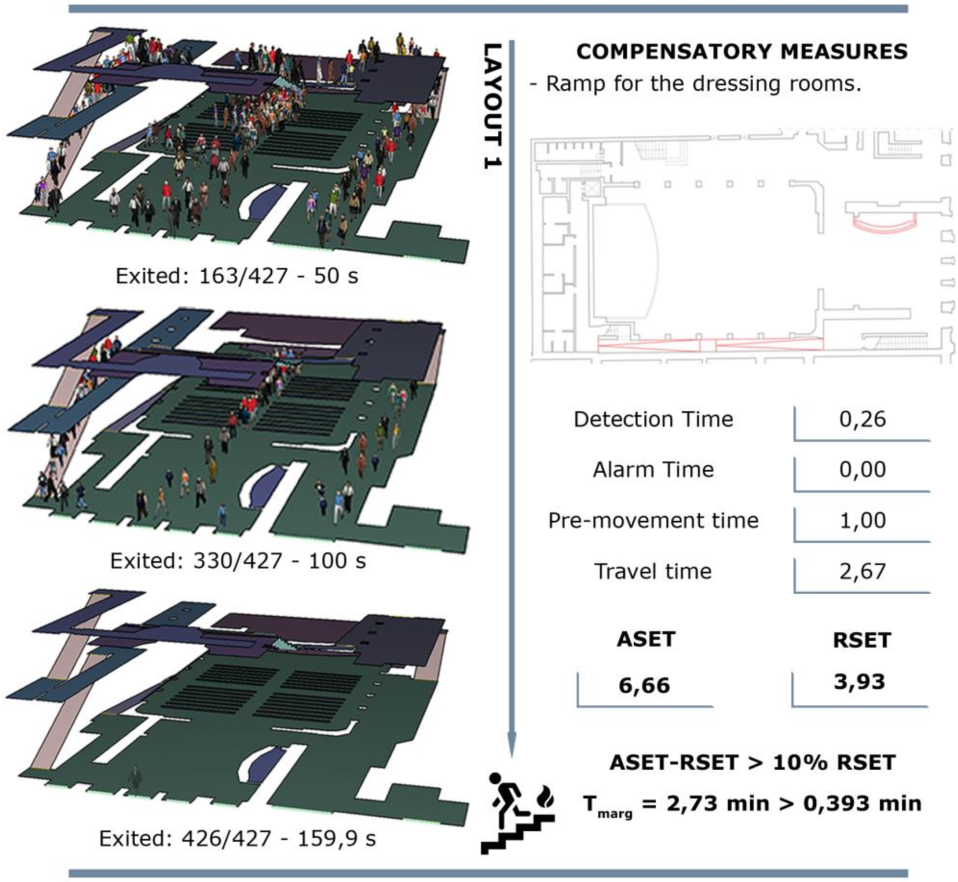
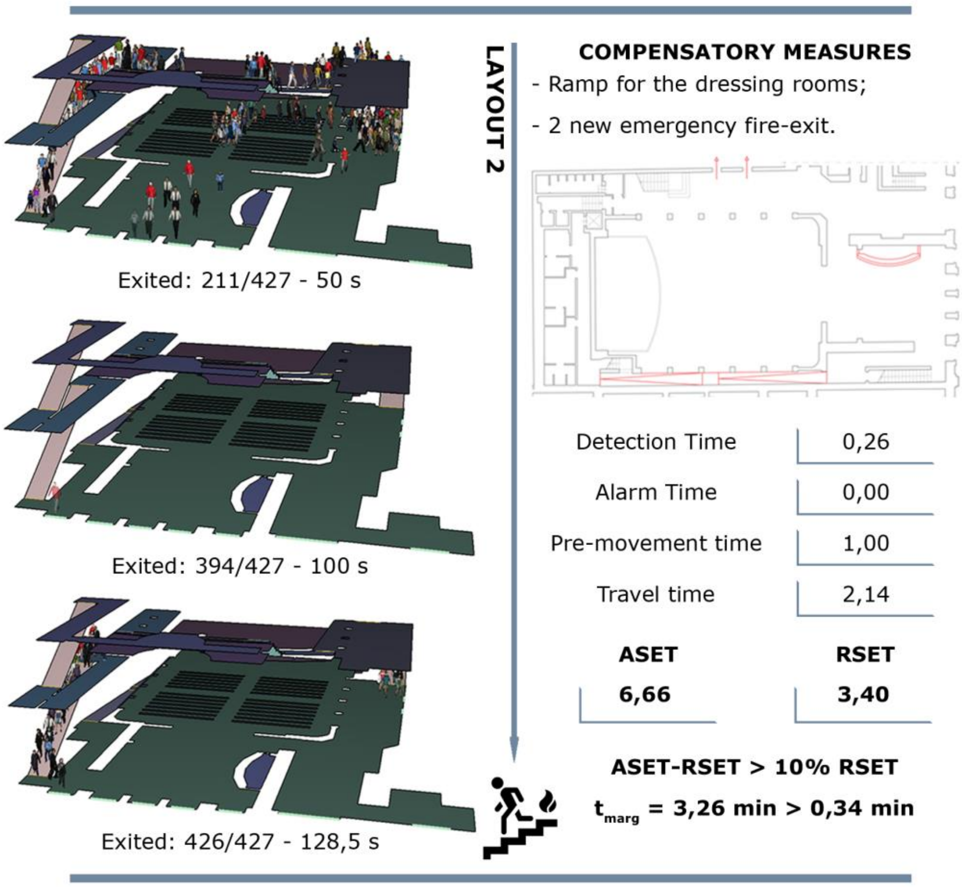


Fig. 9 – Egress simulation – Layout 2



.

Fig. 10 – Egress simulation – Layout 3

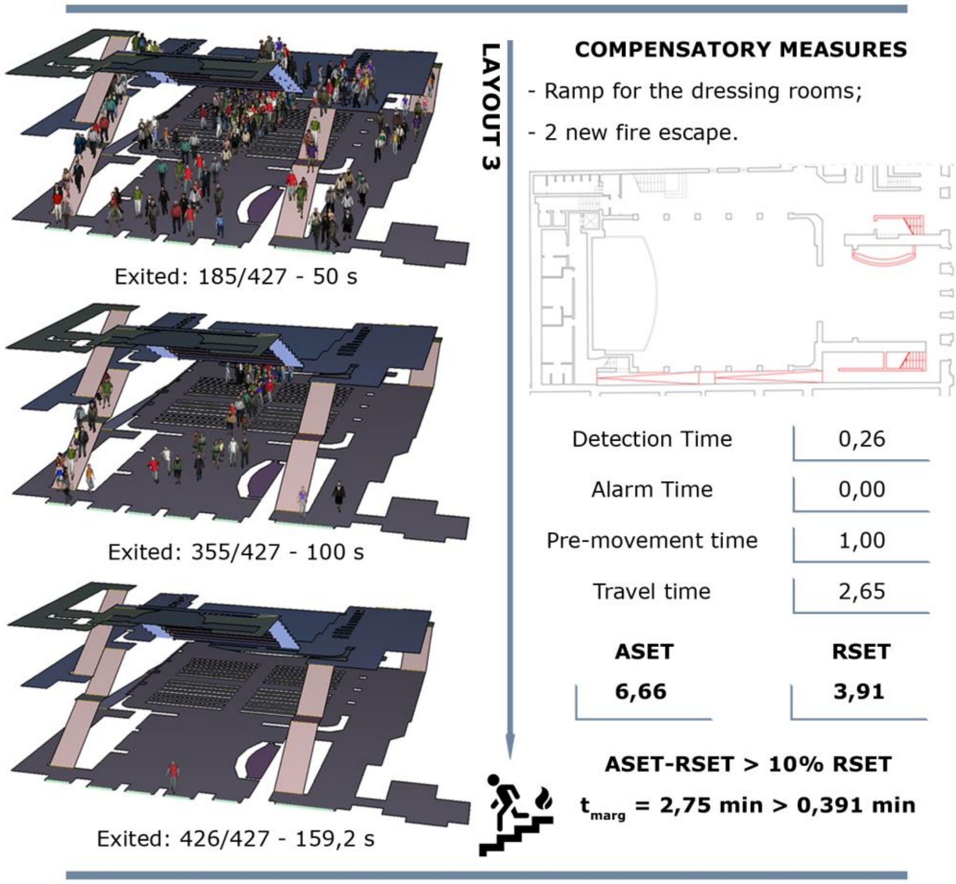
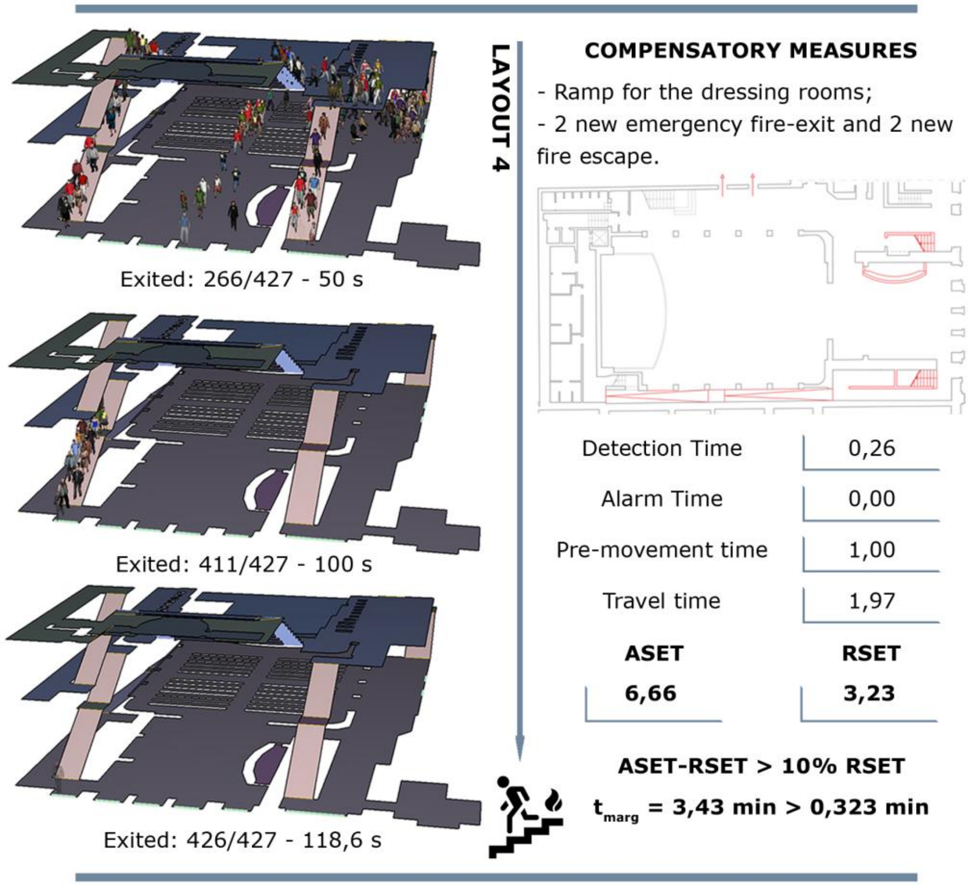


Fig. 11 – Egress simulation - Layout 4



The construction of an access ramp to the dressing rooms of actors allows to increase the performance of internal practicability, without altering the shape and proportions of the stalls and the grandstand.

Finally, the alterations are recognisable, since they are made with materials, construction systems and finishing slightly different from those of the ancient building, but compatible with it.

The verification has enabled to avoid the construction of two new protected stairs to access the grandstand, both of which would have been essential by assessing the redevelopment project with the prescriptive approach. In terms of building preservation, the construction of the two staircases (layouts 3 and 4) would have significantly modified the shape and size of the theatre hall, disregarding the perceptual-cultural and morphological-dimensional constraints.

.

6. Conclusions

The research has addressed a key issue in the redevelopment of the listed buildings for entertainment: the evaluation of the alterations required to meet the needs of fire-fighting in compliance with the use and preservation of buildings with cultural values. An innovative element of the research is the integration of Fire Safety Engineering in an early design phase. This made it possible to assess the effects of design alternatives in terms of both fire safety and protection of buildings' cultural values.

The application of calculation models to simulate fires and people evacuation has allowed an effective evaluation of the building alterations, combining the need of preservation with the opportunity to “reject” from the outset alterations which can deeply modify the buildings’ characteristics, erasing the evidence of the technical culture of a community.

The application of the FSE performance approach in the preliminary phase of the design process is innovative, since the simulation capabilities have addressed the project towards choices compatible with the existing building, minimizing the incidence of alterations.

In the case of the Concordia Theatre, it has been possible, indeed, to “reject” design choices that would have caused a loss of identity and recognisability of the building, with no significant improvement in evacuation performance. Through the simulation models of the four layout hypotheses, it has been possible to understand, for example, that the construction of new staircases, as required by the prescriptive regulations, would not have significantly increased the performance of practicability and accessibility of users to a safe place. On the other hand, their construction would have had a significant impact on the recognisability of the heritage building, by altering shapes and proportions of the stalls and the grandstand. The proposed methodology led to findings that could be immediately transferred to the practice of fire-fighting design for listed buildings, providing effective help for designers.

The constant need of reuse, redevelopment and maintenance of the existing building stock requires defining decision-making and operational methods to predict and verify the effectiveness and compatibility of the alterations. This need is even more urgent in the case of cultural heritage, whose alterations are essential to adapt ancient buildings to fire regulations. However, such alterations can lead to the loss, both qualitatively and quantitatively, of the knowledge that historical buildings can convey and which determines their cultural value.

Prescriptive regulation and guidance are not helpful in rehabilitation of cultural heritage buildings, especially in an environment where building technology and practices continue to evolve. Judith Hackitt in the Final Report on “Building and Safe Future” highlights the following key issues underpinning the failure of safety regulations in UK: *ignorance* (regulations and guidance are not always read by those who need to, and when they do the guidance is misunderstood and misinterpreted); *indifference* (the primary motivation is to do things as quickly and cheaply as possible rather than to deliver quality buildings which are safe for people to live in); *lack of clarity on roles and responsibilities*; *inadequate regulatory oversight and enforcement tools* (the size or complexity of a project does not seem to inform the way in which it is overseen by the regulator) (Secretary of State for Housing, Communities and Local Government, 2018). Such issues, although related to newly designed buildings, also refer to the case of cultural buildings. Heritage buildings needs a new simpler and more effective approach, truly outcomes based (rather than based on prescriptive rules and complex guidance) and it must have real teeth, so that it can drive

.

the right behaviours. Buildings must be considered as a *system*, made of related parts, so that we can consider the different layers of protection on a case-by-case basis as well as the impact of each alteration on the whole building performance and on its values. Furthermore, it is necessary to use a risk-based approach based on the expected risk scenarios, according to the characteristics of the building (shapes, dimensions, materials, building systems, etc.) and the activities it contains.

References

Abu Samah Z., Ibrahim N., Othman S., Hanif M. (2012), "Assessing Quality Design of Interiors: A case study of a Hospital Outpatient Unit in Malaysia". *Procedia Social and Behavioral Sciences*, vol. 35, pp. 245-252.

Arborea A., Cucurachi G., Mossa G. (2015), "Performance-based fire protection of historic buildings in the Italian perspective: a simulative approach". Proceedings of the Summer School Francesco Turco, *Industrial Systems Engineering*, http://www.summerschool-aidi.it/edition-2015/images/paper2012/1.5.pdf

Averill, J.D. (1998), "Performance-based codes: economics, documentation and design", MSc thesis, Worcester Polytechnic Institute, United States.

Babrauskas V., Fleming J., Russell B. (2010), "RSET/ASET, a Flawed Concept for Fire Safety Assessment". *Fire and Materials*, vol. 34, no. 7, pp. 341-355.

Benjamin W. (1969), "The Work of Art in the Age of Mechanical Reproduction", in. Arendt H (ed.), *Illuminations*. Schocken, New York, pp. 217-252.

Bernardini G. (2017), *Fire Safety of Historical Buildings.* Springer International Publishing, United States.

Bernardini G., Azzolini M., D'Orazio M., Quagliarini E. (2016), "Intelligent evacuation guidance systems for improving fire safety of Italian-style historical theatres without altering their architectural characteristics". *Journal of Cultural Heritage,* vol. 22, pp. 1006-1018.

Biao Z., Xiao-meng Z., Ming-yong C. (2012), "Fire protection of historic buildings: A case study of Group-living Yard in Tianjin". *Journal of Cultural Heritage*, vol. 13, no. 4, pp. 389-396.

Borg A. and Njå O. (2013), "Concept of validation in performance-based fire safety engineering". *Safety Science*, no. 52, pp. 57-64.

BS PD 7974-6 (2004), Human factors_Life safety strategies – Occupant evacuation, behaviour and conditions.

BSI. 7974 (2001), Part 1: Application of fire safety engineering principles to the design of buildings. Code of practice. British Standards Institution.

BSI. DD240 (1997), Part 1: Guide to the Application of Fire Safety Engineering Principles. Code of practice. British Standards Institution.

Cameron C.M. (1994), "The destruction of the past: Nonrenewable cultural resource". *Natural Resources Research*, vol. 3, no. 1, pp. 6-24.

Cantell S.F. (2005), "The adaptive reuse of historic industrial buildings: regulation barriers, best practices and case studies". *Unpublished Master Thesis*, Institute and State University, Virginia, United States, http://sig.urbanismosevilla.org/Sevilla.art/SevLab/r001US2_files/r001_US_1.pdf

Conejos S., Langstrom C., Smith J. (2013). "AdaptSTAR model: a climate-friendly strategy to promote built environment sustainability". *Habitat International*, vol. 37, pp. 95-103.

.

Council of Europe (2005), “Council of Europe Framework Convention on the Value of Cultural Heritage for Society”, Council of Europe Treaty Series, no. 199.

DM 03/08/2015: Fire safety criteria (Approvazione di norme tecniche di prevenzione incendi, ai sensi dell’art. 15 del decreto legislativo 8 marzo 2006, n. 139). Ministry of Interior, 2015.

DM 09/05/2007: Guidelines for the implementation of fire safety engineering (Direttive per l'attuazione dell’approccio ingegneristico alla sicurezza antincendio). Ministry of Interior, 2007.

DM 19/08/1996: Fire safety criteria for entertainmentpublic spaces (Regola tecnica di prevenzione incendi per la progettazione,costruzione ed esercizio dei locali di intrattenimento e di pubblico spettacolo). Italian Government, 1996.

Del Prete I., Cefarelli G., Nigro E. (2016), “Application of criteria for selecting fire scenarios for structures within fire safety engineering approach”. *Journal of Building Engineering*, no. 8, pp. 208-217.

D’Orazio M., Bernardini G., Tacconi S., Arteconi V., Quagliarini E. (2016), “Fire safety in Italian-style historical theatres: How photoluminescent wayfinding can improve occupants’ evacuation with no architecture modifications”. *Journal of Cultural Heritage*, no. 19, pp. 492-501.

D’Orazio M., Longhi S., Olivetti P., Bernardini G. (2015), “Design and experimental evaluation of an interactive system for pre-movement time reduction in case of fire”. *Automation in Construction*, vol. 52, pp. 16-28.

European Commission (2015), “Getting cultural heritage to work for Europe Report of the Horizon 2020 Expert Group on Cultural Heritage”. www.eur-lex.europa.eu.

European Commission (2014), *Communication from the commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Towards an integrated approach to cultural heritage for Europe.* Brussels, 22.7.2014 COM(2014) 477 final, www.ec.europa.eu

European Parliament (2017), “Decision (EU) 2017/864 of the European Parliament and of the Council of 17 May 2017 on a European Year of Cultural Heritage (2018)”. www.eur-lex.europa.eu.

Fire Code Reform Centre (1996), Fire Engineering Guidelines. Fire Code Reform Center, Australia.

Fusco Girard L. (2014), “Creative initiatives in small cities management: The landscape as an engine for local development”. *Built Environment*, vol. 40, no. 4, pp. 475-496.

Fusco Girard L. (1987), *Risorse architettoniche e culturali: valutazioni e strategie di conservazione: una analisi introduttiva.* Franco Angeli, Milano.

Gibson, E.J. (ed.) (1982), “Working with the Performance Approach in Building”, CIB W60 Commission Report 64, Rotterdam, The Netherlands.

Greffe X. (2004), “Is heritage an asset or a liability?”. *Journal of Cultural Heritage*, no. 5, pp. 301-309.

Gwynne S.M.V., Kuligowski E.D., Kinsey M.J., Hulse L.M. (2017), “Modelling and influencing human behaviour in fire”. *Fire and Materials*, vol.41, pp. 412-430.

Heinisuo M., Laasonen M., Outinen J. (2010), “Fire Design in Europe”, in Mazzolani F.M. (ed.), *Urban habitat construction under catastrophic events,* CRC Press, Naples, Italy, pp. 375-402.

.

Holtorf C.J. (2001), "Is the past a non-renewable resource?", in Layton R., Stone P.G., Thomas J. (eds), *Destruction and conservation of cultural property.* Routledge, New York, United States, pp. 286-297.

IRCC (2010), *Guidelines for the introduction of performance-based building regulations*. ABCB, Canberra, Australia.

INSTA. TR 950 (2013), *Draft for comment, Fire safety engineering – Verification of fire safety design in buildings using a comparative approach.* Inter-Nordic Standardization Cooperation, Sweden,

ISO/TR 13387-1 (1999), *Fire Safety Engineering - Part 1: Application of Fire Performance Concepts to Design Objectives. Technical Report, International Organization for Standardization*. Geneva, Switzerland, p. 60.

Italian National Council of Engineers (2016), Circ. no. 787/XVlll Sess, 09/09/2016, http://cni-online.it/Attach/DV12290.pdf.

Kobes M., Helsloot I., de Vries B., Post J.G. (2010), "Building safety and human behaviour in fire: a literature review". *Fire Safety Journal*, vol. 45, pp. 1-11.

Kurul E. (2007), "A qualitative approach to exploring adaptive re-use processes". *Facilities*, vol. 25, no.13-14, pp. 554-570.

Lay S. (2007), "Alternative evacuation design for high rise buildings, the structural design of tall and special buildings". *Journal of Council on Tall Buildings and Urban Habitat*, vol 16, no. 4, pp. 487-500.

Lo S.M., Lam K.C., Fang Z., Yuen K.K. (2002), "An investigation on the building officials' perception for the use of performance-based fire engineering approach in building design". *Fire Technology*, no. 38, pp. 273-288.

Marrion C.E. (2016), "More effectively addressing fire/disaster challenges to protect our cultural heritage". *Journal of Cultural Heritage*, no. 20, pp. 746-749.

Meacham B.J. (2014), "Fire safety engineering at a crossroad". *Case Studies in Fire Safety*, no. 1, pp. 8-12.

Meacham B.J. (2010), *The Evolution of Performance-Based Codes and Fire Safety Design Methods NIST-GCR-98-761.* National Institute of Standards and Technology, US Department of Commerce, United States.

Merci, B., van Hees, P., Taerwe, L., Jönsson, R., Torero, J.L., (2012), "Education as Support for Performance-Based Fire Safety: Ajoint International Effort", Proceedings of 9th International Conference *Performance-Based Codes and Fire Safety Design Methods.* Hong Kong, China, June 20-22, 2012.

Mısırlısoy D., Günçe K., (2016), "Adaptive reuse strategies for heritage buildings: A holistic approach". *Sustainable Cities and Society*, vol. 26, pp. 91-98.

Naziris I. A., Lagaros N. D., Papaioannou K. (2016), "Optimized fire protection of cultural heritage structures based on the analytic hierarchy process". *Journal of Building Engineering*, no. 8, pp. 292-304.

NFPA 101 (2000), Life Safety Code, National Fire Protection Association, Quincy. MA 02269, 2018 Edition.

NFPA 909 (2001), Code for Fire Protection of Historic Structures, National Fire Protection Association, Quincy. MA 02269, 2015 Edition.

Nigro E., Ferraro A., Cefarelli G. (2010a), "Member, substructure and global structural fire analyses of steel-concrete composite frames", in Mazzolani F.M. (ed.), *Urban habitat construction under catastrophic events,* CRC Press, Naples, Italy, pp. 261-269.

.

Nigro E., Ferraro A., Cefarelli G. (2010b), "Application of FSE approach to the structural fire safety assessment of steel-concrete composite structures", in Mazzolani F.M. (ed.), *Urban habitat construction under catastrophic events,* CRC Press, Naples, Italy, pp. 255-260.

Ost C. (2016), "Innovative financial approaches for culture in urban development, in UNESCO, Culture: urban future". *Global report on culture for sustainable urban development,* pp. 229-235, https://unesdoc.unesco.org/ark:/48223/pf0000260645.

Östman B., Brandon D., Frantzich H. (2017), "Fire safety engineering in timber buildings". *Fire Safety Journal*, no. 91, pp. 11-20.

Pinto M. R., De Medici S., Senia C., Fabbricatti K., De Toro P. (2017), "Building reuse: multi-criteria assessment for compatible design*". International Journal of Design Sciences and Technology,* vol. 22, no. 2, pp. 165-193.

Poon S.L. (2014), "A Dynamic Approach to ASET/RSET Assessment in Performance based Design". *Procedia Engineering*, vol. 71, pp. 173-181.

Robert, P. (1989), *Adaptations, new uses for old buildings*. Princeton Architectural Press, New York.

Secretary of State for Housing, Communities and Local Government by Command of Her Majesty, United Kingdom (2018), "Building a Safer Future. Independent Review of Building Regulations and Fire Safety: Final Report" presented to Parliament, May 2018. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/707798/Building_a_Safer_Future_-_print.pdf

Stahel W.R. (2016), "Circular economy". *Nature*, vol. 531, pp. 435-438.

Spinardi G. (2016), "Fire safety regulation: Prescription, performance, and professionalism". *Fire Safety Journal*, no. 80, pp. 83-88.

Society of Fire Protection Engineers and National Fire Protection Association (2007), *The SFPE Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings*. National Fire Protection Association, Massachusetts, United States.

UNESCO (2015), *Policy Document for the Integration of a Sustainable Development Perspective into the Processes of the World Heritage Convention*, https://whc.unesco.org/en/sustainabledevelopment/

Van der Voordt, T. (2004), "Costs and benefits of flexible workspaces; work in progress in the Netherlands". *Facilities*, vol. 21, no. 13-14, pp. 306-314.

Velthius K., Spennemann D.H.R. (2007), "The future of defunct religious buildings: Dutch approaches to their adaptive re-use". *Cultural Trends*, vol. 16, no. 1, pp. 43-66.

Watts Jr J.M.., Solomon R.E. (2002), "Fire safety code for historic structures". *Fire Technology*, vol. 38, no. 4, pp. 301-310.

Watts Jr. J.M. (2001), "Fire protection performance evaluation for historic buildings". *Journal of Fire Protection Engineering*, vol. 11, pp. 197-208.

Watts Jr. J.M., Kaplan M.E. (2001), "Fire risk index for historic buildings". *Fire Technology*, vol. 37, no. 2, pp. 167-180.

Woodrow M., Bisby L., Torero Jose L. (2013), "A nascent educational framework for fire safety engineering". *Fire Safety Journal,* vol. 58, pp. 180-194.

Zang Y. (2016), "Research on cost-benefit evaluation model for performance-based fire safety design of buildings". *Procedia Engineering*, no. 135, pp. 537-543.

.

Stefania De Medici
Department of Civil Engineering and Architecture,
SDS of Architecture, University of Catania,
Piazza Federico di Svevia, s.n., 96100 Siracusa (Italy)
Tel.: +39 0931489454; fax: +39 0931489430; email: sdemedi@unict.

Martina Bellomia
Via Paestum n. 19, 97100 Ragusa (Italy)
Tel.: +393315385736; email: martina.bellomia@gmail.com

Carla Senia
Department of Civil Engineering and Architecture,
SDS of Architecture, University of Catania,
Piazza Federico di Svevia, s.n., 96100 Siracusa (Italy)
Tel.: +39 0931489454; fax: +39 0931489430; email: c.senia@tin.it

.