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Flood damage model: Development of INSYDE in the Po River basin

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Abstract

Due to the increasing socioeconomic impact that floods have on society, economic models of flood damage have been developed to support more rational decision-making on flood risk management.

The present work regards the update of one of these models, i.e., the INSYDE model for the calculation of direct flood damage to residential buildings in the Italian context. INSYDE is a micro-scale, synthetic, multivariable model, considering 23 explicative hazard and vulnerability variables, for which default values were defined to be assumed if related information is missing during the implementation process. The updating consisted in the calculation of default values, and the identification of the relations among INSYDE parameters, in the Po River basin, considering a more rigorous statistical analysis of residential buildings than the one performed in the original INSYDE formulation. Statistical analysis comprised hazard parameters and building characteristics compiled from databases and previous works, while missing data related to building characteristics has been obtained from virtual survey of residential buildings located within the floodplain of rural and urban areas. Subsequently, as part of the structure of the damage model, fragility functions (if necessary) and unit prices have been updated.

Reported damage data from the flood events involving the Adda river (2002) and the Bacchiglione river (2010) have been used for the validation of the updated INSYDE. Additionally, considering the failure of the original INSYDE in the estimation of extensive parameters for larger buildings, the validation datasets were subdivided into two subsets considering small and large buildings, making a comparison between the closeness of damage calculated with original and updated INSYDE to the observed damage. From the validation of the entire datasets, updated INSYDE seems to overestimate the reported losses, however, there is a reduction of relative error of about the half with respect to the original INSYDE. From the subset of small buildings, damage calculated with updated INSYDE tends to underestimate the reported losses, being different to the overestimation of damages identified with original INSYDE. From the subset of larger buildings, both original and updated INSYDE tends to strongly overestimate the reported damages, discouraging the use of INSYDE. Additionally, having the availability of hazard and building characteristics from both case studies, a check of representativeness with respect to the default values is realized, obtaining a partial agreement.

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Chapter 1: Introduction

In 2020, 193 flood disasters were the most frequent event worldwide accounting for around 62% of all major natural disasters worldwide. These flood disasters affected about 33 million inhabitants and generated direct economic losses of about USD 51.5 billion, which represented around 30% of direct economic losses among all type of disasters (Academy of Disaster Reduction and Emergency Management et al., 2021). In the European context, between 1998 and 2009, 213 recorded events caused about 1126 fatalities, the displacement of about half a million people and at least EUR 52 billion in insured economic losses (EEA, 2011). In addition, northern Italy is one of the areas with the highest concentration of repeated flooding over the 1998 to 2002 period (EEA, 2003). The increase of flood risk over the years may be caused by the development of infrastructures and urban growth in flood-prone areas, which raise the number of exposed inhabitants and assets (Konrad C., 2003). Regarding buildings exposed to flood risk in a medium probability scenario (i.e. 100-200 years return period), near 1.4 million buildings located in Emilia-Romagna, Toscana, Veneto, Lombardia and Piemonte may be affected, being these regions considered with the highest number of buildings at risk (ISPRA, 2018). Considering the socio-economic impact of flood damage, the European Commission developed the Directive 2007/60/EC for the assessment and management of flood risks. The assessment of flood risk comprises the distinction of river basins and coastal areas with likelihood of overflowing occurrence, and the identification of exposed areas. Whereas, as part of the flood risk management, flood risk maps are developed and based on these results, plans for the reduction of flood consequences are applied . As part of the support of flood risk management, the flood damage models have been incrementally used as a tools which provide support in the determination of vulnerability of exposed elements, the definition of flood mapping considering both hazard and exposure (e.g. assets and inhabitants), the decision-making on the measures to be taken for flood risk reduction, the financial appraisal for the insurance sector, and for a comparative of risk analysis which may help for the correct assignment of risk reduction measures and definition of policies (Merz et al., 2010).

Flood damage models can estimate relative damage (i.e. percentage estimation of losses respect to the total value of the building) and absolute damage, the latter considers the unit prices of cost of damage. Flood damage models can be subdivided by their type of approach, being empirical models based on the reported damage data of previous events (Merz et al., 2010) and, therefore, applied to a specific spatial context, while synthetic models are based on expert-based knowledge which considers a what-if analysis for the definition of expected damage which may have a better transferability to other spatial context than empirical models (Amadio M. et al., 2019). In addition, flood damage models can be classified by considering the amount of variables involved in the model, having univariable and multivariable models (Amadio M. et al., 2019). Univariable models study water depth as unique hazard parameter, which simplifies the complexity and interpretation of flood damage, while multivariable models additionally use other hazard parameters (e.g. flow velocity, flow duration) as well as exposure and vulnerability characteristics of buildings to better explain the process of damage. However, the application of multivariable models may show reliable damage estimation if there is enough data to develop the model, which may not happen due to the lack of standardized compilation data of hazard and building parameters (Amadio M. et al., 2019). For example, INSYDE (Dottori et al. 2016) is a synthetic model for the estimation of direct damage to residential buildings considering a multivariable complexity of 24 parameters. INSYDE estimates flood damage by considering the flooding processing of component-by-component, and therefore it requires abundant data for its development and transferability; however, foreseeing this problem, INSYDE considers the definition of default values in case of lack of data. Nonetheless, if there is not pre-existing reliable data for the definition of default values, the damage estimation could suffer from uncertainty problems.

This thesis aims to update the default values (i.e. building and hazard characteristics) and the relationship between INSYDE parameters considering a more rigorous statistical analysis of residential buildings located in the Po River basin. To develop the update, a methodological procedure has been defined which starts from the data collection of building characteristics and hazard parameters. Subsequently, the statistical analysis of the collected data has been realized to calculate the updated default values and the adjustment of damage functions. Having the updated INSYDE model, two recent floods that occurred in northern Italy (Adda 2002 and Bacchiglione 2010) have been tested for its validation. Additionally, considering the availability of the hazard and building characteristics reported in both flood events, a check of representativeness of default values in the datasets has been performed.

Chapter 2: Flood damage assessment models

Flood is treated as an important natural phenomenon due to the impact (e.g., economic) that it generates to the society. Hence, flood policies such as the directive 2007/60/EC of the European union have been created to promote the assessment and management of flood risk. This directive encourages the evaluation of flood-prone areas, the identification of entities exposed to flood risk, and the formulation of flood risk maps as part of the flood risk assessment. The reduction of socioeconomic losses and flood risk are proposed as part of the flood risk management, which includes management methods that can be applied during periods of preparedness, intervention, and recovery. There is a correlation between damage and risk, considering the latter as the expected damage and as a function of hazard, exposure, and vulnerability. Regarding the management methods, flood damage models are considered as important tools for the support of decision-making in flood risk management.

The flood damage can be classified considering the type of the damage impact (direct and indirect) and the damaged entities (tangible and intangible). Direct damage is related to the damage of objects or humans due to the direct contact with floodwater, while indirect damages are induced by the ripple effect of direct damage in space or time. In the case of indirect damage, the extension of the flood could affect non flooded areas generating damage due to disruption of means of transport and power outages (Merz et al., 2010).

Tangible damage is the damage of entities which can be measured in monetary terms, such as buildings and infrastructure. Intangible damage corresponds to the non-measurable damage in monetary terms, such as loss of life. Flood risk analyses often only comprise an assessment of tangible flood damages, which are easier and more reliable to estimate than intangible flood damages (Merz et al., 2010). The direct tangible damage to dwellings caused by flooding may be related to damage to household items (e.g., furniture), building components (e.g., building systems, windows, doors), building materials (e.g., masonry) and clean-up cost of flood water (Penning-Rowsell et al., 2005).

Flood damage assessments can be defined depending on spatial scales. It can be subdivided into micro-scale for the analysis of single units of assets, meso-scale for the spatial aggregation of units and macro-scale for large-scale spatial aggregation (Merz et al., 2010). Assessments at different scales have different objectives. For example, in case of a regional scale, simple spatial statistics of frequent flood events can signal the areas where flood damages are higher (Ocio D. et al., 2015). In the case of micro-scale and meso-scale damage assessment of buildings in a municipality, the micro-scale assessment may better consider the differentiation of generic classes (e.g. residential buildings) due to there is less heterogeneity than in a meso-scale assessment (Moel H. et al., 2015) such as, for example, considering the aggregation of industrial buildings and cultural heritage.

Flood damage models have been developed considering different damage results (relative and absolute), approaches (empirical and synthetic), number of variables (univariable and multivariable), assumptions, and spatial scale (e.g., micro-scale, meso-scale). Absolute damage is expressed as cost per unit of measure (e.g., square meter) of assets, while the relative damage refers to the percentage lost with respect to the total value of the building. The main parameter for direct tangible damage estimation is the water depth, being used in univariable models as correlation with economic loss. This direct damage is assessed based on depth-damage curves which denote the vulnerability to flooding by relating the water depth to the damage of a specific asset, economic sector, or land use category (Merz et al. 2004; Freni et al. 2010; De Moel and Aerts 2011). In case of residential building, direct damage can be estimated using depth-damage curves (Ujeyl et al, 2012) for houses with similar characteristics as building typology, construction material and use of ground floor (Burzel et al., 2012). Because of the complexity of flood damage to buildings, some authors recommend the consideration of other variables, such as flow velocity (Kreibich et al. 2009), flood duration and water contamination as well as variables related to the exposure and vulnerability of buildings (Molinari et al., 2014; Thieken et al.,2005). Empirical approaches are developed based on damage data compiled after flood events, while synthetic damage models are expert-based models obtained by a what-if analysis. Because empirical approaches are based on past flood events, models depend on the quantity and quality of flood data records, and it is difficult to transfer the model in an external spatial and temporal context due to differences in warning time, flood experience, building type and contents (Smith, 1994). As an example of multivariable empirical model, FLEMO-ps (Flood Loss Estimation Model for the private household sector) is developed based on the damage data compiled after the flooding of Elbe and Danube rivers occurred in 2002 (Germany). FLEMO-ps estimates relative monetary flood loss to residential buildings in micro- and mesoscale considering five classes of water depth, three building types, two building quality, three level of contamination of water (Thieken et al., 2008).

Different from empirical approaches, synthetic approaches are not based on past events, instead they are based on datasets with information related to each building typology, therefore, the collection data is an important step. As an example of multivariable synthetic model, tools of Multicoloured Manual (Penning-Rowsell et al., 2005) calculates the absolute damage based on economic values considering direct, indirect, tangible, and intangible losses of residential buildings and householders. The model, which have been developed in United Kingdom, uses five type houses, seven classes of building age and four different social classes of householders. An additional multivariable synthetical model is INSYDE, developed in Italy, which analyzes the direct tangible damage to buildings considering damage functions supported on existing scientific and technical literature, loss adjustment studies, and damage surveys carried out for past flood events in Italy (Dottori F. et al., 2016).

As aforementioned in this section, the development of damage models is based on the quantity and quality of available data, however, there is still a paucity of reliable, consistent, and comparable damage data (Merz et al., 2010). The problem of reliability is related to the damage estimation. For example, in 2002, there were updates of different estimates of damage caused by a severe flood occurred in Germany, showing a first estimate of 22 billion € in August 2002, then a corrected estimate of 9 billion € in December 2002, and then the repair cost of 11.6 billion € (Merz et al., 2010). The problem of consistency is related to the low standardization of collection of flood damage data (Wind et al., 1999; Gissing and Blong, 2004), taking as an example the subjectivity of surveyors when compiling data (Merz et al., 2010). Regarding the problem of comparable damage data, it refers to the lack of databases collecting damage data within different spatial scales (e.g. single building, local, regional) to analyze variations in damage and to investigate causal relations between the hazard characteristic and the amount of damage (Downton et al.,2005; Jonkman, 2005). The lack of the availability of flood damage data and data consistency of past flood events generates the uncertainty on the validation of damage model and the damage prediction in unexpected events.

To conclude, there are several damage assessments models which have been based on different approaches and amount of variables, however their reliability strongly depends on the quality and quantity of data used for their calibration and the consequent validation (if realized). The current work is related to the update of INSYDE for the Po River district considering, for its calibration, a more numerous datasets than in the original version, as well as including the best knowledge available on hazard characteristics, exposure and vulnerability features of the buildings, in the investigated area.

Chapter 3: Methodological approach

3.1 Model description

INSYDE (In-Depth Synthetic for Flood Damage Estimation) is a synthetic model that estimates the direct damage to residential buildings caused by flooding. The direct damage is assessed on a micro-scale by considering a component-by-component analysis using physically based mathematical functions which are related to hazard features, building characteristics and unit prices. The hazard features consist of the physical variables which describe the flood event; the building characteristics, building components and building geometry. The unit prices are related to the cost of replacement or reparation of building components which are derived from price lists (Francesco Dottori et al., 2016).

The total monetary damage to single building D is derived from the sum of n number of damage components C_i which are subdivided in m_i subcomponents C_{ij} as seen in Equation 3.1. The damage components consist of clean-up and removal activities, non-structural and structural damage, damage to finishing elements, damage to windows and doors, and damage to building systems. While the subcomponents consist of the reparation, removal and replacement of the damaged elements considered in each damage component.

$$D = \sum_{i=1}^{n} C_i = \sum_{i=1}^{n} \sum_{j=1}^{m_i} C_{ij} \qquad \text{Equation 3.1}$$

Cost of damage of each subcomponent is composed by the unit price up_{ij}, extension ext_{ij}, and probability of damage occurrence r_{ds} in case of probabilistic damage mechanism as seen in Equation 3.2. Extension refers to the physical measurement of the damage triggered by the flood to the building. Unit price refers to the monetary cost of damage subcomponents considering their unit of measure. Probability of damage occurrence covers the uncertainty of damage to building components considering probable damage states triggered by different hazard intensity measure IM.

$$C_{ij} = up_{ij} \,.\, ext_{ij} \,.\, r_{ds} \qquad \text{Equation 3.2}$$

INSYDE uses 18 parameters as building characteristics and 6 hazard parameters which are shown in Table 3.1 and Table 3.2, respectively. These parameters can directly affect the extent of damage or indirectly affect other parameters as year of construction YY could affect the variable heating system distribution PD and heating system type PT (Francesco Dottori et al., 2016). Therefore, considering the big amount of variables and their sensitive influence, their data collection for the damage model application is important, but in case there is not enough information, default values shown in Table 3.1 and Table 3.2 can be used. These default values are obtained from the statistical analysis of quantiles, median values, and comparison of categories of variables of a sample data applied in the Italian context.

Table 3.1 Building characteristics considered in INSYDE

Variable	Description	Unit of measurement	Range of values	Default values
FA	Footprint area	m^2	>0	100
IA	Internal area	m^2	>0	$0.9 \cdot FA$
BA	Basement area	m	≥0	$0.5 \cdot FA$
EP	External perimeter	m	>0	$4 \cdot \sqrt{FA}$
IP	Internal perimeter	m	>0	$2.5 \cdot \sqrt{FA}$
BP	Basement perimeter	m	>0	$4 \cdot \sqrt{FA}$
NF	Number of floors	-	≥1	2
IH	Interfloor height	m	>0	3.5
BH	Basement height	m	>0	3.2
GL	Ground floor level	m	[IH;>0]	0.1
BL	Basement level	m	<0	-GL-BH-0.3
BT	Building type	-	1: Detached house 2: Semidetached house 3: Apartment house	1
BS	Building structure	-	1: Reinforced concrete 2: Masonry	2
FL	Finishing level (i.e. building quality)	-	0.8: Low 1: Medium 1.2: High	1.2
LM	Level of maintenance	-	0.9: Low 1: Medium 1.1: High	1.1
YY	Year of construction	-	≥0	1994
PD	Heating system distribution	-	1: Centralized 2: Distributed	1 if YY≤1990 2 otherwise
PT	Heating system type	-	1: Radiator 2: Pavement	2 if YY>2000 1 otherwise

Damage mechanisms considered in INSYDE adopt probabilistic and deterministic functions.

Deterministic functions are adopted when the damage mechanism is well understood based on literature and author’s opinion, and when the uncertainty of variability between parameters is small. For example, the assumption of a flooded basement when the building is flooded due to rare implementation of flood risk mitigation, and the assumption of damage in electrical system if the flood reaches the components considering that height of components has low variation between buildings (Francesco Dottori et al., 2016).

Probabilistic functions are adopted when there is uncertainty of influence of parameters in the damage mechanism and uncertainty of thresholds for damage occurrence. To cover this uncertainty, fragility function $P(DS = ds_1|IM)$ is defined considering thresholds for the hazard feature which could trigger damage states DS not damaged (ds_0) and damaged (ds_1).

Table 3.2 Flood features considered in INSYDE

Variable	Description	Unit of measurement	Range of values	Default values
h_e	Water depth outside the building	m	≥0	[0;5] Incremental step: 0.01 m
h	Water depth inside the building (for each floor)	m	[0;IH]	$h = f(h_e, GL)$
v	Maximum velocity of the water perpendicular to the building	ms^{-1}	≥0	0.5
s	Sediment load	% on the water volume	[0;1]	0.05
d	Duration of the flood event	h	>0	36
q	Water quality (presence of pollutants)	-	0: No 1: Yes	1

INSYDE uses eight fragility functions whose hazard features are related to flood duration, water depth and flow velocity. Fragility function of flood duration (FF1) consider hazard thresholds of no damage state at a maximum of 24 hours and complete damage state from 48 hours as seen in Figure 3.1.

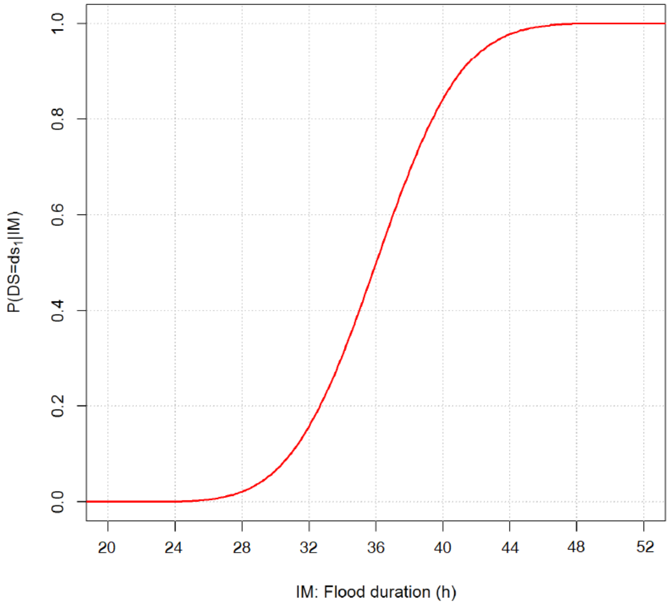
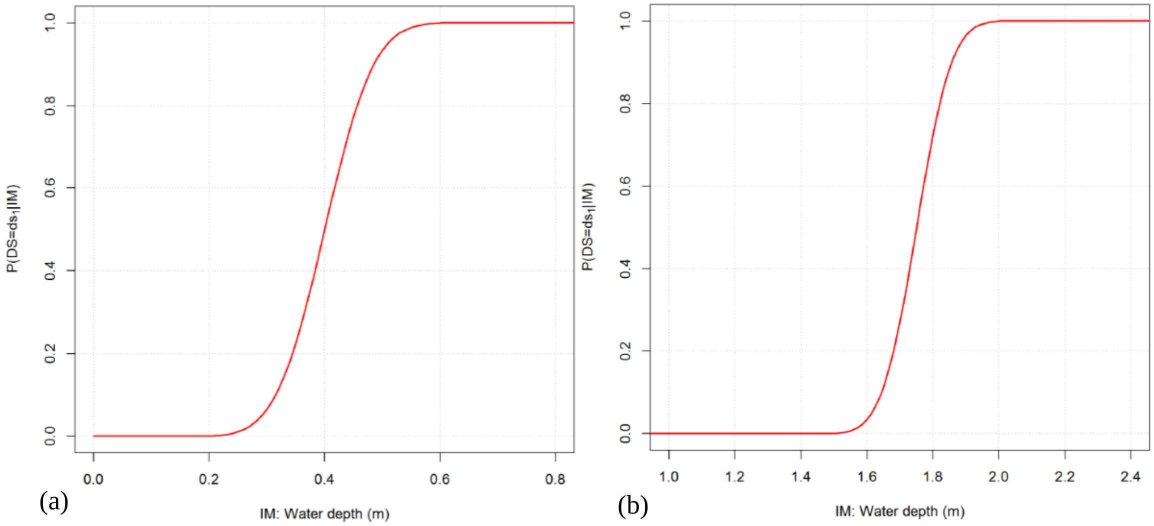


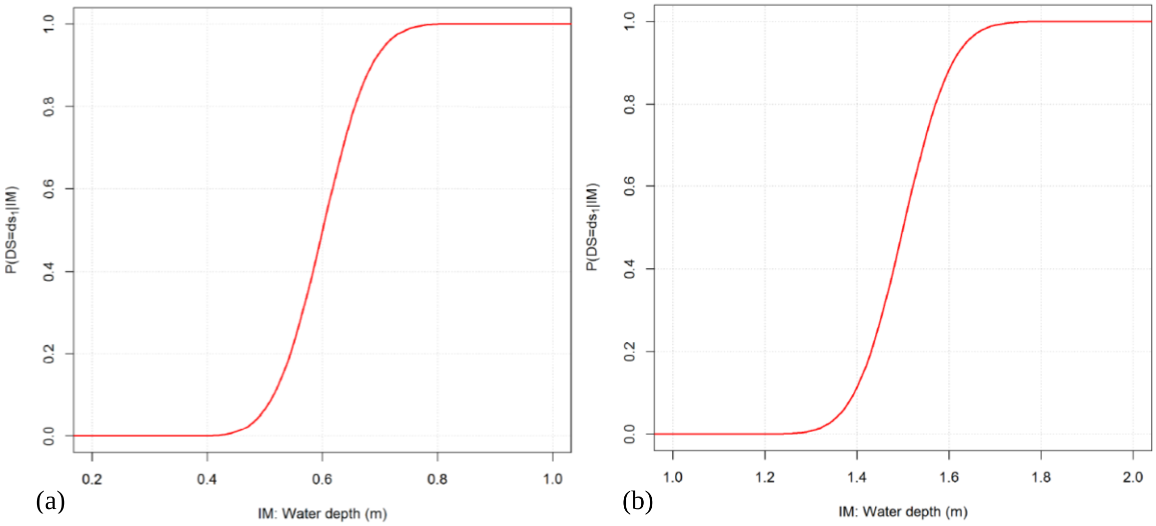
Figure 3.1 Fragility function of flood duration (FF1)

Fragility function of water depth affects to different building subcomponents depending on their position and dimension in the storeys, therefore, different thresholds are defined as seen below.



(a) (b)

Figure 3.2 Fragility function of water depth in each flooded storey that affects (a) wood floors (FF2) and (b) partition walls (FF3)



(a) (b)

Figure 3.3 Fragility function of water depth in each flooded storey that affects (a) doors (FF4) and (b) windows (FF5)

Flow velocity fragility functions are considered to affect plaster, doors and windows, triggering severe damage in case of high velocity flows. Thresholds for different subcomponents are shown below.

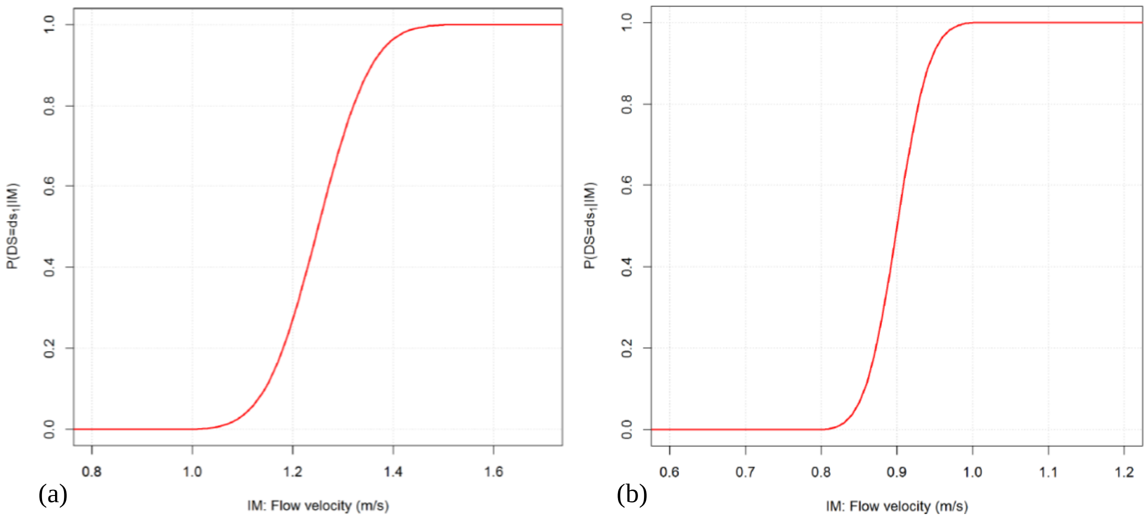


Figure 3.4 Fragility function of flow velocity that affects external plaster and doors (FF6), and windows (FF7)

Structural damage is considered to occur from the combination of thresholds of water depth and velocity. Important partial damage as soil consolidation, local repair and pillar repair is considered when $v > 2\ m/s\ and\ 3 < v \cdot he \leq 7m^2/s$ as seen below.

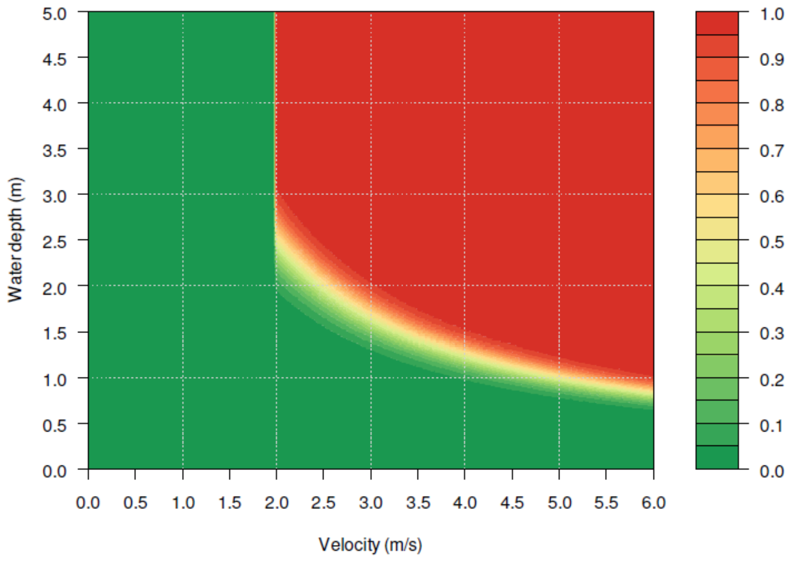


Figure 3.5 Fragility function of flow velocity and water depth that affects structural components (FF8)

The description of damage functions and their assumptions are explained and summarized below for all damage subcomponents.

a) Clean-up activities

Clean-up activities are related to the management of floodwater located within the building to restore the original dry condition. When pollutants are present ($q = 1$), cost of some activities are incremented by 40%. The summary of clean-up subcomponents, their damage function type and their damage function equations are shown in Table 3.3.

Pumping cost (C1) is related to the accumulated floodwater stored below ground level (GL<0) and in basement if it exists.

Water disposal cost (C2) is considered when accumulated floodwater of ground floor and basement present sediment concentration or pollutants. The latter increment the cost in 40%.

Cleaning cost (C3) is estimated for building surfaces in contact with floodwater such as internal floor area and internal perimeter of basement and flooded floors N_{FF}.

Dehumidification cost (C4) is calculated based on the volume of flooded floors and flooded basement during a long duration flood (FF1).

Table 3.3 Clean-up subcomponents

Subcomponent	Damage function type	Damage function equations
Pumping (c1)	Deterministic	$ext_{c1} = IA \cdot (-GL) + BA \cdot (-BL)$ $C_{C1} = up_{C1} \cdot ext_{C1}$
Waste disposal (C2)	Deterministic	$ext_{c2} = (IA \cdot h + BA \cdot BH) \cdot s$ $C_{C2} = \begin{cases} up_{C2} \cdot ext_{C2}, q = 0 \\ 1.4 \cdot up_{C2} \cdot ext_{C2}, q = 1 \end{cases}$
Cleaning (C3)	Deterministic	$ext_{c3} = (IP \cdot h + BA + BP \cdot BH + IA \cdot N_{FF})$ $C_{C3} = \begin{cases} up_{C3} \cdot ext_{C3}, q = 0 \\ 1.4 \cdot up_{C3} \cdot ext_{C3}, q = 1 \end{cases}$
Dehumidification (C4)	Probabilistic (FF1)	$ext_{c4} = IA \cdot IH \cdot N_{FF} + BA \cdot BH$ $C_{C4} = up_{C4} \cdot ext_{C4}.r_{ds}$

b) Removal activities

Removal activities are related to subcomponents that could not be reestablished after the clean-up activities. The summary of removal subcomponents, their damage function type and their damage function equations are shown in Table 3.4.

Screed removal cost (R1) is calculated when, due to the presence of long duration flood (FF1) and presence of water depth in the storey (FF2), it is necessary to remove the screed of the wooden pavement, which is considered in case of high finishing level (FL>1).

Pavement removal cost (R2) is necessary when there is wooden pavement affected by long duration flood (FF1) and presence of water depth in the storey (FF2).

Baseboard removal (R3) is calculated when water depth inside the storey is greater than 0.05 m and when long duration flood occurs (FF1).

Removal of partition walls (R4) is calculated when they are unable to be dry due to long duration floods (FF1) and presence high water depth (FF3). As default, the perimeter of partition walls is supposed to be equal to the 50% of the internal perimeter, and this value is incremented by 20% for reinforced concrete structures, to account for external walls (Francesco Dottori et al., 2016).

Plasterboard removal (R5) is considered as the removal of the finishing plaster ceiling, which are only installed in high quality buildings, when it is reached by the water depth. By default, it is considered to be installed 0.5 m below the original ceiling and that it is 20% of internal area of building (Francesco Dottori et al., 2016).

External plaster removal (R6) and internal plaster removal (R7) are estimated as the water depth plus one meter due to capillary rise if there is long duration of water penetration (FF1), damage of the plaster due to high velocity (FF6), presence of contaminants in floodwater (q=1) or presence of vulnerable plaster due to "average" or "poor" level of maintenance (LM≤1).

Table 3.4 Removal cost subcomponents

Subcomponent	Damage function type	Damage function equation
Screed removal (R1)	Probabilistic (FF1, FF2)	$ext_{R1} = IA \cdot N_{FF}$ $C_{R1} = up_{R1} \cdot ext_{R1}.r_{ds}$
Pavement removal (R2)	Probabilistic (FF1, FF2)	$ext_{R2} = IA \cdot N_{FF}$ $C_{R2} = up_{R2} \cdot ext_{R2}.r_{ds}$
Baseboard removal (R3)	Probabilistic (FF1)	$ext_{R3} = IA \cdot N_{FF}$ $C_{R3} = up_{R3} \cdot ext_{R3}.r_{ds}$
Removal of partition of walls (R4)	Probabilistic (FF1, FF3)	$ext_{R4} = \begin{cases} 0.5 \cdot IP \cdot IH \cdot N_{FF}, BS = 2 \\ 1.2 \cdot 0.5 \cdot IP \cdot IH \cdot N_{FF}, BS = 1 \end{cases}$ $C_{R4} = up_{R4} \cdot ext_{R4}.r_{ds}$
Plasterboard removal (R5)	Deterministic	$ext_{R5} = 0.2 \ \cdot IA \cdot N_{FF}$ $C_{R5} = up_{R5} \cdot ext_{R5}$
External plaster removal (R6)	Probabilistic (FF1, FF6)	$ext_{R6} = EP \cdot (h_e + 1 \cdot (h_e > 0.2))$ $C_{R6} = up_{R6} \cdot ext_{R6}.max(r_{ds})$
Internal plaster removal (R7)	Probabilistic (FF1)	$ext_{R7} = IP \cdot (h + 1 \cdot (h_e > 0.2)) + BP \cdot BH$ $C_{R7} = up_{R7} \cdot ext_{R7}.max(r_{ds})$
Door removal (R8)	Probabilistic (FF1, FF6)	$ext_{R8} = 0.12 \cdot IA \cdot N_{FF} + 0.03 \cdot BA$ $C_{R8} = up_{R8} \cdot ext_{R8}.max(r_{ds})$
Windows removal (R9)	Probabilistic (FF1, FF7)	$ext_{R9} = 0.12 \cdot IA \cdot N_{FF}$ $C_{R9} = up_{R9} \cdot ext_{R9}.max(r_{ds})$
Boiler removal (R10)	Deterministic	$ext_{R10} = \begin{cases} IA \cdot N_{FF},\ h > 1.6\, m\ when\ PD = 2 \\ IA,\ h > 0\, m\ when\ PD = 1, BA > 0 \\ IA, h > 1.6\, m\ when\ PD = 1, BA = 0 \\ 0, else \end{cases}$ $C_{R10} = up_{R10} \cdot ext_{R10}$

Door removal (R8) is assumed when there is presence of high-water depth (FF4). Additionally, removal is estimated under probability of swell due to long duration flood

(FF1) or damage to doors due to high velocity flow (FF6). For area of 100 m2, 2 doors and 7 doors of 0.8x2.1 m are considered by default for the basement and the storey, respectively.

Window removal (R9) is assumed when there is presence of high-water depth (FF5). Additionally, removal is estimated under probability of swell due to long duration flood (FF1) or damage to windows due to high velocity flow (FF7). For area of 100 m2, no windows are considered for basement and 6 windows of 1.4x1.4 m are considered by default in a storey.

Boiler removal (R10) is necessary when water level is greater than 1.60 m (height defined as default) in buildings with distributed heating system. In case of centralized heating system, removal is realized if basement exist due to assumption of complete flood and, therefore, existence of flooded boiler room or if there is not basement, but water level is greater than 1.60 m on the ground floor.

c) Non-structural damage

Non-structural damage depends on the replacement of partition wall, screed and plasterboard that were previously removed as mentioned in function R4, R1 and R5. The summary of non-structural damage subcomponents, their damage function type and their damage function equations are shown in Table 3.5.

Table 3.5 Non-structural damage subcomponents

Subcomponent	Damage function type	Damage function equation
Partitions replacement (N1)	Probabilistic (FF1, FF3)	$ext_{N1} = ext_{R4}$ $C_{N1} = up_{N1} \cdot ext_{N1}.r_{ds}$
Screed replacement (N2)	Probabilistic (FF1, FF2)	$ext_{N2} = ext_{R1}$ $C_{N2} = up_{N2} \cdot ext_{N2}.r_{ds}$
Plasterboard replacement (N3)	Deterministic	$ext_{N3} = ext_{R5}$ $C_{N3} = up_{N3} \cdot ext_{N3}.r_{ds}$

d) Structural damage

Soil consolidation (S1) is required due to possible soil foundation scour caused by the intensity of the flood (FF8), and it is estimated as a portion of building volume.

Local repair (S2) is required due to possible external structural damage of masonry buildings. Estimated damaged in considered as the reparation of 0.05 m of two sides of building as assumption of sides being in contact to flow.

Pillar repair (S3) is considered in reinforced concrete buildings. Damaged pillars are considered as 15% of external perimeter of the building and that the damage occurs in two sides of building as assumption of sides being in contact to flow.

Table 3.6 Structural damage subcomponents

Subcomponent	Damage function type	Damage function equation
Soil consolidation (S1)	Probabilistic (FF8)	$ext_{S1} = \begin{cases} IA \cdot NF \cdot IH \cdot 0.01, BS = 2 \\ IA \cdot NF \cdot IH \cdot 0.02, BS = 1 \end{cases}$ $C_{S1} = up_{S1} \cdot ext_{S1}.r_{ds}$
Local repair (S2)	Probabilistic (FF8)	$ext_{S2} = 0.5 \cdot EP \cdot h_e \cdot 0.05 \cdot (1+s)$ $C_{S2} = up_{S2} \cdot ext_{S2}.r_{ds}$
Pillar repair (S3)	Probabilistic (FF8)	$ext_{S3} = 0.5 \cdot 0.15 \cdot EP \cdot h_e \cdot (1+s)$ $C_{S3} = up_{S3} \cdot ext_{S3}.r_{ds}$

e) Finishing elements, Windows and Doors

Cost due to finishing elements refers the reestablishment of removed subcomponents to their original state considering their finishing level, therefore, for subcomponents as plaster replacement (F1 and F2) and painting (F3 and F4), cost is affected by the finishing level. In case of windows and doors (W1 and W2), cost of damage due to replacement is considered as double for high finishing level buildings.

Table 3.7 Finishing elements, windows and doors

Subcomponent	Damage function type	Damage function equation
External plaster replacement (F1)	Probabilistic (FF1, FF6)	$ext_{F1} = ext_{R6}$ $C_{F1} = up_{F1} \cdot ext_{F1}.\max(r_{ds}).FL$
Internal plaster replacement (F2)	Probabilistic (FF1)	$ext_{F2} = ext_{R7}$ $C_{F2} = up_{F2} \cdot ext_{F2}.\max(r_{ds}).FL$
External painting (F3)	Deterministic	$ext_{F3} = EP \cdot N_{FF} \cdot IH$ $C_{F3} = up_{F3} \cdot ext_{F3}.FL$
Internal painting (F4)	Deterministic	$ext_{F4} = \begin{cases} IP \cdot N_{FF} \cdot IH, FL \leq 1 \\ IP \cdot N_{FF} \cdot IH + BP \cdot BH, FL < 1 \text{ and } BT = 1 \end{cases}$ $C_{F4} = up_{F4} \cdot ext_{F4}.FL$
Pavement replacement (F5)	Probabilistic (FF1, FF2)	$ext_{F5} = ext_{R2}$ $C_{F5} = up_{F5} \cdot ext_{F5}.r_{ds}$
Baseboard replacement (F6)	Probabilistic (FF1)	$ext_{F6} = ext_{R3}$ $C_{F6} = up_{F6} \cdot ext_{F6}.r_{ds}$
Door replacement (W1)	Probabilistic (FF1, FF6)	$ext_{W1} = ext_{R8}$ $C_{W1} = \begin{cases} up_{W1} \cdot ext_{W1}.\max(r_{ds}), FL \leq 1 \\ 2 \cdot up_{W1} \cdot ext_{W1}.\ \max(r_{ds}), FL > 1 \end{cases}$
Window replacement (W2)	Probabilistic (FF1, FF7)	$ext_{W2} = ext_{R9}$ $C_{W2} = \begin{cases} up_{W2} \cdot ext_{W2}.\max(r_{ds}), FL \leq 1 \\ 2 \cdot up_{W2} \cdot ext_{W2}.\ \max(r_{ds}), FL > 1 \end{cases}$

f) Building systems

Boiler replacement (P1) is required when boiler is replaced (R10). In case of detached and semi-detached buildings, boilers are considered as oversized, therefore damage cost is incremented by 25%.

Radiator painting (P2) is necessary when it is reached by floodwater (h>0.2 m). By default, per each 20 m2 of internal area, one radiator is considered.

Replacement of underfloor heating system (P3) is required when there is removal of screed (R1) in buildings with underfloor system type.

Electrical system replacement (P4) depends on the water depth that could reach the different electrical components. Between 0.20 to 1.10 m of water depth, 40% of damage is considered due to presence of lower sockets and cables. Between 1.10 to 1.50 m of water depth, 70% of damage is considered due to presence of upper sockets and cables. For water depth greater than 1.50 m, 100% of damage is considered due to presence of control panel.

Plumbing system replacement (P5) depends on the presence of contaminants, sediment load (s>0.1) and water depth that could reach different plumbing components. Between 0.15 to 0.4 m water depth, 10% of damage is considered due to presence of shower. Between 0.4 to 0.9 m of water depth, 30% of damage is considered due to presence of toilet bowl and bidet. For water depth greater than 0.9 m, 50% of damage is considered due to presence of sinks.

Table 3.8 Building systems

Subcomponent	Damage function type	Damage function equation
Boiler replacement (P1)	Deterministic	$ext_{P1} = ext_{R10}$ $C_{P1} = \begin{cases} 1.25 \cdot up_{P1} \cdot ext_{P1}, BT = 1\ or\ 2 \\ up_{P1} \cdot ext_{P1}, BT = 3 \end{cases}$
Radiator painting (P2)	Deterministic	$ext_{P2} = N_{FF} \cdot IA/20$ $C_{P2} = up_{P2} \cdot ext_{P2}$
Replacement of underfloor heating system (P3)	Probabilistic (FF1)	$ext_{P3} = N_{FF} \cdot IA$ $C_{P2} = up_{P3} \cdot ext_{P3} \cdot r_{ds}$
Electrical system replacement (P4)	Deterministic	$ext_{P4} = \begin{cases} 0, h \leq 0.2m \\ 0.4 \cdot IA \cdot N_{FF}, 0.2 < h < 1.1m \\ 0.7 \cdot IA \cdot N_{FF}, 1.1 < h < 1.5m \\ IA \cdot N_{FF}, h \geq 1.5m \end{cases}$ $C_{P4} = \begin{cases} up_{P4} \cdot ext_{P4}, FL \leq 1 \\ 2 \cdot up_{P4} \cdot ext_{P4}, FL > 1 \end{cases}$
Plumbing system replacement (P5)	Deterministic	$ext_{P5} = \begin{cases} 0, h \leq 0.15m \\ 0.1 \cdot IA \cdot N_{FF}, 0.15 < h < 0.4m \\ 0.3 \cdot IA \cdot N_{FF}, 0.4 < h < 0.9m \\ 0.5 \cdot IA \cdot N_{FF}, h \geq 0.9m \end{cases}$ $C_{P5} = \begin{cases} up_{P5} \cdot ext_{P5}, FL \leq 1 \\ 2 \cdot up_{P5} \cdot ext_{P5}, FL > 1 \end{cases}$

INSYDE has been updated and validated over time since its formulation in the Italian context. INSYDE has been validated considering the 2010 flood event that occurred in the municipality of Caldogno, which generated EUR 7.5 million of losses in residential buildings, and which has been compared among other deterministic micro-scale damage models, obtaining the closest calculated loss of EUR 7.42 million of losses with -1.7% as the relative error (Francesco Dottori et al., 2016). In Amadio et al. (2019), INSYDE has taken part in a cross-comparison with different models regarding uni-variable vs multi-variable and empirical vs synthetic damage models, concluding that synthetic model can be considered as the best option for damage prediction purposes in the Italian context, in cases where no extensive loss data are available to derive a location-specific flood damage model. As part of the cross-comparison, INSYDE has been tested considering three flood events, obtaining the calculated damage in Adda 2002 flood event of about EUR 5.6 million (+19.1% relative error), in Bacchiglione 2010 flood event of around EUR 8.3 million (+5.1% relative error), and in Secchia 2014 flood event of about EUR 28.8 million (+36.5% relative error). The original model of INSYDE has been already amended (bugs corrected, etc.) for the use in the present thesis.

In this thesis, it is proposed to update the original assumptions on default values and relations among INSYDE parameters on the bases of a more rigorous statistical analysis of residential buildings located within the districts of the Po River basin.

3.2 Model development procedure

To adjust INSYDE to the districts within the Po River basin, a methodological procedure is defined as seen in Figure .3.6 and it is explained below.

- Data collection: Represents the compilation of existing data related to building characteristics and hazard parameters, and the detection of missing data. In case of building characteristics, statistical data is obtained from Italian government database, geometrical information at regional scale is obtained from open database as Open Street Map. Missing data at single building level as interior features is detected, and therefore, the collection of raw data from virtual survey is proposed. In case of hazard parameters, data is obtained from hazard maps, previous works, and records.
- Data statistics: Consist in the interpretation of the data to define default values of building characteristics and hazard parameters, and the position and dimension of building subcomponents.
- Damage function adjustment: Represents the definition of the structure of the model and it depends on the unit prices, damage function assumptions and possible fragility function. The two last parameters depend on data statistics of the building subcomponents and the understanding of the damage mechanisms. Unit prices are considered as the updated unitary cost of removal and replacement of damaged

subcomponents.

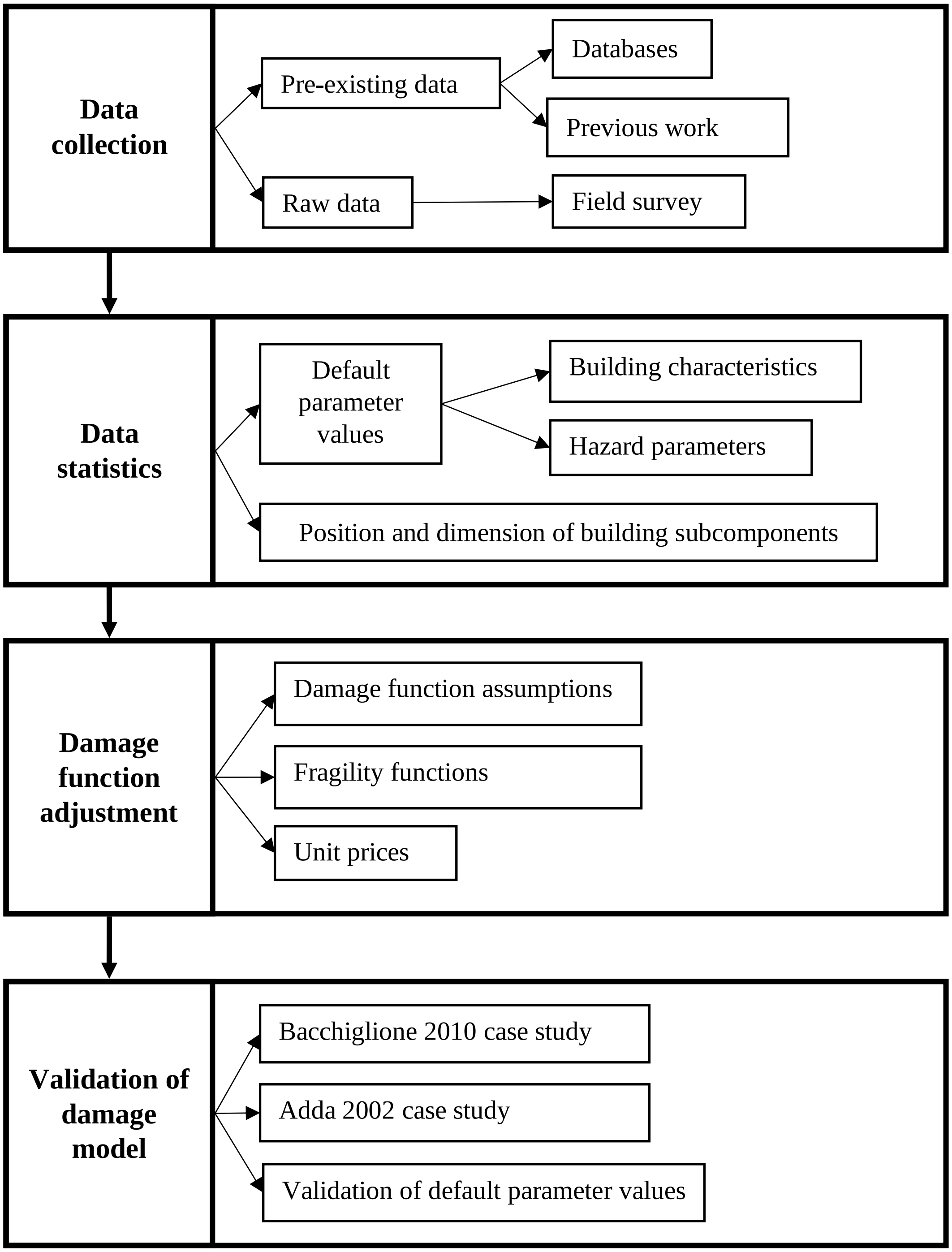


Figure .3.6 Methodology flowchart of INSYDE model in Po River basin

- Validation of damage model: Represents the proximity between the calculated loss and the observed loss during flood events. Additionally, the collected parameters related to the damage of buildings are used to check the representativeness of the default values of INSYDE parameters.

Chapter 4: Model development

4.1 Context

Po River is the longest Italian river having the mainstream of 652 km starting from the Cottian Alps and emptying into the Adriatic Sea with a mean annual discharge of 1500 m^3/s (Giacomo et al., 2021). Po River and its 141 tributaries comprise a basin that covers small areas in France and Switzerland, and about 71,000 km^2 in the territory of northern Italy, being the biggest Italian basin as seen in Figure 4.1. In the Italian context, the Po River basin involves the regions of Piemonte, Valle d'Aosta, Lombardia, Veneto, Liguria, Emilia Romagna, and the Provincia Autonoma di Trento.

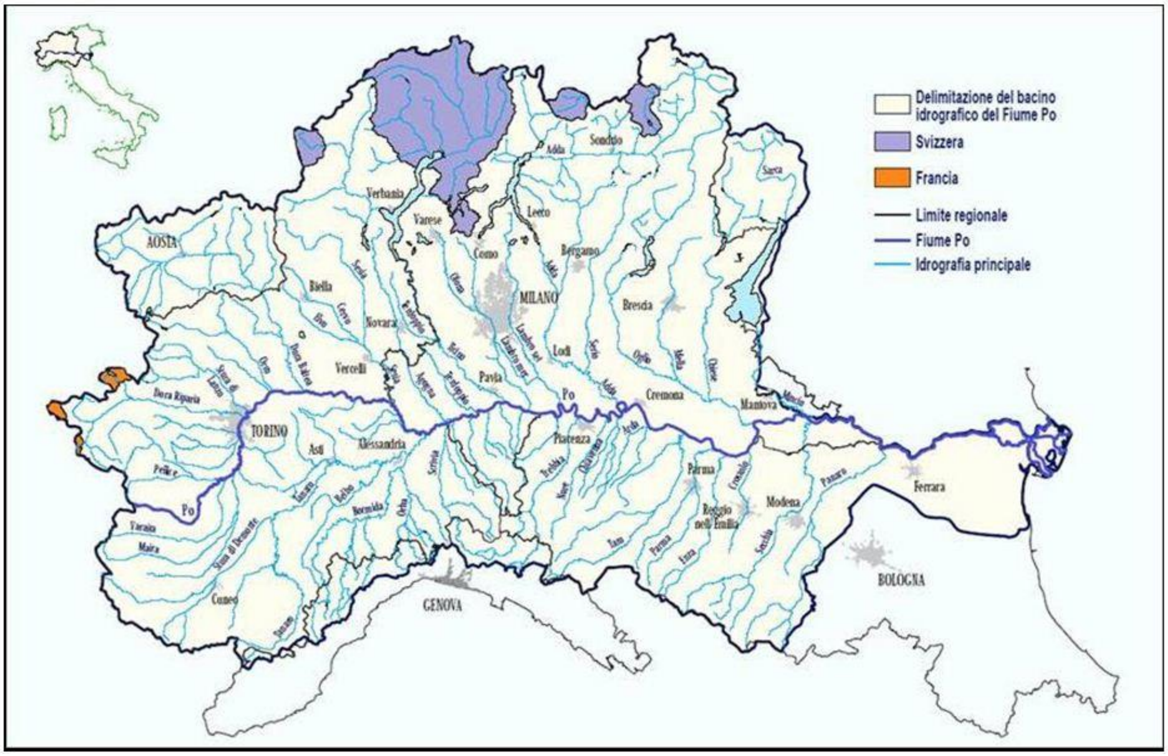


Figure 4.1 Po River and all its tributaries

The water regime in the Po River basin is characterized for presenting two low-water periods during winter and summer, and two flood periods during late autumn and spring, showing a minimum daily discharge of 168 m^3/s and maximum daily discharges up to 10,300 m^3/s. The flood periods are characterized by the contribution of intensive rainstorms during late autumn, and snowmelt in the highest part of the basin during spring (Cattaneo et al. 2003). The Po River basin presents heterogeneous fluvial regimes as seen in Figure 4.2, having the main contribution from sub-regions in Piemonte, Lombardia and Emilia, and which are also reflected during high total discharges (Cati 1981).

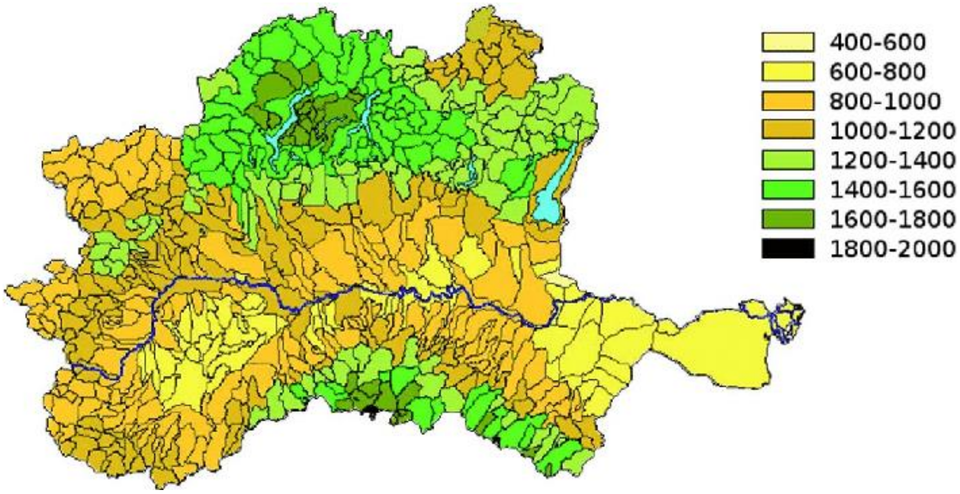


Figure 4.2 Average annual rainfall in the Po River basin (Po River Basin Authority, 2006)

The Po River basin is studied and monitored by the Po River Basin District Authority (Autorità di Bacino Distrettuale del Fiume Po, AdBPo) to generate tools for the hydrogeological risk mitigation and sustainability of the basin and surrounding areas. As a part of the tools, AdBPo is in charge of developing and updating the Flood Risk Management Plans (Piano di Gestione del Rischio di Alluvioni, PGRA) related to the rivers within the Po River basin.

From an economic point of view, about 38% of the Italian GDP is produced within the Po River basin, considering industrial activities, agricultural activities, and tourism realized within the basin area. Agricultural activities in the plain area of the basin are known for being used from the middle age with higher development after the Second World War. About 40% of the Po River basin is used for agriculture, representing 36% of agricultural production in Italy. Due to the importance of this economic activity, the required irrigation and the canalized amount of water used as hydropower, different reservoirs were built to also overcome the periods of drought but modifying the water flow between tributaries of the Po River basin.

In addition to the economic importance, about 28% of the Italian population (17 million people) lives within the Po River basin. Based on population census 2001 realized by ISTAT, the average population density is about 225 inhabitants/km^2 in the Po River basin, which shows population concentrated in the urban areas, but also in the floodplain areas that lead to exposed people and exposed assets.

Several flood events in the Po River basin occurred long ago, however, there is only information related to 22, 14, 18 and 19 floods recorded in the 16th, 17th, 18th, and 19th century, with the 1705 flood being recorded as a particularly destructive event and the 1951 flood reported as an inundation caused by broken embankments (A. Montanari 2012).

Considering the open-source EM-DAT, there is registration of flood events occurred since 1936 in Italy. Among the recent floods that occurred within the Po River basin, Piemonte was affected by a flood event in 2000, a flood affected Lombardy in 2002, a riverine flood was recorded in Veneto in 2010, and in 2017 a riverine flood caused by snowmelt and rain was recorded in Emilia Romagna.

With respect to building assets in the Italian context, they can be classified considering their climate zone, their period of construction and their building type. In the case of the Po River basin, it covers the "media" climatic zone "E" (2100<GG≤3000) and the alpine climatic zone "F" (GG>3000), being degree days (GG) correlated with the energy performance of the building. Regarding the period of construction, over the 60% of building stock is older than 45 years old, and within the Po River basin, about 60% of residential buildings were built before 1970 showing a decline of construction in the last decades as seen in Table 4.1.

Table 4.1 Frequency of residential buildings per period of construction recorded in Po River basin (census 2011)

Period of construction	Frequency of buildings [%]
Before 1919	17.0
1919-1945	10.6
1946-1960	13.8
1961-1970	17.6
1971-1980	16.3
1981-1990	9.6
1991-2000	7.1
2001-2005	4.3
After 2005	3.6

Based on TABULA-Italy project (Corrado V. et al, 2014), building typology can be classified considering the extension and geometry of the buildings, and classifying them into detached houses, attached houses, multi-family building and block of apartments. Nonetheless, in the Po River basin, the building types considering their geometry and position within the extension of block of houses (if present) are detailed below.

- Detached house: It is characterized for being a single-family dwelling that does not share a lateral side with other houses, therefore, it is independent.
- Semidetached house: It is a duplex dwelling house which shares a common side with the next house.
- Attached house: It is a type of dwelling which is in a block with several housing units, one next to the other. The house generally has a narrow front to develop in depth. Inside this classification, there could be variation of dimension between the corner dwellings and the middle dwellings.
- Apartment: It is a housing unit which is part of a building (block of apartment) with several floor levels.

4.2 Data collection

To update INSYDE in the Po River basin, data related to river flooding features and vulnerability parameters regarding dwelling stock were compiled. Existing data on flood and building vulnerability parameters were collected from databases and previous works, however, missing data of characteristics at the single building level prompted the development of a virtual survey. Additionally, to validate the adjustment of the damage model, damage data from previous events were considered.

4.2.1 Flood hazard parameters

The flood features, as flood water depth and flow velocity, have been obtained from the flood maps of the flood risk assessment plans developed by the Po River Basin District Authority (2021 update). In case of flood duration, sediment load, and presence of pollutants, the default parameters defined in previous INSYDE with application in northern Italy (see chapter 3, section 1) have been kept constant because no extra information was found to support changes to the original version.

4.2.2 Building vulnerability parameters

In Italy, there is quite a lot of data related to the characteristics of buildings at the mesoscale considering a compilation from a city to a regional scale which are performed by their respective Italian authorities, being ISTAT the principal institution compiling census data. Moreover, there is a previous study which describe and classify dwelling by considering a classification of energy performance of the building systems. From the evaluation of building characteristics considered in INSYDE, the data collected comprises the position and characteristics of the exposed building components to flood that represent the vulnerability of buildings, and which help in the definition of damage estimation.

For a complete understanding of the vulnerability of dwelling at a single building scale, INSYDE also requires data as interior and exterior features which were not found between the sources, therefore a virtual survey was developed by considering an adaptation of the survey applied in the Walloon region, Belgium (Rodriguez D., 2020) compiling additional data as the basement height, basement perimeter, floor height, height of windows from street level and the dimension of windows and doors. The virtual survey consisted in the compilation of data obtained from building real estate (i.e. Inmobiliare.it) with respect to detached, semidetached, attached and apartment housing units located in the floodplain of urban and rural areas in the Po River basin. The sample of buildings was selected considering the largest amount of data provided, having at least the building characteristics, photos of the building and the presence of a building plan that could help to compile the geometric characteristics and understand the distribution of areas. From the survey, 119 buildings were assessed compiling data related to the building material, building system, building quality, position and dimension of building components when mentioned in building plans, among others. The list of compiled data is shown in Table 4.3.

4.2.3 Damage data

In case of damage data compiled in the Po River basin, there are flood damage records of the Adda and Bacchiglione rivers occurred in 2002 and 2010, respectively, which were used for the validation of INSYDE applied in Po River basin. The case studies are mentioned in Table 4.4.

Table 4.2 Data sources of building characteristics

Data name	Data format	Description of collected data	Data source
Housing census 2011 and 2001	Table	Statistics about characteristics of residential buildings at the regional scale within the Po River basin.	National Institute of Statistics (ISTAT)
Building typology brochure-Italy (TABULA and EDISCOPE project)	Pdf file (project)	Residential building typology considering energy performance	Politecnico di Torino
Building areas	Vector file	Shapefile with area and perimeter of single buildings within the regions of the Po River basin.	OpenStreetMap
Built-up areas	Vector file	Shapefile with area and perimeter of built-up areas in Piemonte region.	Piemonte Region
Residential real state	Raw data	Building plans, referential dimension and position of building components, construction description, internal and external characteristics of single buildings.	Inmobiliare.it

Table 4.3 Compiled data in virtual survey

General Information	Exterior features	Interior features	Interior level features	Geometric features
Building type Province/Comune Year/period of construction Recent renovation (year) Level of maintenance Finishing level Intended use	Number of floors External material 1 External material 2 Height of external material 1 Height of external material 2 Height of ground floor level	Total built area Presence of basement Area of basement Basement perimeter Height of basement	Floor area Floor height Average room size Presence of plumbing system Presence of electric system Approx. height of lower sockets Approx. height of middle sockets Approx. height of light switches Presence of heating system Heating system type Height of radiator from floor Distribution type Number of doors Material of doors Height & width of door Number of windows Material of windows Height of windows from floor Height of windows from street level Height & width of window Type of pavement Material of internal walls Finishing material	External perimeter Internal perimeter

Table 4.4 Data sources of damage data

Data name	Data format	Description of collected data	Data source
Adda 2002	Table	Recorded flood damage of 271 buildings compiling hazard parameters, building characteristics and damage cost.	Politecnico di Milano
Bacchiglione 2010	Table	Recorded flood damage of 294 buildings compiling hazard parameters, building characteristics and damage cost.	University of L'Aquila

4.3 Data statistics

To update INSYDE to the Po River basin, it is important to perform the statistical analysis of the datasets to determine representative values of hazard parameters, building characteristics and position of building components. Based on the statistical analysis, the median values of building characteristics and hazard parameters are defined in case of missing information on input data for the damage calculation (i.e., default values of the input variables in INSYDE).

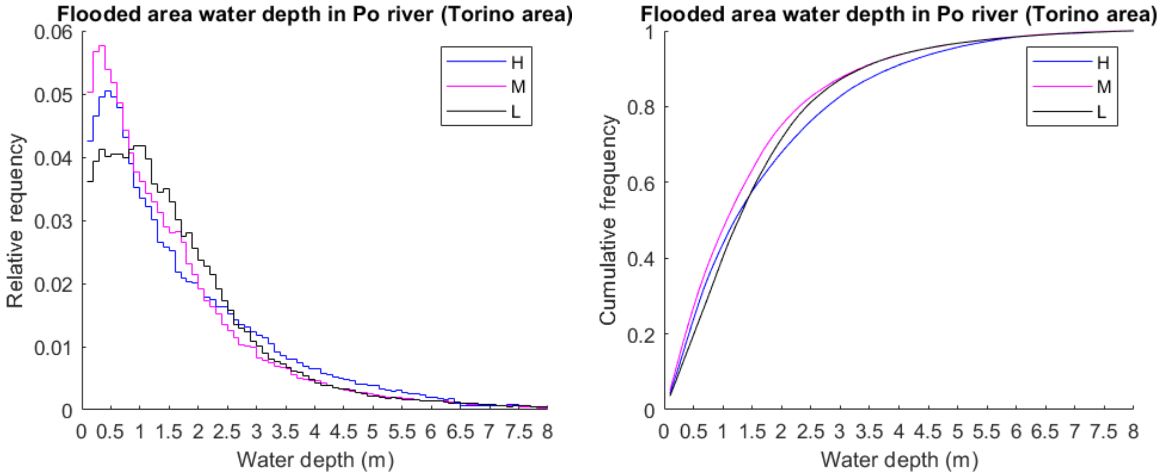
4.3.1 Hazard parameters

a) Flood water depth

Flood water depth is the main parameter analyzed in flood damage assessment because it allows to estimate the damage to buildings considering the building components reached by the flood water. Therefore, by analyzing the ranges of flood water depth for different frequency events, it is possible to identify the exposed elements in a building.

For the analysis of floodwater depth in the Po River basin, flood maps elaborated by the Po River Basin District Authority have been analyzed. The selected flood maps are related to Po River (Torino area), Parma and Baganza river (from the municipality of Parma to the confluence in Po), Mella and Garza River (in city of Brescia), and Adda river (in Lodi area), which represent the flood scenarios with high, medium, and low frequency (i.e. a return period of 20, 200 and 500 years).These maps have been chosen to represent urban and rural flooding areas. For the analysis of the raster data of flood water depth (with a spatial resolution of 5 m), the river channel has been excluded from the flood maps.

In Figure 4.3, the histograms of water depth in flooded areas in Po River (Torino area) show that high and medium frequency events present a similar distribution for water depth smaller than 1 m, and with respect to the three events, the 80% of flooded area have water depth smaller than 3 m, approximately.

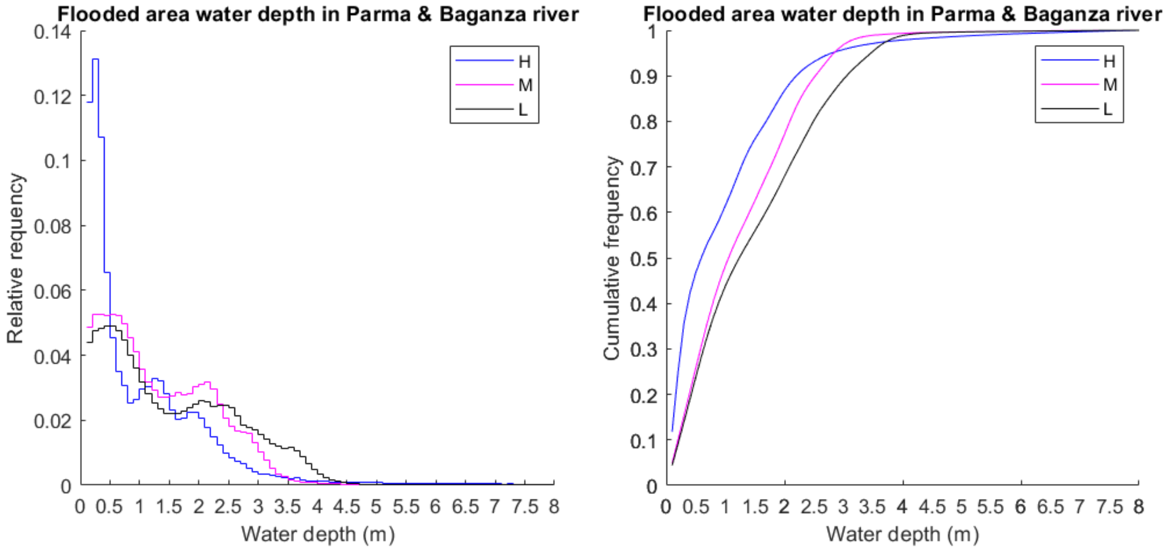

Flooded area water depth in Po river (Torino area)

Flooded area water depth in Po river (Torino area)

(a) (b)

Figure 4.3 Relative (a) and cumulative (b) frequency of water depth of low, medium, and high frequency flood in Po River (Torino area)

In Figure 4.4, the flood water depth histograms in Parma and Baganza river display high accumulation of water depth smaller than 0.5 m for high frequency events, while the medium and high frequency events show a more homogeneous distribution. From the three analyzed events, at least the 80% of flooded area have water depth smaller than 3 m.

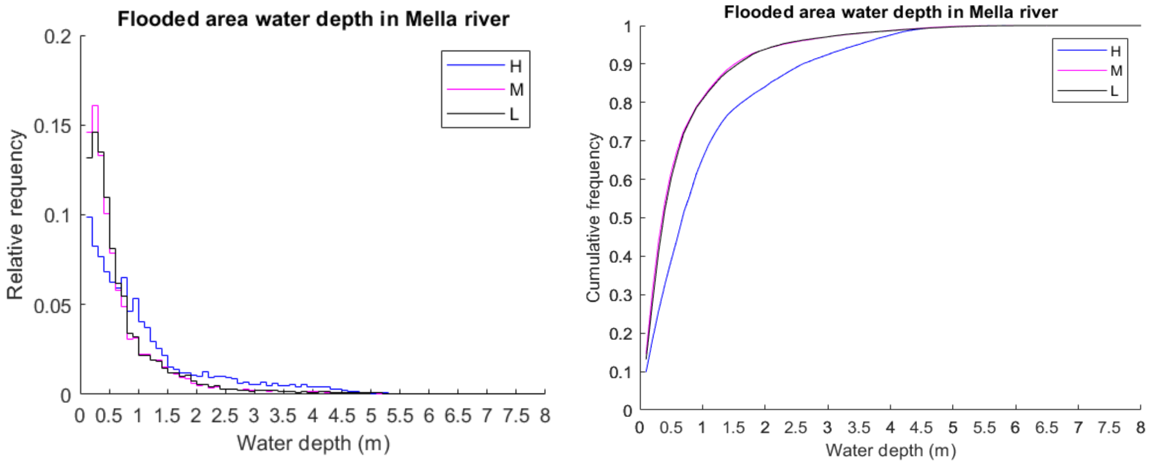

Flooded area water depth in Parma & Baganza river

Flooded area water depth in Parma & Baganza river

(a) (b)

Figure 4.4 Relative (a) and cumulative (b) frequency of water depth of low, medium, and high frequency flood in Parma and Baganza River

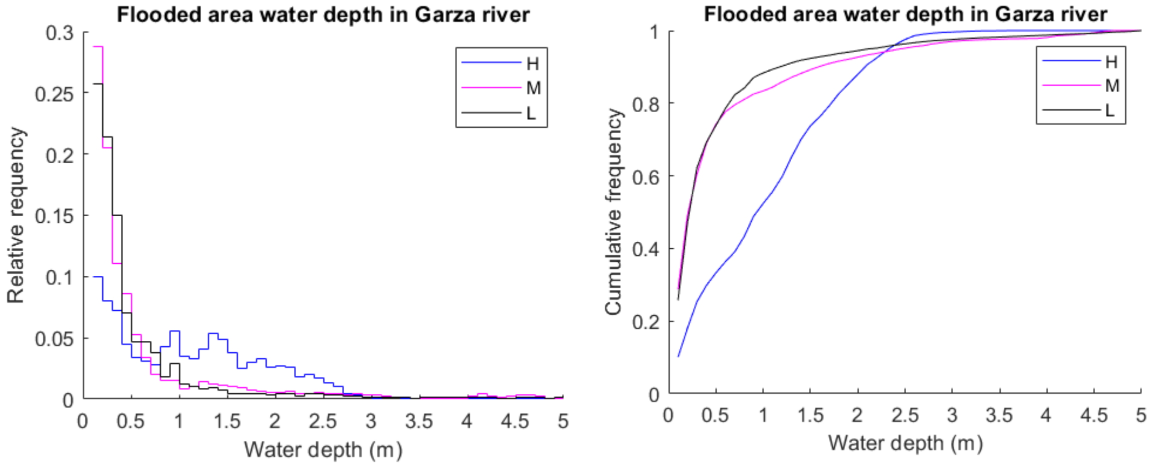
In Figure 4.5 the histograms of water depth in the Mella river show a similar distribution between medium and low frequency events, a bigger distribution of water depth values higher than 1 m, and that at least the 80% of the flooded area of the three cases present water depth smaller than 1.5 m, approximately.



(a) (b)

Figure 4.5 Relative (a) and cumulative (b) frequency of water depth of low, medium, and high frequency flood in Mella River

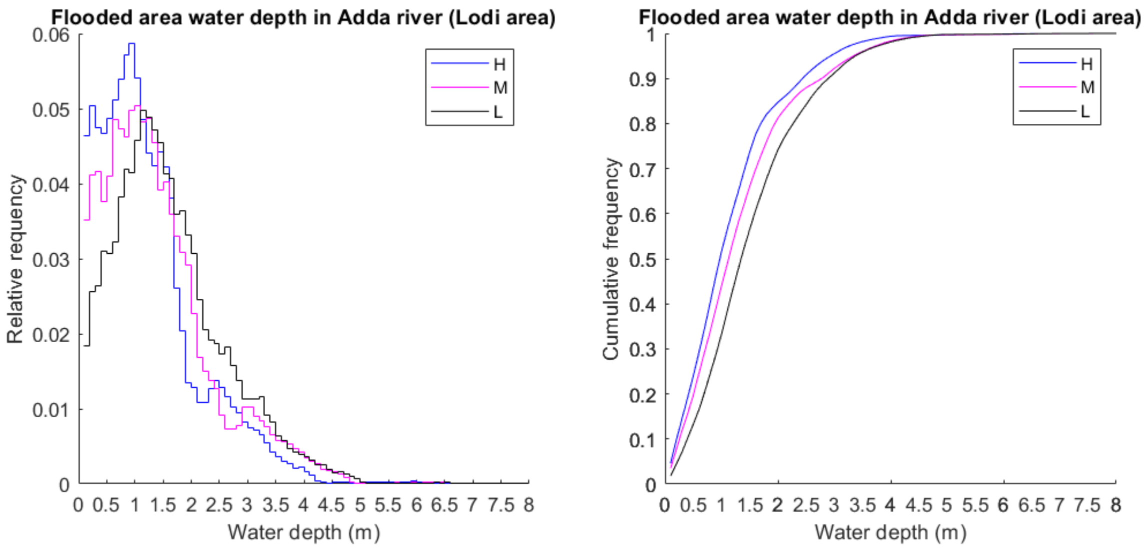
From the histograms of flood water depth in the Garza River shown in Figure 4.6, there is a high accumulation of water depth smaller than 0.5 m in low and medium frequency events, while a higher accumulation of water depth greater than 0.5 m in high frequency events. This variation can be explained by the evidence that in the case of high frequency events, the flood water covers the extent near the embankments, while for low and medium frequency, the flood water extent mostly covers floodplain areas with water depth lower than 0.5 m.



(a) (b)

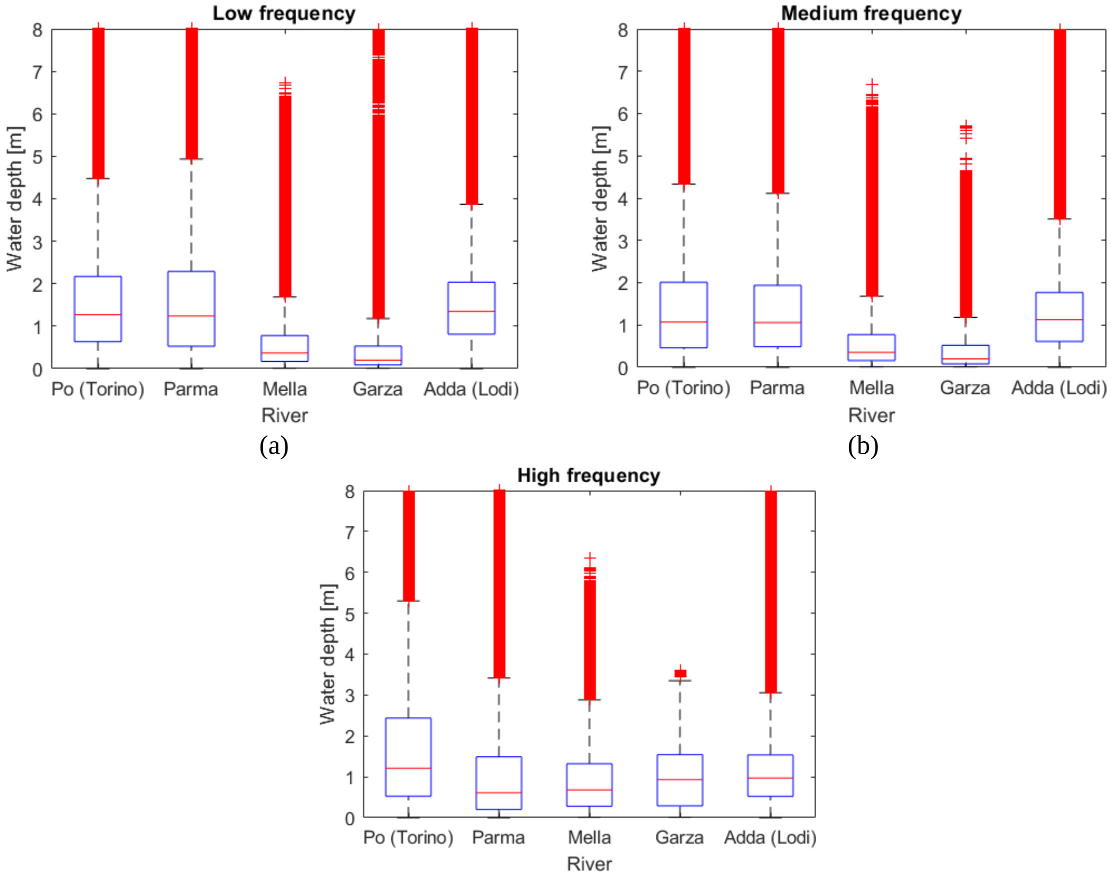
Figure 4.6 Relative (a) and cumulative (b) frequency of water depth of low, medium, and high frequency flood in Garza River

From the flood water depth histograms in Adda river (Lodi area) and which is shown in Figure 4.7, there is a high accumulation of water depth distribution between 0.8 to 1.5 m, and that at least the 80% of flooded area present flood water depth smaller than 2.5 m in the three cases.



(a) (b)

Figure 4.7 Relative (a) and cumulative (b) frequency of water depth of low, medium, and high frequency flood in Adda River (Lodi area)

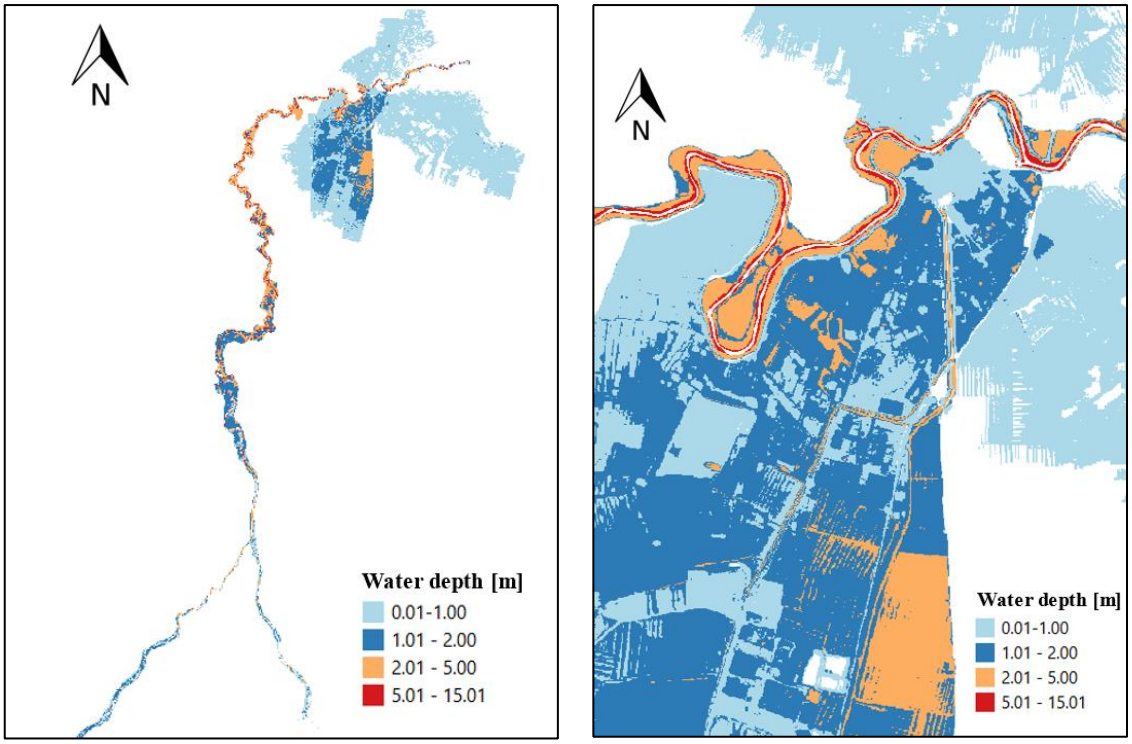


(a) (b)

(c)

Figure 4.8 Flood water depth in Po River basin considering (a) low, (b) medium and (c) high frequency event

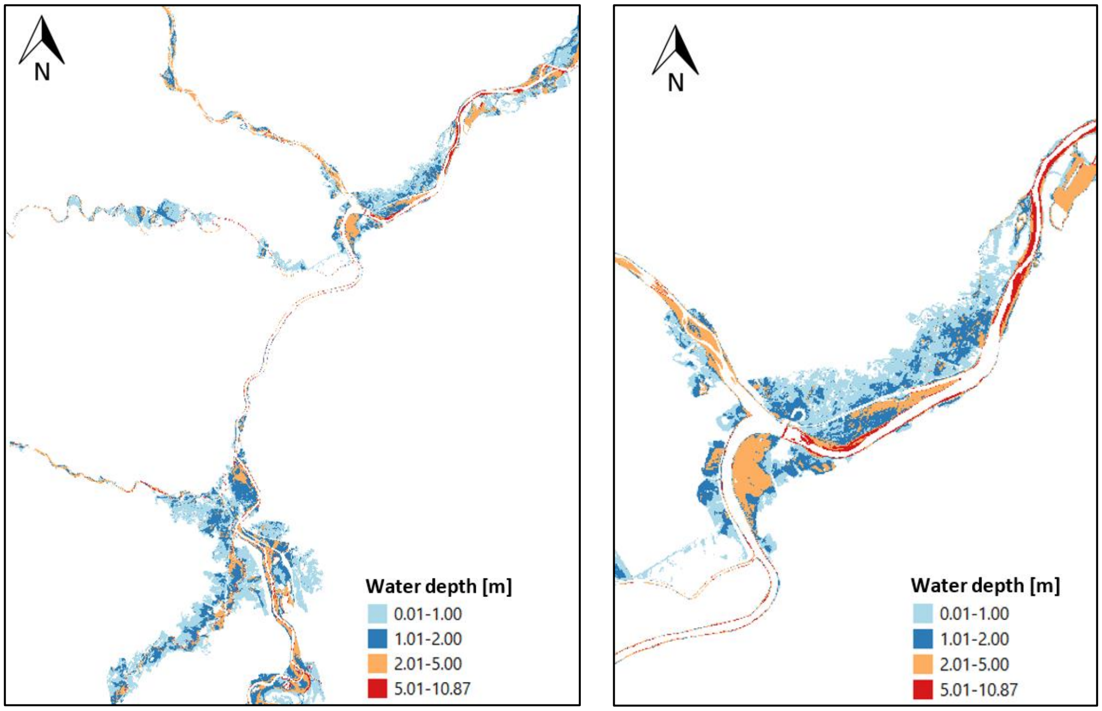
From Figure 4.8, the results of quartiles, median values and outliers of flood water depth obtained from low, medium, and high frequency flood events are shown. The ranges of median values of water depth of high frequency events are between 0.6 and 1.2 m, in medium frequency events between 0.2 and 1.6 m, and in low frequency events between 0.2 and 1.4 m. The maximum extreme values of water depth between the events are 3 m for Mella and Garza River, 4 m for Adda river (Lodi area), and 5 m for Po river (Torino area), Parma and Baganza river. All the events, independently of the frequency, show outliers when the water depth is greater than 5 m. When outliers are compared with the flooded areas, it is obtained that these atypical values represent the edges of the rivers and the presence of bridges as seen in Figure 4.9, Figure 4.10 and Figure 4.11. Taking into account the aforementioned analysis, the representative water depth obtained from the different frequency events is between 0.2 to 1.6 m, having an extreme value up to 5 m. Hence, a range of up to 5 m has been assumed as range of variations of external water depth, confirming the previous assumptions of original INSYDE.



(a) (b)

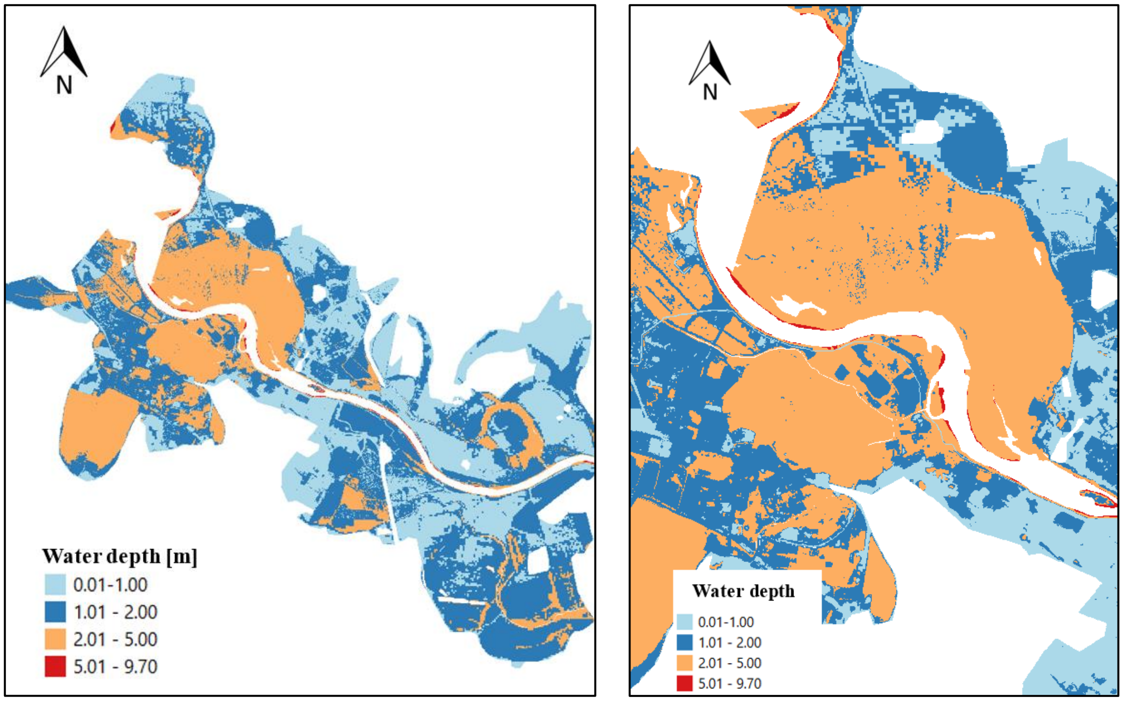
Figure 4.9 Flood areas of high frequency flood event in Parma and Baganza river

Another parameter obtained from the flood maps is the areal extent of inundation triggered by events of different frequencies that allows to have an estimation of exposed assets. The areal extension of the flooded areas of all the frequency events, being the river areas already excluded, are shown Figure 4.12.



(a) (b)

Figure 4.10 Flood areas of medium frequency flood event in Po River (Torino area)



(a) (b)

Figure 4.11 Flooded areas of low frequency flood event in Adda river (Lodi area)

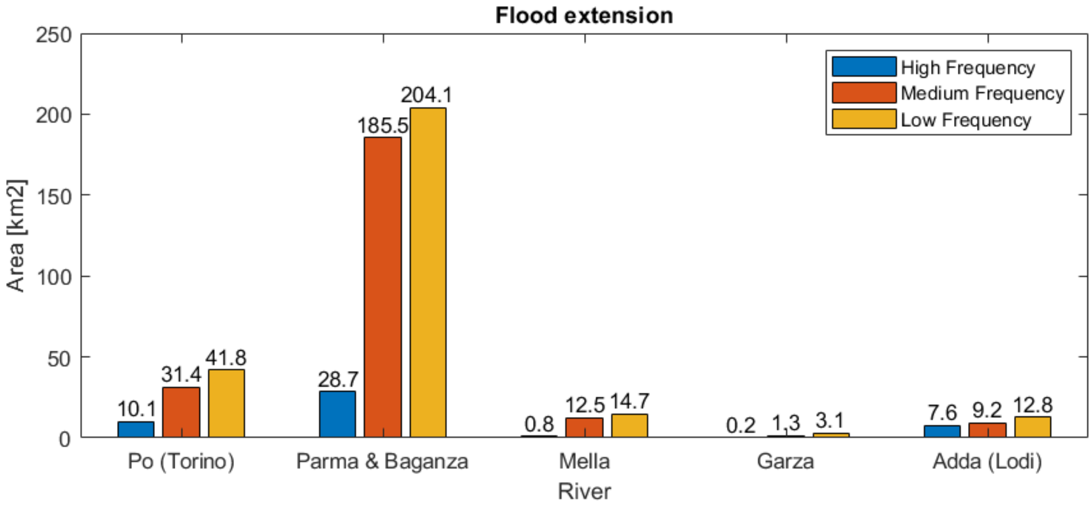


Figure 4.12 Areal extension of low, medium, and high frequency flood events in Po River basin

b) Flow velocity

Flow velocity is considered to trigger severe damage to structural and non-structural building components. For the analysis of flow velocity, Po River (Torino area), Parma and Baganza River were selected between the rivers considered in water depth analysis as the velocity maps were not available for the other three rivers. The analysis of flow velocity shows similar frequency distribution of velocity within the flooded area; therefore, the datasets have been joined showing percentiles 75th up to 0.58 m/s for all frequency of events as seen in Table 4.5. Hence, based on the range of percentiles and median values, the defined default value has been set at 0.3 m/s. In addition, the cumulative frequency of flow velocity is shown in Figure 4.13.

Table 4.5 Percentile values of velocity (m/s)

	High frequency	Medium frequency	Low frequency
Percentile 75th	0.58	0.43	0.47
Median	0.17	0.23	0.27
Percentile 25th	0.04	0.10	0.13

c) Inundation duration

Based on literature (Penning-Rowsell et al., 2005), building components tend to have different damage level depending on the duration of the flood event. In the original INSYDE (see chapter 3, section 1), the default value of inundation duration has been set to 36 hours, considering a threshold of no damage occurrence and damage occurrence between 24 to 48 hours, respectively. In the current work, the default value is also assumed to be 36 hours due to the applicability of previous work in northern Italy.

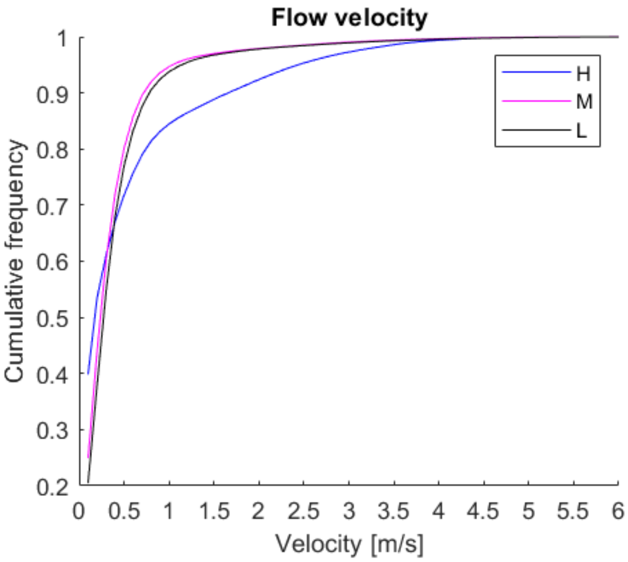


Figure 4.13 Velocity of low, medium, and high frequency flood

d) Sediment load and Water quality

Sediment load and water quality affect the damage cost due to the elimination of contaminated water stored in floor levels or due to the impact in the plumbing system. From the original INSYDE (see chapter 3, section 1), the default value of sediment load is 0.05 (5% of presence on water volume), and water quality is 1 (presence of pollutants). In the present work, due to no additional information being found, mentioned default values are assumed considering the applicability of previous work in northern Italy.

4.3.2 Vulnerability parameters

Building characteristics are obtained from sources at the regional and local levels. At the regional level, the area of three building typologies is obtained from OpenStreetMap, and some building characteristics are obtained from housing census 2011 realized by ISTAT. Missing data related to area of single unit of apartments and detail characteristics of single buildings are obtained through a virtual survey that involves 119 buildings considering all building typologies (see Appendix A – Virtual survey).

a) Building type

As previously mentioned from the building stock within the Po River basin, 5 types of buildings were identified.

- Detached: Independent house which present four exposed lateral sides.
- Semidetached: House in contiguity with another, which present three exposed lateral sides and a shared side.
- Attached (corner): House located at the edge of a block of houses, which present three exposed lateral sides and a shared side.

- Attached (middle): House located at the center of a block of houses, which present two exposed lateral sides and two shared sides.
- Apartment: Housing unit inside a block of apartments.

From the housing census 2001 realized by ISTAT, the most frequent building type, in the Italian context, is the house which does not share any lateral side with another building, therefore, detached building is defined as default value.

b) Footprint area

Footprint areas of detached, semidetached, and attached buildings are analyzed from OpenStreetMap instead of government sources due to the detail of information that the shapefiles present. As seen in Figure 4.14, the representation of attached buildings is mostly shown as a block in Piemonte government source and as individual housing units in OpenStreetMap, the latter being the proper representation to be used in INSYDE. In the case of areas of apartments, it has been obtained from virtual survey instead of OpenStreetMap due to its representation as single unit and no block of apartments.

Piedmont government source OpenStreetMap

Figure 4.14 Representation of attached buildings between Piemonte government source and OpenStreetMap

A sample of about 885 buildings between detached, semidetached, and attached houses, and a sample of 29 apartments has been analyzed for the estimation of ranges of footprint area in the Po River basin as seen in Figure 4.15. The sample data present footprint areas smaller than 320 m^2, being congruent with the footprint areas found in the virtual survey. Detached and attached center houses are the building typologies with the highest and smallest range of footprint area between percentile 25th and 75th. The median values of footprint areas per building typology, and therefore default values, are shown in Table 4.6.

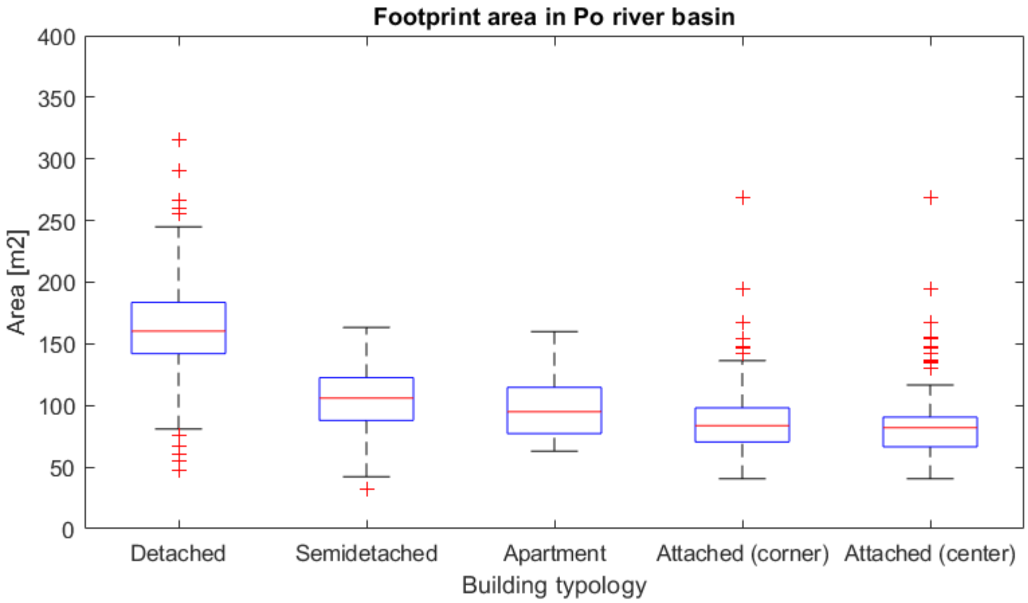


Figure 4.15 Building type footprint area

Table 4.6 Median footprint area

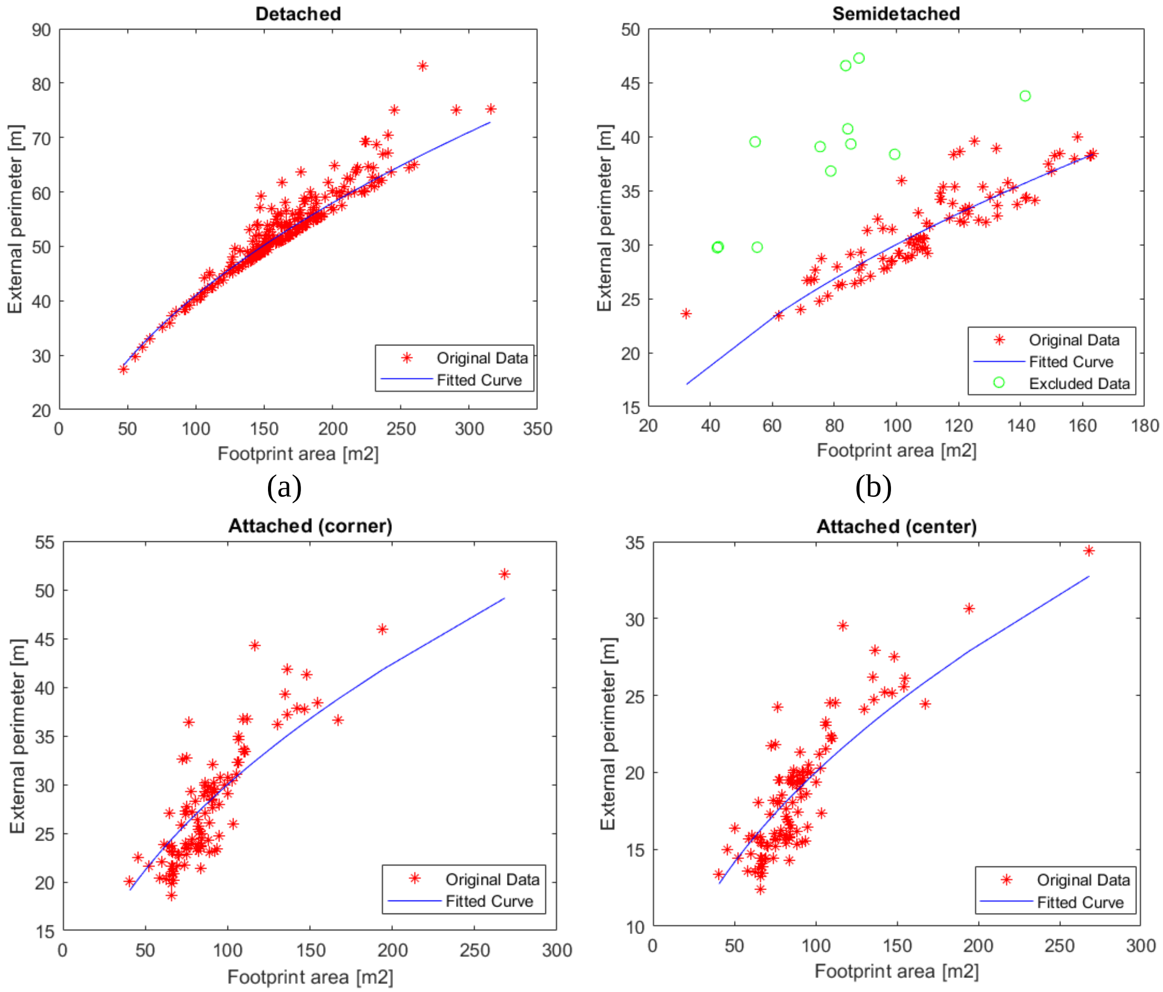
Building type	Median footprint area [m^2]
Apartment	95
Detached	160
Semidetached	110
Attached	85

c) External perimeter

External perimeter is analyzed as the outer sides of a building which have a direct contact with the flood. In case of detached houses, the four sides of the building are considered. For semidetached and attached corner houses, three over four sides are considered for the calculation, and for attached middle houses, two over four sides are measured. In case of apartment, it is analyzed as a single housing unit, therefore the external perimeter is measured based on the number of outer sides.

The external perimeter of detached, semidetached, and attached buildings is calculated from the set of building obtained from OpenStreetMap. A quadratic regression was found from the correlation of footprint areas and external perimeter obtaining R^2 coefficient greater than 0.7

as shown in Figure 4.16. In case of semidetached houses (see Figure 4.16.b), 11 buildings were excluded because they were affecting the definition of the quadratic regression of the buildings which follow a trend. To exclude the buildings, the difference between calculated and real external perimeter greater than 1.5 times the deviations standard was considered.



(a) (b)

(c) (d)

Figure 4.16 Fitting relationship between external perimeter and footprint area for (a) detached, (b) semidetached, (c) attached corner, and (d) attached center houses

In case of apartment, the housing units were assessed from the virtual survey obtaining a linear regression with R^2 coefficient of about 0.64 as seen in Figure 4.17. The position of the apartment within the block was analyzed to define if it affects the linear regression, obtaining that the external perimeter follows the linear regression as seen in Figure 4.18.

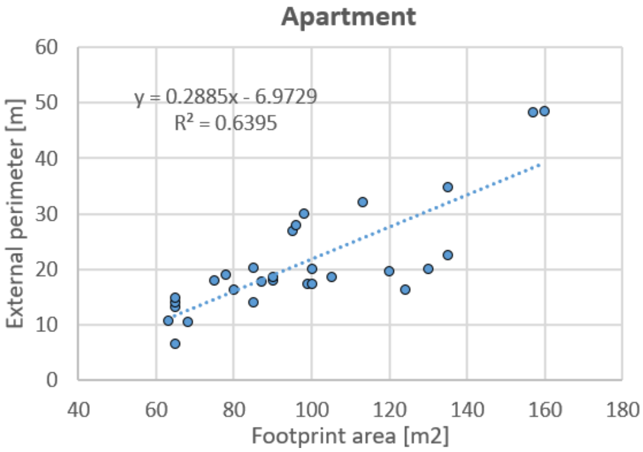


Figure 4.17 Linear regression of external perimeter of apartment versus footprint area

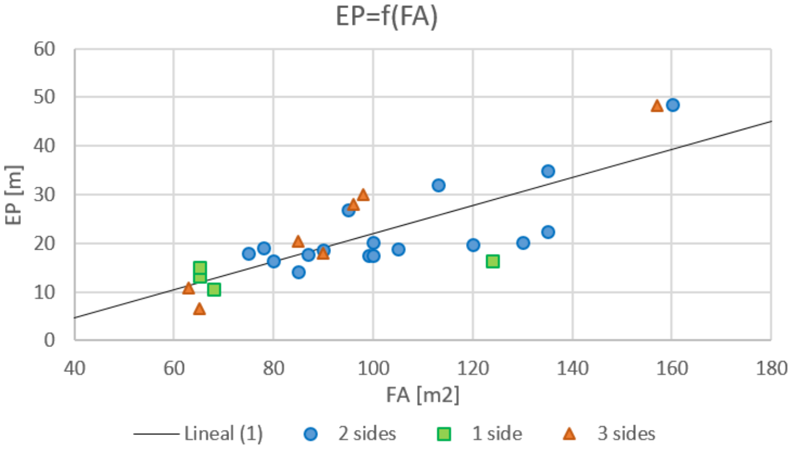


Figure 4.18 External perimeter of apartment considering the number of lateral sides and linear regression

The summary of linear and quadratic regression between external perimeter and footprint area of all building typologies is shown below.

Table 4.7 External perimeter equations

Building type	External perimeter [m]	R^2
Apartment	$EP = 0.2885\,FA - 6.9729$	0.64
Detached	$EP = 4.1\sqrt{FA}$	0.89
Semidetached	$EP = 3\sqrt{FA}$	0.72
Attached corner	$EP = 3\sqrt{FA}$	0.74
Attached center	$EP = 2\sqrt{FA}$	0.71

The linear and quadratic regression is calculated based on the footprint area of several buildings, therefore, a range of validation of the function EP=f(FA) is defined as seen in Table 4.8.

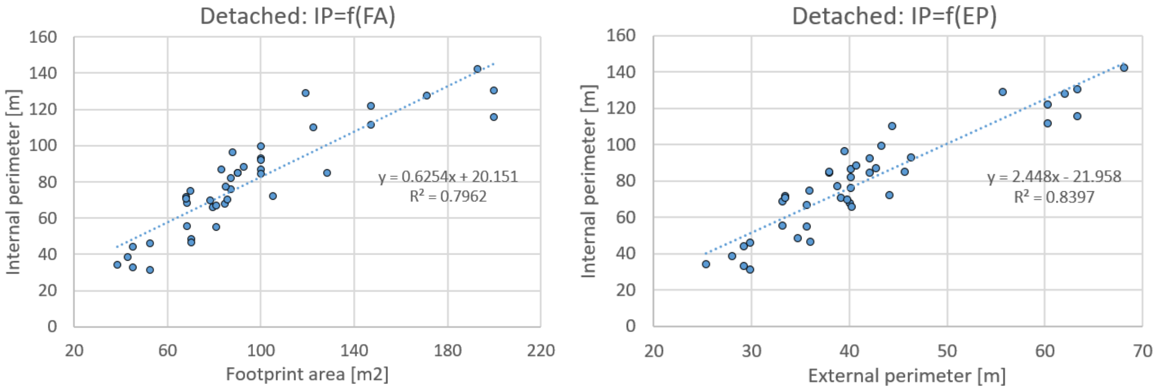
Table 4.8 Validation range of external perimeter equations

Building type	Range of validated footprint area [m^2]	Number of assessed buildings
Detached	50 to 300	237
Semidetached	60 to 160	189 (*)
Attached corner	50 to 150	200
Attached middle	50 to 150	248
Apartment	65 to 160	29

(*) 189 buildings without considering the 11 excluded buildings

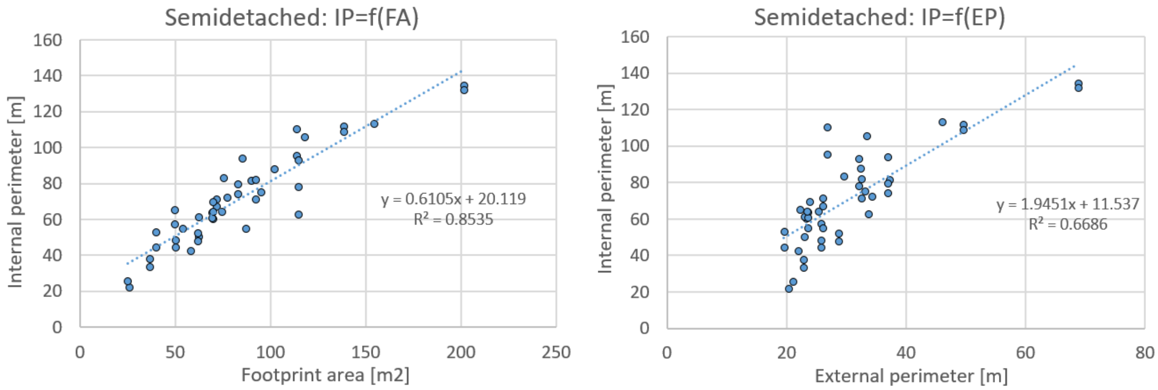
d) Internal perimeter

From the virtual survey, the calculation of the internal perimeter (IP) was obtained from the building's layouts. For each building typology, two types of linear relationship were found based on the correlation with footprint area (FA) and external perimeter (EP). As seen from Figure 4.19 to Figure 4.23, the R^2 coefficient between internal perimeter and footprint area is greater than 0.70 for all building types, being more reliable than the correlation with external perimeter, therefore, the IP=f(FA) is considered as the default function to be used in the Po River basin, as seen in Table 4.9.



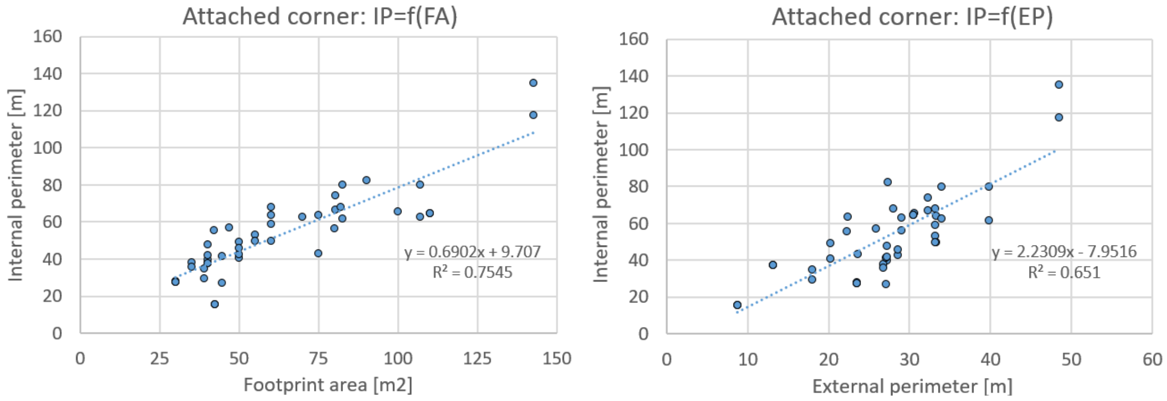
(a) (b)

Figure 4.19 Linear regression of internal perimeter of detached houses with (a) footprint area and (b) external perimeter



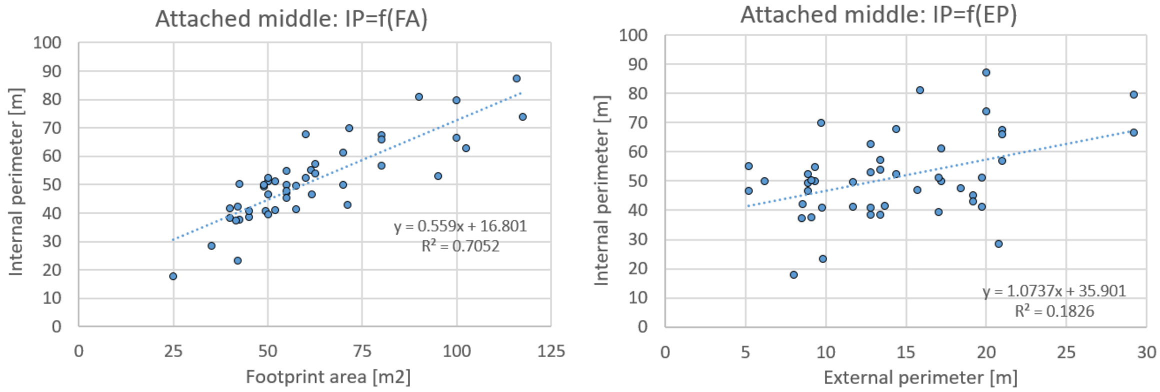
(a) (b)

Figure 4.20 Linear regression of internal perimeter of semidetached houses with (a) footprint area and (b) external perimeter



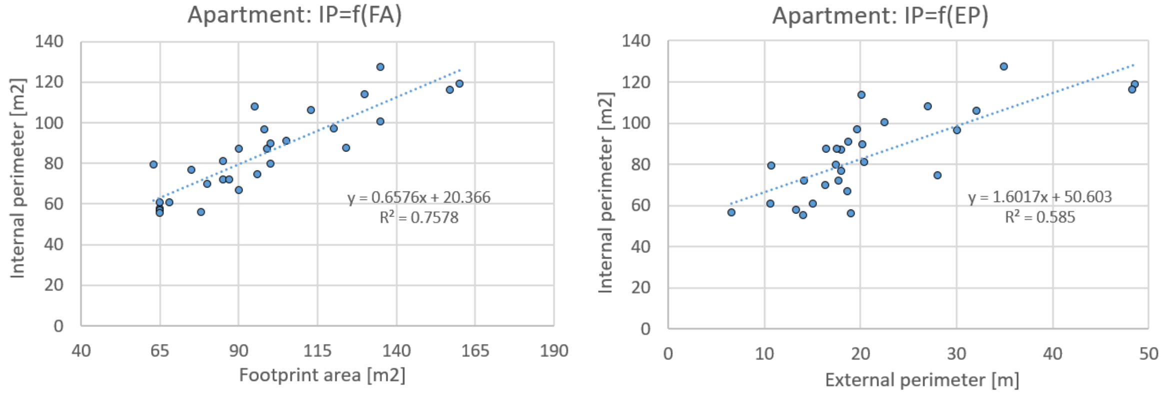
(a) (b)

Figure 4.21 Linear regression of internal perimeter of attached corner houses with (a) footprint area and (b) external perimeter



(a) (b)

Figure 4.22 Linear regression of internal perimeter of attached middle houses with (a) footprint area and (b) external perimeter



(a) (b)

Figure 4.23 Linear regression of internal perimeter of apartment with (a) footprint area and (b) external perimeter

Table 4.9 Internal perimeter equations

Building type	Internal perimeter [m]	R^2
Detached	$IP = 0.6254 \cdot FA + 20.151$	0.80
Semidetached	$IP = 0.6105 \cdot FA + 20.119$	0.85
Attached corner	$IP = 0.6902 \cdot FA + 9.707$	0.75
Attached middle	$IP = 0.559 \cdot FA + 16.801$	0.71
Apartment	$IP = 0.6576\ FA + 20.366$	0.76

The linear regression is calculated based on the footprint area of a set of buildings per building typology, therefore, the range of validation of function IP=f(FA) is defined as seen in Table 4.10.

Table 4.10 Validation range of internal perimeter equations

Building type	Range of validated footprint area [m^2]	Number of assessed buildings
Detached	40 to 200	23
Semidetached	30 to 200	23
Attached corner	30 to 140	21
Attached middle	25 to 120	23
Apartment	65 to 160	29

e) Basement area

From the virtual survey, no evident regression (i.e. linear and quadratic) was found between basement area (BA) and footprint area (FA) as seen in Figure 4.24. The analyzed sample consist of 19 buildings; therefore, a bigger dataset could generate better results. Hence, the relationship used in Po River basin is retained, i.e. $BA = 0.5\ FA, R^2 = 0.35$, as considered in the original INSYDE.

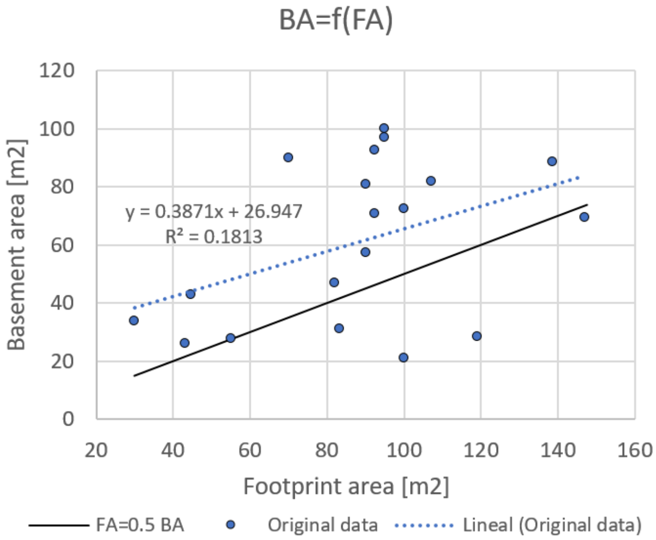


Figure 4.24 Fitting relationship between external perimeter and footprint area

f) Basement perimeter

From the virtual survey, a relationship between basement perimeter (BP) and basement area (BA) was found, being $BP = 4.2\sqrt{BA}$ with a coefficient of determination $R^2 = 0.88$ as seen in Figure 4.25.

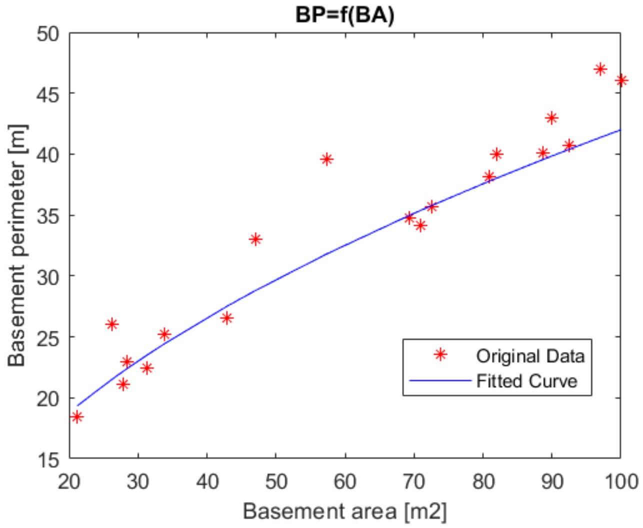


Figure 4.25 Fitting relationship between basement perimeter and basement area

g) Basement height

From building layouts obtained in the virtual survey, the 25th and 75th percentiles of basement height oscillate between 2.25 m and 2.57 m as seen in Figure 4.26. Considering median basement height value of 2.5 m and the presence of 0.3 m slab, the final default value of basement height is 2.8 m, being smaller than the 3 m considered in original INSYDE.

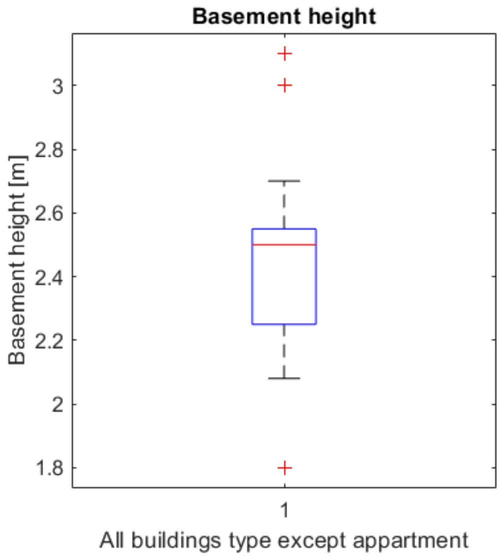


Figure 4.26 Basement height from virtual survey

h) Ground floor level

From virtual survey, the 25th and 75th percentiles of ground floor level oscillate between 0 to 0.2 m between building typologies as seen in Figure 4.27. A few attached, semidetached, and detached houses were identified having ground floor level from 0.40 to 0.80 m. The average ground floor level between building typologies ranges from 0.05 up to 0.16 m and their median values, from 0.05 to 0.1 m. Due to small variations between average and median values, 0.1 m is considered as ground floor level for all building typologies, as assumed in the original INSYDE.

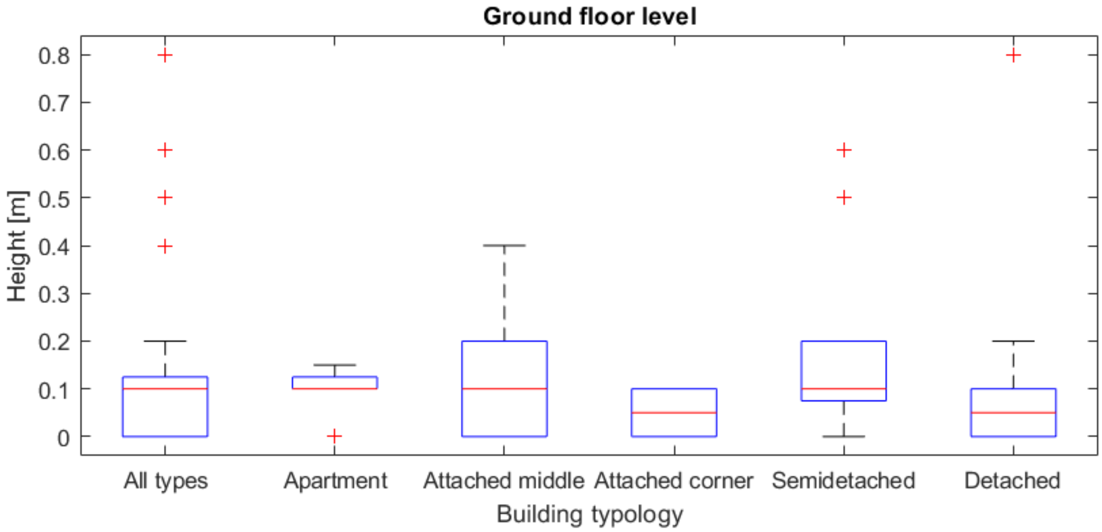


Figure 4.27 Ground floor level from virtual survey

i) Interfloor height

From building plans obtained in the virtual survey, the median value of interfloor height between building typologies ranges from 2.7 to 2.75 m as seen in Figure 4.28. Additionally, considering interfloor height per floor level, the median value is 2.7 m for ground floor and first floor as seen in Figure 4.29. Considering 2.7 m height and the presence of 0.3 m slab, the final estimated interfloor height for Po River basin is 3.0 m, being lower than the 3.5 m considered in the original INSYDE.

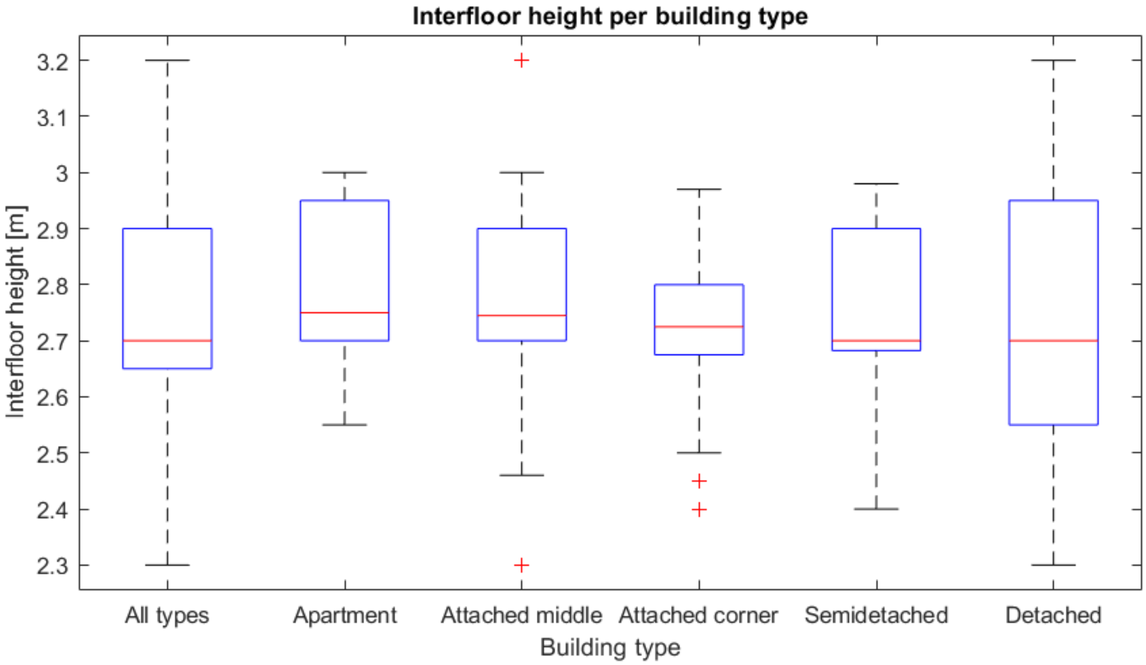


Figure 4.28 Interfloor height per building type

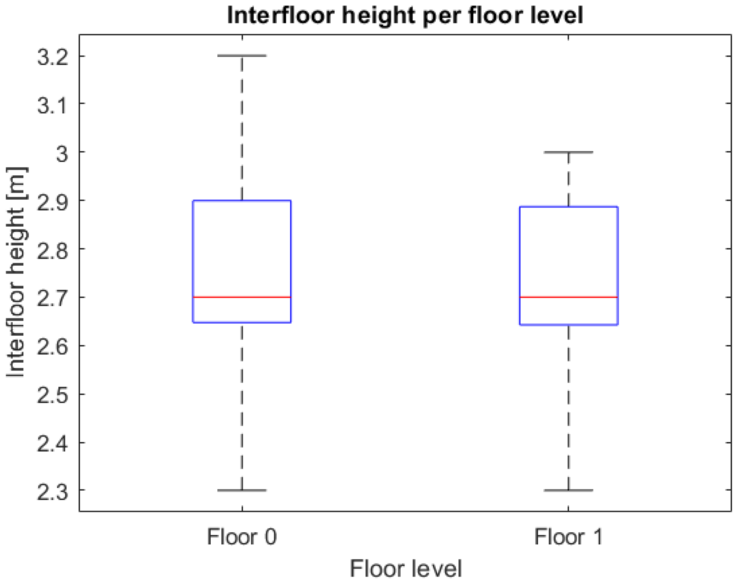


Figure 4.29 Interfloor height per floor level in all building type except apartment

j) Number of floors

From housing census 2011 realized by ISTAT and as shown in Figure 4.30, 2 floors are the representative value of the number of floors for residential buildings in regions within the Po River basin, as assumed in the original INSYDE.

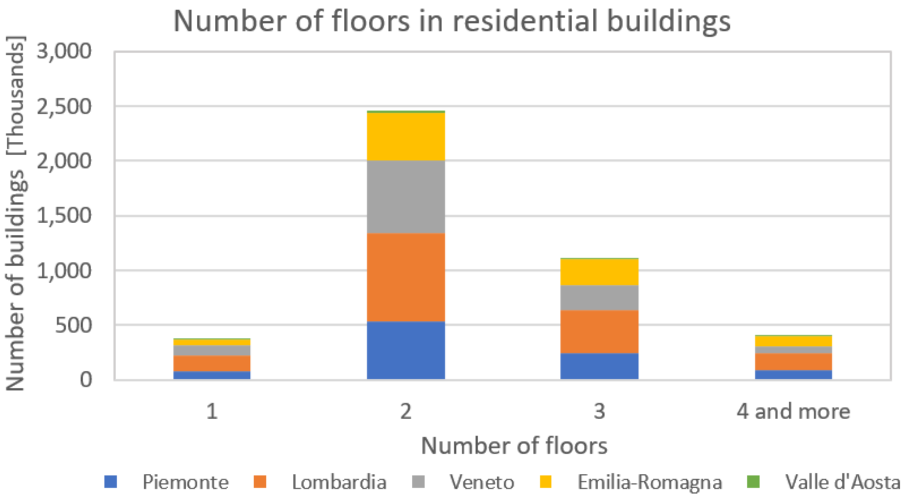


Figure 4.30 Number of floors in residential buildings from ISTAT census 2011

k) Building structure

From housing census 2011 and as seen in Figure 4.31, masonry and reinforced concrete are identified as principal types of building structure, being masonry the predominant material and default value for dwellings within the Po River basin.

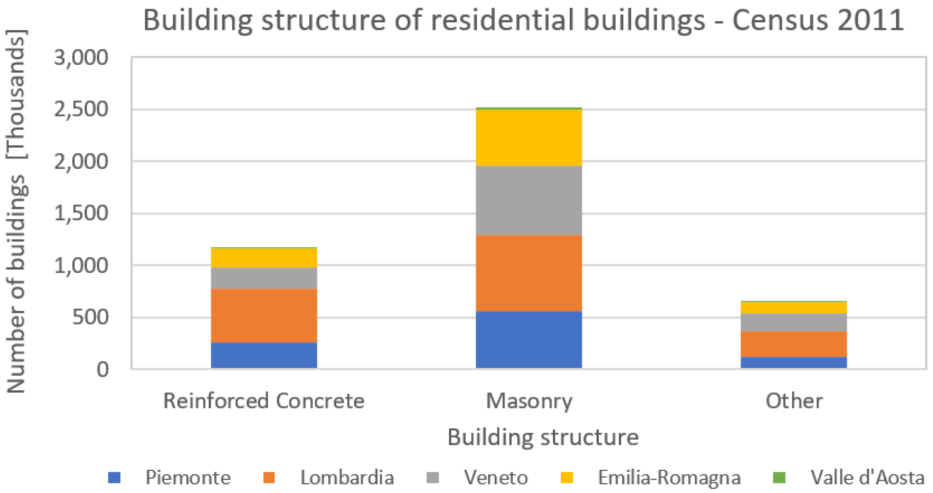


Figure 4.31 Building structure of residential buildings from ISTAT census 2011

l) Finishing level

From the virtual survey and as displayed in Figure 4.32, 52% of the housing units present high finishing level followed by 42% of the housing units with medium finishing level. Therefore, the estimated default value is 2 (i.e. high level) as assumed in the original INSYDE.

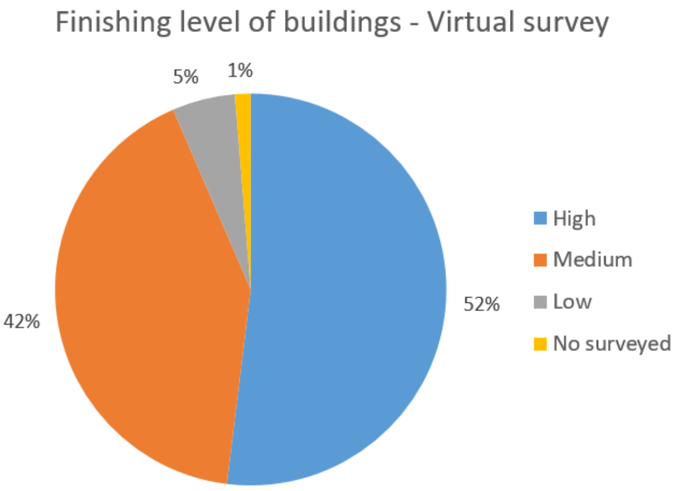


Figure 4.32 Finishing level of residential buildings from virtual survey

m) Level of maintenance

From housing census 2011, a significant number of dwellings in the Po River basin present medium level of maintenance being followed by high level of maintenance as seen in Figure 4.33. This tendency is also identified from the virtual survey as seen in Figure 4.34, therefore, 1 is assumed as default value (i.e. medium level).

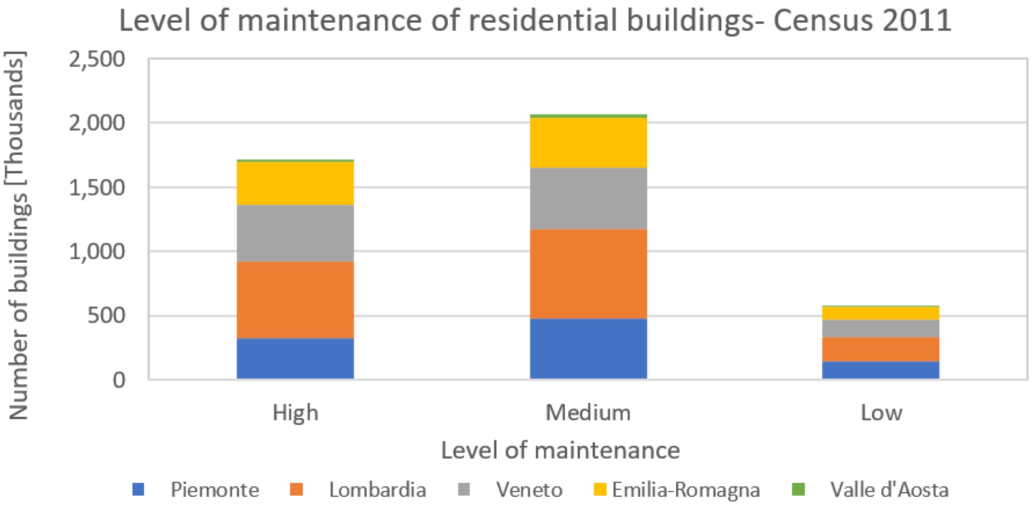


Figure 4.33 Level of maintenance of residential buildings from ISTAT census 2011

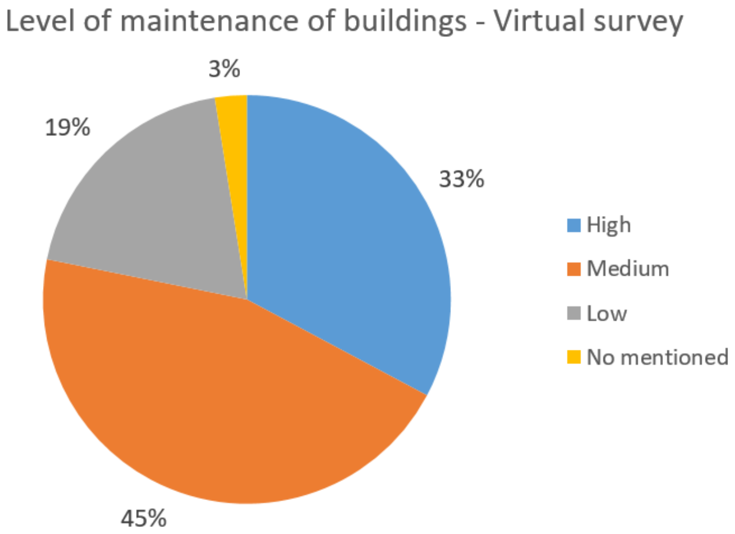


Figure 4.34 Level of maintenance of residential buildings from virtual survey

n) Year of construction

From housing census 2011 and as shown in Figure 4.35, the construction of buildings in Po River basin regions had a continuous growth until 1980 and a rapid decline from 2001. In comparison between the housing census 2011 and the virtual survey, about 80% of buildings were built before 1990 showing a decrease after this year as seen in Figure 4.36. Therefore, built houses before 1990 are assumed as the default value of period of construction.

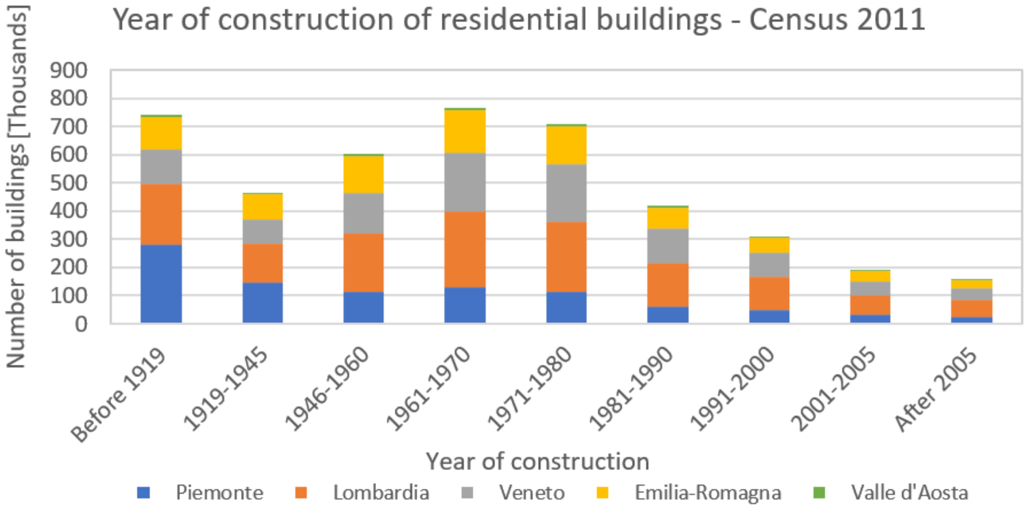


Figure 4.35 Year of construction of residential buildings from ISTAT census 2011

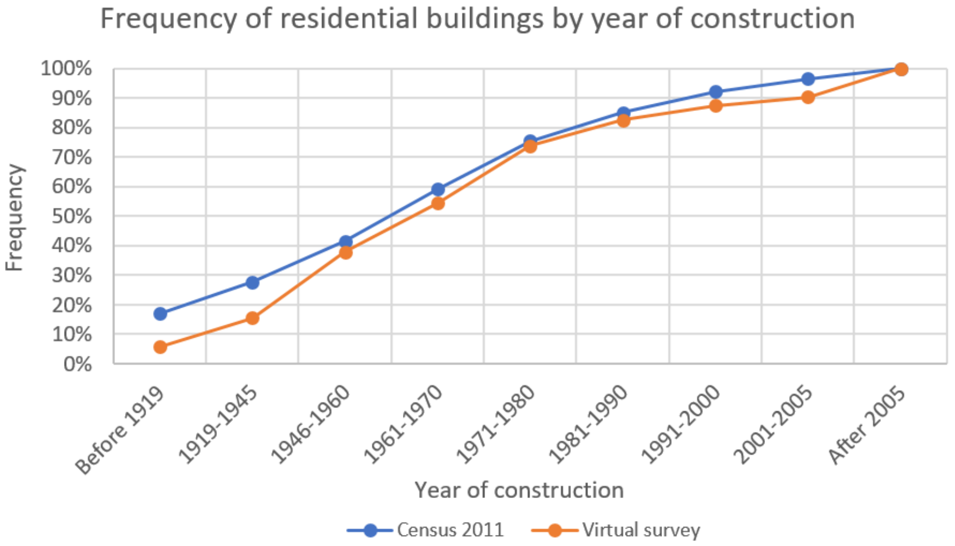


Figure 4.36 Frequency of residential buildings by year of construction from ISTAT census 2011 and virtual survey

o) Heating system distribution

From TABULA project (Vincenzo Corrado et al., 2014), in Italy, the heating systems distribution are subdivided in distributed and centralized systems, considering distributed systems in case of apartments built between 1991 and 2005, and centralized system as the typical system used in detached and attached houses for all periods of construction. According to the assumptions made in the original INSYDE, buildings built before 1990 are mostly characterized by having centralized heating systems with a unique boiler located in the basement (if present) or on the ground floor, while recently built buildings have distributed heating systems with an independent boiler per floor. From the virtual survey and as seen in Figure 4.37, 76% of surveyed buildings have distributed system, of which 82% were built before 1990 being only the 25% recently renovated. The results from the virtual survey show a predominance of distributed heating system on buildings built before 1990, however, TABULA project, which mainly considers a classification based on the energy performance of buildings systems, shows the prevalence of centralized system in buildings built before 1990. Hence, the assumptions made in original INSYDE have been kept.

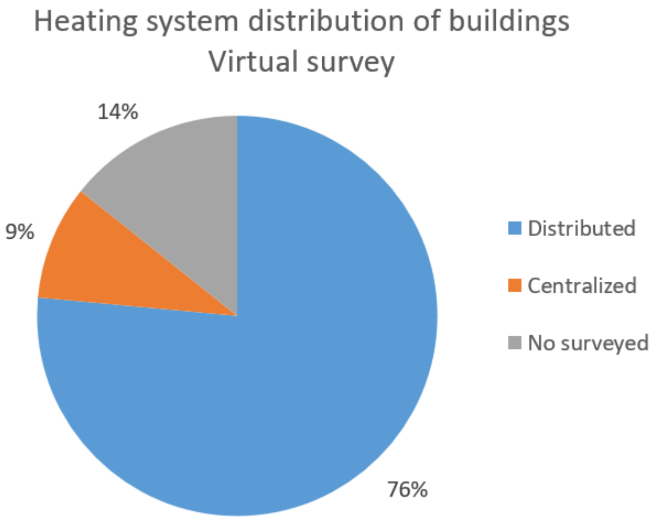


Figure 4.37 Heating system distribution of residential buildings from virtual survey

p) Heating system type

In Italy, there is a correlation between the period of construction and the heating system type, considering radiators being used before 1990 and underfloor heating after 1991 (Vincenzo Corrado et al., 2014). From the virtual survey, about 69% of buildings use radiators, of which 78% of buildings were built before 1990 and 22% after 1990. In addition, from the virtual survey, no underfloor heating was identified, and a few buildings present a different heating type such as heat pumps and warm air, as seen in Figure 4.38. Consequently, considering the presence of radiators also in newer buildings, radiators are assumed to be used in buildings built before 2005 and underfloor heating in recent buildings.

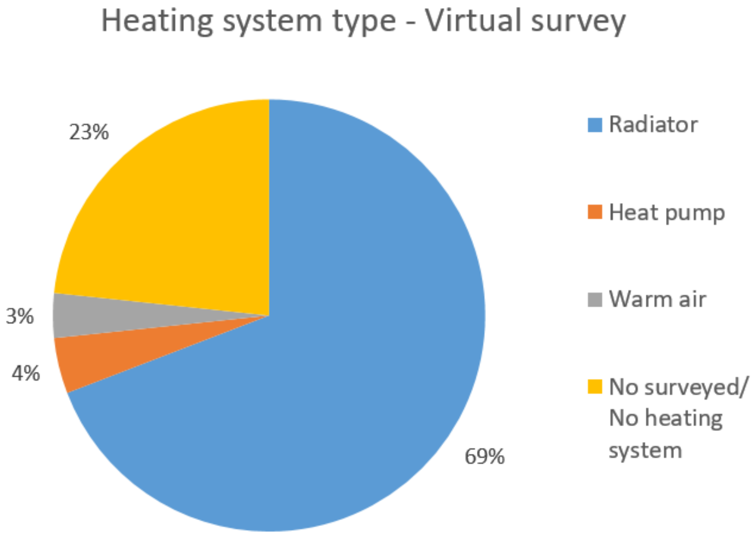


Figure 4.38 Heating system type of residential buildings from virtual survey

4.3.3 Position and dimension of building subcomponents

The assessment of the field survey allows to have a better perception of the dimension and position of building components in case there is a reference distance from their floor plans. Additionally, depending on the level of detail of plans, it is possible to realize a count of some building components as windows and doors. This evaluation is useful for the corroboration of assumptions on buildings features included the original INSYDE.

a) Electrical subcomponents

As part of electrical subcomponents, the position of sockets, light switches, and control panels were assessed. From the assumptions made in INSYDE related to the position of electrical components, the height range from 0.2 to 1.1 m considers the presence of middle sockets and cables, from 1.1 to 1.5 m considers upper sockets and cables, and higher than 1.5 m for the presence of panel control. From the virtual survey, lower and middle sockets were mostly located between 0.2 to 1.15 m with respect to the floor level, being their median height 0.3 m and 1 m, respectively. The median and average position of light switches is 1.1 m, having a maximum height of 1.4 m respect to the floor level, and in case of control panel, the median value is about 1.5 m. Hence, the assumptions made in original INSYDE are verified.

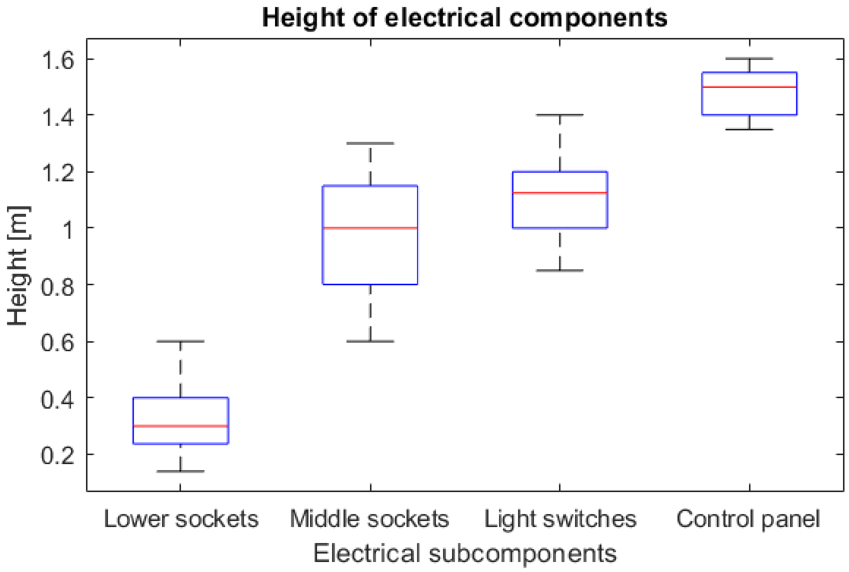


Figure 4.39 Height of electrical subcomponents measured from floor level

b) Radiator

The height of the radiator considering the distance from the floor level to the bottom of the radiator fluctuates between 0.16 m to 0.2 m, being the median and average height 0.19 and 0.2 m, respectively. Therefore, the standard height is assumed as 0.2 m.

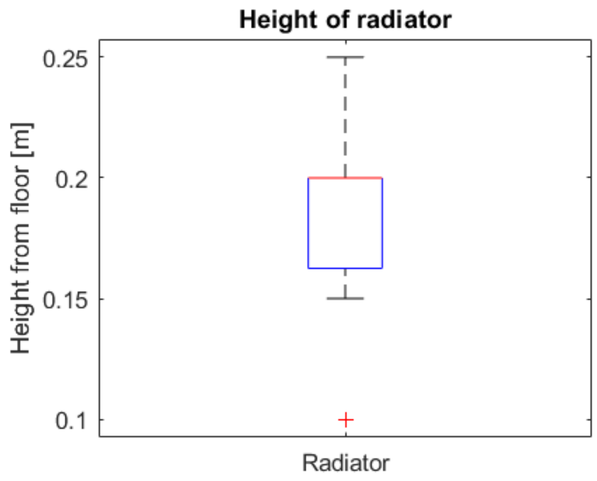


Figure 4.40 Height of radiator from floor level

c) Doors

The range of number of doors is variable between building typology, but there is a median value of about 7 doors per 100 m^2 of floor area as seen in Figure 4.41. Additionally, the common door dimension obtained for plans is 0.8 m width per 2.1 m heigh as seen in Figure 4.42. These results are coherent with the assumptions made in the original INSYDE

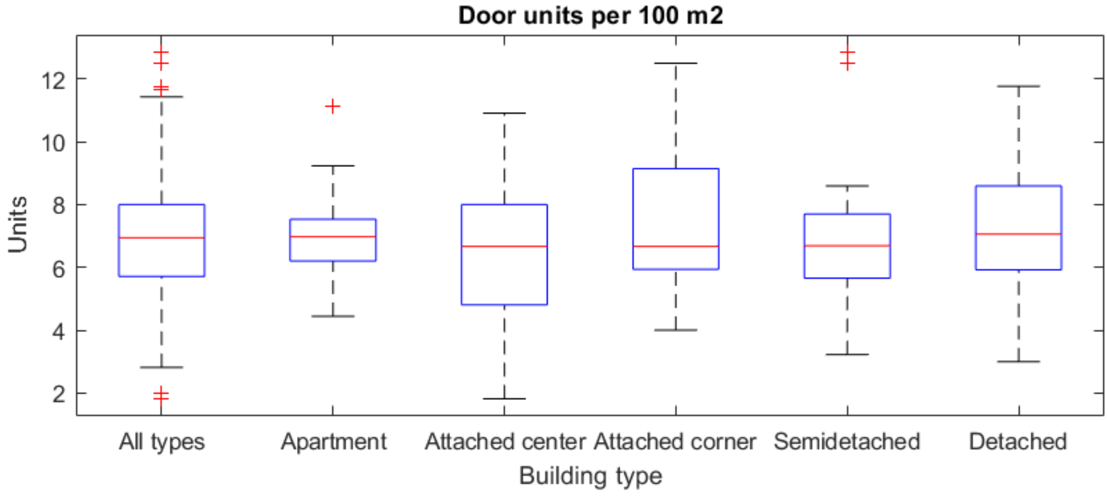


Figure 4.41 Door units per 100 m2 floor area

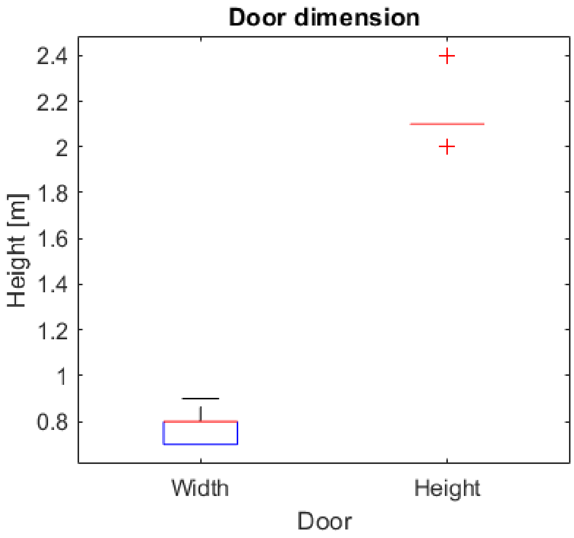


Figure 4.42 Door dimensions from virtual survey

d) Windows

The number of windows fluctuates between building type as seen in Figure 4.43, however, its median value fluctuates between 5.5 and 6.6 windows per 100 m^2, as the case of apartment and attached corner buildings, respectively. Therefore, 6 is the estimated number of windows per 100 m^2.

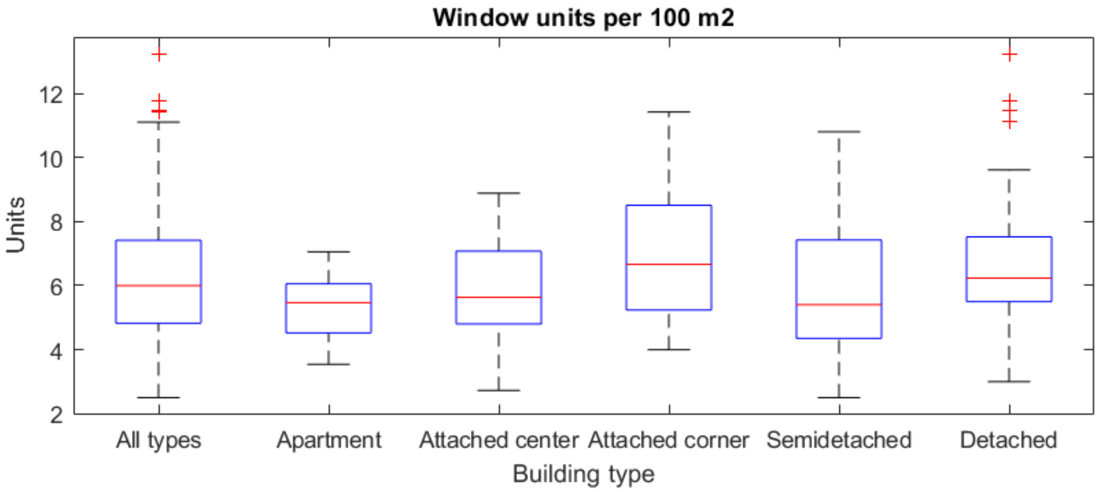


Figure 4.43 Window units per 100 m^2 floor area

In case of window dimensions, their typical height is between 1.4 to 1.5 m, and there is a larger variation between width due to their location between rooms, being its median dimension 1.4x1.4 m as seen in Figure 4.44.

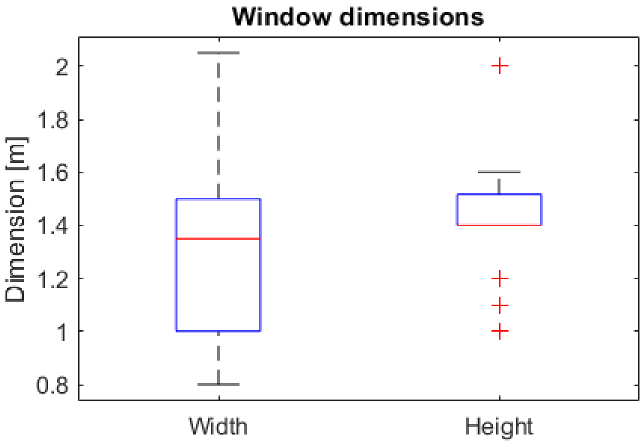


Figure 4.44 Window dimensions from virtual survey

The location of windows with respect to the ground floor and first floor mostly fluctuates between 0.9 m to 1.0 m having a shorter median height for the first floor as seen in Figure 4.45. When the location of window was measured from the street level, a higher range from 1 m to 1.25 m height was found due to the presence of ground floor level or due to the building located on a slope. Considering the median height from street level as 1.15 m, the standard height is assumed as 1.1 m.

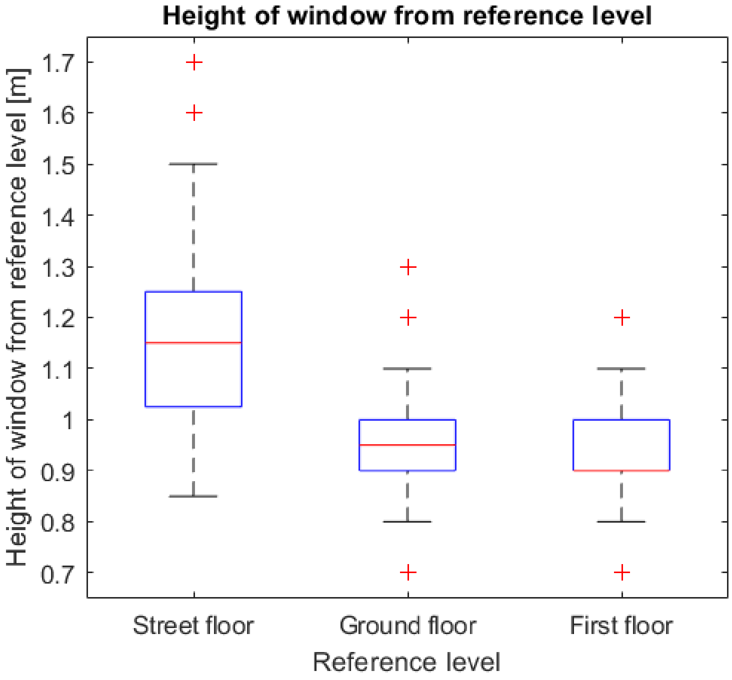


Figure 4.45 Height of window from reference level

As a summary of the hazard parameters and building characteristics evaluated for the regions within the Po River basin, the default parameters considered in INSYDE are shown in the following tables.

Table 4.11 Default hazard parameters in Po River basin

Variable	Description	Unit of measure-ment	Range of values	Default values
h_e	Water depth outside the building	m	≥0	[0;5] Incremental step: 0.01 m
h	Water depth inside the building (for each floor)	m	[0;IH]	$h = f(h_e, GL)$
v	Maximum velocity of the water perpendicular to the building	ms^{-1}	≥0	0.3
s	Sediment load	% on the water volume	[0;1]	0.05
d	Duration of the flood event	h	>0	36
q	Water quality (presence of pollutants)	-	0: No 1: Yes	1

Table 4.12 Default building characteristics in Po River basin

Variable	Description	Unit of measu-rement	Range of values	Default values
FA	Footprint area	m^2	>0	160: Detached 110: Semi-detached 95: Apartment 85: Attached corner and Attached center
IA	Internal area	m^2	>0	$0.9 \cdot FA$
BA	Basement area	m	≥0	$0.5 \cdot FA$
EP	External perimeter	m	>0	4.1 √FA (Detached) 3 √FA (Semi-detached) 0.2885 FA-6.9729 (Apartment) 3 √FA (Attached corner) 2 √FA (Attached center)
IP	Internal perimeter	m	>0	0.6254 FA+20.151 (Detached) 0.6105 FA+20.119 (Semi-detached) 0.6576 FA+20.366 (Apartment) 0.6902 FA+9.707 (Attached corner) 0.559 FA+16.801 (Attached center)

Table 4.13 Default building characteristics in Po River basin (continuation)

Variable	Description	Unit of measu-rement	Range of values	Default values
BP	Basement perimeter	m	>0	$4.2 \cdot \sqrt{FA}$
NF	Number of floors	-	≥1	2
IH	Interfloor height	m	>0	3
BH	Basement height	m	>0	2.8
GL	Ground floor level	m	[IH;>0]	0.1
BL	Basement level	m	<0	-GL-BH-0.3
BT	Building type	-	1: Detached house 2: Semidetached house 3: Apartment house 4: Attached corner 5: Attached center	1
BS	Building structure	-	1: Reinforced concrete 2: Masonry	2
FL	Finishing level	-	0.8: Low 1: Medium 1.2: High	1.2
LM	Level of maintenance	-	0.9: Low 1: Medium 1.1: High	1
YY	Year of construction	-	≥0	≤1990
PD	Heating system distribution	-	1: Centralized 2: Distributed	1 if YY≤1990 2 otherwise
PT	Heating system type	-	1: Radiator 2: Pavement	1 if YY≤2005 2 otherwise

4.4 Damage function adjustment

Updating of the original INSYDE aimed also at verify and modify, if required, assumed damage functions, fragility functions, and unit prices.

4.4.1 Damage function assumptions

There is no modification of the predefined damage function assumptions. In addition, from the virtual survey and data statistics, the damage subcomponents assumptions related to the quantification and dimensions of doors and windows as part of removal damage component, the position of the radiator from the floor level as part of damage component of building systems, and the position of the electrical subcomponents from the floor level as part of building systems component have been verified.

4.4.2 Fragility function

The fragility functions defined in the original INSYDE are also contemplated to be used in the Po River basin with the defined thresholds, except for the water depth fragility function that affects windows.

In the case of water depth fragility function that affects the windows in each flooded storey (FF5), windows are considered to start to be affected when water reaches the height of 1.1 m from the street level due to being the mean height value obtained from the statistical analysis of the virtual survey (see subchapter 4.3.3). Therefore, the threshold for no damage scenario is reduced from 1.2 m (original INSYDE) to 1.1 m as seen in Figure 4.46.

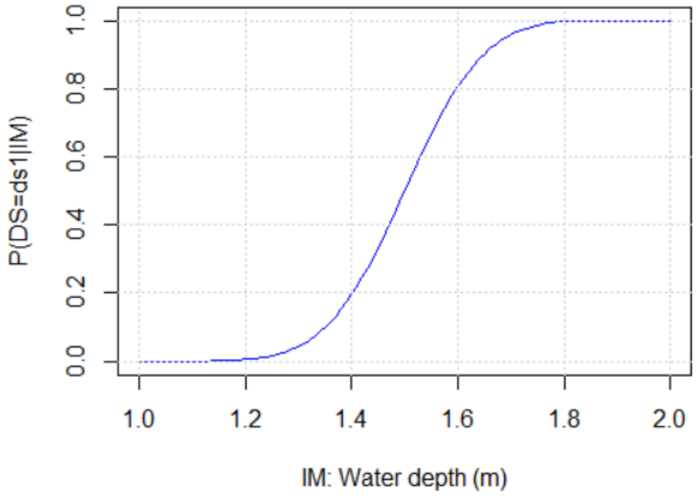


Figure 4.46 New water depth fragility function that affects windows in each flooded storey (new FF5)

4.4.3 Unit prices

The Italian price list of the year 2013, applied in the original INSYDE (Dottori F. et al., 2016) has been considered as an initial reference for the cost damage of each subcomponent. Price list has been updated up to 2021 by considering the discount rate supplied by ISTAT.

Updated unit prices for the cost of damage of subcomponents to be applied in Po River basin are shown below.

Table 4.14 Unitary prices for damage subcomponents (2021)

Components	Subcomponents	Unit	Default value
Clean-up	C1 - Pumping	€/m^3	2.67
	C2 - Waste disposal	€/m^3	37.31
	C3 - Cleaning	€/m^2	2.56
	C4 - Dehumidification	€/m^3	5.33
Removal	R1 - Screed	€/m^2	12.58
	R2 - Pavement (wood)	€/m^2	6.61
	R3 - Baseboard	€/m^2	0.67
	R4 - Partition walls	€/m^2	15.88
	R5 - Plasterboard	€/m^2	12.58
	R6 - External plaster	€/m^2	7.57
	R7 - Internal plaster	€/m^2	7.57
	R8 - Doors	€/m^2	22.49
	R9 - Windows	€/m^2	22.49
	R10 - Boiler	€/m^2	0.27
Non-structural	N1 - Partitions replacement	€/m^2	71.64
	N2 - Screed replacement	€/m^2	19.93
	N3 - Plasterboard replacement	€/m^2	48.5
Structural	S1 - Soil consolidation	€/m^2	309.14
	S2 - Local repair	€/m^2	39.98
	S3 - Pillar repair	€/m^2	341.12
Finishing	F1 - External plaster replacement	€/m^2	29.32
	F2 - Internal plaster replacement	€/m^2	26.97
	F3 - External painting	€/m^2	10.98
	F4 - Internal painting	€/m^2	8.63
	F5 - Pavement replacement	€/m^2	120.46
	F6 - Baseboard replacement	€/m	2.56
Windows & Doors	W1 - Door replacement	€/m^2	207.87
	W2 - Window replacement	€/m^2	286.22

Table 4.15 Unitary prices for damage subcomponents (2021) (Continuation)

Building systems	P1 - Boiler replacement	€/m^2	18.97
	P2 - Radiator painting	€/n	66.09
	P3 - Replacement of underfloor heating system	€/m^2	76.75
	P4 - Electrical system replacement	€/m^2	45.73
	P5 - Plumbing system replacement	€/m^2	30.81

Chapter 5: Validation

The following chapter reports the results of the validation of the updated INSYDE for two flood events occurred in the last years in northern Italy (Adda 2002 and Bacchiglione 2010). The availability of detailed information of hazard and building features for the two case studies also allowed a check for the representativeness of the default values assumed in the updated INSYDE.

5.1 Case studies

5.1.1 Adda 2002

In November 2002, the province of Lodi, located in Lombardy region, was affected by several floods which were triggered by intense precipitation that occurred between Piemonte and Lombardy region affecting the Adda basin. Between 26 and 27 November 2002, a mix of peak flow of the Brembo river and a flood wave coming from Como Lake generated a peak discharge of about 2000 m^3/s, with an estimated 100-year return period (Rossetti S. et al., 2010) which caused the inundation of Lodi, starting from the rural areas to the commercial and residential areas (Amadio M. et al., 2019).

From the flooded area, a sample of 271 buildings with reported loss of about EUR 5.1 million (at 2021 values) present the compiled hazard and vulnerability parameters mentioned below:

- Hazard parameters: Presence of pollutants (q), velocity (v) and water depth outside the building (he).
- Vulnerability parameters: Footprint area (FA), building structure (BS), finishing level (FL), year of construction (YY), level of maintenance (LM), building type (BT) between detached, semidetached and apartment, and basement area (BA, if it exists) are compiled for entire dataset, while number of floors (NF) and ground floor level (GL) are partially recorded in the dataset. Missing data related to hazard parameters and vulnerability parameters are defined as default values as mentioned in chapter 4, section 3.

5.1.2 Bacchiglione 2010

From 31 October to 2 November 2010, the Veneto Region was affected by persistent rain, particularly in the pre-Alpine and foothill areas, with accumulated rainfall exceeding 500 mm in some locations (Regione del Veneto, 2011). In addition to the continuous rain, the sirocco winds raised the temperature triggering snow melting, and so the water depth in Bacchiglione river and its tributaries. On the morning of 1 November, the water flowing at 330 m^3/s opened a breach on the right levee of the river, flooding the countryside and the settlements of Caldogno, Cresole and Rettorgole with an average water depth of 0.5m (ARPAV, 2010). The inundation lasted about 48 h and its extent was about 33 ha, 26 ha of which consisted of agricultural land and 7 ha of urban areas (Amadio M. et al., 2019).

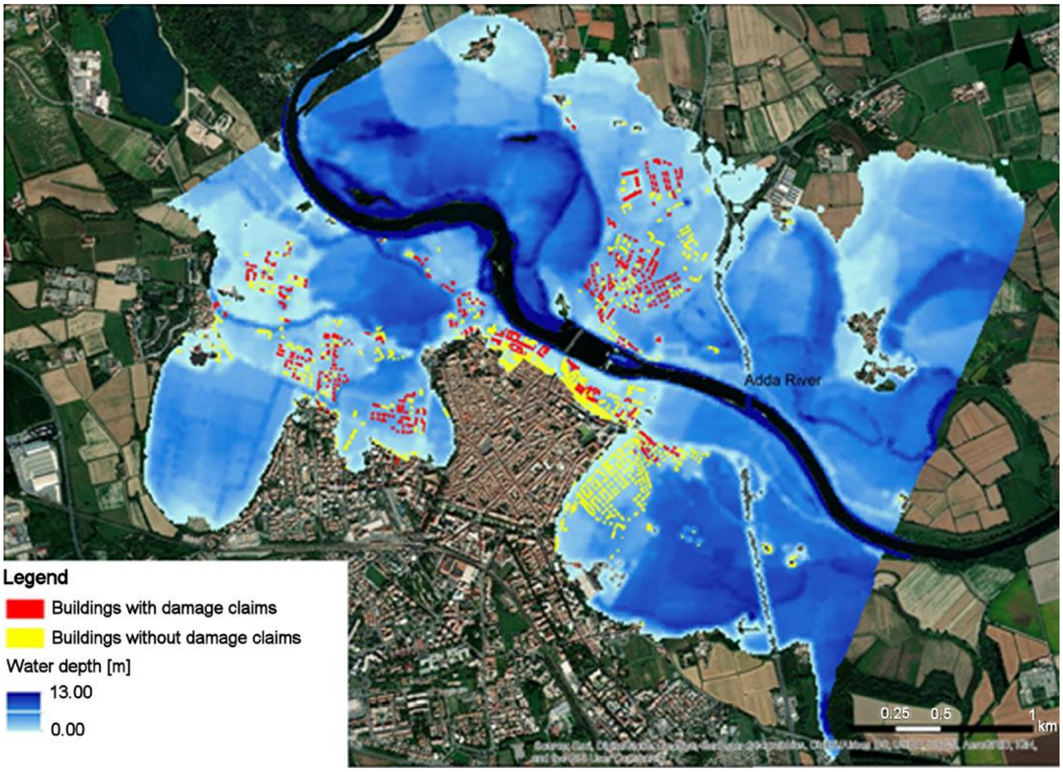


Figure 5.1 Flooded areas and affected buildings within Adda river flood in 2002. (Molinari D. et al., 2020)

From the flooded area in Caldogno, a sample of 294 buildings with reported losses of around EUR 8.3 million (at 2021 values) is used for the validation. The buildings dataset presents the following compiled parameters of hazard and vulnerability:

- Hazard parameters: For the entire dataset, there is data related to flow velocity (v), inundation duration (d) and water depth outside the building (he). The recorded values for the latter being less than 1.6 m.
- Vulnerability parameters: For the entire dataset, Footprint areas (FA), external perimeter (EP), number of floors (NF), building structure (BS), finishing level (FL), year of construction (YY), building type (BT) between detached, semidetached and apartment, and basement area (BA) if it exists. Missing data related to hazard parameters and vulnerability parameters are defined as default values as mentioned in chapter 4, section 3.

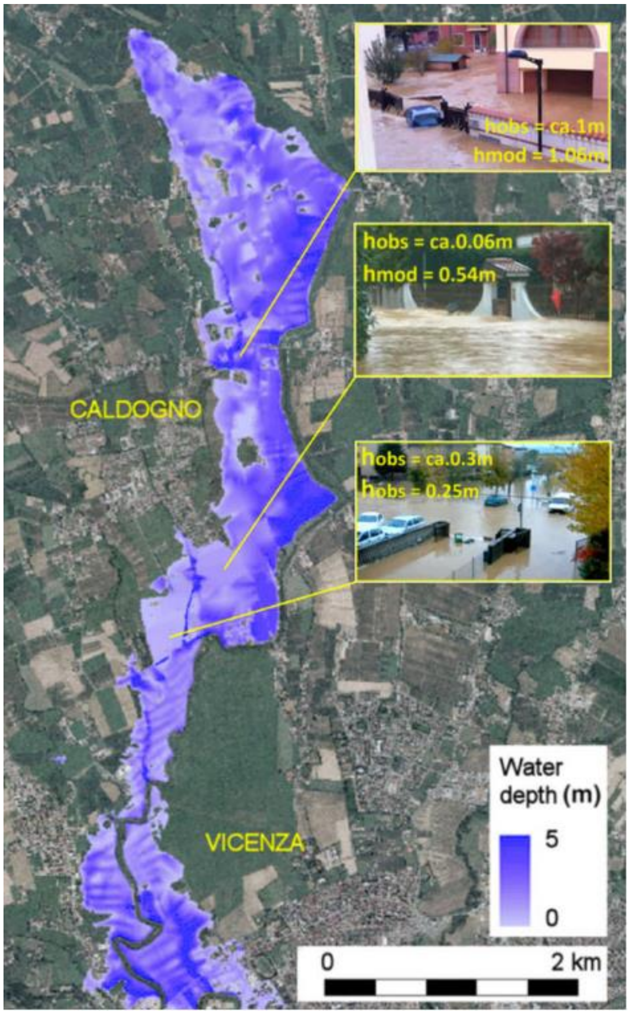


Figure 5.2 Modeled flooded area within Bacchiglione river flood in 2010 with examples of comparison between observed and calculated water depth. (Scorzini A. R. et al., 2017)

5.2 Data statistics check

5.2.1 Hazard parameters

a) Water depth

Lodi and Caldogno case study present maximum values of water depth of about 2 and 1.6 m, respectively, being inside the range of extreme values of water depth. Moreover, the mean values of water depth are also inside the mean values range of 0.2 to 1.6 m, defined in chapter 4.

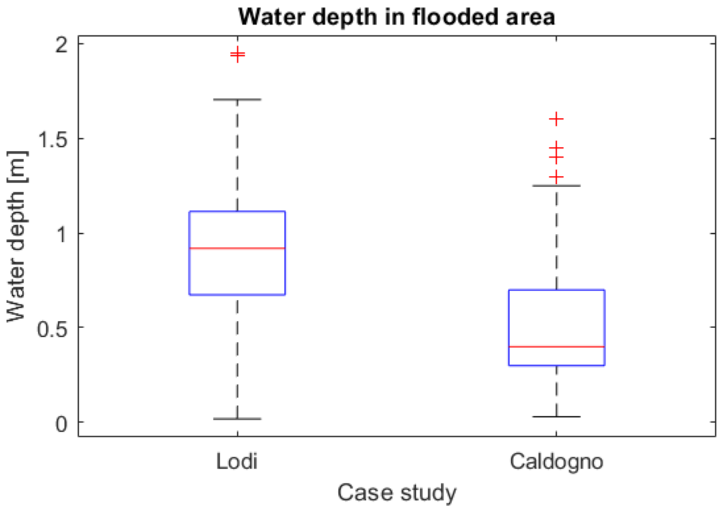


Figure 5.3 Water depth in flooded area

b) Flow velocity

From flooded area of Lodi and Caldogno case study, the median velocities are between 0.2 and 0.3 m/s, showing closeness to the default value 0.3 m/s defined in data statistics.

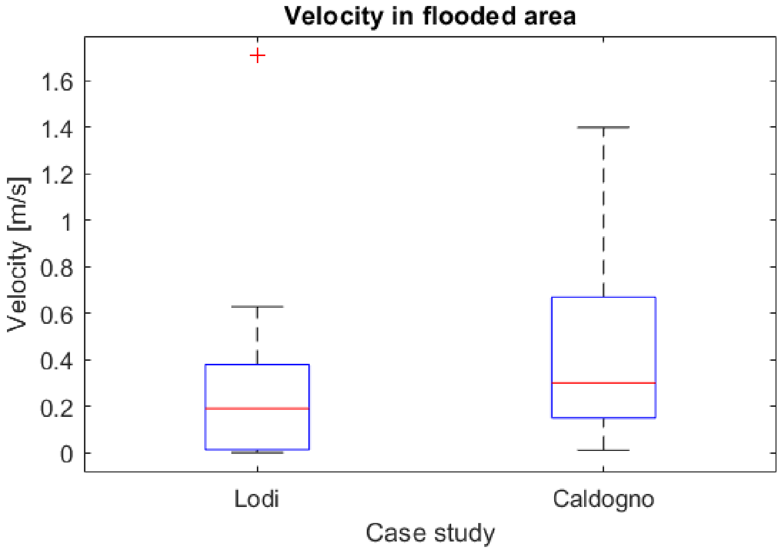


Figure 5.4 Velocity in flooded area of case studies

5.2.2 Building characteristics

a) Footprint area

For footprint areas in detached houses, the default value is 160 m^2, being lower than the mean value found for the Lodi case study (110 m^2) and larger for the Caldogno case study (210 m^2). In case of semidetached houses, the default value is 110 m^2, being slightly lower than the one observed in both case studies. With respect to apartment, the default value is 95 m^2, being lower than that in both case studies. Moreover, both case studies present some buildings with footprint areas greater than 300 m^2, being outside the range of considered sample for data statistics (≤ 300 m^2).

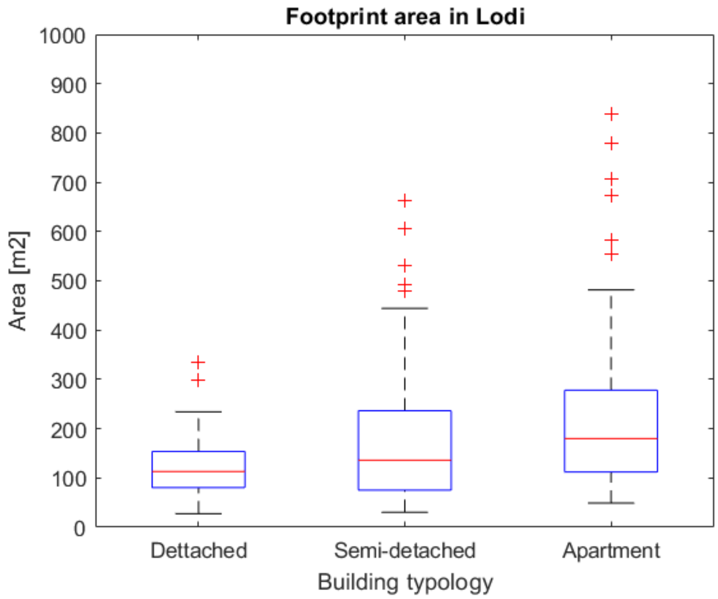


Figure 5.5 Footprint area of buildings in 2002 flood occurred in Lodi

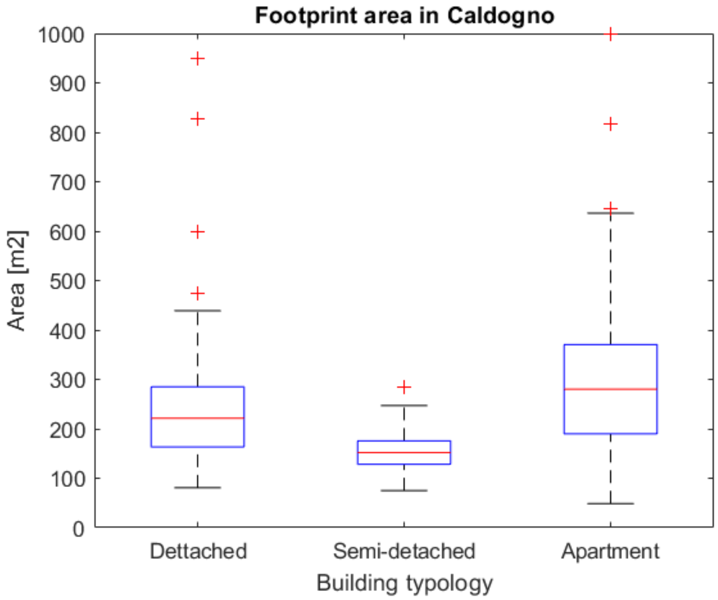


Figure 5.6 Footprint area of buildings in 2010 flood occurred in Caldogno

b) External perimeter

From Caldogno case study, the footprint areas and external perimeter per building typology have been compared considering the equations defined in updated and original INSYDE. With respect to footprint areas smaller than 300 m^2, the equations of updated INSYDE are consistent for detached and apartments, while the equation of semidetached buildings underestimating the external perimeter as seen from Figure 5.7 to Figure 5.9.

In case of buildings with footprint areas greater than 300 m^2, the equations of updated INSYDE and original INSYDE tend to underestimate significatively for detached and semidetached houses, while overestimated apartment housing units. Finally, the external perimeter equations related to original INSYDE are consistent with the observed data for footprint areas smaller than 300 m^2 for all three building types.

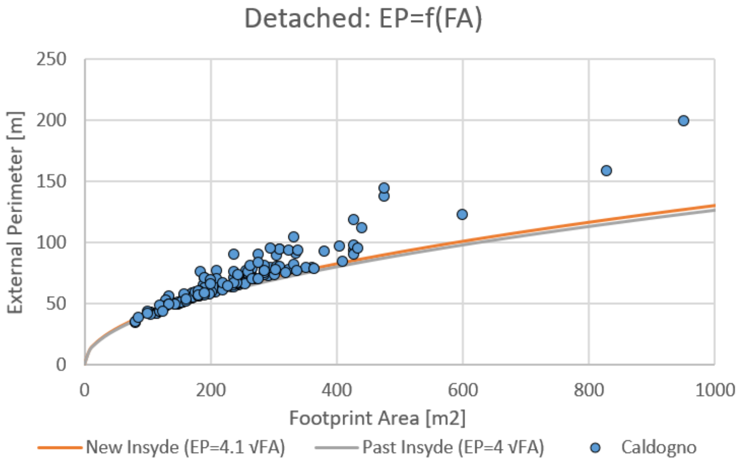


Figure 5.7 Comparison of EP=f(FA) for detached houses considering updated and original INSYDE

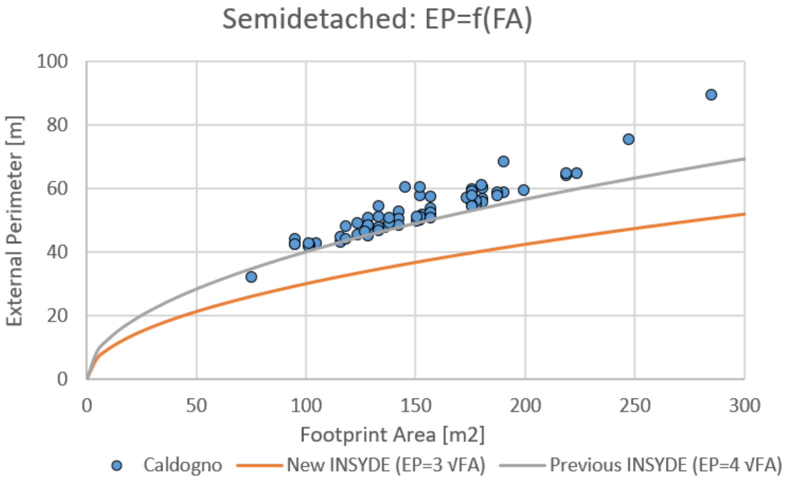


Figure 5.8 Comparison of EP=f(FA) for semidetached houses considering updated and original INSYDE

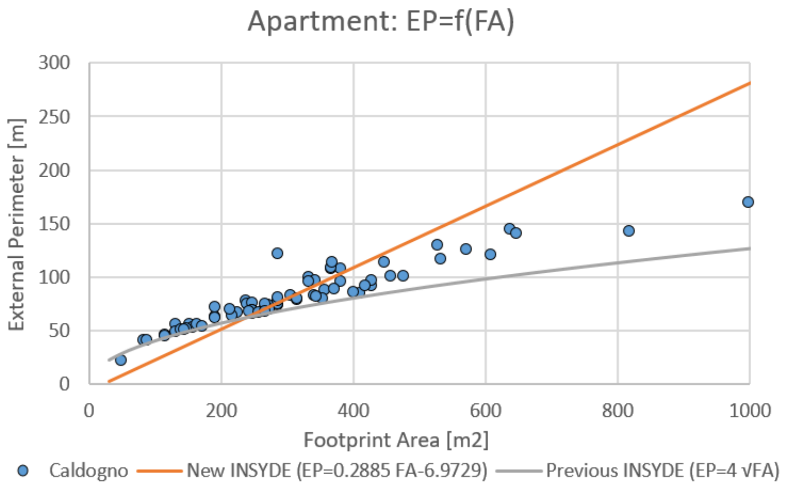


Figure 5.9 Comparison of EP=f(FA) for apartments considering updated and previous INSYDE

c) Building type

From both case studies, the buildings type identified from the flooded areas are detached, semidetached houses and apartment, being most of the flooded buildings detached houses and apartment in Caldogno and Lodi case study, respectively. The three building types are compatible with the ones analyzed in the data statistics.

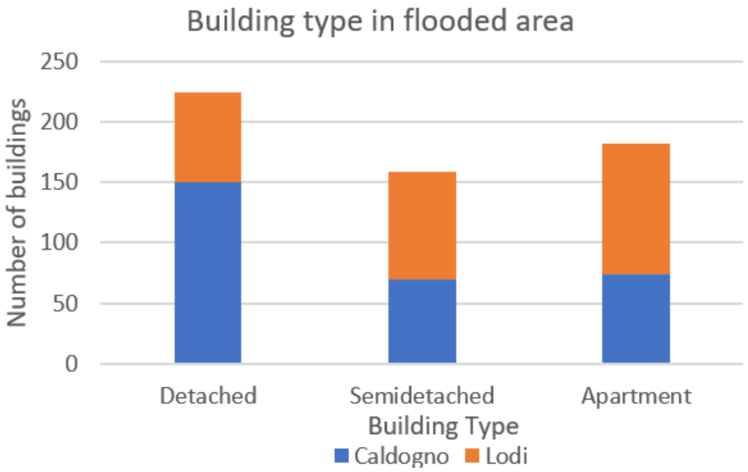


Figure 5.10 Building type in flooded areas of case studies

d) Building structure

Most of the buildings located within the analyzed flooded areas are built with reinforced concrete, differently to the masonry default value considered as default values on INSYDE. Comparison of building structure of both flooded areas is shown in Figure 5.11.

e) Finishing level

In both case studies, most of the flooded buildings have medium finishing level, being different from the high finishing level of default value obtained from the data statistics. It is worth mentioning that the default value of finishing level was defined from the sample of 119 buildings of the virtual survey with the purpose to define the typical finishing level of buildings located within the floodplain of Po River basin, while the damage data of 565 reported buildings located within the flooded areas were compiled due to the presentation of a claim. Comparison of finishing level between case studies is shown in Figure 5.12.

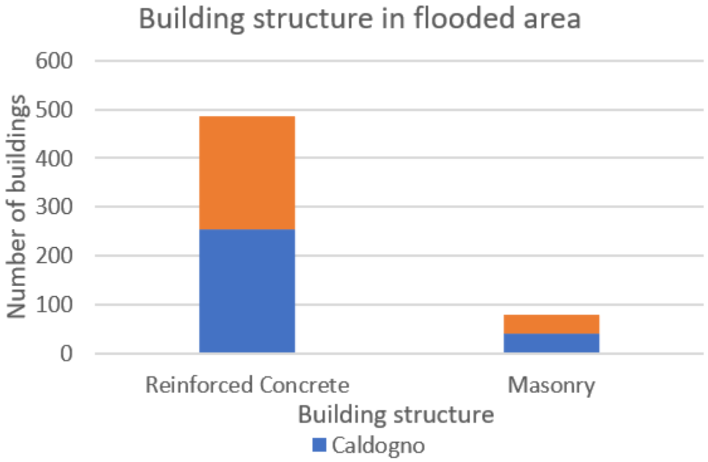


Figure 5.11 Building structure type in flooded areas of case studies

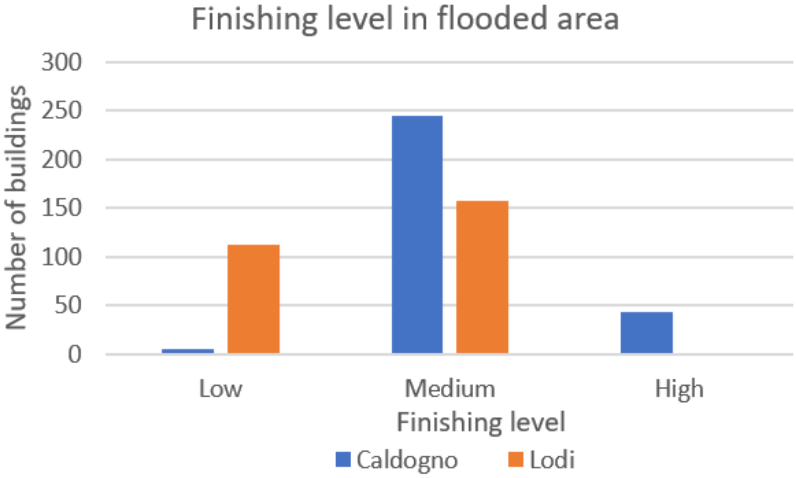


Figure 5.12 Finishing level of buildings in flooded areas of case studies

f) Number of floors

From both case studies, most of the flooded buildings have two floors, being compatible with the defined default value in data statistics.

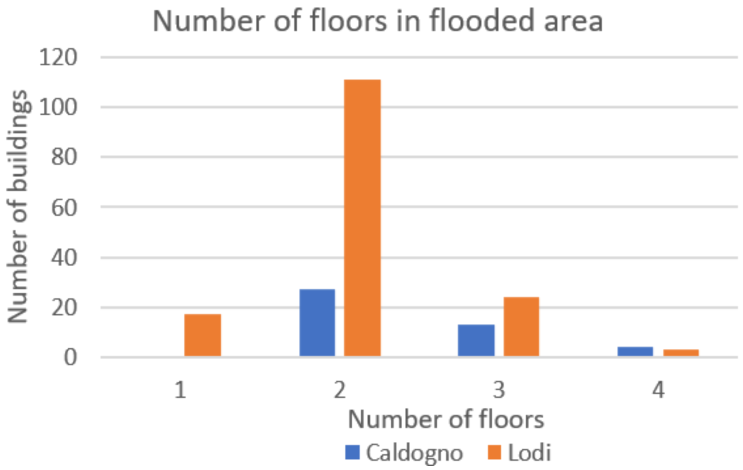


Figure 5.13 Number of floors of buildings in flooded areas of case studies

g) Year of construction

From the compiled damage buildings of flood events occurred in 2002 (Lodi) and 2010 (Caldogno), the 97% and around 70% of buildings from mentioned cases were built before 1990, showing agreement with the default value.

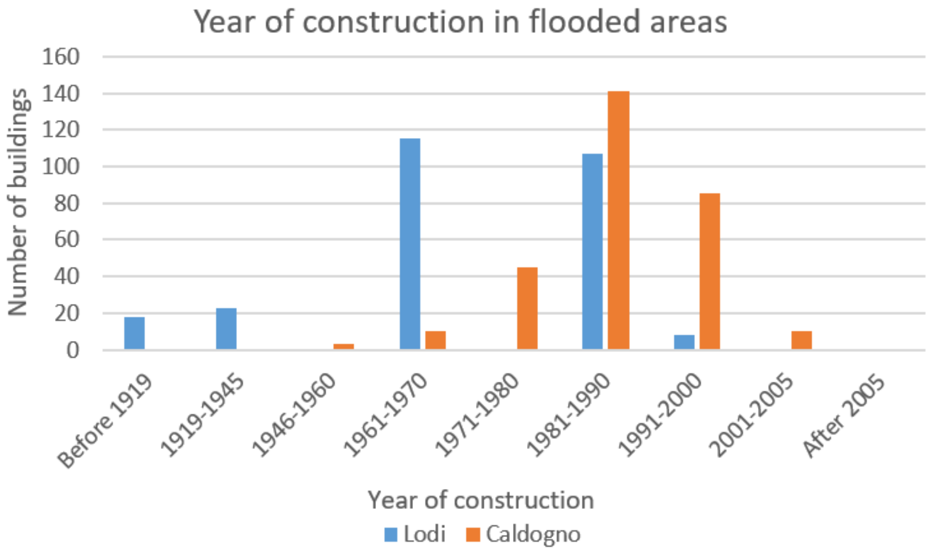


Figure 5.14 Year of construction in flooded areas of case studies

h) Ground floor level

From the flooded area of Lodi case study, the median and average ground floor level are 0.3 and 0.4 m, respectively, being outside the 25th and 75th percentiles of the ground floor levels compiled in the field survey (from 0 to 0.2 m) for the definition of default value. However, values of ground floor level up to 0.8 m were identified in the virtual survey, therefore, the ground floor level of Lodi cases study is comparable to the values found in the virtual survey, but they are not considered as representative.

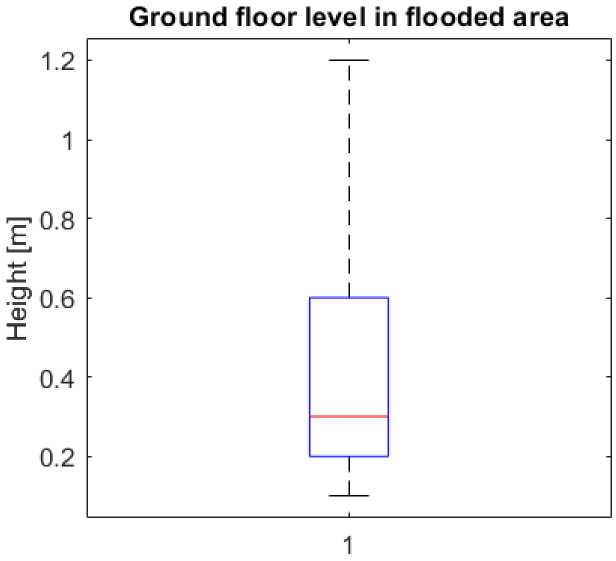


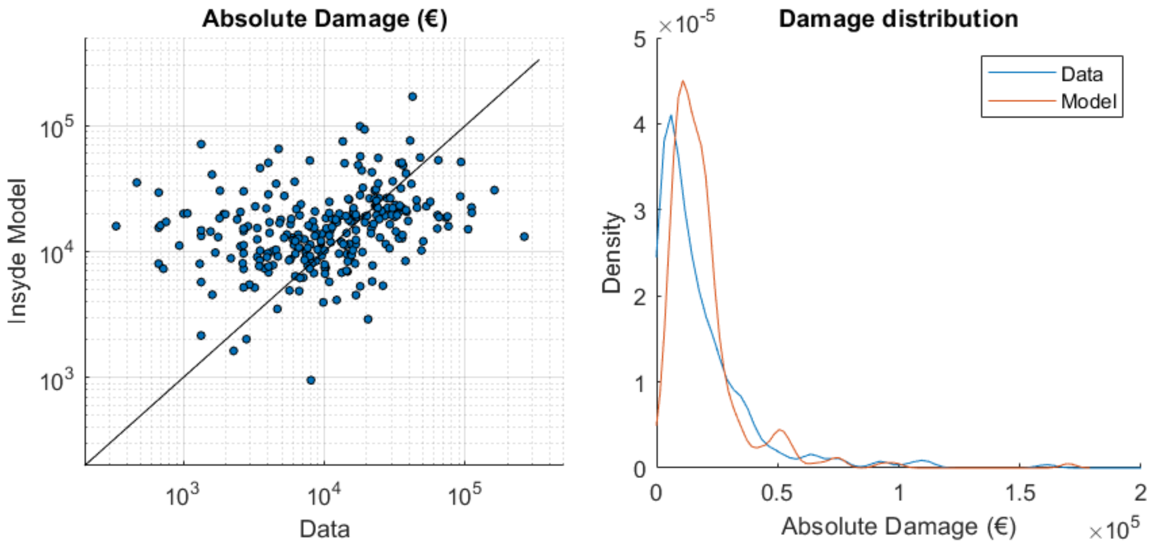
Figure 5.15 Ground floor level in flooded area of Lodi case study

5.3 Validation of damage model

5.3.1 Adda 2002

From the updated version of INSYDE, the calculated loss is about EUR 5.26 million, with a relative error of about +4.1% (RMSE=EUR 28,000) with respect to the reported loss in Adda river flood. Additionally, as a comparison with the original INSYDE, and as seen in Table 5.1, a calculated loss of about EUR 5.58 million with an approximate +10.4 % relative error is obtained, reaching a reduction of about half amount of relative error and a slight incrementation of the root mean square error (RMSE) with the updated INSYDE. From Figure 5.16.a, the comparison between updated INSYDE absolute calculated damage and reported damage shows that the calculated losses tend to overestimate low values and to underestimate high values. However, even though the variability between reported and calculated damage, there is a similar damage distribution as seen in Figure 5.16.b.

In updated INSYDE, the analysis of extensive parameters of dwellings (e.g. external perimeter) realized within data statistics has a validation range of up to 300 m^2 of footprint area (see chapter 4, section 3). Furthermore, the original INSYDE fails in estimating default extensive parameters for large buildings, therefore, to see the performance of damage estimation of the updated INSYDE respect to small and large buildings, the validation analysis is then focused on two subsets of buildings, characterized by footprint areas larger or smaller than 300 m^2. In this case, 239 buildings were smaller than 300 m^2 and 32 bigger than 300 m^2.



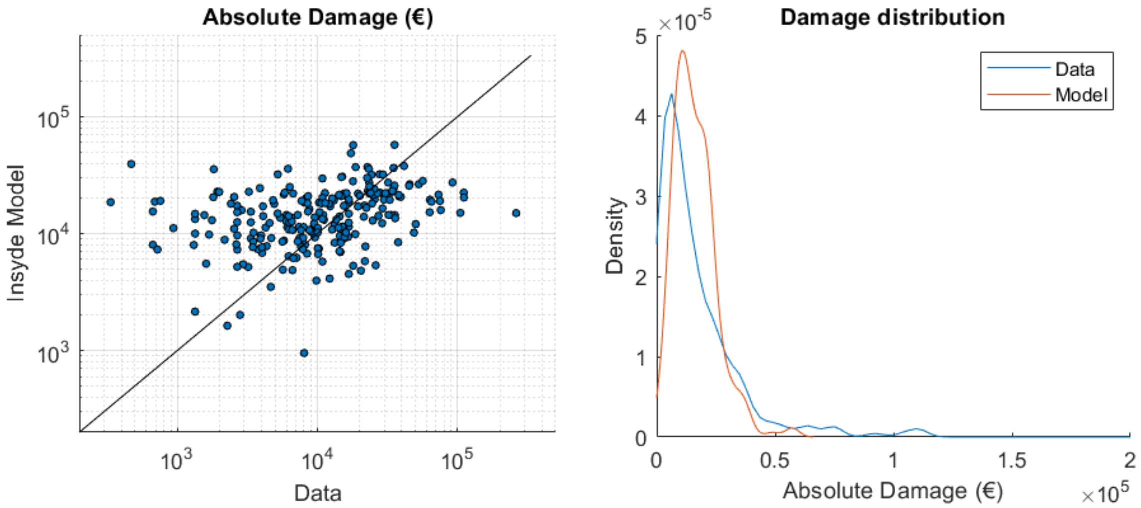
(a) (b)

Figure 5.16 Comparison of observed and modeled absolute damage of buildings affected by the 2002 flood in Lodi area considering updated INSYDE. (a) Scatter plot (b) Kernel density plot

Table 5.1 Comparison of observed and modeled total damage obtained by original and update INSYDE model (Lodi case study)

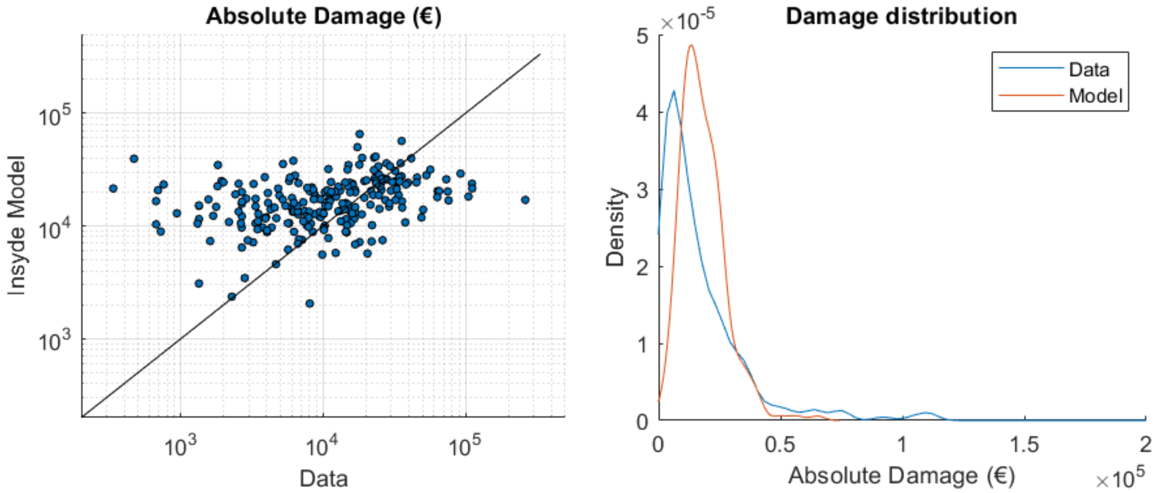
	Real Damage	Original INSYDE	Updated INSYDE
Total [EUR million]	5.05	5.58	5.26
Relative error [%]		+10.4	+4.1
RMSE [EUR]		26,800	28,000

For the first category, the calculated losses with updated INSYDE are about EUR 3.86 million, having a -9% relative error with respect to the observed loses, while the original INSYDE shows an overestimation of +2.7% respect to observed losses. Therefore, in Lodi case study, updated INSYDE tends to underestimate the total damage of buildings for footprint areas smaller than 300 m^2, showing a slight decrement of root mean square error (RMSE) with respect to original INSYDE, as seen in Table 5.2. From Figure 5.17 and Figure 5.18, the calculated damage shows the overestimation of low damages and the underestimation of high damages cost in both models, however, there is a similar damage distribution between observed and calculated damage data in both models.



(a) (b)

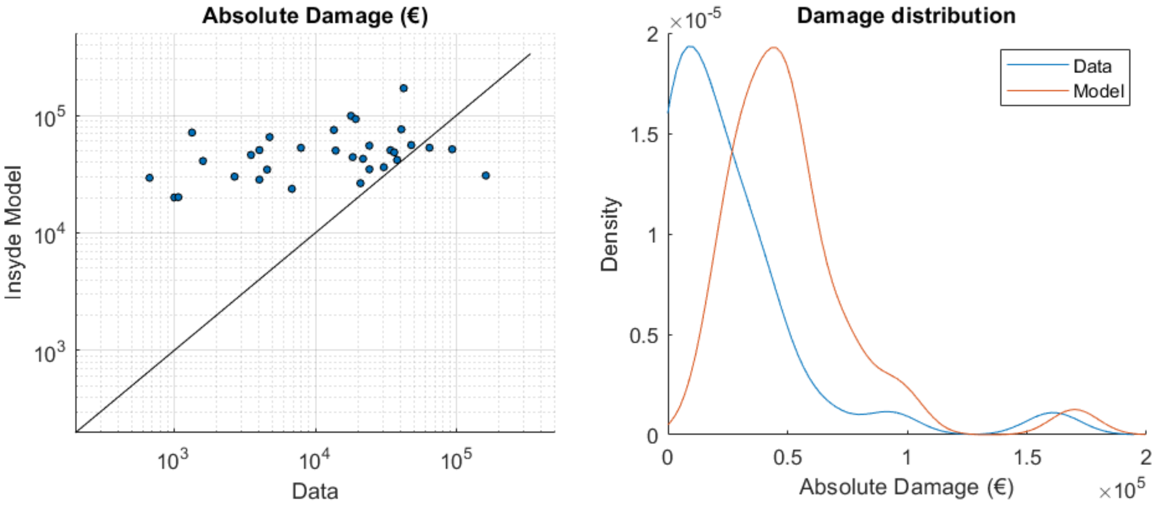
Figure 5.17 Comparison of observed and modeled absolute damage of buildings smaller than 300 m^2 affected by the 2002 flood in Lodi area considering updated INSYDE. (a) Scatter plot (b) Kernel density plot



(a) (b)

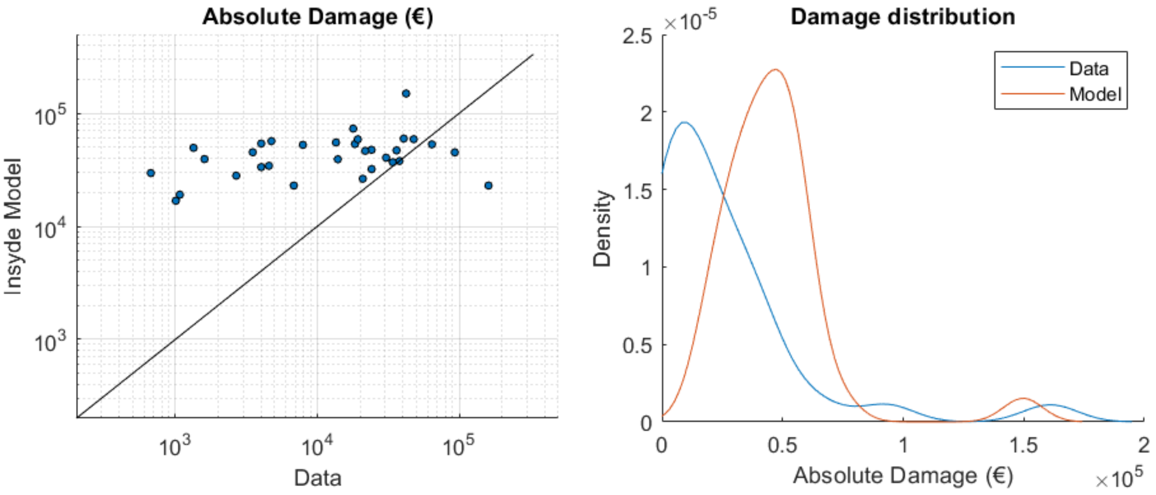
Figure 5.18 Comparison of observed and modeled absolute damage of buildings smaller than 300 m^2 affected by the 2002 flood in Lodi area considering original INSYDE. (a) Scatter plot (b) Kernel density plot

With respect to buildings larger than 300 m^2, the calculated losses with updated INSYDE are about EUR 1.65 million with a +104.4% relative error respect to the reported losses and showing a RMSE of around EUR 48,900 which is about the double value found in buildings smaller than 300 m^2,while the original INSYDE shows an overestimation of about +82%. Additionally, the calculated absolute damage tends to overestimate the observed damage cost of most buildings, having a variation which is also detected in the damage distribution in both in original and updated INSYDE, as seen in Figure 5.19 and Figure 5.20. It is worth mentioning that the large error of the subset could be affected due to its limited size (32 buildings).



(a) (b)

Figure 5.19 Comparison of observed and modeled absolute damage of buildings larger than 300 m^2 affected by the 2002 flood in Lodi area considering updated INSYDE. (a) Scatter plot (b) Kernel density plot



(a) (b)

Figure 5.20 Comparison of observed and modeled absolute damage of buildings larger than 300 m2 affected by the 2002 flood in Lodi area considering original INSYDE. (a) Scatter plot (b) Kernel density plot

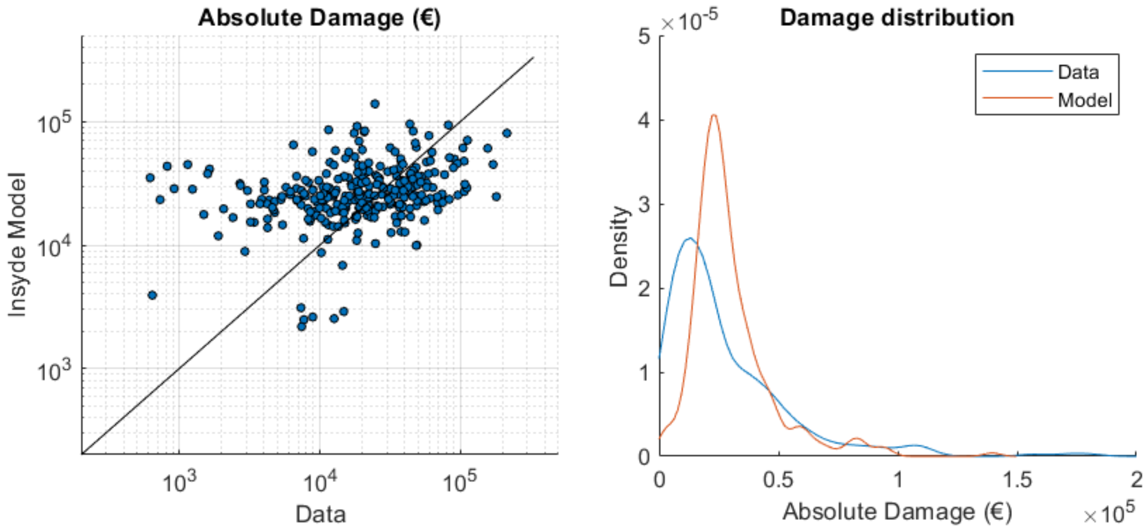
Table 5.2 Comparison of observed and modeled total damage for buildings smaller and larger than 300 m^2 obtained by original and update INSYDE model (Lodi case study)

	Smaller than 300 m^2			Larger than 300 m^2		
	Real Damage	Original INSYDE	Updated INSYDE	Real Damage	Original INSYDE	Updated INSYDE
Total [EUR million]	4.25	4.36	3.86	0.81	1.47	1.65
Relative error [%]		+2.7	-9.0		+82.0	+104.4
RMSE [EUR]		24,000	23,900		43,300	48,900

5.3.2 Bacchiglione 2010

Considering the updated INSYDE, the calculated loss is about EUR 8.81 million, having a relative error of about +5.5% (RMSE=EUR 29100) with respect to the reported loss in Bacchiglione river flood. The calculated loss of around EUR 9.42 million with an approximate +12.9% relative error is obtained using original INSYDE, getting a reduction of about half value of relative error and a slight increment of root mean square error with the updated INSYDE. In addition to updated INSYDE, the comparison between absolute calculated damage and reported damage (see Figure 5.21) shows that there is presence of both underestimation and overestimation of reported absolute damage, while the damage distribution of calculated damage and reported loses cases differ between them.

Remark: From Dottori et al. (2016), the calculated damage with original INSYDE shows a relative error of -1.7%. While in this work the relative error is +12.9%. It can be explained by the fact that in this thesis the analyses have been performed by using an amended version of the original model (bugs corrected, etc.).



(a) (b)

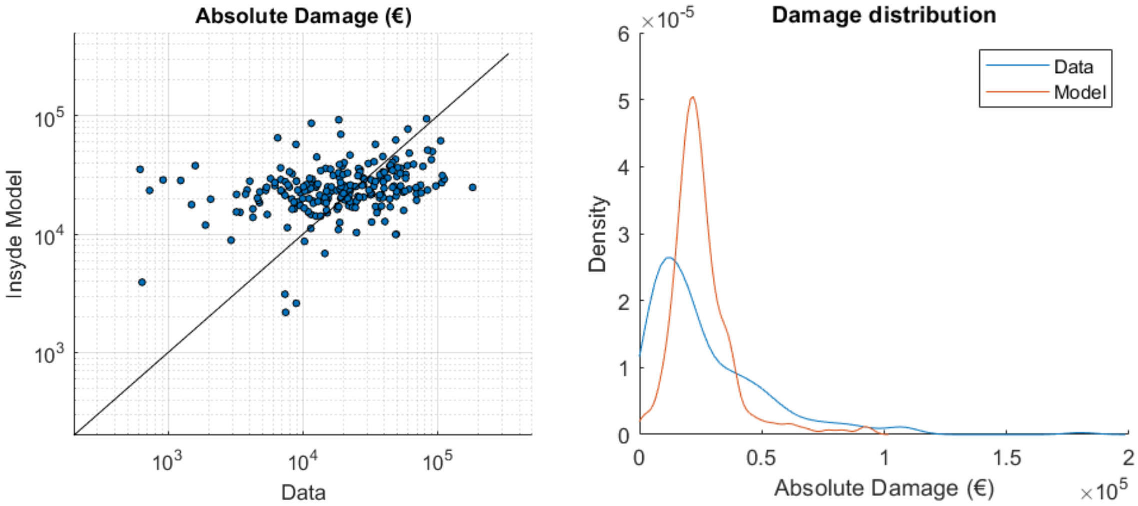
Figure 5.21 Comparison of observed and modeled absolute damage cost of buildings affected by the 2010 flood in Caldogno area. (a) Scatter plot (b) Kernel density plot

Table 5.3 Comparison of observed and modeled total damage obtained by original and update INSYDE model (Bacchiglione case study)

	Real Damage	Original INSYDE	Updated INSYDE
Total [EUR million]	8.35	9.42	8.81
Relative error [%]		+12.9	+5.5
RMSE [EUR]		29,000	29,100

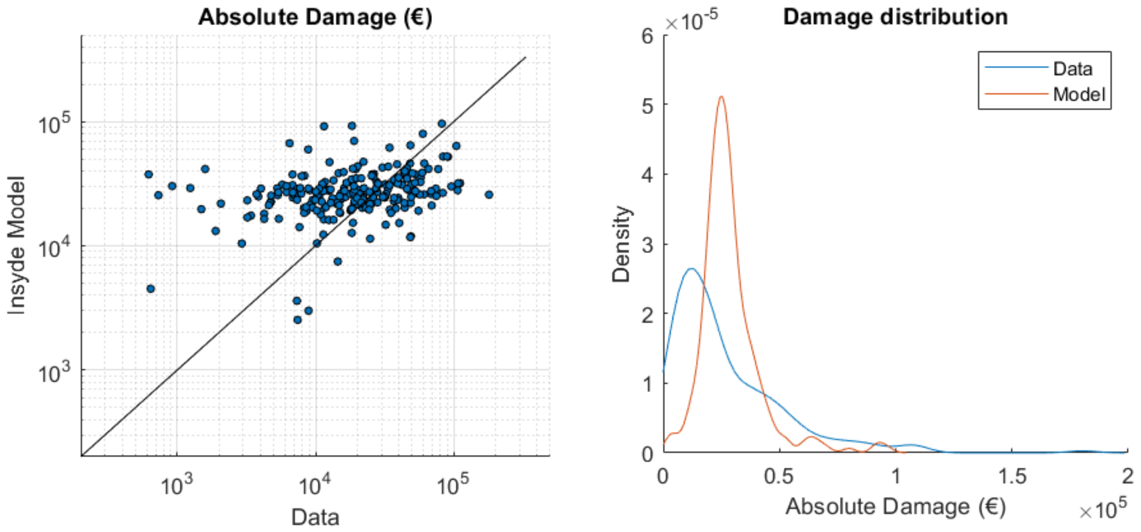
As for the Adda case, the analysis is also performed by considering two subsets of buildings, the ones larger than 300 m^2 (64 buildings) and the ones smaller than 300 m^2 (230 buildings).

For buildings smaller than 300 m^2, the calculated losses with updated INSYDE are about EUR 6.04 million, having a -2.6% relative error with respect to the observed losses, while the calculated losses with original INSYDE shows an overestimation of about +6.5%. From Figure 5.22 and Figure 5.23, the calculated damage shows the overestimation of low damage and the underestimation of high damage on both original and updated INSYDE, while there are different damage distributions between calculated damage and reported damage.



(a) (b)

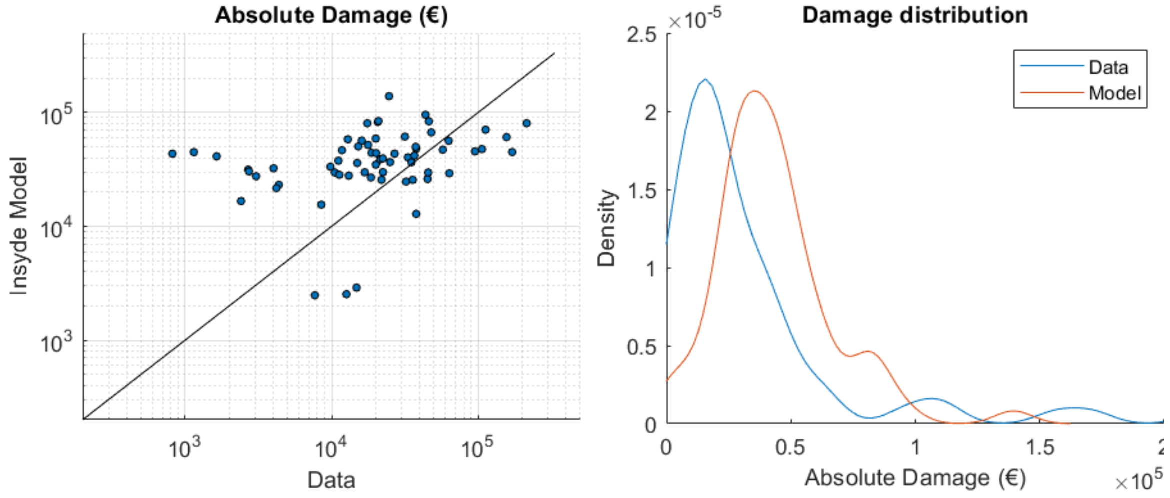
Figure 5.22 Comparison of observed and modeled damage cost of buildings smaller than 300 m^2 affected by the 2010 flood in Caldogno area considering updated INSYDE. (a) Scatter plot (b) Kernel density plot



(a) (b)

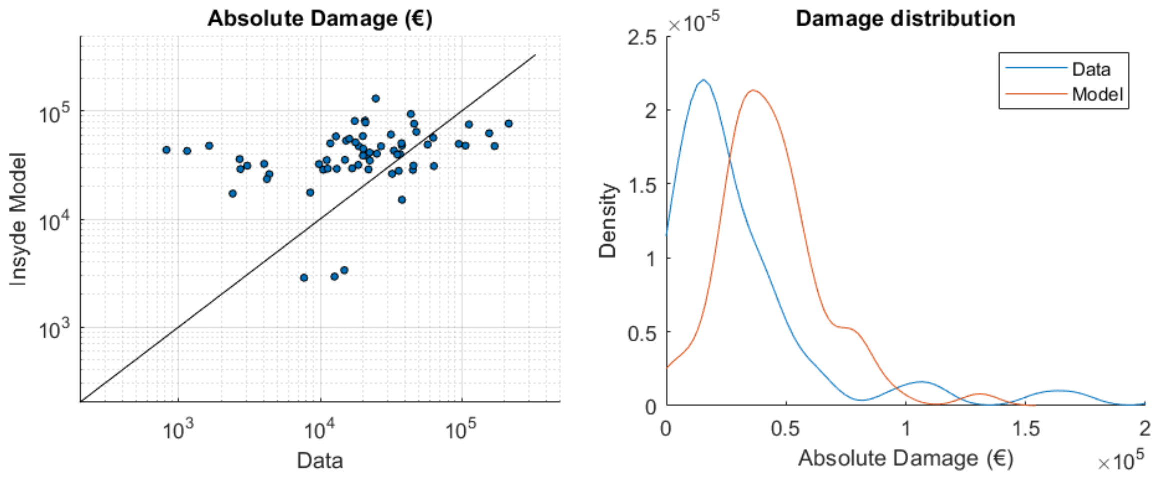
Figure 5.23 Comparison of observed and modeled damage cost of buildings smaller than 300 m2 affected by the 2010 flood in Caldogno area considering original INSYDE. (a) Scatter plot (b) Kernel density plot

For buildings bigger than 300 m^2, the calculated losses with updated INSYDE are around EUR 2.76 million, having a +29% relative error with respect to the observed losses and EUR 41,100 as RMSE, which represents about the double value determined in buildings smaller than 300 m^2. In addition, calculated losses with original INSYDE show a relative error of about +31.2% with a RMSE slightly smaller than updated INSYDE, as seen in Table 5.4. From Figure 5.24. and Figure 5.25, the calculated damage values with both updated and original INSYDE show the overestimation of low damage and the underestimation of high damage cost.



(a) (b)

Figure 5.24 Comparison of observed and modeled damage cost of buildings greater than 300 m^2 affected by the 2010 flood in Caldogno area considering updated INSYDE. (a) Scatter plot (b) Kernel density plot



(a) (b)

Figure 5.25 Comparison of observed and modeled damage cost of buildings greater than 300 m2 affected by the 2010 flood in Caldogno area considering original INSYDE. (a) Scatter plot (b) Kernel density plot

Table 5.4 Comparison of observed and modeled total damage for buildings smaller and larger than 300 m^2 obtained by original and update INSYDE model (Bacchiglione case study)

	Smaller than 300 m^2			Larger than 300 m^2		
	Real Damage	Original INSYDE	Updated INSYDE	Real Damage	Original INSYDE	Updated INSYDE
Total [EUR million]	6.21	6.61	6.04	2.14	2.81	2.76
Relative error [%]		+6.5	-2.6		+31.2	+29
RMSE [EUR]		24,800	24,800		40,600	41,100

From the two considered case studies, it can be concluded that there is an improvement of closeness between calculated and observed losses for the entire datasets showing relative errors being reduced to about the half (i.e. from +10.4 to +4.1% in Lodi), but with an slight increment of the root mean square error (RMSE) of EUR 100 in Caldogno case study (Bacchiglione 2010) and EUR 1,200 in Lodi case study (Adda 2002), relative to original INSYDE. With respect to the check of the data statistics, the hazard parameters of the case study are compatible with the default values, and in case of the building characteristics, the results partially agree with the default values. Most flooded buildings have building structure as reinforced concrete being different from the default value (i.e. masonry) and most building present medium finishing level being different from the default value (i.e. high). The representative number of floors is 2 and most buildings were built before 1990 agreeing with default values in both cases, while the median ground floor level in Lodi case study is 0.3 m being different to the default value assumed in updated INSYDE. The default value of footprint areas in both case studies differ from the calculated default values reporting maximum footprint areas up to 1000 m^2. In addition, in case of external perimeter for building smaller than 300 m^2 reported in Caldogno case study, updated and original INSYDE are consistent for detached houses, semidetached houses and apartments, with exception of the underestimation in semidetached houses with updated INSYDE, while for building larger than 300 m2, both models show the underestimation of external perimeters with exception of the overestimation in apartments with updated INSYDE. In addition, considering that original INSYDE fails in the estimation of extensive parameters (e.g. external perimeter) for large buildings, and that updated INSYDE has a validation area range up to 300 m^2 for default values of extensive parameters (see chapter 4, section 3), the dataset of both case studies have been subdivided in subsets of footprint areas smaller than 300 m^2 and bigger than 300 m^2 to see the performance of damage estimation of small and large buildings with updated INSYDE. For the first category, the total damage calculated with updated INSYDE has relative errors of -9% and -2.6% in Lodi and Caldogno case study, respectively, while with the original INSYDE the relative errors are +2.7% and +6.5%, respectively, having a slight variation of RMSE smaller than EUR 100 between both models and in both case studies. In addition to subset of footprint areas smaller than 300 m2, the damage calculated with updated and original INSYDE shows the overestimation of low damages and the underestimation of high damage of buildings in both case studies, having different observed and calculated damage distributions in Caldogno case study and similar observed and calculated damage distributions in Lodi case study. In case of the subset of buildings larger than 300 m2, the total damage calculated with updated INSYDE is +104.4% and +29% in Lodi and Caldogno case study, respectively, while the relative errors with the original INSYDE are +82% and +31.2%, respectively, showing RMSE range between EUR 40,000 and EUR 48,000 which is about the double value found in buildings smaller than 300 m^2. In addition, the overestimation of low damages and underestimation of high damages is observed in both cases, having most buildings of Lodi case study the overestimation of damage which is also detected in the damage distribution. Nevertheless, it is worth mentioning that the high relative error in buildings larger than 300 m^2 in Lodi case study could be caused due to the limited size of the subset (32 buildings). Therefore, it can be concluded that for footprint areas smaller than 300 m^2 the total damage calculated with updated INSYDE tends to underestimate the reported damages being different to the overestimation calculated with original INSYDE, while for footprint areas bigger than 300 m^2, both updated and original INSYDE overestimate the reported damage of buildings.

Chapter 6: Conclusions

Floods have a high socio-economic impact that can be reduced by proper flood risk assessment and management. Flood damage models are key tools of such process. Based on the literature, some authors recommend the consideration of multivariable flood damage models to perform a better understanding of the complex process of flood damage taking into account additional (hazard and building) parameters to water depth. INSYDE is a synthetic model that estimates direct flood damage to residential buildings using 18 parameters of building characteristics and 6 hazard parameters. Multivariable synthetic damage model can get to use abundant data which may be not available, therefore, INSYDE proposes the definition of default values. In the updating process performed in this study, the latter was obtained from a rigorous statistical analysis of hazard, exposure, and vulnerability data in the Po River basin. However, not enough pre-existing data was found to support the calculation of all parameters included in INSYDE. Hence, default values of hazard parameters as flood duration, sediment load and water quality were assumed as the values defined in the original INSYDE due to their applicability in northern Italy, while missing data related to building characteristics was supplemented by the statistical analysis of compiled data from a virtual survey of residential buildings located in rural and urban areas prone to flooding. In the case of updated hazard parameters, the range of water depth variation (i.e. 0 to 5 m) assumed in the original INSYDE has been verified, and the flow velocity has been reduced from 0.5 to 0.3 m/s according to the analysis of flood maps elaborated by the Po River Basin District Authority. Regarding the updated building characteristics, five building types are considered, adding attached buildings (corner and center position) with respect to original INSYDE and introducing the concept of housing unit characterization as in the case of apartment units instead of block of apartments. Hence, the default values of footprint areas, external perimeter and internal perimeter were defined per each building typology, these last two parameters being expressed as a function of the footprint areas with a range of validation up to 300 m^2 and that have a R^2 greater than 0.70 in most cases. For the default values of basement characteristics, the basement height has been reduced from 3 to 2.8 m, the equation for the basement perimeter as function of footprint area has been updated, and no regression equation for basement areas as function of footprint areas was found, therefore, default value defined in original INSYDE has been assumed. Regarding default values of characteristics of storeys, the number of floors and ground floor level assumed in original INSYDE have been verified, and the interfloor height has been reduced from 3.5 to 3 m. In addition, the default values of building structure, finishing level and heating system distribution assumed in original INSYDE have been verified, the year of construction has been reduced to the period before 1990, the level of maintenance of buildings have been reduced from 1.1 to 1, and the application of heating system type such as radiator has been incremented until the year 2005 due to its recognition in newer buildings during the virtual survey.

For the adjustment of damage functions, there was no modification of damage assumptions defined in original INSYDE and, in addition, the quantification and position of some building components have been verified from the virtual survey. The unit prices have been updated to

2021 price values considering discount rate supplied by ISTAT, and most fragility functions have been assumed as in original INSYDE with the exception of the water depth fragility function that affects windows in each flooded storey; from the virtual survey, the median height of windows considered from the street level was 1.1 m, therefore the threshold of no damage of original INSYDE has been reduced from 1.2 to 1.1 m.

The validation of updated INSYDE has been carried out by considering two flood events that occurred in recent years in northern Italy (Adda 2002 and Bacchiglione 2010). The datasets of both events present reported hazard and vulnerability parameters, with missing data replaced by the default values calculated in updated INSYDE. Considering the availability of hazard and vulnerability features in both case studies, a check of representativeness of the default values assumed in updated INSYDE has been realized, obtaining an integral agreement for hazard parameter such as water depth and flow velocity in both case studies, while a partial agreement in building characteristics. In addition, considering that original INSYDE fails in the estimation of extensive parameters (i.e. external perimeter) for large buildings and that updated INSYDE has a validation area range up to 300 m^2 for default values (see chapter 4, section 3), the datasets have been subdivided in subsets of footprint areas smaller than 300 m^2 and bigger than 300 m^2 to see the performance of damage estimation of small and large buildings with updated INSYDE. From the validation of the entire datasets in both case studies, updated INSYDE tends to overestimate the total reported damages having a reduction on the relative error of about the half in comparison with the damage calculated with original INSYDE and a slight increment of root mean square error (RMSE). From the subset of buildings smaller than 300 m^2, the total damage calculated with updated INSYDE tends to underestimate the reported losses (i.e. -9% and -2.6%) with slight decrease of RMSE with respect to original INSYDE which tends to overestimate reported losses (i.e. +12.9% and +6.5%) in both case studies. In addition, considering a comparison of calculated damage and reported losses per each building, both updated and original INSYDE tend to overestimate low damages and to underestimate high damages of buildings in both case studies. From the subset of buildings larger than 300 m^2, both original and updated INSYDE tends to overestimate the reported damages having relative error of about +104.4% with updated INSYDE and +82% with original INSYDE in Lodi case study, and +29% and 31.2% in Caldogno case study, respectively. Therefore, the implementation of INSYDE for buildings larger than 300 m^2 should be avoided. Furthermore, the overestimation of low damages and underestimation of high damages is also observed in both cases for large buildings, with most of the overestimated damage on buildings in Lodi case study. It is worth mentioning that the relative error in buildings larger than 300 m^2 may be affected due to a limited size of the dataset, especially in Lodi case study which consist of 32 buildings.

Problems related to data availability have been faced during the data collection and data validation of the current thesis which are recommended to be solved for future improvement of INSYDE. First, missing data related to some hazard parameters and building characteristics were identified, having a compilation of data in different spatial scale such as micro-scale (i.e. single building) and meso-scale (i.e. regional scale) for building characteristics. Hence, the development of additional investigations considering the building characterization at building components spatial level, and the creation of a standardized format for the compilation of reliable reported damages considering hazard and building characteristics are recommended.

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Chapter 8: Appendix A – Virtual survey

General Information						
	Building type	Year/period of construction	Recent renovation	Level of mainte-nance	Finishing level	Intended use
1	Apartment	1960	Yes	High	High	Dwelling
2	Apartment	1900	Yes	High	High	Dwelling
3	Apartment	1951	Yes (2022)	High	High	Dwelling
4	Apartment	1830	No	Medium	High	Dwelling
5	Apartment	1975	Yes	High	Medium	Dwelling
6	Apartment	1960	No	Medium	Medium	Dwelling
7	Apartment	1970	Yes	High	Medium	Dwelling
8	Apartment	1970	No	Medium	Medium	Dwelling
9	Apartment	1960	Yes	High	Medium	Dwelling
10	Apartment	2000	Yes	High	Medium	Dwelling
11	Apartment	1965	No	Low	Medium	Dwelling
12	Apartment	1967		Medium	Medium	Dwelling
13	Apartment	1960			Medium	Dwelling
14	Apartment	1990	Yes	Medium	Medium	Dwelling
15	Apartment	1975		Medium	Medium	Dwelling
16	Apartment	1960		Medium	Medium	Dwelling
17	Apartment	1960	Yes (2019)	Medium	Medium	Dwelling
18	Apartment	1980	No	Medium	Medium	Dwelling
19	Apartment	2018	Yes	High	Medium	Dwelling
20	Apartment	1975		Medium	Medium	Dwelling
21	Apartment	1960	No	Low	Medium	Dwelling
22	Apartment	1960		Medium	Medium	Dwelling
23	Apartment	1980	Yes	High	High	Dwelling
24	Apartment	1980	Yes	Medium	Medium	Dwelling
25	Apartment	1970	Yes (2010)	High	High	Dwelling
26	Apartment	1940		Medium	High	Dwelling
27	Apartment	1960	No	Medium	High	Dwelling
28	Apartment	2012	Yes	High	Low	Dwelling
29	Apartment	1975	No	Medium	Medium	Dwelling
1	Terrace middle	1960	Yes	High	High	Dwelling
2	Terrace middle	1965	No	Medium	High	Dwelling
3	Terrace middle	1950	No	Low	Medium	Dwelling
4	Terrace middle	1940	Yes	Medium	High	Dwelling
5	Terrace middle	1970	No	Low	High	Dwelling
6	Terrace middle	1975	No	Low	Low	Dwelling
7	Terrace middle	1967	No	Medium	High	Dwelling

	General Information					
	Building type	Year/period of construction	Recent renovation	Level of mainte-nance	Finishing level	Intended use
8	Terrace middle	2000	No	Low	Low	Dwelling
9	Terrace middle	1980	No	Low	Low	Dwelling
10	Terrace middle	2005	Yes	High	High	Dwelling
11	Terrace middle	1960	No	Medium	High	Dwelling
12	Terrace middle	1975	No	Low	High	Dwelling
13	Terrace middle	1963		Low	High	Dwelling
14	Terrace middle	1960		Medium	Medium	Dwelling
15	Terrace middle	1980		Medium	Medium	Dwelling
16	Terrace middle	1990	Yes	High	Medium	Dwelling
17	Terrace middle	1970		Medium	Medium	Dwelling
18	Terrace middle	1980	Yes	High	Medium	Dwelling
19	Terrace middle	1975		Medium	Medium	Dwelling
20	Terrace middle	2000	Yes	High	High	Dwelling
21	Terrace middle	1990	No	Low	High	Dwelling
22	Terrace middle	2000		High	High	Dwelling
23	Terrace middle	1990		High	High	Dwelling
1	Terrace corner	1960		Medium	High	Medium
2	Terrace corner	1960		Medium	High	Medium
3	Terrace corner		Yes (2006)	High	High	Dwelling
4	Terrace corner	1980		Medium	Medium	Dwelling
5	Terrace corner	1920		Medium	High	Dwelling
6	Terrace corner		No	Low	Medium	Dwelling
7	Terrace corner	1960		Medium	High	Dwelling
8	Terrace corner	1900	No	Low	Medium	Dwelling
9	Terrace corner			Medium	Medium	Dwelling
10	Terrace corner		No	Medium	High	Dwelling
11	Terrace corner	2001	Yes	High	High	Dwelling
12	Terrace corner	1980		Medium	Medium	Dwelling
13	Terrace corner	1960		Medium	Medium	Dwelling
14	Terrace corner	1930		Medium	High	Dwelling
15	Terrace corner	1950		Medium	High	Dwelling
16	Terrace corner			Medium	Medium	Dwelling
17	Terrace middle	1970		Medium	Medium	Dwelling
18	Terrace middle	1980	Yes	High	Medium	Dwelling
19	Terrace middle	1975		Medium	Medium	Dwelling
20	Terrace middle	2000	Yes	High	High	Dwelling
21	Terrace middle	1990	No	Low	High	Dwelling
22	Terrace middle	2000		High	High	Dwelling
23	Terrace middle	1990		High	High	Dwelling

	General Information					
	Building type	Year/period of construction	Recent renovation	Level of mainte-nance	Finishing level	Intended use
1	Terrace corner	1960		Medium	High	Medium
2	Terrace corner	1960		Medium	High	Medium
3	Terrace corner		Yes (2006)	High	High	Dwelling
4	Terrace corner	1980		Medium	Medium	Dwelling
5	Terrace corner	1920		Medium	High	Dwelling
6	Terrace corner		No	Low	Medium	Dwelling
7	Terrace corner	1960		Medium	High	Dwelling
8	Terrace corner	1900	No	Low	Medium	Dwelling
9	Terrace corner			Medium	Medium	Dwelling
10	Terrace corner		No	Medium	High	Dwelling
11	Terrace corner	2001	Yes	High	High	Dwelling
12	Terrace corner	1980		Medium	Medium	Dwelling
13	Terrace corner	1960		Medium	Medium	Dwelling
14	Terrace corner	1930		Medium	High	Dwelling
15	Terrace corner	1950		Medium	High	Dwelling
16	Terrace corner			Medium	Medium	Dwelling
17	Terrace corner	1940		Medium	High	Dwelling
18	Terrace corner	90's		Medium	High	Dwelling
19	Terrace corner	1968		High	High	Dwelling
20	Terrace corner	2016		High	Medium	Dwelling
21	Terrace corner	2018	Yes	High	Low	Dwelling
1	Semidetached			Medium	High	Dwelling
2	Semidetached	2012		High	High	Dwelling
3	Semidetached	1967		Medium	Medium	Dwelling
4	Semidetached	1960		Medium	High	Dwelling
5	Semidetached	1980		Medium	High	Dwelling
6	Semidetached	90's		Medium	Medium	Dwelling
7	Semidetached	90's	No	Low	Medium	Dwelling
8	Semidetached		No	Low	High	Dwelling
9	Semidetached	1960	No	Low	High	Dwelling
10	Semidetached	1940			Medium	Dwelling
11	Semidetached	90's		Medium	Medium	Dwelling
12	Semidetached	1987		Medium	High	Dwelling
13	Semidetached	1940		Medium	Medium	Dwelling
14	Semidetached		Yes (2021)	High	Medium	Dwelling
15	Semidetached	1940	No	Low		Dwelling
16	Semidetached	1940		Medium	High	Dwelling
17	Semidetached	1900	Yes	High	High	Dwelling
18	Semidetached	2009	Yes	High	High	Dwelling

General Information						
	Building type	Year/period of construction	Recent renovation	Level of mainte-nance	Finishing level	Intended use
19	Semidetached	1960	Yes	High	High	Dwelling
20	Semidetached	1980		Medium	High	Dwelling
21	Semidetached			High	High	Dwelling
22	Semidetached	1981		High	High	Dwelling
23	Semidetached	2008		High	High	Dwelling
1	Detached		No	Low	High	Dwelling
2	Detached	1967	No	Low	Medium	Dwelling
3	Detached	2002	Yes	High		Dwelling
4	Detached	1970	Yes	High	High	Dwelling
5	Detached			Medium	Medium	Dwelling
6	Detached				High	Dwelling
7	Detached	1976		Medium	High	Dwelling
8	Detached	1967		Medium	High	Dwelling
9	Detached		Yes	High	High	Dwelling
10	Detached	1990	Yes	High	High	Dwelling
11	Detached	1962	No	Low	Medium	Dwelling
12	Detached	1960		Low	Medium	Dwelling
13	Detached			Medium	Medium	Dwelling
14	Detached		Yes	High	High	Dwelling
15	Detached	1975	No	Low	High	Dwelling
16	Detached			Low	High	Dwelling
17	Detached	1930		Medium	Medium	Dwelling
18	Detached	2008	Yes	High	High	Dwelling
19	Detached	1967		Medium	Medium	Dwelling
20	Detached	1975		Medium	High	Dwelling
21	Detached	2013	No	Low	Medium	Dwelling
22	Detached	1998	Yes	High	Low	Dwelling
23	Detached	2014	Yes	High	High	Dwelling

Exterior features							
Building type		Number of floors	External building material 1	Height of external building material 1	External building material 2	Height of external building material 2	Height of ground-floor level
1	Apartment	1	Masonry				
2	Apartment	1	Plaster				
3	Apartment	1	Masonry				0.15
4	Apartment	1	Plaster				0
5	Apartment	1	Plaster				
6	Apartment	1	Plaster				
7	Apartment	1	Plaster				
8	Apartment	1	Plaster				
9	Apartment	1	Plaster				
10	Apartment	1	Plaster				
11	Apartment	1	Plaster				0.1
12	Apartment	1	Plaster				
13	Apartment	1	Plaster				
14	Apartment	1	Plaster				0.1
15	Apartment	1	Plaster				0.1
16	Apartment	1	Plaster				
17	Apartment	1	Plaster				
18	Apartment	1	Plaster				
19	Apartment	1	Plaster				
20	Apartment	1	Plaster				
21	Apartment	1	Plaster				
22	Apartment	1	Plaster				
23	Apartment	1	Masonry				
24	Apartment	1	Plaster				0.1
25	Apartment	1	Plaster				0.1
26	Apartment	1	Plaster				0.15
27	Apartment	1	Plaster				
28	Apartment	1	Plaster				
29	Apartment	1	Plaster				
1	Terrace middle	2	Plaster				0
2	Terrace middle	2	Plaster				0.2
3	Terrace middle	2	Ceramic	0.65	Plaster	>0.65	0.1
4	Terrace middle	2	Stone	0.6	Plaster	>0.60	0
5	Terrace middle	2	Plaster				
6	Terrace middle	3	Stone	0.5	Plaster	>0.50	0.1
7	Terrace middle	2	Plaster				0.2
8	Terrace middle	1	Plaster				0
9	Terrace middle	2	Plaster				0.2

Exterior features							
	Building type	Number of floors	External building material 1	Height of external building material 1	External building material 2	Height of external building material 2	Height of ground-floor level
10	Terrace middle	2	Plaster				
11	Terrace middle	3	Plaster				0.1
12	Terrace middle	2	Plaster				
13	Terrace middle	2	Ceramic	0.5	Plaster		0.2
14	Terrace middle	2	Plaster				0
15	Terrace middle	2	Plaster				0.1
16	Terrace middle	2	Plaster				0.4
17	Terrace middle	2	Plaster				0.1
18	Terrace middle	2	Plaster				
19	Terrace middle	2	Plaster				
20	Terrace middle	2	Plaster				
21	Terrace middle	2	Plaster				0
22	Terrace middle	2	Plaster				0
23	Terrace middle	2	Plaster				0
1	Terrace corner	2	Masonry				0
2	Terrace corner	2	Plaster				0.1
3	Terrace corner	2	Plaster				0
4	Terrace corner	2	Plaster				0
5	Terrace corner	2	Plaster				0.05
6	Terrace corner	2	Plaster				0
7	Terrace corner	3	Plaster				
8	Terrace corner	2	Plaster				
9	Terrace corner	2	Plaster				0.1
10	Terrace corner	2	Plaster				0.1
11	Terrace corner	2	Plaster				
12	Terrace corner	3	Plaster				0.1
13	Terrace corner	2	Plaster				
14	Terrace corner	2	Plaster				0.1
15	Terrace corner	3	Plaster				0.05
16	Terrace corner	2	Plaster				0
17	Terrace corner	2	Stone	0.6	Plaster	>0.6	0
18	Terrace corner	2	Stone	0.6	Plaster	>0.6	0
19	Terrace corner	2	Plaster				0.05
20	Terrace corner	2	Plaster				
21	Terrace corner	2	Plaster				
1	Semidetached	2	Stone	0.4	Plaster	>0.4	0
2	Semidetached	2	Ceramic	0.2	Plaster	>0.2	0.1
3	Semidetached	2	Stone	0.6	Plaster	>0.6	0.1

			Exterior features				
	Building type	Number of floors	External building material 1	Height of external building material 1	External building material 2	Height of external building material 2	Height of ground-floor level
4	Semidetached	2	Plaster				0.05
5	Semidetached	2	Plaster				0.15
6	Semidetached	2	Plaster				
7	Semidetached	2	Plaster				
8	Semidetached	2	Plaster				
9	Semidetached	2	Plaster				
10	Semidetached	2	Plaster				
11	Semidetached	2	Plaster				0.1
12	Semidetached	2	Plaster				0.05
13	Semidetached	2	Ceramic	0.6	Plaster	>0.6	0.2
14	Semidetached	2	Plaster				0.2
15	Semidetached	2	Plaster				0.1
16	Semidetached	2	Plaster				0.6
17	Semidetached	2	Plaster				0.1
18	Semidetached	2	Plaster				0.1
19	Semidetached	2	Plaster				0.2
20	Semidetached	2	Plaster				
21	Semidetached	2	Plaster				0.05
22	Semidetached	2	Plaster				
23	Semidetached	2	Plaster				0.5
1	Detached	2	Plaster				
2	Detached	2	Plaster				0
3	Detached	2	Plaster				0.1
4	Detached	2	Masonry				0.1
5	Detached	2	Plaster				
6	Detached	2	Ceramic				0.05
7	Detached	1	Plaster				
8	Detached	2	Plaster				0
9	Detached	2	Plaster				
10	Detached	2	Plaster				
11	Detached	1	Plaster				0
12	Detached	2	Plaster				0.1
13	Detached	1	Plaster				
14	Detached	2	Stone				0
15	Detached	2	Ceramic				0.8
16	Detached	2	Plaster				0
17	Detached	2	Plaster				0

Exterior features							
	Building type	Number of floors	External building material 1	Height of external building material 1	External building material 2	Height of external building material 2	Height of ground-floor level
18	Detached	2	Plaster				
19	Detached	2	Plaster				0
20	Detached	1	Plaster				
21	Detached	2	Plaster				0.1
22	Detached	2	Plaster				0
23	Detached	2	Plaster				0.2

Interior features						
	Building type	Total built area	Presence of basement	Area of basement (if any)	Basement perimeter	Height of basement
1	Apartment	85	No			
2	Apartment	68	No			
3	Apartment	135	No			
4	Apartment	124	No			
5	Apartment	78	No			
6	Apartment	135	No			
7	Apartment	65	No			
8	Apartment	95	No			
9	Apartment	113	No			
10	Apartment	65	No			
11	Apartment	120	No			
12	Apartment	90	No			
13	Apartment	87	No			
14	Apartment	85	No			
15	Apartment	99	No			
16	Apartment	63	No			
17	Apartment	105	No			
18	Apartment	90	No			
19	Apartment	160	No			
20	Apartment	100	No			
21	Apartment	130	No			
22	Apartment	98	No			
23	Apartment	100	No			
24	Apartment	96	No			

			Interior features			
	Building type	Total built area	Presence of basement	Area of basement (if any)	Basement perimeter	Height of basement
25	Apartment	157	No			
26	Apartment	65	No			
27	Apartment	65	No			
28	Apartment	75	No			
29	Apartment	80	No			
1	Terrace middle	115	No			
2	Terrace middle	104	No			
3	Terrace middle	125	No			
4	Terrace middle	90	No			
5	Terrace middle	113	No			
6	Terrace middle	100	No			
7	Terrace middle	200	No			
8	Terrace middle	90	No			
9	Terrace middle	85	No			
10	Terrace middle	120	No			
11	Terrace middle	240	No			
12	Terrace middle	95	No			
13	Terrace middle	110	No			
14	Terrace middle	98	No			
15	Terrace middle	123	No			
16	Terrace middle	100	No			
17	Terrace middle	110	No			
18	Terrace middle	83.6	No			
19	Terrace middle	121	No			
20	Terrace middle	140	No			
21	Terrace middle	100	No			
22	Terrace middle	233.3	No			
23	Terrace middle	197.4	Yes	100	46	3
1	Terrace corner	100	No			
2	Terrace corner	220	No			
3	Terrace corner	100	No			
4	Terrace corner	150	No			
5	Terrace corner	80	No			
6	Terrace corner	78	No			
7	Terrace corner	250.8	Yes	57.33	39.57	
8	Terrace corner	120	No			
9	Terrace corner	110	Yes	27.87	21.12	1.8
10	Terrace corner	285	No			

	Interior features					
	Building type	Total built area	Presence of basement	Area of basement (if any)	Basement perimeter	Height of basement
11	Terrace corner	165	No			
12	Terrace corner	60	Yes	33.92	25.23	2.7
13	Terrace corner	120	No			
14	Terrace corner	89	Yes	42.92	26.52	2.55
15	Terrace corner	120	No			
16	Terrace corner	70	No			
17	Terrace corner	100	No			
18	Terrace corner	85	No			
19	Terrace corner	214	Yes	82	40	
20	Terrace corner	150	Yes	90	43	
21	Terrace corner	124	Yes	47	33	
1	Semidetached	101	No			
2	Semidetached	100	No			
3	Semidetached	125	No			
4	Semidetached	166	No			
5	Semidetached	139	No			
6	Semidetached	144	No			
7	Semidetached	80	No			
8	Semidetached	272.7	No			
9	Semidetached	74	No			
10	Semidetached	140	No			
11	Semidetached	186	No			
12	Semidetached	165.8	No			
13	Semidetached	128.8	No			
14	Semidetached	128.2	No			
15	Semidetached	163.2	No			
16	Semidetached	185	Yes	70.94	34.18	3.1
17	Semidetached	228	No			
18	Semidetached	230	No			
19	Semidetached	277	Yes	88.62	40.09	2.55
20	Semidetached	51	No			
21	Semidetached	202.2	No			
22	Semidetached	404	No			
23	Semidetached	197.3	Yes	97	47	2.2
1	Detached	174	No			
2	Detached	178.2	No			
3	Detached	155	No			
4	Detached	364	No			
5	Detached	137	No			

	Interior features					
	Building type	Total built area	Presence of basement	Area of basement (if any)	Basement perimeter	Height of basement
6	Detached	180	Yes	80.95	38.10	2.5
7	Detached	100	Yes	72.59	35.66	2.5
8	Detached	200	Yes	21.22	18.45	2.2
9	Detached	136	No			
10	Detached	152.9	Yes	31.23	22.40	2.5
11	Detached	92.5	Yes	92.50	40.72	2.5
12	Detached	294	Yes	69.36	34.79	2.4
13	Detached	100	No			
14	Detached	400	No			
15	Detached	206.9	Yes	28.36	22.96	2.5
16	Detached	164.1	No			
17	Detached	105	No			
18	Detached	162	No			
19	Detached	90	No			
20	Detached	85.8	No			
21	Detached	81.5	Yes	26.2	26	2.08
22	Detached	250.9				
23	Detached	175.1				

Interior features - Ground floor

	Building type	Floor area	Floor height	Average room size	Facilities - Plumbing & sanitary system	Approx. Heigh of different elements	Facilities - Electric system	Approx. Height of lower sockets	Approx. Height of middle sockets	Approx. Height of light switches
1	Apartment	85		9	Yes	Typical	Yes			1.05
2	Apartment	68		9	Yes	Typical	Control panel (1.4)	0.14	0.8	0.85
3	Apartment	135	2.8	12	Yes	Typical	Control panel (1.5)	0.25	1	1
4	Apartment	124		12	Yes	Typical	Yes			
5	Apartment	78		14	Yes	Typical	Yes			
6	Apartment	135		11	Yes	Typical	Yes			
7	Apartment	65		10	Yes	Typical	Yes	0.30	1	1
8	Apartment	95		13	Yes	Typical	Yes			
9	Apartment	113		12	Yes	Typical	Yes			
10	Apartment	65		12	Yes	Typical	Yes			
11	Apartment	120	3	16	Yes	Typical	Control panel			
12	Apartment	90		11	Yes	Typical	Yes			
13	Apartment	87		15	Yes	Typical	Yes			
14	Apartment	85		11	Yes	Typical	Yes			
15	Apartment	99	2.95	12	Yes	Typical	Yes			
16	Apartment	63		8	Yes	Typical	Yes	0.25	1	1
17	Apartment	105		15	Yes	Typical	Yes			
18	Apartment	90		11	Yes	Typical	Yes			
19	Apartment	160		11	Yes	Typical	Yes			
20	Apartment	100		15	Yes	Typical	Yes			
21	Apartment	130		15	Yes	Typical	Yes			
22	Apartment	98		15	Yes	Typical	Yes			
23	Apartment	100	2.7	9	Yes	Typical	Yes	0.3	1	1
24	Apartment	96	2.7	16	Yes	Typical	Yes	0.2	0.6	1.1

Interior features - Ground floor										
	Building type	Floor area	Floor height	Average room size	Facilities - Plumbing & sanitary system	Approx. Heigh of different elements	Facilities - Electric system	Approx. Height of lower sockets	Approx. Height of middle sockets	Approx. Height of light switches
25	Apartment	157		17	Yes	Typical	Yes			
26	Apartment	65	2.55	13	Yes	Typical	Yes	0.2	0.8	1
27	Apartment	65		9	Yes	Typical	Yes			
28	Apartment	75		13	Yes	Typical	Yes			
29	Apartment	80		12	Yes	Typical	Yes			
1	Terrace middle	57.5	2.85	10	Yes	Typical	Yes			
2	Terrace middle	52		15	Yes	Typical	Yes			
3	Terrace middle	62.5		10	Yes	Typical	Yes			
4	Terrace middle	45	2.85	8	Yes	Typical	Yes			
5	Terrace middle	42		13	Yes	Typical	Yes			
6	Terrace middle	40		16	Yes	Typical	Yes	0.25	0.9	1.1
7	Terrace middle	100	3.2	14	Yes	Typical	Control panel (1.6)			1.2
8	Terrace middle	90		15	Yes	Typical	Yes			
9	Terrace middle	42.5		14	Yes	Typical	Yes			
10	Terrace middle	60	2.7	15	Yes	Typical	Yes	0.4		1
11	Terrace middle	80		20	Yes	Typical	Yes	0.3	1	1.1
12	Terrace middle	55	2.3	18	Yes	Typical	Yes		0.9	0.9
13	Terrace middle	55		18	Yes	Typical	Yes			
14	Terrace middle	49		12	Yes	Typical	Yes			
15	Terrace middle	61.3	2.9	15	Yes	Typical	Yes	0.6	1	1
16	Terrace middle	50	2.7	13	Yes	Typical	Control panel (1.6)	0.25	0.6	1.2
17	Terrace middle	55		14	Yes	Typical	Yes			
18	Terrace middle	42	2.82	14	Yes	Typical	Yes			
19	Terrace middle	71.5	2.65	10	Yes	Typical	Yes			
20	Terrace middle	70	3	18	Yes	Typical	Yes			

Interior features - Ground floor										
	Building type	Floor area	Floor height	Average room size	Facilities - Plumbing & sanitary system	Approx. Heigh of different elements	Facilities - Electric system	Approx. Height of lower sockets	Approx. Height of middle sockets	Approx. Height of light switches
21	Terrace middle	50		13	Yes	Typical	Yes			
22	Terrace middle	117.5		20	Yes	Typical	Yes			
23	Terrace middle	95	3	24	Yes	Typical	Yes	0.25		1.2
1	Terrace corner	100	2.95	20	Yes	Typical	Yes			
2	Terrace corner	110		15	Yes	Typical	Yes			
3	Terrace corner	50		17	Yes	Typical	Yes			
4	Terrace corner	75	2.78	19	Yes	Typical	Yes	0.4		1.2
5	Terrace corner	40	2.45	16	Yes	Typical	Yes			1
6	Terrace corner	39	2.7	20	Yes	Typical	Yes			
7	Terrace corner	90		13	Yes	Typical	Yes	0.3	1	1
8	Terrace corner	60		12	Yes	Typical	Yes			
9	Terrace corner	55	2.8	11	Yes	Typical	Yes			
10	Terrace corner	142.5	2.75	14	Yes	Typical	Yes			
11	Terrace corner	82.5		15	Yes	Typical	Yes			
12	Terrace corner	30	2.5	10	Yes	Typical	Control panel (1.5)	0.25	1	1
13	Terrace corner	60		15	Yes	Typical	Yes			
14	Terrace corner	44.5	2.7	22	Yes	Typical	Yes			
15	Terrace corner	40		13	Yes	Typical	Yes	0.4	1	1
16	Terrace corner	35	2.65	9	Yes	Typical	Yes			1.3
17	Terrace corner	50	2.93	13	Yes	Typical	Yes	0.2		1.15
18	Terrace corner	42.5	2.85	11	Yes	Typical	Yes	0.45		1.15
19	Terrace corner	107	2.8	18	Yes	Typical	Yes			
20	Terrace corner	70		14	Yes	Typical	Yes			
21	Terrace corner	82		14	Yes	Typical	Yes			
1	Semidetached	50.5		17	Yes	Typical	Yes			

Interior features - Ground floor										
	Building type	Floor area	Floor height	Average room size	Facilities - Plumbing & sanitary system	Approx. Heigh of different elements	Facilities - Electric system	Approx. Height of lower sockets	Approx. Height of middle sockets	Approx. Height of light switches
2	Semidetached	50		13	Yes	Typical	Yes			1.3
3	Semidetached	62.5	2.9	21	Yes	Typical	Yes			
4	Semidetached	83		17	Yes	Typical	Yes			
5	Semidetached	69.5	2.98	14	Yes	Typical	Yes	0.3		
6	Semidetached	72	2.7	12	Yes	Typical	Yes			
7	Semidetached	40		7	Yes	Typical	Yes			
8	Semidetached	154.6		19	Yes	Typical	Yes			
9	Semidetached	37		12	Yes	Typical	Yes			
10	Semidetached	70		14	Yes	Typical	Yes			
11	Semidetached	62	2.45	21	Yes	Typical	Yes			
12	Semidetached	90		13	Yes	Typical	Yes			
13	Semidetached	74.8	2.7	19	Yes	Typical	Yes	0.25		1.2
14	Semidetached	58.2		12	Yes	Typical	Yes			
15	Semidetached	77.6	2.7	16	Yes	Typical	Yes			
16	Semidetached	92.5	2.55	19	Yes	Typical	Control panel (1.4)	0.3	1.2	1.2
17	Semidetached	114	2.7	16	Yes	Typical	Yes			
18	Semidetached	115	2.7	23	Yes	Typical	Yes			
19	Semidetached	138.5	2.9	17	Yes	Typical	Yes			
20	Semidetached	26.1		13	Yes	Typical	Yes			
21	Semidetached	114.8		15	Yes	Typical	Yes			
22	Semidetached	202		18	Yes	Typical	Yes			
23	Semidetached	95		14	Yes	Typical	Yes			
1	Detached	87		13	Yes	Typical	Yes			
2	Detached	100	2.75	14	Yes	Typical	Yes		1.2	1.3
3	Detached	70	2.7	10	Yes	Typical	Yes			

Interior features - Ground floor										
	Building type	Floor area	Floor height	Average room size	Facilities - Plumbing & sanitary system	Approx. Heigh of different elements	Facilities - Electric system	Approx. Height of lower sockets	Approx. Height of middle sockets	Approx. Height of light switches
4	Detached	171	2.6	19	Yes	Typical	Control panel (1.35)	0.25		
5	Detached	68.5	2.64	10	Yes	Typical	Control panel (1.4)			
6	Detached	90	2.95	13	Yes	Typical	Yes	0.5		1.15
13	Semidetached	74.8	2.7	19	Yes	Typical	Yes	0.25		1.2
14	Semidetached	58.2		12	Yes	Typical	Yes			
15	Semidetached	77.6	2.7	16	Yes	Typical	Yes			
16	Semidetached	92.5	2.55	19	Yes	Typical	Control panel (1.4)	0.3	1.2	1.2
17	Semidetached	114	2.7	16	Yes	Typical	Yes			
18	Semidetached	115	2.7	23	Yes	Typical	Yes			
19	Semidetached	138.5	2.9	17	Yes	Typical	Yes			
20	Semidetached	26.1		13	Yes	Typical	Yes			
21	Semidetached	114.8		15	Yes	Typical	Yes			
22	Semidetached	202		18	Yes	Typical	Yes			
23	Semidetached	95		14	Yes	Typical	Yes			
1	Detached	87		13	Yes	Typical	Yes			
2	Detached	100	2.75	14	Yes	Typical	Yes		1.2	1.3
3	Detached	70	2.7	10	Yes	Typical	Yes			
4	Detached	171	2.6	19	Yes	Typical	Control panel (1.35)	0.25		
5	Detached	68.5	2.64	10	Yes	Typical	Control panel (1.4)			
6	Detached	90	2.95	13	Yes	Typical	Yes	0.5		1.15
7	Detached	100	2.7	13	Yes	Typical	Yes	0.5		1
8	Detached	100	2.95	17	Yes	Typical	Yes			
9	Detached	68		10	Yes	Typical	Yes			

Interior features - Ground floor										
	Building type	Floor area	Floor height	Average room size	Facilities - Plumbing & sanitary system	Approx. Heigh of different elements	Facilities - Electric system	Approx. Height of lower sockets	Approx. Height of middle sockets	Approx. Height of light switches
10	Detached	83.2	2.5	12	Yes	Typical	Yes			
11	Detached	92.5	3.2	10	Yes	Typical	Yes	0.25	1.3	1.4
12	Detached	147	3.05	18	Yes	Typical	Yes	0.4		
13	Detached	100		13	Yes	Typical	Yes			
14	Detached	200	2.5	22	Yes	Typical	Yes	0.2		1.1
15	Detached	119	3	9	Yes	Typical	Yes			
16	Detached	84.7	2.35	21	Yes	Typical	Yes	0.2		
17	Detached	52.5		26	Yes	Typical	Yes			
18	Detached	81		16	Yes	Typical	Yes			
19	Detached	45	2.3	11	Yes	Typical	Yes	0.4		1.15
20	Detached	85.8		14	Yes	Typical	Yes			
21	Detached	43	2.55	9	Yes	Typical	Yes	0.35		1
22	Detached	128.5		26	Yes	Typical	Yes			
23	Detached	105.1	2.7	15	Yes	Typical	Control panel (1.4)	0.35		1.1

Interior features - Ground floor

	Building type	Facilities-Heating system	Type	Height of radiator from floor	Distribution type	Number of doors	Material of doors	Height of door	Width of door
1	Apartment	Yes (boiler)	Radiator (gas)	0.1	Central heating	4	Wood		
2	Apartment	Yes	Radiator	0.1	Distributed	4	Wood+PVC+Glass		
3	Apartment	Yes (boiler)	Radiator (gas)	0.15	Central heating	6	Wood	2.4	0.8
4	Apartment	Yes (boiler)	Radiator (gas)		Distributed	9	Wood+Glass		
5	Apartment	Yes (boiler)	Radiator (gas)		Central heating	5	Wood		
6	Apartment	Yes (boiler)	Radiator (gas)		Central heating	7	Wood		
7	Apartment	Yes (boiler)	Radiator (gas)		Distributed	6	Wood		
8	Apartment	Yes (boiler)	Radiator (gas)		Central heating	7	Wood+Glass		
9	Apartment	Yes	Radiator		Central heating	8	Wood	2.1	0.8
10	Apartment	Yes (boiler)	Radiator (gas)		Distributed	5	Wood	2.1	0.8
11	Apartment	Boiler (1.6)	Radiator	0.15	Distributed	8	Wood+Glass		
12	Apartment	Yes	Radiator		Central heating	6	Wood+Glass		
13	Apartment					6			
14	Apartment	Yes	Radiator		Distributed	7	Wood		
15	Apartment	Yes	Radiator		Distributed	9			
16	Apartment	Yes	Radiator		Central heating	7			
17	Apartment	Yes	Radiator		Distributed	6	Wood+PVC+Glass		
18	Apartment	Yes	Other (Ad aria)		Distributed	7	Wood+Glass		
19	Apartment	Yes	Radiator		Distributed	10	Wood+PVC+Glass	2.1	0.8
20	Apartment					7			
21	Apartment	Yes	Radiator		Distributed	8	Wood		
22	Apartment					7	Wood+Glass		
23	Apartment	Yes	Radiator		Distributed	7	Wood+Glass		
24	Apartment	Yes	Radiator	0.2	Distributed		Wood+PVC+Glass		

Interior features - Ground floor									
	Building type	Facilities-Heating system	Type	Height of radiator from floor	Distribution type	Number of doors	Material of doors	Height of door	Width of door
25	Apartment	Yes (gas)	Radiator		Distributed		Wood+Glass		
26	Apartment	Yes (gas)	Radiator	0.2	Central heating		Wood+Glass		
27	Apartment	Yes	Radiator		Distributed		Wood		
28	Apartment	Yes	Radiator		Distributed		PVC		
29	Apartment	Yes	Radiator		Distributed		Wood		
1	Terrace middle	Yes	Radiator		Distributed	4			
2	Terrace middle	Yes (gas)	Radiator		Distributed	2	Wood		
3	Terrace middle	Yes			Distributed	5	Wood+Glass		
4	Terrace middle	Boiler (1.6)	Radiator		Distributed	4	Wood		
5	Terrace middle					2	Wood		
6	Terrace middle	Yes	radiator	0.2	Distributed	3	Wood		
7	Terrace middle	Yes	Radiator	0.2	Distributed	8	Wood		
8	Terrace middle	No				5	Wood		
9	Terrace middle	Yes			Distributed	3	Wood	2.1	0.7
10	Terrace middle	Yes	radiator		Distributed	4	Wood		
11	Terrace middle	Yes	Other (heat pump)	0.2	Distributed	5	Wood+Glass		
12	Terrace middle	Yes	Other (heat pump)		Distributed	3	Wood		
13	Terrace middle	Yes	Other (heat pump)		Distributed	6	Wood+Glass		
14	Terrace middle					5		2.1	0.8
15	Terrace middle	Yes	Radiator		Distributed	4	Wood+Glass		
16	Terrace middle	Yes	other (warm air)		Distributed	2	Wood		
17	Terrace middle	Yes	Radiator		Distributed	4	Wood+PVC+Glass		
18	Terrace middle	Yes			Distributed	3	Wood		
19	Terrace middle					6	Wood		
20	Terrace middle	Yes			Distributed	5	Wood		
21	Terrace middle					5	Wood+Glass		

Interior features - Ground floor									
	Building type	Facilities-Heating system	Type	Height of radiator from floor	Distribution type	Number of doors	Material of doors	Height of door	Width of door
22	Terrace middle	Yes	Radiator		Distributed		Wood+Glass		
23	Terrace middle	Yes	Radiator	0.2	Distributed		Wood+Glass		
1	Terrace corner	Yes	Radiator	0.2	Distributed	7	Wood		
2	Terrace corner	Yes (gas)	radiator		Distributed	6	Wood	2	0.7
3	Terrace corner	Yes (gas)	radiator		Distributed	3	Wood		
4	Terrace corner	Yes	radiator		Distributed	3	Wood+PVC+Glass		
5	Terrace corner	Yes	radiator		Distributed	2	Wood+Glass		
6	Terrace corner					3			
7	Terrace corner	Yes	Radiator	0.2	Distributed	6			
8	Terrace corner	Yes	radiator		Distributed	5	Wood		
9	Terrace corner					4	Wood		
10	Terrace corner					9	Wood+Glass		
11	Terrace corner	Yes	radiator		Distributed	6	Wood		
12	Terrace corner	Boiler (1.5)	radiator		Distributed	2	Wood+PVC+Glass		
13	Terrace corner					4	Steel		
14	Terrace corner	Yes	radiator		Distributed	2	Wood		
15	Terrace corner	Yes	Radiator	0.2	Distributed	5	Wood+Glass		
16	Terrace corner	Boiler	radiator	0.15	Distributed	4	Wood+Glass		
17	Terrace corner	Yes	radiator		Distributed	4	Wood+Glass		
18	Terrace corner	Boiler (1.3)	radiator	0.15	Distributed	4	Wood+PVC+Glass		
19	Terrace corner	Yes	radiator	0.2	Central heating		Wood		
20	Terrace corner	Yes	radiator		Central heating			2.1	0.9
21	Terrace corner	Yes	radiator		Distributed			2.1	0.7
1	Semidetached	Yes	radiator		Distributed	3	Wood+PVC+Glass		
2	Semidetached	Yes	radiator	0.2	Distributed	3	Wood+Glass	2.1	0.8
3	Semidetached	Yes	radiator	0.2	Distributed	4	Wood		

Interior features - Ground floor									
	Building type	Facilities-Heating system	Type	Height of radiator from floor	Distribution type	Number of doors	Material of doors	Height of door	Width of door
4	Semidetached	Yes	radiator		Distributed	5	Wood+Glass		
5	Semidetached	Yes	Other (heat pump)	0.2	Distributed	4	Wood+Steel+PVC+Glass		
6	Semidetached					6			
7	Semidetached	Yes	radiator		Distributed	5	Wood+PVC+Glass		
8	Semidetached					6			
9	Semidetached	Yes	Other (warm air)		Distributed	3	Wood		
10	Semidetached					5			
11	Semidetached					2	Wood		
12	Semidetached	Yes	radiator		Distributed	5	Wood		
13	Semidetached	Yes	radiator	0.2	Distributed	4	Wood+PVC+Glass		
14	Semidetached	Yes (gas)	radiator		Distributed	5	Wood+Glass		
15	Semidetached					6			
16	Semidetached	Boiler (1.3)	radiator		Distributed	6	Wood+Glass		
17	Semidetached	Yes (gas)	radiator		Distributed	8	Wood		
18	Semidetached	Yes	radiator		Distributed	5	Wood		
19	Semidetached	Yes (gpl)	radiator	0.2	Distributed	8	Wood+Glass		
20	Semidetached	Yes	radiator		Distributed	2			
21	Semidetached	Yes	radiator		Distributed		Wood+Glass		
22	Semidetached	Yes	radiator		Distributed		Wood+Glass		
23	Semidetached	Yes	radiator		Distributed		Wood+Glass	2.1	0.7
1	Detached	Yes	radiator		Distributed	7	Wood		
2	Detached	Yes	Other (heat pump)		Distributed	7	Wood+Glass		
3	Detached	Yes	radiator		Distributed	5			
4	Detached	Yes	radiator	0.2	Distributed	7	Wood+Glass		
5	Detached	Yes			Distributed	6	Wood+Glass		
6	Detached	Yes	radiator	0.2	Distributed	6	Wood+Steel+Glass		

Interior features - Ground floor

	Building type	Facilities- Heating system	Type	Height of radiator from floor	Distribution type	Number of doors	Material of doors	Height of door	Width of door
7	Detached	Yes		0.2	Distributed	7	Wood+Glass		
8	Detached	Yes	radiator		Distributed	7	Wood		
9	Detached	Yes	radiator		Distributed	8	Wood		
10	Detached	Yes	radiator		Distributed	7	Wood		
11	Detached	Yes	radiator	0.2	Distributed	8	Wood+Glass		
12	Detached	Yes	radiator	0.2	Distributed	10	Wood		
13	Detached	Yes			Distributed	9			
14	Detached	Yes	radiator	0.2	Distributed	8	Wood		
15	Detached	Yes	radiator		Distributed	10	Wood		
16	Detached	Yes		0.2	Distributed	6	Wood		
17	Detached	Yes	radiator		Distributed	2	Wood+Glass		
18	Detached	Yes	radiator		Distributed	4	Wood		
19	Detached	Yes	radiator	0.2	Distributed	4	Wood		
20	Detached	Yes	radiator		Distributed	6	Wood		
21	Detached	Yes			Distributed		Wood		
22	Detached	Yes			Distributed		Wood+PVC+Glass		
23	Detached	Yes (gas)	radiator		Distributed		Wood		0.8

Interior features - Ground floor

	Building type	Material of window	Height of windows (from floor level)	Height of windows (from street level)	Height of window	Width of window	Type of pavement	Material of internal walls	Finishing type of internal walls
1	Apartment	PVC	0.8				Parquet	Masonry	Plaster+wallpaper
2	Apartment	PVC					Parquet+ceramic	Drywall	Plaster
3	Apartment	Wood	0.9		2	1.4	Parquet+ceramic	Drywall	Plaster
4	Apartment	Wood					Ceramic	Masonry	Plaster
5	Apartment	PVC					Ceramic	Drywall	Plaster
6	Apartment	PVC					Ceramic	Masonry	Plaster
7	Apartment	PVC					Ceramic	Masonry	Plaster
8	Apartment	PVC					Ceramic	Drywall	Plaster
9	Apartment	PVC			1.4	1.8	Ceramic	Drywall	Plaster
10	Apartment	PVC			1.5	1.4	Ceramic	Drywall	Plaster
11	Apartment	PVC	0.9				Parquet+Ceramic	Masonry	Plaster+wallpaper
12	Apartment	PVC					Parquet+Ceramic	Masonry	Plaster
13	Apartment						Parquet+ceramic		Plaster
14	Apartment	PVC					Ceramic		Plaster
15	Apartment						Parquet+ceramic		Plaster
16	Apartment						Parquet+ceramic		Plaster
17	Apartment	PVC					Ceramic		Plaster
18	Apartment	PVC					Ceramic		Plaster
19	Apartment	PVC			1.57	1.4	Ceramic	Masonry	Plaster+ceramic
20	Apartment						Parquet+ceramic		Plaster
21	Apartment	PVC					Ceramic	Masonry	Plaster+wallpaper
22	Apartment	Wood					Parquet+Ceramic		Plaster
23	Apartment	Wood	1				Parquet+Ceramic	Masonry	Plaster

Interior features - Ground floor									
	Building type	Material of window	Height of windows (from floor level)	Height of windows (from street level)	Height of window	Width of window	Type of pavement	Material of internal walls	Finishing type of internal walls
24	Apartment	PVC	1.2				Ceramic	Masonry	plaster
25	Apartment	Wood			1	1.5	Ceramic	Masonry	plaster+wallpaper
26	Apartment	Wood					Parquet+Ceramic	Masonry	plaster+wallpaper
27	Apartment	Wood					Ceramic		plaster
28	Apartment	PVC					Linoleum+Ceramic		plaster+wallpaper
29	Apartment	PVC					Linoleum+Ceramic		plaster
1	Terrace middle						Parquet+ceramic		plaster
2	Terrace middle	Wood					Ceramic	Masonry	plaster
3	Terrace middle	PVC					Linoleum+Ceramic	Masonry	plaster+wallpaper
4	Terrace middle	Wood	1.1		1.4		Ceramic	Masonry	plaster+wood
5	Terrace middle	Wood					Ceramic	Masonry	Plaster
6	Terrace middle	Wood					Ceramic	Masonry	Plaster
7	Terrace middle	Wood+PVC	0.9	1.25	2.1		Wood+Ceramic	Masonry	Plaster
8	Terrace middle	Wood	1	1.2	1.5	0.9	Ceramic	Masonry	Plaster
9	Terrace middle	Wood	0.9	1.1	1.4	1.2	Parquet+ceramic	Masonry	plaster+ceramic
10	Terrace middle	Wood					Ceramic	Masonry	Plaster
11	Terrace middle	Wood					Ceramic	Masonry	Plaster
12	Terrace middle	Wood	0.7				Ceramic	Masonry	plaster+ceramic
13	Terrace middle	Wood					Ceramic	Masonry	plaster
14	Terrace middle				1.6	1.2	Parquet+ceramic		plaster
15	Terrace middle	Wood	1.1				Ceramic+Wood	Masonry	plaster+wood
16	Terrace middle	PVC	1	1.6	1.45		Ceramic	Masonry	plaster+wallpaper
17	Terrace middle	PVC					Ceramic	Masonry	plaster+wallpaper

	Interior features - Ground floor								
	Building type	Material of window	Height of windows (from floor level)	Height of windows (from street level)	Height of window	Width of window	Type of pavement	Material of internal walls	Finishing type of internal walls
18	Terrace middle	PVC					Ceramic	Masonry	plaster
19	Terrace middle	Wood					Parquet+ceramic		plaster
20	Terrace middle	Wood					Parquet+ceramic		plaster
21	Terrace middle	Wood					Ceramic+Concrete	Masonry	plaster
22	Terrace middle	Wood					Ceramic	Masonry	plaster+wallpaper
23	Terrace middle	Wood	1				Ceramic	Masonry	plaster+wallpaper
1	Terrace corner	PVC	1	1	1.3		Ceramic	Masonry	Plaster
2	Terrace corner	PVC		1.15	1.1	0.8	Linoleum+Ceramic	Masonry	Plaster
3	Terrace corner	Wood					Ceramic	Masonry	Plaster
4	Terrace corner	PVC	0.9	1	1.5		Ceramic		Plaster
5	Terrace corner	Wood	0.9	1	1.3		Ceramic		Plaster
6	Terrace corner						Parquet+ceramic		Plaster
7	Terrace corner						Parquet		Plaster
8	Terrace corner	Wood					Parquet+ceramic		Plaster
9	Terrace corner	Wood					Parquet		Plaster
10	Terrace corner	Wood					Parquet		Plaster
11	Terrace corner	Wood			1.5	1.4	Ceramic		Plaster
12	Terrace corner	PVC	0.8				Ceramic		plaster+wallpaper
13	Terrace corner	Wood					Parquet+ceramic		
14	Terrace corner	Wood					Parquet+ceramic		
15	Terrace corner	Wood					Concrete		Plaster
16	Terrace corner	PVC	1.05				Ceramic		Plaster
17	Terrace corner	Wood					Parquet+ceramic		plaster+wallpaper

	Interior features - Ground floor								
	Building type	Material of window	Height of windows (from floor level)	Height of windows (from street level)	Height of window	Width of window	Type of pavement	Material of internal walls	Finishing type of internal walls
18	Terrace corner	Wood	1.3	1.5	1.7		Ceramic		plaster
19	Terrace corner	Wood	0.95	1.1	1.45		Parquet+Ceramic	Masonry	plaster+wallpaper
20	Terrace corner			1.5	1.4	1	Parquet+Ceramic	Masonry	Plaster
21	Terrace corner						Parquet+Ceramic	Drywall	Plaster
1	Semidetached	Wood					Ceramic		Plaster
2	Semidetached	Wood	1	1.1	1.4	0.9	Ceramic	Masonry	Plaster
3	Semidetached	PVC					Ceramic	Masonry	Plaster
4	Semidetached	Wood					Ceramic+Granolithic concrete	Masonry	Plaster
5	Semidetached	Wood	1	1.2	1.4		Ceramic+Wood	Masonry	Plaster
6	Semidetached						Parquet+ceramic	Masonry	Plaster
7	Semidetached	PVC					Ceramic		Plaster
8	Semidetached						Parquet+ceramic		Plaster
9	Semidetached	Wood					Parquet+ceramic		Plaster
10	Semidetached						Ceramic+Wood		Plaster
11	Semidetached	PVC					Parquet+ceramic		Plaster
12	Semidetached	Wood					Ceramic		Plaster
13	Semidetached	PVC	1.2				Ceramic		Plaster
14	Semidetached	PVC					Linoleum+Ceramic		Plaster+wallpaper
15	Semidetached						Parquet+ceramic		Plaster
16	Semidetached	Wood	0.9				Ceramic		Plaster
17	Semidetached	Wood					Parquet+ceramic		Plaster
18	Semidetached	PVC					Ceramic+Wood		Plaster

Interior features - Ground floor									
	Building type	Material of window	Height of windows (from floor level)	Height of windows (from street level)	Height of window	Width of window	Type of pavement	Material of internal walls	Finishing type of internal walls
19	Semidetached	Wood	0.95	0.95	1.55		Ceramic		Plaster
20	Semidetached						Parquet+ceramic		Plaster+wallpaper
21	Semidetached	Wood					Ceramic		Plaster
22	Semidetached	Wood					Ceramic		Plaster+wallpaper
23	Semidetached	Wood			1.4	1.3	Ceramic		Plaster
1	Detached	Wood					Ceramic		Plaster
2	Detached	PVC	0.9				Ceramic		Plaster
3	Detached								
4	Detached	Wood	0.9	1	1.4		Ceramic		Plaster
5	Detached	PVC	0.95				Ceramic		Plaster+wallpaper
6	Detached	PVC	0.9	1.05	1.45		Ceramic		Plaster
7	Detached	Wood	1.05	1.15	0.8		Ceramic+Wood		Plaster+wallpaper
8	Detached	Wood	1						
9	Detached	Wood							
10	Detached	Wood							
11	Detached	PVC	0.8				Concrete+Ceramic+Carpet		Wallpaper
12	Detached	PVC	1.1	1.25	1.45		Ceramic		Plaster
13	Detached	PVC					Ceramic		Plaster
14	Detached	Wood	1	1.15	1.2		Ceramic		Plaster
15	Detached	Wood		1.7	1		Masonry		Plaster
16	Detached	Wood	0.7	0.85	1.4		Ceramic		Plaster
17	Detached	PVC					Ceramic		Plaster
18	Detached	Wood					Ceramic		Plaster+wallpaper

	Interior features - Ground floor								
	Building type	Material of window	Height of windows (from floor level)	Height of windows (from street level)	Height of window	Width of window	Type of pavement	Material of internal walls	Finishing type of internal walls
19	Detached	PVC	1.05	1.1	1.4		Concrete+Ceramic		Plaster+ceramic
20	Detached	Wood							
21	Detached	PVC	0.9	1.35	1.1		Concrete	Masonry	Plaster
22	Detached	PVC						Drywall	Plaster
23	Detached	Wood	0.95	1.15	0.9	1.2	Concrete	Masonry	Plaster

Interior features - First floor

	Building type	Floor area	Floor height	Average room size	Facilities - Plumbing & sanitary system	Approx. Heigh of different elements	Facilities - Electric system	Approx. Height of lower sockets	Approx. Height of middle sockets	Approx. Height of light switches
1	Terrace middle	57.5	2.7	15	Yes	Typical	Yes			
2	Terrace middle	52		11	Yes	Typical	Yes			
3	Terrace middle	62.5		13	Yes	Typical	Yes			
4	Terrace middle	45	2.7	7	Yes	Typical	Yes			
5	Terrace middle	71		11	Yes	Typical	Yes			
6	Terrace middle	25		18	Yes	Typical	Yes	0.25	0.9	1.1
7	Terrace middle	100	2.9	14	Yes	Typical	Yes			1.2
8	Terrace middle				Yes	Typical	Yes			
9	Terrace middle	42.5		11	Yes	Typical	Yes			
10	Terrace middle	60	2.7	12	Yes	Typical	Yes	0.4		1
11	Terrace middle	80		27	Yes	Typical	Yes	0.3	1	1.1
12	Terrace middle	40	2.46	20	Yes	Typical	Yes		0.9	0.9
13	Terrace middle	55		18	Yes	Typical	Yes			
14	Terrace middle	49		12	Yes	Typical	Yes			
15	Terrace middle	61.7	2.84	12	Yes	Typical	Yes	0.6	1	1
16	Terrace middle	50	2.7	17	Yes	Typical	Yes	0.25	0.6	1.2
17	Terrace middle	55		14	Yes	Typical	Yes			
18	Terrace middle	41.6	2.88	14	Yes	Typical	Yes			
19	Terrace middle	49.5	2.64	17	Yes	Typical	Yes			
20	Terrace middle	70	3	18	Yes	Typical	Yes			
21	Terrace middle	50		25	Yes	Typical	Yes			
22	Terrace middle	115.8		19	Yes	Typical	Yes			
23	Terrace middle	102.4	3	26	Yes	Typical	Yes	0.25		1.2
1	Terrace corner				Yes	Typical	Yes			

Interior features - First floor

	Building type	Floor area	Floor height	Average room size	Facilities - Plumbing & sanitary system	Approx. Heigh of different elements	Facilities - Electric system	Approx. Height of lower sockets	Approx. Height of middle sockets	Approx. Height of light switches
2	Terrace corner	110		15	Yes	Typical	Yes			
3	Terrace corner	50		10	Yes	Typical	Yes			
4	Terrace corner	75	2.6	15	Yes	Typical	Yes	0.4		1.2
5	Terrace corner	40	2.7	16	Yes	Typical	Yes			1
6	Terrace corner	39	2.5	16	Yes	Typical	Yes			
7	Terrace corner	80.4		13	Yes	Typical	Yes	0.3	1	1
8	Terrace corner	60		10	Yes	Typical	Yes			
9	Terrace corner	55	2.85	14	Yes	Typical	Yes			
10	Terrace corner	142.5	2.75	16	Yes	Typical	Yes			
11	Terrace corner	82.5		13	Yes	Typical	Yes			
12	Terrace corner	30	2.7	10	Yes	Typical	Yes	0.25	1	1
13	Terrace corner	60		10	Yes	Typical	Yes			
14	Terrace corner	44.5	2.7	11	Yes	Typical	Yes			
15	Terrace corner	40		8	Yes	Typical	Yes	0.4	1	1
16	Terrace corner	35	2.4	9	Yes	Typical	Yes			1.3
17	Terrace corner	50	2.97	13	Yes	Typical	Yes	0.2		1.15
18	Terrace corner	42.5	2.8	9	Yes	Typical	Yes	0.45		1.15
19	Terrace corner	107	2.8	15	Yes	Typical	Yes			
20	Terrace corner	80		16	Yes	Typical	Yes			
21	Terrace corner	42		11	Yes	Typical	Yes			
1	Semidetached	50.5		17	Yes	Typical	Yes			
2	Semidetached	50		13	Yes	Typical	Yes			1.3
3	Semidetached	62.5	2.85	16	Yes	Typical	Yes			
4	Semidetached	83		17	Yes	Typical	Yes			

Interior features - First floor

	Building type	Floor area	Floor height	Average room size	Facilities - Plumbing & sanitary system	Approx. Heigh of different elements	Facilities - Electric system	Approx. Height of lower sockets	Approx. Height of middle sockets	Approx. Height of light switches
5	Semidetached	69.5	2.98	14	Yes	Typical	Yes	0.3		
6	Semidetached	72	2.8	14	Yes	Typical	Yes			
7	Semidetached	40		13	Yes	Typical	Yes			
8	Semidetached	118.1		17	Yes	Typical	Yes			
9	Semidetached	37		9	Yes	Typical	Yes			
10	Semidetached	70		18	Yes	Typical	Yes			
11	Semidetached	62	2.4	16	Yes	Typical	Yes			
12	Semidetached	75.8		11	Yes	Typical	Yes			
13	Semidetached	54	2.79	18	Yes	Typical	Yes	0.25		1.2
14	Semidetached	70		14	Yes	Typical	Yes			
15	Semidetached	85.6	2.9	14	Yes	Typical	Yes			
16	Semidetached	92.5	2.55	15	Yes	Typical	Yes	0.3	1.2	1.2
17	Semidetached	114	2.7	14	Yes	Typical	Yes			
18	Semidetached	115	2.7	19	Yes	Typical	Yes			
19	Semidetached	138.5	2.95	17	Yes	Typical	Yes			
20	Semidetached	24.9		8	Yes	Typical	Yes			
21	Semidetached	87.4		16	Yes	Typical	Yes			
22	Semidetached	202		17	Yes	Typical	Yes			
23	Semidetached	102.3	2.63	15	Yes	Typical	Yes			
1	Detached	87		14	Yes	Typical	Yes			
2	Detached	78.2	2.75	16	Yes	Typical	Yes		1.2	1.3
3	Detached	85	2.7	11	Yes	Typical	Yes			
4	Detached	193	2.8	21	Yes	Typical	Yes	0.25		
5	Detached	68.5	2.62	17	Yes	Typical	Yes			

Interior features - First floor

	Building type	Floor area	Floor height	Average room size	Facilities - Plumbing & sanitary system	Approx. Heigh of different elements	Facilities - Electric system	Approx. Height of lower sockets	Approx. Height of middle sockets	Approx. Height of light switches
6	Detached	90	2.95	13	Yes	Typical	Yes	0.5		1.15
7	Detached									
8	Detached	100	2.95	14	Yes	Typical	Yes			
9	Detached	68		10	Yes	Typical	Yes			
10	Detached	69.7	3	9	Yes	Typical	Yes			
11	Detached									
12	Detached	147	3	16	Yes	Typical	Yes	0.4		
13	Detached									
14	Detached	200	2.3	22	Yes	Typical	Yes	0.2		1.1
15	Detached	87.9	3	9	Yes	Typical	Yes			
16	Detached	79.4	2.65	16	Yes	Typical	Yes	0.2		
17	Detached	52.5		13	Yes	Typical	Yes			
18	Detached	81		16	Yes	Typical	Yes			
19	Detached	45	2.4	9	Yes	Typical	Yes	0.4		1.15
20	Detached									
21	Detached	38.5	2.7	10	Yes	Typical	Yes	0.35		1
22	Detached	122.4		17	Yes	Typical	Yes			
23	Detached	70	2.5	13	Yes	Typical	Yes	0.35		1.1

Interior features - First floor

	Building type	Facilities-Heating system	Type	Height of radiator from floor	Distribution type	Number of doors	Material of doors	Height of door	Width of door	Number of windows
1	Terrace middle	Yes	Radiator		Distributed	2				4
2	Terrace middle	Yes (gas)	Radiator		Distributed	3	Wood			4
3	Terrace middle	Yes			Distributed	3	Wood+Glass			3
4	Terrace middle	Yes	Radiator		Distributed	3	Wood			4
5	Terrace middle					2	Wood			4
6	Terrace middle	Yes	Radiator	0.2	Distributed	1	Wood			1
7	Terrace middle	Yes	Radiator	0.2	Distributed	4	Wood			6
8	Terrace middle	No								
9	Terrace middle	Yes			Distributed	3	Wood	2.1	0.8	2
10	Terrace middle	Yes	radiator		Distributed	5	Wood			3
11	Terrace middle	Yes	Other (heat pump)	0.2	Distributed	4	Wood+Glass			5
12	Terrace middle	Yes	Other (heat pump)		Distributed	4	Wood			2
13	Terrace middle	Yes	Other (heat pump)		Distributed	5	Wood+Glass			3
14	Terrace middle					3		2.1	0.8	4
15	Terrace middle	Yes	Radiator		Distributed	4	Wood+Glass			3
16	Terrace middle	Yes	other (warm air)		Distributed	4	Wood			3
17	Terrace middle	Yes	Radiator		Distributed	4	Wood+PVC+Glass			3
18	Terrace middle	Yes			Distributed	2	Wood			2
19	Terrace middle					2	Wood			3
20	Terrace middle	Yes			Distributed	4	Wood			3
21	Terrace middle					1	Wood+Glass			4
22	Terrace middle	Yes	Radiator		Distributed		Wood+Glass			
23	Terrace middle	Yes	Radiator	0.2	Distributed		Wood+Glass			
1	Terrace corner	Yes	Radiator	0.2	Distributed		Wood			

Interior features - First floor										
	Building type	Facilities-Heating system	Type	Height of radiator from floor	Distribution type	Number of doors	Material of doors	Height of door	Width of door	Number of windows
2	Terrace corner	Yes (gas)	radiator		Distributed	2	Wood	2	0.8	3
3	Terrace corner	Yes (gas)	radiator		Distributed	3	Wood			4
4	Terrace corner	Yes	radiator		Distributed	4	Wood+PVC+Glass			5
5	Terrace corner	Yes	radiator		Distributed	4	Wood+Glass			3
6	Terrace corner					2				3
7	Terrace corner	Yes	Radiator	0.2	Distributed	5				6
8	Terrace corner	Yes	radiator		Distributed	7	Wood			6
9	Terrace corner					3	Wood			5
10	Terrace corner					8	Wood+Glass			7
11	Terrace corner	Yes	radiator		Distributed	6	Wood			4
12	Terrace corner	Yes	Radiator	0.2	Distributed	3	Wood+PVC+Glass			3
13	Terrace corner					4	Steel			6
14	Terrace corner	Yes	radiator		Distributed	3	Wood			4
15	Terrace corner	Yes	Radiator	0.2	Distributed	4	Wood+Glass			3
16	Terrace corner	Yes	radiator	0.15	Distributed	4	Wood+Glass			4
17	Terrace corner	Yes	radiator		Distributed	3	Wood+Glass			3
18	Terrace corner	Yes	radiator	0.15	Distributed	4	Wood+PVC+Glass			2
19	Terrace corner	Yes	radiator	0.2	Central heating		Wood			
20	Terrace corner	Yes	radiator		Central heating					
21	Terrace corner	Yes	radiator		Distributed					
1	Semidetached	Yes	radiator		Distributed	3	Wood+PVC+Glass			5
2	Semidetached	Yes	radiator	0.2	Distributed	3	Wood+Glass	2.1	0.8	4
3	Semidetached	Yes	radiator	0.2	Distributed	3	Wood			6
4	Semidetached	Yes	radiator		Distributed	6	Wood+Glass			3
5	Semidetached	Yes	Other (heat pump)	0.2	Distributed	4	Wood+Steel+PVC+Glass			3
6	Semidetached					5				5

Interior features - First floor									
	Building type	Facilities-Heating system	Type	Height of radiator from floor	Distribution type	Number of doors	Material of doors	Height of door	Width of door
7	Semidetached	Yes	radiator		Distributed	3	Wood+PVC+Glass		1
8	Semidetached					6			6
9	Semidetached	Yes	Other (warm air)		Distributed	3	Wood		4
10	Semidetached					3			3
11	Semidetached					3	Wood		6
12	Semidetached	Yes	radiator		Distributed	6	Wood		7
13	Semidetached	Yes	radiator	0.2	Distributed	4	Wood+PVC+Glass		2
14	Semidetached	Yes (gas)	radiator		Distributed	5	Wood+Glass		3
15	Semidetached					11			9
16	Semidetached	Yes	radiator		Distributed	6	Wood+Glass		5
17	Semidetached	Yes (gas)	radiator		Distributed	8	Wood		5
18	Semidetached	Yes	radiator		Distributed	7	Wood		6
19	Semidetached	Yes	radiator	0.2	Distributed	7	Wood+Glass		7
20	Semidetached	Yes	radiator		Distributed	2			2
21	Semidetached	Yes	radiator		Distributed		Wood+Glass		
22	Semidetached	Yes	radiator		Distributed		Wood+Glass		
23	Semidetached	Yes	radiator		Distributed		Wood+Glass		
1	Detached	Yes	radiator		Distributed	6	Wood		9
2	Detached	Yes	Other (heat pump)		Distributed	4	Wood+Glass		4
3	Detached	Yes	radiator		Distributed	6			6
4	Detached	Yes	radiator	0.2	Distributed	8	Wood+Glass		11
5	Detached				Distributed	4	Wood+Glass		4
6	Detached	Yes	radiator	0.2	Distributed	7	Wood+Steel+Glass		7
7	Detached			0.2	Distributed				
8	Detached	Yes	radiator		Distributed	8	Wood		3
9	Detached	Yes	radiator		Distributed	6	Wood		9

Interior features - First floor

	Building type	Facilities-Heating system	Type	Height of radiator from floor	Distribution type	Number of doors	Material of doors	Height of door	Width of door	Building type
10	Detached	Yes	radiator		Distributed	5	Wood			8
11	Detached			0.2	Distributed					
12	Detached	Yes	radiator	0.2	Distributed	10	Wood			11
13	Detached				Distributed					
14	Detached	Yes	radiator	0.2	Distributed	6	Wood			10
15	Detached	Yes	radiator		Distributed	8	Wood			5
16	Detached	Yes		0.2	Distributed	7	Wood			5
17	Detached	Yes	radiator		Distributed	4	Wood+Glass			3
18	Detached	Yes	radiator		Distributed	5	Wood			5
19	Detached	Yes	radiator	0.2	Distributed	5	Wood			5
20	Detached				Distributed					
21	Detached	Yes			Distributed		Wood			
22	Detached	Yes			Distributed					
23	Detached	Yes (gas)	radiator		Distributed		Wood			

Interior features - First floor								
	Building type	Material of window	Height of windows (from floor level)	Height of window	Width of window	Type of pavement	Material of internal walls	Finishing type of internal walls
1	Terrace middle							
2	Terrace middle	Wood				Ceramic	Masonry	Plaster
3	Terrace middle	PVC				Linoleum+Ceramic	Masonry	plaster+wallpaper
4	Terrace middle	Wood				Ceramic	Masonry	plaster+wood
5	Terrace middle	Wood				Ceramic	Masonry	Plaster
6	Terrace middle	Wood				Ceramic	Masonry	
7	Terrace middle	Wood+PVC				Wood+Ceramic	Masonry	Plaster
8	Terrace middle					Ceramic	Masonry	Plaster
9	Terrace middle	Wood	0.9	1.2	2.05		Masonry	plaster+ceramic
10	Terrace middle	Wood				Ceramic	Masonry	Plaster
11	Terrace middle	Wood				Ceramic	Masonry	Plaster
12	Terrace middle	Wood	0.7			Ceramic	Masonry	plaster+ceramic
13	Terrace middle	Wood				Ceramic	Masonry	plaster
14	Terrace middle			1.6	1.2			
15	Terrace middle	Wood	1.1			Ceramic+Wood	Masonry	plaster+wood
16	Terrace middle	PVC	1			Ceramic	Masonry	plaster+wallpaper
17	Terrace middle	PVC				Ceramic	Masonry	plaster+wallpaper
18	Terrace middle	PVC				Ceramic	Masonry	plaster
19	Terrace middle	Wood						
20	Terrace middle	Wood						
21	Terrace middle	Wood				Ceramic+Concrete	Masonry	Plaster
22	Terrace middle	Wood				Ceramic	Masonry	plaster+wallpaper
23	Terrace middle	Wood	1			Ceramic	Masonry	plaster+wallpaper
1	Terrace corner	PVC	1			Ceramic	Masonry	Plaster

Interior features - First floor

	Building type	Material of window	Height of windows (from floor level)	Height of window	Width of window	Type of pavement	Material of internal walls	Finishing type of internal walls
2	Terrace corner	PVC				Linoleum+Ceramic	Masonry	Plaster
3	Terrace corner	Wood				Ceramic	Masonry	Plaster
4	Terrace corner	PVC	0.9			Ceramic		Plaster
5	Terrace corner	Wood	1.2			Ceramic		Plaster
6	Terrace corner							Plaster
7	Terrace corner							
8	Terrace corner	Wood						
9	Terrace corner	Wood						
10	Terrace corner	Wood						
11	Terrace corner	Wood		1.5	1.5	Ceramic		plaster
12	Terrace corner	PVC	0.8			Ceramic		plaster+wallpaper
13	Terrace corner	Wood						
14	Terrace corner	Wood						
15	Terrace corner	Wood				Concrete		Plaster
16	Terrace corner	PVC	1.05			Ceramic		Plaster
17	Terrace corner	Wood				Ceramic+Concrete		plaster+wallpaper
18	Terrace corner	Wood	0.8			Ceramic		plaster
19	Terrace corner	Wood				Parquet+Ceramic	Masonry	plaster+wallpaper
20	Terrace corner						Masonry	Plaster
21	Terrace corner						Drywall	Plaster
1	Semidetached	Wood				Ceramic		Plaster
2	Semidetached	Wood	1	1.4	0.9	Ceramic		Plaster
3	Semidetached	PVC				Ceramic		Plaster
4	Semidetached	Wood				Ceramic+Granolithic concrete		Plaster

Interior features - First floor								
	Building type	Material of window	Height of windows (from floor level)	Height of window	Width of window	Type of pavement	Material of internal walls	Finishing type of internal walls
5	Semidetached	Wood	1			Ceramic+Wood		Plaster
6	Semidetached							
7	Semidetached	PVC				Ceramic		Plaster
8	Semidetached							
9	Semidetached	Wood						
10	Semidetached							
11	Semidetached	PVC						
12	Semidetached	Wood				Ceramic		Plaster
13	Semidetached	PVC	1.2			Ceramic		Plaster
14	Semidetached	PVC				Linoleum+Ceramic		Plaster+wallpaper
15	Semidetached							
16	Semidetached	Wood	0.8			Ceramic		Plaster
17	Semidetached	Wood						
18	Semidetached	PVC						
19	Semidetached	Wood	0.85			Ceramic		Plaster
20	Semidetached							
21	Semidetached	Wood				Ceramic		Plaster
22	Semidetached	Wood				Ceramic		Plaster+wallpaper
23	Semidetached	Wood				Ceramic		Plaster
1	Detached	Wood				Ceramic		Plaster
2	Detached	PVC	0.9			Ceramic		Plaster
3	Detached							
4	Detached	Wood	0.9			Ceramic		Plaster
5	Detached	PVC	0.95			Ceramic		Plaster+wallpaper

Interior features - First floor								
	Building type	Material of window	Height of windows (from floor level)	Height of window	Width of window	Type of pavement	Material of internal walls	Finishing type of internal walls
6	Detached	PVC	0.9			Ceramic		Plaster
7	Detached							
8	Detached	Wood	1					
9	Detached	Wood						
10	Detached	Wood						
11	Detached							
12	Detached	PVC	1			Ceramic		Plaster
13	Detached							
14	Detached	Wood	0.9			Ceramic		Plaster
15	Detached	Wood				Masonry		Plaster
16	Detached	Wood	0.8			Ceramic		Plaster
17	Detached	PVC				Ceramic		Plaster
18	Detached	Wood				Ceramic		Plaster+wallpaper
19	Detached	PVC	0.9			Concrete+Ceramic		Plaster+ceramic
20	Detached							
21	Detached	PVC	0.9			Concrete	Masonry	Plaster
22	Detached						Drywall	Plaster
23	Detached	Wood	0.95			Concrete	Masonry	Plaster

Interior features - Second floor

	Building type	Floor area	Floor height	Average room size	Facilities - Plumbing & sanitary system	Approx. Heigh of different elements	Facilities - Electric system	Approx. Height of lower sockets	Approx. Height of middle sockets	Approx. Height of light switches
6	Terrace middle	35		15	Yes	Typical	Yes	0.25	0.9	1.1
11	Terrace middle	80		27	Yes	Typical	Yes	0.3	1	1.1
7	Terrace corner	80.4		13	Yes	Typical	Yes	0.3	1	1
12	Terrace corner	30	2.7	10	Yes	Typical	Yes	0.25	1	1
15	Terrace corner	40		10	Yes	Typical	Yes	0.4	1	1

Interior features - Second floor

	Building type	Facilities- Heating system	Type	Height of radiator from floor	Distribution type	Number of doors	Material of doors	Number of windows	Material of window
6	Terrace middle	Yes	Radiator	0.2	Distributed	1	Wood	1	Wood
11	Terrace middle	Yes		0.2	Distributed	3	Wood+Glass	4	Wood
7	Terrace corner	Yes	Radiator	0.2	Distributed	5		5	
12	Terrace corner	Yes	Radiator	0.2	Distributed	2	Wood+PVC+Glass	4	PVC
15	Terrace corner	Yes	Radiator	0.2	Distributed		Wood+Glass		Wood

	Interior features - Second floor						
	Building type	Height of windows (from floor level)	Height of window	Width of window	Type of pavement	Material of internal walls	Finishing type of internal walls
6	Terrace middle				Ceramic	Masonry	
11	Terrace middle				Ceramic	Masonry	Plaster
7	Terrace corner						
12	Terrace corner				Ceramic		plaster+wallpaper
15	Terrace corner				Concrete		Plaster

		Geometrical Features					
Building type		Level 1: External perimeter	Level 1: Internal perimeter	Level 2: External perimeter	Level 2: Internal perimeter	Level 3: External perimeter	Level 3: Internal perimeter
1	Apartment	14.14	72.17				
2	Apartment	10.6	61				
3	Apartment	22.5	100.6				
4	Apartment	16.45	87.8				
5	Apartment	19	56.1				
6	Apartment	34.9	127.6				
7	Apartment	13.3	57.8				
8	Apartment	26.97	108.12				
9	Apartment	32.1	106.12				
10	Apartment	6.6	56.8				
11	Apartment	19.64	97.1				
12	Apartment	18	87.1				
13	Apartment	17.74	72.23				
14	Apartment	20.4	81.1				
15	Apartment	17.5	87.4				
16	Apartment	10.73	79.5				
17	Apartment	18.72	91.1				
18	Apartment	18.6	66.79				
19	Apartment	48.53	119.08				
20	Apartment	20.17	89.93				
21	Apartment	20.07	113.96				
22	Apartment	30	96.77				
23	Apartment	17.4	79.9				
24	Apartment	28	74.7				
1	Terrace middle	11.7	49.7	11.7	41.3		

		Geometrical Features					
Building type		Level 1: external perimeter	Level 1: internal perimeter	Level 2: external perimeter	Level 2: internal perimeter	Level 3: external perimeter	Level 3: internal perimeter
2	Terrace middle	19.7	41.14	19.7	51.08		
3	Terrace middle	13.42	57.3	13.42	53.84		
4	Terrace middle	12.8	38.6	12.8	40.9		
5	Terrace middle	9.8	23.3	19.2	42.9		
6	Terrace middle	13.7	41.6	8	17.9	20.8	28.44
7	Terrace middle	29.2	79.72	29.2	66.52		
8	Terrace middle	15.89	81.1				
9	Terrace middle	9.1	37.7	9.1	50.3		
10	Terrace middle	14.4	52.42	14.4	67.74		
11	Terrace middle	21	67.6	21	65.9	21	56.8
12	Terrace middle	15.73	47.1	13.4	38.4		
13	Terrace middle	19.2	45.3	18.4	47.7		
14	Terrace middle	8.9	49.5	6.2	50.1		
15	Terrace middle	5.2	55.2	5.2	46.73		
16	Terrace middle	8.9	46.7	8.9	52.42		
17	Terrace middle	9.31	50.01	9.31	54.89		
18	Terrace middle	8.58	42.18	8.5	37.3		
19	Terrace middle	9.72	69.98	9.78	40.8		
20	Terrace middle	17.18	50	17.18	61.24		
21	Terrace middle	17.05	51.33	17.05	39.5		
22	Terrace middle	20	73.8	20	87.3		
23	Terrace middle	12.8	53	12.8	62.8		
1	Terrace corner	30.6	65.7	25.8	57.1		
2	Terrace corner	30.4	64.8	30.4	64.6		
3	Terrace corner	20.2	41	20.2	49.2		

Geometrical Features							
Building type		Level 1: external perimeter	Level 1: internal perimeter	Level 2: external perimeter	Level 2: internal perimeter	Level 3: external perimeter	Level 3: internal perimeter
4	Terrace corner	22.35	63.9	23.6	43.4		
5	Terrace corner	13.13	37.75	13.13	37.73		
6	Terrace corner	18	29.51	18	35.02		
7	Terrace corner	27.3	82.47	32.2	66.93	32.2	74.23
8	Terrace corner	33.17	59.06	33.17	68.03		
9	Terrace corner	33.12	53.37	33.12	50.03		
10	Terrace corner	48.46	135.16	48.46	117.83		
11	Terrace corner	39.81	61.82	39.81	80		
12	Terrace corner	23.51	28.3	23.51	27.6	23.51	27.75
13	Terrace corner	33.29	49.85	33.29	63.96		
14	Terrace corner	27.04	27.28	27.04	41.56		
15	Terrace corner	27.21	39.77	27.21	42.1	27.21	48.09
16	Terrace corner	26.75	38.24	26.75	36.16		
17	Terrace corner	28.5	42.85	28.5	45.9		
18	Terrace corner	8.75	15.9	8.75	16		
19	Terrace corner	33.9	62.8	33.9	80		
20	Terrace corner	29	63	29	56.5		
21	Terrace corner	28	68.2	22.2	55.8		
1	Semidetached	25.9	48.4	25.9	44.5		
2	Semidetached	25.9	57.36	22.1	65.1		
3	Semidetached	22.9	50.3	22.9	61.4		
4	Semidetached	36.8	74.3	36.8	79.6		
5	Semidetached	23.5	63.62	23.5	60.8		
6	Semidetached	26	71.1	26	67.1		
7	Semidetached	19.6	52.8	19.6	44.4		

Geometrical Features							
Building type		Level 1: external perimeter	Level 1: internal perimeter	Level 2: external perimeter	Level 2: internal perimeter	Level 3: external perimeter	Level 3: internal perimeter
8	Semidetached	45.9	113.27	33.4	105.55		
9	Semidetached	22.74	37.78	22.74	33.37		
10	Semidetached	23.26	60.2	23.28	64.2		
11	Semidetached	28.6	47.65	28.6	52.16		
12	Semidetached	37.29	81.46	29.58	83.18		
13	Semidetached	25.3	64.11	23.5	54.69		
14	Semidetached	21.86	42.2	23.73	69.4		
15	Semidetached	34.17	72.25	36.82	94.11		
16	Semidetached	32.5	71.3	32.4	82.09		
17	Semidetached	26.75	95.5	26.75	110.13		
18	Semidetached	32	92.87	32	77.94		
19	Semidetached	49.52	111.84	49.52	108.66		
20	Semidetached	20.44	21.9	21.06	25.43		
21	Semidetached	33.8	62.6	26.2	54.9		
22	Semidetached	68.7	134.4	68.7	132.2		
23	Semidetached	33	75.2	32.3	87.9		
1	Detached	40.16	76.1	40.16	82.32		
2	Detached	46.27	92.83	39.79	69.73		
3	Detached	34.72	48.36	38.76	77.19		
4	Detached	62.05	127.78	68.1	142.53		
5	Detached	33.12	68.55	33.12	55.62		
6	Detached	37.95	84.74	37.95	84.94		
7	Detached	43.24	99.57				
8	Detached	42.06	92.3	42.06	84.41		
9	Detached	33.42	71.66	33.42	70.76		

Geometrical Features							
Building type		Level 1: external perimeter	Level 1: internal perimeter	Level 2: external perimeter	Level 2: internal perimeter	Level 3: external perimeter	Level 3: internal perimeter
10	Detached	40.1	86.71	35.96	74.86		
11	Detached	40.72	88.45				
12	Detached	60.31	111.67	60.31	122.13		
13	Detached	42.73	86.88				
14	Detached	63.28	130.27	63.28	115.9		
15	Detached	55.68	129.11	39.49	96.41		
16	Detached	40.05	67.92	40.24	65.94		
17	Detached	29.85	31.31	29.85	46.17		
18	Detached	35.65	54.97	35.65	66.77		
19	Detached	29.19	43.97	29.19	32.96		
20	Detached	39.18	70.49				
21	Detached	28	38.6	25.3	34.3		
22	Detached	45.7	85	44.4	110		
23	Detached	44.1	72	36	46.5		