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HT_BIM: Parametric modelling for the assessment of risk in historic centers

HT_BIM: La modellazione parametrica per l’analisi del rischio nei centri storici

The small historic centers are “environment monuments” to be safeguarded because of their vulnerability both from seismic and environmental point of view. The management of these urban realities is particularly complex due to the heterogeneity of data of individual building units, structural aggregates, and entire urban areas. Recently, BIM parametric systems have contributed enormously in the design, planning, construction, etc, of new buildings and also in cultural heritage management. The aim of this work is to develop the historical town information modeling system (HT_BIM), that is a specific BIM system for historical building aggregates that detects vulnerabilities both in structural aspects and in wind exposure and sunshine degradation phenomena.

I centri storici minori sono dei monumenti d’ambiente da salvaguardare perché vulnerabili sia dal punto di vista sismico che ambientale. La gestione di queste realtà urbane è particolarmente complessa a causa dell’eterogeneità dei dati relativi alle singole unità edilizie, aggregati strutturali e intero ambito urbano. Negli ultimi anni i sistemi parametrici BIM hanno dato un enorme contributo alla progettazione, pianificazione, costruzione etc. di nuovi edifici e anche alla gestione del patrimonio culturale. L’obiettivo di questo lavoro è lo sviluppo del sistema Historical Town Building Information Modeling (HT_BIM), ovvero di un sistema BIM specifico per gli aggregati di edifici storici che, sulla base del rilievo, consente di individuare vulnerabilità legate sia ad aspetti strutturali sia a fenomeni di degrado da vento e soleggiamento.

Keywords: BIM, historic towns, wind exposure, sunshine, structural analysis

Parole chiave: *BIM, centri storici, esposizione al vento, soleggiamento, analisi strutturale*

INTRODUCTION

After the seismic events that have recently affected the central Italy, the debate on the preservation of the historical small towns has been re-opened forcefully. Due to the originality of their urban composition, those towns are considered as environmental monuments to be preserved and protected: the loss of the “genius loci” of the small communities would in fact undermine the cultural identity of the whole country. Many Italian historic centres are allocated on the Apennine chain, in areas classified by the most recent seismic hazard maps at the first or second category. Apart from this risk, the historic buildings are affected by other environmental hazard factors, such as the degradation of the facades due to the exposure to wind, rainfalls and other atmospheric agents (Pelliccio, 2016) or due to the continuous anthropic transformation that frequently turns out into the addition of structural parts that aggravate the seismic vulnerability. Considering the above situation, the rehabilitation of historic centres should start from the identification of the main factors of vulnerability, the evaluation of risk and the possible evolutive sceneries of the centres and the whole territory. This analysis must be performed looking at these centres not as a cumulation of single architectural events, but considering them as unique organisms characterised by a peculiar socio-economical, architectural, urbanistic, technical, legislative, environmental path. Their knowledge requires a particularly complex process of survey, acquisition and management of largely heterogeneous data regarding the single architectural unit, aggregates of buildings and whole urban systems. In this process, an important is played by the representation, as the characterization, reproduction and visualization of all the relevant factors is a fundamental step for the whole analysis (Cardone, 2015). Nowadays, the information technology offers a variety of graphical and analytical models able simulate different phenomena, immediately communicate results and enable comprehensive and detailed analyses.
Nowadays BIM’s (acronym of Building Information Modelling) are becoming very popular as they allow to integrate the design of the different components of the building and their construction together with management of the entire lifecycle. These systems couple the multidimensional geometrical representation with parametric databases representative of the various components, easing in this way the interaction among the different designers and executors and the communication with the stakeholders (Russell & Elger, 2008). Being initially conceived for new buildings, these systems are now being used in the analysis and management of the historic heritage to base the rehabilitation and restoration of old buildings on detailed reliefs (Centofanti & Brusaporci, 2013). A system called HT_BIM, acronym of Historical Town Building Information Modelling, is here in proposed as a tool to plan the management and protection of historic aggregates. The system includes general as well as detailed information, derived from direct or instrumented survey, with the aim of comprehensively identifying the different risk factors (e.g. structural and environmental) that may affect the urban aggregate. In the particular example shown in this paper, attention is focused on the seismic vulnerability of the historic aggregate, i.e. on the effects that the collapse of buildings may induce on the functionality of the urban system, and on the degradation of the facades produced by the action of wind and solar exposition. The multiparameter 3D HT_BIM model has been built coupling two photogrammetric digital surveys, one performed on the whole aggregate of buildings by a camera mounted on a drone and processed with a dedicated software (Agisoft PhotoScan), the other performed on the single units by a direct relief. HT_BIM is thus conceived as a unique system including information of various nature regarding the conservation of the building, structural systems, materials etc. All these informations are handled and combined each other depending on the scope of the analysis and application.
In fact, thanks to the data models IFC (Industry Foundation Classes) HT_BIM is able to interact combine with different analytical software and combining their results for a comprehensive interpretation. For instance, software for the structural analysis can be used to evaluate the seismic response of single units as well as structural aggregates starting from the set of information regarding the geometry, materials and structural details contained in the HT_BIM. At the same time, environmental analyses can be performed. In the present

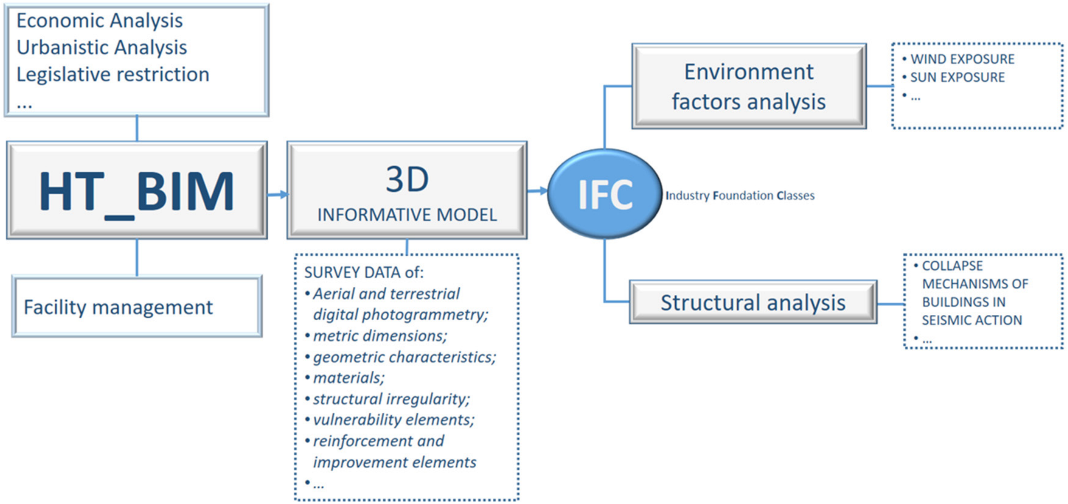
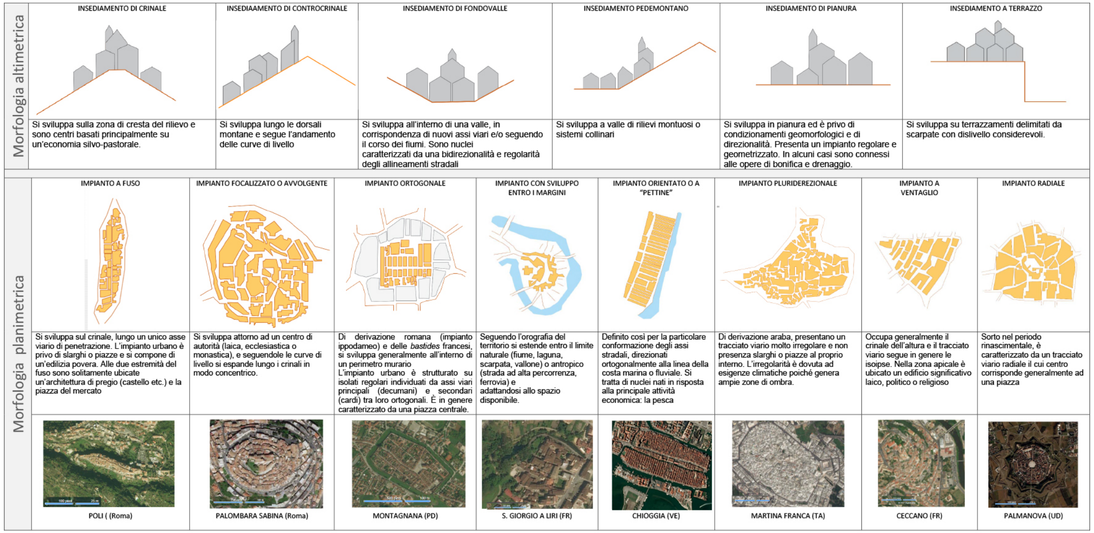


Fig. 1. Structure of HT_BIM informative model



Si sviluppa sulla zona di cresta del rilievo e sono centri basati principalmente su un'economia silvo-pastorale.

Si sviluppa lungo le dorsali montane e segue l'andamento delle curve di livello

Si sviluppa all'interno di una valle, in corrispondenza di nuovi assi viari e/o seguendo il corso dei fiumi. Sono nuclei caratterizzati da una bidirezionalità e regolarità degli allineamenti stradali

Si sviluppa a valle di rilievi montuosi o sistemi collinari

Si sviluppa in pianura ed è privo di condizionamenti geomorfologici e di direzionalità. Presenta un impianto regolare e geometrizzato. In alcuni casi sono connessi alle opere di bonifica e drenaggio.

Si sviluppa su terrazzamenti delimitati da scarpate con dislivello considerevoli.

Si sviluppa sul crinale, lungo un unico asse viario di penetrazione. L'impianto urbano è privo di slarghi o piazze e si compone di un'edilizia povera. Alle due estremità del fuso sono solitamente ubicate un'architettura di pregio (castello etc.) e la piazza del mercato

Si sviluppa attorno ad un centro di autorità (laica, ecclesiastica o monastica), e seguendole le curve di livello si espande lungo i crinali in modo concentrico.

Di derivazione romana (impianto ippodameo) e delle *bastides* francesi, si sviluppa generalmente all'interno di un perimetro murario
L'impianto urbano è strutturato su isolati regolari individuati da assi viari principali (decumani) e secondari (cardi) tra loro ortogonali. È in genere caratterizzato da una piazza centrale.

Seguendo l'orografia del territorio si estende entro il limite naturale (fiume, laguna, scarpata, vallone) o antropico (strada ad alta percorrenza, ferrovia) e adattandosi allo spazio disponibile.

Definito così per la particolare conformazione degli assi stradali, direzionati ortogonalmente alla linea della costa marina o fluviale. Si tratta di nuclei nati in risposta alla principale attività economica: la pesca

Di derivazione araba, presentano un tracciato viario molto irregolare e non presenza slarghi o piazze al proprio interno. L'irregolarità è dovuta ad esigenze climatiche poiché genera ampie zone di ombra.

Occupa generalmente il crinale dell'altura e il tracciato viario segue in genere le isoipse. Nella zona apicale è ubicato un edificio significativo laico, politico o religioso

Sorto nel periodo rinascimentale, è caratterizzato da un tracciato viario radiale il cui centro corrisponde generalmente ad una piazza

Fig. 2. Framework of altimetric and planimetric morphology of the most common small historic centers

case the wind flow over the entire aggregates and the solar irradiation over the facades of single units have been analysed and represented using internal plug-in of the BIM system (Fig.1). The HT_BIM aims to support the local authorities in the planning of development/maintenance policies or in the management of emergency (Pelliccio, Saccucci, & Grande, 2017) and the technicians for the design and execution of remediation works.

HT_BIM has been designed, improved and validated with reference to a real case study, a small village named San Rocco in the city of Sora.

SMALL HISTORIC TOWNS AND THE VILLAGE OF SAN ROCCO

The historic towns, especially the smaller ones, form an important part of the Italian Cultural Heritage due to the high quality of aggregative life and the meaningful aesthetic identity of the urban shape, this last deriving in most cases from the sharp empathic relationship of the town with the natural environment (morphological/locational, material/technological characteristics) (Pelliccio, 2016).

Mostly arisen in the Medieval or Renaissance ages, the shape of these villages follows specific layouts (spindle, enveloping, multidirectional, radial etc.) depending on the geomorphological feature of the site where they are located ridges, slopes, bottoms of the valley, plain, foothill etc. Those models can be repeatedly found in different regions (Fig. 2)

The relationship between the altimetric morphology of the site and their architectural features plays a fundamental role on the vulnerability of the buildings as well as on the whole urban context. For instance, the seismic analyses refer to aggregates or structural units, the latter being strongly conditioned by the geometry of the urban system, and thus the knowledge of the characteristics of the place are fundamental. Likewise, the urban morphology may generate street canyons, where inappropriate wind exposure and solar irradiation may trigger extrinsic degradation. Among the numerous examples of smaller historical towns, the herein considered case of S. Rocco village is particularly interesting. The village dates back to VI b.C. and it assumes the present urban shape in the first half of the 16th century. Located in a plain settlement, close to the Liri River and the hillside of S. Casto Mount, the village presents a urban morphology constrained within its natural boundaries. The village is made up of two parallel curtains of building where each can be considered as a large structural aggregate, being the outer walls of the building structurally unified or connected by arches (Fig.3)

DIGITAL AND TRADITIONAL SURVEY USED IN BIM

The design of BIM model for existing architectures or engineering works requires a noticeable effort to acquire all the necessary data. In fact, the parametric approach links the geometry to the numerical dimension or to the mutual physical constraints of all components of the architectural organism.

Despite the use of instruments capable of reading "hidden information", often the lack of documentation stemming from the use of not invasive surveys, implies that the geometric and topological information must be deducted and expressed in terms of functionality of the components and interconnections (Garagnani & Manferdini, 2013).

Although the use of digital technologies can accelerate and improve the knowledge of the architectural object, the role of the detector in post-processing is unchanged for the discretization and segmentation of individual components and component parts. Also, the construction of the dataset to support the parametric model requires the integration of digital and traditional data obtained through direct relief procedures.

For the definition of the geometric model, the use of RPV (Remotely Piloted Vehicle), commonly known as drones, has been spreading for some years. It is based on the use of sensors mounted on board such as cameras, thermocouples, etc. to acquire data for the geometric 3D modeling of the detected object. Up to a few years ago, this remarkable methodology was applied mainly in the topographic field for the analysis of surfaces of large extensions.

Recently, thanks to the reduced cost of the equipment and the development of new software applied to digital photogrammetry, this technology has been extended to the architectural surveys.

The 3D graphic model of the case study was obtained with a digital photogrammetric processing of drone-captured frames: in particular, the DJI Phantom 3 Advanced Drone with 12 Mpixels (4000 x 3000) mounted mounted 3-axis gimbal. To obtain the point cloud, a result of the digital photogrammetry, with a good resolution (less than 5 cm / pixel) and an appropriate nominal representation scale, the flying rate was set at 70mt. By keeping the speed of the drone constant, photo cracks have been made in the longitudinal and transverse directions, based on a double regular grid. During the take-up, particular attention was paid to the recommended overlap between two consecutive frames: at least 70-75% longitudinally to the overlap direction and at least 50-60% between two contiguous creases [oversize] (Fig. 4). The frames were taken with prescribed time lapses and the waypoints were specified during the planning of the flight and set in the management software (Flylitchi).

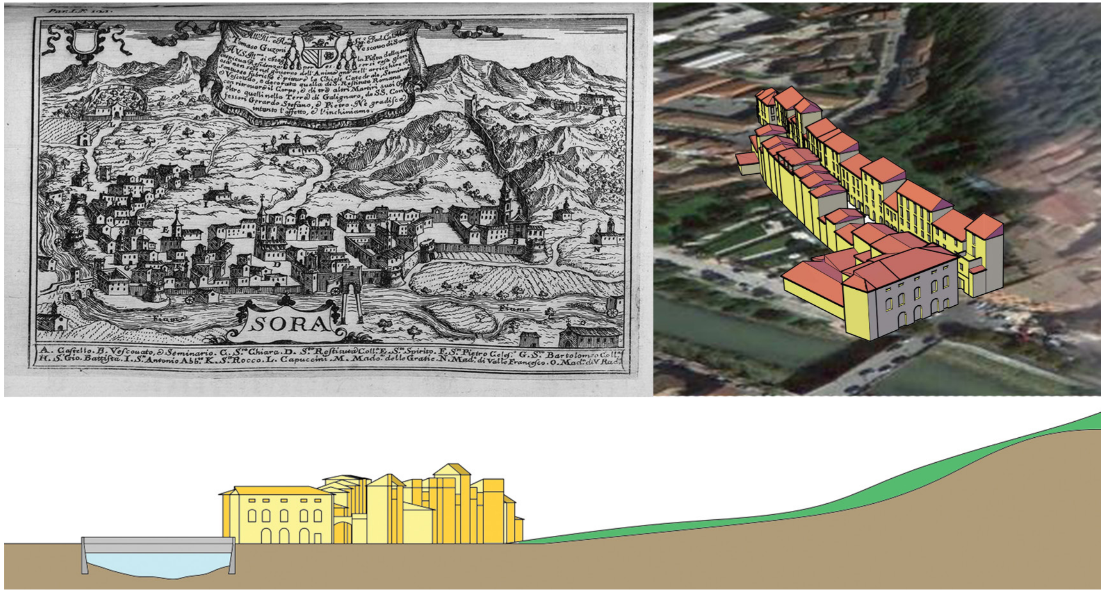
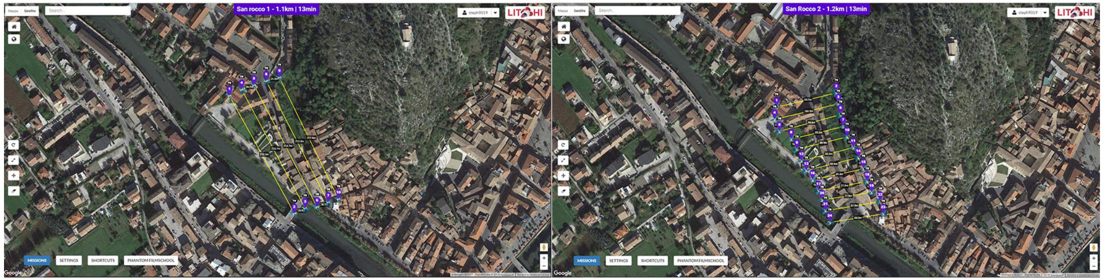


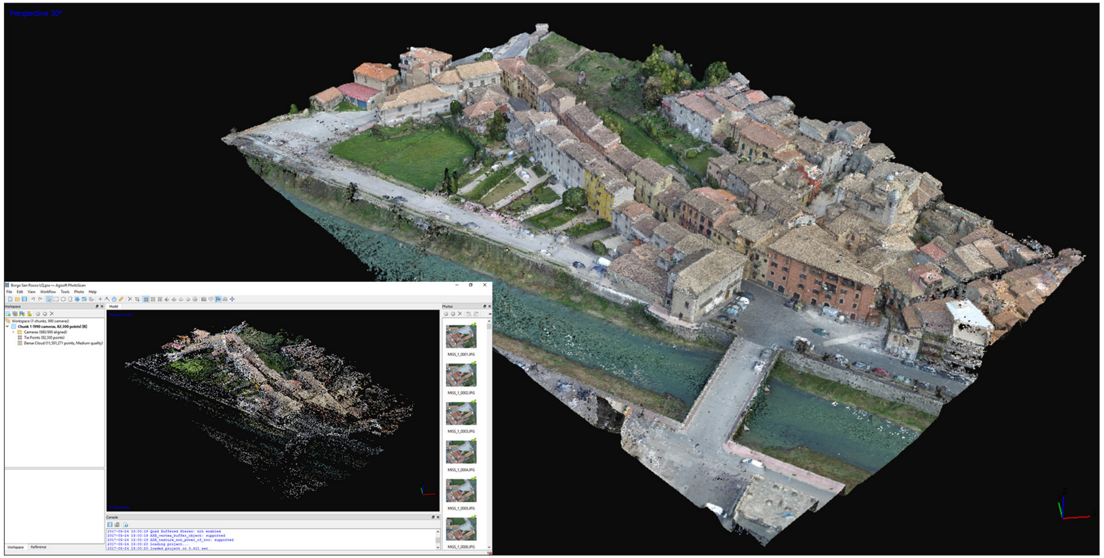
Fig. 3. San Rocco village in Sora. a) 1703. Etching incision by G.B. Piacichelli; b) and c) 3D graphic model of the village (Autodesk)

The photogrammetric survey was performed with good weather and solar lighting conditions. After checking the correct shots, quality and exposure of the scanned images, using a Agisoft PhotoScan software, a geometric 3D model was created as a point cloud with a rather good metric approximation. In fact, an error lower than 1% was found comparing the drone and metric surveys (Fig. 5).

The management of the obtained point cloud within the graphic modelling software requires the pre-processing within an additional software, designed to import, view, and edit the scanned objects (Autodesk ReCap). This software reads, in fact, the dot cloud as a text file containing the XYZ coordinates and the "RGB information" of each point in the cloud. In the present case 11,591,271 points were recorded and processed. With an internal AutoClear application, it is also possible to reduce the noise and increase the precision of the model automatically eliminating the points that exhibit an uncertain position. After the cloud is optimized, it is possible to verify the reliability of the graphic return using a series of internal tools to the same software. In particular, using the navigation and query tools specific reference distances can be measured, the orthogonality between plans can be assigned and the elevation can by identified for homogeneous zones (Fig. 6).

The digital photogrammetry is a fairly economical technology that allows to quickly create simplified volumetric models. The construction of a detailed parametric model requires to import the recorded cloud into a graphic modeling software (e.g. Revit) and to assign the geometry of individual architectural components associated to a database obtained by direct survey, based on previous documents, metric assessment, determination of materials and damage or, where necessary, with instrumental investigation (thermocameras).





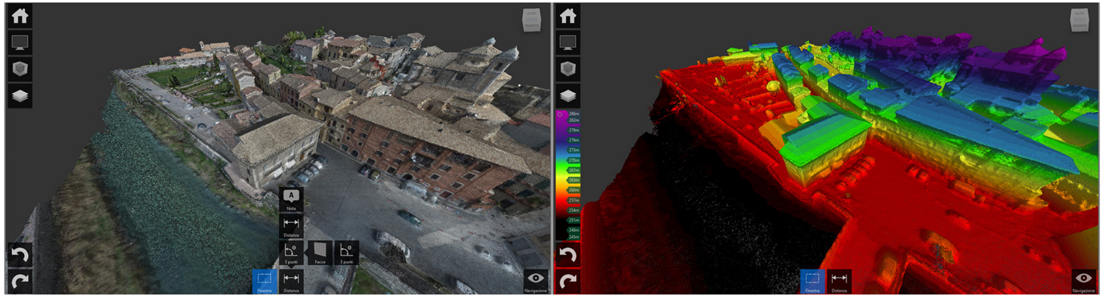


Fig. 4. Direction of photo slides performed by RPV
Fig. 5. San Rocco village. Visualization and editing of the dense cloud point
Fig. 6. San Rocco village. Navigation and questioning of thecolud point within Recap software: a) analysis of planes orthogonality; b) determination of elevation bands

HT_BIM: HISTORICAL TOWNS_ BUILDING INFORMATION MODELLING

The numerical model of the whole village can be then built with a Building Information Modeling (BIM) system. The use of these systems in the design and construction of new buildings is now widespread so that some may be considered as "... a policy initiative to address poor productivity in the construction sector" (Mihindu & Arayici, 2008).
BIM is based on the interoperability between 3D graphic models and dataset of information about geometry, materials, load-bearing structures, thermal characteristics and energy performance, installations, costs, security, maintenance, demolition, disposal etc. The set of these data returns a dynamic model where, from the design stage to its current management, each graphic variation is representative of variations of the building organization and performance of its basic technical elaborates (plants, prospects, sections) (Fai, Graham, Duckworth, Wood , & Attar, 2011.) In the case of existing building assets, the use of BIMs has to deal with uncertainties about the state of conservation, lack of documentation and conversion of the semantic data acquired from the reading of the work Architectural design (Volk, Stengel, & Schultmann, 2014).
Nonetheless, in the last few years there are numerous information models developed to solve the interrelationship between important (digital or traditional) data and the parametric graphical model. Some of them are based on a reasoned synthesis of data since the amount of information does not always correspond to a precise knowledge of the structure (Lo Turco, Santagati, Parrinello, Valenti, & Inzerillo, 2016); other models have been designed to improve the definition of the object morphology acquired by digital photogrammetry or laser scanning. In fact, their importation often requires some hand-work due to a not fully effective automatic extraction with the presently available software (Garagnani & Manferdini, 2013).
Numerous steps forward are also being made in the use of BIM models, derived from point clouds for structural simulation of finite elements: it is demonstrated that a FEM analysis on a BIM model no longer requires to drastically reduce the quality of the model itself (Barazzetti, et al., 2015). In the literature there is a limited application of HBIM models to urban areas for the analysis and management of their environmental and structural vulnerabilities, whose main peculiarity is the multi-scalarity.
For the analysis of environmental phenomena (e.g. the effects of wind) a simplified 3D volumetric model of the entire urban nucleus can be defined, while for structural or energetic analysis more detailed parametric 3D models are needed, including information about the structural aggregates and individual housing units. In the present case study, the design of the 3D parametric model has been obtained with the Autodesk_Revit software based on the dot cloud recorded with a photogrammetric digital survey. This allowed a noticeable rapidity in the modelling of volumes, fundamental when the studied object is large and complex. The cloud file with extension (.rcp) was then imported into the BIM system and georeferenced. The software reads the set of cloud points as snap and automatically detects the prevailing directions (those on which most points converge), that is, the outline of detected objects (external to the aggregate) (Fig.7).
Once the metric correctness and the exact geographic location are verified, the levels of the various planes of the single buildings (including that of the gutter and the overflow of the roof covering that characterize the village) have been identified taking as a reference the


Proprietà
Vista 3D
Vista 3D: {3D}

Grafica	
Scala vista	1 : 100
Scala 1:	100
Livello di detta...	Alto
Visibilità stratig...	Mostra origin...
Sostituzioni visi...	Modifica...
Opzioni di visu...	Modifica...
Disciplina	Coordiname...
Mostra linee na...	Per disciplina
Stile visualizzaz...	Nessuno
Percorso del sole	☐
Dati identità	
Modello vista	<Nessuno>

Fig. 7. Integration of the 3D parametric model to the dense cloud points of the digital photogrammetric survey

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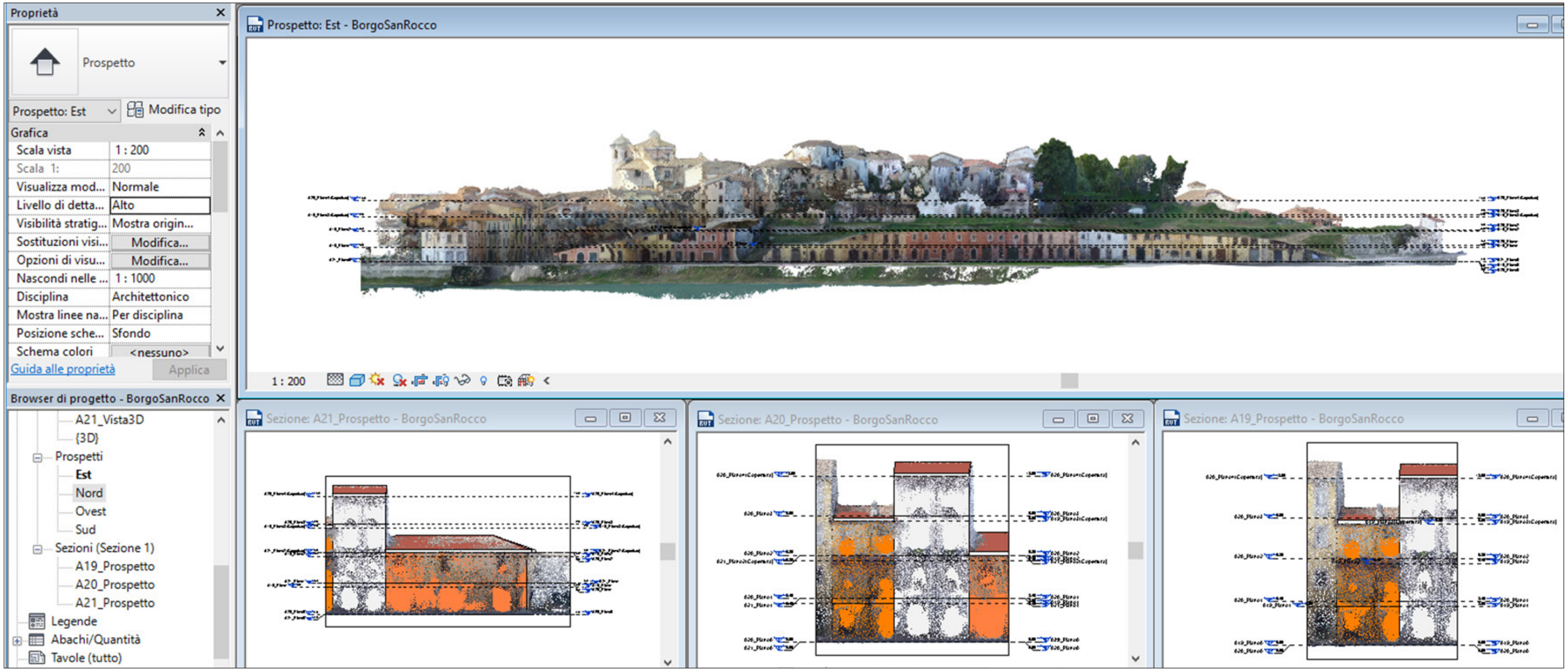


Proprietà

Prospetto

Prospetto: Est | Modifica tipo

Grafica

Scala vista	1 : 200
Scala 1:	200
Visualizza mod...	Normale
Livello di detta...	Alto
Visibilità stratig...	Mostra origin...
Sostituzioni visi...	Modifica...
Opzioni di visu...	Modifica...
Nascondi nelle ...	1 : 1000
Disciplina	Architettonico
Mostra linee na...	Per disciplina
Posizione sche...	Sfondo
Schema colori	<nessuno>

Guida alle proprietà

Browser di progetto - BorgoSanRocco

- A21_Vista3D
- {3D}
- Prospetti
  - Est
  - Nord
  - Ovest
  - Sud
- Sezioni (Sezione 1)
  - A19_Prospetto
  - A20_Prospetto
  - A21_Prospetto
- Legende
- Abachi/Quantità
- Tavole (tutto)

Prospetto: Est - BorgoSanRocco

1 : 200

Sezione: A21_Prospetto - BorgoSanRocco

Sezione: A20_Prospetto - BorgoSanRocco

Sezione: A19_Prospetto - BorgoSanRocco

Fig. 8. Identification of the levels inside the dense cloud points for the construction of the 3D parametric model
Fig. 9. 3D parametric BIM model of structural units

system of openings (windows and doors) and comparing their dimensions with those derived from a direct survey data (Garagnani & Manferdini, 2013) (Fig. 8). From a structural viewpoint, the two curtains of building facing each other appear as two large aggregates, as all the units have a common perimeter of walls or are interconnected by arches.

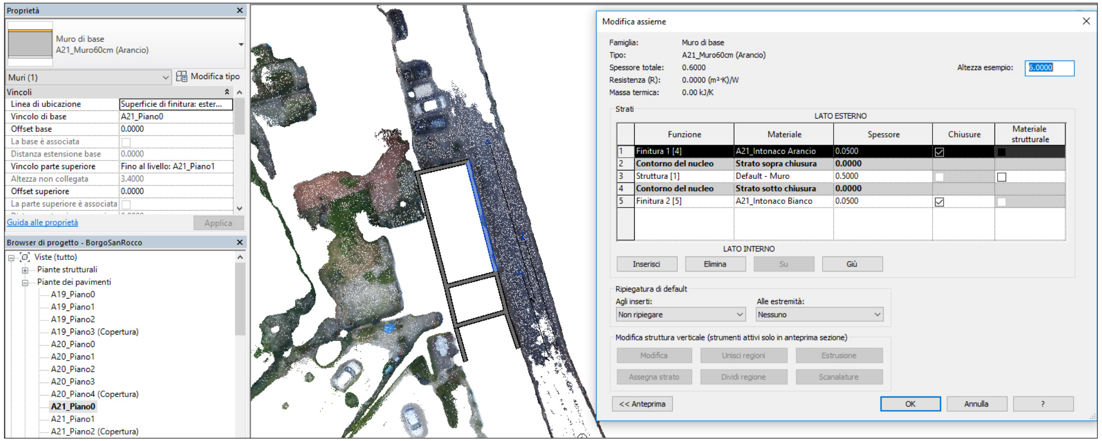
The buildings have a variable height, from two to four floors above ground, up to a maximum of 12 meters and are built with load-bearing masonry walls. The transition from the general volumetric model to the detailed 3D parameter model has required the reproduction on BIM of each single structural unit. In particular, from the documentary evidence (coming from the relief made after the 1984 earthquake) and the direct relief, the structural and architectural components have been modeled with their geometrical and material characteristics. In details, the walls have a variable thickness along their heights, being 50-70 cm thick at the ground level, and presenting a number of reductions of the order of 15% progressively going to the top. The wall are generally assembled with an unclear fabric of calcareous stones, with an appropriate ratio between the amount of mortar and stone.

The horizontal planes are heterogeneous and exhibit frequent misalignments. Some of them have wooden soles with circular cross-sectional beams and regular walks, but rarely for the entire development of the building. Further typologies such as cast in place cement soles, with barrels and vaulted surfaces characterize the units of the village. Based on the local constructive tradition and the stratigraphy of the terrain, the foundations can be hypothesized as shallow. At the end of the aggregate the roofs are of pavilion type, while in the central portion form huts or single decks, and in some cases present wooden trusses. The structural elements forming the vertical link are located longitudinally in all units.

All the above information have been included in the parametric model (Fig. 9). In addition, since one of the main purposes of the proposed HT_BIM is to analyze the seismic response of the aggregate, additional information has been provided, such as the degree of joint among orthogonal walls, the presence of curbs horizontally forcing structures, chains, tiebacks, the latter identified with thermal imaging (Figs. 10-11).

This data, together with the other typical information contained in the BIM, is an indispensable support for the development of a reliable model for finite elements that can analyze the behavior of the historical aggregate in case of seismic events (Garagnani, Luciani, & Mingucci , 2011).

Furthermore, taking advantage of the results from the seismic analysis, the level of seismic vulnerability has been evaluated in accordance with the guidelines provided by the most recent regulation (Fig. 12).



Muro di base
A21_Muro60cm (Arancio)

Vincoli

Linea di ubicazione	Superficie di finitura: ester...
Vincolo di base	A21_Piano0
Offset base	0.0000
La base è associata	☐
Distanza estensione base	0.0000
Vincolo parte superiore	Fino al livello: A21_Piano1
Altezza non collegata	3.4000
Offset superiore	0.0000
La parte superiore è associata	☐

Browser di progetto - BorgoSanRocco

- Viste (tutto)
  - Piante strutturali
  - Piante dei pavimenti
    - A19_Piano0
    - A19_Piano1
    - A19_Piano2
    - A19_Piano3 (Copertura)
    - A20_Piano0
    - A20_Piano1
    - A20_Piano2
    - A20_Piano3
    - A20_Piano4 (Copertura)
    - **A21_Piano0**
    - A21_Piano1
    - A21_Piano2 (Copertura)

Famiglia: Muro di base
Tipo: A21_Muro60cm (Arancio)
Spessore totale: 0.6000
Resistenza (R): 0.0000 (m²·K)/W
Massa termica: 0.00 kJ/K
Altezza esempio: 6.0000

Strati

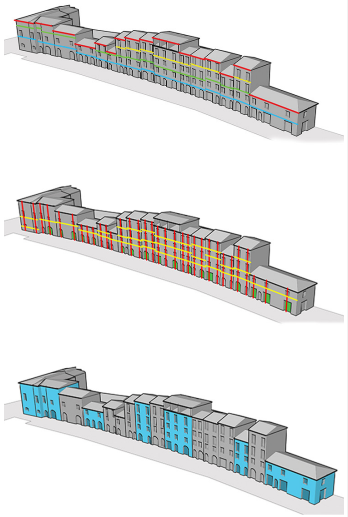
LATO ESTERNO

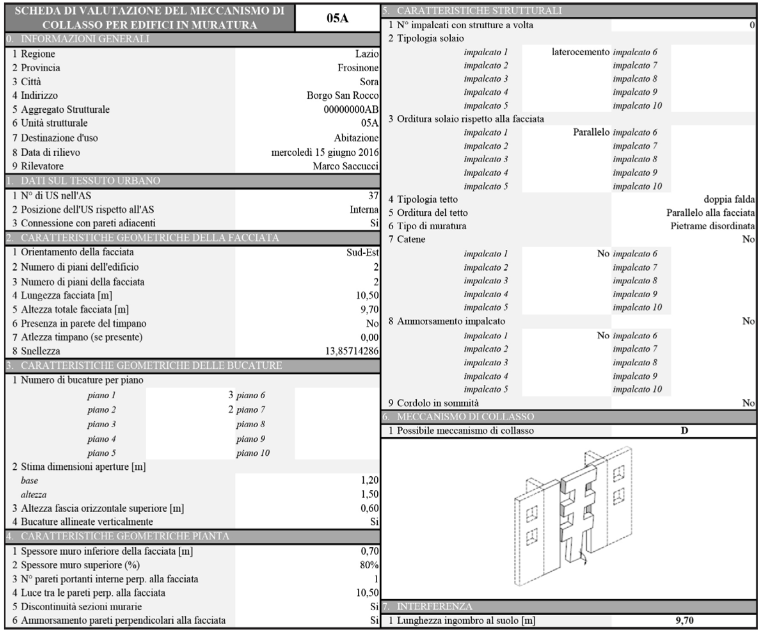
	Funzione	Materiale	Spessore	Chiusure	Materiale strutturale
1	Finitura 1 [4]	A21_Intonaco Arancio	0.0500	☑	
2	**Contorno del nucleo**	**Strato sopra chiusura**	**0.0000**		
3	Struttura [1]	Default - Muro	0.5000		☐
4	**Contorno del nucleo**	**Strato sotto chiusura**	**0.0000**		
5	Finitura 2 [5]	A21_Intonaco Bianco	0.0500	☑	

LATO INTERNO

Ripiegatura di default
Agli inserti: Non ripiegare
Alle estremità: Nessuno

Modifica struttura verticale (strumenti attivi solo in anteprima sezione)





SCHEDA DI VALUTAZIONE DEL MECCANISMO DI COLLASSO PER EDIFICI IN MURATURA	05A
0. INFORMAZIONI GENERALI	
1 Regione	Lazio
2 Provincia	Frosinone
3 Città	Sora
4 Indirizzo	Borgo San Rocco
5 Aggregato Strutturale	00000000AB
6 Unità strutturale	05A
7 Destinazione d'uso	Abitazione
8 Data di rilievo	mercoledì 15 giugno 2016
9 Rilevatore	Marco Saccucci
1. DATI SUL TESSUTO URBANO	
1 N° di US nell'AS	37
2 Posizione dell'US rispetto all'AS	Interna
3 Connessione con pareti adiacenti	Si
2. CARATTERISTICHE GEOMETRICHE DELLA FACCIATA	
1 Orientamento della facciata	Sud-Est
2 Numero di piani dell'edificio	2
3 Numero di piani della facciata	2
4 Lungezza facciata [m]	10,50
5 Altezza totale facciata [m]	9,70
6 Presenza in parete del timpano	No
7 Atlezza timpano (se presente)	0,00
8 Snellezza	13,85714286
3. CARATTERISTICHE GEOMETRICHE DELLE BUCATURE	
1 Numero di bucature per piano	

piano 1	3	*piano 6*	
piano 2	2	*piano 7*	
piano 3		*piano 8*	
piano 4		*piano 9*	
piano 5		*piano 10*	

2 Stima dimensioni aperture [m]	
base	1,20
altezza	1,50
3 Altezza fascia orizzontale superiore [m]	0,60
4 Bucature allineate verticalmente	Si
4. CARATTERISTICHE GEOMETRICHE PIANTA	
1 Spessore muro inferiore della facciata [m]	0,70
2 Spessore muro superiore (%)	80%
3 N° pareti portanti interne perp. alla facciata	1
4 Luce tra le pareti perp. alla facciata	10,50
5 Discontinuità sezioni murarie	Si
6 Ammorsamento pareti perpendicolari alla facciata	Si

5. CARATTERISTICHE STRUTTURALI	
1 N° impalcati con strutture a volta	0
2 Tipologia solaio	

impalcato 1	laterocemento	*impalcato 6*	
impalcato 2		*impalcato 7*	
impalcato 3		*impalcato 8*	
impalcato 4		*impalcato 9*	
impalcato 5		*impalcato 10*	

3 Orditura solaio rispetto alla facciata

impalcato 1	Parallelo	*impalcato 6*	
impalcato 2		*impalcato 7*	
impalcato 3		*impalcato 8*	
impalcato 4		*impalcato 9*	
impalcato 5		*impalcato 10*	

4 Tipologia tetto	doppia falda
5 Orditura del tetto	Parallelo alla facciata
6 Tipo di muratura	Pietrame disordinata
7 Catene	No

impalcato 1	No	*impalcato 6*	
impalcato 2		*impalcato 7*	
impalcato 3		*impalcato 8*	
impalcato 4		*impalcato 9*	
impalcato 5		*impalcato 10*	

8 Ammorsamento impalcato	No

impalcato 1	No	*impalcato 6*	
impalcato 2		*impalcato 7*	
impalcato 3		*impalcato 8*	
impalcato 4		*impalcato 9*	
impalcato 5		*impalcato 10*	

9 Cordolo in sommità	No
6. MECCANISMO DI COLLASSO	
1 Possibile meccanismo di collasso	**D**
7. INTERFERENZA	
1 Lunghezza ingombro al suolo [m]	**9,70**

Fig. 10. Database visualization inside the HT_BIM 3D parametric model
Fig. 11. a) floors misalignment; b) incongruous opening system; c) structural units subject to improvement and reinforcement
Fig. 12. Set of informations for seismic verification

THE HT_BIM FOR THE ASSESSMENT OF ENVIRONMENTAL FACTORS: WIND EXPOSURE AND SUNSHINE IRRADIATION

The elevation profile and the layout morphology of the historical towns generates often street canyons in which urban heat island together with wind exposure affect air quality, resulting in degradation of building surfaces, such as for instance, the phenomenon of "alveolizatione" (keyholes of the rock). For some years now, on the market computational software has been used to visualize streamlined airflows in the aerodynamic field and solar energy input on buildings to optimize solar exposure or improve energy efficiency (Konrath, Klein, & Schröder, 2008). Such software (eg Flow Design), which is based on fluid dynamics (CFD) applications, allows to simulate, in a very simple manner, a virtual parametric wind tunnel, built on the basis of anemometric data of the literature, around the 3D Graphic Model: The system displays areas with lower wind speeds and is able to handle transient flow using the Finite Volume Method

In addition to displaying the flow lines, the software can also simulate the surface wind pressure values (Fig.13). Comparing the results of virtual analysis with data detected directly thought the fieldwork survey it's possible to obtain a discrete correlation about the degradation phenomena. As is well known, applications for wind analysis on architectures imply a very high degree of uncertainty: wind speeds and wind directions are never stabilized as real data.

The case study looks as a street canyon: oriented N.N.O, has a longitudinal development of 146 meters and the variable cross section (4m ÷ 11m). The strong asymmetry in height does not allow this urban structure to be uniquely classified as a single "street canyon" family: on the basis of the aspect ratio in section (H = height of building W = roadway width), in function of the point of minimum and maximum width of the road, the village can be defined respectively as deep and regular canyon; While in relation to the aspect ratio in the plant (L = road length, H = height of the buildings) it is correct to define it as a very long canyon. These singular characteristics of the Village have generated in time significant degradation phenomena such as "alveolizzazione" and plaster detachment: the analysis and display of flow distribution and wind speeds aim to identify the most problematic causes and areas. For this purpose, the application of the Revit (plug-in Flow Design) software has defined the virtual wind tunnel in which the velocity values is derived from the Wind Italian Atlas and the dimensions of the tunnel are defined according to the size features of the model. The system shows different flow distributions in different wind conditions. (Fig. 14).

The accuracy of the simulation of wind pressure on the buildings facades (Flow Design) depends on the reliability of the graphical model: in the case of study, the model is deliberately devoid of the topographical elements characterizing the area (S. Casto and river Liri), but which affect the speed of the wind. In addition, the correlation between the air velocity range and the

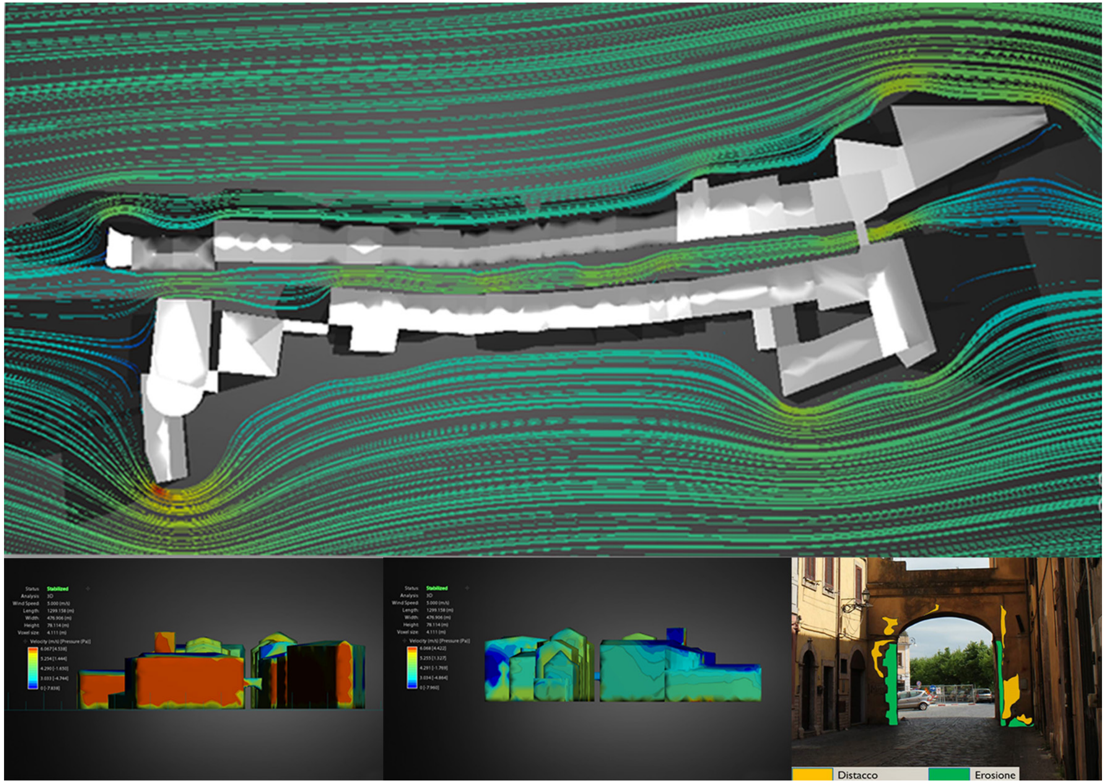
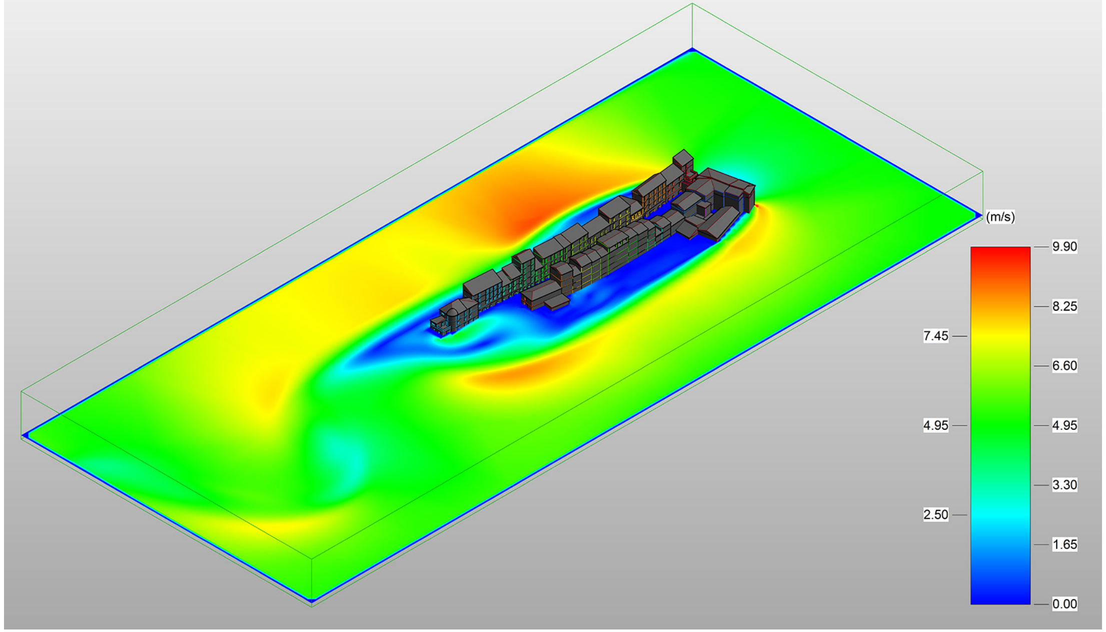
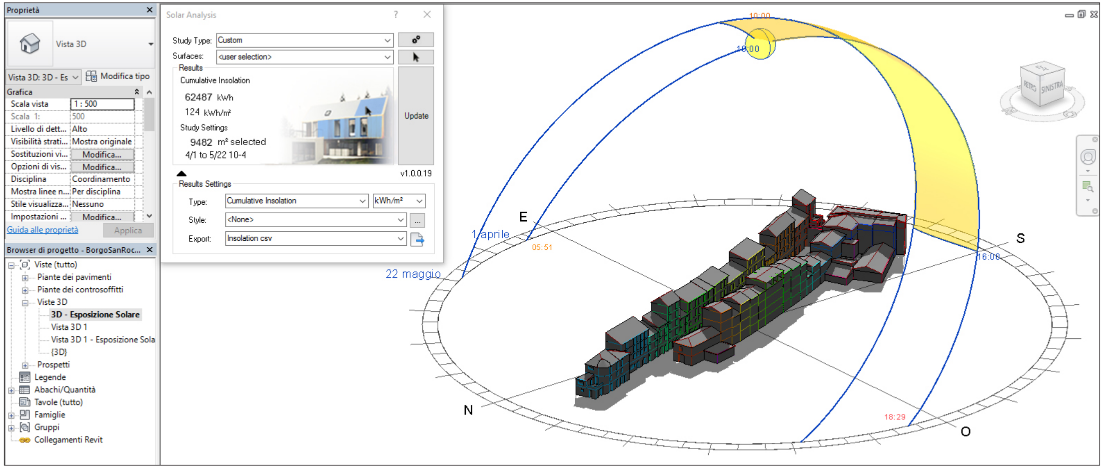


Fig. 13. Analysis of wind action in a virtual wind tunnel (Flow Design). a) visualization of wind stream line; b) and c) visualization of wind pressure over buildings facades; d) deterioration effetcts due to wind





Vista 3D: 3D - Es Modifica tipo

Grafica

Scala vista	1 : 500
Scala 1:	500
Livello di dett...	Alto
Visibilità strati...	Mostra originale
Sostituzioni vi...	Modifica...
Opzioni di vis...	Modifica...
Disciplina	Coordinamento
Mostra linee n...	Per disciplina
Stile visualizza...	Nessuno
Impostazioni ...	Modifica...

Guida alle proprietà Applica

Solar Analysis

Study Type: Custom
Surfaces: <user selection>

Results
Cumulative Insolation
62487 kWh
124 kWh/m²
Study Settings
9482 m² selected
4/1 to 5/22 10-4

v1.0.0.19

Results Settings
Type: Cumulative Insolation kWh/m²
Style: <None>
Export: Insolation csv

pressure distribution of the wind on the buildings facades have to be validated numerically thanks to the help of the Particle Image Velocimetry (PIV) analysis by means of a real wind tunnel.

Defining the virtual wind tunnel in the HT_BIM it will be possible to check, for instance, how any urban designs can reduce wind degradation phenomena: the insertion of a curtain of trees can in fact generate changes in the field of motion of the wind.

Similarly, some software also analyses solar radiation which generates first of all colour chromatic alteration on facades of buildings than the deformations and micro-fractures to the plaster due to the thermal expansion of materials (uniform and differential). Thanks to Revit's Solar analysis, the system evaluates the actual sunshine conditions to which the building aggregate is subject. The system, in fact, automatically creates solar diagrams and simulates the sun's path in each season and with customizable time intervals relative to the model; It displays animated and complex shadows and reflections, generating diagrams for shading analysis; it calculates the incident solar radiation on a surface and displays the cumulative annual insolation.

The procedure was tested in the HT_BIM system and applied to the case study. For the correct detection of the solar parabola, the model has been geolocated; then, the most significant time intervals (equinox and solstice) were choosing and the daily time interval for which to simulate. The system returns for each surface element of the village's building units, various information including solar input (Fig. 15). The aim of this analysis is to identify the elements for which energy efficiency interventions are needed, avoiding action on the entire casing. The dynamism of the BIM system also allows to check the energy class improvement after performing the intervention itself.

Fig. 14. Analysis of windflow distribution around the village. From blue to red the areas of higher and lower wind velocity
Fig. 15. Sunshine analysis and solar contribution over buildings facades

HT_BIM: STRUCTURAL ANALYSIS

The introduction of the BIM and the possibility to connect it with software for structural analysis has represented a significant step forward. Indeed, it is possible to 'translate' the information contained in the BIM model directly into input parameters for the structural analysis.

The reliability of the obtained FE model and the results of the subsequent structural analysis, is strictly influenced by the data derived from the BIM, and, therefore, by the survey activity. In the case of historical buildings, the information concerning the geometry, the arrangement of structural elements and the materials are often not sufficient to guarantee a reliable FE model. Further information, in particular concerning structural details (connections among the walls, lintels, steel tie, etc.), play an important role in the seismic response. Moreover, in the case of building aggregates it is very important to account for the heterogeneity of structural details since the structural behavior of a single unit could particularly influence the behavior of the other ones.

These aspects clearly underline that the connection between the BIM and the software of structural analysis cannot be assumed to be an automatic process: the designer assumes a central role for the analysis of information derived from the survey, their introduction into the BIM and the subsequent translation into the finite element model (Formisano, 2017).

For this reason, the HT_BIM here proposed with reference to historical masonry buildings in aggregates is based on different sets of information: a set of information specifically concerning the structural details in addition to the one concerning the geometry. While the first set of information is used for deriving the geometry of the FE model and, also, the properties of the finite elements, the second set is used for introducing graphic symbols and construction lines (vertical lines at the intersection of orthogonal walls, horizontal lines at the intersection between slabs and walls, symbols representing additional details). In a subsequent phase, the graphic symbols and the construction lines are converted into constraint or release conditions just considering the effective configuration of structural details. The results of the analysis are indeed devoted to emphasize the influence of structural details on the

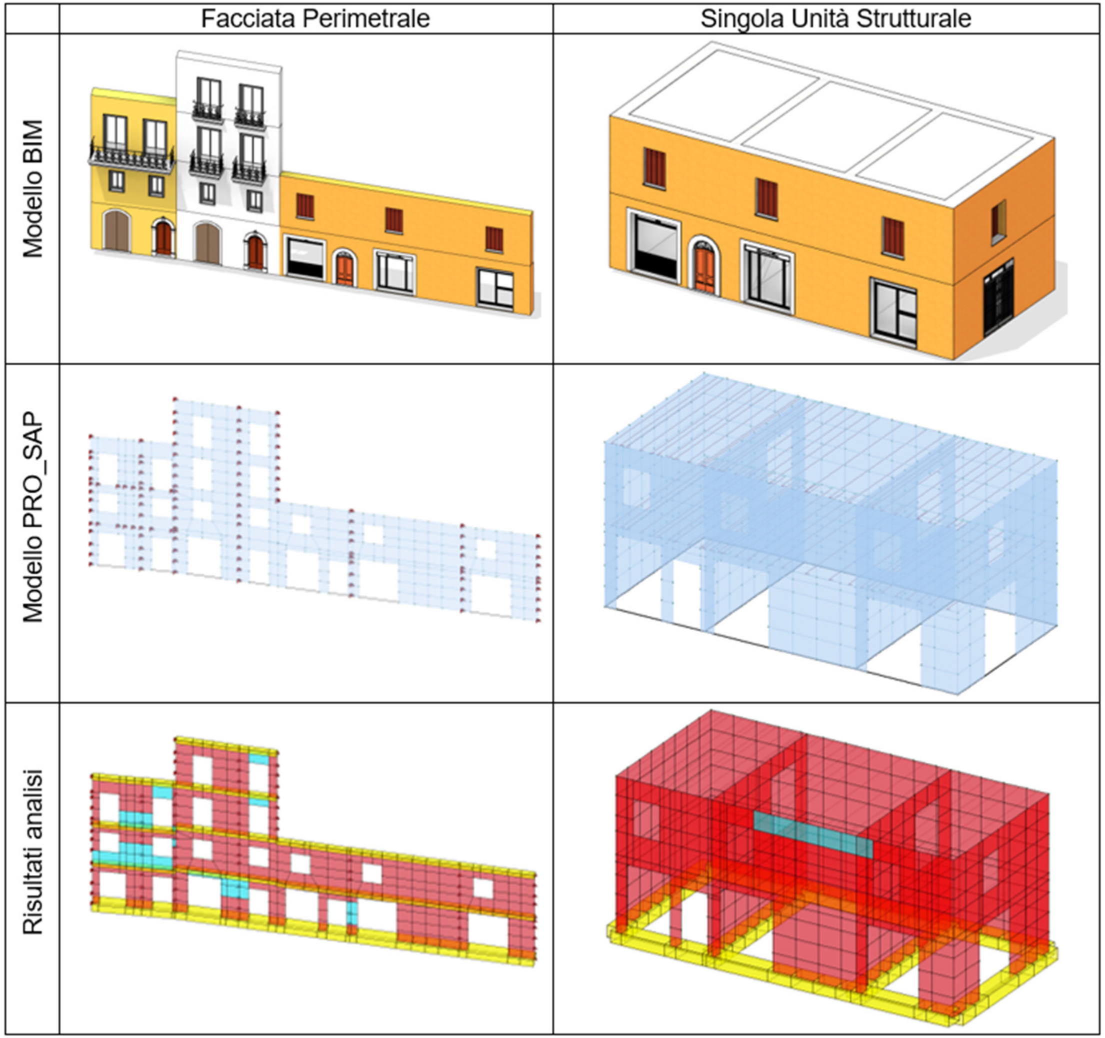


Fig. 16. Modeling in PROSAP: state of verifications with seismic project actions as spectrum of response. The unverified items are displayed in pink

seismic response.

The main advantage of using this approach is the possibility to perform a preliminary simplified analysis of the out-of-plane response of the perimeter wall of the whole aggregate: it is devoted to identify the most vulnerable units. Then, a global analysis of just these units extracted from the aggregate, is performed. This allows to account for the role of the aggregate in terms of interaction among each units and, moreover, to analyze different scenarios in the case of lack of information with low computational efforts.

The proposed approach has been applied to the case study. In particular, the steps characterizing the import phase of the data of the HT_BIM to the FE model here carried out through the software Pro_SAP are shown in figure 16 for both the perimeter wall of the aggregate and a single unit. In particular, it is shown the import of the geometry of the wall, where the parameters in terms of thickness and material properties are directly assigned by using the HT_BIM database, and the presence of graphic symbols, subsequently converted into constraint or release conditions. In the same figure are also reported the results emerged from the structural analysis performed by considering the design seismic actions. Although the two models are different, it is interesting to observe that the check in terms of out-of-plane behavior underline similar evidences for the case of the whole perimeter wall of the aggregate and the perimeter wall of the single unit extracted from the aggregate.

CONCLUSIONS

The HT_BIM system is an important tool for the management of small historic centers for both seismic vulnerability and environmental phenomena, such as wind exposure and solar irradiation.

It is a multiscale parametric system that can provide local authorities with information on buildings with structural vulnerabilities, and thus enable them to implement planning based on the priority of interventions. It also provides the information needed for a proper drafting of the recovery plan as it guides the choice of construction equipment and components strictly needed for energy efficiency interventions, increasingly demanded by the European Community.

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