A digitized environment for H&S and fire safety management in the heritage building "Palazzo Vecchio"

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Abstract

Target

This contribution is part of a wider research dealing with management of complex activities in Palazzo Vecchio in Florence. The goal of the research is to individuate the best combination of building intervention and management strategies to reach both safety and comfort for occupants.

The goal of this contribution is to describe the research first results with respect to H&S and fire safety engineering studies.

Context

Palazzo Vecchio is the town hall of Firenze and it is an ancient building, since its origins built to be the representative location of the political power of the town. Palazzo Vecchio hosts a lot of very important activities for the city and the goal of the public administration is to assure health and safety both to the workers and to the public visiting the building.

Description

Fire and Health and Safety requirements can be managed in such a complex framework only making use of innovative approaches preferably by using digitized design processes, in order to reach design objectives managing building constraints and design requirements within a Common Data Environment (CDE). Such study allow us to suggest some intervention on the building useful to reach the main objective (people safety).

A large part of the research is related with building modelling to understand fire spread and exodus performances of the building, defining as consequence the management strategies to assure the fixed performances; this together with Health and Safety management for workers inside the building.

The second part of the research is related with the creation of the CDE, that stores the validated and collected information and provides exactly the information to the decision maker.

Future results and developments

Important results are related to FSE design and to the definition of safety masterplan of the building. Future developments are related with the CDE construction.

Keywords: Models for design and construction, Building Information Management, Innovative technologies for new process management.

1. Introduction

This contribution intend to explain the first important results of the research project dealing with management of complex activities in Palazzo Vecchio. The research project puts together Dipartimento di Ingegneria Civile e Ambientale of the Università degli Studi di Firenze and Comune di Firenze, in order to reduce health and safety risks in the historical heritage building of Palazzo Vecchio, with the specific interest in fire risk management.

The compatibility between building and activities requirements is a complex problem, both in terms of occupant comfort and in terms of compliant to regulations. National construction regulations often consider peculiar exceptions in the case of historical buildings application, compensating

expected building performance with management procedures, in order to obtain an equivalent level of compliant. The manager of historical buildings inside which today activities are performed, has to guarantee safety and comfort of occupants, together with the preservation of the building and artistic contents (Giusti, 2014). A simple application of existing regulations cannot be adopted because of a lacking harmonization among them (Nassi et al, 2008, Marsella et al. 2010); such a complex framework can only be managed making use of innovative approaches, preferably by using digitized design processes in order to reach design objectives managing building constraints and design requirements within a Common Data Environment (CDE). This way both safety and comfort goals are reached, combining respectful interventions on building with activity management strategies.

Such an approach has been used to manage Fire Prevention together with Health and Safety in the Florentine building "Palazzo Vecchio". The whole research is split into three steps: the first and the second are concluded and produced a methodological approach that leaded to the fire safety masterplan of the building together with health and safety for workers; the third step is related to the CDE development to provide a information system containing data relating to the building and activities in order to create a database, a reference point for retrieving information and making subsequent analyses.

1.1 Palazzo Vecchio

Palazzo Vecchio is the town hall of Firenze, since its origins built to be the representative location of the political power of the town. In Palazzo Vecchio three different blocks can be identified, corresponding to the historical extensions of the building. The original nucleus is the medieval one, characterised by the tall tower facing "Piazza della Signoria"; the second block is the renaissance extension that comprehends the "Salone dei Cinquecento", the main hall of the palace; the latest part is the one rises around the third courtyard.

The building has one underground level, four levels out of ground and two mezzanine floors; the architectonical layout of rooms and stairs is quite complex because of the historical development of the palace. Almost all the rooms in use today were created in the past with different purposes with respect to the today use; only the two main halls (Salone dei Cinquecento and Salone dei Duecento) were originally create to host public assemblies and this is the today destination of use. The medieval and the renaissance parts are open to the public because they are a museum; the most recent part contains offices of the local administration.

As said, Palazzo Vecchio hosts a lot of very important activities for the city and one of the main goal of the public administration is to assure health and safety both to the workers and to the public visiting the building.

2. Research proposal

The research proposal, well described in (Giusti, 2017), has the goal to create a system of management strategies and building interventions to assure the goal of safety for occupants in Palazzo Vecchio. The aim of the study is to harmonize safety of occupants and workers, preserving the building characteristics, with an all-inclusive approach able to complete the gap to reach the building and occupants safety.

The research is developed in three main branches (Figure 1):

1. Fire Safety Engineering (FSE): it is necessary to make the building able to have the required performance with respect to people and contents protection.
2. Buiding Design for Safety (BDS): health and safety for workers can be guaranteed applying the BDS method to working places, as referred in literature (Ciatti et al, 2017).
3. Common Data Environment (CDE): the creation of a BIM-based collaborative process by using a Common Data Environment is the chosen way to ensure the harmonisation of the adopted design and maintenance strategies to assure H&S Management in Palazzo Vecchio, keeping them efficient for a long time.

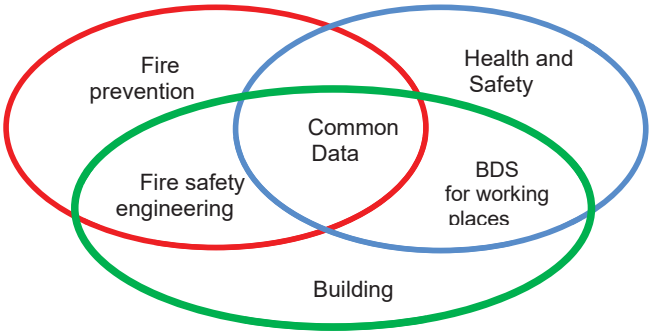


Figure 1: Research framework (modified from Giusti, 2017)

This contribution describes points 1 and 2 of the list, performed with instruments able to create data to be used for the CDE, that is currently under construction.

3. FSE for the fire safety masterplan

This part of the research is based on a methodological working flow that was produced (Giusti, Getuli, Capone, 2018) and it was applied to the building we study. The proposed approach represents a general technical reference for the organic integration between the prescriptive approach and the performance one in fire prevention in historic buildings. Workflow consists of eight steps and follows a logical process that involves the use of cyclical analysis for the in-depth analysis necessary to resolve the identified critical issues.

The main outcomes of the approach are related to:

1. Strategical mitigation actions;
2. Fire prevention masterplan definition;
3. FSE simulations.

Strategical mitigation actions

As a result of the identification of the main fire risk factors on a building scale, strategic decisions have been implemented to mitigate the factors that can deeply influence the whole project. The reiteration of the mapping-analysis-mitigation actions of the risk factors at scale of the building, leads to optimizing the interventions aimed at eliminating the maximum possible number of macroscopic criticalities.

Fire prevention masterplan definition

Once defined the strategical mitigation actions, was possible to outline the fire prevention masterplan of the whole building, that is based upon four main items (1. Division of the areas to the museum destination from those to the offices, 2. creation of fire prevention filter in the middle of the building, corresponding with the main hall Salone dei Cinquecento, 3. Creation of a "circulation" of the escape routes, in order to guarantee more exit routes in case of fire, 4. Definition of a new emergency plan for the whole building evacuation and management actions to maintain unchanged in time the stated level of risk).

Masterplan definition is one of the most remarkable result of this part of the research (Figure 2). Building's needs of conservation were safeguarded exploiting the hidden potential of the palace. It was possible to create an effective network of paths and compartments just giving back dignity to some of the building's rooms today reviled.

Figure 2: example of the fire prevention masterplan at the third floor of the building.

Fire Safety Engineering simulations

Fire Safety engineering simulations were undertaken to resolve the critical issues that cannot be tackled with prescriptive interventions. This is because the particular artistic-architectural constraints have limited, under various aspects, the respect of the current regulations. The performance approach has been configured as the only one able to find an effective solution to the problems encountered and, at the same time, to be non-invasive while respecting the context in which it is inserted.

For each area of the building affected by an analysis with a performance approach, in-depth analyses are carried out relating to:

- identification of the safeguard objectives (safeguarding human life, protection of the works or of the building);
- identification of fire scenarios and computational modelling of fire spread, also in order to monitor the presence of pollutants compatible or not with decorated surfaces and works of art;
- determination of the reference parameters for safeguarding life (and works, if required by the specific context);
- analytical determination and by means of computational modelling of exodus times from the areas identified.

Specifically, studies and performance modelling were carried out regarding the spread of the fire, and therefore of temperatures, smokes and pollutants, on:

- main staircases (Vasariano staircase, Stairway connecting the Elements Quarter and the Salone dei Cinquecento);
- Arnolfo tower;
- Salone dei Cinquecento.

Fire simulations are performed using FDS software, having output related to temperature, visibility and pollutant; from the models of staircases and tower we demonstrated that the building is not able to guarantee a sufficient time for building's occupant exodus; the only way to mitigate fire risk in those spaces is to apply procedures that are able to avoid the fire starting.

From the model of Salone dei Cinquecento, we demonstrated how is possible to make the hall working as a "fire filter" for the whole building, just by means of the installation of automatic opening mechanism on the windows. From the fire spread simulations we determined the Available Safe Escape Time (ASET=800s).

Furthermore, performance modelling was carried out regarding the determination of the exodus times on:

- Museum of Palazzo Vecchio, with all the connected environments and Salone dei Cinquecento;
- Nineteenth-century portion used as offices.

Required Safe Escape Time (RSET), referred to the ISO/TR 16738, was calculated using an exodus modelling software (Pathfinder software in SFPE mode).

Two main models were done, one for the whole museum part and another for the offices part. From each model we found the total escape time RSET.

In Table 1, results in terms of ASET and RSET are resumed for the considered main scenarios, together with some notes useful to explain important practical relapses involving building and management.

4. BDS for H&S of workers

A deep analysis about Health and Safety for workers in Palazzo Vecchio was performed applying Building Design for Safety (BDS) approach (Figure 3). BDS tents to link all the collected data (1) concerning H&S, both material (equipment, furniture, …) and intangible (working activity, risk evaluation indexes, …) to the workstation occupied by the man – Figure x. A further step (2) is the risk assessment for each workstation, taking into account also all the relationships between building and workplace. Every workstation can be, this way, analysed in terms of dimensional and performance requirements; then, combining ergonomic issues with H&S risk mitigation, an optimised typological working place is defined (3), able to reduce risk to the root. Combining all the optimised workplace in the rooms we deal with, lead to the creation of a work environment (4) that is Health and Safety upgraded. Passing from step 3 to step 4, compatibility between working activities and building, with respect to fire risk management become essential.

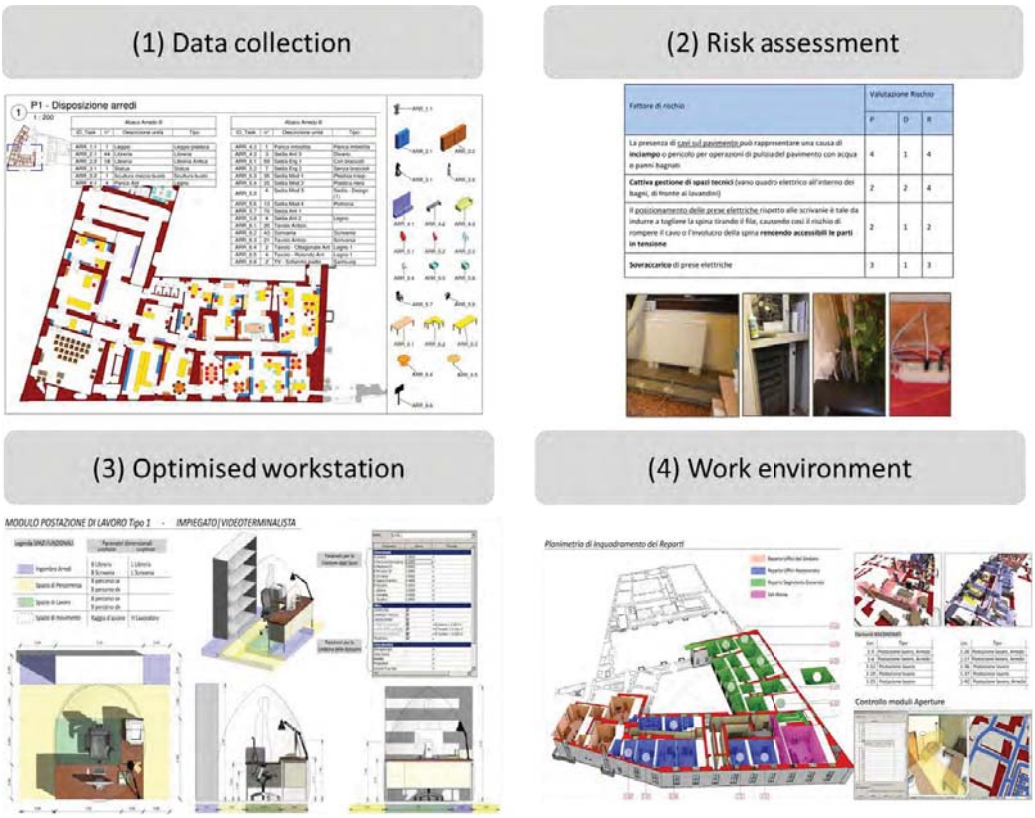
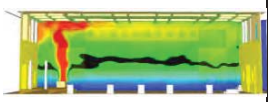
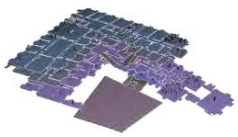


Figure 3: application of BDS approach to Palazzo Vecchio.

Table 1: Synthesis of the FSE modelling and results

CFD fire spread models		ASET	Exodus model		RSET	Description
Main staircase		240 s	Main staircase		930 s	Not acceptable scenario. Scenario that has to be avoid acting with management strategies. No motor vehicle can be stationed near the base of the staircase, each vehicle must be accompanied by personnel trained in fire-fighting and equipped with fire extinguisher.
Arnolfo tower		300 s			654 s	Not acceptable scenario. Scenario that has to be avoid moving combustible materials from the offices at the base of the tower.
Salone dei Cinquecento		800 s			600 s	Acceptable scenario, with installing automatic opening mechanism on the windows and new fire prevention masterplan execution
-		-	Offices staircase		540 s	Acceptable scenario with respect to fire fighter's intervention time. In favour of safety, this scenario neglects the presence of the internal stairs that have been re-opened.

5. BIM-based collaborative process by using a CDE

It is essential to deal with all the aforementioned structural issues (Health and Safety Management and Fire Safety Management in complex buildings) by using a collaborative and integrated workflow in order to avoid approaching matters with traditional paper-based design flows which result labor-intensive, error-prone and highly inefficient. Due to the large quantity of data to be collected and project participants at different levels, the requirements for the technical support of this collaboration in terms of consistency and coherence are very high. For this reasons, a collaborative BIM-based planning for a resilient and technically supported definition of management, data and communication processes has been defined as an essential requirement by the authors. For this purpose, a federated model approach which provides a central coordination model, the so-called Common Data Environment (CDE) has been proposed (Figure 4).

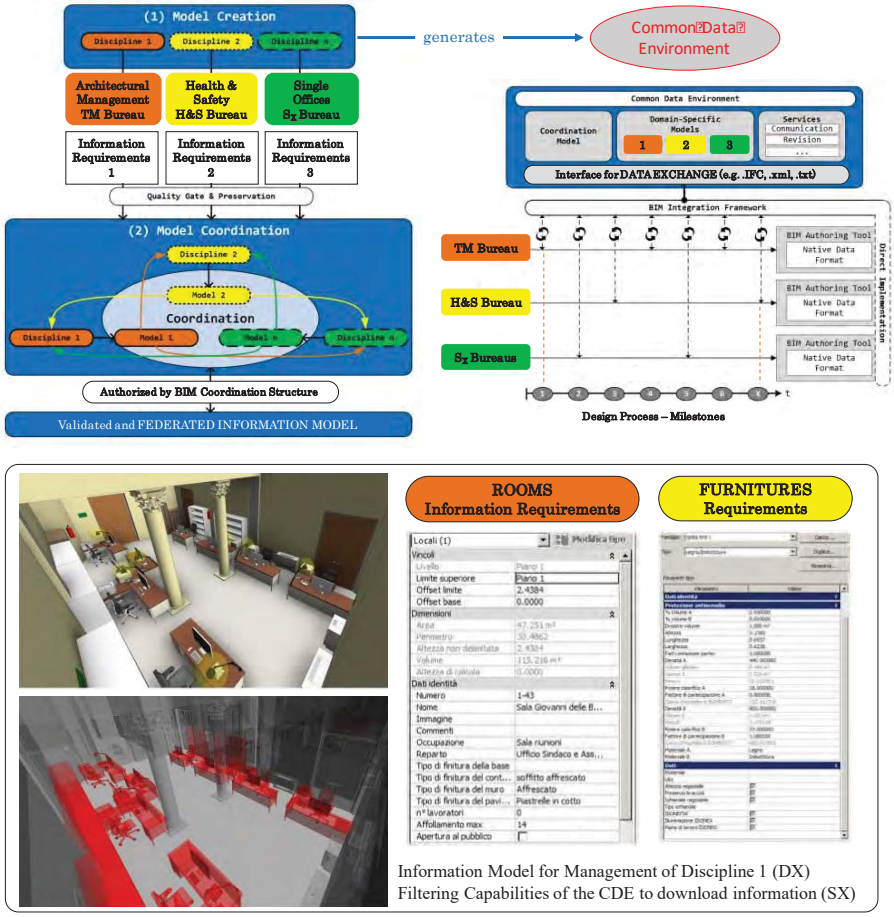


Figure 4: Architecture of the Common Data Environment (from istea 2017).

This model stores the validated and collected information and in turn provides exactly the information, which is required for the collaboration of the three disciplines: (1) Management of the Architectural features of the entire building, (2) Safety and Fire Management, (3) Occupancy Requirements to be guarantee for each office. The CDE, under development, is a single source of information used to collect, manage and disseminate documentation, the graphical model and non-graphical data for the whole project team that will work in such a project. All project participants retrieve the data from the CDE and in turn store their data here after single design flow are carried out. A layered structure architecture of the CDE has been proposed according to details given in Figure 5. At the first level, the Information Requirement for each discipline has been structured. Due to the fact

that the investigations in the different disciplines will need different software applications, a file exchange format has been established. This means that individual models produced by different investigations do not interact, they have clear authorship and remain separate. After the investigation, the output data are uploaded within the CDE in order keep the Federated Model updated.

6. Conclusions

The proposed approach, applied to Palazzo Vecchio, brought a series of remarkable results for the improvement of the safety conditions of the occupants and of the goods, above all with reference to fire risk. The methodological approach leaded to define the Fire prevention masterplan, totally respectful of the building's architecture. Most significant results of this part of the research are linked to the exodus time estimation and fire spread simulation. The application of FSE is, this way, related to the determination of the fire-fighting strategies to compensate the risk of safeguarding occupants life. Further, a remarkable improvement of H&S conditions for workers was reached adopting BDS approach for Palazzo Vecchio. Important data and management strategies useful for fire risk control, originated from such an accurate analysis. A huge data gathering of CDE definition has been performed for the whole building, with respect to H&S and fire safety.

In order to make the decision maker able to maintain in time fixed levels of fire risk and H&S risk for workers, in this complex framework is necessary to adopt an innovative source of information used to collect, manage and disseminate documentation; for this reason CDE is currently underway.

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