

# Re-shaping the construction industry

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# **“Management of complex activities in historical heritage buildings: a digitized environment for H&S and fire safety in Palazzo Vecchio”**

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**Topic:** Models for design and construction, Building performance engineering, Innovative technologies for new process management, Building Information Management.

## **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 create a sartorial shell of building intervention and management strategies to reach both safety and comfort for occupants.

The goal of this contribution is to describe the research framework and to give some first results with respect to 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).

### **Future results and developments**

The first results obtained are related to FSE modelling of Salone dei Cinquecento and data gathering for the whole building. Future developments are related with the CDE construction and with the definition of safety masterplan of the building.

## **1. Introduction**

Managing today activities in historical heritage buildings is often a complex problem of compatibility between the architectural characteristics of the building and the modern needs. Every today activity, both working activities and recreational ones, has to be performed paying attention to the specific needs of the people involved. The building inside which people operate can strongly contribute both in hinder and, on the other side, facilitate the satisfaction of occupants needs; in some cases, the building can ever determine peculiar discomfort to occupants with respect to the modern criteria of living. In the case of still today used historical heritage buildings, such considerations strongly influence the possibility to act on the building in order to adapt it to the activity needs, since together with the goal of occupants comfort, also the goal of building preservation must be reached.

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 issue is particularly interesting when one have to deal with safety regulations that, with the aim of occupants safeguard, give rules both to the activities management and to building features. 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 e Marsella, 2008 e 2010); the only way is to create a sartorial shell of regulations and demonstrate that, both safety and comfort goals are reached, combining respectful interventions on building with activity management strategies.

Health and Safety (H&S) issue, together with fire prevention, is the optimal situation to study a building and its activities with the aim to intervene both on the building itself and on the management. Health and Safety and fire prevention regulations involve both the building and the activities in order to reach the occupants safety. In 2007 in Italy Fire Safety Engineering (FSE) became law and it gives the possibility of analytically study the building system with specific dynamic simulations, in order to demonstrate the real building behaviour in the case a fire breaks out. At the same time, 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).

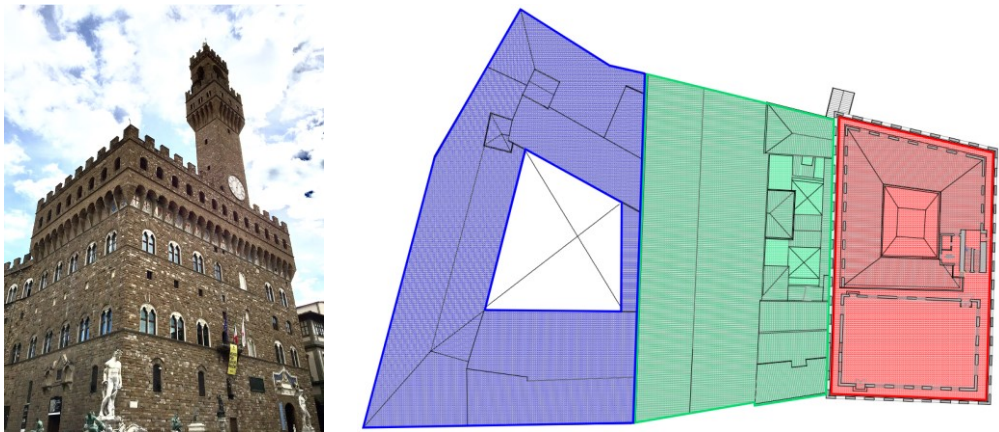
Such an approach has been used to manage Fire Prevention together with Health and Safety in the Florentine building “Palazzo Vecchio”.

## 2. Palazzo Vecchio in Firenze

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.

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 (Fig. 1).



*Fig. 1 Palazzo Vecchio and a representation of the three blocks constituting the building.*

The building has one underground level, four levels out of ground and two mezzanine floors; the architectural 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.

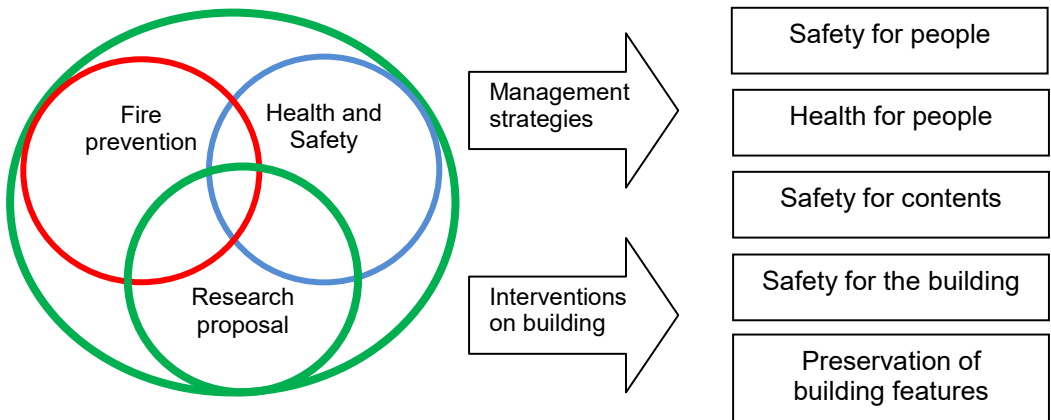
The medieval and the renaissance parts are open to the public since they are a museum; the most recent part contains offices of the local administration.

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.

The two main set of regulation which we refer to, are the Health and Safety Italian regulation (D.Lgs. 81/08) and the whole national legislation regarding the Fire Prevention in historical buildings issue (D.M. 569/1992, D.P.R. 418/1995, guidelines 3181/2016). The regulations concern both the building and the activities management, giving specific duties to the building manager and to the managers of working activities. The palace should be in compliance with both the regulations, at the same time with the compliance to the building preservation regulations. The impossibility to satisfy all together such complex regulations by using a standard design approaches leads actually to inaction. For this reason, a high-level modelling, design and management *Design Approach* has to be developed which should be able to manage the building in its entire. The presented paper shows the general approach the authors are working on to manage the problem.

### 3. Research goals

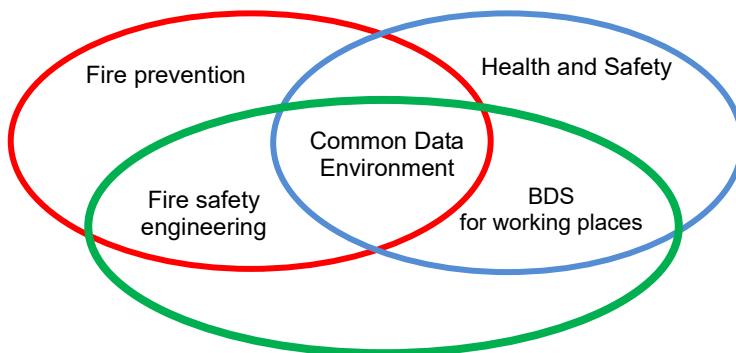
The research proposal moves from this premises and has the goal to create a system of management strategies and building interventions to assure the goal of safety. The aim of the study is to harmonize safety of occupants and workers, preserving the building characteristics, with an all-inclusive approach able to complete the gap to reach the building and occupants safety (Fig. 2).



*Fig. 2 Research context and objectives.*

The research is developed in three main branches (fig. 4):

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. FSE has to be performed because fire prevention regulations cannot be completely applied in Palazzo Vecchio.
2. Building Design for Safety (BDS): health and safety for workers can be guaranteed applying the BDS method to working places, as referred in literature (Capone e Ciatti, 2017). This issue it is not included in this contribution and will be explained in a specific paper.
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.



*Fig. 4 Research framework.*

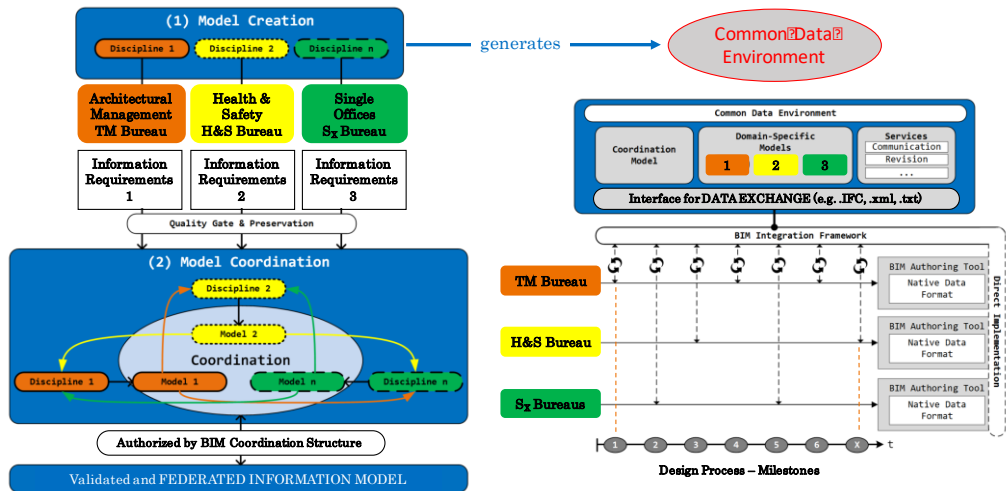
This contribution describes the first steps done in building a research framework which is still missing in the literature, due to a poor integration of such a fields. In the follow, will be depicted: a first FSE application to Salone dei Cinquecento and the CDE framework.

## **4. BIM-based collaborative process by using a CDE**

It was stressed that 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

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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 (fig. 5).



**ROOMS**  
Information Requirements

Locali (1)	
Modifica tipo	
Vincoli	
Livello	Piano 1
Limite superiore	2,4384
Offset limite	0,0000
Offset base	0,0000
Dimensioni	
Area	47,251 m²
Perimetro	30,4862
Altezza non delimitata	2,4384
Volume	115,216 m³
Altezza di calcolo	0,0000
Dati identità	
Numero	1-43
Nome	Sala Giovanni delle B...
Immagine	
Commenti	
Occupazione	Sala riunioni
Reparto	Ufficio Sindaco e Ass...
Tipo di finitura della base	
Tipo di finitura del cont...	soffitto affrescato
Tipo di finitura del muro	Affrescato
Tipo di finitura del pavim...	Pastrelle in cotto
m² lavoratori	0
Affollamento max	14
Apertura al pubblico	

**FURNITURES**  
Requirements

Parametri	
Dati identità	
Nome	...
Descrizione	...
Quantità	...
Prezzo	...
...	...

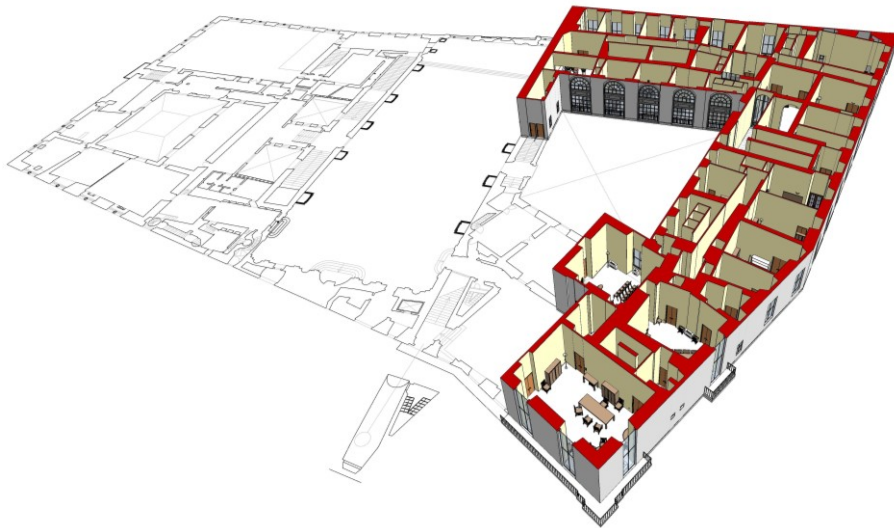
Information Model for Management of Discipline 1 (DX)  
Filtering Capabilities of the CDE to download information (SX)

Fig. 5 Architecture of the Common Data Environment.

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 (Fig. 6). After the investigation, the output data are uploaded within the CDE in order keep the *Federated Model* updated.



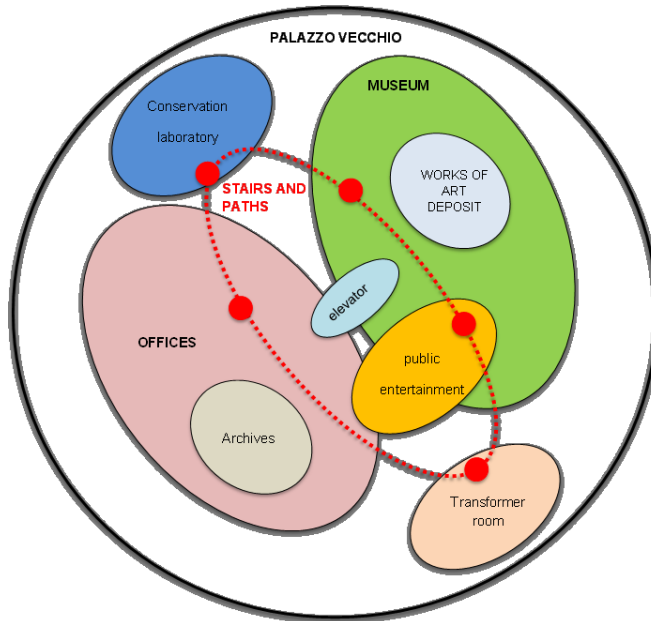
*Fig. 6 Part of the model produced for H&S management for offices (BIM modeller T. Sorbi).*

## **5. Fire prevention in Palazzo Vecchio**

Palazzo Vecchio has been at first analysed making use of traditional fire regulations that can be applied to the activities performed in the palace. Activities that must respect specific regulations are: the museum, the offices, archives and public entertainment. The set of all the activities, performed inside historical rooms and connected by means of monumental stairs, create a complex system that needs a unique fire prevention masterplan (Fig. 7).

According to the Florence public administration, the research focused at first on the medieval and renaissance blocks that were deeply analysed, gathering together all the data useful to understand the building behaviour in case of fire and emergency management.

One of the most significant nodes in the fire prevention system of Palazzo Vecchio is the presence of the big public hall Salone dei Cinquecento.



*Fig. 7 The complex system of Palazzo Vecchio activities for fire prevention.*

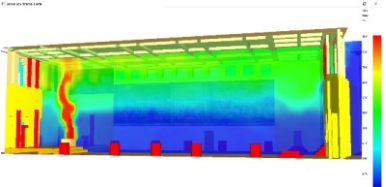
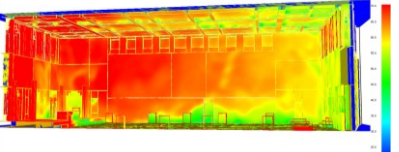
The hall is still nowadays used for concerts and public meetings and, at the same time, is part of the museum touristic tour. According to the prescriptive fire regulations, the hall can be crowded maximum by 375 people, regardless of the real specific use of the hall. The first objective of the FSE research has been to define the maximum crowding number of the hall, defining it by means of performance based design.

## **5.1 Salone dei Cinquecento modelling for FSE purpose**

Salone dei Cinquecento is a room 1150m<sup>2</sup> wide, with a height of 18 meters. There are only 3 fire exits and only one of these is used as entrance and exit during regular use of the hall.

The study aimed to reduce as much as possible the building interventions on the monumental hall, considering the most efficient one to allow a safe egress for the maximum number of people. This is the reason why we chose at first to model the hall in its real situation, making little boundary variation with respect to the possibility to control opening of doors and windows. Such chose allows just the installation of special plants useful to coordinate, by means of a detectors, and automate the opening of existing windows. In table 1 the main technical data of the model are described. The software we used is Fire Dynamics Simulator, by means of the a graphical user interface PyroSim.

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<b>Mesh and domain definition</b>	The domain of computational analysis is a simplified volume of the hall: 25mx58mx19m. The volume of the domain was discretized following a 25 cm reference size and modeling each object as a multiple of that size to create a perfect match with the mesh vertices.
<b>Mesh dimension</b>	25cmx25cm (2.156.800 elements) - 50cmx50cm (236.800 elements)
<b>Mesh Verify</b>	$D^* = \left( \frac{Q}{\rho_{\infty} c_p T_{\infty} \sqrt{g}} \right)^{\frac{1}{3}} = 1,82 \text{ m}$ $0,1xD^* < \delta < 0,4xD^* \quad 18\text{cm} < 25\text{cm} (50\text{cm}) < 73 \text{ cm}$
<b>Shell domain characteristics</b>	Due to the the presence of stones and bricks walls and due to the lasting of analysis time, the domain shell materials are considered as inert.
<b>Slices</b>	Control surfaces (slices) were used to analyze: <ul style="list-style-type: none"> <li>• Temperature</li> <li>• Fluid Speed</li> <li>• View distance</li> <li>• Concentration of carbon monoxide and pollutants</li> <li>• Particulate yield</li> </ul> 
<b>Boundary quantities</b>	<ul style="list-style-type: none"> <li>• Gas temperatures on surfaces</li> <li>• Particulate deposits</li> </ul> 

*Tab. 1 Summary of the main characteristics of the model (FSE modeller G. Rigacci.)*

Fire in the model is defined according to Italian D.M. 03/08/2015, as referred in table 2. Times of fire growth and pollution distribution are the quantities we look at, in order to protect both occupants and the precious architectural features of the hall.

<b>Growth speed <math>\tau\alpha</math></b>	<b>Stationary fire start time</b>	<b>RHR<sub>max</sub>TOT (RHR<sub>max</sub>/m<sup>2</sup>)</b>	<b>Particulate yield Y<sub>soot</sub></b>	<b>CO yield Y<sub>CO</sub></b>	<b>Heat <math>\Delta H_c</math></b>	<b>RHR(t) irradiation fraction</b>
150 sec	335 sec	5 MW (500kW/m <sup>2</sup> )	0,07 kg/kg	0,10 kg/kg	20MJ/kg	35%

*Tab. 2 Fire characteristics*

A first occupants egress time estimation has been done according to D.M. 03/08/2015 and compared with simulation results. This preliminary approach suggested that, in order to minimize architectural intervention, it is necessary to install special plants useful for occupants safe egress.

## **6. First results ad future developments**

First results are related both with the museum with regard to FSE and the offices blocks.

In the first FSE simulation a very heavy fire condition has been chosen; despite of this, the volume of the hall is so huge that is sufficient to manage windows opening to control smoke view and temperatures.

Further studies must be performed to investigate:

- Realistic definition of fire characteristics;
- Exodus time of people from the hall and on the monumental stair. Such study will be performed making use of exodus simulation since we are now working on the characterisation of people occupying the hall.

Data gathering of CDE definition has been performed for the whole building, with respect to H&S and fire safety; CDE is currently underway.

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