WP3–Representative models of Built Environment Typologies (BETs) prone to SUOD/SLOD. Case studies selection and data collection

T3.2 Identification of BETs and their typical risks related to the selected SUOD/SLOD including typical users' exposure

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Abstract

The risk of Built Environment (BE) under SLOD and SUOD threats essentially depends on the physical assets as well as on the user-related factors. Emergency conditions are influenced at short and long terms, by the users' number, features and reactions in whichever kind of disastrous events. In this sense, the users' vulnerability (how the individuals are vulnerable to the risk?) and exposure (how many individuals are in danger?) issues should be merged. Although SUOD and SLOD induce different effects on the BE and its users, definitions provided by the previous risk matrix (D1.2.3, D1.3.1, D2.2.5) and behavioral-related analyses (D1.2.5, D1.3.3, D2.2.3) ensure to trace a list of users' social (i.e. individual) vulnerability and exposure issues for the typological BE definition. Basing on previous state-of-art considerations, this deliverable aims at tracing a collection of such typical users' exposure and vulnerability factors. In this sense, it provides significant and recurring features to characterize the BE by considering a typological approach (compare to D3.1.1). Results define a characterization of each typical factor. Data sources to derive such characterization are evaluated by preferring quick to apply approach, thus ensuring the possibility of application to different contexts, also by low trained technicians and in case of poor available databases at the local scale. Some of these factors can be determined by adopting reliable literature databases, while others can be determined through local-scale analysis (e.g. data collection into the BE). Investigations on D3.1.1 BE sample are performed to provide statistical-based characterizations of typical user-related issues. Results also represent a basic step for simulations and scenarios creation of the next T3.3 and WP4.

Keywords

Users' typical exposure; Individual vulnerability; Human exposure; factors characterization;

Approvals

Role	Name	Partner
Coordinator	Quagliarini Enrico	UNIVPM
Task leader	Quagliarini Enrico	UNIVPM

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1.1	10.02.2021	updating references; check of the case studies from D3.1.1; final revision of parameters terms according to D3.2.2	Bernardini	UNIVPM
1.2	06.04.2022	Language checking; coherence assessment for terminologies and definitions in respect to ongoing publication	Bernardini, Romano	UNIVPM

Summary

1. Introduction

Including a holistic standpoint in the Built Environment (BE) assessment by considering its users should face both vulnerability-related issues and exposure-related issues. Vulnerability can refer to the question "how much damage can the users receive by the event because of their features?", while exposure can refer to the question "how many users can suffer the damage?" In this sense, previous BE S²ECURe tasks related to behavioural-oriented assessment (D1.2.5, D1.3.3 and D2.2.3) concerning the specific SUODs/SLODs considered in this work were analysed in a synthetic manner by the holistic discussion in Annex D2.2.5 (Section 1)[1].

In fact, according to (Pelling 2003), the BE vulnerability is subdivided into physical vulnerability (as the vulnerability of the physical environment) and social vulnerability (as experienced by people and their social, economic, and political systems). Social vulnerability refers to the BE users and is then subdivided into Individual vulnerability and Collective vulnerability regarding the whole community. *Social vulnerability* (in the following, *Users' Vulnerability*), according to (Villagràn De León 2006), can include factors concerning the BE users such as physical features of individuals, their psychological and behavioural aspects, since these elements compose the "set of characteristics and circumstances" of individuals' and communities towards the damaging effects of the considered disaster hazard. Different impacts are registered in relation to the different disaster event typologies (SLOD and SUOD). People's characteristics (e.g.: age, gender, disabilities, difficulties in motion (D'Orazio et al. 2014a), health fragility (Barrow and Clark 1998; Delfino et al. 2010), culture, socioeconomic status of the household (Koks et al. 2015)) and people's response to the hazard (Cardona et al. 2012) (e.g.: susceptibility, disaster preparedness, coping capacity, which also refers to their behavioural aspects and their reactions) can influence positively or negatively their propensity to be threatened by disaster effects (Liu et al. 2018). These elements can be evaluated for the whole disaster-prone community (*collective vulnerability*, e.g. evacuation and emergency management issues; social issues at the community scale) and for the specific individual (*individual vulnerability*, e.g. behaviours, gender, age, health fragility, other features and motion quantities).

From a qualitative perspective, common BE users' behaviours in literature in SUODs are discussed in D1.2.5 (Section 2.2). Further discussions are reported on results Section 4.1 and 4.2 from both qualitative and quantitative point of view, in view of an earthquake as significant SUOD. The same approach is employed to inquire BE users' behaviours under terrorist attacks in D1.3.3 (Section 1.1 and 3.1). SLOD effects on BE users' behaviour and habits are in quired in D2.2.3 Section 1, 3.1, 3.2 and 3.3. Therefore, the concept of users' vulnerability could be essentially investigated according to the same pillars, although significant differences in retrieving typical (or rather, common) elements can exist (e.g. peculiar behaviors, motion quantities, health state of the individuals).

Exposure-related issues, in general terms, are focused on the BE users' presences (i.e. exposed individuals, calculated as human lives in the BE), the historic and artistic heritage and the presence of relating services (Mouroux and Brun 2006). The last two mentioned material goods are considered in the exposure assessment only in disastrous events where destroying effects can reflect on them (e.g.: earthquakes, bombing attack). The presence of industrial and manufacturing activities and commercial transportation systems in stricken areas could lead to economic losses and to the interruption of productive capacity as a consequence of such SUODs. Therefore, socio-economic issues are other factors to be encompassed in

[1] In this sense, Annex D2.2.5, Section 2 also deeply discussed each factor in respect to the SUOD and SLOD-related characterization.

exposure (Sarabia et al. 2020). In SUODs, for instance, the exposure is strictly related to the presence of persons in a specific environment (Wardhani 2015) defined as risky, thus expressing it in terms of human lives (e.g.: the total number of exposed people, eventual overcrowding conditions, and correlation between the individuals' quantification and the proximity to the risk sources). The same considerations are valid both for earthquakes, considering people in high seismic intensity areas, and both terrorist attacks, where one or more individuals are exposed to the risk of becoming a terrorism victim. Nevertheless, concerning SLOD events, the exposure is connected to the presence of people in a defined urban place for a certain period of time on a regular basis when their health and wellbeing are under risky conditions; or their health is slowly degrading (e.g. air pollution disease burden, see WHO (2016)). In such areas, pedestrians are exposed to Urban Heat Island and increasing temperatures (that affect their body temperature) or to the inhalation of particulate matter (Luo et al. 2018) (that affect their respiratory systems). The exposure increases when citizens pass repetitively through a zone with certain critical levels registered or when they remain there for long time. Therefore, the concept of exposure can be defined in the same way for SUOD and SLOD events and it is only connected to the human lives in the proximity of the risk source for a specific instant (for SUODs and SLODs); or, either for a longer period or their presence factored by the recurrence of their presence (for SLODs). In this sense, the activities hosted by the built environment (including both indoor areas and outdoor spaces) highly alter the exposure value in both spatial and temporal terms (Li et al. 2019; Dai et al. 2020). Thus, a classification of the intended use-related factors (including the sensible ones, e.g. for terrorist acts (National Consortium for the Study of Terrorism and Responses to Terrorism (START); Matsika et al. 2016; Karlos et al. 2018), please also compare with D1.3.1), as well as of the main features of the built environment (e.g. the built density) can be useful to trace the exposure and users' vulnerability levels in it (Villagràn De León 2006).

In view of the above, this report tries to define typical users' vulnerability and exposure, by considering BEs under SUOD and SLOD risk conditions. To this end, the definition of a list of relevant factors should be organized before the application to significant contexts, by collecting, analysing and modelling quantitative factors and their variations by also considering the "number of elements" and their "spatiotemporal distribution" as the leading key-factors (Bernardini et al. 2018; Hassanzadeh 2019; Li et al. 2019; Zlateski et al. 2020). In this process, the work aims at preferring quick-to-apply and sustainable approaches to boost the assessment application in real contexts, by also providing such tools for non-expert users, such as technicians from local authorities.

To this end, the critical review of previous D1.2.5, D1.3.3 and D2.2.3 is assessed also in relation to the Built Environment Typologies definition process (compare to D3.1.1) thus considering the possibility to collect data in real context according to the D1.1.2 and D2.1.2 results. The provided parameters are then compared to those of general risk assessment in D3.2.2, so as to integrate the key findings of these actions in a unique approach for the Built Environment representation and typological analysis.

2. Work phases

The activities are organized in the following phases:

- factors that characterize the typical exposure and users' vulnerability are individuated thanks to the available knowledge of previous deliverable and by literature works (Section 3). The presence of additional variables related to the risk source (SLOD and SUOD) or to specific environmental conditions that can influence factors characterizations is also assessed in a literature-based perspective and according to the previous BE S2ECURe results;

- the characterization process of the previous determined typical exposure and vulnerability factors is supported by the definition of possible data sources and ways to collect necessary information to solve the aim (Section 4). This process can support the definition of: statistical identification of recurring BE conditions; peak conditions of the BE.

3. Exposure and users' vulnerability factors definition

Table 1 collects all those factor that can be retrieved from previous research activities of this project (D1.2.5, D1.3.3, D2.2.3 and Annex D2.2.5) especially for what concerns the state of the art on BE users' behaviors and effects of disasters on the exposed individuals. Factors are subdivided according to the definitions outlined in the Annex D2.2.5 by including users' vulnerability issues (e.g.: age, gender, disabilities and emergency responds) and the aspects related to the exposure (i.e.: human lives in space and time). Each factor is associated to previous works concerning specific studies in order to justify their relevance on this key-elements collection process.

The factors are discussed by Table 1 in order to understand how they can be affected and change by considering different disasters, not only in relation to their duration (SUOD or SLOD) but also by distinguishing the disaster-related features and how it can be perceived by the BE users. Specific environmental conditions related to BE structural and geometrical features, as well as the possibility of significant overcrowding conditions that could occur in presence of mass gathering events, can also heavily influence the characterization of such factors, as shown by the last column of Table 1,.

Table 1. Collected exposure and vulnerability factors, by organizing them into general classes (first level, bold definition), secondary classes (second level, in italics) and specific factors (third level). Each of them is linked to other factors where needed, by using the same identification codes (ID) in the first column.

ID	***Factors classes***	***Literary studies***	***Combination with other factors or disaster-related features***
1	***Users' vulnerability***	**-**	**-**
1.1	*individual vulnerability*	-	-
1.1.1	motion quantities	(Bosina and Weidmann 2017)	In relation to 1.1.2, 1.1.4, 1.1.5
1.1.2	Disabilities in motion	(Cardona et al. 2012)	BE accessibility, use of wheelchair
1.1.3	health of the person	(Manigrasso et al. 2017)	Increasing temperatures and air pollution in relation to respiratory disease
1.1.4	age	(de Nazelle et al. 2009)	In relation to 1.1.1 and 1.1.2
1.1.5	gender	(de Nazelle et al. 2009)	In relation to SLOD effects on health
1.2.	*(main) behavioral issues, cultural and socioeconomic status*	-	-
1.2.1	motion issues	(Bernardini et al. 2019)	Related to users' preparedness and awareness
1.2.2	risk perception issues	(Piselli et al. 2018)	In relation to the type and closeness of the risk sources
1.2.3	Familiarity with places and emergency procedures	(Bernardini et al. 2016)	Related to SUOD events
1.3	*collective vulnerability*	-	-
1.3.1	management of emergency conditions	(Chung et al. 2017)	In relation to mass gathering and public events, personnel presence

1.3.2	evacuation layout	(US Department of Homeland Security 2009)	In relation to mass gathering and public events
2	***Exposure***	**-**	**-**
2.1	position of the users in the BE during the time	(Yang et al. 2018)	Time intervals related to SLOD/SUOD
2.2	users' paths in the BE and occupancy issues	(Quagliarini et al. 2018)	Mass gathering, the period of the year and the day moments have an effect on occupancy, weather
2.3	number of exposed individuals per individual vulnerability and behavioral issues class	(D'Orazio et al. 2014b)	In relation to 1.1.2, 1.1.3., 1.1.4, 1.1.5
2.4	Total number of exposed individuals	(Wardhani 2015)	Mass gathering, public events, the period of the year and the day moments, weather
2.5	Strategic/monumental buildings	(Dedesko et al. 2015)	Considering users' vulnerability issues of hosted people (hospitals schools)
2.6	Ordinary buildings	(Francini et al. 2020)	In relation to the intended use and day moments
2.7	Open spaces	(Langenheim et al. 2020)	Mass gathering, public event, weather
2.8	Sensitive Target	(FEMA-426/BIPS-06 2011)	Specific for terrorist acts

4. Exposure and users' vulnerability characterization for typological definition of the BETs

Factors reported in Table 1 have to be synthetically characterized in relation to the possibility to collect data on them to move towards the creation of possible typological issues. Data collection techniques can provide data for the statistical analysis of recurring conditions of the BE (thus defining the BETs from exposure and users' vulnerability standpoints), depending on a quick approach for data detection, as discussed in Section 4.1. Then, input data are organized to effectively manage the parameters describing the BETs, as discussed in above.

Table 2 synthetizes factors characterization trying to explain the adopted methodology and associating (to each row) the possible available source to acquire information useful in defining typical combinations. Hence, each factor is jointly combined with available data sources (from qualitative and quantitative points of view), by mainly preferring quick approaches to data collection, which can boost the application possibility of the proposed classification methodology (compare also to D3.1.1, Section 3). Insights on the related quantities to be collected are provided. The last column discusses the possibility to aggregate values for statistical analysis of the BE configurations while comparing different case studies according to the overall sample proposed by D3.1.1.

Some of Table 2 items can be immediately characterized (e.g. the age; supposed Level of Service – LOS (Fruin 1971)) having the possibility to consult population registers or census databases but others are not so easy to quantify. Some data can be adopted according to relevant and reliable literary studies (e.g.: motion quantities). Furthermore, although general sources can be applied, data strictly related to a specific BE (also in relation to the urban areas in which they are placed) should be also analysed depending on the specificities of each application case study, also in the view of the peculiar variations of the data to be assessed over time and space (Bernardini et al. 2018; Li et al. 2019; Zlateski et al. 2020).

In this sense, the application of Table 2 outline will can boost the detection of each typical factor and be able to define most frequent variations describing different Built Environment Typology (BET) scenarios during the emergency conditions. At the same time, the assessment can provide the characterization of possible peak conditions in the BE, as reported by Section 1. The identification of peak conditions can move towards the identification of critical scenarios for users-related factors basing on the main parameters concerning the exposure in terms of people hosted in the built environment.

Data collection techniques can provide data for the statistical analysis of recurring conditions of the BE (thus defining the BETs from exposure and users' vulnerability standpoints), depending on a quick approach for data detection, as discussed in Section 4.1. Then, input data are organized to effectively manage the parameters describing the BETs, as discussed in above.

Table 2. Exposure and vulnerabiliy factors characterization and available data sources

ID	*Factors classes*	*Characterization*	*Sources*	*Unit of measure / modeling quantity*	*Possibility to take into account statistics for the BE application*	*Parameter in the typical BE modelling*
1	***Users' vulnerability***	-	-			
1.1	*individual vulnerability*	-	-			
1.1.1	motion quantities	by literature critical values for adults, child and elderly (Bosina and Weidmann 2017)	Literature works on evacuation motion quantities depending on the SUOD/SLOD to be considered	m/s		
1.1.2	Disabilities in motion	No disabilities, moderate, wheelchair	Official register of health care organizations	m/s		
1.1.3	health of the person	Healthy, respiratory disease, cardiological disease	Official register of health care organizations (at least national statistics/regional statistics)	specific of the health condition	percentage of people per specific health condition [%]	
1.1.4	age	Necessary to essentially determine 1.1.1	From population census database	years, years range	percentage of people per age range [%]	x
1.1.5	gender	Necessary to determine 1.1.1 and 1.1.3	From population census database	percentage of people by gender	percentage of people per gender [%]	x
1.2.	*(main) behavioral issues, cultural and socioeconomic status*	-	-			
1.2.1	motion issues	Users' preparedness levels	Official countries guidelines, local surveys, literature works	Probability of path selection according to recommended rules		
1.2.2	risk perception issues	Pre-movement time from literature values	Literature works on evacuation for SUODs/ on SLODs risk perception	level of knowledge of the safety procedures in SUODs and correct perception of environmental conditions and effects on health in SLODs		
1.2.3	Familiarity with places and emergency procedures	Familiar-residents; unfamiliar-non-residents including tourists, visitors and passers-by	Regional tourist offices and population census database	Probability of proper path selection	ratio between residents and visitors [-], [%]	x
1.3	*collective vulnerability*	-	-			

1.3.1	management of emergency conditions	Presence, absence of prevention measure and emergency management solution	Municipality offices according to countries regulations in presence of public events	number of personnel for supporting the users, presence (Boolean) of emergency plan (distinguished by SUOD and SLOD)	number of BE having management solutions	x
1.3.2	evacuation layout	Presence, absence of wayfinding signs and evacuation facilities, personnel	Municipality offices according to countries regulations in presence of public events	number of personnel for supporting the users, number of wayfinding/risk signs, presence (Boolean) of emergency plan (distinguished by SUOD and SLOD)	number of BE having emergency plans/layout	x
2	***Exposure***	-	-			
2.1	*position of the individuals in the BE during the time*	The Level of Service (LOS) unifying LOS A, B moderate occupation; LOS C, D, E, F crowding conditions	Statistical investigations for specific BETs	pp, pp/m²	[pp], [pp/m²] per time range (e.g. 4hours long intervals, morning/afternoon/evening/night, differences between working days and holidays, seasonal differences)	x
2.2	*users' paths in the BE and occupancy issues*	Main paths/secondary related to LOS conditions 2.1, also in respect to users' flows	Statistical investigations for specific BETs	pp, pp/m², pp/s		
2.3	*number of exposed individuals per individual vulnerability and behavioral issues class*	In relation to 1.1.2, 1.1.3., 1.1.4, 1.1.5	Statistical investigations for specific BETs	pp, pp/m², pp/s		x
2.4	*Total number of exposed individuals*	Different ranges in relation to their number statistically determined	Statistical investigations for specific BETs	pp, pp/m²		x
2.5	Strategic/monumental buildings	Different ranges in relation to their number statistically determined, combined to 2.1	Cadastral maps, official land registers	Boolean (compare to D3.1.1, section 3)	number of items/presence of items per typology	x
2.6	Ordinary buildings	Different ranges in relation to their number statistically determined, combined to 2.1	Cadastral maps, official land registers	Boolean (compare to D3.1.1, section 3)		
2.7	Open spaces and their occupancy	Different ranges in relation to their extension statistically determined, combined to 2.2 (i.e. in case of mass-gatherings), also in respect to users' flows	Cadastral maps, official land registers	pp, pp/m², pp/s	see 2.1 to 2.4	x
2.8	Sensitive Target and their occupancy	Hard target/soft target according to D1.3.2	Building intended use, official land registers	pp, pp/m²	number of items/presence of items per typology	x

4.1 Data collection methodology

According to previous works The methodological steps are: 1) the characterization of outdoor and indoor areas of the BE in terms of intended uses and dimension (Section 4.1.3), as well as of maximum number of users (Section 4.1.4); 2) identification of users' individual vulnerability and behavioural patterns (Section 4.1.5), so as to provide the organization of data over time; 3) the analysis of collective vulnerability-related issues in the BE (Section 4.1.6).

The data collection methodology can be generally applied to all the case studies of BE S²ECURe collection, as well as to other BE. The process developed in this study is mainly based on remote data collection from open access sources (freely available on the web, such as via Google Maps or statistical databases) to accelerate the data collection operations in view of the rapid applicability of the entire workflow at the BE scale, as well as in view of the possibility of application by low trained stakeholders in preliminary assessment activities (Quagliarini et al. 2021). Indeed, employed tools are available for whatever city and not strictly related to a specific tool provided by each single municipality. In this perspective, the proposed methodology is aimed at moving towards the quantification of possible statistical trends (including exposure peaks), by collecting and managing data from homogenous sources, which can be easily comparable and used. The data sources are collected in reference to the Italian application context, although similarities with other Countries ensure the extension of the proposed methodology. Nevertheless, rapid data derived from the proposed methodology trace a general overview of the users' exposure and vulnerability, also in the view of the parametric description of recurring conditions for the BETs. Thus, they can be integrated by specific tools, such as the ones of local GIS-based repositories or the ones from individuals' positing tracking methodologies, and methodologies, such as in-situ surveys, to improve the reliability of the results (Ranjbar et al. 2017; Solmaz and Turgut 2017; Hossain and Meng 2020; Yao et al. 2021). In this sense, Appendix A offers a summary of the methodology description in case of GIS tools or specific surveys are available online, in the application context of the case studies of Milano, Italy, previously introduced in D2.2.2.

The methodology is currently applied to 100 of the BEs considered in D3.1.1, referring to the convex sample of the squares in D3.1.1.

4.1.1 Areas of the built environment considered by this work

The considered BE includes: (a) the effective area of the square, according to the definition in D3.1.1, that is considering the limit of the geometry of the square as an Open Space (see Figure 4-A in the example of Narni, TR), so so as to make a perfect correspondence between the users-related evaluation and the morphological assessment of the BETs; and (b) the closest part of the access streets to the square (see Figure 4 in the example of Narni, TR).

In particular, concerning previous point (b), the shortest path criterion is assumed to define the closest part of the access street, according to consolidated criteria for evacuation plan organization and to the experimental-based attraction of people towards the nearest wide open spaces, i.e. during immediate earthquake evacuation phases (D'Orazio et al. 2014c; Rojo et al. 2017; Shrestha et al. 2018; Aalami and Kattan 2020; Chen and Cheng 2020)[2]. The same shortest path criterion can also refer to normal traffic conditions towards and from the square, although this assumption tends to simplify the centrality of the BE in the urban

[2] this assumption can be considered as valid when all possible evacuation directions are available.

layout and moves towards an idealization of the urban fabric where the BE are placed (Pearce et al. 2021; Salazar Miranda et al. 2021). In this sense, the idealization purposes fits with the ones of the BET definition in D3.2.1, and additionally fits with microscale behaviors according to other wayfinding and pedestrians' flows approaches (e.g. the least directional change approach) (Shatu et al. 2019). Furthermore, conservative scenarios in the estimation of users' presences due to the movement of people can be assumed because of the extended area of the square along the access streets, thus being a unique spatial entity.

Anyway, the shortest path is also arranged according to the morphological features of the access streets so as to define the length of area of the access street that should be considered for exposure calculations. The following assumptions are performed.

Firstly, morphological criteria for access streets exclusion are defined. At least one of the following features implies the exclusion of the street from the next evaluations (see :

1) *access street having an archway or porticoes at the BE entrance side*. In fact, archways are considered as interruption of the access street, in view of possible vulnerability to earthquakes, as well as to the users' preference to move far from buildings during the earthquake evacuation (D'Orazio et al. 2014c);

2) *streets having a positive slope > 8% towards the BE* (that is, users along them should move uphill to reach the BE). This accessibility threshold is coherent with D3.1.1, Section 4. In fact, it is assumed that users prefer to use next to flat paths or preferably move downhill while moving in the urban fabric (Salazar Miranda et al. 2021). Additional travel costs are assumed when the slope increases, especially if moving uphill (Meeder et al. 2017) also in the view of the least effort theory (Zipf 1950). Points of sensible variations along the paths should be hence evaluated, by dividing the access streets into homogeneous areas considering their slope under the threshold;

3) similarly to previous point 2, *access streets having a stairway at the BE side*, regardless of their slope since they can represent an accessibility obstacle as discussed above.

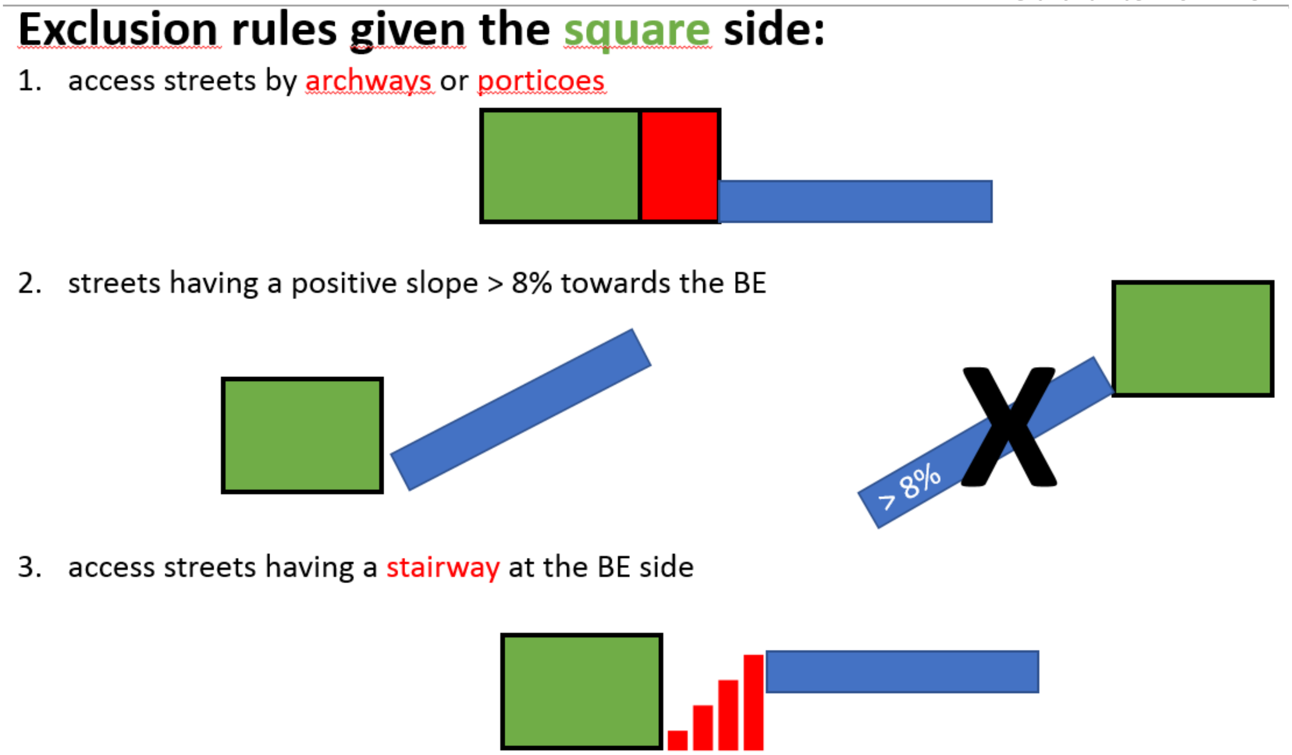


Figure 1: Rules for excluding the access streets.

Then, for the considered access streets, the access street length L_{street} [m] is calculated as shown by Figure 2. L_{street} is equal to the distance between the access side to the BE and (Figure 2-A) the nearest relevant crossroad, that is a crossroad that connects streets having a comparable or larger width, or (Figure 2-B) the nearest wider area along the street, such as a widening of the street itself (e.g. 2 times wider than the original street or more). In fact, these points can provide a relevant and wide space where people can gather in emergency conditions (D'Orazio et al. 2014c). According to (Figure 2-A), crossroads between a main access street and the secondary alleys are not considered. Furthermore, in case of streets with vehicular access (2.5 or 3m or more as for rescuers' access vehicles (Aguado et al. 2018)), relevant crossroads can be considered as the ones with other driveways.

As shown in Figure 2-C, in case an obstacle to movement is present, e.g. archways, porticoes or stairway, L_{street} is equal to the distance between the access side to the BE and first along the access street. The same criterion is selected in case of significant slope changes along the path, as in Figure 2-D (including sub-conditions which can occur in the access street.

Finally, the length considered for exposure evaluations $L_{s,c}$ [-] is based on the shortest path criterion (see Figure 3-A), thus being generally equal to L_{street} /2. Anyway, $L_{s,c}= L_{street}$ in case of presence of archways, porticoes and staircases because of their aforementioned obstacle effects to users' motion, as in Figure 3-B. Finally, in case the access street has asymmetric entrances, as in Figure 3-C, will be linearly calculated as in Equation 1:

$$L_{s,c} = L_{street} * w_{BE}/(w_{BE} + w_{ex}) \quad (1)$$

where w_{BE} is the width of the entrance side to the BE [m] and w_{ex} is the width of the opposite entrance side [m]. This correlation ensures limiting or increasing the area to be considered depending on the geometry of the access street.

Calculating Lstreet:

The distance between the entrance at the square side and:

A) the nearest relevant crossroad
B) the nearest wider area along the access street, such as a widening of the street itself (e.g. 2 times wider than the original street or more);
C) the first archways, porticoes or stairway along the access street
D) the first significant slope change (≥8%)

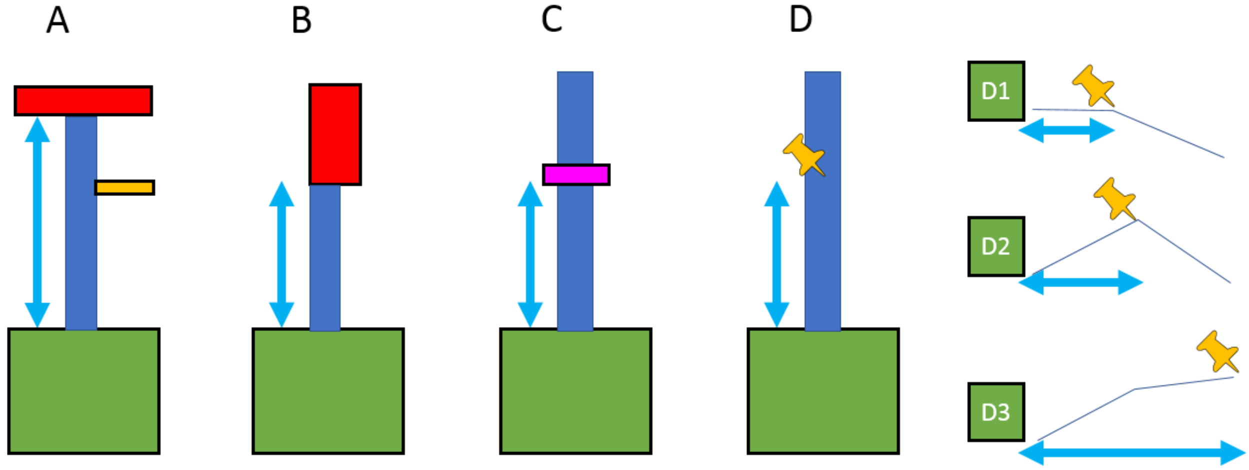
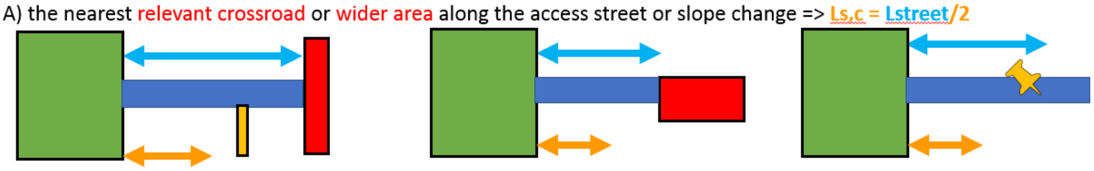


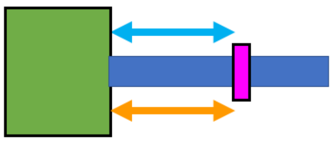
Figure 2: Rules for Lstreet calculation.

Calculating Ls,c:

A) the nearest relevant crossroad or wider area along the access street or slope change => Ls,c = Lstreet/2



B) the first archways, porticoes or stairway along the access street => Ls,c= Lstreet



C) in case the access street has asymmetric entrances, according to a linear proportion => see Equation 1

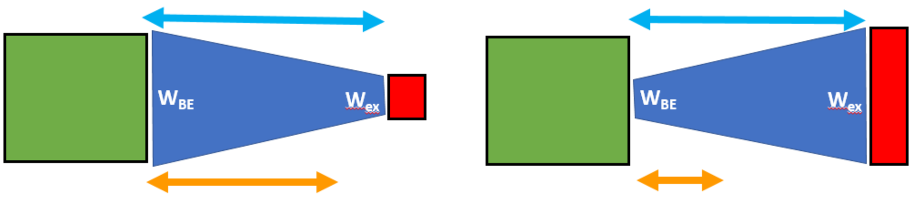


Figure 3: Rules for Ls,c calculation.

All the areas between the access street entrance at the BE side and the considered access street length will be analysed as for the areas inside the BE (both indoor and outdoor areas).

Figure 4-A: Areas of the BE considered for the analysis: orange-the square itself; green-access streets areas according to the shortest path rule; red-not considered access street; yellow-buildings and related intended uses facing the square or the considered access streets; blue- buildings and related intended uses facing only the considered access streets.

4.1.2 Characterization of the dehor areas[3]

The dehors positioning within the squares (Figure 4-B) is investigated according to the following features:

- Their position within the square, according to five different options, i.e., at the center of the square (dehors separated from the side by a carriable street are also considered as "at the center") or one of four the cardinal points the side (when the axes are not clearly oriented with respect to the cardinal points, the one axis with the lower inclination with respect to the vertical was considered the North);
- The number of different positions occupied by the overall number of dehors within the square, that can range from 0 (no dehors) to 5 (dehors located at N, W, S, E and C for "at the center");
- The dehor position in respect to the carriable streets, that is on the same side or on the opposite side.

In particular, according to the latest point, the relationship between streets and dehor within the square has also been studied, by considering the case of streets crossing the square and the number and position of the streets as follow:

[3] Developed in collaboration with RM: Martina Russo and Edoardo Currà (supervision)

- Square with no streets
- one street crossing one of the square sides
- Two opposite streets, that is placed at two opposite sides of the square
- Two adjacent streets, that is placed ad two adjacent sides of the square
- Tre streets on three different sides of the square
- Four streets on the four sides of the square

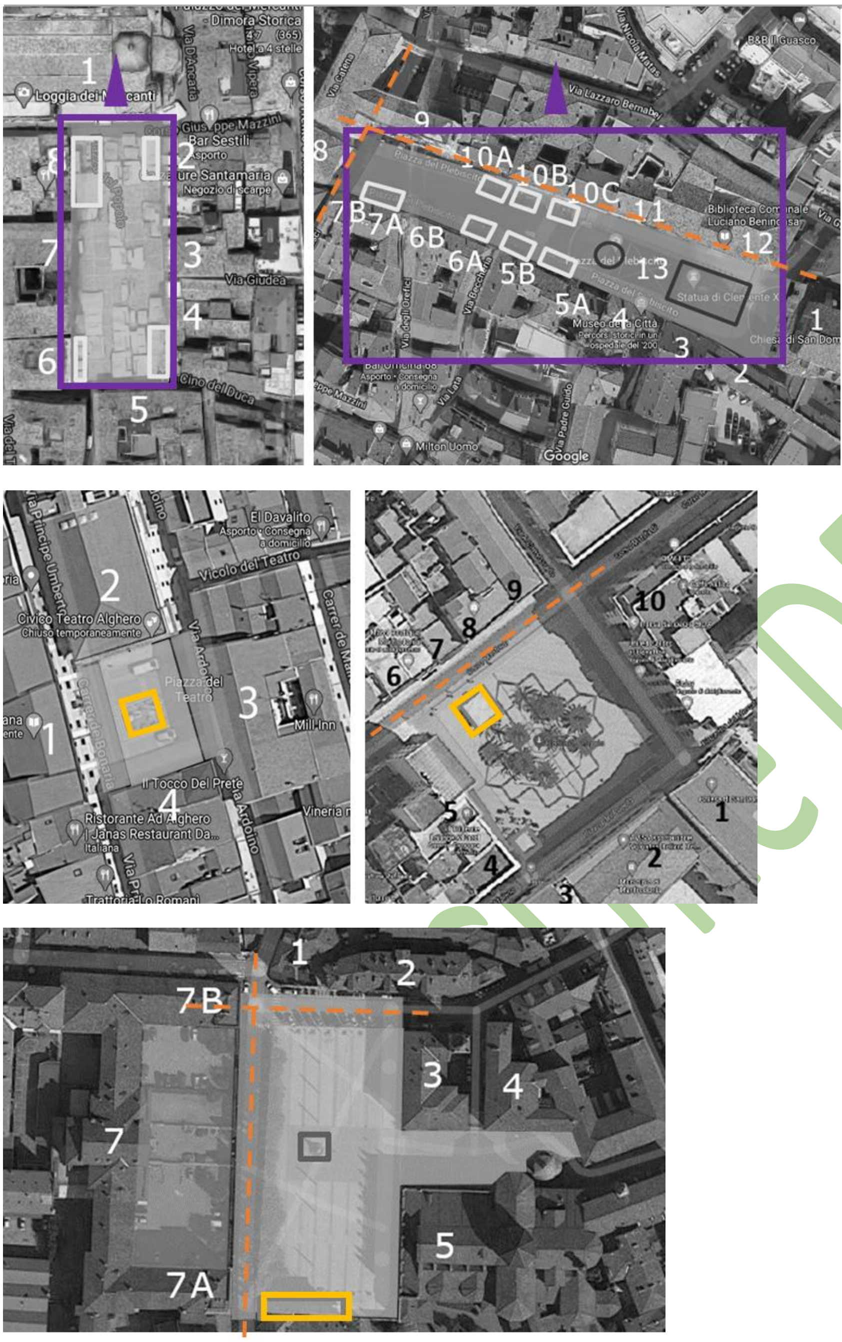


Figure 5-B: Areas of the BE and dehors characterization (yellow rectangle) considering the position of the square (dashed orange line) and the BE orientation (nord shown by the purple arrow).

4.1.3 Characterization of outdoor areas

The overall outdoor area geometry and dimension is identified according to the related P1 characterization in D3.1.1 referring to both the square and the access streets to the square (within $L_{s,c}$ from the square side). Anyway, the geometrical characterization of the BE for exposure aims will only concern the square.

Concerning outdoor areas, pedestrians areas (and sidewalks), vehicle accessible areas, areas occupied by monuments that are not walkable (e.g.: statues, fountains, obelisks, fenced areas including not accessible garden areas), green areas that are walkable (e.g. accessible gardens), the eventual presence of dehors (such as open-air terrace of restaurants placed at the ground levels, both removable and permanent ones) and private courtyards (e.g. private fenced areas) are singularly evaluated, by collecting the related surface for each of them (m^2) by the online tools Calcmaps, available at https://www.calcmaps.com/it/map-area/ (last access on 25/01/2021). According to a conservative approach, the eventual presence of porticos is considered as an extension of the indoor areas. The individuation of the outdoor areas is represented on a map to rapidly visualize the overall case study situation.

As for outdoor areas, the indoor areas characterization is focused on the identification of buildings facing the previously-defined BE outdoor area for the square itself and the closest parts of the access streets to the square. The Calcmaps tool is employed as mentioned before to calculate all the covered surface of buildings that have a direct access on the outdoor area, by identifying the specific indoor intended uses and estimating their surface into the buildings. This action ensures considering only those intended use hosted in the buildings/building aggregates that are directly connected to the analysed BE. Data from Google Maps and Street Maps application, available at https://www.google.it/maps/?hl=it (last access on 25/01/2021), are used to check:

- the direct access of each intended use hosted in the buildings/building aggregates, thus identifying those elements that are directly connected to the outdoor areas of the considered BE;
- additional detail on geometrical aspects which can affect the morphological homogeneity of the intended uses from the plan and the elevation characterization, such as the number of floors or the presence of passageways and covered walks;
- the intended use homogeneity (e.g. different intended use inside the building), thanking to the possibility to detect, via Google maps, commercial activities, shops, restaurants, bars, hospitals, churches, schools and offices (both private and public) in the BE[4]. In particular, according to the Italian regulation of the educational stages, schools should be classified into primary (mainly involving users from 5 or 6 years to 14 years) and secondary (mainly involving users from 15 to 19 years) schools, as well as into universities (involving users over 20 years).

The building intended uses are classified according to Table 3 (first column), so as to include special uses of buildings into the BE, according to the Environmental Classes defined in D.1.3.1, which are strictly correlated to the possibility of terrorist acts (compare Appendix B). In particular, main churches (i.e. duomo, cathedral) are considered for the Environmental Class B.

According to a quick approach for indoor surface estimation, the covered areas of a homogeneous portion of each intended use hosted in the buildings/building aggregates (including the porticos areas, as mentioned before) are multiplied for the related number of floors (Li et al. 2019; Quagliarini et al. 2021).

4.1.4 Characterization of the maximum number of BE users

The users in the BE are distinguished into: 1) outdoor users by distinguishing only *outdoor users* OO (such as passers-by) and *prevalent outdoor users* PO (that are those from outdoor areas hosting a specific building use, such as dehors, and users in mass gathering events); 2) indoor users by distinguishing *residents* R and *non-residents* NR, such as those in offices, schools, churches, accommodation facilities and so on. These data

[4] In process, when no supplementary data were retrieved on the net, the buildings/building aggregates that are not assigned to other intended uses are assigned to residential uses, since of Google maps data do not directly provides specific information on the matter.

will can be managed by distinguishing or not the contribution of the square space and of the considered accesses streets.

Thus, the occupant load (pp/ m²) is firstly associated to each of the above-mentioned indoor and outdoor areas, so as to calculate the number of users before the SUODs emergency or also during the normal use of spaces in SLODs. In particular, for outdoor areas, according to D1.2.1 and to previous works on rapid exposure assessment in terms of human lives in the BE (De Lotto et al. 2019; Quagliarini et al. 2021) and considering the Italian application context, it is assumed that:

- 0 pp/m² for vehicle accessible areas, thus reasonably assigning the use of the carriageway only to vehicles;
- 0.1pp/m² for the pedestrian areas, thus considering a low level of crowding in ordinary conditions (up to level of service A) during the daily hours (Bloomberg and Burden 2006). These data essentially refer to passers-by (Yıldız and Çağdaş 2020; Cheliotis 2020). The users in such areas are considered as *only outdoor users* **OO**;
- Three type of dehors can be distinguished:
  a. Dehor generally related to bars and restaurants, and the index of 0.4 pp/m² can characterize such areas according to the Italian Fire Safety Codes suggestion. The users in such areas are defined as *prevalent outdoor users* **PO***;*
  b. Covered/partially covered areas within the square, whose destination can be different during the day (e.g. open market in the morning, pedestrian area or parking in the afternoon/night). During the service hours, the previous index of 0,4 pp/m² is split into two rates in order to distinguish between two type of users: 0,3 pp/m² to compute *prevalent outdoor users* **PO**, whose presence is strictly related to the hours in which the market is working; 0,1 pp/m² to compute *outdoor users* **OO,** whose presence is constant during the day and non-related to the market opening;
  c. Covered/partially covered areas adjoining the square (e.g. open market), and the index of 0,4 pp/m² can characterize such areas in order to compute *prevalent outdoor users* **PO**, whose presence is strictly related to the hours in which the market is working. It is worth noting that in this case, the dehor' surface is excluded from the overall square surface (m²).
- monuments are excluded by this count considering that also in case of an emergency those areas should be subtracted by the overall available areas, since they represent and obstacles to the users' motion.

Finally, in case of mass gatherings in the BE outdoor areas, the occupant load can be considered equal 2 or up to 4 pp/m². This load should be assigned to the effective area of the mass gathering (i.e. only pedestrian areas or pedestrian areas plus vehicle accessible areas). The number of users in each indoor area is similarly calculated as the multiplication of the intended use-based occupant load (pp/m²) determined by Table 3, based on the Italian Fire Safety Codes suggestions (Quagliarini et al. 2021), and the covered area for the related intended use. Since the process considers the covered area rather that the net internal area, the outcoming small overestimation of the users' number in indoor areas moves towards a conservative approach in users' exposure quantification. In this sense, the methodology is able to quickly esteem the maximum number of individuals simultaneously contained inside the buildings. However, the results could represent a critical but marginal situation in the BE. Therefore, further in-situ surveys or the collection of local data by BE stakeholders and citizens could improve the reliability of the users' number assessment analysis.

4.1.5 Characterization of the BE users in terms of individual vulnerability and behavioural patterns in BE use

Considering the individual vulnerability, the following age ranges are provided according to previous works (De Lotto et al. 2019; Quagliarini et al. 2021) and to the possibility of distinguishing some main common conditions in motion (Bosina and Weidmann 2017):

- toddlers **TU** from 0 to 4 years, who directly depends on their parents to move in the BE;
- parent-assisted children **PC** from 5 to 14 years, who can autonomously move but are generally strictly influenced by their parents' use of the BE;
- young autonomous users **YA** from 15 to 19 years, who can be considered as autonomous users of the BE, but scholars;
- adult users **AU** from 20 to 69 years, who can be considered as autonomous users of the BE, but potentially workers;
- elderly **EU** from 70 to 100+ years, who can have a reduced use of the BE with respect to the AU.

Data about population distribution are adopted to evaluate statistics on gender and age-related features of the users. For each Italian Municipality, the online website http://demo.istat.it/ (last access on 25/01/2021) provides the distribution of population in relation to different age-range in reference to the last census campaign (i.e.: for 2020, http://demo.istat.it/popres/index.php?anno=2020&lingua=ita), basing on the analysis of ISTAT reports (e.g. (Istat 2012; ISTAT 2018))[5]. This source has been adopted in view of its quickness in data analysis in view of the different city-related applications of data collection, as well as because of the continuously-update source of data. According to the need of a quick methodological approach in users' gender and age-related features assessment, it is reasonably assumed that these data: 1) are extended to all the users in the BE, although they are mainly referred to residents only, because of the statistics sources; 2) are valid for the analysed BE as a part of the whole urban scenario in which it is placed, thus confirming the possibility that gender and age trends for non-resident users are the same of the area in which the BE is placed. This source allows to retrieve the percentage **p** [%] for each of the age ranges mentioned in the above (e.g. Tup, AUp…). At the same time, the statistical data allows to estimate male percentages Mp [%] and female percentages Fp [%] for the BE.

Considering the behavioural patterns in BE use, data collected by Section 4.1.4 methodology are also organized to trace the users' number and typologies in reference to outdoor (that are OO and PO) and indoor (R and NR) users of the BE, by distinguishing The organization of these data tries to outline possible recurring patterns in users' behaviours in respect to the space use in the BE, by mainly focusing on indoor contexts (i.e. buildings) (Li et al. 2019; Yuan et al. 2019; Quagliarini et al. 2021).

Table 4 traces the correlation between the users' typologies organized into the previous age ranges and the **R**, **NR**, **PO** and **OO** categories to calculate the users' number over the time, that are Rn, NRn, POn and OOn [pp]. In particular, for resident users R, the following assumptions are considered as valid according to a quick but reliable application approach of the methodology:

- **TU** and **EU** mainly spend their time at home or in the neighbouring areas;
- **PC** and **YA** are scholars spending the morning hours (i.e. from 8am to 1pm included) at schools, away from the BE. These timings could change if specific sources on daytime openings are available, such as in full-time elementary or secondary schools, or universities;

[5] As an alternative, the data from the tuttitalia.it website could be used (e.g. https://www.tuttitalia.it/abruzzo/58-altino/statistiche/popolazione-eta-sesso-stato-civile-2020/) by referring to each Municipality and not the Provincial data. This repository adopts ISTAT values, but creates 5years-wide classes of population in an automatic way.

- **AU** are distinguished between: 1) employed users, spending their time depending on their away from the BE from 8am to 6pm included; 2) unemployed users, considered to spending their time at home or in the nearby, so as to also consider housemakers. The unemployed percentage AUEp [%] is calculated according to national statistics[6].

Concerning non-resident users NR, data from Google Maps are used to derive the opening time of related intended uses during the single day as well as during the week. Opening data are checked by taking into account: 1) Google (i.e. Google Maps) data; 2) https://www.paginegialle.it/ or https://www.paginebianche.it/ or https://www.oraridiapertura24.it/ (last access: 09/02/2021), since these database contains information on companies in the Italian context; 3) social network pages of the companies and activities open to the public, which are noticed through the Google Maps analysis (e.g. company page on Facebook). In case no data on opening time can be assigned depending on such steps, standard opening times of public buildings in Italy are assumed depending on the use of the indoor area, and according to national regulations and standards[7].

Considering outdoor users, the same opening-time-based criterion is applied to outdoor uses for **PO** number assessment. On the contrary, the number of *only outdoor users* **OO** (e.g. passers-by) is defined depending on the conditions of general use of the BE because of mass gathering events affecting the users' number. In particular, mass gathering-affected situations are considered according to local administration webpages or social network data on past events (i.e. before 2020, so as to ensure the inclusion of events in pre-COVID19 emergency conditions). Recurring mass gathering events such as local fairs, which can be weekly hosted by the BE, are included in the weekly variation of the users (Quagliarini et al. 2021). One-off events, such as festivals, are considered as exceptional events for users' number conditions.

As a consequence, the following main day-related classes are considered: 1) "standard" working days, to represent the daily normal use conditions without other events; 2) "standard" holidays (i.e. Sundays, other national holidays without mass gatherings events); 3) working days with fairs/recurring mass gatherings; 4) one-off mass gatherings. The following conditions in terms of users' typologies in respect to indoor/outdoor spaces can be evidenced:

- **for "standard" working days and standard holidays:** NR and PO depend on the building use activities opening time, thus differences between working days and holidays can exit. R depends on the general rules of Table 4 and the previous defined assumption. According to a quick assessment approach, OO is a non-variable component equal to: 0pp from 0am to 6am, thus considering that no passers-by are present during the night; the maximum assumed low level of crowding in ordinary conditions (up to level of service A) during the daily hours (7am to 24 pm), as stated in Section 4.1.4;
- **for working days with fairs/recurring mass gatherings and one-off mass gatherings:** NR and R are considered as for working days and holidays. PO are calculated considered as the sum of PO for standard uses in the BE (i.e. dehors) and PO for the fairs/mass gatherings. OO can be reasonably excluded when the fair/mass gathering area is close to the whole BE outdoor areas or the number of OO is under the 10% of PO, since OO assumes a limited influence on the overall exposure conditions.

Finally, it is operatively considered that users coming from the considered access streets can be herein considered as **OO**, since they can be passers-by coming from the out of the square or exiting from the square itself. However, this work will consider the related data into the general statistical analyses framework (compare with 4.2).

[6] https://www.istat.it/it/archivio/occupati+e+disoccupati (last access: 12/02/2021)
[7] https://www.mise.gov.it/index.php/it/mercato-e-consumatori/concorrenza-e-commercio/risposte-ai-quesiti/orari-di-apertura-e-chiusura (last access: 09/02/2021)

In view of the above, weekly variations in the number of users depends on the maximum crowding conditions of each day, thus evidencing possible differences between working days and holidays. Anyway, in-situ surveys could be used to improve the detail of such data on behavioural patterns (Yıldız and Çağdaş 2020; Cheliotis 2020).

4.1.6 Characterization of the BE collective vulnerabilty

Considering the BE features affecting the collective vulnerability of users in SUODs (see also Table 2), elements of the built environment and its management concerning the evacuation plan and layout are investigated through Google Maps or the access to evacuation plan maps and document of the municipality (online documents), so as to trace if:

- a specific emergency plan is available for the BE (from municipal document);
- wayfinding signs and evacuation facilities are implemented (e.g. via Google Street View);
- safety personnel actions are available (from municipal document);
- the area is used for emergency management and evacuation purposes according to the municipal plan (from municipal document).

Table 3 Quick occupant load factor for different intended use are reported referred to Italian fire safety codes.

Building intended use [environmental class according to Appendix B]	Methodology	Quick occupant load factor	References to Italian regulations
Residential buildings [E]	The crowding density for private dwellings is related to their surface	0.05 pp/m² (imposed by regulations)	For residential buildings: DM 3/8/2015
Institutional buildings including architectural and historic ones used as offices, museum, art gallery, [B], administrative/government offices/buildings [N], police stations/military bases [D]	Infield survey to trace information about the number of the occupant (personnel) with a precautional increase of 25% rounded to the upper bound. The number of possible visitors has to be added by considering the area extension of public office In the absence of further information, use the quick occupant load factor.	Offices closed to public: 0.1 pp/m² Offices open to public: 0.4 pp/m² Areas gathering public: 0.7 pp/m²	Generally, assimilable to the crowding of working place: DM 10/3/1998, DM 3/8/2015; for other public exhibition places, i.e. hosted by historical buildings: DM 20/5/1992, DPR 30/6/1995; for areas hosting cultural events with the public: DM 19/8/1996, DM 6/3/2001, DM 3/8/2015;
Religious buildings [B]	For each building, the number of seats has to be counted adding the number of standing places	0.7 pp/m² applied to the available area extension	For this intended use, assimilable to entertainment and public exhibition places: DM 19/08/1996, DM 6/3/2001, DM 18/12/2012;
Hospital and healthcare buildings [C]	Infield survey to trace the information regarding the number of available beds. The number of in-service personnel is added and the variation due to visitors esteemed through the average data of at least three typical days	Ambulatory and similar: 0.1 pp/m² Spaces for visitors: 0.4 pp/m²	For this intended use, assimilable to the crowding for working places: DM 10/3/1998
School buildings [C]	The number of seats for each classroom and eventual annexes (e.g.: refectory, gym) has to be collected in relation to the number of students, teachers, and personnel, according to the headteacher declaration	Refectory and gymnasium: 0.4 pp/m² A maximum of 26 individuals can be considered for each classroom In case no data on the number of classrooms is available: 0.4 pp/m² applied to the covered area (as gross area)	DM 26/8/1992, DM 12/5/2016, DM 3/8/2015

		During the afternoon (non-lessons time): 0.1 pp/m² as for Offices closed to public	
Cultural and entertainment buildings (public exhibition such as museums and cinemas, and sports facilities) [B]	Evaluation of the main activities and the presence of seats for the public (number of seats)	In a precautional way: ballroom - 0.7 or 1.2 pp/m²; theaters parterre -3 pp/m², standing places - 3.5 pp/m² Sports facilities: 2 pp/m²	DM 18/3/1996, DM 6/6/2005, DM 19/8/1996, DM 18/12/2012
Commercial buildings [B]	The crowding index is related to the surface of the overall floor	0.4 pp/m²	DM 27/7/2010, DM 3/8/2015
Accommodation facilities [B]	Data about a general scale could be provided by tourism organizations subdivided for periods or seasons (e.g.: the municipal tourism promotion companies, regional tourism management bodies, trade organizations). Infield surveys are necessary to obtain the single structures maximum capacity, the number of beds and personnel (increased by 20%)	0.4 pp/m² (i.e. common spaces)	DM 27/7/2010, DM 3/8/2015
Public shops such as restaurants bars and cafes [B]	The crowding values can be reasonable esteemed in relation to the extension of the area, for bars and cafes infield surveys are desirable to esteem the number of costumers during each time slot	0.7 pp/m² (precautionary evaluations)	For this intended use, assimilable to public exhibition places: DM 19/8/1996, DM 6/3/2001, DM 18/12/2012; from a general point of view: DM 3/8/2015

Table 4 Correlation table for users' number quantification considering: age ranges as the main individual vulnerability factor (rows); users' typology considering the familiarity with places and emergency procedures (supercolumns), by including BE uses and opening to the public (sub-columns).

Individual vulnerability by age ranges	Residents R			Prevalent Outdoor users PO	Only Outdoor users OO
		Educational buildings: primary and secondary schools	All the uses (including all the educational buildings)	All the uses	

		lesson time (depending on the educational stage system, e.g. 8am to 1pm)	normal closure to scholars, that is out of lessons time	open to the public (excluding universities)	universities (depending on the lesson time, e.g. 8am to 8pm)	close to the public (i.e. where offices are present)	closure time	open to the public	closure time	
Toddlers TU (0-4 years)	constant over the time, equal to Rn [pp] * TUp [%]	0	0	equal to NRn [pp] for the considered building * Tp [%]	0	0	0	equal to POn [pp] for the considered outdoor area use * Tp [%]	0	equal to OOn [pp] * Tp [%]
Parent-assisted Children PC (5-14 years)	Working days: equal to 0 from 8am to 1pm; elsewhere Rn [pp] * PCp [%] Holidays: constant over the time, equal to Rn [pp] * PCp [%]	considering 0.4pp/m^2, all the users are PC in case of primary schools	0	equal to NRn [pp] for the considered building * PCp [%]	0	0	0	equal to POn [pp] for the considered outdoor area use * PCp [%]	0	equal to OOn [pp] * PCp [%]
Young Autonomous users YA (15-19 years)	Working days: equal to 0 from 8am to 1pm;	considering 0.4pp/m^2, all the users are YA in case of secondary schools	0	equal to NRn [pp] for the considered building * YAp [%]	0	0	0	equal to POn [pp] for the considered outdoor area use * YAp [%]	0	equal to OOn [pp] * YAp [%]

	elsewhere Rn [pp] *YAp [%] Holidays: constant over the time, equal to Rn [pp] * YAp [%]									
Adult Users AU (20-69 years)	Working days: equal to Rn [pp] * AUp [%] * AUEp [%] from 8am to 6pm; elsewhere Rn [pp] *AUp [%] Holidays: constant over the time, equal to Rn [pp] * AUp [%]	4% of the users in the school, derived from PC (primary schools) or YA (secondary schools)[8]	considering 0.1pp/m², all the users are AU	equal to NRn [pp] for the considered building * AUp [%]	considering 0.4pp/m², all the users are AU	considering 0.1pp/m², all the users are AU	0	equal to POn [pp] for the considered outdoor area use * AUp [%]	0	equal to OOn [pp] * AUp [%]

[8] The 4% relates to at least 1 teacher over 26 students, according to the national regulations on average classes dimension. The conservative approach in the users' number estimation is adopted by summing the scholars and the adults. Example: secondary school with a gross area of 1000m² and no information on the number of classes. YAn=0.4pp/m²*1000m²=400pp; And=400*4%=16pp

Elderly Users EU (70+ years)	constant over the time, equal to Rn [pp] *EUp [%]	0	0	equal to NRn [pp] for the considered building * EUp [%]	0	0	0	equal to POn [pp] for the considered outdoor area use * EUp [%]	0	equal to OOn [pp] * EUp [%]

4.2 Data managing methodology to derive the parameters for BETs definition

According to the last column of Table 3, some parameters can be quickly assessed starting from the data collected by the Section 4.1 methodology, thus organized collected inputs into quantitative values for the assessment of recurring conditions in the BE. At the same time, these data can be also implemented as inputs for simulation activities in WP4, since they can define the overall range of variations for the parameters characterizing the exposure and the vulnerability of BE users.

In view of the above, Table 5 resumes the parameters considered in the following analysis for BET definition. Table 5 define each parameter by providing specific calculation methods and the meaning of the parameter in respect to BET definition and simulation activities in WP4, also in correlation with Table 3 general overview of the factors (i.e. last column). Sub-parameters are defined where necessary to distinguish secondary conditions for the classification. Each parameter and sub-parameter in Table 5 is evaluated for each BE assessed according to the data derived from Section 4.1 methodology, and evaluated in respect to three classes of descriptors for the BE and its users:

- **OUC – Overall Users' Characterization:** these parameters trace a general overview of the BE typologies, considering the day/night-time as a whole. For each BE, maximum, minimum, median and mean values referring to the are firstly calculated and organized to match all the BE case studies. The contribution of users (OO, PO, R, NR, per age classes and so on) will be evaluated for the whole number of assessed users, as well as for those placed inside the square areas (and the connected buildings) and for those placed along the closest parts of the access streets (defined according to Section 4.1.1 method), in a separated manner. This last choice ensures the evaluation of the impact of the surrounding built environment on the square exposure;
- **TDC – Time Dependent Characterization:** these parameters trace a time-dependent overview of the BE typologies, basing on hourly sampling methodologies or by even combining similar hourly conditions into unique classes;
- **BEC – Built Environment Characterization:** these parameters do not directly relate with the users' quantification or typologies but trace exposure and collective vulnerability-influencing issues depending on the BE features (i.e. the characterization of outdoor areas in the OSs).

According to Section 4.1 data collection methodology, the users in the BE are distinguished into: 1) indoor users by distinguishing *residents* R and *non-residents* NR; 2) outdoor users by distinguishing only *outdoor users* OO (such as passers-by) and *prevalent outdoor users* PO (that are those from outdoor areas hosting a specific building use, such as dehors, and users in mass gathering events). Related data are collected in absolute and relative terms according to Table 5 parameters.

As shown by the second column of Table 5 (meaning of the parameters), some parameters have different meaning in respect to users' exposure assessment in SUODs and SLODs. In terrorist acts, users' placed outdoor can move inside the building to face the emergency conditions (i.e. "invacuation" strategies in terrorist acts (BSI 2010), please also compare with D1.3.2), while, in SLODs, users could minimize their permanence time in outdoor areas (compare with D2.2.3). Such conditions can be characterized by the users' density considering the built-up areas (indoor) [pp/m²]. In this case, the built-up areas will be only the ones having a direct access to the square, thus not computing those placed along the closest parts of the considered access streets.

On the contrary, SUODs like earthquake can imply the immediate evacuation of indoor areas, thus evidencing the critical interactions conditions in the BE by the users' density considering the outdoor areas in the BE [pp/m^2]. As for the indoor density, the outdoor users' density is calculated only referring to the outdoor areas in the square. In these cases, vehicle accessible areas and carriageways should be considered into the available space where users can gather.

Parameters assessed for OUC and TDC purposes are organized into the 4 day-related classes defined in Section 4.1.5: 1) "standard" working days, to represent the daily normal use conditions without other events; 2) standard holidays (i.e. Sundays, other national holidays without mass gatherings events); 3) working days with fairs/recurring mass gatherings; 4) one-off mass gatherings.

BEC parameters are organized in a unique classification, but the presence of emergency plan is organized by distinguishing "standard" working days and holidays and, if specific emergency plans are available:1) working days with fairs/recurring mass gatherings; 2) one-off mass gatherings.

4.2.0 Statistical analyses

The following statistical analyses are performed on the whole sample, to evidence the recurring conditions for BET definition.

Boolean parameters are investigated in respect to the two possible classes (true or false). The recurring condition of the BET is represented by the most probable class.

Parameters expressed in [number of items per BE] are organized in discrete classes (1 item of width), thus being assessed in terms of integer values of median and mean for the whole sample, as well as of median, modal, minimum and maximum values. The modal value is assumed to represent recurring conditions of the BE.

The other parameters are organized in continuous classes according to the Sturges' rule (Scott 2009) and are assessed according to statistical analyses through a quartile-based approach, so as to evidence significant trends in their values. Outliers according to the InterQuartile Range IQR method (fence: 1.5 IQR) (Rousseeuw and Hubert 2011), so as to define boundary conditions in the sample which cannot be considered as recurring. Nevertheless, maximum values of these outliers can be still considered to depict exceptional exposure conditions of the BE. The median value is assumed to represent recurring conditions of the BE. Quartile-based representation of the TDC-related parameters are provided during the time, according to the previous defined day-related classes.

In particular, for OUC values, quartile-based analyses are perfomed for each case study BE. Then, quartiles values are collected for each BE and analysed in an aggregate sample, thus limiting secondary effects of outliers for each BE, but just working on the main representative values in the distribution. As a consequence, for instance, the mean OUC value representing the selected BEs is calculated as the sample mean rather than by considering the whole BE-related data.

*Table 5. Exposure and vulnerability parameters for BETs definition. The parameters are organized in classes of descriptors: OUC – Overall Users' Characterization; TDC – Time Dependent Characterization; BEC – Built Environment Characterization. The final column provides the direct correlation with the general factors in Table 2. * means that the value is distinguished considering working days/holidays without mass gatherings, working days with fairs/recurring mass gatherings and one-off mass gatherings.*

Parameter [unit of measure]	***C: Calculation methods. M: Meaning for BET definition and simulation activities***	***Specific conditions of sub-parameters and related symbol (if needed)***	***OUC***	***TDC***	***BEC***	***Related ID/IDs in Table 2***
BE users' number [pp]	C: the number of exposed BE users in outdoor and indoor areas, calculated as the sum of users depending on the specific conditions of the sub-parameters. M: tracing the "dimension" of simulated users	users' overall number **UOn**, regardless of the typology	x			2.4
		depending on their familiarity with places and emergency procedures, that is in reference to: residents **Rn**; non-residents **NRn** (including visitors, workers, users in indoor spaces open to the public); only outdoor users **OOn** (such as passers-by)**;** prevalent outdoor users **POn** (such as users of dehors); $\mathbf{Un}_{int,use}$ is also considered to trace the effects users from interfering SoR along the access streets (as incoming flows in the square or as OOn)	x			1.2.3, 2.3
percentage of users' considering the familiarity with places and emergency procedures [%]	C: percentage ratio between specific users' typologies and the overall users' number M: scaling the number of users into the BE in respect to main behavioral issues such as those due to risk-perception and preparedness issues	depending on their familiarity with places and emergency procedures, that is in reference to: residents **Rp**; non-residents **NRp** (including visitors, workers, users in indoor spaces open to the public); only outdoor users **OOp** (such as passers-by)**;** prevalent outdoor users **POp** (such as users of dehors); $\mathbf{Up}_{int,use}$ is also considered to trace the effects users from interfering SoR along the access streets (as incoming flows in the square or as OOp)	x	x		1.2.3, 2.3
percentage of users' considering individual vulnerability [%]	C: percentage ratio between specific users' typologies and the overall users' number M: scaling the number of users into the BE in respect to main individual vulnerability affecting response and motion	depending on their age ranges: toddlers **TUp** 0-4 years old, parent-assisted children **PCp** 5-14years old, young autonomous users **YAp** 15-19 years old, adult **AUp** users 20-69 years old, elderly **EUp** for more than 70 years old.	x			1.1.4
		depending on their gender: male **Mp**, female **Fp**	x			2.1, 1.1.5, 2.3
users' density considering the outdoor areas in the BE [pp/m^2]	C: the ratio between the BE users' number and the outdoor area (not walkable areas not included). M: it essentially considers that all the users can contemporarily move outdoor spaces (such as for a SUOD). In respect to the users' number, this value can be scaled for the outdoor BE area, thus moving towards its parametrization	users' overall outdoor density **UOOd** regardless of the typology	x	x		2.4, 2.7
		depending on their familiarity with places and emergency procedures, that is in reference to: residents **Rd**; non-residents **NRd** (including visitors, workers, users in indoor spaces open to the public); only outdoor users **OOd** (such as passers-by)**;** prevalent outdoor users **POd** (such as users of dehors); $\mathbf{Ud}_{int,use}$ is also considered to trace the effects users from interfering SoR along the access streets (as incoming flows in the square or as OOd)	x	x		1.2.3, 2.3, 2.7

users' density considering the built-up areas (indoor) [pp/m^2]	C: the ratio between the BE users' number and the indoor area. M: it essentially considers an average density of users in indoor spaces, to replicate general indoor conditions for the simulation inputs	users' overall indoor density **UOId** depending on UOn, so as to consider the outdoor users into the buildings	x	x		2.1, 2.4
		users' indoor density **UId** depending on NRn and Rn (not Pn and OOn), so as to consider normal fruition of the buildings	x	x		2.1, 2.4
BE users' normalized number [-]	C: the number of exposed individuals in the BE normalized in respect to its daily peak. By this way, the parameters range is [0;1] M: defining the peak conditions during the time to trace differences in density values applications	users' overall normalized number **UOnn** regardless of users' typologies		x		2.1, 2.3, 2.4
		depending on their age ranges: toddlers **TUnn** 0-4 years old, parent-assisted children **PCnn** 5-14years old, young autonomous users **YAnn** 15-19 years old, adult **AUnn** users 20-69 years old, elderly **EUnn** for more than 70 years old.		x		2.1, 1.1.4, 2.3
		depending on their familiarity with places and emergency procedures, that is in reference to: residents **Rnn**; non-residents **NRnn** (including visitors, workers, users in indoor spaces open to the public); only outdoor users **OOnn** (such as passers-by)**;** prevalent outdoor users **POnn** (such as users of dehors);)**Unn**$_{int,use}$ is also considered to trace the effects users from interfering SoR along the access streets (as incoming flows in the square or as OOnn)		x		2.1, 1.2.3, 2.3
presence and area of special buildings or special uses [Boolean], [number of items per BE],[m^2]	C: presence or not of special buildings or uses and their surface area also depending on the Environmental Classes of D1.3.1 M: defining special buildings or uses to be considered into the BE (i.e. for terrorist acts purposes and collective vulnerability analysis)	presence of special buildings/uses **SB** (at least one item for class A, B, C, D, N) [Boolean]			x	2.5, 2.8
		number of special buildings/uses per environmental classes **SBn** [number of items] according to Table 5 of D1.3.1 (see Appendix B)			x	2.5, 2.8
		median surface area occupied by special buildings/uses **SBa** [m^2]			x	2.5, 2.8
presence and position of the dehors [-], [%]	C: presence or not of dehors and their position within the square (number of items and percentage of occurrence) M:	dehor number **Dn**, position within the square **Dp** (that is N,W,S,E or C), and number of different positions occupied **Dnp** (that range between 0-5) [-]			x	
		the dehor position in respect to the carriable streets **Ds**, that is on the same side or on the opposite side (only for Dnp=1)[-]			x	
percentage of outdoor areas per typology [%]	C: ratio between the typology area and the overall outdoor area	percentage values per typology: pedestrian areas (and sidewalks) **OPAp**, vehicle accessible areas **OVAp**, not walkable areas (including			x	2.7

	M: tracing the quality of open spaces to define areas with particular users' behavioural patterns depending on their accessibility and use rules	monuments, fountains) **ONWp**, accessible green areas **OGAp**, dehors **ODHp**, private courtyards (e.g. private fenced areas) **OPCp**				
presence of emergency plan [Boolean]	C: the value is true if at least one of the following issues is true: emergency plan available for the BE; wayfinding signs and evacuation facilities implemented; safety personnel actions available; the area is used for emergency management and evacuation purposes according to the municipal plan M: collective vulnerability can be managed through existing emergency management strategies	presence of an emergency plan for the BE **EPp** [Boolean]			x*	1.3.1, 1.3.2
		use of the BE as gathering areas, evacuation path or similar uses in the municipal emergency plan [Boolean] **EAp**. In this case, it should be considered that the BE could be used to host additional users coming from the surrounding urban area, in SUODs (i.e. earthquake)			x	1.3
ratio between indoor and outdoor features [-]	C: ratio between the specific feature of the indoor and outdoor spaces in the BE M: defining the ratio between areas to be simulated as well as of the users' number in outdoor and indoor areas, thus rapidly defining the spaces in which the exposure component is higher. This parameter can highlight when outdoor use due to mass gathering affect the overall exposure terms	ratios between: the Built-up Areas (as the sum of all the building areas at each building levels) and the outdoor areas **BAr** [-]; the Accessible Built-up Areas (as the sum of all the building areas actually accessible by individuals from the outdoor spaces) and the outdoor areas ABAr.			x	2.7
		ratios **UIOr** between NRn+Rn (users in indoor spaces) and OOn+POn (users in outdoor spaces) [-]	x	x		2.3, 2.7

5. Results: typological characterization of the BE

The methodological framework application described in Section 4.2.1 outlines different data representing the collected sample of Italian squares. Such data (related to different occupant categories) can be both managed by keeping them separated (by individuating single factors influence) or combining among them (to reach an overall descriptive statistics). The current work is performed by considering an initial ordinary condition of the scenario without considering the presence of mass gathering events that could bring simultaneously in the studied square a considerable number of pedestrians. Working days represents the majority of recurring conditions in the BE (about 80% of the year days).

Additionally, although data are also collected for non-working days (mainly Saturday and Sundays) such current results of this application considers only the weekday (where economical activities and the service industry are considered open). However, possible differences could emerge in relation to specific buildings intended use (e.g.: churches, pubs, bars, restaurants especially in the evening) and only for the non-resident category. At the same time the assumption related to the time spent at home by resident should be reformulated.

The most interesting outputs concern the overcrowding index for each hour summing the overall people presence and subdividing them for the total surface available of the square (constituted by pedestrian areas and the carriageways). Such results allow to delineate a risk profile of each square along the entire day.

Results show how some elements sample are characterised by high level of overcrowding (pp/m^2) only in specific time of the day overcoming the threshold imposed by Italian regulations. Such exposure peaks are clearly related to the hosted function of building in the studied squares.

5.1 OUC DESCRIPTORS:

5.1.1 BE users' number [pp] as the number of exposed individuals in outdoor and indoor areas

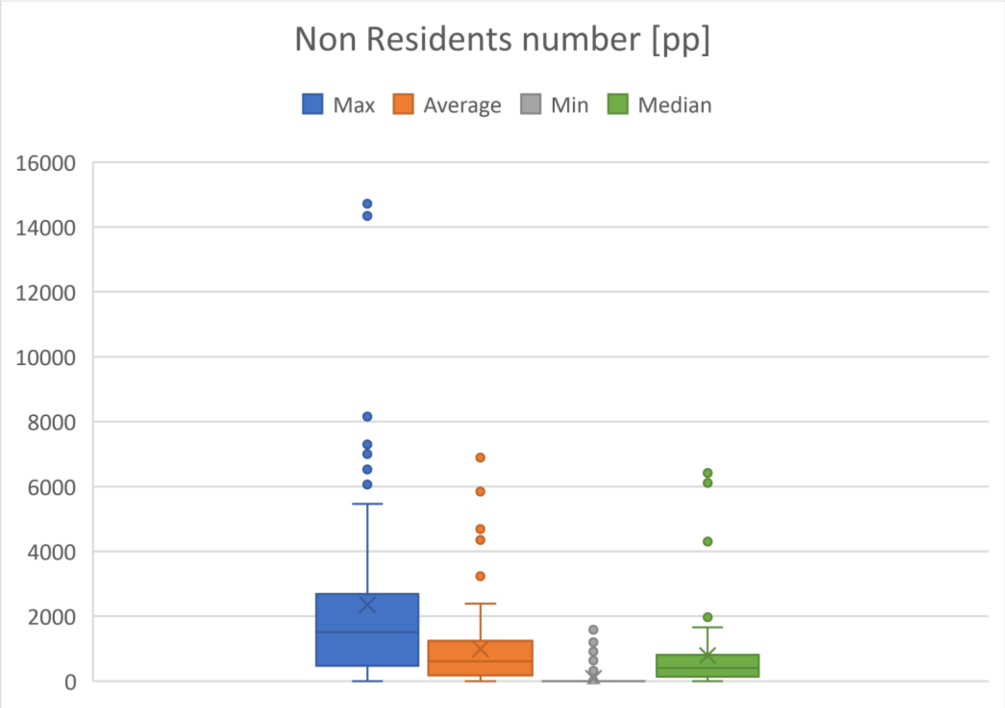


Figure 6: Box-and-whiskers plot representation of the number of Non-Residents users exposed in outdoor and indoor areas (RNn), by tracing daily maximum, average, minimum and median trends.

Non-Residents (Figure 6) are the users' typology with the higher variability, since their presence is related to the opening time and the dimension (m^2) of the activities within the BE. Maximum critical values excessively overestimate NRn, since they represent the case when all the activities are open and fully loaded. On the other hand, minimum values underestimate NRn since they are representative of the night-time, when activities are generally closed, except for outliers like hotels. Hence, considering each case median values (that are close to average values too), NRn can be considered varying between 130 and 760 (1st and 3rd quartiles) while the median values is 400 people (2nd quartile).

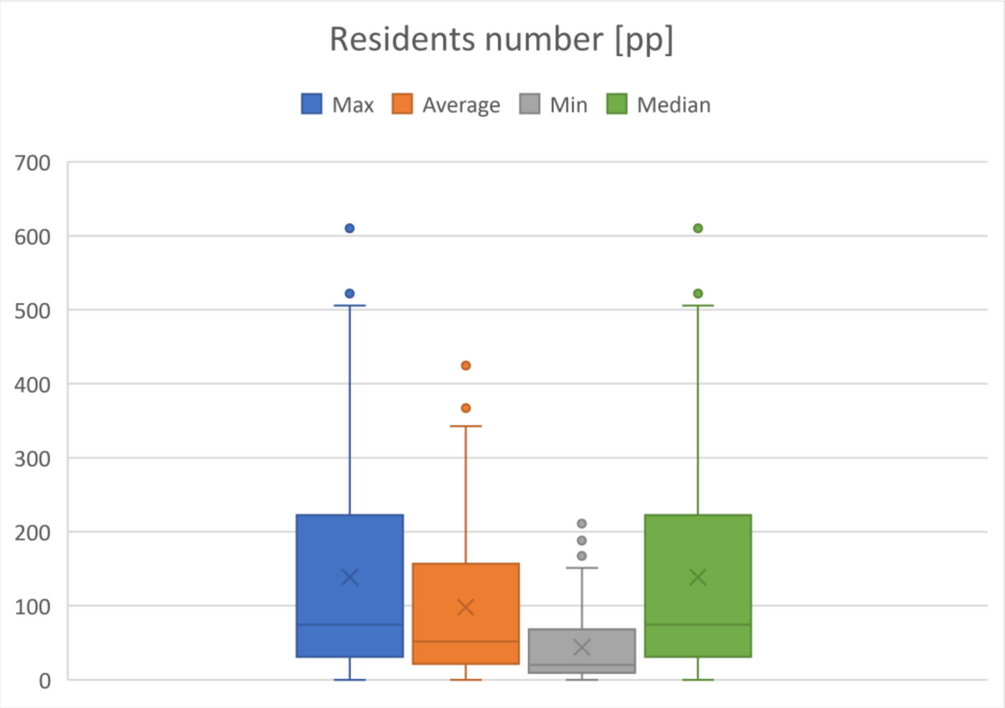


Figure 7: Box-and-whiskers plot representation of the number of Residents users exposed in outdoor and indoor areas (Rn), by tracing daily maximum, average, minimum and median trends.

Residents users (Figure 7) are evenly distributed during the day (i.e., according to Table 4, all residents are counted in non-working hours, that is 7pm to 7 am, while during the day scholars and workers are considered absent). As a result, since most of the daytime they can be considered at home, median data coincide with the maximum ones, while minimum data can be traced back to the working hours. For what it concerns the number of users, Rn maximum and median critical values range from 32 to 238 people (1st and 3rd quartiles) while the median is 75 residents (2nd quartile).

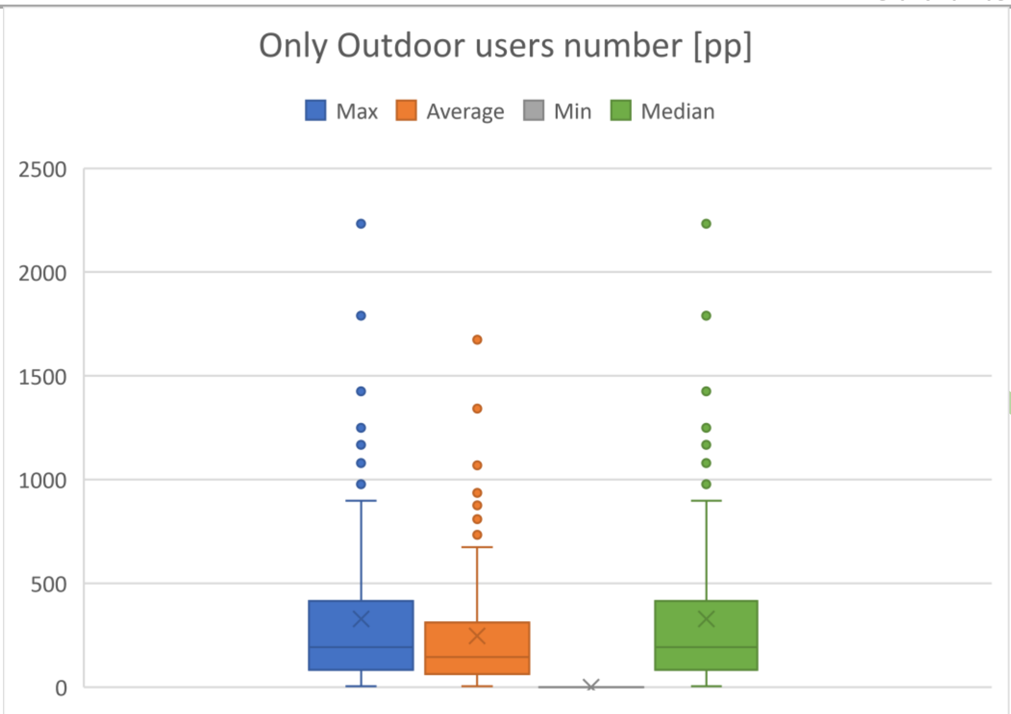


Figure 8: Box-and-whiskers plot representation of the number of Only Outdoor users exposed in outdoor and indoor areas (OOn), by tracing daily maximum, average, minimum and median trends.

According to Table 4, Only Outdoor users are constant during the daytime except for the night hours (i.e., 1-6 am). As a result (Figure 8), median data coincide with the maximum ones, while minimum data can be traced back to the night-time. OOn maximum and median critical values range from about 80 to 380 people (1^{st} and 3^{rd} quartiles) while the median is 193 users (2^{nd} quartile). Outliers depends on the squares' dimension (e.g., Piazza del Plebiscito, Napoli).

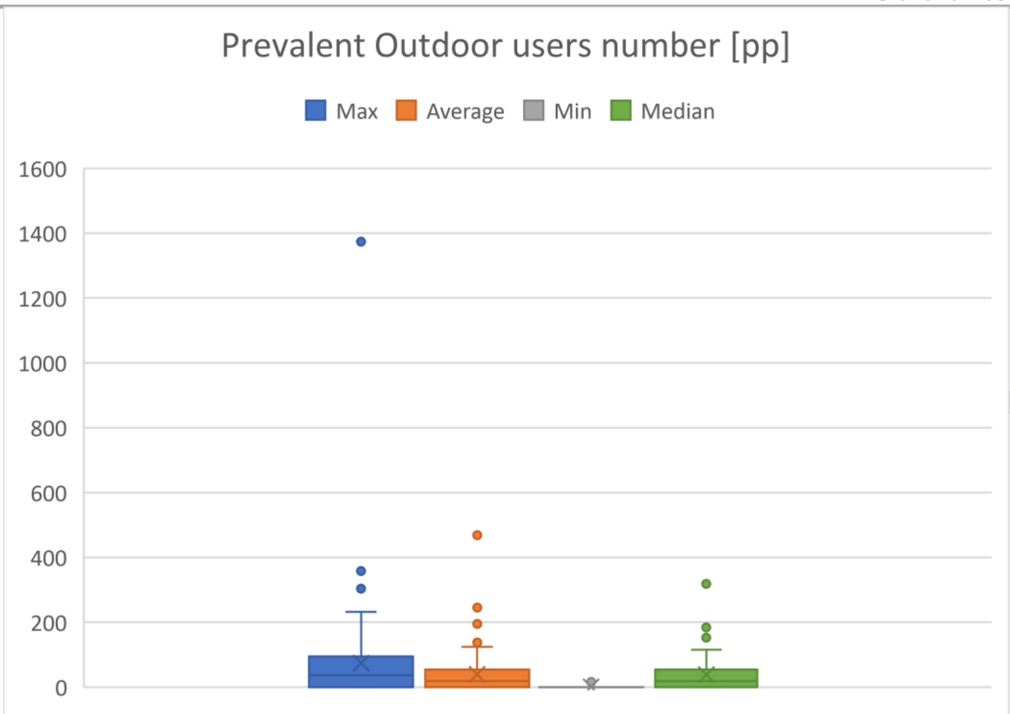


Figure 9: Box-and-whiskers plot representation of the number of Prevalent Outdoor users exposed in outdoor and indoor areas (POn), by tracing daily maximum, average, minimum and median trends.

Prevalent Outdoor users depend on the presence of dehor areas within the BE, together with their dimension (m^2) and opening time. Figure 9 shows that median and average data are comparable, as critical values range from 0 to 50 people (1st and 3rd quartiles) while the median is 17 users (2nd quartile). POn maximum values represent the case when all the activities are open and fully loaded, while minimum data are for closing time (or absent dehor areas). Outliers are for covered/partially covered areas within the BE, like open markets, whose dimensions are considerably higher than the ones generally related to bars and restaurants.

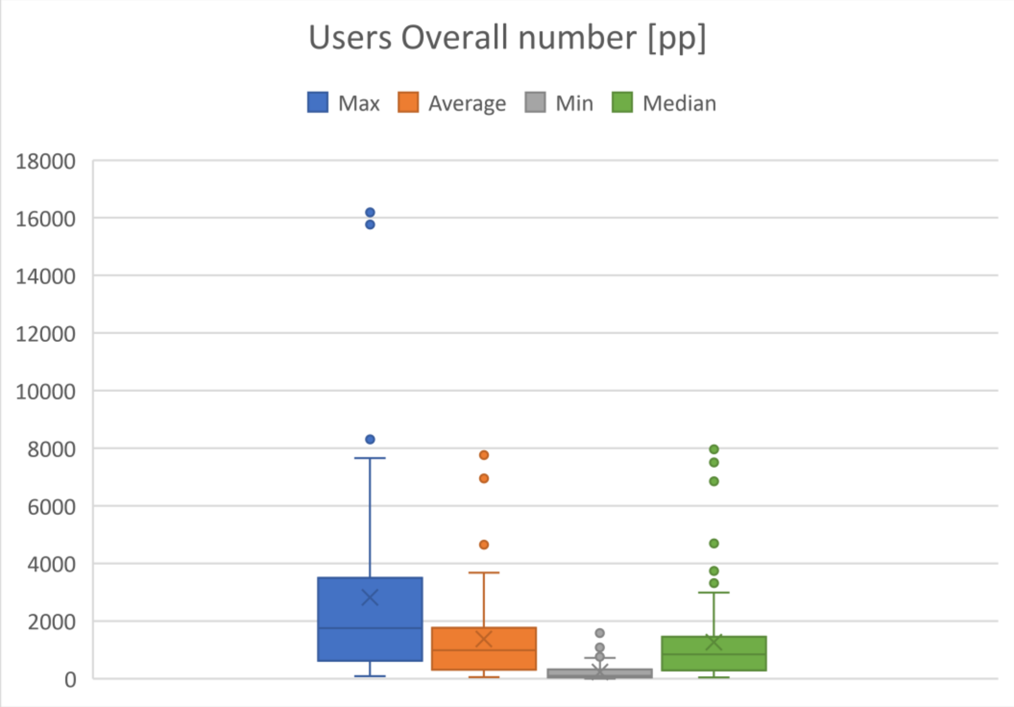


Figure 10: Box-and-whiskers plot representation of the number of Overall Users exposed in outdoor and indoor areas (UOn), by tracing daily maximum, average, minimum and median trends.

Regarding the Users Overall sample (Figure 10), maximum critical values maximize the presence of all the aforementioned categories (NRn+Rn+OOn+POn), thus implying an extremely overestimated number of people accounted for within the BE. On the other hand, considering the median trends, which appear to be comparable to the average ones too, critical values range from about 280 up to about 1400 users (1^{st} and 3^{rd} quartiles), while the median is 825 overall users (2^{nd} quartile).

5.1.2 Percentage of users considering the familiarity with places and emergency procedures [%]

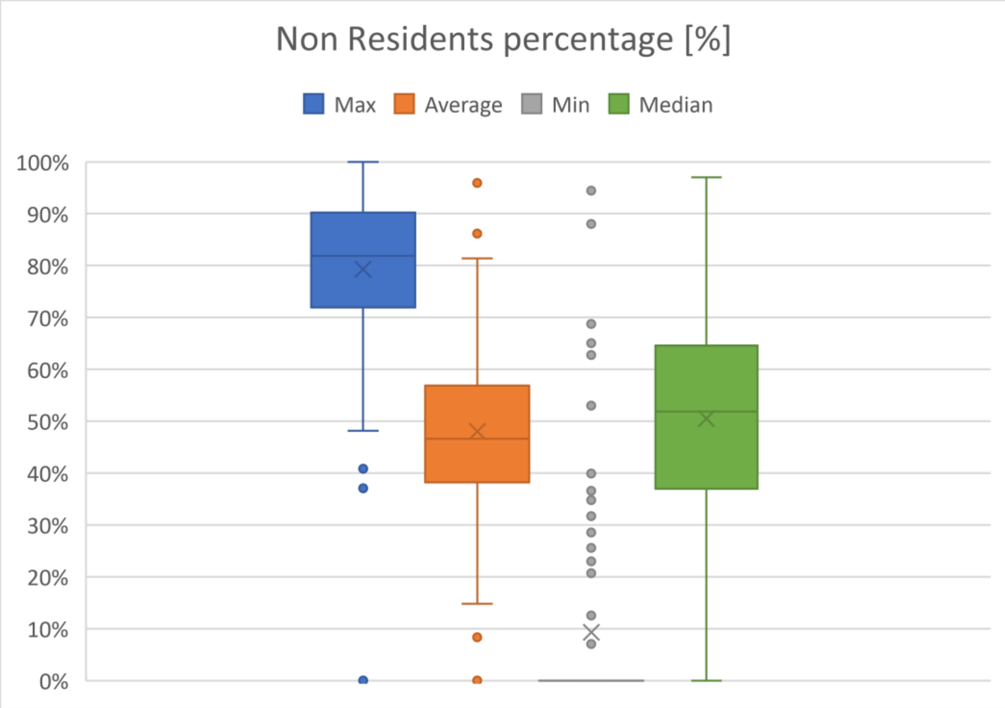


Figure 11: Box-and-whiskers plot representation of the percentage of Non-Residents users (RNp), by tracing daily maximum, average, minimum and median trends.

Figure 11 show that Non-Residents are the main part of the users populating the BE, as NRp average and median critical values range between about 40 and 60% (1st and 3d quartiles), while the median is about 50%. Maximum values refer to the working hours when Residents are not accounted for, while minimum are for the night hours, which are correlated to the maximum residents' percentages. Outliers in the minimum values distribution refer to activities open 24/7 such as hotels.

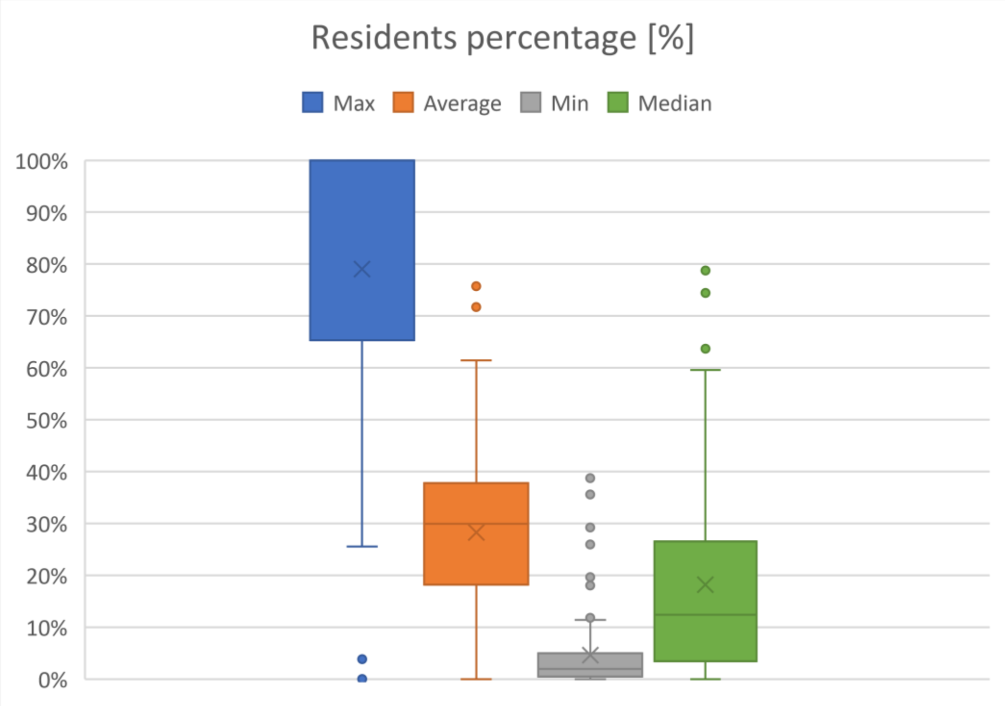


Figure 12: Box-and-whiskers plot representation of the percentage of Residents users (Rp), by tracing daily maximum, average, minimum and median trends.

During the day, Rp can vary from lesser than 10% (minimum data, which is in working time) up to >70% (maximum data, during the night), thus implying that the average trends are strongly influenced by the great difference depending on time of the day (Figure 12). Hence, median critical values appear to be more effective, registering about 5%, 15%, and 25% Rp for the quartiles 1, 2, and 3.

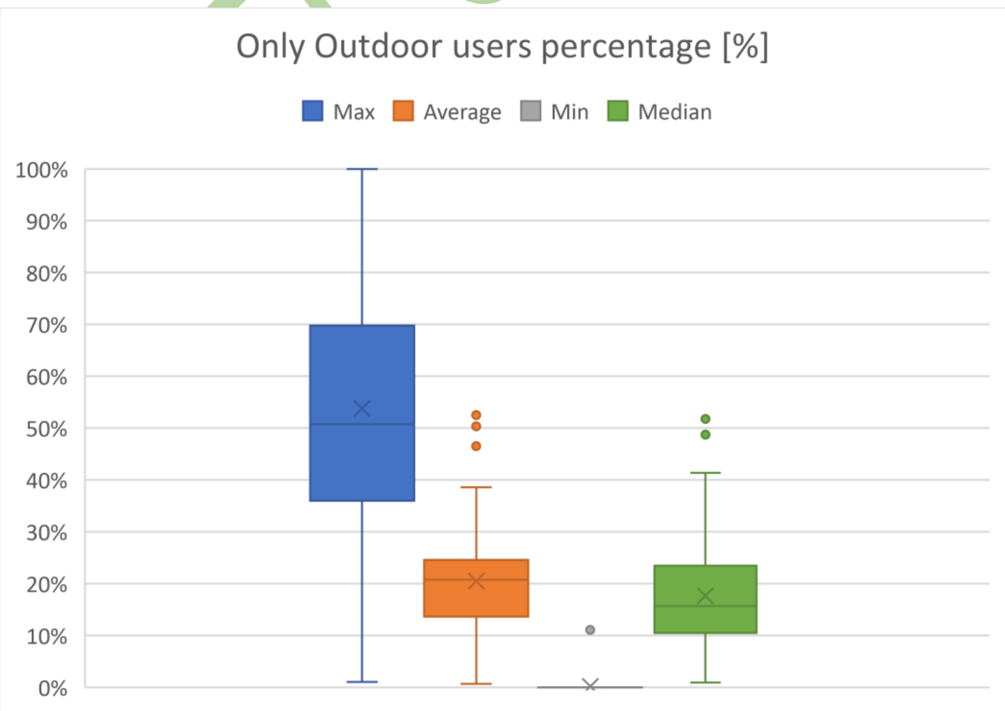


Figure 13: Box-and-whiskers plot representation of the percentage of Only Outdoor users (OOp), by tracing daily maximum, average, minimum and median trends.

Figure 13 shows that OOp average and median data are comparable (being OOn constant during the day, except for the night-time), ranging between about 10% and 24% (quartiles 1 and 3) while 2nd quartile is between 14 and 20%. Minimum values are for the night-time, maximum refers to particular time of the day in which other categories are absent (e.g., early in the morning).

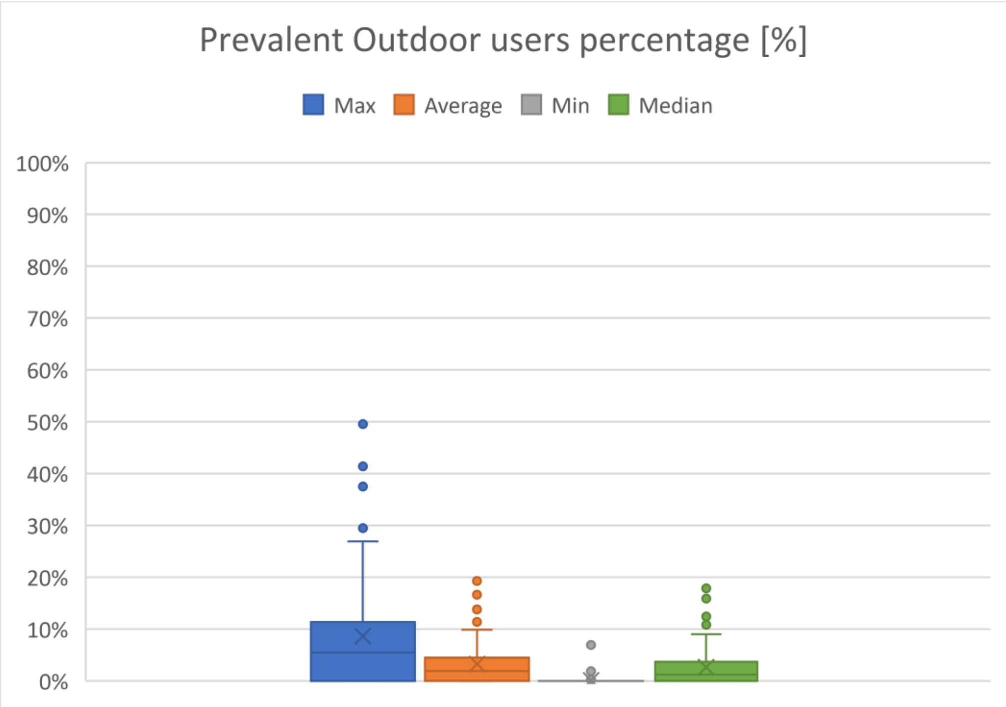


Figure 14: Box-and-whiskers plot representation of the percentage of Prevalent Outdoor users (POp), by tracing daily maximum, average, minimum and median trends.

Prevalent Outdoor users depend on the presence of dehor areas within the BE, together with their dimension (m^2) and opening time. Figure 14 shows that median and average data are the comparable, as critical values range from 0 to 4% people (1st and 3rd quartiles) while the median is just 1% (2nd quartile). POp maximum values represent the case when all the activities are open and fully loaded, while minimum data are for closing time (or absent dehor areas). Outliers are for covered/partially covered areas within the BE, like open markets, whose dimensions are considerably higher than the ones generally related to bars and restaurants.

5.1.3 Percentage of users considering individual vulnerability [%]

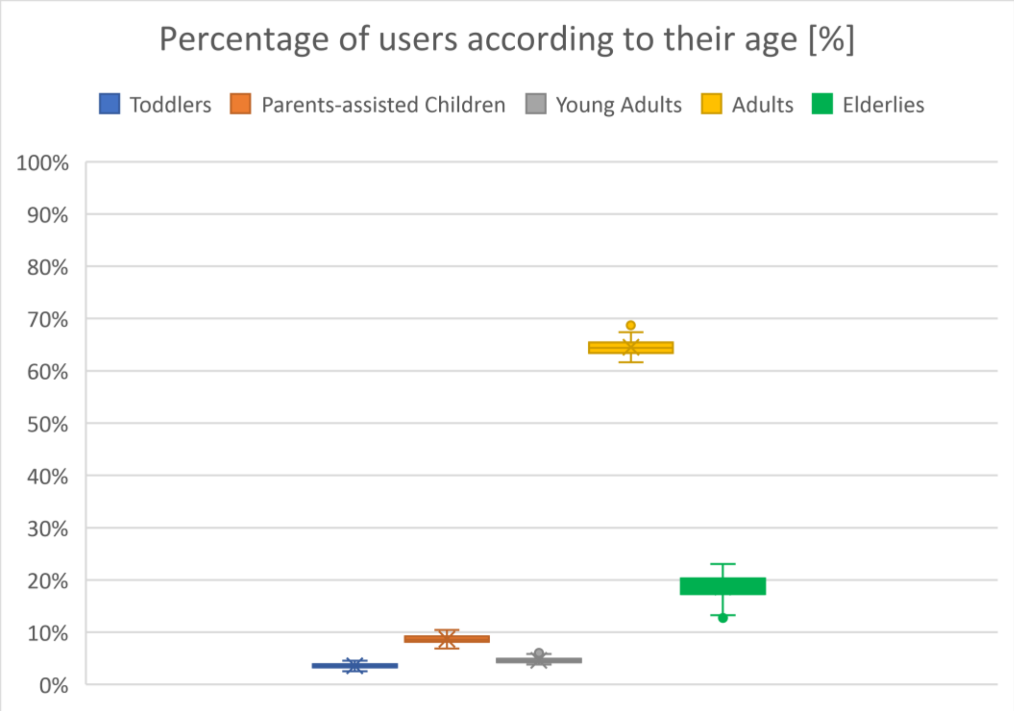


Figure 15: Box-and-whiskers plot representation of the percentage of users depending on their age range.

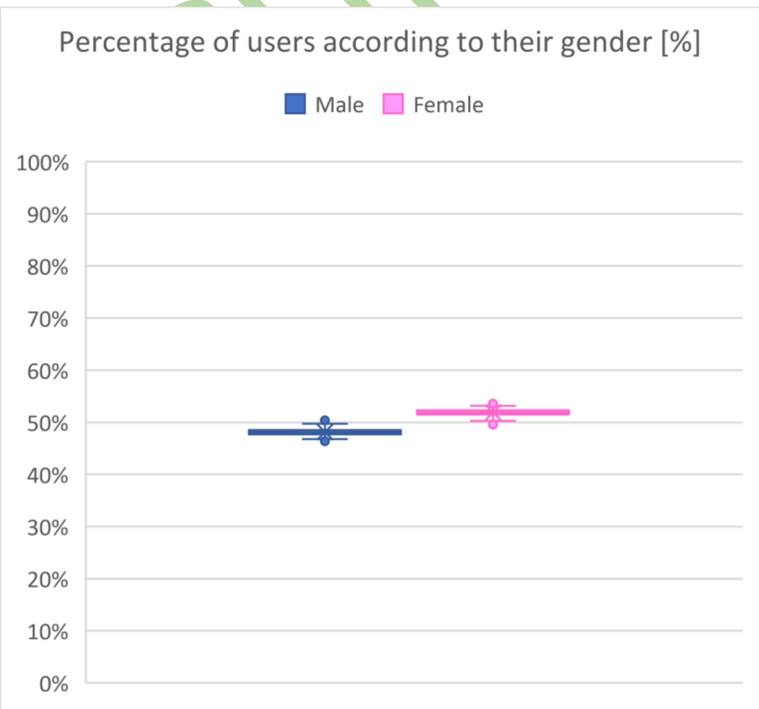


Figure 16: Box-and-whiskers plot representation of the percentage of users depending on their gender.

Considering the individual vulnerability, national trends are entirely confirmed (ISTAT 2018), being: Tp=4%, PC=9%, YA=5%, AU=64%, EU=18% (Figure 15, median values) and Mp=48%, Fp=52% (Figure Figure 16, median values).

5.1.4 Users' density considering the outdoor areas in the BE [pp/m2]

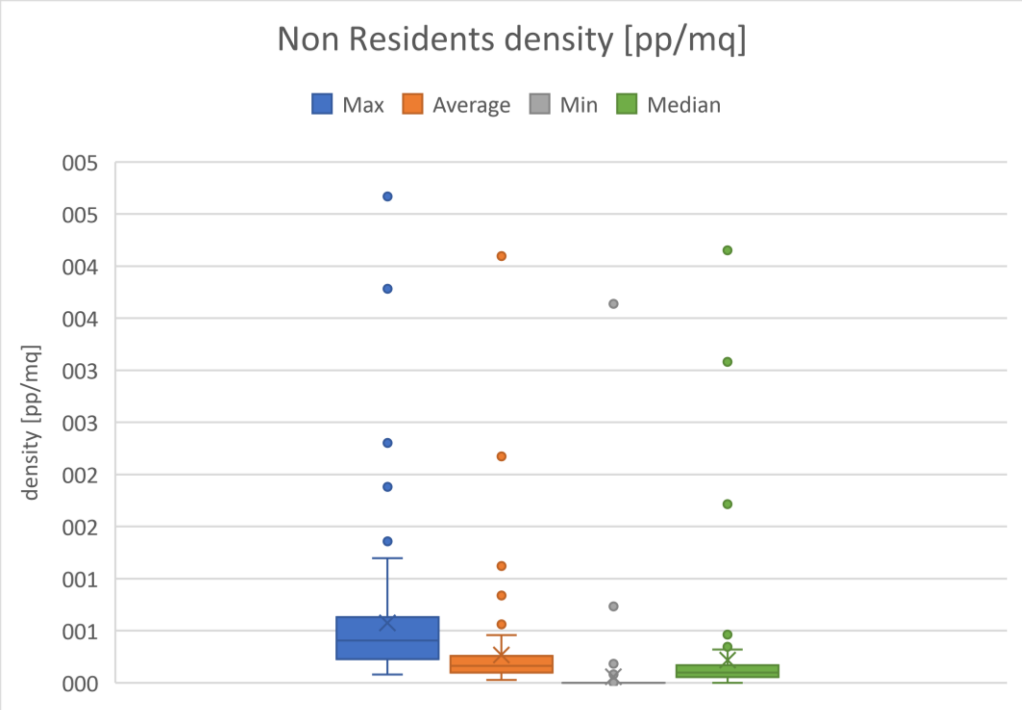


Figure 17: Box-and-whiskers plot representation of the Non-Residents users' density considering the outdoor areas (NRd), by tracing daily maximum, average, minimum and median trends.

Non-Residents outdoor density (Figure 17) depends on the feature of the activities within the BE (built-up areas, building intended use, opening time), besides of the outdoor areas. Maximum critical values overestimate NRd, since they represent the case when all the activities are open and fully loaded. On the other hand, minimum values underestimate NRd since they are representative of the night-time, when activities are generally closed, except for outliers like hotels. Hence, considering the median trend (that is similar to average too), NRd can be considered ranging between 0.06 and 0.17 pp/m^2 (1st and 3rd quartiles) while the median values is 0.10 pp/m^2 (2nd quartile).

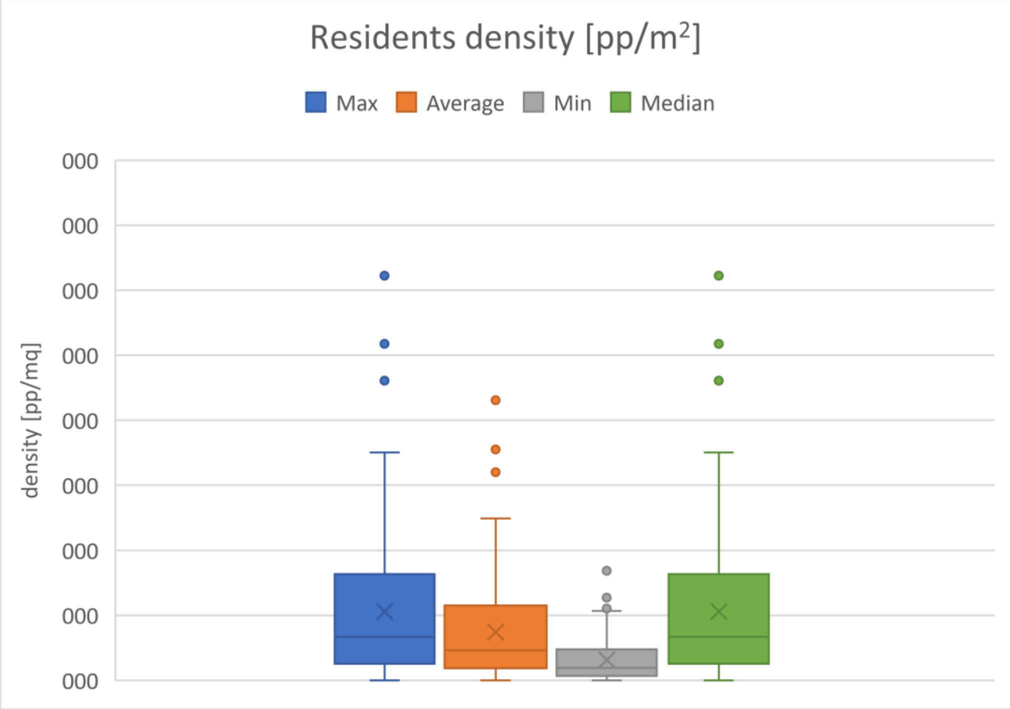


Figure 18: Box-and-whiskers plot representation of the Residents users' density considering the outdoor areas (Rd), by tracing daily maximum, average, minimum and median trends.

Rd (Figure 18), as well as Rn, is strictly related to the fact that Residents users are evenly distributed during the day (i.e., according to Table 4, all residents are counted in non-working hours, that is 7pm to 7 am, while during the day scholars and workers are considered absent). As a result, since most of the daytime they can be considered at home, median data coincide with the maximum ones, while minimum data can be traced back to the working hours. Rd maximum and median critical values range from 0.01 to 0.08 pp/m^2 (1st and 3rd quartiles) while the median is 0.03 pp/m^2 (2nd quartile).

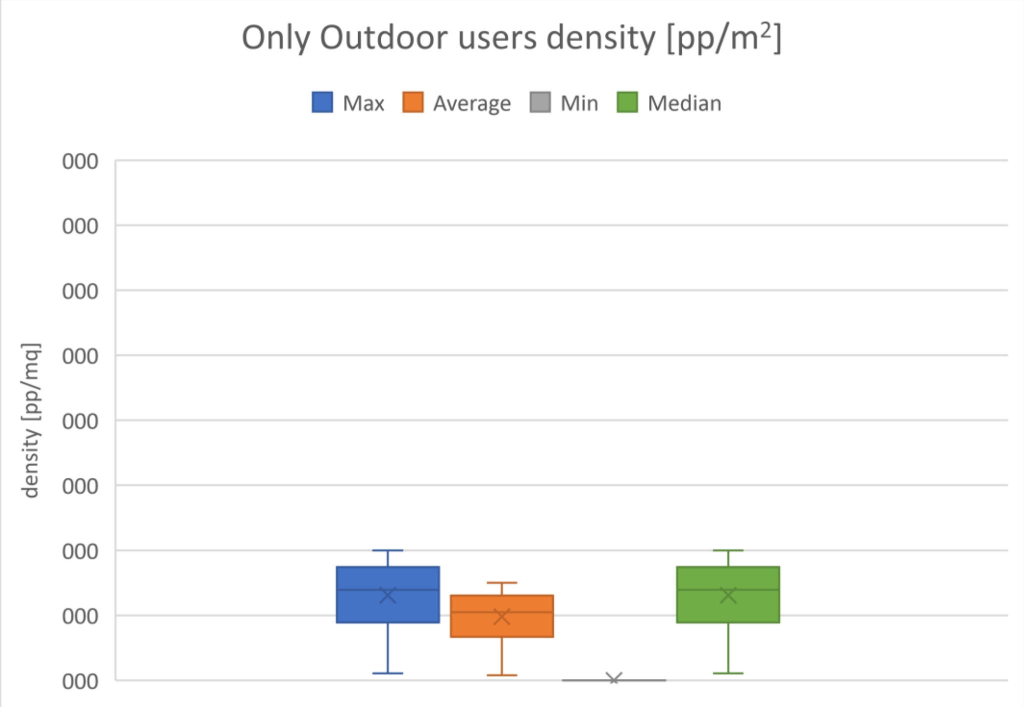


Figure 19: Box-and-whiskers plot representation of the Only Outdoor users' density considering the outdoor areas (OOd), by tracing daily maximum, average, minimum and median trends.

According to Table 4, Only Outdoor users are constant during the daytime except for the night hours (i.e., 1-6 am). As a result (Figure 19), median data coincide with the maximum ones, while minimum data can be traced back to the night-time (0 pp/m^2). OOn maximum and median critical values range from 0.04 to 0.08 pp/m^2 (1st and 3rd quartiles) while the median is 0.07 pp/m^2 (2nd quartile). Outliers depends on the squares' dimension (e.g., Piazza del Plebiscito, Napoli). Upper threshold is 0.10 pp/m^2, which is in line with prescriptions in Section 4.1.2.

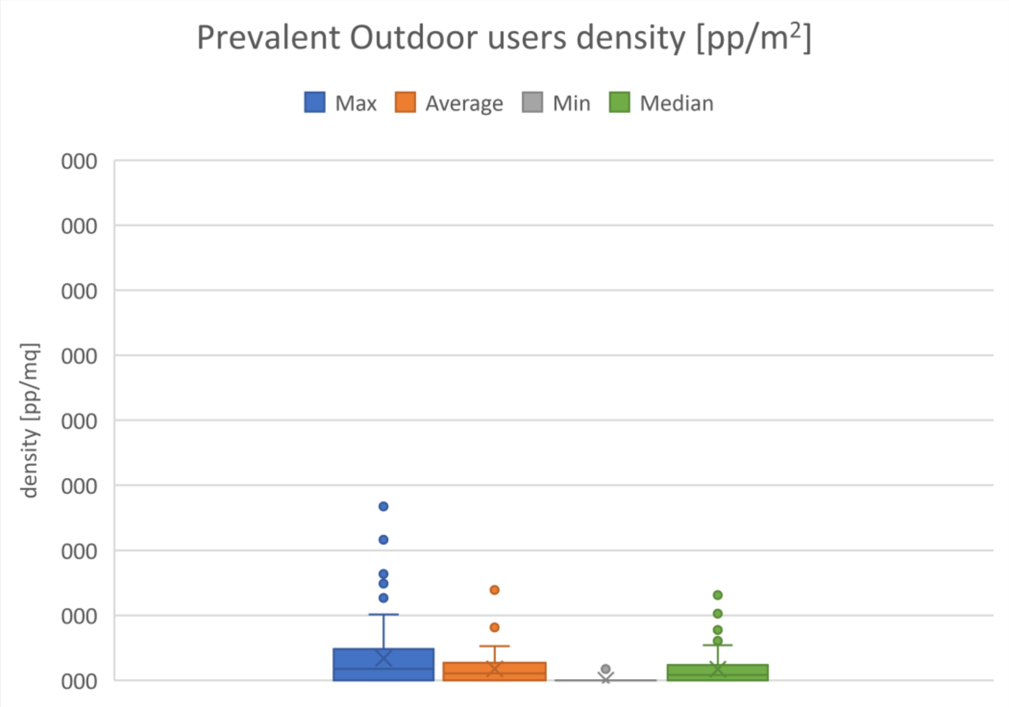


Figure 20: Box-and-whiskers plot representation of the Prevalent Outdoor users' density considering the outdoor areas (POd), by tracing daily maximum, average, minimum and median trends.

As well as POn, Prevalent Outdoor users density POd depends on the presence of dehor areas within the BE, together with their dimension (m^2) and opening time. Figure 20 shows that median and average data are comparable, as critical values range from 0 to 0.01 pp/m^2 (1st and 3rd quartiles) while the median is 0.005 pp/m^2 (2nd quartile). POd maximum trend represents the case in which all the activities are open and fully loaded, while minimum data are for closing time (or absent dehor areas). Outliers are for covered/partially covered areas within the BE, like open markets, whose dimensions are considerably higher than the ones generally related to bars and restaurants, thus implying uncommon POn and POd outcomes.

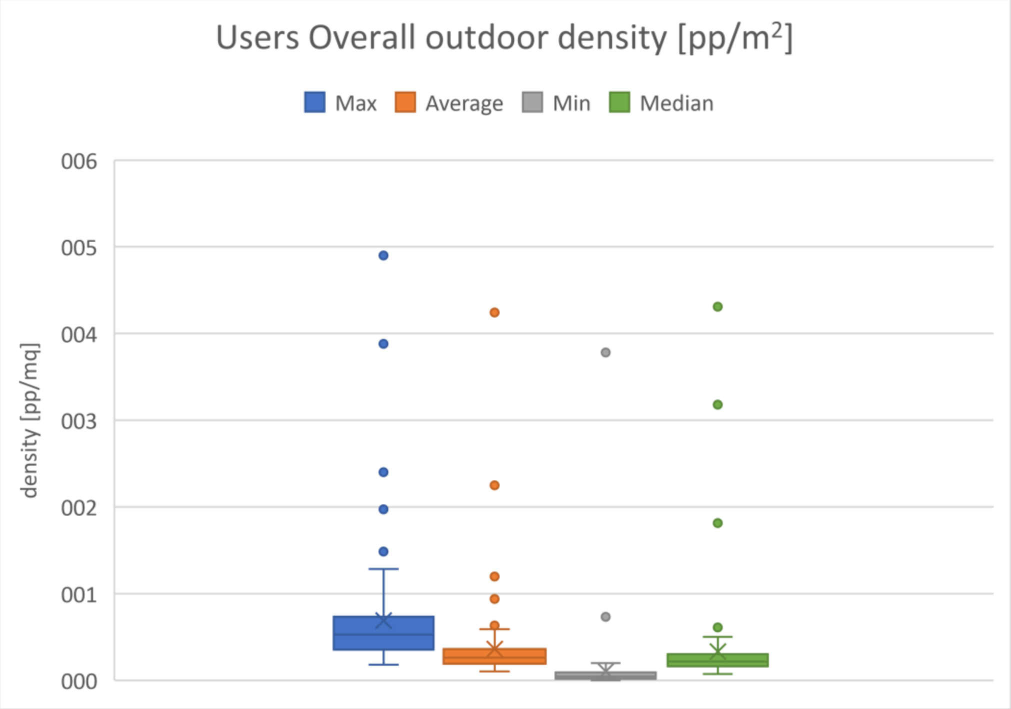


Figure 21: Box-and-whiskers plot representation of the Users Overall density considering the outdoor areas (UOOd), by tracing daily maximum, average, minimum and median trends.

Considering the Users Overall sample (Figure 21Figure 10), UOOd maximum trend describe the case in which all of the aforementioned categories stand together within the BE (NRn+Rn+OOn+POn), thus implying an extremely overestimated number of people. Nevertheless, excluding outliers and upper thresholds (4th quartiles), the maximum critical value is lesser than 1.00 pp/m² (maximum trend 3rd quartile is equal to 0.74 pp/m²). On the other hand, referring to the median trends, which appear to be comparable to the average ones too, UOd critical values range between about 0.15 and 0.30 pp/m² (1st and 3rd quartiles), while the median is 0.20 pp/m² (2nd quartile).

5.1.5 Users' density considering the built-up areas (indoor) [pp/m2], by tracing maximum, average, minimum and median trends

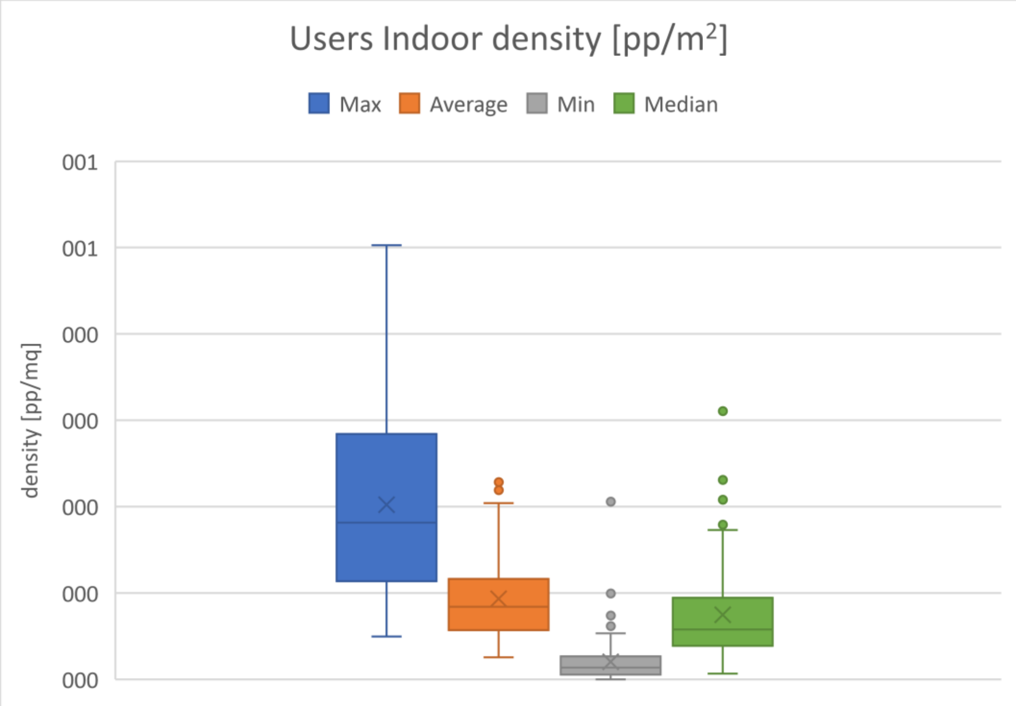


Figure 22: Box-and-whiskers plot representation of the Users Indoor density depending on RNn and Nn and considering the indoor areas (UId), by tracing daily maximum, average, minimum and median trends.

Figure 22 shows the indoor density in normal condition of fruition of the buildings (UId), that is considering NRn+Rn users. Maximum trend refers mainly to hours between 10-12am, that are the opening time for most of the offices and government buildings (i.e., the ones that can host the higher number of users because of their dimension and occupant load). Excluding outliers and upper thresholds (4th quartiles), the maximum critical value is lesser than 0.30 pp/m² (maximum trend 3rd quartile is equal to 0.28 pp/m²). Concerning the median trend, that is comparable to the average one too, critical values are between about 0.04 and 0.10 pp/m² (1st and 3rd quartiles) while the median value is 0.06 pp/m² (2nd quartile). Minimum data mainly concern the night-time, in which residents and some non-residents users (i.e., bar, restaurants) are considered (0.03 pp/m²).

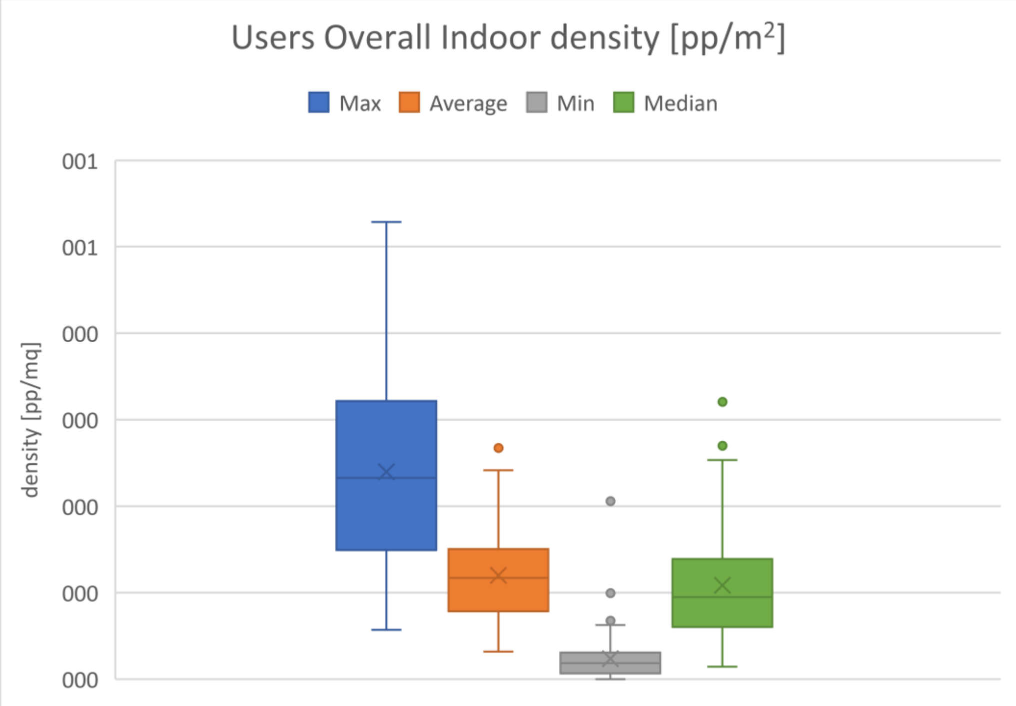


Figure 23: Box-and-whiskers plot representation of the Users Overall Indoor density depending on UOn and considering the indoor areas (UOId), by tracing daily maximum, average, minimum and median trends.

In case of terrorist acts or SLODs, outdoor users can be forced to move inside the buildings searching for safety/shelter (i.e., invacuate). Considering the Users Overall sample (UOId), the previous outcomes look confirmed as the median critical values only increase to 0.06, 0.09 and 0.14 pp/m^2 (quartiles 1,2 and 3), along with the maximum (blue box) and minimum (grey box) ones that remain the same of UId, as shown in Figure 23.

5.1.6 Ratio between indoor and outdoor users [-]

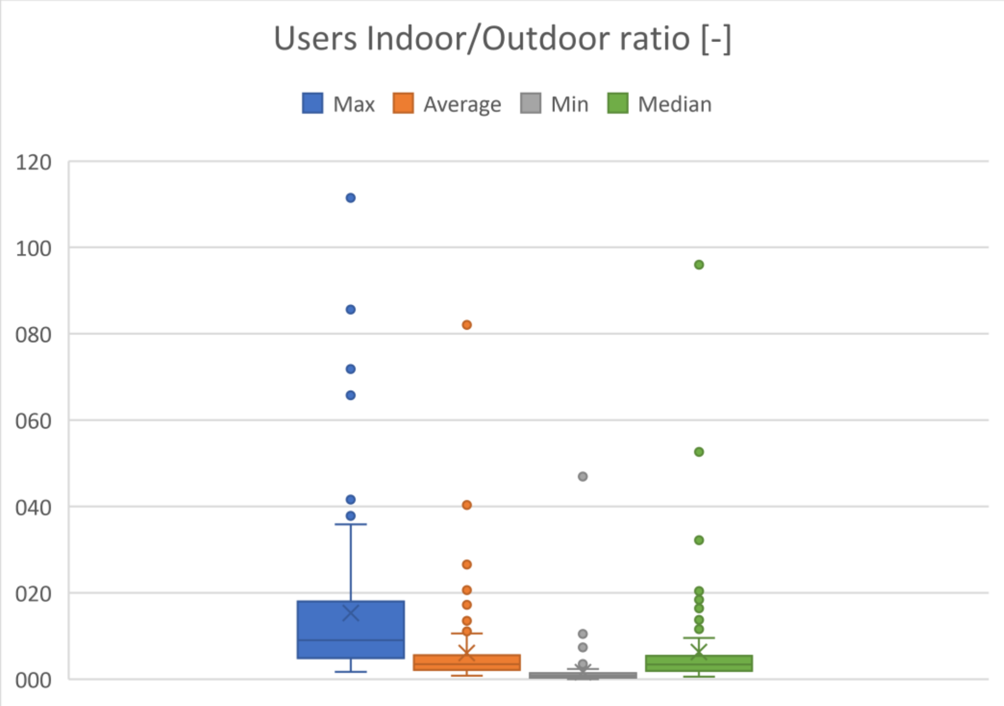


Figure 24: Box-and-whiskers plot representation of the ratio between the number of Users in Indoor spaces and in Outdoor spaces (UIOr), by tracing daily maximum, average, minimum and median trends.

The previous outcomes for UId and UOId find confirmation as the UIOr values on average range between 2 and 5, with maximum peak of almost 20 (maximum trend, 3rd quartile), hence highlighting how outdoor users represent a limited quantity on the overall (Figure 24). In addition to this, also the minimum values are around 1, meaning that indoor and outdoor users are at least equal.

5.2 TDC DESCRIPTORS:

5.2.1 Percentage of users' considering the familiarity with places and emergency procedures [%]

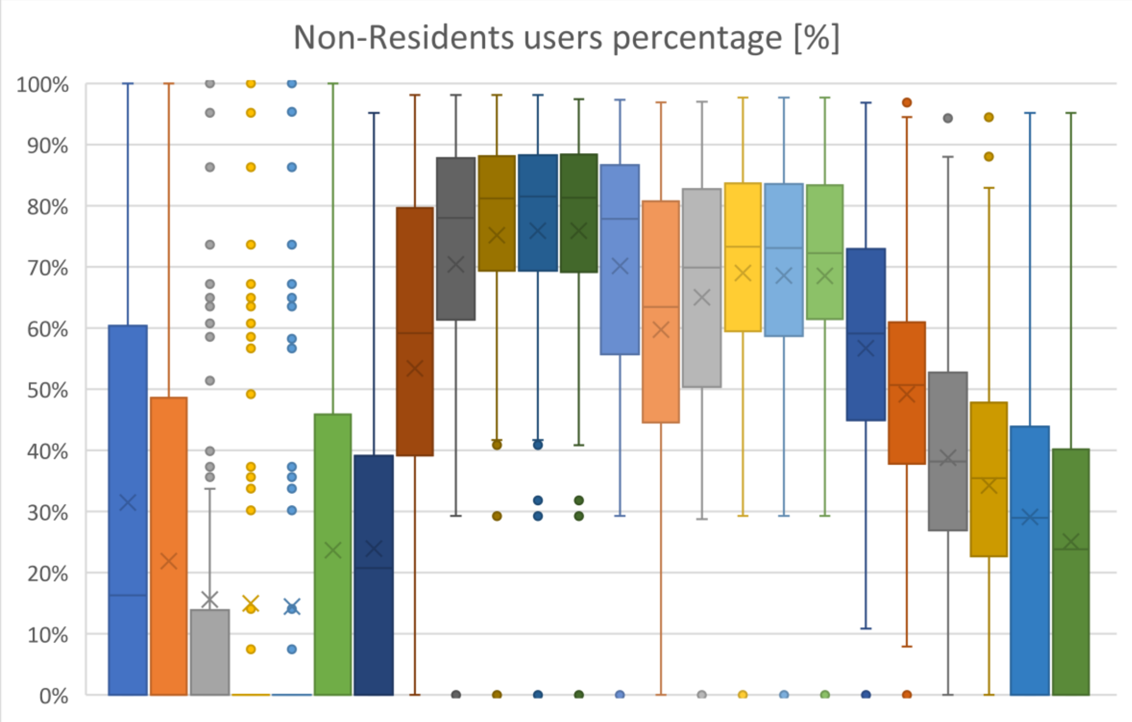


Figure 25: Box-and-whiskers plot representation of the percentage of Non-Residents users (NRp), by tracing the daily trend basing on hourly sampling.

As expected, Non-Residents presence is maximized during the working hours (8am to 7pm, Figure 25), as NRp is always higher than 50%, and minimized in the night-time (lesser than 50%), even if some exceptions can ensure the presence of a small percentage of NR users, like the presence of bar or restaurants closing late (1-2pm). Outliers refer to hotels and accommodation structures.

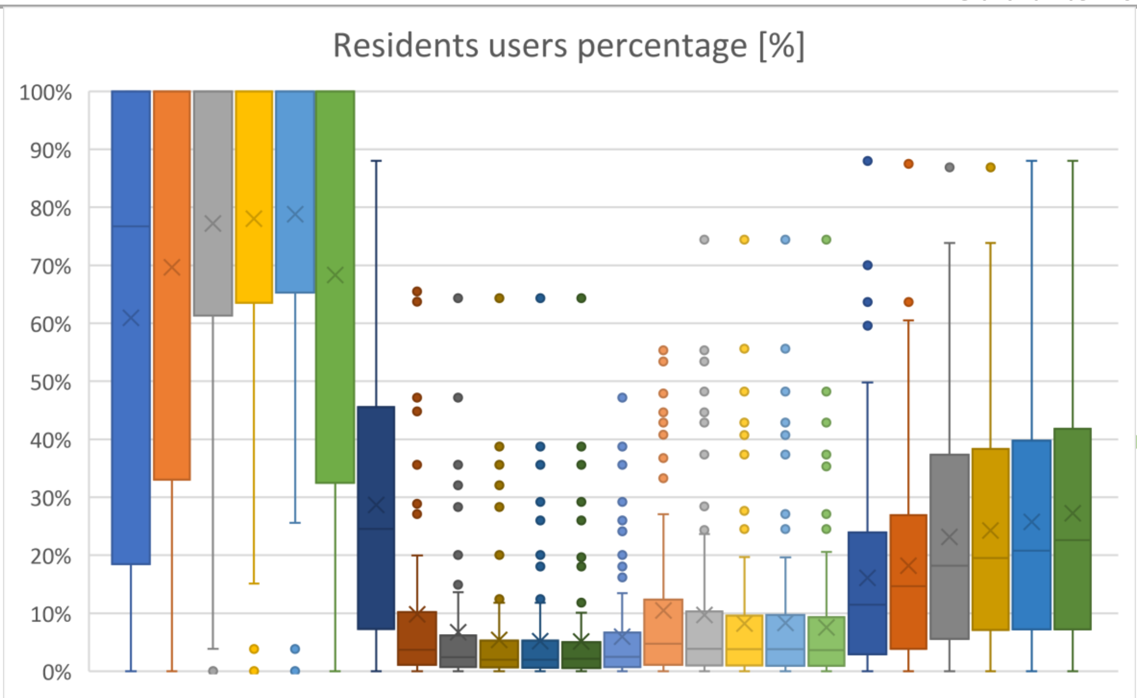


Figure 26: Box-and-whiskers plot representation of the percentage of Residents users (Rp), by tracing the daily trend basing on hourly sampling.

Residents represents a small part of the population within the BE during the working hours (Figure 26), since Rp is at most equal to 10% from 8 am to 6 pm (Figure 26). These percentages increase to 10-40% (7-12 pm) in the evening, and up to 70-100% during the night (1-5am) when Only Outdoor users are not accounted for, and most of the activities are closed.

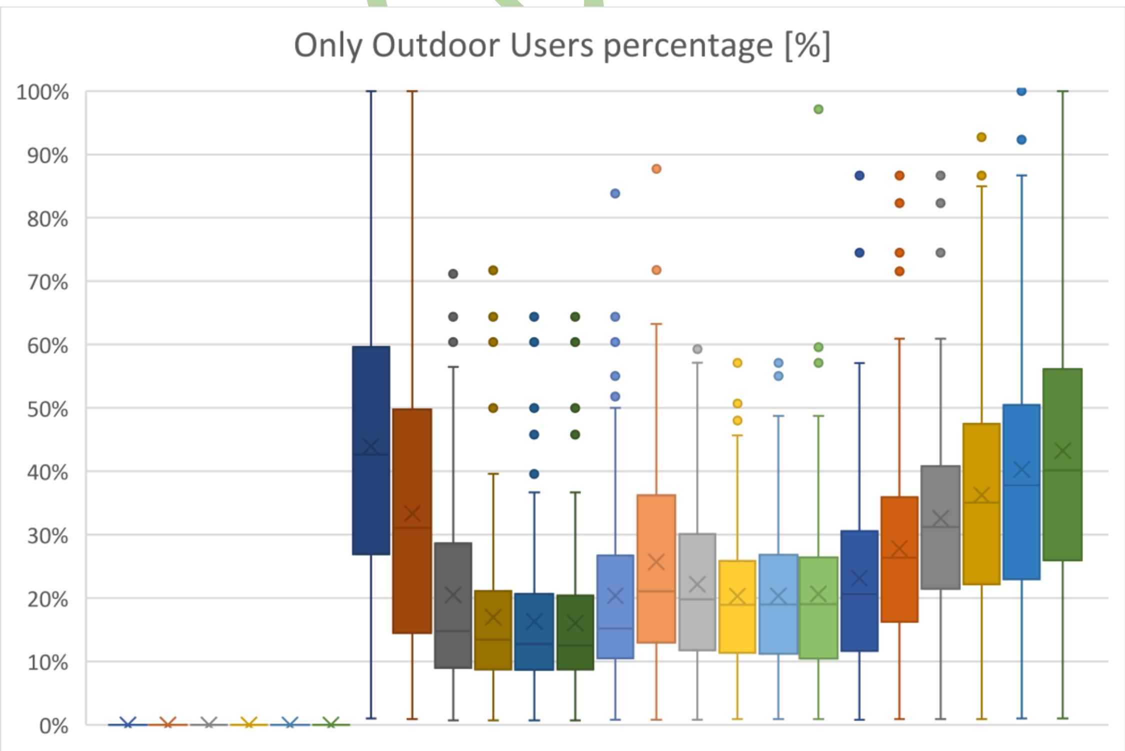


Figure 27: Box-and-whiskers plot representation of the percentage of Only Outdoor users (OOp), by tracing the daily trend basing on hourly sampling.

Except for the night hours, Only Outdoor users' have been considered constant during the day, hence their percentage presence OOp strictly depends on the other typologies of users. As a result, OOp range between 10-20% during the working times, increasing up to 30-50% in the remaining hours (Figure 27).

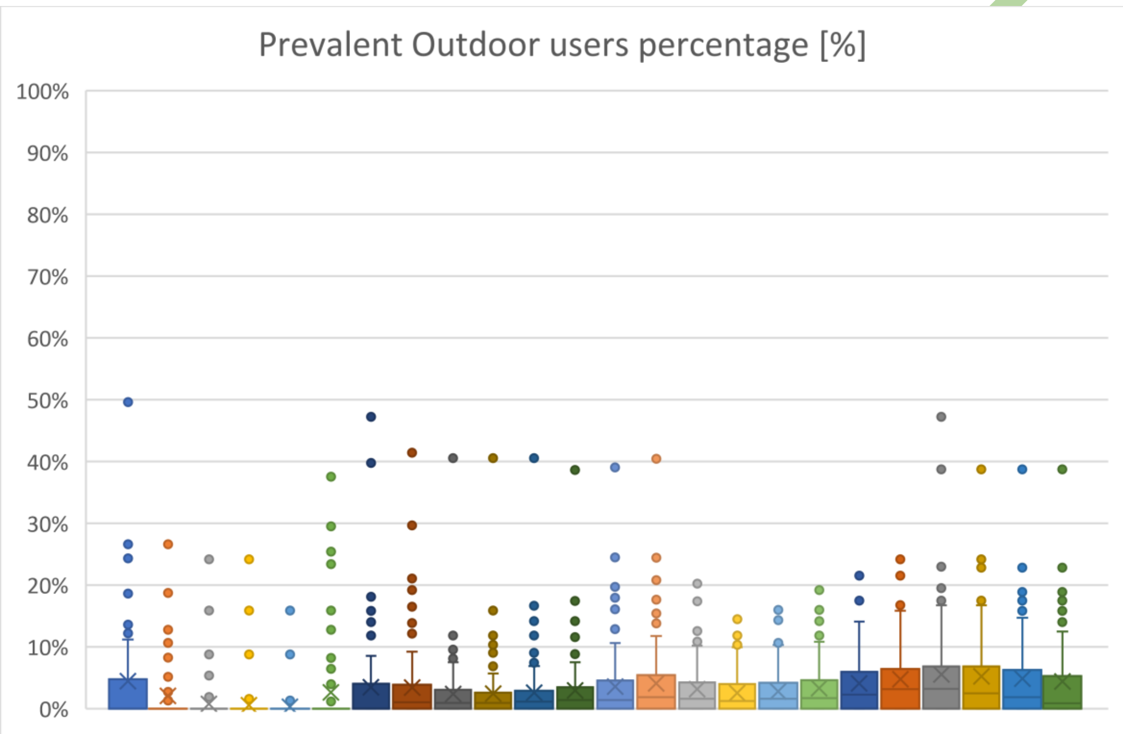


Figure 28: Box-and-whiskers plot representation of the percentage of Prevalent Outdoor users (POp), by tracing the daily trend basing on hourly sampling.

Prevalent Outdoor users percentage depends on the presence of dehor areas within the BE, together with their dimension (m^2) and opening time. Figure 20 shows that, excluding the night hours (2am to 6 am), POp always ranges between 0 and 5%. Outliers are for activities with continued schedule, and for open markets, whose dimensions are considerably higher than the ones generally related to bars and restaurants.

5.2.2 Users' density considering the outdoor areas in the BE [pp/m2]

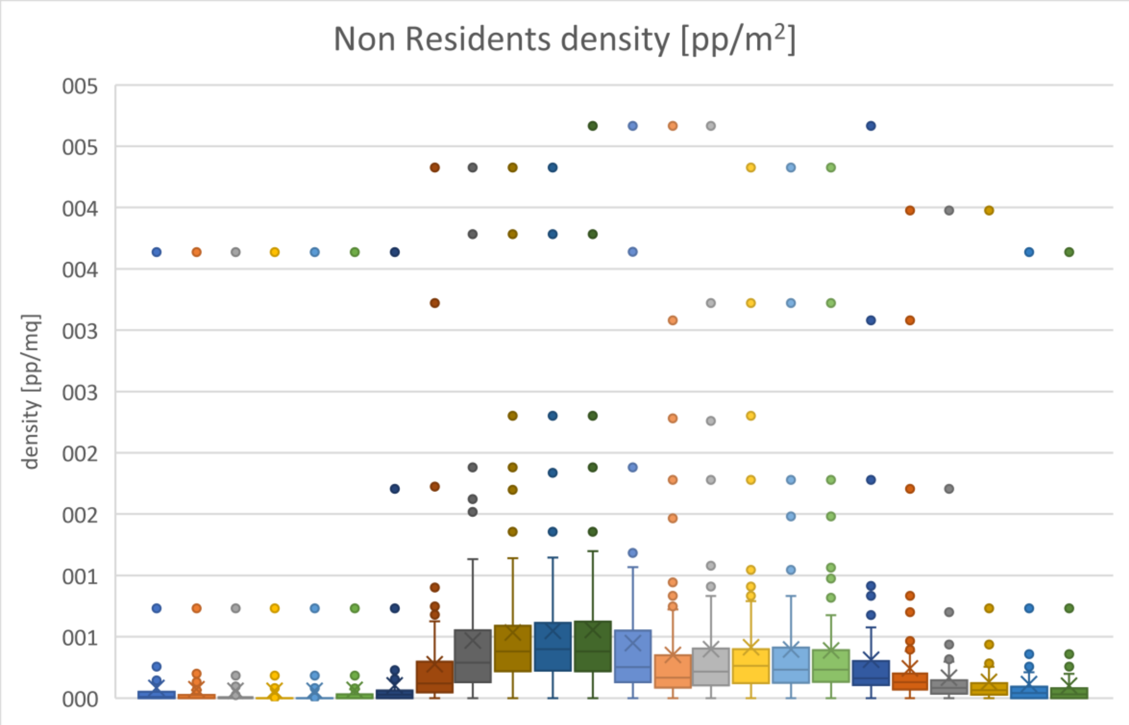


Figure 29: Box-and-whiskers plot representation of the Non-Residents users' outdoor density (NRd), by tracing the daily trend basing on hourly sampling.

Non-Residents density is maximized in the morning (9am to pm, Figure 29), when NRd is between about 0.15 and 0.60 pp/m^{2}mainly because of the offices and government buildings opening hours (Figure 29). These values decrease in the afternoon (0.10-0.45 pp/m^2) and in the evening (0.05-0.15 pp/m^2), until arrive essentially to 0 in the night hours (3-5 am). Outliers refer to hotels, accommodation structures, and bar/restaurants with continued schedule.

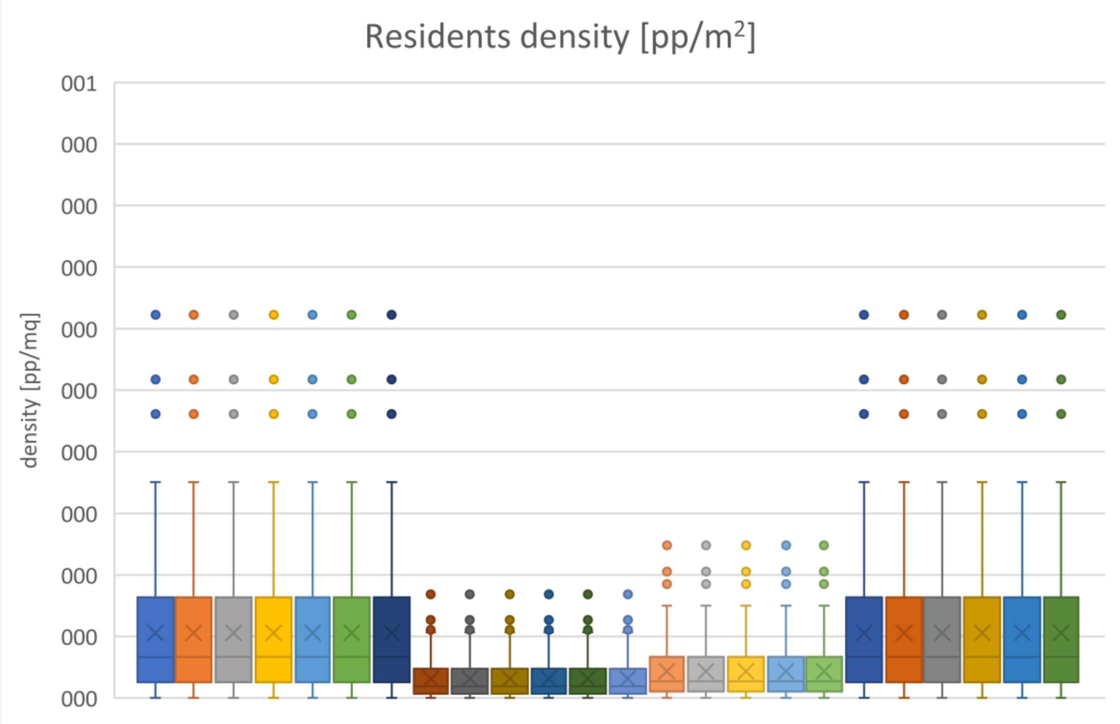


Figure 30: Box-and-whiskers plot representation of the Residents users' outdoor density (Rd), by tracing the daily trend basing on hourly sampling.

By virtue of the Residents in-time distribution within the BE (see Table 4), Rd only depends on the residential built-up and outdoor areas. As show in Figure 30, when all the residents users are at home, that is from 7pm to 7am, Rd critical values range between 0.01 and 0.08 pp/m^2, while in the working hours they decrease to 0.01-0.02 pp/m^2 (in the morning) and 0.01-0.03 pp/m^2 (in the afternoon). Outliers refer to particular conditions of small BEs and multiple storeys residential buildings.

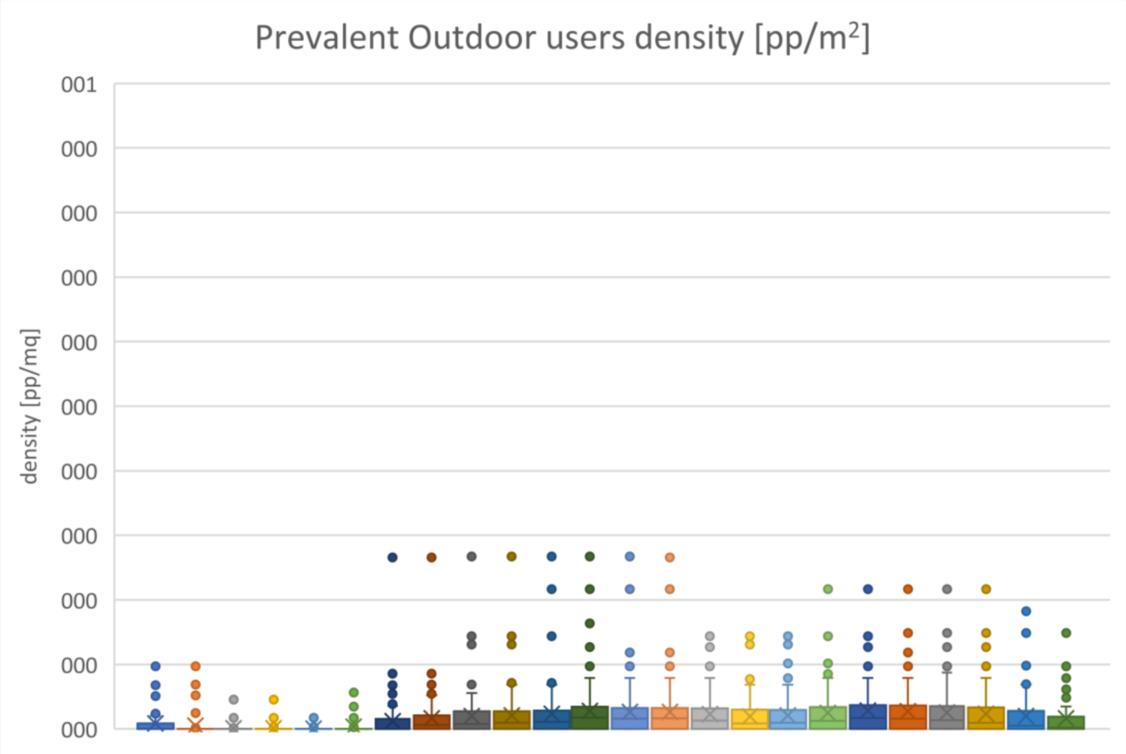


Figure 31: Box-and-whiskers plot representation of the Prevalent Outdoor users' outdoor density (POd), by tracing the daily trend basing on hourly sampling.

As well as POp, Prevalent Outdoor users density depends on the presence of dehor areas within the BE, together with their dimension (m^2) and opening time. Figure 31 shows that, excluding the night hours (2am to 6 am), POp always ranges between 0 and 0.02 pp/m^2. Outliers are for activities with continued schedule, and for open markets, whose dimensions are considerably higher than the ones generally related to bars and restaurants.

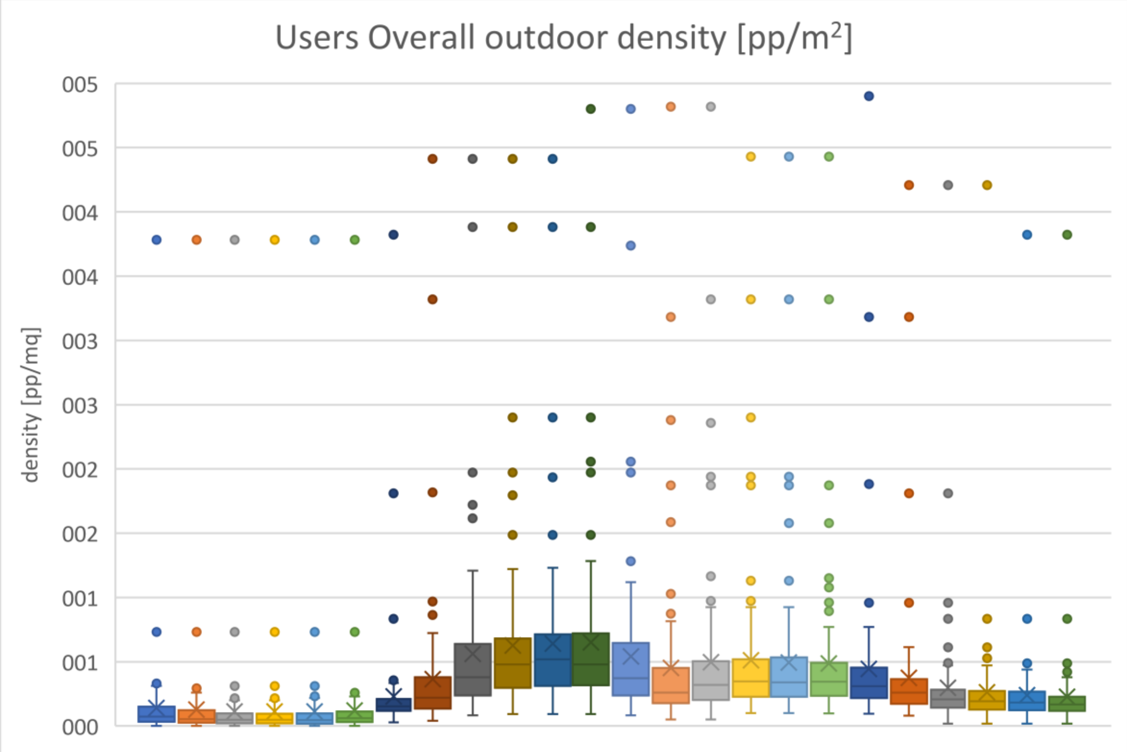


Figure 32: Box-and-whiskers plot representation of the Users Overall outdoor density (UOOd), by tracing the daily trend basing on hourly sampling.

Considering the Users Overall sample (Figure 32), UOOd maximum critical values are reached in the morning, as UOOd is up to 0.74 pp/m², when all of the aforementioned categories stand together within the BE (NRn+Rn+OOn+POn). These values decrease in the afternoon (0.20-0.55 pp/m²) and in the evening (0.15-0.30 pp/m²), until arrive to about 0.05/0.10 pp/m² in the night hours (3-5 am) when most of the users are Residents.

5.2.3 Users' density considering the built-up areas (indoor) [pp/m2]

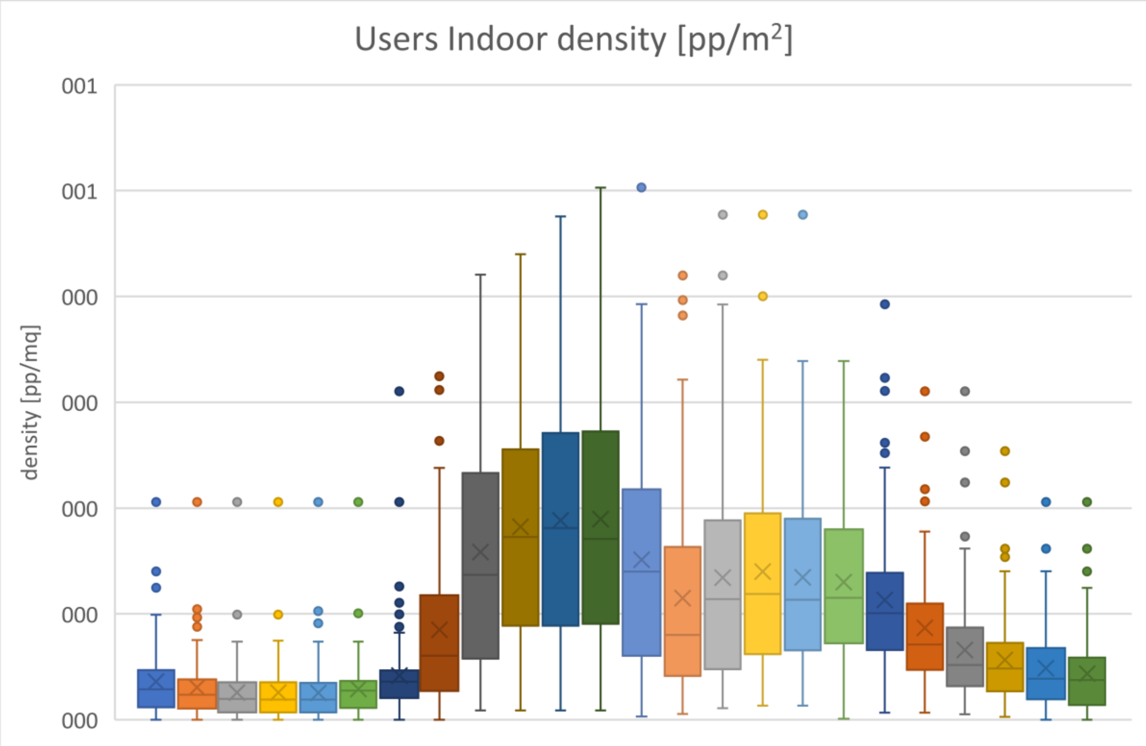


Figure 33: Box-and-whiskers plot representation of the Users Indoor density (UId), by tracing the daily trend basing on hourly sampling.

Figure 33 shows the indoor density in normal condition of fruition of the buildings (UId), that is considering NRn+Rn users. Maximum values of density are between 10-12am with about 0.10-0.25pp/m², that correspond to the opening time for most of the offices and government buildings (i.e., the ones that can host the higher number of users because of their dimension and occupant load). These values slowly decrease in the afternoon (0.06-0.20 between 3-6pm), down to about 0.02-0.08 pp/m² in the evening (9-11pm) and 0.01-0.05 pp/m² in the night (1-5am).

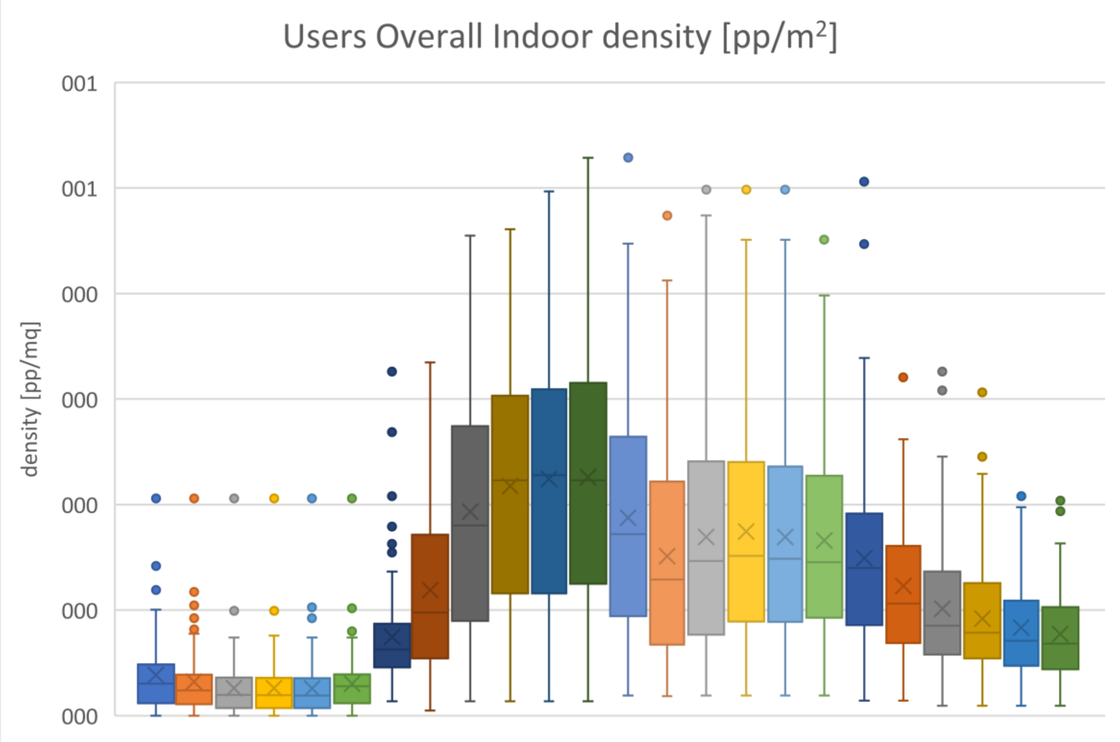


Figure 34: Box-and-whiskers plot representation of the Users Indoor density (UOId), by tracing the daily trend basing on hourly sampling.

Previous indoor density outcomes are confirmed considering the overall sample of users for what it concerns the daily trend. In particular, from 1am to 6am UOId is equal to UId as outdoor users are almost absent, while in the daytime an increase of about 0.02-0.05 pp/m² is recorded (Figure 34).

5.2.4 Ratio between indoor and outdoor users [-]

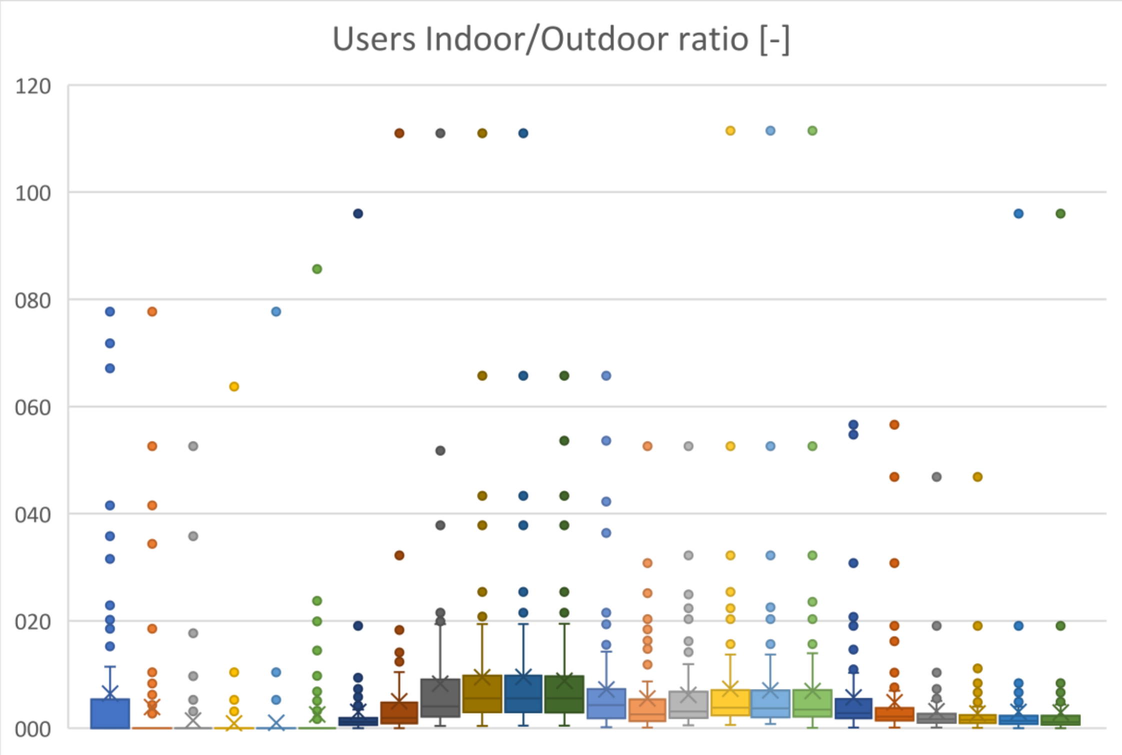


Figure 35: Box-and-whiskers plot representation of the ratio between the number of Users in Indoor spaces and in Outdoor spaces (UIOr), by tracing the daily trend basing on hourly sampling.

The previous UId and UOId outcomes find confirmation as the UIOr values follow the same trend during the day, as shown in Figure 35. Indeed, higher values are recorded in the morning hours (between 3 and 10 from 9am to 12am), that decrease in the afternoon (between 2 and 7 from 1pm to 6pm) and in the evening (between 1 and 2 from 9 to 12pm). The latter represent the minimum UOIr values, meaning that indoor and outdoor users are always at least equal, except for the night hours when outdoor users are almost absent (UOIr=0).

5.2.5 BE users' normalized number [-] considering the familiarity with places and emergency procedures

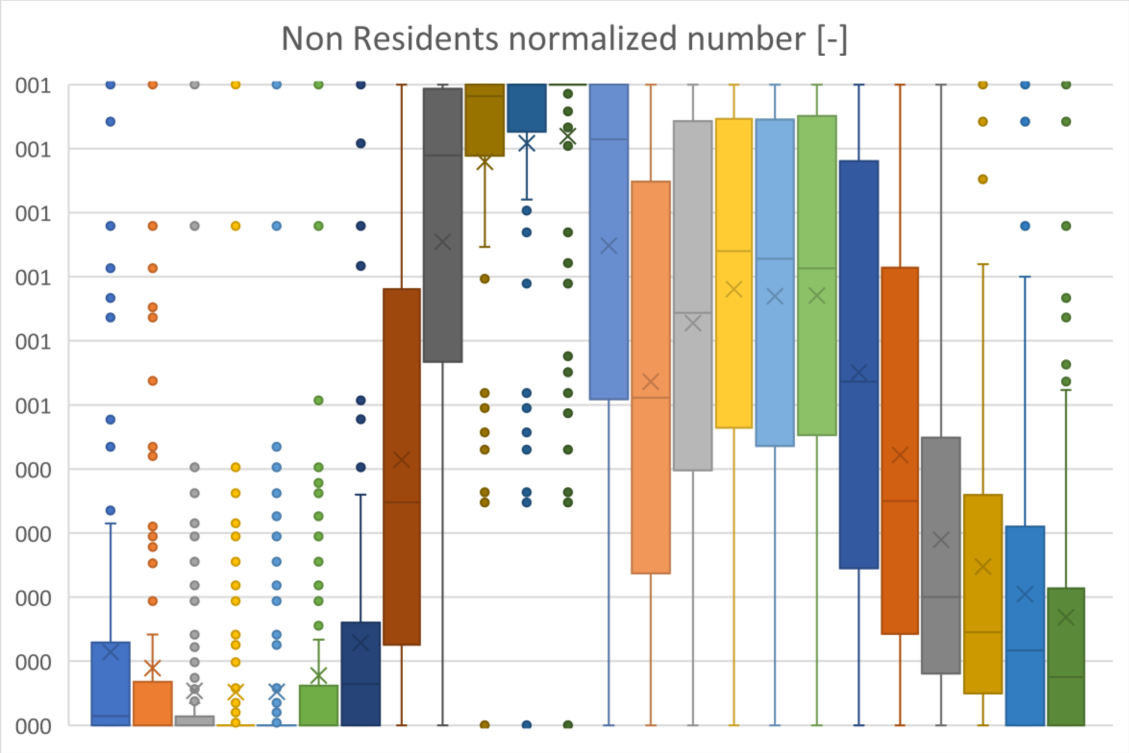


Figure 36: Box-and-whiskers plot representation of the Non-Residents users' normalized number (NRnn), by tracing the daily trend basing on hourly sampling.

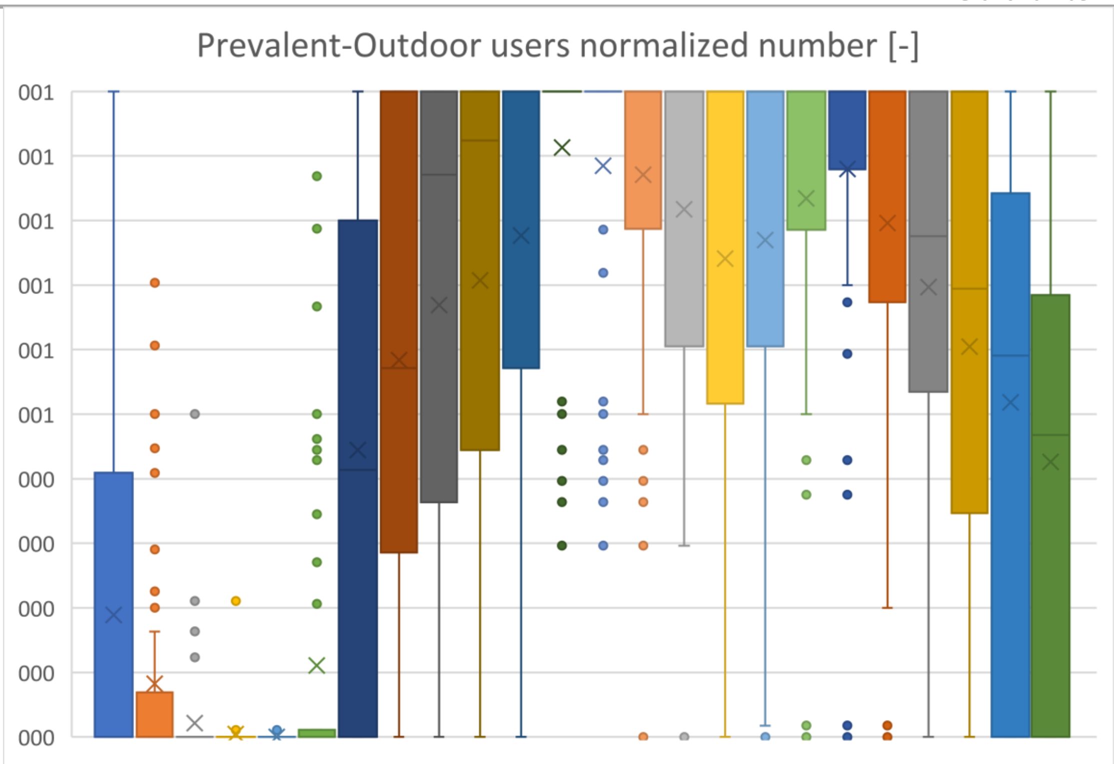


Figure 37: Box-and-whiskers plot representation of the Prevalent Outdoor users' normalized number (POnn), by tracing the daily trend basing on hourly sampling.

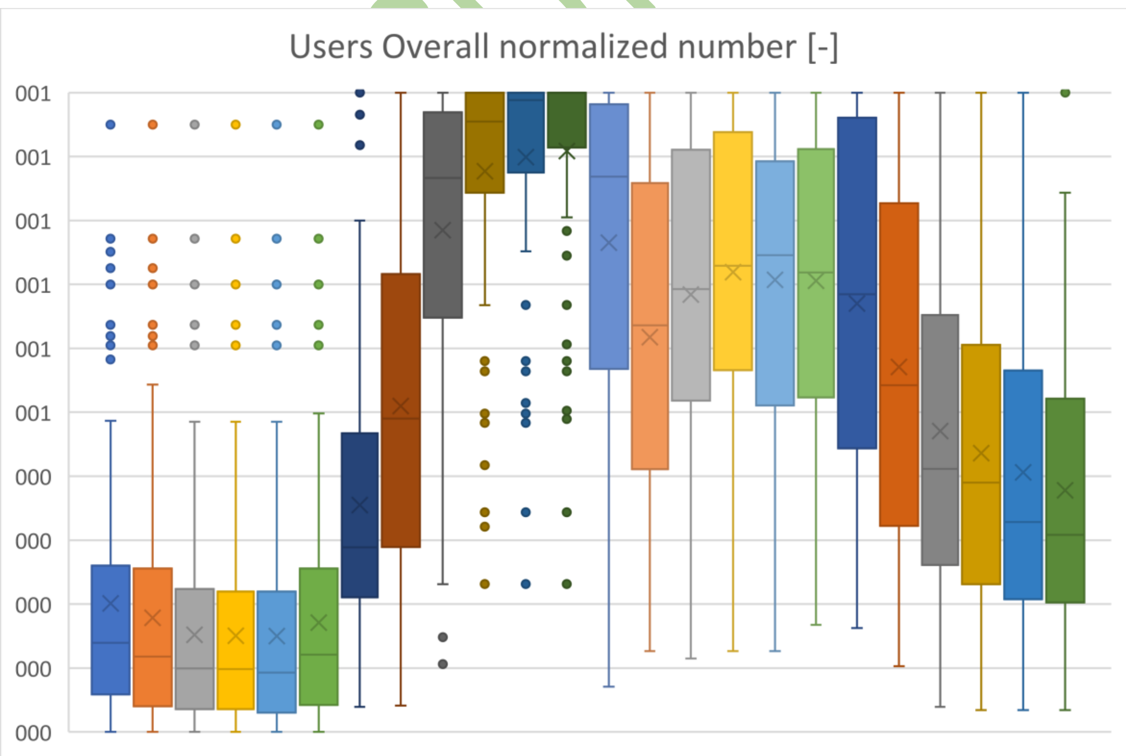


Figure 38: Box-and-whiskers plot representation of the Users Overall normalized number (UOnn), by tracing the daily trend basing on hourly sampling.

5.2.6 BE users' normalized number [-] considering individual vulnerability

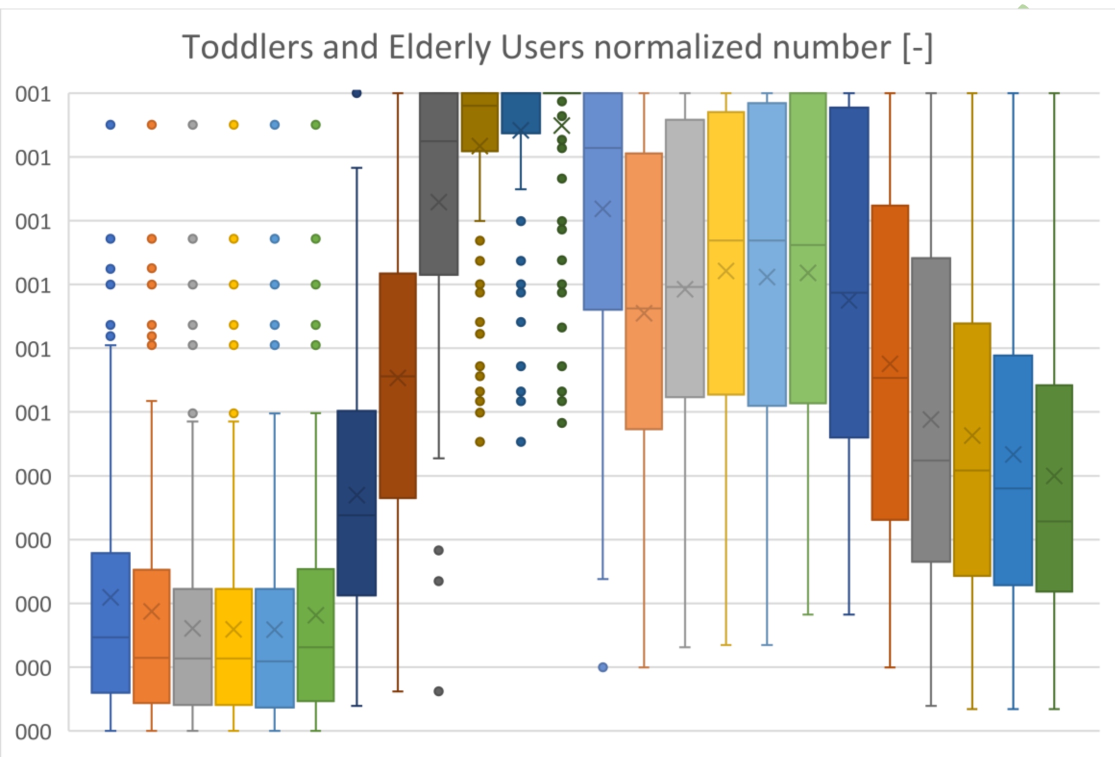


Figure 39: Box-and-whiskers plot representation of the Toddlers and Elderly users' normalized number (TUnn, EUnn), by tracing the daily trend basing on hourly sampling.

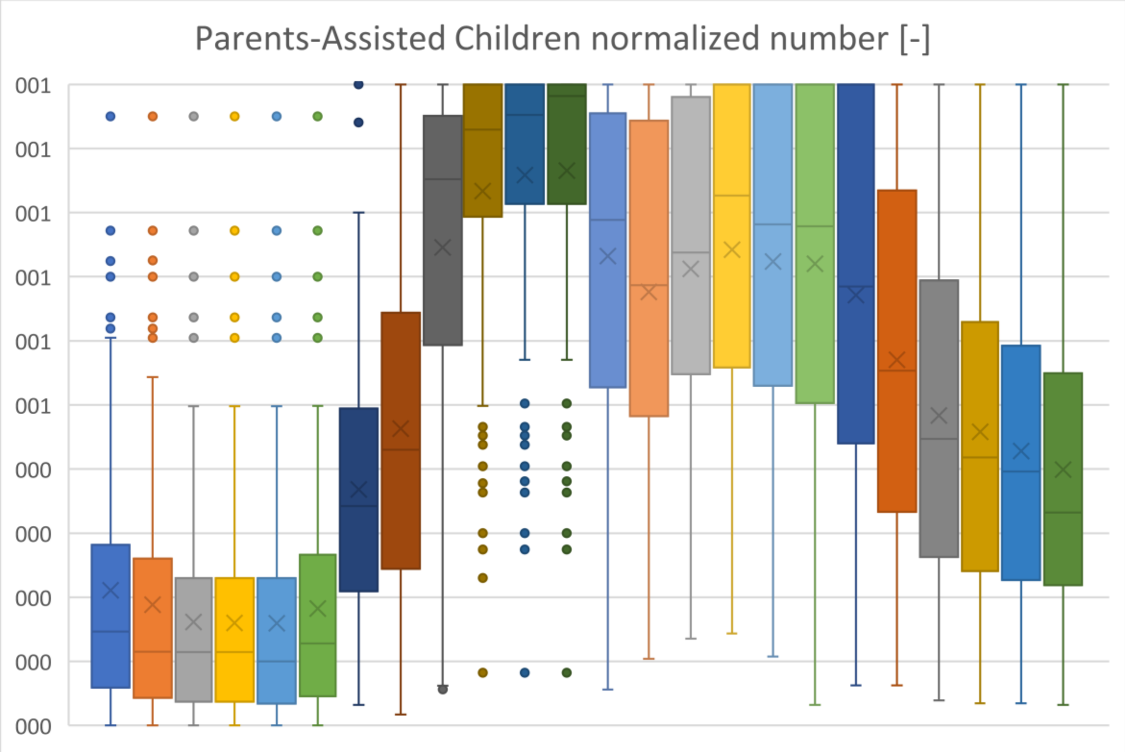


Figure 40: Box-and-whiskers plot representation of the Parents-assisted Children normalized number (PCnn), by tracing the daily trend basing on hourly sampling.

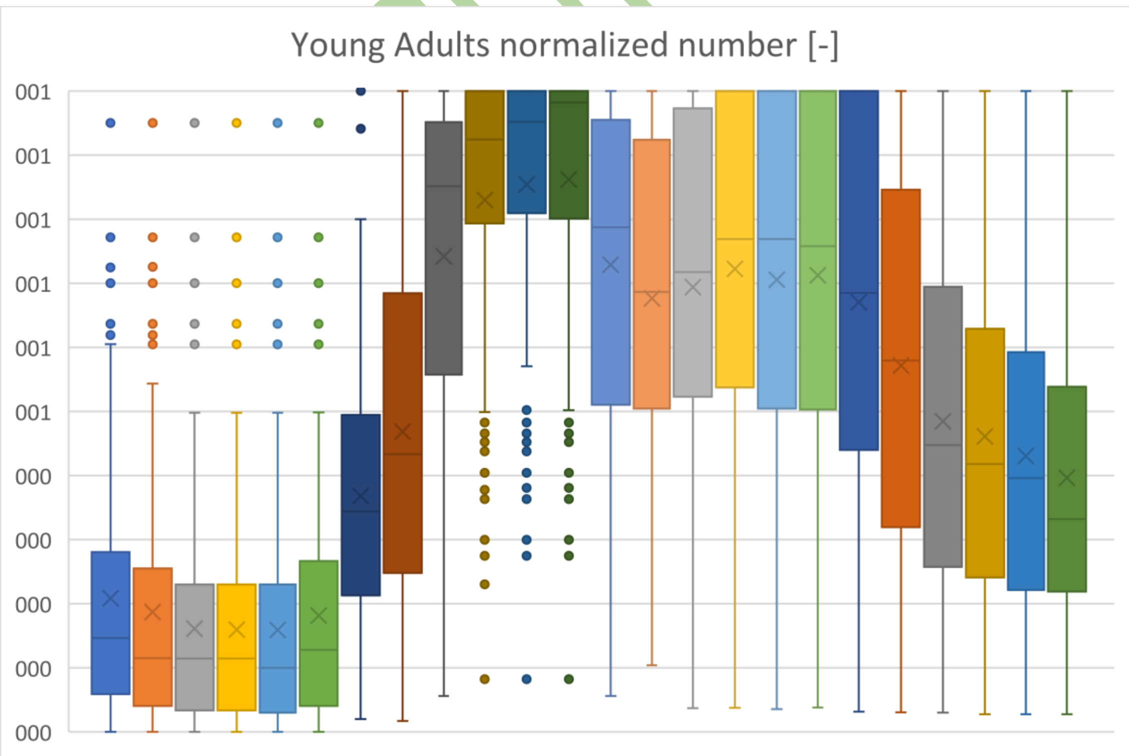


Figure 41: Box-and-whiskers plot representation of the Young Autonomous users' normalized number (YAnn), by tracing the daily trend basing on hourly sampling.

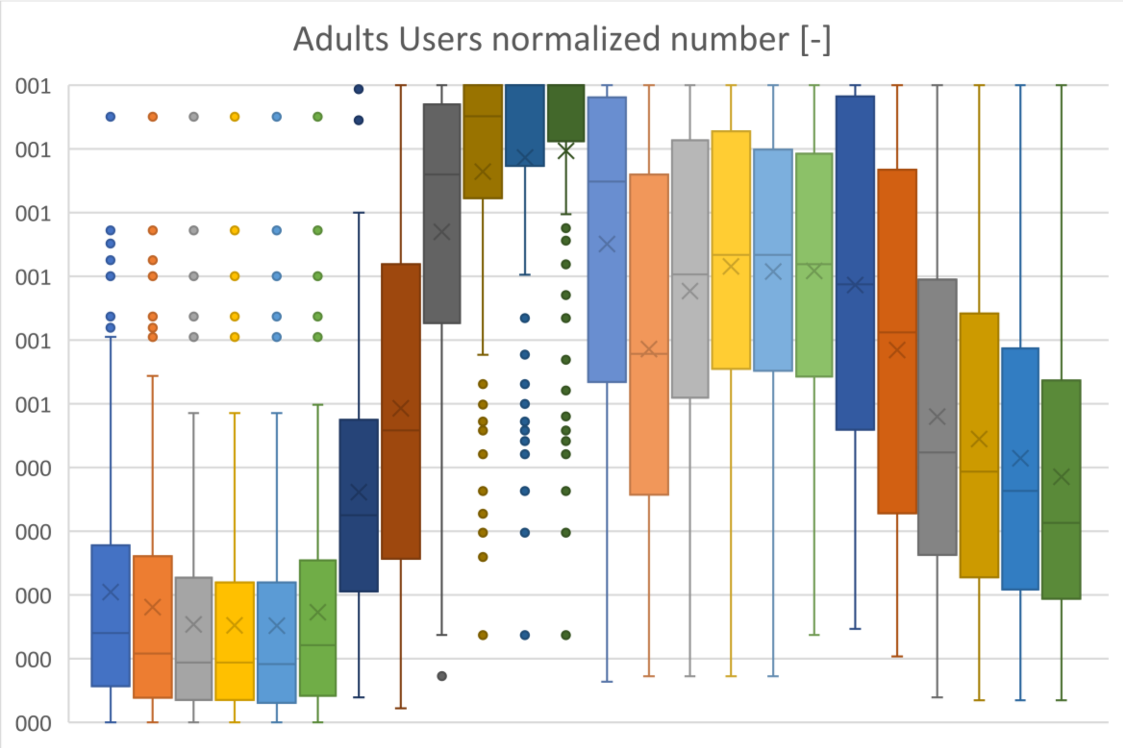


Figure 42: Box-and-whiskers plot representation of the Adult users' normalized number (AUnn), by tracing the daily trend basing on hourly sampling.

5.3 BEC DESCRIPTORS:

5.3.1 Presence and area of special buildings or special uses [Boolean][number of items per BE][m²]

Figure 43According to the types and distributions described in Figure 42~~Figure 38~~, 85% of BEs are characterized by the presence of at least 1 special buildings or special use. Between them, on average, at least one special building is of the type Theatres, Museums or Churches. In the following, the surface areas occupied on average from each of those special buildings is listed: Theatres 1200 m^2, Museums 950 m^2, Churches 1175 m^2.

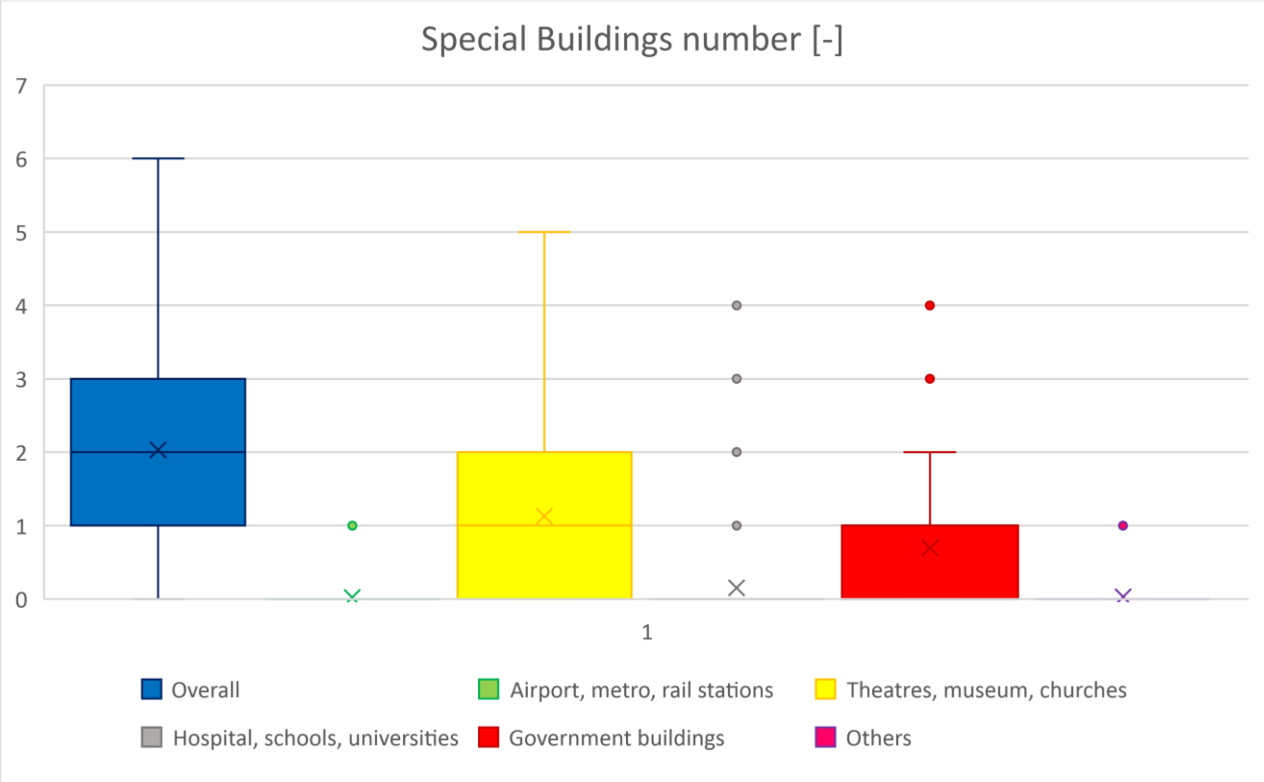


Figure 43: Box-and-whiskers plot representation of the number of each type of special buildings/use within the BEs.

5.3.2 Presence and position of the dehors [-], [%][9]

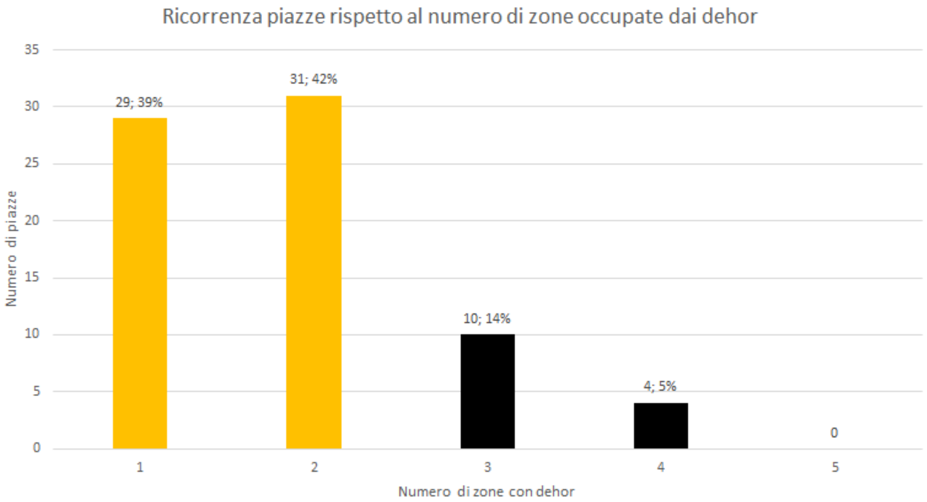
Overall, the case with at least one dehor within the square (54%) is more frequent than whitout (46%). Considering the case with at least one dehor, results show that the most recurring case is for 1 or 2 positions occupied (81%), and in particular:

- When Dnp=1 (39%), the most recurrent Dp are dehor placed at North (31%) or West (21%);
- When Dpn=2 (42%), the most recurrent Dp are dehors placed at W-E (29%) or N-S (19), thus implying dehors placed at the opposite and close to the buildings.

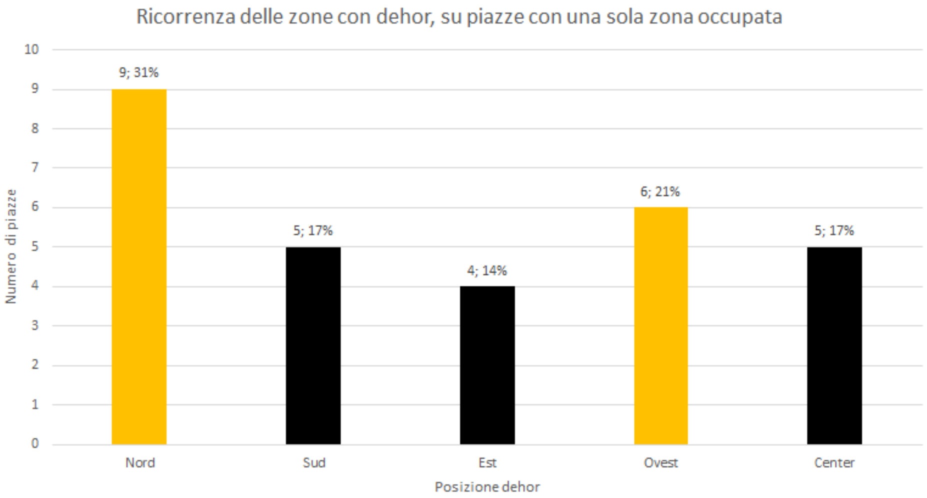
For squares with only one side hosting dehor(s), their position in respect to carriable streets Ds have also been studied. Results shows that in this case (Dnp=1 V Dp ≠ C):

- 69% of the squares have dehor in the walkable area, while 31% next to the carriage street;
- Squares crossed by a street represent 24% of cases
- The most recurrent configuration is that with one street crossing one of the square sides (41%), and in this particular occurrence dehors are placed in walkable areas in 92% of the cases.

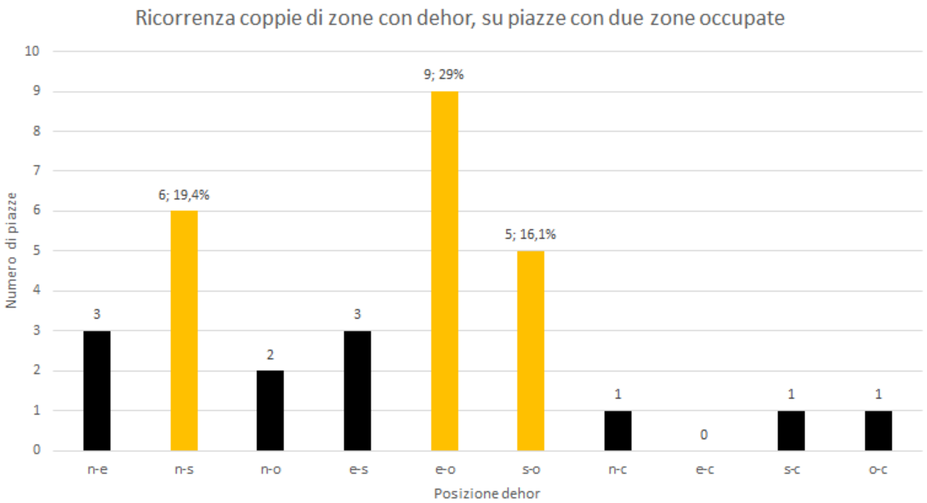
[9] Results assessed in collaboration with RM: Martina Russo, Edoardo Currà


Ricorrenza piazze rispetto al numero di zone occupate dai dehor
Numero di piazze
Numero di zone con dehor
29; 39%
31; 42%
10; 14%
4; 5%
0
1
2
3
4
5

-


Ricorrenza delle zone con dehor, su piazze con una sola zona occupata
Numero di piazze
Posizione dehor
9; 31%
5; 17%
4; 14%
6; 21%
5; 17%
Nord
Sud
Est
Ovest
Center

-


Ricorrenza coppie di zone con dehor, su piazze con due zone occupate
Numero di piazze
Posizione dehor
3
6; 19,4%
2
3
9; 29%
5; 16,1%
1
0
1
1
n-e
n-s
n-o
e-s
e-o
s-o
n-c
e-c
s-c
o-c

-

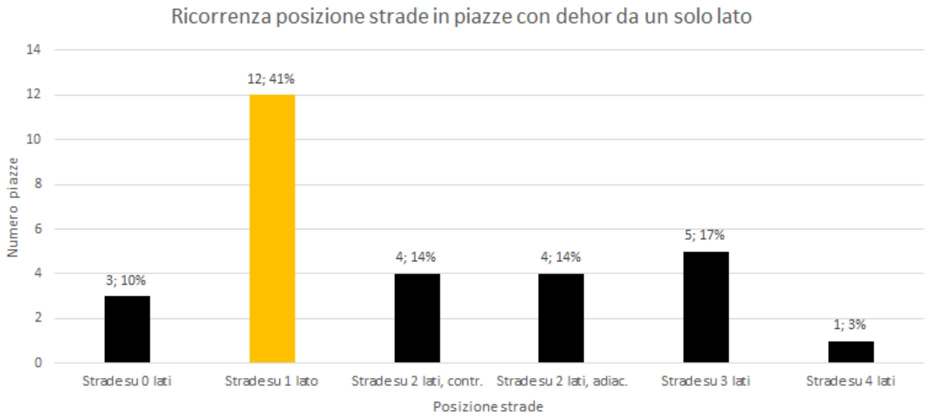


Figure 44: Trends of dehors and street position in the BET (in Italian).

5.3.3 Percentage of outdoor areas per typology [%]

Main areas are related to OPA, as shown by Figure 45

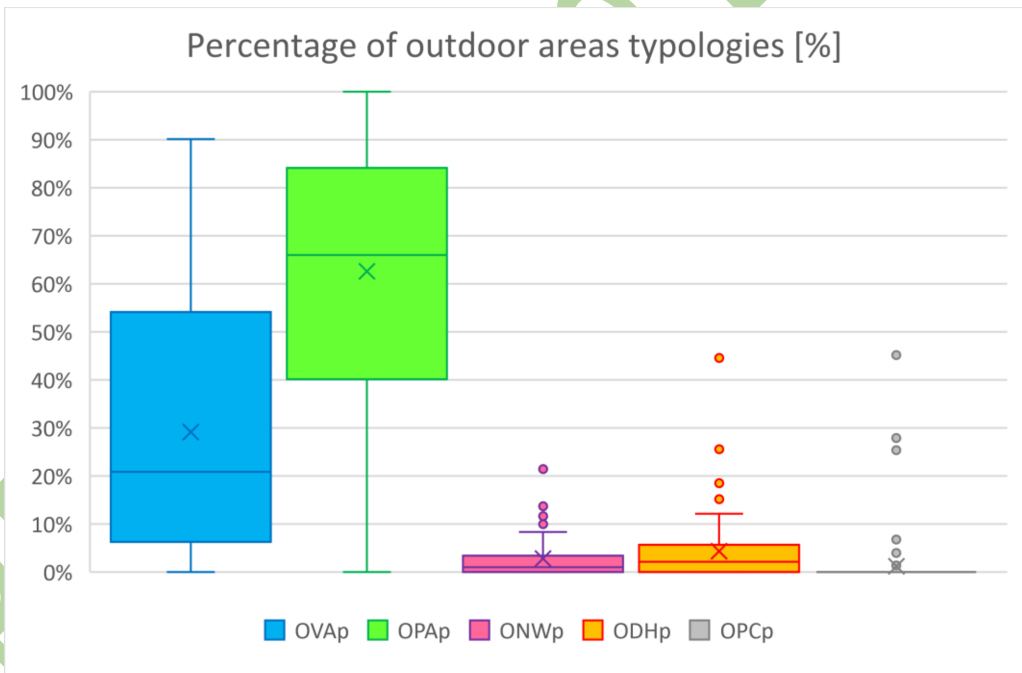
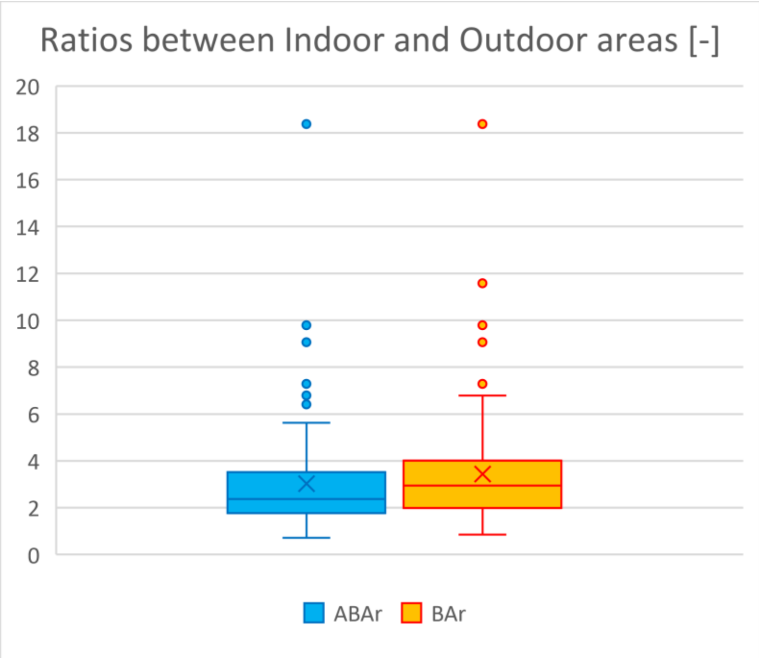


Figure 45: Box-and-whiskers plot representation of the percentage of each type of outdoor area within the BEs.

5.3.4 Ratio between indoor and outdoor areas [-]



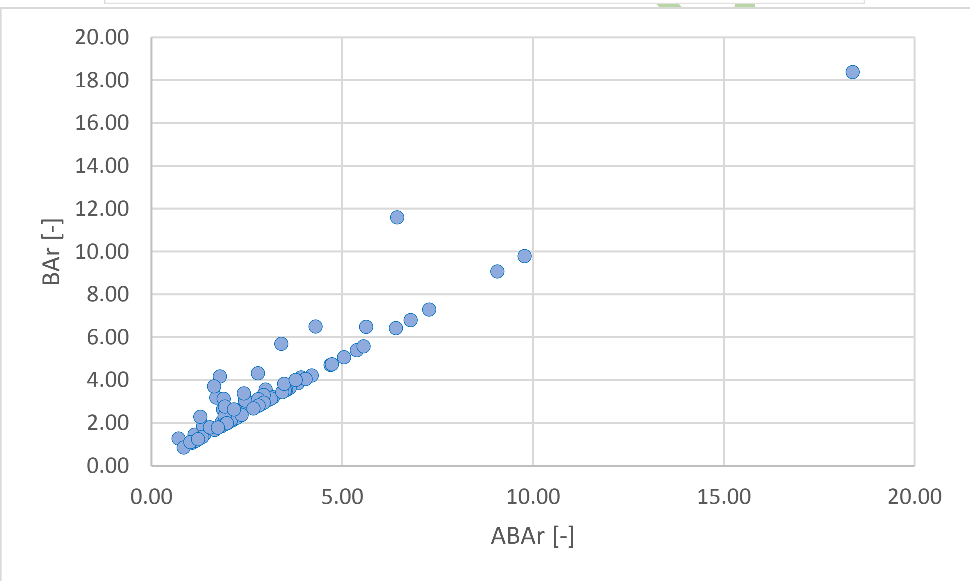


Figure 46: Box-and-whiskers plot representation of the ratios, respectively, between the Accessible Built-up Areas and the Outdoor Areas (ABAr), and between the overall Built-up Areas and the Outdoor Areas (BAr). On the bottom, the correltation between the two values.

5.4 Correlation analysis (linear trends)

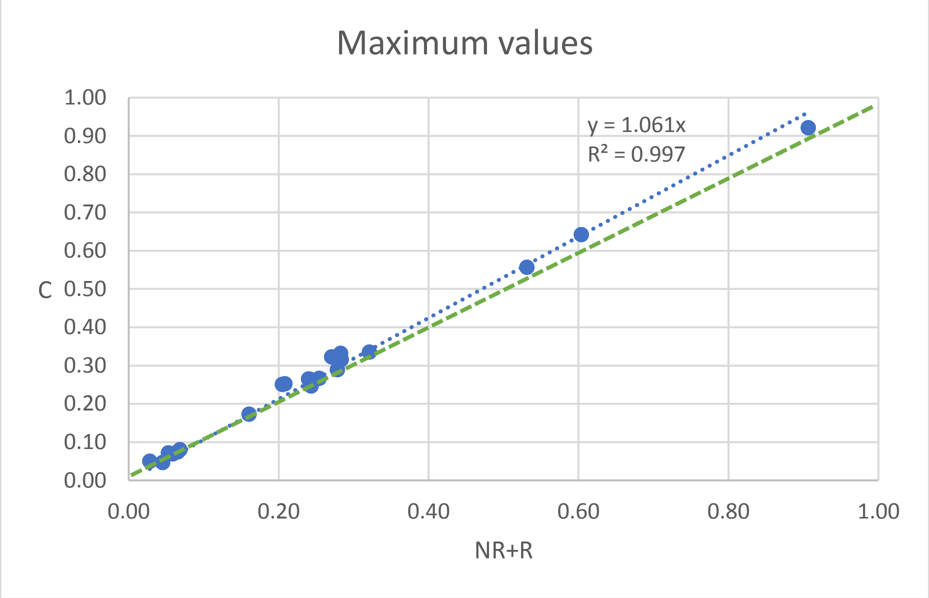


Figure 47: Maximum values of density considering the built-up areas (indoor) [pp/m²] evaluated excluding the prevalent outdoor users (NR+R) versus including them (C). The green dotted line traces the bisector x=y (ideal case in which, in case of invacuation, density does not increase within the built-up areas).

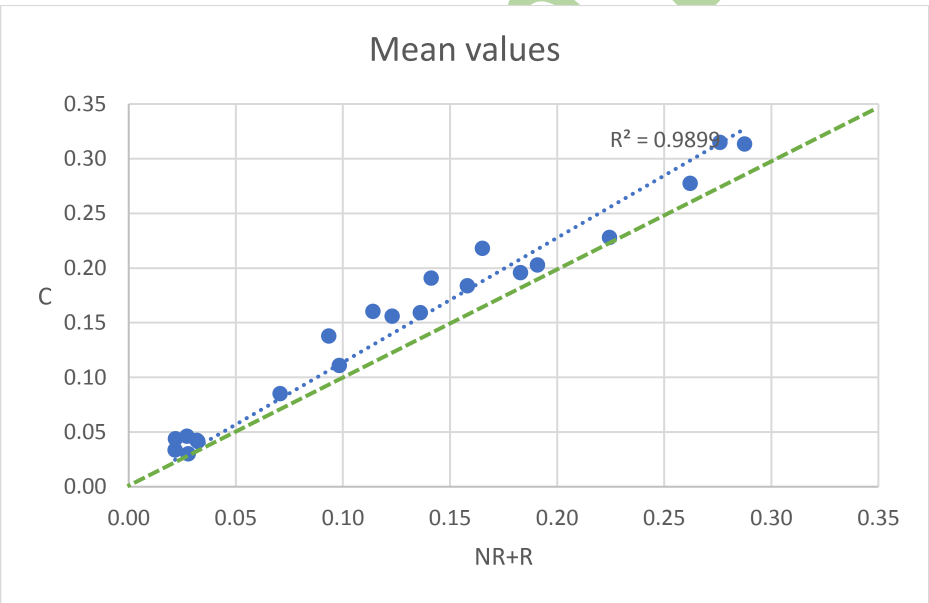


Figure 48: Mean values of density considering the built-up areas (indoor) [pp/m²] evaluated excluding the prevalent outdoor users (NR+R) versus including them (C). The green dotted line traces the bisector x=y (ideal case in which, in case of invacuation, density does not increase within the built-up areas

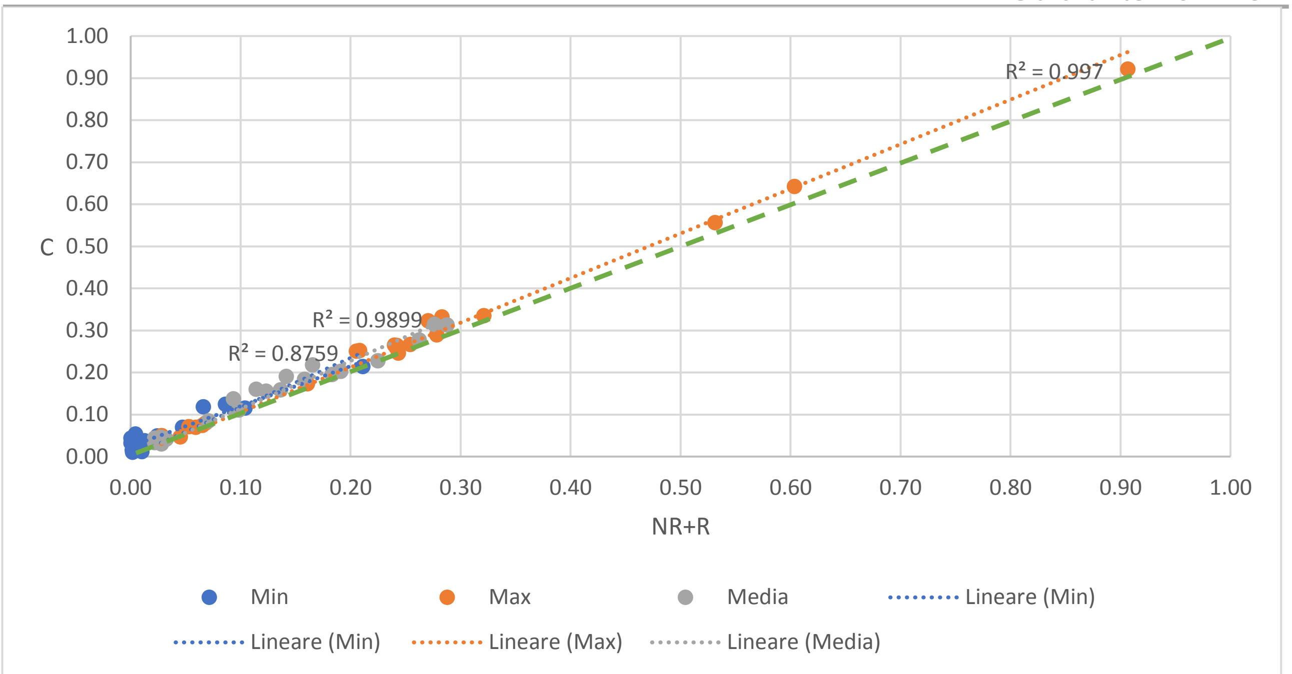


Figure 49: Values of density considering the built-up areas (indoor) [pp/m²] evaluated excluding the prevalent outdoor users (NR+R) versus including them (C). The green dotted line traces the bisector x=y (ideal case in which, in case of invacuation, density does not increase within the built-up areas.

Another discussion of the results emerges from the definition of a mean value (pp/m2) representative of the day for each element sample. This analysis is needed in order to making comparisons among different squares. The aim to trace a general trend is then pursued. The graphic in Figure 50Figure 51Figure 52couples the mean/maximum/mean values of people density of each square by considering only the category "resident" on one axis and the category "non-resident" in the other. The emerged tendency can be limited to the portion of graphic on the right in respect to the red line. The only cases outside this area are reasonably considered as out layer, in fact, in such squares exceptional situations occur.

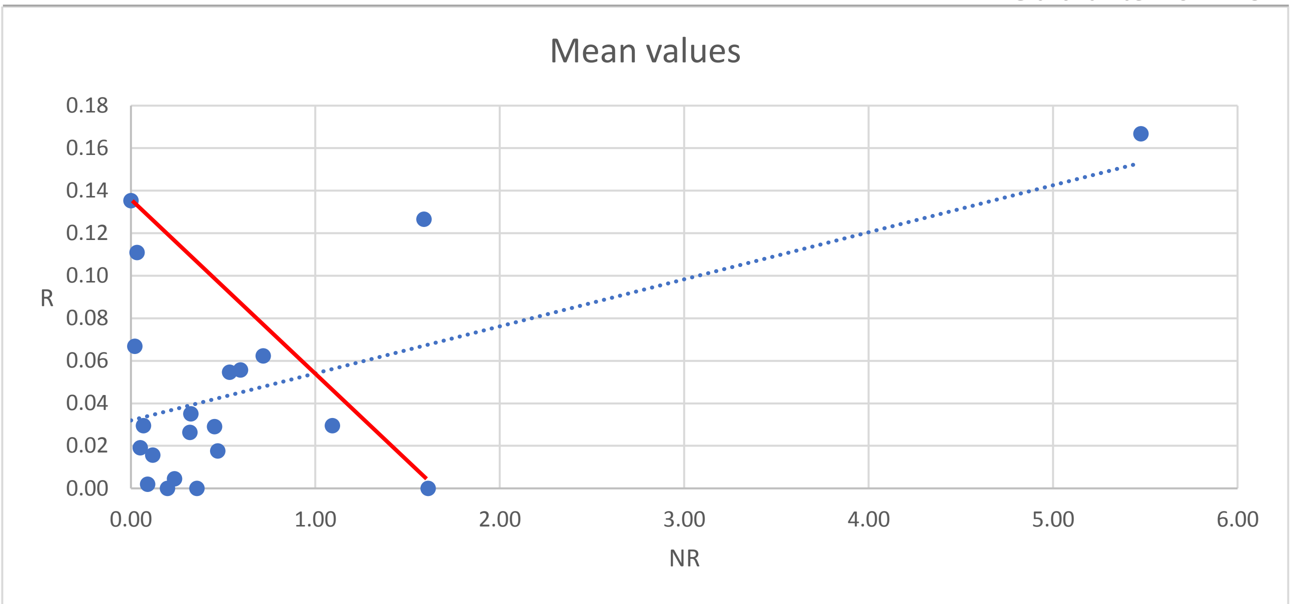


Figure 50. The graph represents the possible relation between the mean values of occupant density between Resident and Non-Resident categories. The red line defines a possible domine for the relation.

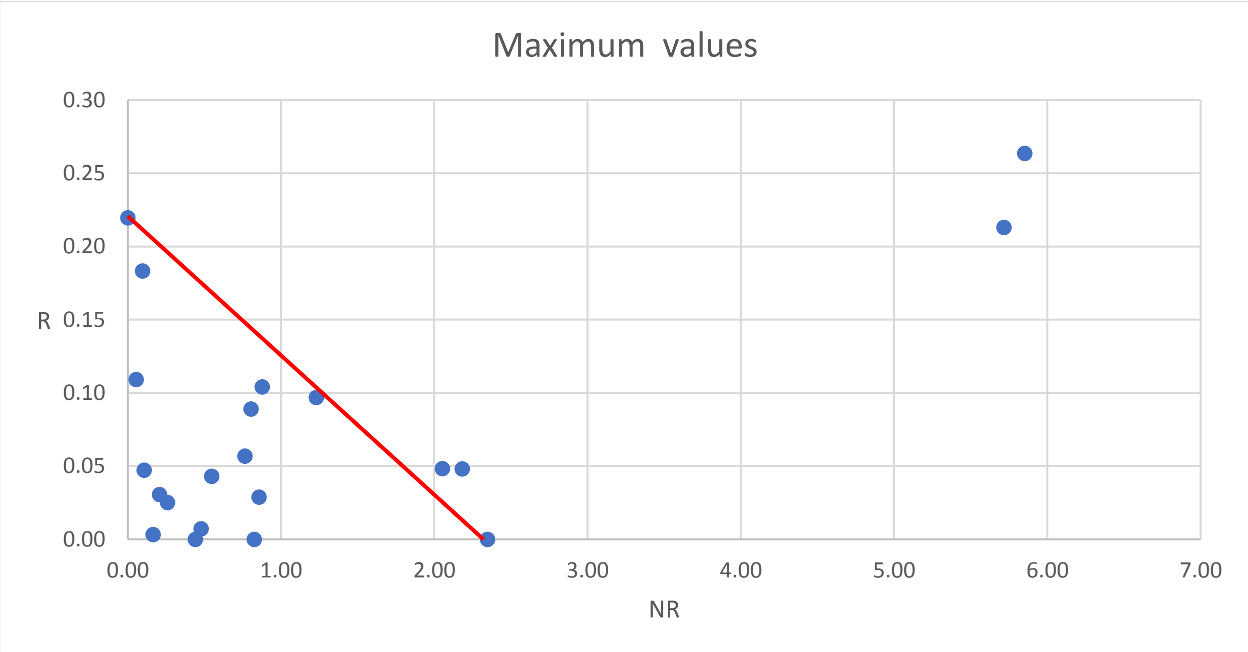


Figure 51: maximum values of occupant density between Resident and Non-Resident categories, which confirm the mean values results (Figure 50). The red line defines a possible domine.

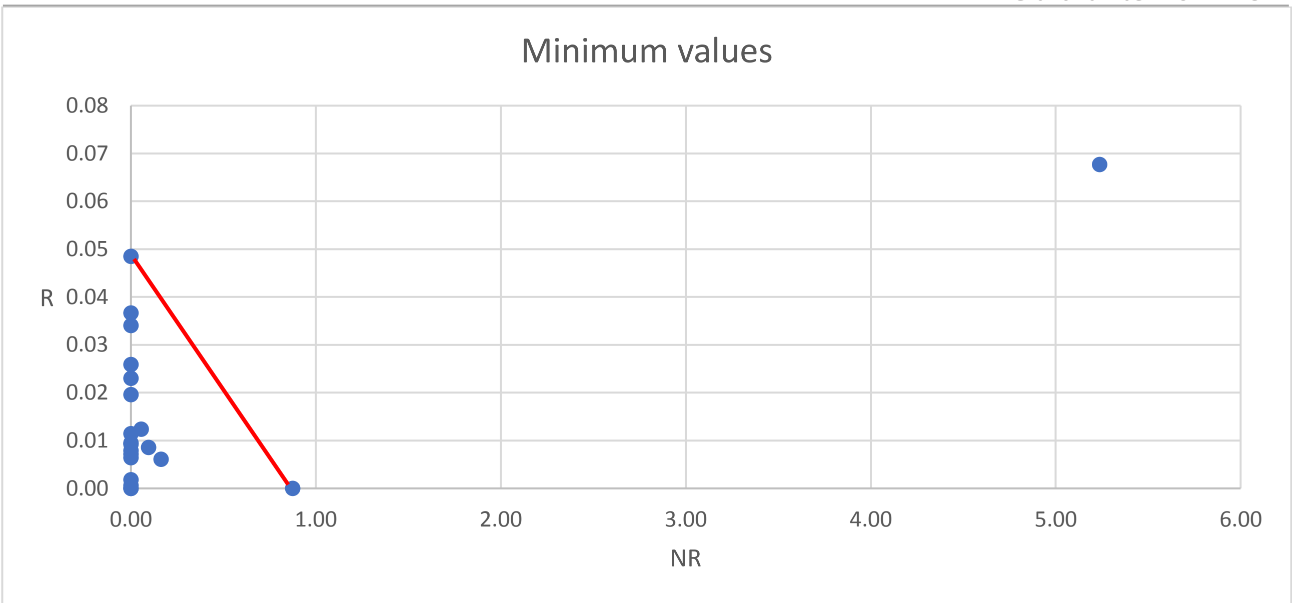


Figure 52: minimum values of occupant density between Resident and Non-Resident categories, which confirm the mean values results (Figure 50). The red line defines a possible domine.

The same values are then reported in Figure 53 that allows to better understand the distribution of each pairs within the proposed domain and the presence of the out layers.

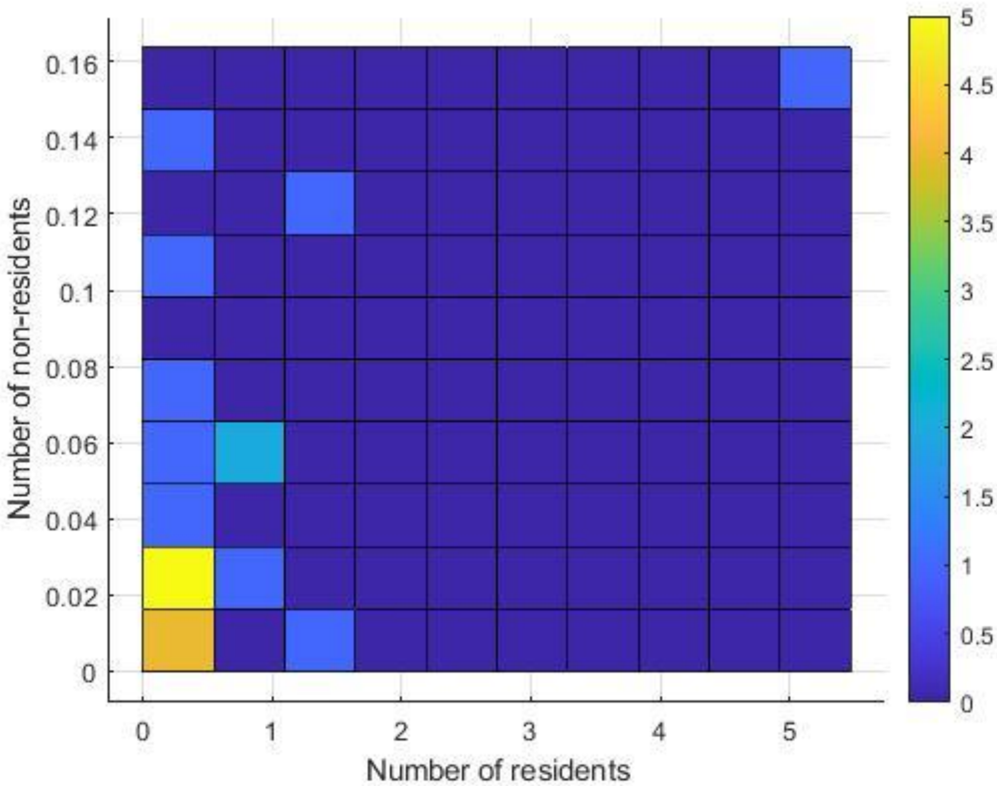


Figure 53 Pairs distribution mean values of occupant density between Resident and Non-Resident categories

Finally, another evaluation from a statistic point of view concerns the frequency distribution of each single obtained data (see Figure 54). For each of these, typical trend can be traced and represented by well-know statistic distribution. The frequency of the overall (resident and non-resident) mean value representing the occupant density (pp/m^2) shows a decreasing tendency in relation to an increasing overcrowding level. This means that the more frequent situation is characterised by level of overcrowding within the safety limits (that can be equal to 2 pp/m^2). The same trends are visible also by separating each occupant category, this fact underlines that high-risk levels occurs less frequently.

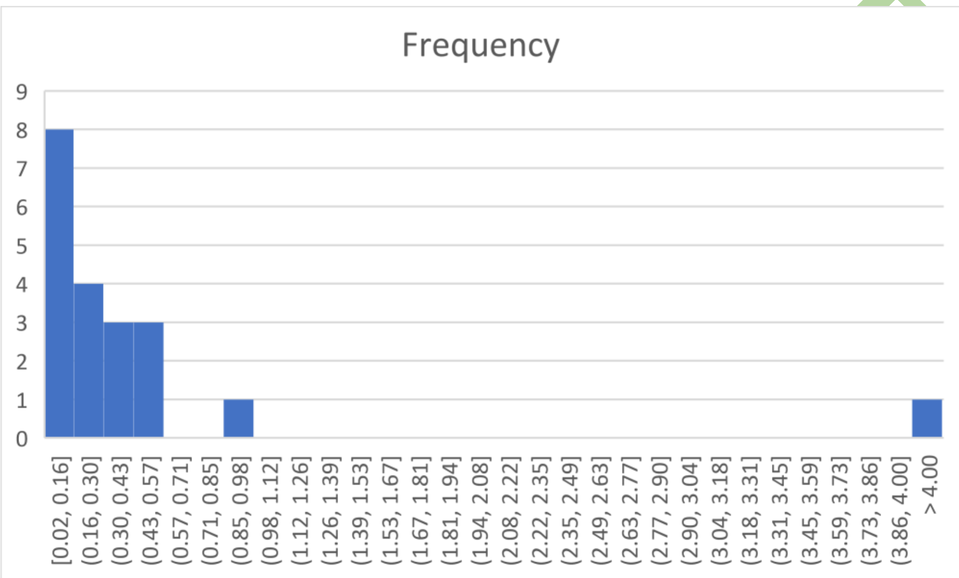


Figure 54 The graph shows the frequency of the non-residents mean density of the overall sample

6. Discussion

6.1 BETs selection for users-related issues characterization

Table 6 describes the BET according to the users-related characterization, that is by resuming the main parameters of Section 5 results. These parameters are supported by experimental-based ranges focusing on the median values, so as to represent the most recurring conditions of the analysed BE. In addition, they are ordered to be applied for the BET scenario creation. It is worth of notice that

Table 6 provides no time-dependent quantification of the BET, but some data could be changed by Section 5.2 results to analyse peak conditions in the BET uses, in particular for what it concerns SUODs since users' behaviors and features can drastically change in relation to the time of occurrence. Data to be used for SUOD and SLOD-related scenario creation are also provided. In SLOD scenarios, the number of people in the BET is identified starting from the analysis of built-up areas, that is by considering that all the people can move indoor to mitigate risk conditions against heatwaves and pollution. In SUOD scenarios, people are supposed to be in outdoor because of the needs for evacuating the built-up areas.

*Table 6. Outline of the BET description according to the median values of section 5. Steps for BET construction are provided in the first column, while interactions with D3.2.1 description are shown in the last column. *: values can relate to TDC in case of specific analysis over the day time, according to Section 5.2 related descriptors. n.a.: not assessed ranges or specific median values.*

Step	**Variable (code according to Table 5 – section reference)**	**Range (eventual explanation of the specific time-related scenario) : median value [unit of measure]**	**SLOD**	**SUOD**	**Correlation with D3.2.1**	
					specific BET code	*parameter*
1	*Defining the area of the building around the outdoor spaces* (ABAr – Section 5.3.4)	2 ÷ 4 :2.5 [-]	x	x		P1
	Defining the dimension of specific areas for:					
	- vehicular only use (OVAp – Section 5.3.3)	10 ÷ 55 : 28 [%]				P1
	- dehors (ODHp – Section 5.3.3)	0 ÷ 5 : 2 [%]	x			P1
2	*Defining the density of the pedestrians:*					
	-in indoor, thus depending on ABAr-related characterization of their dimension (UOId – Section 5.1.5)*	0.06 (mainly, night)÷ 0.14 (mainly, day): 0.09 [pp/m²]	x			
	-in outdoor, so as to move towards the gathering areas (UOOd – Section 5.1.4)*	0.15 (mainly, night) ÷ 0.30 (mainly, day): 0.20 [pp/m²]		x		P1
	-special building uses number to derived crowding conditions in specific parts of the BE, with a random occupant load ranging from 0.4 to 0.7pp/m² (SBn - Section 5.3.1)	1 (as in D3.2.1) or 2 (according to this deliverable results): 1 [number of buildings]	x		1A, 2A, 4A, 4B	P5
3	*People unfamiliar with the BE* (RNp – Section 5.1.2)*	40 (mainly, night) ÷ 60 (mainly, day): 50 [%]	x	x		
	Age characterization (Section 5.1.3)	n.a. : Tp=4%, PC=9%, YA=5%, AU=64%, EU=18%	x	x		
	Gender characterization (Section 5.1.3)	n.a. : Mp=48, Fp=52 [%]	x	x		
4	*Outdoor users' characterization*:		x			

	-outdoor only (OOp – Section 5.1.2)	10 (night) ÷ 20 (day): 15 [%]	x			
	-prevalent outdoor (POp – Section 5.1.2)	0 (night) ÷ 4 (day): 1 [%]	x			

Some details towards the BET creation follow, also in view of WP4 simulation scenario definition.

The BET scenario will consider that PO users will be placed into the dehors areas. Anyway, they could be ignored in the BET, because of their scarce relevance (<10%) in respect to the whole number of users in the BETs). Then, PO could be randomly placed in the outdoor spaces thus contributing to the OOp quantifications. Dehors areas can be randomly identified in the open spaces. Vehicular areas can be considered according to the general scheme of the BET in BET 5. For the other cases, they can be placed near building, that are the frontiers of the BET.

The presence of special buildings will be modelled according to the wider sample recurrences of D3.2.1, Section 3.3.4, for the BET in which they are included (thus, only 1 building with special uses).

6.2 Work perspectives and limitations

Current analyses are focused on the identification of main distribution-based indicators, to quickly derive the BETs characterization depending on the most relevant statistical descriptors. Anyway, all the parameters can be also investigated in terms of distribution functions (tested by using Anderson-Darling, Shapiro-Wilk and Kolgorof-Smirnov tests), to evidence the "shape" of parameters probability in the sample (de Sá 2007). In particular, the following main distribution functions could be tested in respect to the probability density functions: (1) normal distribution, to evaluate if the sample can be described by an average value and its standard deviation, as the simplest description approach; (2) beta distribution, to evaluate distribution in which the mode is different from the average value, and to consider a fine upper and lower bound to the values (in the x axis); (c) the general extreme value distribution to evaluate additional non-beta distributions inside finite bounds, and which can exalt the effects of boundary peaks of frequency.

Finally, the parameters can be also assessed according to a scatter plot matrix to visualize bivariate relationships between their combinations, thus evidencing the presence of Pearson-based correlations (de Sá 2007; Gravetter and Wallnan 2013), or by using cluster analysis based on some of the parameters in Section 6.1, according to the clustering techniques of D3.2.1.

Another limitation of the work is related to the sample dimension. Although the current BEs sample involves tens of squares, the overall dimension is smaller than the one on D3.2.1, because of the retrieved lacks to directly extract the needed parameters in a quick way through GIS tools. Next works should provide the extension of the proposed methodology by using automated techniques and other freeware and open access repository of data.

7. Conclusions and remarks

Creating typical user-related characterization of the BE should need reliable bases of the factors to be considered as significant in BE prone to both SUODs and SLODs. According to a literature-based approach and starting from previous T1.2, T2.2 and T3.1 activities, this work tries to codify the relevant factors in this sense, by additionally providing a discussion of the sources to be used to retrieve and organize the data, and of the quantities to be collected in real case applications.

Result provide evidence on median "use" of the BE thus moving towards the most recurring and ideal BETs conditions ranges in ordinary days, that are the working days. These working days are the most frequent during the year. The defined BET parameters concerning the users' factors are offered for SLODs and SUODs characterization and are correlated to the BETs in D3.2.1 Section 3.3.4, so as to provide the bases for WP4 – T4.1 simulation in ideal conditions.

Anyway, the results also point out how further studies are required by considering the effective characterization of specific BE/BETs and typical conditions in a quantitative and statistic-based manner, so as to converge towards the definition of experimental based typical users-related factor characterization. In this sense, a considerable number of real BE prone to SUOD and SLOD should be selected and the proposed data acquisition methodology should be applied to them, also in the view of the statistical analysis of D3.2.1 and the next case study application in D3.3.1.

Then, future actions to improve the current results should be aimed at introducing a critical evaluation of the collected factors based on empirical observations and statistical analysis of a large quantity of real cases (e.g.: the mean number of people present in a square in different times of the day). This further in-depth analysis will allow to re-create BETs conditions for the case study applications in T3.3 activities and to the simulation process in WP4.

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9. Appendix A –operational framework for peak conditions identification applied to a case study: Milan[10]

This appendix traces the application of the data collection and management methodology in view of the application to BE where GIS-based tools are freely available to increase the data reliability and the rapid assessment of exposure and vulnerability issues. In particular, the methodology is here described towards the peaks identifications in terms of users' number into the BE.

The first necessity is to detect the buildings intended use in the studied area. Referring to the Milan case study the GIS database[11] provided by the Milan Municipality offers a map where indications relate to public facilities (e.g.: offices, schools, hospitals, homeless centres, theatres) are provided through a coloured legend. For each public facility, the remote GIS tool displays further information e.g.: its denomination, the typology of provided service, the address and the overall area extension on the GIS map. The Google Street View[12] application can be employed to detect punctually the economic activities (e.g.: shops, commercial activities, bars, restaurants) placed at the ground level of inspected buildings. In addition, the previously mentioned

[10] Developed in collaboration with MI: Juan Diego Blanco Cadena, Graziano Salvalai. Compare also contents with published results of the BE S2ECURe project, which extends this part of the work: Blanco Cadena, J.D.; Salvalai, G.; Lucesoli, M.; Quagliarini, E.; D'Orazio, M. Flexible Workflow for Determining Critical Hazard and Exposure Scenarios for Assessing SLODs Risk in Urban Built Environments. *Sustainability* **2021**, *13*, 4538. https://doi.org/10.3390/su13084538

[11] Milan Municipality opens source GIS portal for public facilities identification: https://geoportale.comune.milano.it/MapViewerApplication/Map/App?config=%2FMapViewerApplication%2FMap%2FConfig4App%2F477&id=ags (last access on: 04/11/20)

[12] Google Street View: https://www.google.it/streetview/ (last access on: 04/11/20)

GIS application gives the possibility to consult a map[13] where eventual abandoned buildings are indicated. Finally, it is assumed that the remaining built volume constitutes the residential part. Further verification can be done by crossing the house numbers position (subdivided in commercial and residential) provided by the same GIS portal[14] with the Street View visualization.

The second step regards the estimation of the maximum admissible occupancy (in terms of the number of people) of indoor environments for all the previously detected buildings intended use. To reach this goal, Italian fire safety regulations prescribe for each intended use a quick load capacity factor. Such factors and the related Ministerial Decrees in which they are regulated are reported in Table 3. Now, an additional passage is required. The load capacity factor is given in terms of the number of people for a squared meter. Hence, the total area of each intended use has to be calculated and multiplied for the corresponding factor. In this way, the maximum admissible occupancy for a specific place (determined area) is reached (in number of people), and it can be assumed as a critical peak of the exposure. From a practical point of view, the extension area for each building has to be determined according to a remote data collection approach. Using the tool "ruler" sheet "polygon" of the software Google Earth Pro freely available online[15], the planar area is quickly detected. The counting building floors are pursued through Street View visualization. The planar area is now multiplied for the evinced number of floors, and each intended use extension is sized.

A deeper focus on the average presence of people in commercial spaces can be performed through the remote sensing. In this case, the free-of-charge Google toolbox[16] (Popular times, wait times, and visit duration) is employed to qualitatively estimate the crowding variation (including the peak) during the day and in the different days of the week in which the commercial activities are attended by users. Additionally, the same tool allows to quantitatively trace the average time spent by occupant within the inquired activity. Popular times provide a time-dependent bar chart without the quantification of occupants. However, the bar chart can be subdivided in quartiles. The maximum level can be assumed equal to the maximum admissible occupancy determined in the previous point for each examined place. In this way, a quantification of the occupancy variability can be done in terms of number of people per hours and in different days of the week. in this sense, statistics can be traced for commercial and public activities. From such purpose emerges the necessity to subdivide the day in different time slices mainly four (early morning, lunch time, afternoon and evening). Comparisons can be made between different intended use (e.g.: schools versus cinemas) and different commercial activities (e.g.: restaurants versus bakeries). Where data are not available assumptions can be made among similar commercial activities. Additional data can be collected for specific intended use detected in the study area. According to Table 3 to detect occupancy of certain intended use the seats can be counted (e.g.: in churches, concert halls, theatres) in others (e.g.: schools, universities) the number of occupants can be determined in relation to the number of classrooms.

[13] Milan Municipality opens source GIS portal for abandoned buildings and areas detection: https://geoportale.comune.milano.it/MapViewerApplication/Map/App?config=%2FMapViewerApplication%2FMap%2FConfig4App%2F405&id=ags (last access on: 04/11/20)

[14] Milan Municipality opens source GIS portal for house numbers: https://geoportale.comune.milano.it/MapViewerApplication/Map/App?config=%2FMapViewerApplication%2FMap%2FConfig4App%2F218&id=ags (last access on: 04/11/20)

[15] Google Earth Pro available at: https://www.google.it/earth/download/gep/agree.html (last access on: 04/11/20)

[16] Google toolbox for popular times detection: https://support.google.com/business/answer/6263531?hl=en (last access on: 04/11/20)

The last step regards the estimation of the study area inhabitants. Census data17 for the population are used to quantify the population by using municipal or sub-scale data as representative of the whole number of exposed people (residents). Milan Municipality area is subdivided into different NIL (Local Identity Nucleus). For each of this BE portion the inhabitant density is provided. However, the studied area is less extended and contained within the related NIL. The inhabitant density (number of people for squared kilometre) is multiplied for the extension of the study area calculated taking advantages from Google Erath Pro tools as previously explained for buildings. Hence, a reliable estimation of the total number of residents of the studied area are achieved due to the high representativeness of the NIL inhabitant density. To conclude, some words have to be spent for inhabitant's presence variation during the day. According to the census data inhabitants can be divided into different functional ranges age-related (youngers adults and elders). Census databases provide the percentages of such ranges that composing the entire population. In this study is assumed that youngers and adults leave their dwelling during the day for working and studying, while elders stay at home. In the evening all inhabitants return to their homes. Different conditions can be considered during the weekend. Seasonal variations are not here considered.

This operational framework is here applied to the Milan (Italy) case study, in order to evidence its effective operability. The case study building intended uses are evaluated through the employment of the Milan Municipality open source GIS portal. Figure 55 highlights the presence of four main public activities located in the study area: a homecare centre for young mothers, a school with different grades of instruction, a theatre with 250 seats and finally the church of "Santa Maria Assunta". Additionally, through the employment of Google Maps and its application Google Street View has been possible to determine the presence, at the ground level of several buildings in the case study area, of commercial activities. Especially, commercial places are detected such as shops, restaurants, bars and other specific activities that could be attractive for citizens such as the bank, a travel agency, and private professional studies (e.g.: doctors and dentist). The remaining buildings in grey are private dwellings each one identified by their own civic number. Moreover, through the use of the same GIS portal is possible to verify in the studied area the absence of abandoned buildings that could influence the overall estimation of inhabitants.

[17] Census data available for the case study at: http://sisi.comune.milano.it/ (last access on: 04/11/20)

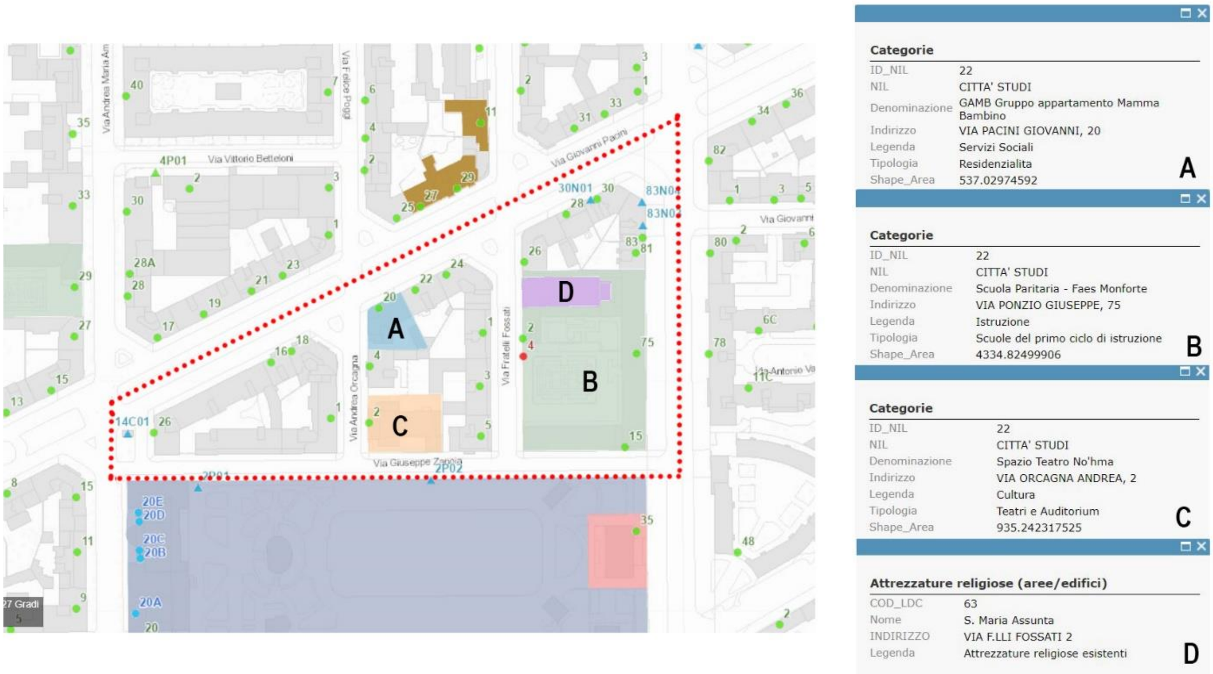

Figure 55 Case study area (dotted red line) with the identification of public facilities and related intended use; Civic numbers are provided in correspondence of the green points for both public buildings and private dwellings. The map provided derive from Milan Municipality opens source GIS portal (https://geoportale.comune.milano.it/MapViewerApplication/Map/App?config=%2FMapViewerApplication%2FMap%2FConfig4App%2F477&id=ags last access on: 02/12/20) and furtherly elaborated by the authors.

The second performed step regards the necessity to evaluate some required geometrical features of buildings in order to determine the maximum crowd conditions. Table 7 associates each building its number of floors, the planar area extension of a single floor and the total covered area. Table 3 provides the load capacity factor for each building's intended use, in such way the total estimation of people presence (Exposure Peak in [pp]) is given in the last column of Table 7.

Table 7 Evaluation of the maximum exposure peak esteemed by considering the maximum load capacity factor according to Table 3 multiplied for the total area of each building's intended use. Here, geometrical features of buildings are provided to obtain the total area covered by each intended use.

Address	Map ID/civic number	Building intended use	Planar Area Extension [m2]	No. Floors	total covered area [m2]	Load capacity factor [pp/m2]	Exposure Peak [pp]
VIA PACINI GIOVANNI, 20	A	Homecare centre	310	7	1860	0.1	186
VIA PONZIO GIUSEPPE, 75	B	School	1120	6	6720	0.4	2688
			700	2	1400	0.4	560

VIA ORCAGNA ANDREA, 2	C	Theatre	562	2	1124	3	3372
VIA F.LLI FOSSATI 2	D	Church	603	1	603	0.7	422
VIA PONZIO GIUSEPPE	81	Residential	200	8	1400	0.05	70
VIA PACINI GIOVANNI	30 (83)	Residential	515	8	3605	0.05	180
VIA PACINI GIOVANNI	28	Residential	195	7	1170	0.05	59
VIA PACINI GIOVANNI	26	Residential	327	7	1962	0.05	98
VIA FRATELLI FOSSATI	5	Residential	305	5	1525	0.05	76
VIA FRATELLI FOSSATI	3	Residential	310	5	1550	0.05	78
VIA FRATELLI FOSSATI	1	Residential	284	5	1420	0.05	71
VIA PACINI GIOVANNI	24	Residential	330	7	1980	0.05	99
VIA PACINI GIOVANNI	22	Residential	232	8	1624	0.05	81
VIA ORCAGNA ANDREA	4	Residential	210	4	840	0.05	42
VIA PACINI GIOVANNI	26	Residential	775	7	5425	0.05	271
			480	4	1920	0.05	96
VIA PACINI GIOVANNI	16	Residential	157	7	942	0.05	47
VIA PACINI GIOVANNI	18	Residential	285	7	1710	0.05	86
VIA ORCAGNA ANDREA	1	Residential	610	4	2440	0.05	122
VIA PACINI GIOVANNI, 20	A	Commercial	310	1	310	0.4	124
VIA PONZIO GIUSEPPE	81	Commercial	200	1	200	0.7	140

VIA PACINI GIOVANNI	30 (83)	Commercial	515	1	515	0.4	206
VIA PACINI GIOVANNI	28	Commercial	195	1	195	0.7	137
VIA PACINI GIOVANNI	26	Commercial	327	1	327	0.4	131
VIA PACINI GIOVANNI	24	Commercial	330	1	330	0.4	132
VIA PACINI GIOVANNI	22	Commercial	232	1	232	0.4	93
VIA PACINI GIOVANNI	16	Commercial	157	1	157	0.4	63
VIA PACINI GIOVANNI	18	Commercial	285	1	285	0.7	200

According to the methodological section 2.2 Figure 56 analyses all the available Google Popular times for the case study commercial activities and shops. Subdividing each range of the provided histograms into four quartiles for different affluence, the crowding peak is observed in correspondence to different daily time slices (early morning, lunchtime, afternoon and evening). During the week the main populated time slice are the ones coincident with lunchtime (from 12 a.m. to 3 p.m.) and with the afternoon (from 3 p.m. to 9 p.m.) where the affluence of visitors reach the third quartile, almost all the activities in these hours reach at least the 75% of their total capacity. Only during the weekend, the exposure peak of commercial activities especially for bars and restaurants is reached during the evening from 9 p.m. to 12 p.m.). Results can be managed through a statistical analysis giving the representation of the main hours in which visitors (i.e.: people coming from outside the study area) populates commercial activities. Similar data can be reasonably extended to the other remaining shops in the area where such data are not available.

Figure 56 All the available Google Popular times for the economic activities in the case study area are reported, organised in the day of the week and subdivided in quartiles.

Additional information about hosted residents in the case study area can be retrieved by available census data. The overall inhabitant density for the considered NIL, representative of the case study urban tissue, amount to 16,505 pp/km2 that in reference to the case study area can be brought back to 443 residents in an investigated area of 0.027 km2. Such data allow understanding how the related esteemed value from the exposure peak methodology application seems to be overestimated (1476 pp). However, this last esteemed value concerns a maximum peak that could not be equally compared to a simplified inhabitant density. Moreover, from census data reported in Figure 57, ages-related percentages of ranges that composing the entire population highlights the sensible presence of residents with an age included between 25 and 55 years old. According to the methodological section 2.2 the NIL is populated by the 14.4% of youngers, 60.7% of adults and the remaining 24.9% by elders.

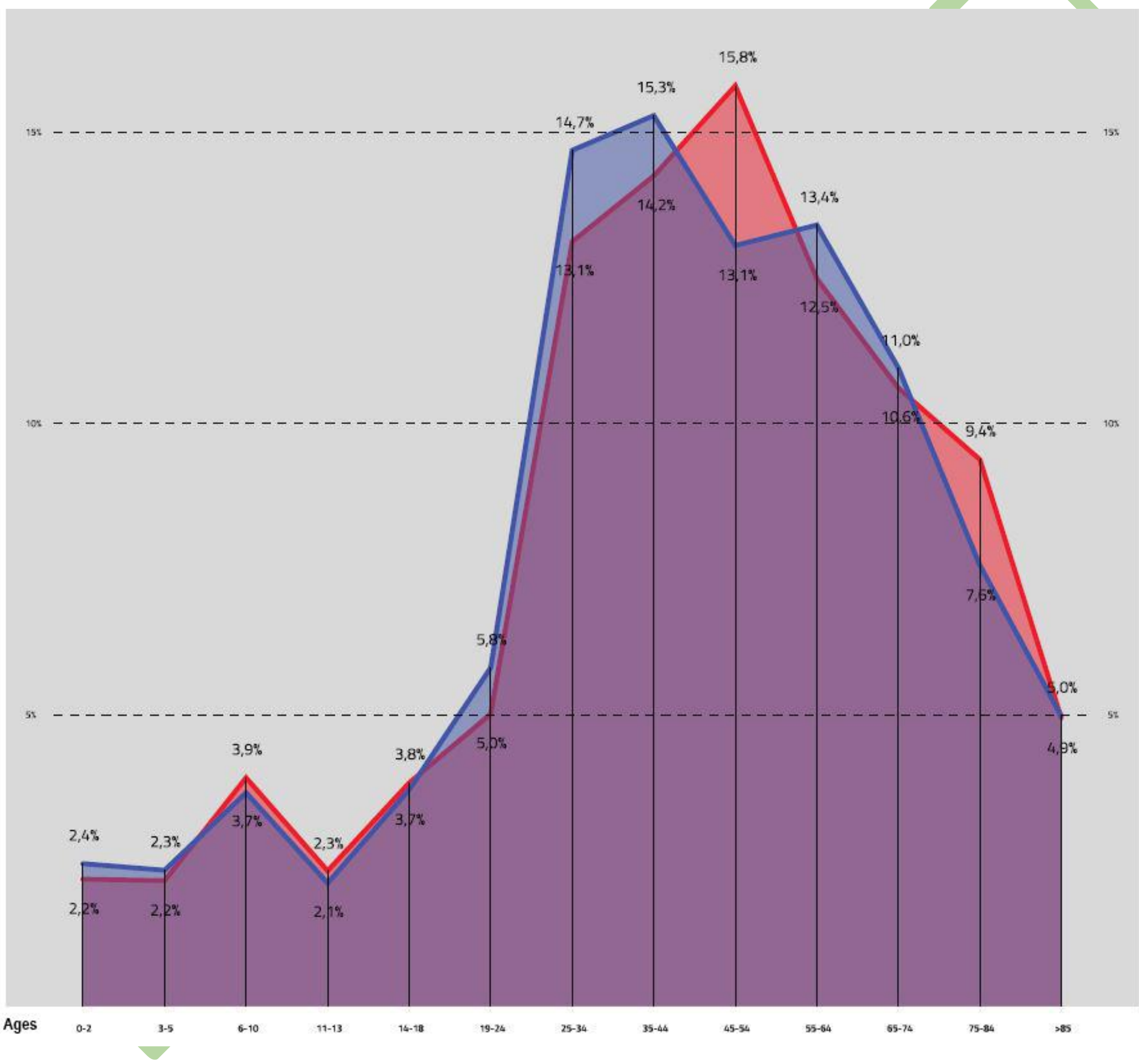

Figure 57 Population distribution for different age-related ranges of the Local Identity Nucleus (LIN) where the case study is adopted. Source: http://allegati.comune.milano.it/territorio/PGT_NIL/NIL_22.pdf last access 02/12/20.

10. Appendix B – Environmental classes for special buildings/use classification in Table 4

The Environmental Classes for buildings/space uses is derived according to Table 5 in D1.3.1, as reported in Figure 58. Buildings and spaces that are not associable to this classification (e.g. municipal offices, government offices and buildings) are classified as N, according to previous base classification rules

(National Consortium for the Study of Terrorism and Responses to Terrorism (START) 2019). Class D mainly include military bases and police stations.

As described in section 3, the GTD uses a wide classification of target types and sub-types (see Annex I). However, according to the Catastrophist Woo G. and following the necessity to focus on BE, the reduction of parameters is fundamental to the sharp comprehension of the phenomenon. For these reasons, classes of targets have been defined identifying environmental homogeneous classes taking into account: i) potential crowd levels (*impact Factor criteria*); ii) political/religious meaningfulness of urban spaces (*Publicity impact Criteria*); iii) security and check systems present (*impact factor on micro/macro terror*); iv) Built Environment typology (*Open area / building*). As the combination of these parameters, 6 **Environmental Classes** (EC) have been identified (Table 5).

Table 5 - Environmental Classes (EC) of terrorist attack targets

Environmental Classes (EC)	
Code	**Built Environmental Typologies**
[A]	Airport, docks, metro and rail stations
[B]	Theatres, museum, bar, restaurant, hotel, shopping centres, churches
[C]	Hospital, schools, universities
[D]	Representative (symbolic) or strategic buildings
[E]	Residential buildings and industries
[F]	Open areas, squares and streets

Figure 58 Environmental classes according to Table 5 in D1.3.1.