WP 3: Representative models of Built Environment Typologies (BETs) prone to SUOD/SLOD. Case studies selection and data collection

T3.3 - Selection and survey of significant real-World case studies. Scan to BIM and implementation of risk parameters to set scenarios for VR. Case studies VR/AR representation. Users' exposure data collection.

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Abstract

The methodology set up and validated in the D3.3.1 for the BIM modeling of the BE (D3.1.2) and the implementation of the related risk parameters (D3.2.2) is here applied to a selection of three case studies. These case studies were chosen to represent different multi-hazard conditions (S+P, S+H, and T+H+P), identified as the most probable conditions (D3.2.2), and different BET (D3.2.1). The selection also considered the feasibility or availability of laser scanning surveys, exposure data, and climatic data. For each case study, the workflow encompasses the following phases: scan-to BIM modeling, parameter organization based on each multi-hazard combination, data collection, and data implementation with Dynamo setting, which allow automating the calculation of the values of some parameters. Describing the procedure of the digitalization of the three squares, this deliverable supports the following steps of the research, among them the extraction and data analysis of the case studies (WP4, T2), the definition of solutions for the improvement of BET resilience (WP5, T2), and the virtual training tools development (WP6, T2; WP7, T1).

Keywords

Built Environment BIM modeling, parameters for multi-risk assessment, SUOD, SLOD, BET, case studies.

Approvals

Role	Name	Partner	Date
Coordinator	Quagliarini Enrico	UNIPM	
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Revision versions

Revision	Date	Short summary of modifications	Name	Partner

Summary

1. Introduction

The Historical Built Environment (HBE) is particularly subject to a combination of SLODs (Salvalai et al. 2021; Cadena et al. 2021) and SUODs events (Quagliarini et al. 2019, 2021; Bernabei et al. 2020; Bernardini et al. 2020). The factors influencing the effects that these multi-hazard conditions can cause depend on the characteristics of the urban built environment, from a micro-, meso-, and macro-scale point of view. The meso-scale allows an intermediate evaluation of the urban security condition, since it considers the composition of the aggregates and blocks, the structure and connection of the streets, and the open spaces form and distribution, all elements that affect the safety of urban spaces users (Russo et al. 2020, 2021; Blanco Cadena et al. 2022; Romano et al. 2022; D'Amico et al. 2022).

The methodology set up and validated in the D3.3.1 allowed the evaluation of the potential of BIM models to represent the urban meso-scale and be an effective repository of information for its multi-risk assessment. The workflow was tested on a real case study – Piazza dei Priori, Narni – accomplished both geometrical modelling and risk parameters implementation phase (for S+P multi-hazard condition). Each geometrical element of the model was used to implement the related risk parameters identified as key multi-risk factors (D3.2.2) (Angelosanti et al. 2022).

In the herein deliverable the previous experimented methodology and workflow has been applied to a selection of two case studies (Figure 1). These case studies, and the previous one, were chosen to represent different multi-hazard conditions (Narni: S+P; Caldarola: S+H; Bari: T+H+P), identified as the most probable conditions (D3.2.2), and different BET (D3.2.1) (D'Amico et al. 2021; Rosso et al. 2022) (Figure 2). The selection also considered the feasibility or availability of laser scanning surveys, exposure data, and climatic data.

For each case study, the workflow encompasses the following phases in line with the workflow elaborated and tested in D3.3.1:
scan-to BIM modelling, using Terrestrial Laser Scanner (TLS);
selection and implementation of specific risk parameters in each BIM model, based on the specific multi-hazard combination;
data collection and implementation both manually and with Dynamo setting, which allows automation of calculating of the values of some parameters.

Describing the procedure of the digitalization of the three squares, this deliverable supports the following steps of the research, among them the extraction and data analysis of the specific case studies (WP4, T2), the definition of solutions for the improvement of BET resilience (WP5, T2), and the virtual training tools development (WP6, T2; WP7, T1) using virtual reality (Fatiguso et al. 2022).

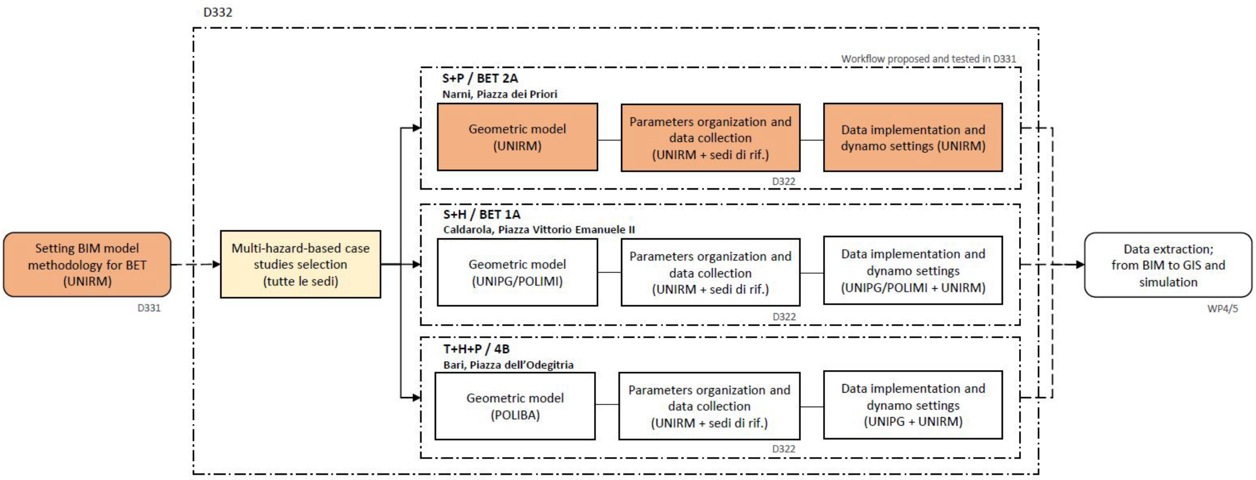


Figure 1. Case studies SUOD and SLOD data collection report workflow in relation to the BeS2cure project.

Square	M-Hazard	BET	BET pertinence	Survey	BIM Model	Exposure data	Climatic data
Piazza dei Priori, Narni	S+P	2A	V	V	V	V	
Piazza V. Emanuele II, Caldarola	S+H	1A	V	V	V	V	V
Piazza dell'Odegitria, Bari	T+H+P	4B	V	V	V		V

Figure 2. Case studies selected based on different multi-hazard combination and type of BET. From the left: Piazza dei Priori (Narni, TR), Piazza dell'Odegitria (Bari), Piazza Vittorio Emanuele II (Caldarola, MC).

2. Methodology

2.1 Summary of the methodology set up and validated in the D3.3.1

As previously done for Piazza dei Priori in Narni (D331), a Terrestrial Laser Scanner (TLS) survey were carried out also for Piazza dell'Odegitria in Bari (§2.2) and Piazza Vittorio Emanuele II in Caldarola (§2.3), in order to obtain a point cloud for the Scan-to-BIM process. Geometric and informative modelling of the Scan-to-BIM process is compatible with the BIM and GIS environments, as well as with the OS LOD definition given in D312 §4.1.

As mentioned above, the survey of Piazza Vittorio Emanuele II in Caldarola was also carried out with the use of the TLS. As for photogrammetry, priority was given to both accuracy and speed of survey operations. Eleven scans were acquired at each access to the square, in the center of the square and under the covered areas e.g., porches and canopies. The TLS was set to acquire only the reflectance of the surveyed objects, without recording their colours. This allowed for a faster process that took 5 minutes per scan (including moving the TLS to the next position) for a total of 55 minutes in a single day.

The digital survey of Piazza dell'Odegitria was performed using TLS equipment Faro Focus 3D 120 Laser Scanner. The digital survey campaign consisted of 8 scans within the square, near the buildings, in order to cover the entire region of interest (Figure 3). Less rapid scans were made, in order to ensure accurate acquisition of object reflectance (with millimetre precision) and colour acquisition. The settings provided automatic overlay without parallax. The resulting point cloud had good overlap, good balance, and high percentages of over-exposed points. The process took 10 min per scan, including moving the instrument to the next location, for a total of 90 minutes in one day campaign.

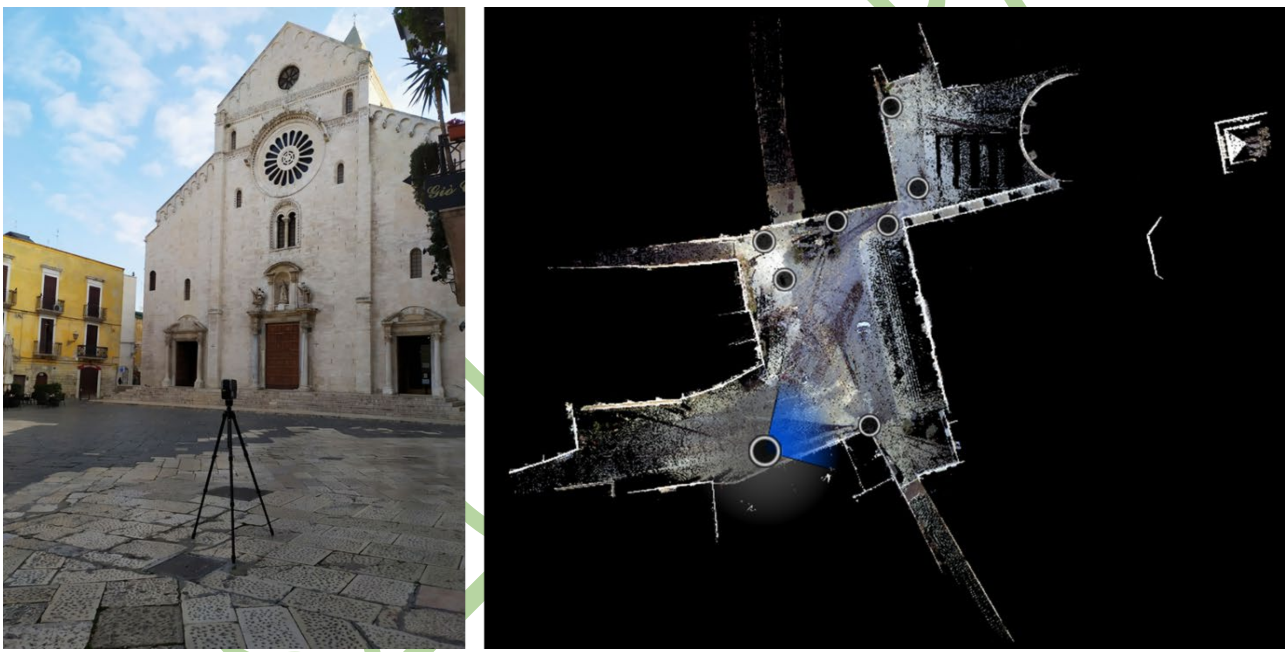


Figure 3. Laser scanning campaign in piazza dell'Odegitria, Bari (left); localization of scans (right).

The elements in the models were associated with two types of family categories: the High Level (HL), that represents the OS, the Interferent Structural Unit (SUi) and the Interferent Structural Aggregate (SAi); and the Low Level (LL), that represent the building and space components, e.g., wall, roofs, windows, paving, topography, road, parking, urban furniture (Table 1). To accomplish this organization, SUs and SAs are preliminary identified in each case study, according to the definition given in the D331 (Italian technical commission for seismic micro-zoning 2014; DPC-Reluis 2010) (for Narni see: Figure 4; for Caldarola, Figure 6; for Bari, Figure 5).

Table 1.BIM models families' structure, proposed by the authors to organize the following risk factors implementation.

Types of family category	Associated elements	Revit families
High Level (HL)	Open Space (OS) Interferent Structural Unit (SUi) Interferent Structural Aggregate (SAi)	Space Generic model (GM)
Low Level (LL)	Building components	Wall Floor Roof Road Windows/door Furniture Parking

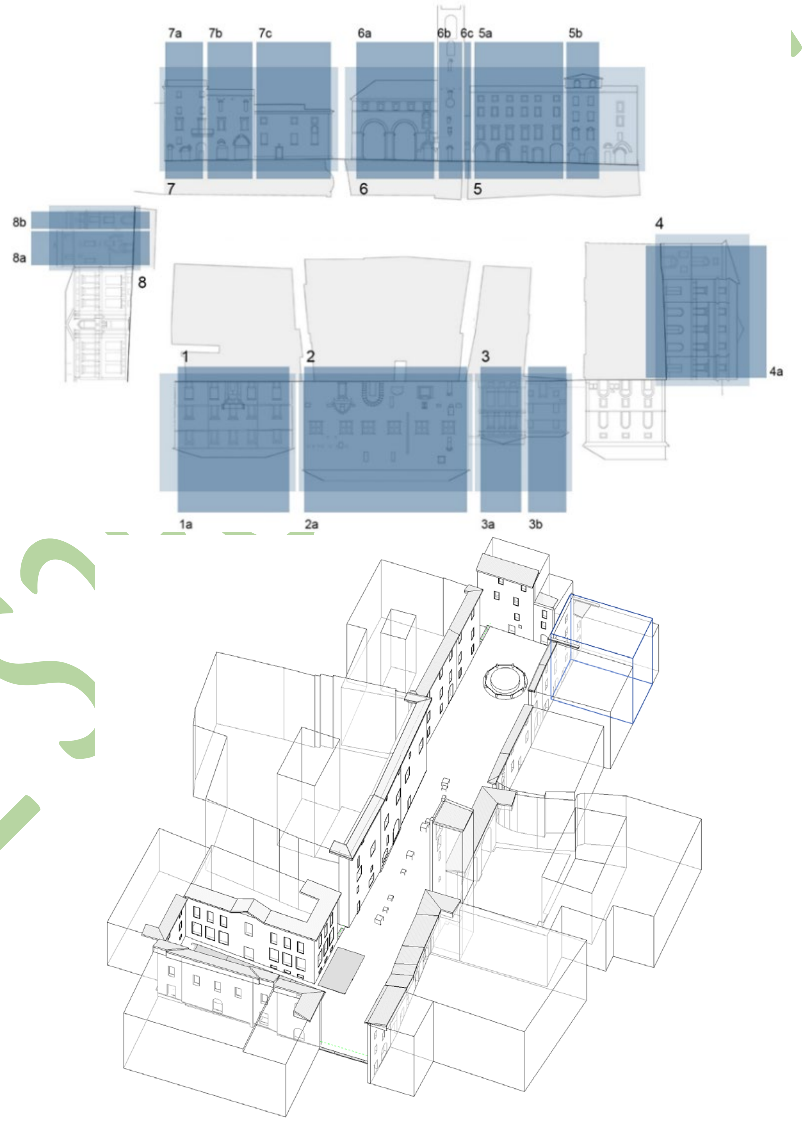


Figure 4. Analysis of SUs and SAs in Piazza dei Priori in Narni (on the left) and the resulted BIM model (on the right).

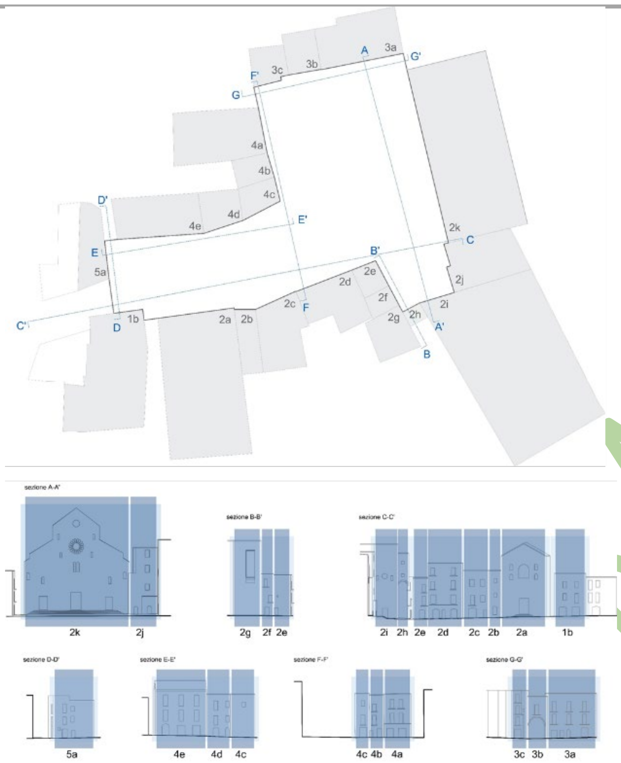


Figure 5. Analysis of SUs and SAs in Piazza dell'Odegitria, Bari.

Figure 6. Analysis of SUs and SAs in Piazza Vittorio Emanuele II, Caldarola.

2.2 BIM modelling strategies for Bari and Caldarola

2.2.1 Piazza dell'Odegitria, Bari

The BIM model of Piazza dell'Odegitria, Bari, has been created through a manual Scan-to-BIM process, using the point cloud as a metric reference to model the structural aggregates and unit identified within the Open Space (Figure 7). In addition, GIS shape data in scale 1:2000 (Carta Tecnica Regionale – CTR), converted into CAD data have been employed for ownership details. Piazza dell'Odegitria presents a non-compact and regular morphology, and two special buildings (Cattedrale di San Sabino and San Giacomo Church).

According to the methodology developed in D331, firstly, High Level (HL) and Low Level (LL) elements have been identified and modelled. Within the HL elements, The Interferent Structural Unit (Su_i) and the Interferent Structural Aggregate (Sa_i) (see D331 §2.2.2) (Figure 5). Among the LL identified in the general framework, Piazza dell'Odegitria also contains the "*Stairs*" to represents the stairs of the two churches in the built frontier. They are BIM objects that are not involved in any information exchange (filled or computable). For this reason, the topography and the pavement of the OS have boundaries that reach the built frontier, in order to allow the computing of those descriptors related with OS dimensions (SECTION 3: MAIN TYPE).

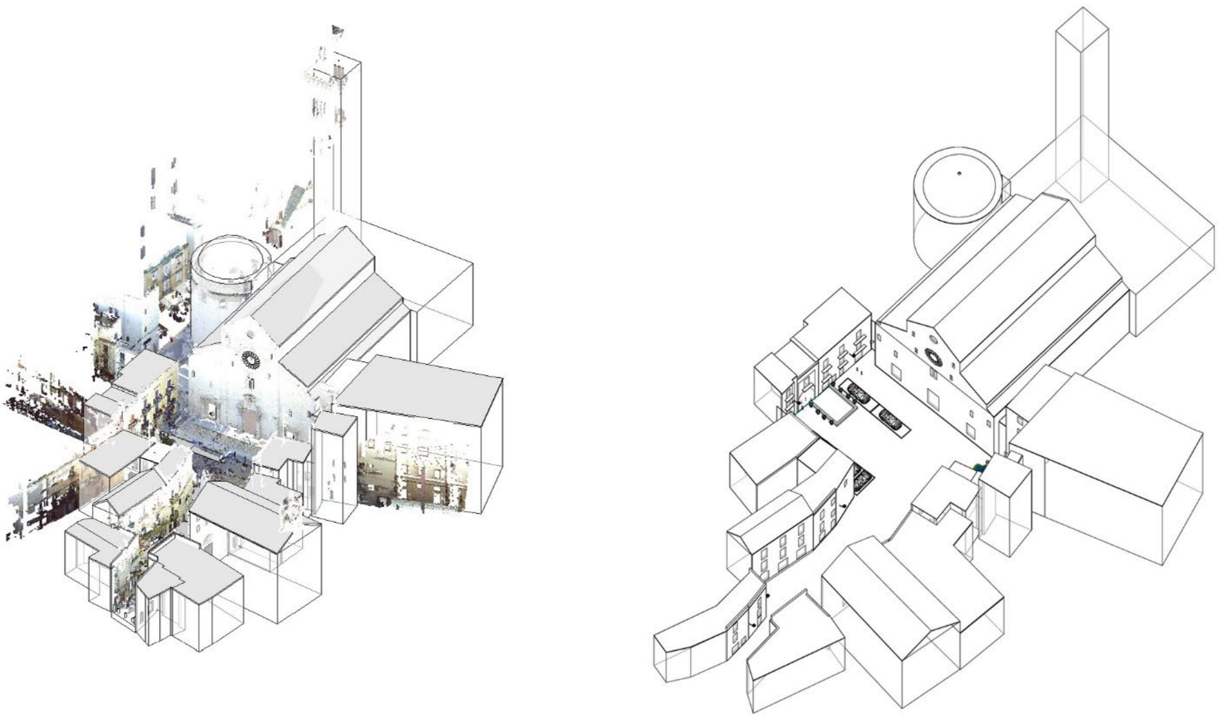


Figure 7. 3D point cloud for BIM modelling of Piazza dell'Odegitria.

2.2.2 Piazza Vittorio Emanuele II, Caldarola

The BIM modelling of Piazza Vittorio Emanuele II in Caldarola has been realized according to the Level of Development (LoD) 350 (D312 §4.1). The geometric model includes detailed definition of both geometrical and informative data relating to the BET classification, as it comes from a Scan-to-BIM survey.

As the first step after importing the point cloud in Revit, the frontiers of Piazza Vittorio Emanuele II have been defined by dividing them into SAs and SUs according to the terminology described in §2.2.1 (Figure 8). The resulting 11 USs were then modelled as Generic Model (GM) from point cloud for the height and width data of the facades, while from CAD sources for the missing information of the planimetric development.

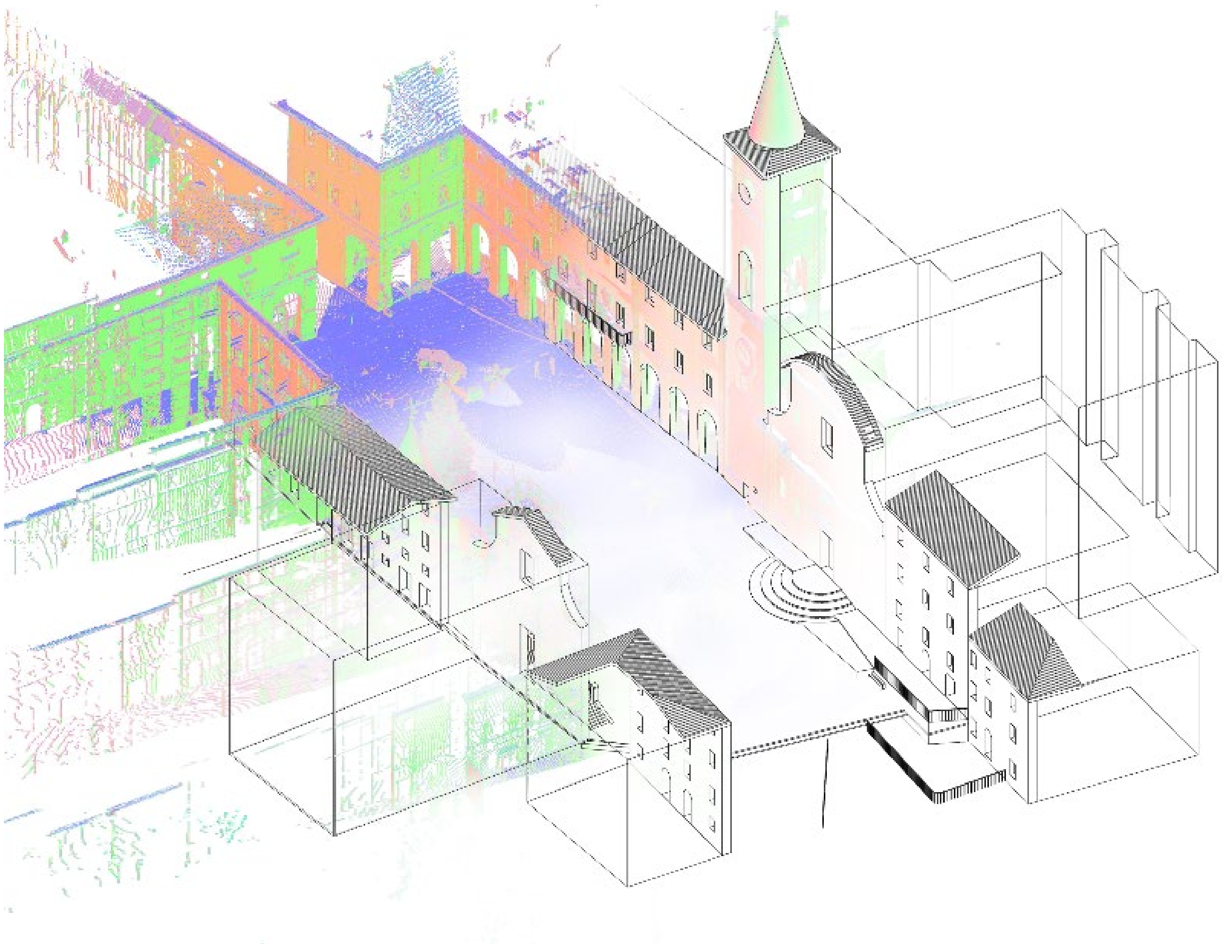


Figure 8. The resulted BIM model of Piazza Vittorio Emanuele II, Caldarola.

The walls of the GMs' facades were modelled as "wall-by-faces". A single wall type has been associated with each SU, since the facades have a uniform configuration and do not have any further disconnections within the SU itself, or at least disconnections are not detectable from the outside. However, some SUs have the same wall thickness, so a total of 6 different wall types were modelled according to the thicknesses 70, 75, 80, 90, 95, 170 cm.

The topography modelled from the point cloud shows a slight slope between SA 1 and 2 in the South-East side of the OS, where the square divides into two streets. Green areas are not present, but several urban furniture such as flowerpots are modelled. Five parking area are also modelled. The accesses to the square are 8 of various sizes and typology: 6 vehicular, 1 public and pedestrian and 2 private and pedestrian. Specifically, the SE side has 2 exclusive accesses to SU 2a and 1f. Due to this specific feature, the two SU have been modelled and considered within the BIM model, as users inside can evacuate to the square during disasters. Moreover, there are two porches in SU 1a/1b and 6a, whose floors have been modelled "covered floor".

The roofs were modelled on the basis of the geometry seen from the drone images. The type is also assumed from the roof layout. The OS frontier was completed with the various openings, such as windows or doors. Once the boundaries of the square were defined by walls and accesses, the space was automatically generated in the BIM model.

Differently from Narni, a new LL family has been added to represent the stairs and ramps in the square. They are in the 3 SUs: 1d, 3a and 2a. The two first are ascending staircases for the entrance to the churches; while, the third is descending steps for the entrance to the building. Such family is considered as "fixed obstacles" in the parameters' calculation.

2.3 Selection and implementation of risk parameters in BIM model for Bari and Caldarola

The procedure of BIM modelling is followed by risk parameters implementation. Risk parameters were preliminary selected based on type of BET and multi-hazard combination associated with the case study in the reduced matrix elaborated in D322, §9:

Table 2.Type of BET associated with the three case studies and related risk factors.

Case study	BET	M-H condition	Matrix	Table
Narni	2A	S+P	Type 2	Table 33, D322
Bari	4B	T+P+H	Type 2	Table 34, D322
Caldarola	1A	S+H	Type 2	Table 32, D322

Each parameter in the reduced matrix was catalogued into two main categories, based on the method to implement them in BIM environment: *fillable*, i.e., parameters that need to be filled by the users; *computable*, i.e., parameters that can be computable through the software (for Bari, see The risk parameters implementation referring to T-P-H is reported in the following table.

Table 4; for Caldarola, see Table 6). Then each parameter was associated to a family category, either HL or LL family, and implemented according to one of the following procedures:

- filled directly in HL families;
- filled in LL families and inherited by HL families with specific synthetic operations (direct transposition, average, sum, count minimum, maximum);
- computed in HL families using geometric properties of LL families with specific synthetic operations (direct transposition, average, sum, count, minimum, maximum).

According to the The IFC standard, the parameters were implemented in the new property set called "BeS2ecure multi-risk factors", organized into the five categories already set for the risk factors classification: Section 1 *Main type*, Section 2 Characteristics of geometry and space, Section 3 *Constructive characteristics*, Section 4 *Characteristics of use*, and Section 5 C*haracteristics of the context*. To each parameter was associated a name as consistent as possible with that of the international standard IFC 4.3. It was set with the following structure of the name: parameter code + associated BE component (i.e., OS or SU) + parameter description (for Bari, see Table 5; for Caldarola, see Table 7).

The parameters are implemented into the BIM models, developed in the Autodesk Revit environment, as "Shared Parameters", using the free add-in "ParaManager" developed by DiRoots.

The authors implemented several Dynamo nodes groups to extract data from Revit elements and systematize them, so to develop a repeatable workflow for other BET multi-risk case studies.

Table 3. Number of parameters implemented in each procedure in the models of Narni, Bari, and Caldarola.

	Narni	Bari	Caldarola
(i) Values implemented directly in HL families (no Dynamo operation are required)	18/77	28/87	26/80
(ii) Values implemented in LL families, then inherited in HL families with direct transposition	31/77	39/87	32/80
(iii) Values implemented in HL families, computing them using LL and HL geometric properties in Dynamo	28/77	19/87	22/80

2.3.1 Piazza dell'Odegitria Bari

The risk parameters implementation referring to T-P-H is reported in the following table.

Table 4. Reduced risk matrix for BET 4B and T-P-H multi-hazard condition, according to Table 34 of D322, suitable for Piazza dell'Odegitria in Bari.

BET multi-hazard parameters				BIM implementation				
Code	Description	Descriptor code	Descriptor	Family category (low level)	LL to HL	Family category (high level)	Comp.	Fill
SECTION 1: MAIN TYPE								
S1_0	Morpho-typology	P1	main class (compact/elongated/very elongated)	(Floor)		Space	X	
		S1_0.2	Canyon aspect ratio	(Wall; floor)		Space	X	
		S1_0.3	Proximity of sidewalk to traffic			Space		X
S1_1	Dimension of OS	S1_1.1	area			Space	X	
		S1_1.3	Width	(Floor)		Space	X	
S1_2	Hmax built front	S1_2.1	H max	(Wall)	Max	Space	X	
		S1_2.2	Average building height	(Wall)	Average	Space	X	
SECTION 2: CHARACTERISTICS OF GEOMETRY AND SPACE								
Frontier								
S2_F_1	Type of Aggregates	S2_F_1.1	% of SA			Space		X
		S2_F_1.2	length of the built front	(Wall)	Sum	Space	X	
		S2_F_1.3	number of SU			GM	X	
		S2_F_1.4	lenght of SU	(Wall)	Sum	GM	X	
		S2_F_1.5	height of SU front	(Wall)	Average	GM	X	
		S2_F_1.9	number of storeys	Wall	Max	GM		X
S2_F_2	Accesses	S2_F_2.1	number	(Road, space separation line)	Count	Space	X	
		S2_F_2.2	width	(Road, space separation line)	Average	Space	X	
		S2_F_2.3	position/orientation (azimuth)	Road	Average	Space		X

		S2_F_2.4	presence of mitigation/control systems	Road	Direct	Space		X
S2_F_3	Special buildings	P5	presence	Wall	Direct	GM		X
		S2_F_3.3	number	(Wall)	Count	Space	X	
S2_F_4a	Town walls	S2_F_4a.1	presence	Wall	Direct	GM		X
S2_F_4b	Porches	P7	presence	Floor	Direct	GM		X
		S2_F_4b.3	position	Floor	Direct	GM		X
		S2_F_4b.4	width or depth	(Floor)	Average	GM	X	
		S2_F_4b.5	area	(Floor)	Average	GM	X	
S2_F_5a	green area	P9f	presence of green area	Floor	Direct	Space		X
		S2_F_5.a2	Crowding potential	Floor	Direct	Space		X
		S2_F_5a.6	Green Area Position (related to LS or AS)	Floor	Direct	Space		X
		S2_F_5a.7	Green area density	Floor	Direct	Space		X
S2_F_5b	Water	S2_F_5b.1	Presence of Water	Floor	Direct	Space		X
		S2_F_5.b.2	Crowding potential	Floor	Direct	Space		X
		S2_F_5.b.3	Extension of water content	Floor	Direct	Space		X
		S2_F_5.b.5	Water body area	Floor	Sum	Space	X	
		S2_F_5.b.6	Water body volume	Floor	Sum	Space	X	
S2_F_6	Quote differences / slope	P8f	Slope	Floor	Direct	Space		X
Content								
S2_C_1	Special buildings	S2_C_1.2	number			GM		X
		S2_C_1.4	area			GM		X
S2_C_2	Quote difference/slope	P8	slope	(Floor, topography)	average	Space	X	
S2_C_4	Monuments (i.e. obelisk, statues, fontaine, archeol. site)	S2_C_4.1	presence fontaine	Furniture	Direct	Space		X
		S2_C_4.2	presence of monuments	Furniture	Direct	Space		X
		S2_C_4.4	number of monuments	(Furniture)	Sum	Space	X	
		S2_C_4.6	area	(Furniture)	Sum	Space	X	
S2_C_5a	Green area	P9c	Presence of Green area	Floor	Direct	Space		X
		S2_C_5a.1	crowding potential	Floor	Direct	Space		X
		S2_C_5a.4	extension (area)	Floor	Direct	Space		X
		S2_C_5a.6	Greenery adsoprtion capacity	Floor	Direct	Space		X
		S2_C_5a.10	Tree crown diameter	Floor	Direct	Space		X
SECTION 3: CONSTRUCTIVE CHARACTERISTICS								
Frontier								
S3_F_2	Homogeneity of constructive techniques	P6	homogeneous/not homogeneous	Floor	Direct	Space		X
		S3_F_2.16	Facade finishing albedo	Wall	Average	GM		X
		S3_F_2.18	Facade finishing current roughness	Wall	Average	GM		X
		S3_F_2.21	Facade heat capacity	Wall	Average	GM		X
		S3_F_2.22	Facade pollutant deposition capacity	Wall	Average	GM		X
S3_F_3	Fixed obstacles	S3_F_3.5	N. of mitigation system	(Furniture)	Sum	Space	X	

		S3_F_3.6	Mitigation systems	Furniture	Direct	Space		X
S3_F_4	Temporary obstacles	S3_F_4.3	N. of mitigation system	(Furniture)	Sum	Space	X	
		S3_F_4.4	Mitigation systems	Furniture	Direct	Space		X
Content								
S3_C_1	Pavement type	S3_C_1.4	Pavement finishing albedo	Floor	Direct	Space		X
S3_C_2	Pavement condition	S3_C_2.1	Classes of conditions	Floor	Direct	Space		X
		S3_C_2.3	Pavement finishing current roughness	Floor	Direct	Space		X
SECTION 4: CHARACTERISTICS OF USE								
S4_1	Crowding	S4_1.1	people presents			Space		X
		S4_1.2	crowding potential			Space		X
		S4_1.3	Tourism attraction			Space		X
		S4_1.4	Exposure duration			Space		X
S4_3	Strategic building / Special uses of building facing OS	S4_3.1	presence of special buildings or special uses	Wall	Direct	GM		X
		S4_3.2	crowding potential	Wall	Average	GM		X
		S4_3.3	Symbolism level	Wall	Max	GM		X
		S4_3.7	Sensitive targets attraction to building use	Wall	Direct	GM		X
S4_4	Accessibility for vehicle	S4_4.1	Incidence of accessibility to vehicles to total accesses			Space		X
		S4_4.2	Traffic intensity			Space		X
		S4_4.4	Level of accessibility			Space		X
S4_5	Accessibility for pedestrian	S4_5.1	Incidence of accessibility to pedestrian to total accesses			Space		X
S4_6	Vehicles (parking)	S4_6.1	Incidence (area for AS)			Space		X
		S4_6.5	Parking area location	(Parking)	Sum	Space	X	
S4_7	Sights	S4_7.1	Presence of sight			Space		X
		S4_7.4	Symbolism level			Space		X
S4_8	Sensitive targets	S4_8.1	Presence of Sensitive target (people as hard target)			Space		X
		S4_8.2	Presence of Sensitive target (elders/frail/gender/youngsters)			Space		X
		S4_8.3	% presence of Sensitive target (elders/frail/gender/youngsters)			Space		X
		S4_8.4	Symbolism level			Space		X
SECTION 5: ENVIRONMENTAL CHARACTERISTICS								
S5_2	Climate classification [DPR 412/1993]	S5_2.1	Climate zone			Space		X
S5_3	Climate conditions	S5_3.1	Wind/breeze speed			Space		X
		S5_3.3	Air temperature			Space		X
		S5_3.4	Solar Irradiation			Space		X
		S5_3.6	Pollutant concentration			Space		X
S5_4	Multi-hazard potential	S5_4.2	Pollution sources presence Boolean			Space		X
S5_5	Ground type	S5_5.2	Ground roughness			Space		X
		S5_5.3	Ground albedo			Space		X

S5_5.4	Ground heat capacity	Space	X

Table 5.Parameters' names, descriptions, and entities associated for Piazza dell'Odegitria in Bari.

SECTION 1		
Parameter Name	**Parameter Description**	**Entities**
S1_0_OpenSpaceMainClass	main class	IfcSpace
S1_0.2_OpenSpaceCanyonAspectRatio	Canyon aspect ratio	IfcSpace
S1_0.3_OpenSpaceProximitySidewalkToTraffic	Proximity of sidewalk to traffic	IfcSpace
S1_1.1_OpenSpaceArea	area	IfcSpace
S1_1.3_OpenSpaceWidth	Width	IfcSpace
S1_2.1_OpenSpaceBuiltFrontMaxHeight	H max	IfcSpace
S1_2.2_OpenSpaceBuiltFrontAverageHeight	Average building height	IfcSpace

SECTION 2		
Parameter Name	**Parameter Description**	**Entities**
S2_F_1.1_OpenSpaceStructuralAggregatePercentage	% of SA	IfcSpace
S2_F_1.2_StructuralUnitLenght	length of the built front	IfcSpace
S2_F_1.3_StructuralUnitNumber	number of SU	IfcBuildingElementProxy
S2_F_1.4_StructuralUnitLenght	lenght of SU	IfcBuildingElementProxy
S2_F_1.5_StructuralUnitHeight	height of SU front	IfcBuildingElementProxy
S2_F_1.9_StructuralUnitStoreysNumber	number of storeys	IfcWall, IfcBuildingElementProxy
S2_F_2.1_OpenSpaceAccessesNumber	number	IfcSpace
S2_F_2.2_OpenSpaceAccessWidth	width	IfcSpace
S2_F_2.3_OpenSpaceAccessOrientation	position/orientation	IfcRoad, IfcSpace
S2_F_2.4_OpenSpaceAccessMitigationSystemsPresence	presence of mitigation/control systems	IfcRoad, IfcSpace
S2_F_3_StructuralUnitSpecialBuildingPresence	presence	IfcWall, IfcBuildingElementProxy
S2_F_3.3_OpenSpaceSpecialBuildingPNumber	number	IfcSpace
S2_F_4a.1_StructuralUnitTownWallsPresence	presence	IfcWall, IfcBuildingElementProxy
S2_F_4b_StructuralUnitPorchesPresence	presence	IfcWall, IfcBuildingElementProxy
S2_F_4b.3_StructuralUnitPorchesOrientation	position	IfcWall, IfcBuildingElementProxy
S2_F_4b.4_StructuralUnitPorchesWidth	width or depth	IfcWall, IfcBuildingElementProxy
S2_F_4b.5_StructuralUnitPorchesArea	area	IfcWall, IfcBuildingElementProxy
S2_F_5a_OpenSpaceGreenAreaPresence	presence of green area	IfcFloor, IfcSpace
S2_F_5.a2_OpenSpaceGreenAreaCrowdingPotencial	Crowding potential	IfcFloor, IfcSpace
S2_F_5a.6_OpenSpaceGreenAreaPosition	Green Area Position (related to LS or AS)	IfcFloor, IfcSpace
S2_F_5a.7_OpenSpaceGreenAreaDensity	Green area density	IfcFloor, IfcSpace
S2_F_5b.1_OpenSpaceWaterPresence	Presence of Water	IfcFloor, IfcSpace
S2_F_5.b.2_OpenSpaceWaterCrowdingPotencial	Crowding potential	IfcFloor, IfcSpace
S2_F_5.b.3OpenSpaceWaterExtension	Extension of water content	IfcFloor, IfcSpace
S2_F_5.b.6_OpenSpaceWaterArea	Water body area	IfcFloor, IfcSpace
S2_F_5.b.7_OpenSpaceWaterVolume	Water body volume	IfcFloor, IfcSpace
S2_F_6_OpenSpaceSlope	Slope	IfcFloor, IfcSpace
S2_C_1.2_StructuralUnitSpecialBuildingsNumber	number	IfcBuildingElementProxy
S2_C_1.4_StructuralUnitSpecialBuildingsArea	area	IfcBuildingElementProxy
S2_C_2_OpenSpaceSlope	slope	IfcSpace
S2_C_4.1_OpenSpaceFontainePresence	presence fontaine	IfcFurniture, IfcSpace
S2_C_4.2_OpenSpaceMonumentsPresence	presence of monuments	IfcSpace

S2_C_4.4_OpenSpaceMonumentsNumber	number of monuments	IfcSpace
S2_C_4.6_OpenSpaceMonumentsArea	area	IfcSpace
S2_C_5a_OpenSpaceGreenAreaPresence	Presence of Green area	IfcFloor, IfcSpace
S2_C_5a.1_OpenSpaceGreenAreaCrowdingPotencial	crowding potential	IfcFloor, IfcSpace
S2_C_5a.4_OpenSpaceGreenAreaExtension	extension (area)	IfcFloor, IfcSpace
S2_C_5a.6_OpenSpaceGreenAreaAdsorptionCapacity	Greenery adsoprtion capacity	IfcFloor, IfcSpace
S2_C_5a.10_OpenSpaceGreenAreaDiameterOfTreeCrown	Tree crown diameter	IfcFloor, IfcSpace

SECTION 3		
Parameter Name	**Parameter Description**	**Entities**
S3_F_2_OpenSpaceConstructionTechniquesHomogeneity	homogeneous/not homogeneous	IfcFloor, IfcSpace
S3_F_2.16_StructuralUnitFinishingAlbedo	Facade finishing albedo	IfcWall, IfcBuildingElementProxy
S3_F_2.18_StructuralUnitFinishingRoughness	Facade finishing current roughness	IfcBuildingElementProxy
S3_F_2.21_StructuralUnitHeatCapacity	Facade heat capacity	IfcBuildingElementProxy
S3_F_2.22_StructuralUnitPollutantDepositionCapacity	Facade pollutant deposition capacity	IfcBuildingElementProxy
S3_F_3.5_OpenSpaceFixedMitigationSystemsNumber	N. of mitigation system	IfcSpace
S3_F_3.6_OpenSpaceFixedMitigationSystemsPresence	Mitigation systems	IfcFurniture, IfcSpace
S3_F_4.3_OpenSpaceTemporaryMitigationSystemsNumber	N. of mitigation system	IfcSpace
S3_F_4.4_OpenSpaceTemporaryMitigationSystemsPresence	Mitigation systems	IfcFurniture, IfcSpace
S3_C_1.4_OpenSpacePavementFinishingAlbedo	Pavement finishing albedo	IfcFloor, IfcSpace
S3_C_2.1_OpenSpacePavementCondition	Classes of conditions	IfcFloor, IfcSpace
S3_C_2.3_OpenSpacePavementFinishingRoughness	Pavement finishing current roughness	IfcFloor, IfcSpace

SECTION 4		
Parameter Name	**Parameter Description**	**Entities**
S4_1.1_OpenSpacePeoplePresence	people presents	IfcSpace
S4_1.2_OpenSpaceCrowdingPotential	crowding potential	IfcSpace
S4_1.3_OpenSpaceTourismAttraction	Tourism attraction	IfcSpace
S4_1.4_OpenSpaceExposureDuration	Exposure duration	IfcSpace
S4_3.1_StructuralUnitSpecialBuildingPresence	presence of special buildings or special uses	IfcWall, IfcBuildingElementProxy
S4_3.2_StructuralUnitStrategicBuildingCrowdingPotential	crowding potential	IfcWall, IfcBuildingElementProxy
S4_3.3_StructuralUnitStrategicBuildingSymbolismLevel	Symbolism level	IfcWall, IfcBuildingElementProxy
S4_3.7_StructuralUnitSensitiveTargetPresence	Sensitive targets attraction to building use	IfcWall, IfcBuildingElementProxy
S4_4.1_OpenSpaceVehiclesAccessibilityIncidence	Incidence of accessibility to vehicles to total accesses	IfcSpace
S4_4.2_OpenSpaceTrafficIntensity	Traffic intensity	IfcSpace
S4_4.4_OpenSpaceVehiclesAccessibilityLevel	Level of accessibility	IfcSpace
S4_5.1_OpenSpacePedestrianAccessibilityIncidence	Incidence of accessibility to pedestrian to total accesses	IfcSpace
S4_6.1_OpenSpaceParkingIncidence	Incidence (area for AS)	IfcSpace
S4_6.5_OpenSpaceParkingAreaLocation	Parking area location	IfcSpace
S4_7.1_OpenSpaceSightPresence	Presence of sight	IfcSpace
S4_7.4_OpenSpaceSightSymbolismLevel	Symbolism level	IfcSpace
S4_8.1_OpenSpaceHardTargetPresence	Presence of Sensitive target (people as hard target)	IfcSpace
S4_8.2_OpenSpaceSensitiveTargetPresence	Presence of Sensitive target (elders/frail/gender/youngsters)	IfcSpace
S4_8.3_OpenSpaceSensitiveTargetPresencePercentage	% presence of Sensitive target (elders/frail/gender/youngsters)	IfcSpace

S4_8.4_OpenSpaceSensitiveTargetSymbolismLevel	Symbolism level	IfcSpace

SECTION 5		
Parameter Name	**Parameter Description**	**Entities**
S5_2.1_OpenSpaceClimateZone	Climate zone	IfcSpace
S5_3.1_OpenSpaceWindSpeed	Wind/breeze speed	IfcSpace
S5_3.3_OpenSpaceAirTemperature	Air temperature	IfcSpace
S5_3.4_OpenSpaceSolarIrradiation	Solar Irradiation	IfcSpace
S5_3.6_OpenSpacePollutantConcentration	Pollutant concentration	IfcSpace
S5_4.2_OpenSpacePollutionSourcesPresence	Pollution sources presence Boolean	IfcSpace
S5_5.2_OpenSpaceGroundRoughness	Ground roughness	IfcSpace
S5_5.3_OpenSpaceGroundAlbedo	Ground albedo	IfcSpace
S5_5.4_OpenSpaceGoundHeatCapacity	Ground heat capacity	IfcSpace

2.3.2 Piazza Vittorio Emanuele II, Caldarola

The risk parameters implementation referring to S-H is reported in the following table.

Table 6. Reduced risk matrix for BET 1A and S-H multi-hazard condition, according to Table 32 of D322, suitable for Piazza Vittorio Emanuele II in Caldarola.

BET multi-hazard parameters				BIM implementation				
Code	**Description**	**Descriptor code**	**Descriptor**	**Family category (low level)**	**LL to HL**	**Family category (high level)**	**Comp.**	**Fill**
SECTION 1: MAIN TYPE								
S1_0	Morpho-typology	P1	main class (compact/elongated/very elongated)	(Floor)		Space	X	
		S1_0.2	Canyon aspect ratio	(Wall; floor)		Space	X	
S1_1	Dimension of OS	S1_1.3	Width	(Floor)		Space	X	
S1_2	Hmax built front	S1_2.1	H max	(Wall)	Max	Space	X	
		S1_2.2	Average building height	(Wall)	Average	Space	X	
SECTION 2: CHARACTERISTICS OF GEOMETRY AND SPACE								
Frontier								
S2_F_1	Type of Aggregates	S2_F_1.1	% of SA			Space		X
		S2_F_1.2	length of the built front	(Wall)	Sum	Space	X	
		S2_F_1.3	number of SU			Mass	X	
		S2_F_1.4	lenght of SU	(Wall)	Sum	Mass	X	
		S2_F_1.5	height of SU front	(Wall)	Average	Mass	X	
		S2_F_1.9	number of storeys	Wall	Max	Mass		X
S2_F_2	Accesses	S2_F_2.1	number	(Road, space separation line)	Count	Space	X	
		S2_F_2.2	width	(Road, space	Average	Space	X	

				separation line)				
		S2_F_2.3	position/orientation (azimuth)	Road	Average	Space		X
S2_F_3	Special buildings	P5	presence	Wall	Direct	Mass		X
		S2_F_3.4	lenght of special buildings front	(Wall)	Sum	Mass	X	
		S2_F_3.5	height	(Wall)	Average	Mass	X	
		S2_F_3.7	height of gable	(Wall, Roof)	Max	Mass	X	
S2_F_4a	Town walls	S2_F_4a.1	presence	Wall	Direct	Mass		X
		S2_F_4a.2	linear extension			Mass		X
		S2_F_4a.3	position			Mass		X
		S2_F_4a.4	width or depth			Mass		X
S2_F_4b	Porches	P7	presence	Floor	Direct	Mass		X
		S2_F_4b.2	linear extension	(Floor)	Sum	Mass	X	
		S2_F_4b.3	position	Floor	Direct	Mass		X
		S2_F_4b.4	width or depth	(Floor)	Average	Mass	X	
		S2_F_4b.5	area	(Floor)	Average	Mass	X	
S2_F_5a	green area	P9f	presence of green area	Floor	Direct	Space		X
		S2_F_5a.6	Green Area Position (related to LS or AS)	Floor	Direct	Space		X
		S2_F_5a.7	green area density	Floor	Direct	Space		X
S2_F_5b	Water	S2_F_5b.1	Presence of Water	Floor	Direct	Space		X
		S2_F_5.b.5	Water body area	Floor	Sum	Space	X	
		S2_F_5.b.6	Water body volume	Floor	Sum	Space	X	
S2_F_6	Quote differences / slope	P8f	slope	Floor	Direct	Space		X
Content								
S2_C_1	Special buildings	S2_C_1.3	height			Mass		X
		S2_C_1.5	lenght			Mass		X
		S2_C_1.6	width			Mass		X
		S2_C_1.7	height of gable			Mass		X
S2_C_2	Quote difference/slope	P8	slope	(Floor, topography)	average	Space		X
S2_C_5a	Green area	P9c	Presence of Green area	Floor	Direct	Space		X
		S2_C_5a.4	extension (area)	Floor	Direct	Space		X
		S2_C_5a.10	Tree crown diameter	Floor	Direct	Space		X
	SECTION 3: CONSTRUCTIVE CHARACTERISTICS							
Frontier								
S3_F_1	Homogeneity of built environment age	S3_F_1.2	last intervention period			Mass		X
		S3_F_1.3	state of conservation			Mass		X
		S3_F_1.4	wall disconnection in plan	Wall	Direct	Mass		X
		S3_F_1.5	wall disconnection in elevation	Wall	Direct	Mass		X
S3_F_2	Homogeneity of constructive techniques	P6	homogeneous/not homogeneous	Floor	Direct	Space		X

		S3_F_2.2	masonry quality	Wall	Min	Mass		X
		S3_F_2.3	wall thickness	(Wall)	Average	Mass	X	
		S3_F_2.5	roofs types	Roof	Min	Mass		X
		S3_F_2.8	% openings	(Wall)	Average	Mass	X	
		S3_F_2.13	no-structural protruding and decorative elements	Wall	Direct	Mass		X
		S3_F_2.14	anti-seismic devices	Wall	Min	Mass		X
		S3_F_2.16	Facade finishing albedo	Wall	Average	Mass		X
		S3_F_2.18	Facade finishing current roughness	Wall	Average	Mass		X
		S3_F_2.22	Facade pollutant deposition capacity	Wall	Average	Mass		X
Content								
S3_C_1	Pavement type	S3_C_1.4	Pavement finishing albedo	Floor	Direct	Space		X
S3_C_2	Pavement condition	S3_C_2.3	Pavement finishing current roughness	Floor	Direct	Space		X
SECTION 4: CHARACTERISTICS OF USE								
S4_1	Crowding	S4_1.1	people presents			Space		X
		S4_1.2	crowding potential			Space		X
		S4_1.4	Exposure duration			Space		X
S4_3	Strategic building / Special uses of building facing OS	S4_3.1	presence of special buildings or special uses	Wall	Direct	Mass		X
		S4_3.2	crowding potential	Wall	Average	Mass		X
		S4_3.4	Presence of Schools	Wall	Direct	Mass		X
		S4_3.5	Presence of Hospitals	Wall	Direct	Mass		X
		S4_3.7	Sensitive targets attraction to building use	Wall	Direct	Mass		X
S4_4	Accessibility for vehicle	S4_4.2	Traffic intensity			Space		X
S4_6	Vehicles (parking)	S4_6.5	Parking area location	(Parking)	Sum	Space	X	
S4_8	Sensitive targets	S4_8.2	presence of Sensitive target (elders/frail/gender/youngsters)			Space		X
		S4_8.3	% presence of Sensitive target (elders/frail/gender/youngsters)			Space		X
SECTION 5: ENVIRONMENTAL CHARACTERISTICS								
S5_1	Seismic intensity	S5_1.1	Ground motion severity			Space		X
		S5_1.2	Seismic microzonation			Space		X
S5_2	Climate classification [DPR 412/1993]	S5_2.1	Climate zone			Space		X
S5_3	Climate conditions	S5_3.1	Wind/breeze speed			Space		X
		S5_3.3	Air temperature			Space		X
		S5_3.4	Solar Irradiation			Space		X
S5_5	Ground type	S5_5.1	classes of types			Space		X
		S5_5.2	Ground roughness			Space		X
		S5_5.3	Ground albedo			Space		X
		S5_5.4	Ground heat capacity			Space		X

Table 7. Parameters' names, descriptions, and entities associated for Piazza Vittorio Emanuele II in Caldarola.

Parameter Name	Parameter Description	Entities
S1_0_OpenSpaceMainClass	main class	IfcSpace
S1_0.2_OpenSpaceCanyonAspectRatio	Canyon aspect ratio	IfcSpace
S1_1.1_OpenSpaceArea	area	IfcSpace
S1_1.3_OpenSpaceWidth	Width	IfcSpace
S1_2.1_OpenSpaceBuiltFrontMaxHeight	H max	IfcSpace
S1_2.2_OpenSpaceBuiltFrontAverageHeight	Average building height	IfcSpace

Table 8. Parameters for "Section 2 Characteristics of geometry and space", their name, and entities associated for Piazza Vittorio Emanuele II in Caldarola.

SECTION 2		
Parameter Name	**Parameter Description**	**Entities**
S2_F_1.1_OpenSpaceStructuralAggregatePercentage	% of SA	IfcSpace
S2_F_1.2_StructuralUnitLeght	Length of the built front	IfcSpace
S2_F_1.3_StructuralUnitNumber	Number of SU	IfcBuilldingElementProxy
S2_F_1.4_StructuralUnitLenght	Length of SU	IfcBuilldingElementProxy
S2_F_1.5_StructuralUnitHeight	Height of SU front	IfcBuilldingElementProxy
S2_F_1.9_StructuralUnitStoreysNumber	Number of storeys	IfcWall, IfcBuilldingElementProxy
S2_F_2.1_OpenSpaceAccessesNumber	Number	IfcSpace
S2_F_2.2_OpenSpaceAccessWidth	Width	IfcSpace
S2_F_2.3_OpenSpaceAccessOrientation	Position/orientation	IfcRoad, IfcSpace
S2_F_3_StructuralUnitSpecialBuildingPresence	Presence	IfcWall, c
S2_F_3.4_StructuralUnitSpecialBuildingBuiltFrontLenght	Length of Special Buildings fronts	IfcBuilldingElementProxy
S2_F_3.5_StructuralUnitSpecialBuildingHeight	Height	IfcBuilldingElementProxy
S2_F_3.7_StructuralUnitSpecialBuildingGableHeight	Height of gable	IfcBuilldingElementProxy
S2_F_4a.1_StructuralUnitTownWallsPresence	Presence	IfcWall, IfcBuilldingElementProxy
S2_F_4a.2_StructuralUnitTownWallsLinearExtension	Linear extension	IfcBuilldingElementProxy
S2_F_4a.3_StructuralUnitTownWallsPosition	Position	IfcBuilldingElementProxy
S2_F_4a.4_StructuralUnitTownWallsDepth	Width or depth	IfcBuilldingElementProxy
S2_F_4b_StructuralUnitPorchesPresence	Presence	IfcFloor, IfcBuilldingElementProxy
S2_F_4b.2_StructuralUnitPorchesLenght	Linear extension	IfcBuilldingElementProxy
S2_F_4b.3_StructuralUnitPorchesOrientation	Position	IfcFloor, IfcBuilldingElementProxy
S2_F_4b.4_StructuralUnitPorchesWidth	Width or depth	IfcBuilldingElementProxy
S2_F_4b.5_StructuralUnitPorchesArea	Area	IfcBuilldingElementProxy
S2_F_5a_OpenSpaceGreenAreaPresence	Presence of green area	IfcFloor, IfcSpace
S2_F_5a.6_OpenSpaceGreenAreaPosition	Green area position	IfcFloor, IfcSpace
S2_F_5a.7_OpenSpaceGreenAreaDensity	Green area density	IfcFloor, IfcSpace
S2_F_5b.1_OpenSpaceWaterPresence	Presence of water	IfcFloor, IfcSpace
S2_F_5b.6_OpenSpaceWaterArea	Area of water	IfcFloor, IfcSpace
S2_F_6_OpenSpaceSlope	Slope	IfcFloor, IfcSpace
S2_C_1.3_StructuralUnitSpecialBuildingHeight	Special building height	IfcBuilldingElementProxy
S2_C_1.5_StructuralUnitSpecialBuildingLenght	Special building length	IfcBuilldingElementProxy
S2_C_1.6_StructuralUnitSpecialBuildingWidth	Special building width	IfcBuilldingElementProxy
S2_C_1.7_StructuralUnitSpecialBuildingGableHeight	Special building height of gable	IfcBuilldingElementProxy
S2_C_2_OpenSpaceSlope	Slope	IfcSpace
S2_C_5a_OpenSpaceGreenAreaPresence	Presence of Green area	IfcFloor, IfcSpace

S2_C_5a.4_OpenSpaceGreenAreaExtension	Extension (area)	IfcFloor, IfcSpace
S2_C_5a.10_OpenSpaceGreenAreaDiameterOfTreeCrown	Tree crown diameter	IfcFloor, IfcSpace

Table 9. Parameters for "Section 3 Characteristics of geometry and space", their name, and entities associated for Piazza Vittorio Emanuele II in Caldarola.

SECTION 3		
Parameter Name	**Parameter Description**	**Entities**
S3_F_1.2_StructuralUnitPeriodOfLastIntervention	Last intervention period	IfcBuildingElementProxy
S3_F_1.3_StructuralUnitStateOfConservation	State of conservation	IfcBuildingElementProxy
S3_F_1.4_StructuralUnitWallDisconnectionPlan	Wall disconnection in plan	IfcWall, IfcBuildingElementProxy
S3_F_1.5_StructuralUnitWallDisconnectionElevation	Wall disconnection in elevation	IfcWall, IfcBuildingElementProxy
S3_F_2_OpenSpaceConstructionTechniquesHomogeneity	Homogeneous/not homogeneous	IfcFloor, IfcSpace
S3_F_2.2_StructuralUnitMasonryQuality	Masonry quality	IfcWall, IfcBuildingELementProxy
S3_F_2.3_StructuralUnitMasonryThickness	Wall thickness	IfcBuildingElementProxy
S3_F_2.5_StructuralUnitRoofType	Roofs type	IfcRoof, IfcBuildingELementProxy
S3_F_2.8_StructuralUnitOpeningsPercentage	% openings	IfcBuildingElementProxy
S3_F_2.13_StructuralUnitDecorativeElementsPresence	Presence of decorative elements	IfcWall, IfcBuildingElementProxy
S3_F_2.14_StructuralUnitAntiSeismicDevicesPresence	Anti-seismic devices	IfcWall, IfcBuildingElementProxy
S3_F_2.16_StructuralUnitFinishingAlbedo	Facade finishing albedo	IfcWall, IfcBuildingElementProxy
S3_F_2.18_StructuralUnitFinishingRoughness	Facade finishing current roughness	IfcWall, IfcBuildingElementProxy
S3_F_2.22_StructuralUnitPollutantDepositionCapacity	Facade pollutant deposition capacity	IfcWall, IfcBuildingElementProxy
S3_C_1.4_OpenSpacePavementFinishingAlbedo	Pavement finishing albedo	IfcFloor, IfcSpace
S3_C_2.3_OpenSpacePavementFinishingRoughness	Pavement finishing current roughness	IfcFloor, IfcSpace

Table 10. Parameters for "Section 4 Characteristics of geometry and space", their name, and entities associated for Piazza Vittorio Emanuele II in Caldarola.

SECTION 4		
Parameter Name	**Parameter Description**	**Entities**
S4_1.1_OpenSpacePeoplePresence	Presence of people	IfcSpace
S4_1.2_OpenSpaceCrowdingPotential	Crowding potential	IfcSpace
S4_1.4_OpenSpaceExposureDuration	Exposure duration	IfcSpace
S4_3.1_StructuralUnitSpecialBuildingPresence	Presence of Special Buildings or special uses	IfcWall, IfcBuildingElementProxy
S4_3.2_StructuralUnitStrategicBuildingCrowdingPotential	Crowding potential	IfcWall, IfcBuildingElementProxy
S4_3.4_StructuralUnitSchoolsPresence	Presence of schools	IfcWall, IfcBuildingElementProxy
S4_3.5_StructuralUnitHospitalsPresence	Presence of hospitals	IfcWall, IfcBuildingElementProxy
S4_3.7_StructuralUnitSensitiveTargetPresence	Sensitive targets attraction to building use	IfcWall, IfcBuildingElementProxy
S4_4.2_OpenSpaceTrafficIntensity	Traffic intensity	IfcSpace
S4_6.5_OpenSpaceParkingAreaLocation	Parking area location	IfcSpace
S4_8.2_OpenSpaceSensitiveTargetPresence	Presence of sensitive target (elders/frail/gender/youngsters)	IfcSpace
S4_8.3_OpenSpaceSensitiveTargetPresencePercentage	% presence of sensitive target (elders/frail/gender/youngsters)	IfcSpace

Table 11. Parameters for "Section 5 Characteristics of geometry and space", their name, and entities associated for Piazza Vittorio Emanuele II in Caldarola.

SECTION 5		
Parameter Name	**Parameter Description**	**Entities**
S5_1.1_OpenSpaceGroundMotionSeverity	Ground motion severity	IfcSpace
S5_1.2_OpenSpaceSeismicMicrozonation	Seismic microzonation	IfcSpace

S5_2.1_OpenSpaceClimateZone	Climate zone	IfcSpace
S5_3.1_OpenSpaceWindSpeed	Wind/breeze speed	IfcSpace
S5_3.3_OpenSpaceAirTemperature	Air Temperature	IfcSpace
S5_3.4_OpenSpaceSolarIrradiation	Solar irradiation	IfcSpace
S5_5.1_OpenSpaceGroundClassType	Pollutant concentration	IfcSpace
S5_5.2_OpenSpaceGroundRoughness	Ground roughness	IfcSpace
S5_5.3_OpenSpaceGroundAlbedo	Ground albedo	IfcSpace
S5_5.4_OpenSpaceGoundHeatCapacity	Ground heat capacity	IfcSpace

3. Results and discussions

As for the case of the BIM model of Piazza dei Priori, also for Piazza dell'Odegitria in Bari and Piazza Vittorio Emanuele II in Caldarola was chosen a Level of Development (LOD) of 350 for the OS digitalization (D312 §4.1) to appropriately represent the characteristics of the two case studies. LOD 350 is informed by the results of the BET classification and includes a more detailed definition of both geometrical and informative data as it comes from a Scan-to-BIM survey.

3.1 Piazza dell'Odegitria Bari

Table 12. Fillable parameters for wall and roof (*) category from the reduced risk matrix from D322 and T-H-P multi-hazard condition.

	SA (Structural aggregates)	1		2											3			4					5	
	SU - Generic Model	1a	1b	2a	2b	2c	2d	2e	2f	2g	2h	2i	2j	2k	3a	3b	3c	4a	4b	4c	4d	4e	5a	5b
Sez. 2																								
S2_F_1.9	number of storeys		3	1	3	3	4	3	3	5	2	4	4	1	3	1	4	3	3	3	3	3	3	
S2_F_3	presence (special building)		no	yes	no	no	no	no	no	no	no	no	yes	yes	no	no	no	no	no	no	no	no	no	
S2_F_4a.1	presence (town walls)	no		no											no			no					no	
S2_F_4b	presence (porches)		no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	
Sez. 3																								
S3_F_2.16	Facade finishing albedo		0,6	0,6	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,6	0,6	0,6	0,5	0,5	0,5	0,5	0,5	0,6	0,5	0,6	0,5	
S3_F_2.18	Facade finishing current roughness		0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	
S3_F_2.22	Facade pollutant deposition capacity		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Sez. 4																								
S4_3.1	presence of special buildings or special uses		no	yes	no	no	no	no	no	no	no	no	no	yes	no	no	no	no	no	no	no	no	no	
S4_3.2	crowding potential		0,4	0,4	0,4	0,4	0,4	0,1	0,4	/	/	0,7	0,7	0,7	0,7	/	/	0,4	/	/	0,1	0,4	/	
S4_3.3	Symbolism level		no	no	no	no	no	no	no	no	no	no	no	yes	no	no	no	no	no	no	no	no	no	
S4_3.7	sensitive targets attraction to building use	no	no	no	no	no	no	no	no	no	no	no	no	yes	no	no	no	no	no	no	no	no	no	
S4_1.4	Exposure duration	***																						

***

Day hour	1	2	3	4	5	6	7	8	9	10	11	12
Value	0.09	0.09	0.09	0.09	0.09	0.12	0.20	0.24	0.29	0.30	0.30	0.30
Day hour	13	14	15	16	17	18	19	20	21	22	23	24
Value	0.26	0.17	0.16	0.27	0.30	0.32	0.37	0.36	0.22	0.20	0.18	0.17

The 21 parameters in Table 13 are associated with the LL family floor representing the OS of the square. Figure 9 shows the floor of the square and the relative parameters.

Table 13: Fillable parameters for floor family category from the reduced risk matrix from D322 and T-H-P hazard condition.

	Paving - Floor	square
S2_C_5a.1	OpenSpaceGreenAreaCrowdingPotencial	
S2_C_5a.4	OpenSpaceGreenAreaExtension	
S2_C_5a.6	OpenSpaceGreenAreaAdsorptionCapacity	
S2_C_5a.10	OpenSpaceGreenAreaDiameterOfTreeCrown	
S2_C_5a	OpenSpaceGreenAreaPresence	No
S2_F_4b.3	StructuralUnitPorchesOrientation	
S2_F_4b	StructuralUnitPorchesPresence	No
S2_F_5.a2	OpenSpaceGreenAreaCrowdingPotencial	
S2_F_5.b.2	OpenSpaceWaterCrowdingPotencial	
S2_F_5.b.3	OpenSpaceWaterExtension	
S2_F_5.b.6	OpenSpaceWaterArea	
S2_F_5.b.7	OpenSpaceWaterVolume	
S2_F_5a.6	OpenSpaceGreenAreaPosition	
S2_F_5a.7	OpenSpaceGreenAreaDensity	
S2_F_5a	OpenSpaceGreenAreaPresence	No
S2_F_5b.1	OpenSpaceWaterPresence	No
S2_F_6	OpenSpaceSlope	0.74°
S3_C_1.4	OpenSpacePavementFinishingAlbedo	0.5
S3_C_2.1	OpenSpacePavementCondition	damaged
S3_C_2.3	OpenSpacePavementFinishingRoughness	0.02
S3_F_2	OpenSpaceConstructionTechniquesHomogeneity	Yes

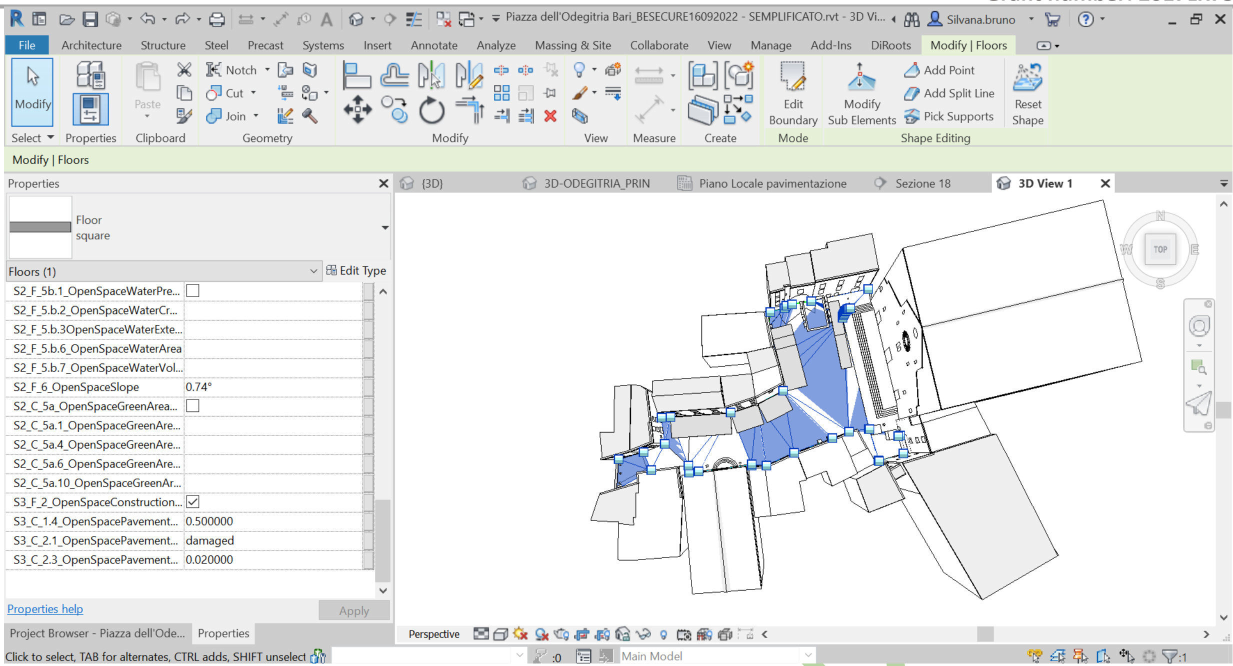


Figure 9 Parameters associated with LL Floor family.

	Access- road	1	2	3	4	5	6	7
S2_F_2.3	position/orientation (azimuth)	95°	0°	330°	257°	170°	270°	176°
S2_F_2.4	OpenSpaceAccessMitigationSystemsPresence	yes	no	no	yes	yes	no	yes

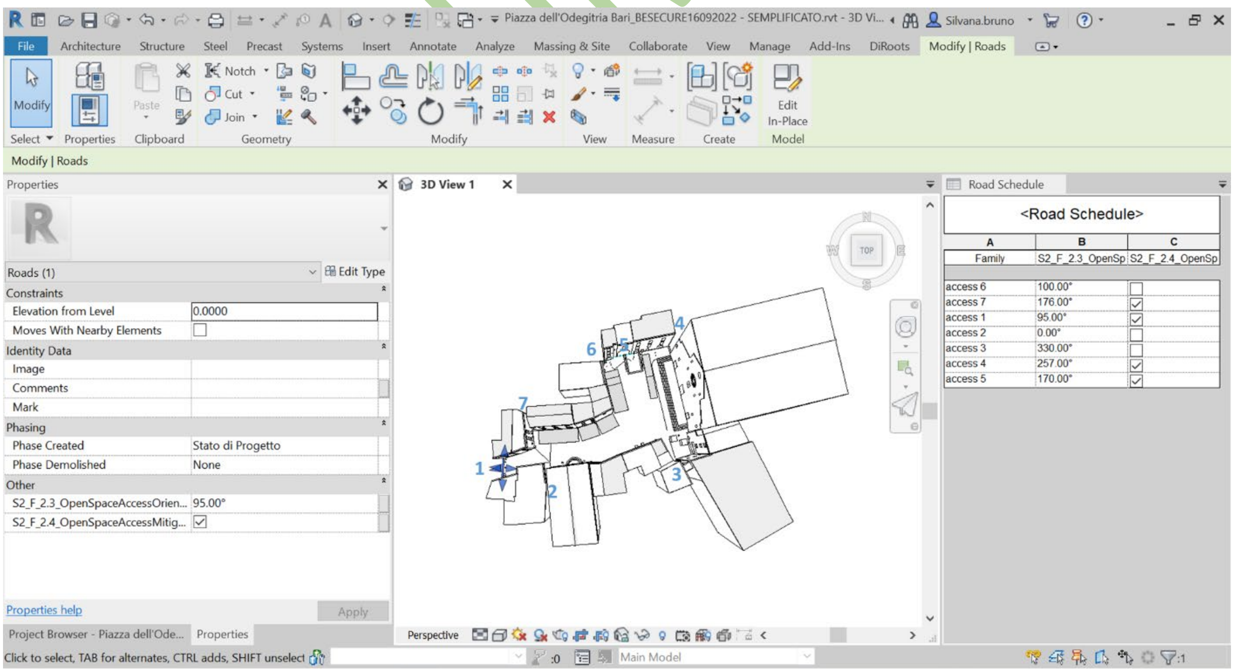


Figure 10 Parameter associated with LL Road family and the resulted schedule.

Further parameters are filled within the Generic Models of Structural Units, as HL family; in particular, they are related to special buildings, providing number and area in square meters (Table 14). The SA 2 presents more special buildings, consisting in Cattedrale di San Sabino (and related offices) and San Giacomo Church.

Table 14: Fillable parameters for GM family category from the reduced risk matrix from D322 and T-H-P multi-hazard condition.

SA (Structural aggregates)		1		2											3			4					5	
	SU - Generic Model	1a	1b	2a	2b	2c	2d	2e	2f	2g	2h	2i	2j	2k	3a	3b	3c	4a	4b	4c	4d	4e	5a	5b
S2_C_1.2	SpecialBuildingsNumber			1								1	1	1										
S2_C_1.4	SpecialBuildingsArea			300,87								501,39	92,44	1798,2										

Table 15 contains the filled values of those parameters (26) related to the Space element of Piazza dell'Odegitria, Bari, according to the reduced matrix from D332 and T-H-P multi-hazard condition.

Table 15 Fillable parameters for space family category from the reduced risk matrix from D322 and T-H-P multi-hazard condition.

	AS-space	square	
S1_0.3	Proximity of sidewalk to traffic	0	Milano/Bari
S2_F_1.1	% of SA	0.93	~~Bari~~
S4_1.1	people presents	-	Ancona
S4_1.2	crowding potential	-	Ancona
S4_1.3	Tourism attraction	-	Bari/Ancona
S4_1.4	Exposure duration	-	Ancona
S4_4.1	Incidence of accessibility to vehicles to total accesses	100%	Bari
S4_4.2	Traffic intensity	-	Milano
S4_4.4	Level of accessibility	-	Bari
S4_5.1	Incidence of accessibility to pedestrian to total accesses	-	Bari
S4_6.1	Incidence (area for AS)	-	Bari
S4_7.1	Presence of sight	Yes	Bari
S4_7.4	Symbolism level	High	Bari
S4_8.1	Presence of Sensitive target (people as hard target)	No	Bari
S4_8.2	Presence of Sensitive target (elders/frail/gender/youngsters)	-	Ancona
S4_8.3	% presence of Sensitive target (elders/frail/gender/youngsters)	-	Ancona
S4_8.4	Symbolism level	-	Bari
S5_2.1	Climate zone	C	Milano
S5_3.1	Wind/breeze speed	-	Milano
S5_3.3	Air temperature	-	Milano
S5_3.4	Solar Irradiation	-	Milano
S5_3.6	Pollutant concentration	-	Milano
S5_4.2	Pollution sources presence Boolean	-	Milano
S5_5.2	Ground roughness	-	Milano
S5_5.3	Ground albedo	-	Milano
S5_5.4	Ground heat capacity	-	Milano

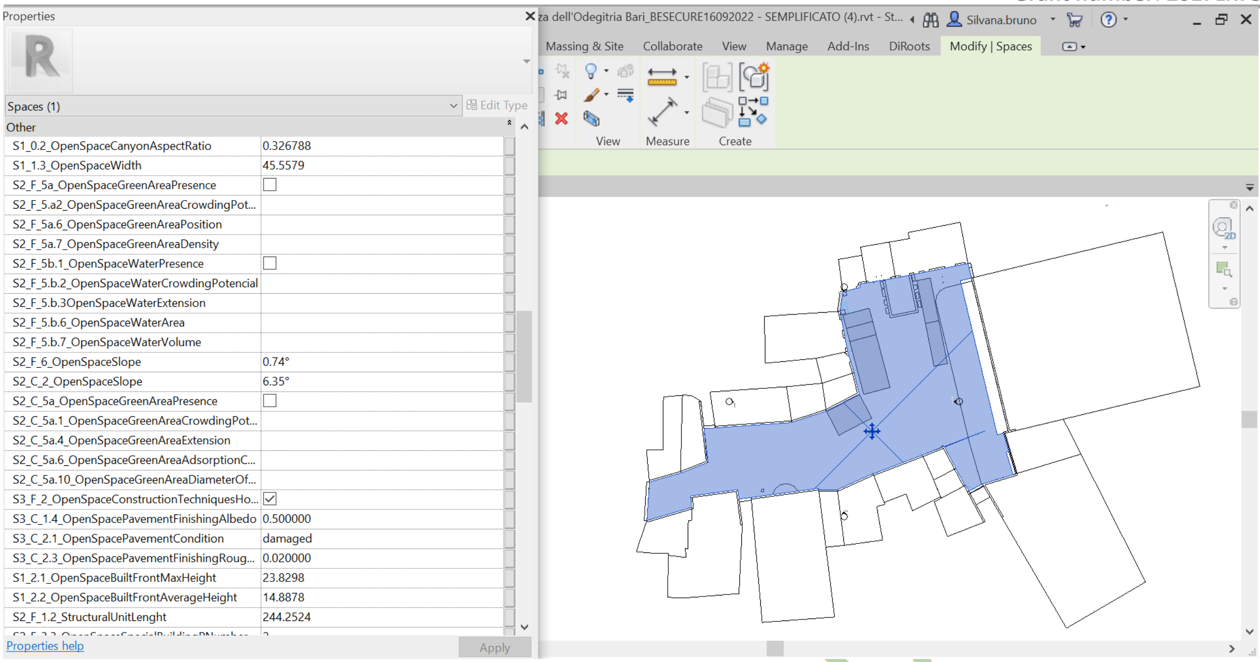


Table 16 collects the values of the 18 computable parameters related the HL element family-Space; Table

Figure 11: Parameters associated with HL Space family.

17 shows 5 parameters for GMs element family.

Table 16: Computable parameters for Space family category from the reduced risk matrix from D322 and T-H-P multi-hazard condition.

	AS-Space	Square
S1_0	main class (compact/elongated/very elongated)	1.477551
S1_0.2	Canyon aspect ratio	0.326788
S1_1.1	area	1302.123 m²
S1_1.3	Width	45.5579
S1_2.1	H max	23.8298
S1_2.2	Average building height	14.8878
S2_F_1.2	length of the built front	244.2524
S2_F_2.1	number	7
S2_F_2.2	width	3.7870
S2_F_3.3	number	2
S2_F_5.b.5	Water body area	-
S2_F_5.b.6	Water body volume	-
S2_C_2	slope	6.35°
S2_C_4.4	number of monuments	-
S2_C_4.6	area	-
S3_F_3.5	N. of mitigation system	3
S3_F_4.3	N. of mitigation system	yes
S4_6.5	Parking area location	262.289 m²

Table 17: Computable parameters for GMs family category from the reduced risk matrix from D322 and T-H-P multi-hazard condition.

SA (Structural aggregates)		1		2											3			4					5	
SU - Generic Model		1a	1b	2a	2b	2c	2d	2e	2f	2g	2h	2i	2j	2k	3a	3b	3c	4a	4b	4c	4d	4e	5a	5b
S2_F_1,3	number of SU	1a	1b	2a	2b	2c	2d	2e	2f	2g	2h	2i	2j	2k	3a	3b	3c	4a	4b	4c	4d	4e	5a	5b
S2_F_1,4	lenght of SU	8,58	16,82	12,45	3,46	7,21	9,66	12,87	12,39	7,56	3,12	13,24	8,28	31,10	13,40	5,34	12,15	15,11	4,43	10,57	6,63	14,05	16,37	5,98
S2_F_1,5	height of SU front	12,43	13,49	18,11	14,31	14,31	16,33	12,20	12,34	21,89	18,42	21,58	19,42	23,83	13,03	12,15	13,66	6,20	12,52	12,83	13,18	13,63	13,28	13,29
S2_F_4b,4	width or depth	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S2_F_4b,5	area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

3.2 Piazza Vittorio Emanuele II, Caldarola

The parameters related to the risk matrix from D322 for S-H multi-hazard condition of Piazza V. Emanuele II are calculated according to the 32 fillable values implemented in LL element families, such as wall and roof (Table 18), floor (Table 19), and road (Table 20), and to the 26 values in HL element, such as GMs (Table 21), and Space (Table 22).

Table 18: Fillable parameters for wall and roof (*) category from the reduced risk matrix from D322 and S-H multi-hazard condition.

	SA (Structural aggregates)	1	2	3	4				5			6
	SU - Generic Model	1a	2	3a	4a	5a	5b	5c	5d	5e	5f	6a
S2_F_1.9	number of storeys	3	4	1	4	3	3	-	1	4	3	3
S2_F_3	presence (special building)	no	no	yes	no	no	no	yes	yes	no	no	no
S2_F_4a.1	presence (town walls)	no	no	no	no	no	no	no	no	no	no	no
S3_F_1.4	wall disconnection in plan	no	no	no	no	no	no	no	no	no	no	no
S3_F_1.5	wall disconnection in elevation	no	no	no	no	no	no	no	no	no	no	no
S3_F_2.2	masonry quality	c	c	c	c	c	c	c	c	c	c	c
S3_F_2.5	roof types	SP	NP	NP	SP	P	SP	NP	NP	SP	P	SP
S3_F_2.13	no-structural protruding and decorative elements	no	no	yes	no	no	no	no	yes	no	no	no
S3_F_2.14	anti-seismic devices	0.65	0.85	0.55	0.85	0.85	0.85	1	1	0.85	1	1
S3_F_2.16	Facade finishing albedo	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5
S3_F_2.18	Facade finishing current roughness	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.005	0.005
S4_3.1	presence of special buildings or special uses	no	no	yes	no	yes	yes	no	yes	no	no	yes
S4_3.2	crowding potential	0.23	0.23	0.70	0.05	0.40	0.42	n/d	0.70	0.14	0.05	0.38
S4_3.4	Presence of Schools	no	no	no	no	no	no	no	no	no	no	no
S4_3.5	Presence of Hospitals	no	no	no	no	no	no	no	no	no	no	no
S4_3.7	sensitive targets attraction to building use	no	no	no	no	yes	yes	no	no	no	no	no

The 15 parameters in Table 19 are associated with the LL family floor, with four instances in the case of Caldarola being the floor describing the OS of the square and the floor describing the porticoes in SUs 05a, 05b and 06a. Notably, in *Figure 12* the floor of the square is selected and the relative parameters entered are shown.

Table 19: Fillable parameters for floor family category from the reduced risk matrix from D322 and S-H multi-hazard condition.

	Paving - Floor	square	porches in 05a	05b	06a
S2_F_4b	presence		yes	yes	yes
S2_F_4b.3	orientation		330°	330°	330°
S2_F_5a	presence of green area	no			
S2_F_5a.6	Green Area Position (related to LS or AS)	0			
S2_F_5a.7	green area density	0			
S2_F_5b.1	Presence of Water	no			
S2_F_6	slope	no			
S2_C_2	slope	no			
S2_C_5a	Presence of Green area	no			
S2_C_5a.4	extension (area)	0			
S2_C_5a.6	Greenery adsoprtion capacity	0			
S2_C_5a.10	Tree crown diameter	0			
S3_F_2	homogeneous/not homogeneous	Homogeneous			
S3_C_1.4	Pavement finishing albedo	0.2			
S3_C_2.3	Pavement finishing current roughness	0.01			

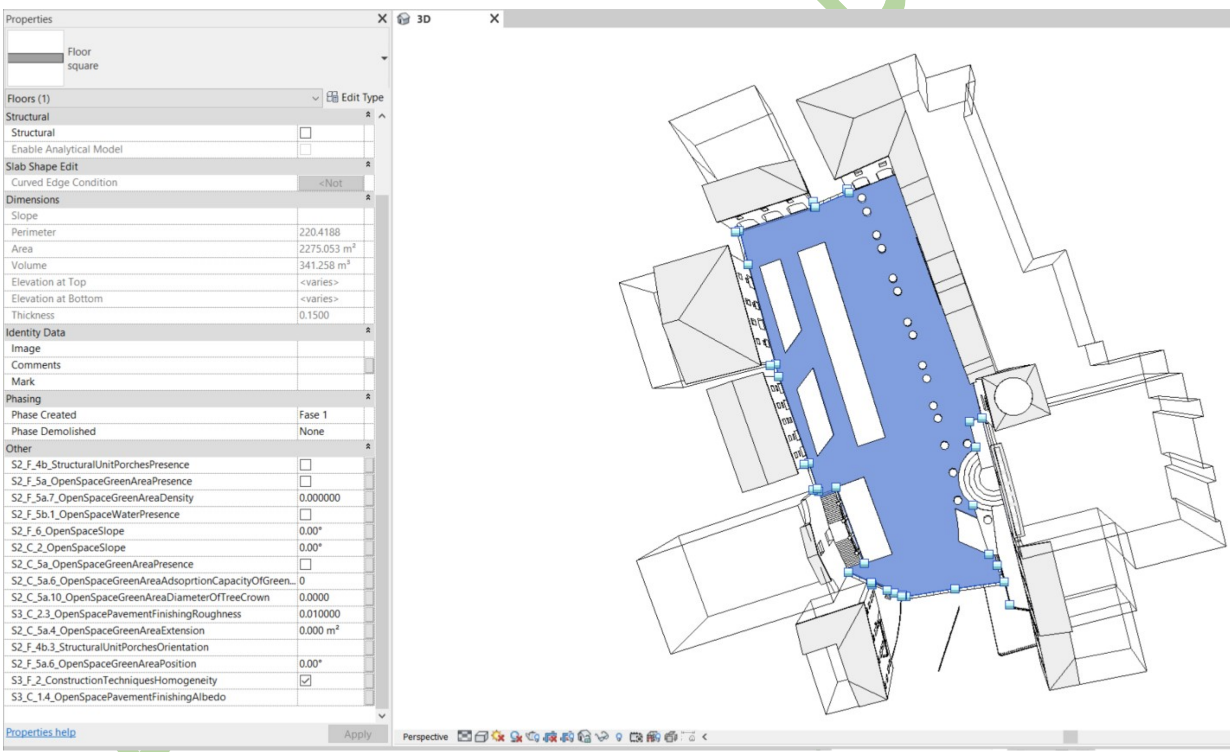
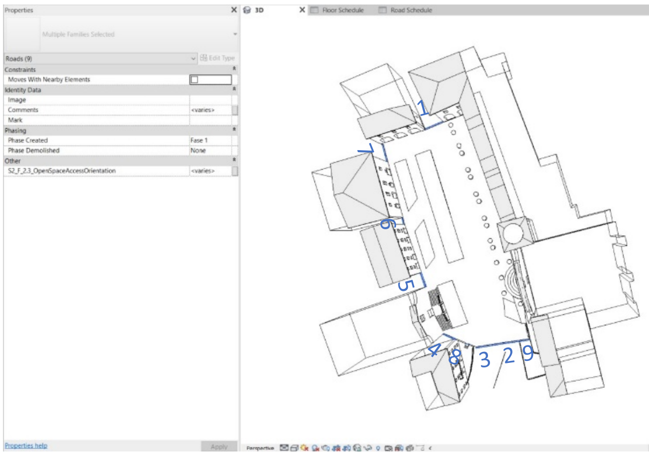


Figure 12: Parameters associated with LL Floor family.

As regards the road family, the only fillable parameter is the position/orientation of the access in relation to the N-S axis. In Table 20 there are the values for the 9 accesses to the square. The accesses 8 and 9 are private and therefore excluded from the simulation.

Table 20: Fillable parameters for road family category from the reduced risk matrix from D322 and S-H multi-hazard condition.

	Access- road	1	2	3	4	5	6	7	8	9
S2_F_2.3	position/orientation (azimuth)	330°	180°	180°	230°	260°	270°	300°	230°	180°



<Road Schedule>

A	B	C
Family	S2_F_2.3_OpenSpaceAcc	Comments
Access 1	330.00°	vehicular
Access 2	180.00°	vehicular
Access 3	180.00°	vehicular
Access 5	260.00°	vehicular
Access 6	270.00°	pedestrian
Access 7	300.00°	vehicular
Access 4	230.00°	vehicular
Access 8	230.00°	private/pedestrian
Access 9	180.00°	private/pedestria

Figure 13: Parameter associated with LL Road family and the resulted schedule.

The next step was to fill in the **HL family parameters** which are the parameters left empty in GMs and space. The Parameters related to the town walls presence (S_F_4a.1) and special in the OS buildings (S2_C_1.3) are empty because they are not present in the square.

Table 21: Fillable parameters for GM family category from the reduced risk matrix from D322 and S-H multi-hazard condition.

	SA (Structural aggregates)	1	2	3	4			5				6
	SU - Generic Model	**1a**	**2**	**3a**	**4a**	**5a**	**5b**	**5c**	**5d**	**5e**	**5f**	**6a**
S2_F_4a.2	Town walls_linear extension											
S2_F_4a.3	position											
S2_F_4a.4	width or depth											
S2_C_1.3	Special buildings_height	no	no	no	no	no	no	no	no	no	no	no
S2_C_1.5	lenght											
S2_C_1.6	width											
S2_C_1.7	height of gable											
S3_F_1.2	last intervention period	n/d	n/d	1997-2010	n/d	1998-2010	1998-2010	n/d	1997-1999	n/d	n/d	n/d
S3_F_1.3	state of conservation	high	high	high	high	high	high	high	high	high	high	high

With regard to Space, in Table 22 the values to be filled in for the case of Piazza V. Emanuele II are reported.

Table 22: Fillable parameters for space family category from the reduced risk matrix from D322 and S-H multi-hazard condition.

AS-space	square
% of SA	91%
people presents	1115
crowding potential	
Exposure duration	***
Traffic intensity	8000 vehicles/24h
presence of Sensitive target (elders/frail/gender/youngsters)	
% presence of Sensitive target (elders/frail/gender/youngsters)	
Ground motion severity	PGA= 0.178 - 0.184 (ingv)
Seismic microzonation	Zone 2
Climate zone	D
Wind/breeze speed	5.1 m/s
Air temperature	From weather file
Solar Irradiation	From weather file
classes of types	T1
Ground roughness	0.01 m
Ground albedo	0.2 grey stone; 0.1 aged asphalt
Ground heat capacity	$2.251*10^6$ J/m^{3}K

*** Exposure duration

Day hour	1	2	3	4	5	6	7	8	9	10	11	12
Value	0.21	0.18	0.18	0.18	0.18	0.21	0.26	0.29	0.33	0.72	0.72	0.72
Day hour	13	14	15	16	17	18	19	20	21	22	23	24
Value	0.71	0.14	0.25	0.39	0.43	0.43	0.43	0.42	0.24	0.24	0.24	0.24

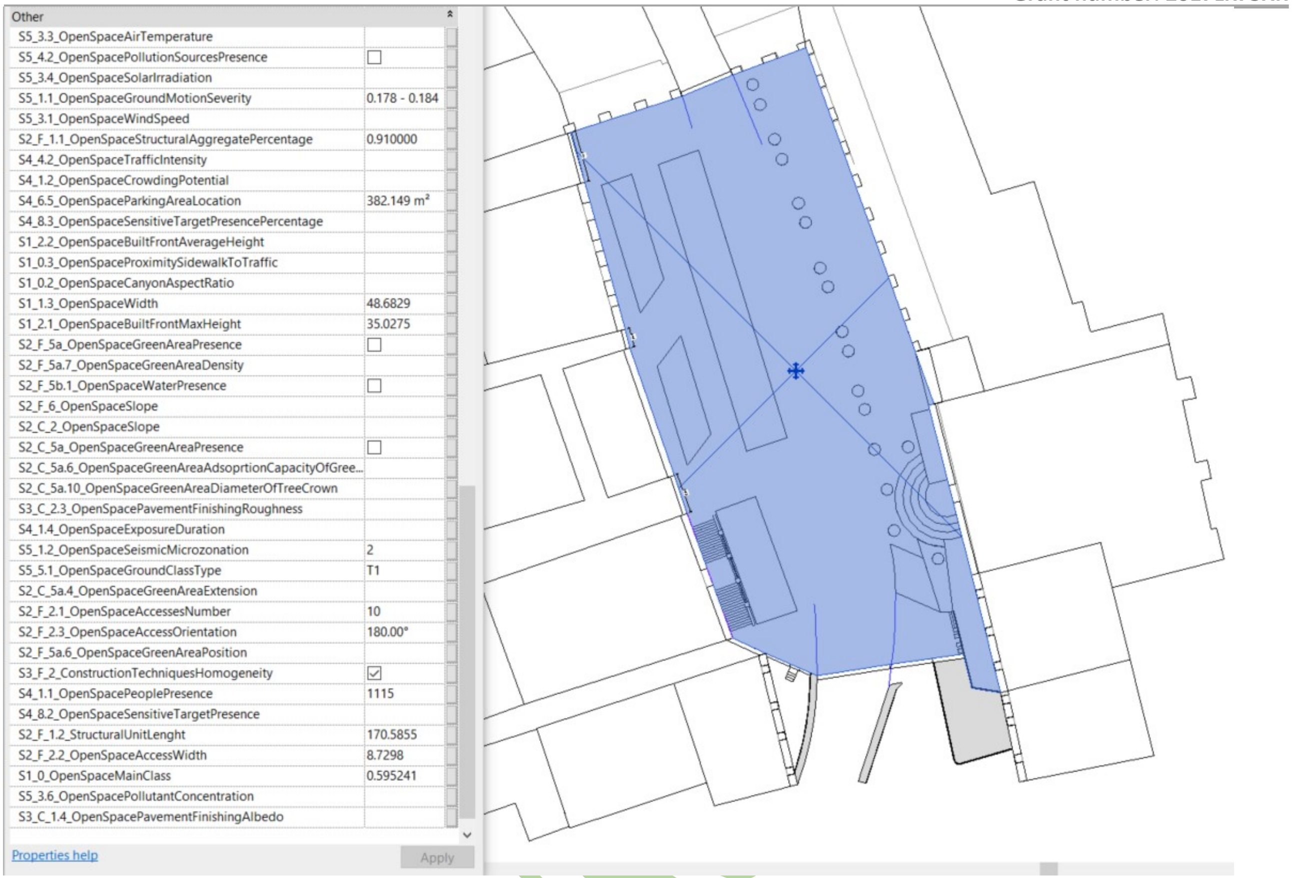


Figure 14: Parameters associated with HL Space family.

The resulted 22 computable parameters are reported in *Table 23* for HL element family-Space and in *Table 24* for GMs element family. The unit of measurement of the reported values is in meters.

Table 23: Computable parameters for Space family category from the reduced risk matrix from D322 and S-P multi-hazard condition.

	AS-Space	Square
S1_0	main class (compact/elongated/very elongated)	0.595
S1_0.2	Canyon aspect ratio	-
S1_1.3	Width	48.68 m
S1_2.1	H max	35 m
S1_2.2	Average building height	16.38 m
S2_F_1.2	length of the built front	170.23 m
S2_F_2.1	number	9
S2_F_2.2	width	46.97 m
S2_F_5.b.5	Water body area	-
S2_F_5.b.6	Water body volume	-
S4_6.5	Parking area location	382.15 mq

Table 24: Computable parameters for GMs family category from the reduced risk matrix from D322 and S-P multi-hazard condition.

	SA (Structural aggregates)	1	2	3	4	5						6
	SU – Generic Model	1a	2	3a	4a	5a	5b	5c	5d	5e	5f	6a
S2_F_1.3	number of SU	1a	2	3a	4a	5a	5b	5c	5d	5e	5f	6a
S2_F_1.4	lenght of SU	17.87	15.82	15.55	15.8	9.17	37.89	6.47	21.62	14.2	10.71	14.30
S2_F_1.5	height of SU front	14.24	13.10	18.9	13.04	14.76	15	35.03	21.89	13.72	8.7	11.80
S2_F_3.4	lenght of special buildings front	-	-	15.5	-	-	-	-	21.62	-	-	-
S2_F_3.5	height	-	-	18.9	-	-	-	-	21.89	-	-	-
S2_F_3.7	height of gable	-	-	2.13	-	-	-	-	2.82	-	-	-
S2_F_4b.2	Porches_linear extension	-	-	-	-	8.1	37.34	-	-	-	-	-
S2_F_4b.4	Porches_width or depth	-	-	-	-	10.75	14.44	-	-	-	-	17.23
S2_F_4b.5	Porches_area	-	-	-	-	48.11	175.49	-	-	-	-	63.36
S3_F_2.3	wall thickness	0.95	0.8	0.80	0.90	0.7	0.7	1.7	0.80	0.90	0.9	0.75
S3_F_2.8	% openings	0.13	0.16	0.06	0.13	0.27	0.27	0.08	0.04	0.14	0.12	0.23

4. Conclusions

The workflow developed in the D331 for the representation of BE in BIM-based model and validated for the case study of Narni was applied in this report to other two case studies, Piazza V. Emanuele II in Caldarola and Piazza dell'Odegitria in Bari. For each case studies have been developed a BIM model to geometrically represent the characteristics of the space and to collect the information related to the risk. This report describes the workflow application to the case studies and represents a collection of multi-hazard data associated with them.

5. Abbreviations

AS – Areal Spaces

BE – Built Environment

BET – Built Environmental Typology

BIM – Building Information Model

GIS – Geographic Information System

HL – High level families

LL – Low level families

LOD – Level of Development

LS – Linear Spaces

OS – Open Spaces

SA – Structural aggregate

SLOD – Slow-onset disaster

SU – Structural unit

SUOD – Sudden-onset disasters

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