Hypotheses on damage mechanisms for the different building components

If the model is applied to calculate expected damages, the formulation for damage estimation to each building component *Cij* can be written as:

$$C_{ij} = up_{ij} \cdot ext_{ij} \cdot E[R]$$

where up_{ij} is the unit price for the removal/replacement of the building component *ij* (default values are shown in Table S1 of this Supplement), ext_{ij} is the extension of the building component to be removed/replaced and *E[R]* is the expected damage ratio.

A more general formulation is used to obtain a distribution of the total building damage, which takes into account the probabilities of occurrence of damage to the different components:

$$C_{ij} = up_{ij} \cdot ext_{ij} \cdot r_{ds}$$

where r_{ds} is the damage ratio of the element computed for damage state *ds*. Note that for some components, r_{ds} may depend on more than one hazard variable.

In the description of the damage functions, the general formulation will be used.

Adaptation of the original functions of INSYDE to the Walloon region

Once the context has been characterized, by identifying the parameters describing the representative flood events in the region and the qualitative features of the exposed dwellings (section 3.1 of the main paper), it is possible to modify the damage functions for the different building components. In this perspective, all the damage functions considered in the original INSYDE are analysed, verifying their suitability for the new context, and in the case they do not apply, amendments are proposed. This Supplement illustrates the new updated functions valid for the Walloon region, with the motivations for the proposed changes.

Clean-up costs

Pumping (C1)

The original function is considered valid also for the Walloon region

The cost for water pumping is calculated by considering water volumes stored in the basement (if present) and in the part of building below ground level (if GL<0). The damage function is deterministic.

$$ext_{C1} = IA \cdot (-GL) + BA \cdot (-BL)$$

$$C_{C1} = up_{C1} \cdot ext_{C1}$$

The basement level *BL* is calculated as $BL = GL - BH - 0.3$, where 0.3 m corresponds to the height of the slab.

Waste disposal (C2)

The original function is considered valid also for the Walloon region

The cost for waste disposal is supposed to depend on water volumes stored in the first floor and in the basement (if present) and on sediment concentration *s*. In the case of contaminated water, waste disposal costs are incremented by 40%. The function is 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)

The original function is considered valid also for the Walloon region

Building surfaces that have been in contact with floodwaters should be cleaned. Cleaning costs are calculated by considering water depth, internal perimeter, and internal floor area of each flooded storey, including the basement, if present. In the case of contaminated water, cleaning costs are incremented by 40%. The function is deterministic.

$$ext_{C3} = (IP \cdot h + BA + BP \cdot BH + IA \cdot N_{FF})$$

$$C_{C3} = \begin{cases} up_{C3} \cdot ext_{C3}, & q = 0 \\ 1.4 \cdot up_{C3} \cdot ext_{C3}, & q = 1 \end{cases}$$

The number of flooded floors N_{FF} is a function of the water depth and the interfloor height of the building.

Dehumidification (C4)

The original function has been adapted for the Walloon region

Dehumidification costs are supposed to appear for long duration floods and to depend on building volume (function of the number of flooded floors, including the basement (if present)). The function is probabilistic.

The field surveys in the Walloon region revealed that dehumidification activities have been seldom carried out by the inhabitants after recent flood events, therefore, compared to the original model, the flood duration damage function thresholds are shifted, starting damages after 24 hours up to a total damage cost after 48 hours of water contact with buildings surfaces. The probability distribution of occurrence of damage related to flood duration is given by the fragility function shown in Figure S1.

$$ext_{C4} = (IA \cdot IH \cdot N_{FF} + BA \cdot BH)$$

$$C_{C4} = up_{C4} \cdot ext_{C4} \cdot r_{ds}(S1)$$

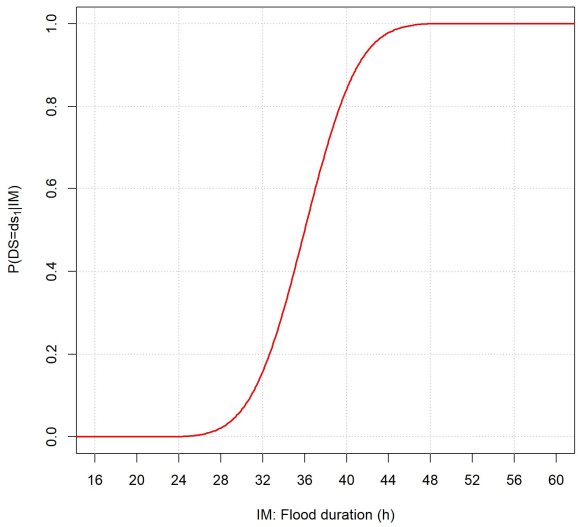


Figure S1. Fragility function for dehumidification, external and internal plaster components, relative to flood duration

Removal costs

Flooring system removal (R1)

The original function has been replaced with a new one for the Walloon region

The Italian flooring system is characterized by the presence of a screed, a thin concrete layer laid on the top of the slab, applied as a floating finish on a layer of rigid insulation material, above which the ceramic or parquet floor is installed. Differently, in Belgium the use of the screed is not very common. Indeed, in the case of old masonry buildings, the flooring system is made of wood, fixed to wooden beams by rivets, while for newer reinforced concrete buildings, especially for apartment houses, composite or precast flooring systems are the adopted solution (considered not to be damageable in a flood). In this perspective, the "Screed removal" damage function in the original INSYDE is changed and replaced by the "flooring system removal" function. This new function considers the removal of the flooring components when the building structure is "Masonry" and the year of construction is older than 1970 (i.e. wooden flooring systems are adopted), with a damage probability according to the fragility function shown in Figure S2.

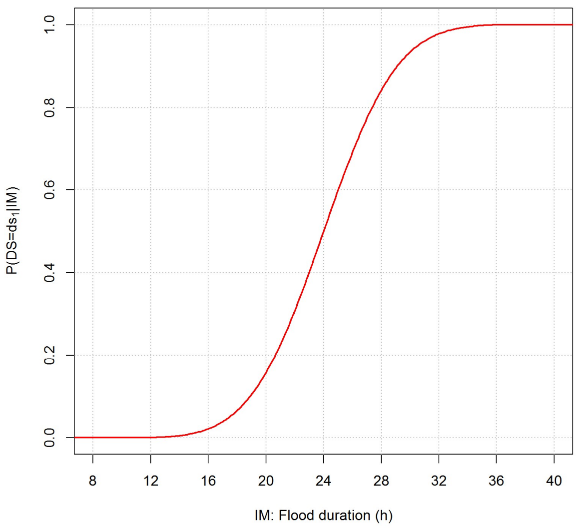


Figure S2. Fragility function for all applicable components (i.e. flooring system, pavement, baseboard, doors and windows), relative to flood duration

$$ext_{R1} = IA \cdot N_{FF}$$

$$C_{R1} = up_{R1} \cdot ext_{R1} \cdot r_{ds} (S2)$$

Pavement removal (R2)

The original function has been adapted for the Walloon region

Coherently with the previous damage function, the pavement is removed when there is a masonry building built before 1970, meaning that just wood pavement will be removed. The function is probabilistic. A full removal of pavements in each flooded storey is considered when a long duration flood occurs, in accordance with the fragility function shown in Figure S2.

$$ext_{R2} = IA \cdot N_{FF}$$

$$C_{R2} = up_{R2} \cdot ext_{R2} \cdot r_{ds} (S2)$$

Baseboard removal (R3)

The original function is considered valid also for the Walloon region

Baseboard is considered to be removed when a long flood duration occurs and h>0.05 m in each flooded storey (Penning-Rowsell et al., 2005). The function is probabilistic. The fragility function relative to flood duration is shown in Figure S2.

$$ext_{R3} = IP \cdot N_{FF}$$

$$C_{R3} = up_{R3} \cdot ext_{R3} \cdot r_{ds} (S2)$$

Removal of partition walls

The original function has been considered not valid for the Walloon region

Based on the surveys and consultation with experts, damage to partition walls has been described as very unlikely for typical events in the Walloon region, therefore the function is removed in the model for new context.

Plasterboard removal (R4)

The original function is considered valid also for the Walloon region

If not specifically indicated, high quality buildings only (FL>1) are assumed to have plaster ceilings, placed 0.5 m below the original ceiling level. Plasterboard area is assumed to be equal to the 20% of the internal area of the building. Plasterboard is considered to be removed when flood depth reaches plaster ceiling level. The function is deterministic.

$$ext_{R4} = 0.2 \cdot IA \cdot N_{FF}$$

$$C_{R4} = up_{R4} \cdot ext_{R4}$$

Removal of external finishing material (R5)

The original function has been adapted for the Walloon region

Differently from Italy, where buildings usually have plaster as external building's material, in the Walloon region there are other, more common, external materials, such as stones, masonry, without any type of plaster, and the combination of the bricks with a lower layer (some centimetres) of stones above the ground. For this reason, the original damage function "external plaster removal" has been changed to "removal of external finishing material", where the original function is retained, but assuming the possibility of damage occurrence only when the external material is plaster (i.e., EFM=1).

Under this condition, external plaster is then considered to be removed if one (or more) of these conditions occur (Penning-Rowsell et al., 2005):

- long duration flood: longer residence time enhances water penetration into the plaster; the fragility function is shown in Figure S1;
- high velocity flow: higher flow velocities cause more serious damage to exterior plaster; the fragility function is shown in Figure S3;

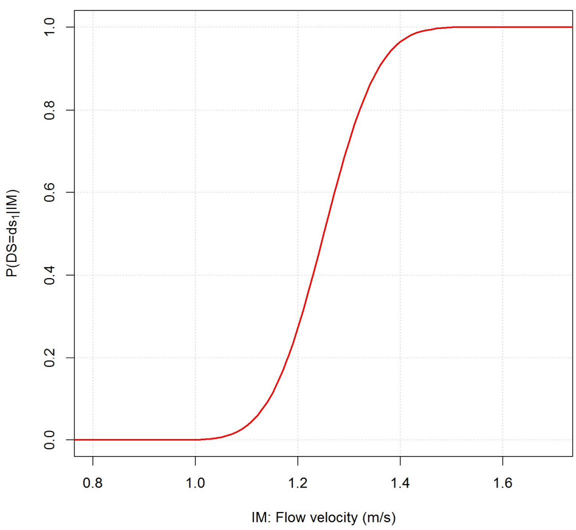


Figure S3. Fragility function for external finishing material (plaster) and doors, relative to flow velocity

- contaminated water (q=1): plaster replacement is usually required in case of contaminated water; in such scenarios, the damage ratio is considered to be 1;
- level of maintenance is “average” or “poor” (i.e. LM≤1), which implies a more vulnerable plaster, even under short duration floods and/or absence of contaminants in the water. In these cases, the damage ratio is considered to be 1.

The function is probabilistic. If more than one of the conditions mentioned above occur, the damage ratio considered is the maximum among the four. The underlying assumption is that the most unfavourable condition dominates the damage mechanism, independently of the others. The height considered in the calculations for plaster removal is equal to the external water depth plus 1.0 m due to capillary rise.

$$ext_{R5} = EP \cdot (h_e + 1.0)$$

$$C_{R5} = up_{R5} \cdot ext_{R5} \cdot \max(r_{ds})$$

Internal plaster removal (R6)

The original function has been adapted for the Walloon region

For this component, the original damage mechanisms are considered valid also for the Walloon region, but with some changes. In particular, an additional minimum threshold for damage occurrence has been set at 0.2 m of water depth, because the surveys revealed that internal plaster is usually not replaced for shallow water depths (walls are just left to dry out). Additionally, in the surveys it was observed that basement walls are not usually plastered; therefore, this contribution has been excluded in the new adapted model. Finally, differently from the original INSYDE, the damage thresholds for flood duration are increased, starting at 24 hours, and reaching a 100% probability of damage after 48 hours (Figure S1), as corroborated by the interviews with flooded people, who very seldom mentioned the repair of internal plaster for the experienced floods.

Therefore, internal plaster is considered to be removed if one (or more) of these conditions occur (Penning-Rowsell et al., 2005):

- long duration flood: longer residence time enhances water penetration into the plaster; the fragility function is shown in Figure S1;
- contaminated water (q=1): plaster replacement is usually required in case of contaminated water; in such scenarios, the damage ratio is considered to be 1;
- level of maintenance is “average” or “poor” (i.e. LM≤1), which implies a more vulnerable plaster, even under short duration floods and/or absence of contaminants in the water. In these cases, the damage ratio is considered to be 1.

The function is probabilistic. If more than one of the conditions mentioned above occur, the damage ratio considered is the maximum among the three. The underlying assumption is that the most unfavourable condition dominates the damage mechanism, independently of the others.

The height considered in the calculations for plaster removal is equal to the internal water depth plus 1.0 m due to capillary rise.

$$ext_{R6} = IP \cdot (h + 1.0)$$

$$C_{R6} = up_{R6} \cdot ext_{R6} \cdot \max(r_{ds})$$

Doors removal (R7)

The original function is considered to be valid also for the Walloon region

The original function is retained, along with the assumption of 2 (wood) doors per 100 m^2 for the basement, and 7 doors per 100 m^2 for the other storeys, which was confirmed from statistical analysis of virtual surveys. If not specifically indicated, a standard door size is considered (0.8 x 2.1 m).

Doors are more likely to require removal with higher water depths in each flooded storey, in accordance with the fragility function shown in Figure S4, and when at least one of these conditions is met (Penning-Rowsell et al., 2005):

- long duration flood: doors may swell under a long contact with water; the fragility function is shown in Figure S2;
- high velocity flow: doors can be seriously damaged under high velocity flows; the fragility function is shown in Figure S3.

The function is probabilistic. If more than one of the conditions mentioned above occur, the damage ratio considered is the maximum among the two. The underlying assumption is that the most unfavourable condition dominates the damage mechanism, independently of the other.

$$ext_{R7} = 0.12 \cdot IA \cdot N_{FF} + 0.03 \cdot BA$$

$$C_{R7} = up_{R7} \cdot ext_{R7} \cdot \max(r_{ds})$$

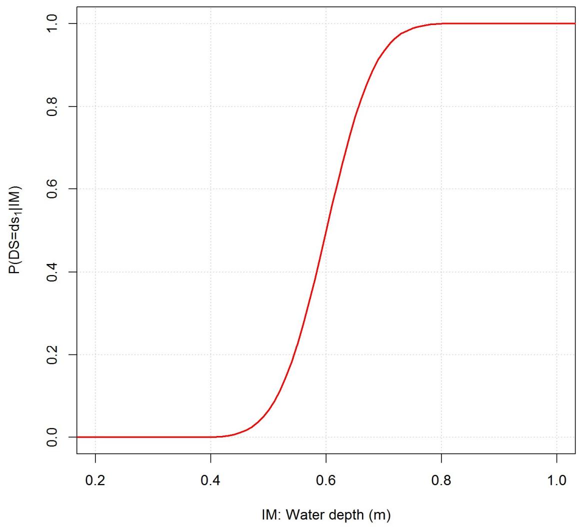


Figure S4. Fragility function for doors relative to water depth in each flooded storey

Windows removal (R8)

The original function has been adapted for the Walloon region

The original function is retained, i.e. windows are more likely to require removal with higher water depths in each flooded storey. However, according to the virtual surveys, the height of the windows from the floor level in the Walloon region has been found to be, on average, 0.75 m; the lower threshold for windows removal has been then shifted from 1.2 m (as tin the original model) to 0.75 m. of water depth. The new fragility function relative to water depth for this component is shown in Figure S5. As default, the number of windows in each building is supposed to depend on the floor level, as in Italy (0 if "basement", 6 windows per 100 m^2 for other storeys), but with a different average size, as resulted from the virtual surveys, which revealed an average size of the windows in the 5 provinces of the Walloon region to be equal to 1.8 m^2 for all the building types (while 1.96 m^2 was considered in the original INSYDE).

Damage to this component is supposed to occur when at least one of these conditions is met:

- long duration flood: windows may swell under a long contact with water; the fragility function is shown in Figure S2;
- high velocity flow: windows can be seriously damaged under high velocity flows; the fragility function is shown in Figure S6.

The function is probabilistic. If more than one of the conditions mentioned above occur, the damage ratio considered is the maximum between the two. The underlying assumption is that the most unfavourable condition dominates the damage mechanism, independently of the other.

$$ext_{R8} = 0.11 \cdot IA \cdot N_{FF}$$

$$C_{R8} = up_{R8} \cdot ext_{R8} \cdot \max(r_{ds})$$

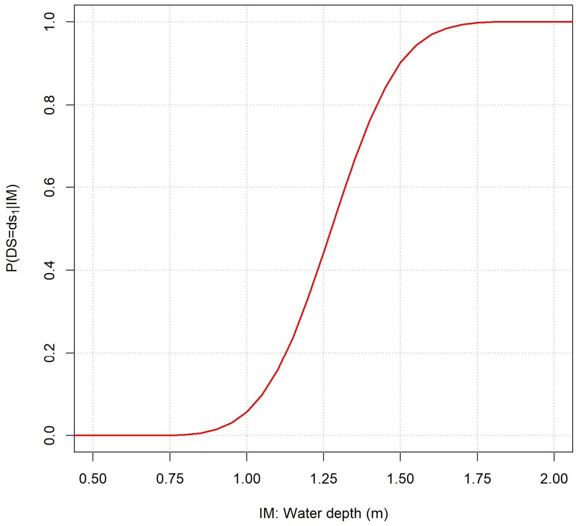


Figure S5. Fragility function for windows relative to water depth in each flooded storey

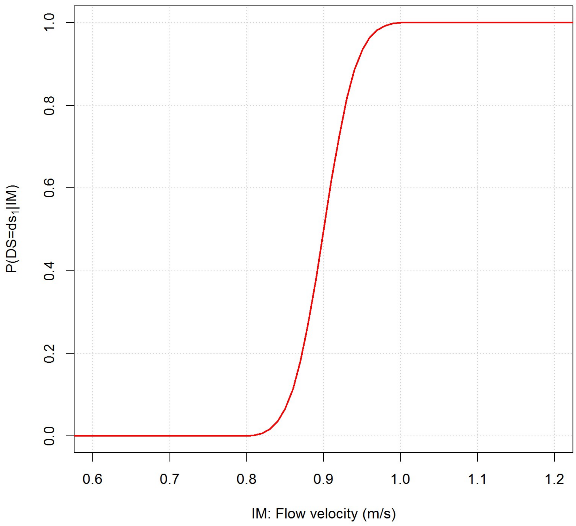


Figure S6. Fragility function for windows relative to flow velocity

Boiler removal (R9)

The original function has been adapted for the Walloon region

Due to the recorded variability of the boiler height, the original damage function considered for Italy is modified, using a probabilistic approach for the condition which estimates that the boiler is placed at an average height ranging from about 1.2 to 1.6 m from the pavement level.

Then, in the case of distributed heating systems (PD=2), the fragility function for the boiler replacement is shown in Figure S7, while for centralised heating systems (PD=1) two conditions are possible:

1) if a basement exists (i.e. BA>0), the boiler room is supposed to be located in the basement: the boiler is always considered to be removed when there is an event (i.e. basement is completely flooded);
2) if a basement is not present (i.e. BA=0), the boiler room is supposed to be located in the ground/first floor: in that case, the boiler is considered to be replaced according to the fragility function shown in Figure S7.

$$ext_{R9} = \begin{cases} IA \cdot N_{FF} \cdot r_{ds}(S7)\,, & h > 1.6\,m\ \ (when\ PD = 2) \\ IA\,, & h > 0\,m\ \ (when\ PD = 1\ and\ BA > 0) \\ IA \cdot r_{ds}(S7)\,, & h > 1.6\,m\ \ (when\ PD = 1\ and\ BA = 0) \\ 0, & else \end{cases}$$

$C_{R9} = up_{R9} \cdot ext_{R9}$

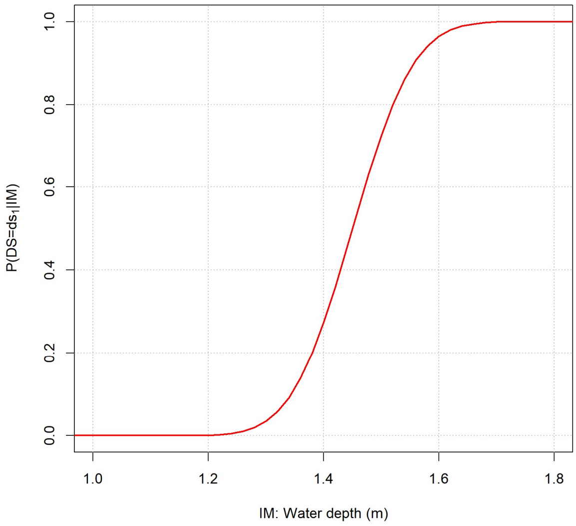


Figure S7. Fragility function for the boiler relative to water depth

<u>*Non-structural damage*</u>

Partitions replacement

The original function has been considered not valid for the Walloon region

Based on the surveys and consultation with experts, damage to partition walls has been described as very unlikely for typical events in the Walloon region, therefore the function is removed in the model for new context.

Flooring system replacement (N1)

The original function has been adapted for the Walloon region

The quantity of removed flooring system is replaced (see function R1).

$ext_{N1} = ext_{R1}$

$C_{N1} = up_{N1} \cdot ext_{N1} \cdot r_{ds}$

Plasterboard replacement (N2)

The original function is considered valid also for the Walloon region

The quantity of removed plasterboard is replaced (see function R4).

$ext_{N2} = ext_{R4}$

$C_{N2} = up_{N2} \cdot ext_{N2}$

<u>*Structural damage*</u>

The original thresholds for damage occurrence are considered valid also for the Walloon region

Given the lack of empirical evidences that could support the development of specific thresholds for the occurrence of structural damages in the Walloon region, the original relationships proposed in INSYDE are retained without any modifications. The details are reported below.

Structural damage is modelled probabilistically using a simple scheme, based on the approach proposed by Clausen and Clark (1990). Two damage classes (i.e. *Inundation* and *Partial damage*) are distinguished based on specific thresholds for flow velocity and intensity (i.e. the product between external flood depth and velocity) (Figure S8):

- *Inundation* ($v \leq 2$ m/s or $v \cdot he \leq 3$ m^2/s): no structural damages occur (i.e. the damage ratio is zero);
- *Partial damage* ($v > 2$ m/s and $3 < v \cdot he \leq 7$ m^2/s): some damages to the major structural elements of the building may occur, including soil consolidation, local repair and pillar repair. The fragility function is given in Figure S8.

At present, INSYDE does not consider the building collapse (which is very unlikely in the case of riverine floods, especially for reinforced concrete and masonry buildings), so the third damage class proposed by Clausen and Clark (1990) (*Total destruction*) is not implemented in the model.

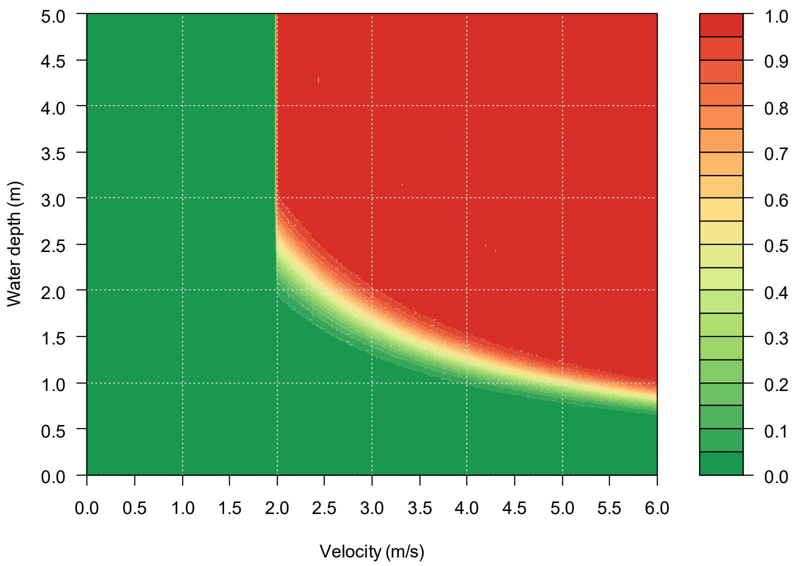


Figure S8. Fragility function for structural components relative to flow velocity and water depth

Soil consolidation (S1)

The original function is considered valid also for the Walloon region

Flood action may produce some scour near building foundations. The costs for soil consolidation are supposed to depend on building structure and on a fraction of building volume. In particular, if building structure is "Masonry" (BS=2), the volume of soil to be consolidated is considered to be equal to building volume, multiplied by 0.01; if building structure is "reinforced concrete" (BS=1), the multiplying coefficient is 0.02. These coefficients should be validated, as they should also depend on soil type, building shape and foundation type.

$$ext_{S1} = \begin{cases} IA \cdot NF \cdot IH \cdot 0.01, & BS = 2 \\ IA \cdot NF \cdot IH \cdot 0.02, & BS = 1 \end{cases}$$

$$C_{S1} = up_{S1} \cdot ext_{S1} \cdot r_{ds}(S8)$$

Local repair (S2)

The original function has been adapted for the Walloon region

Flood action may cause some damage on the external structure of buildings. Local repair costs are considered to be a function of external water depth, sediment load and external perimeter of the building, under the assumption that only two sides of the building may be exposed to flow and that a scour depth of 0.05 m in the masonry should be repaired.

$$ext_{S2} = \begin{cases} 0.5 \cdot EP \cdot h_e \cdot 0.05 \cdot (1+s), & EFM = 1,3 \\ 0.5 \cdot EP \cdot (he - 0.6) \cdot 0.05 \cdot (1+s), & EFM = 4 \\ 0, & EFM = 2 \end{cases}$$

$$C_{S2} = up_{S2} \cdot ext_{S2} \cdot r_{ds}(S8)$$

For the Walloon region, this damage subcomponent has been considered related to the external finishing material of the building: the function is the same as the one in the original INSYDE in the case of masonry or plaster material (EFM=1,3), while for the combined finishing (stone in the lower part of the wall and bricks in the upper one (EFM=2), local repair is expected only if water depth is higher than the level of the lower layer of stone (assumed to be equal to 0.6 m, based on observations from surveyed buildings).

Pillar repair (S3)

The original function is considered valid also for the Walloon region

Flood action may cause some damage on the pillars of reinforced concrete buildings. Therefore, if building structure is "Reinforced concrete" (BS=1), the costs for pillar repair are considered as a function of external water depth, sediment load and external perimeter of the building (under the assumption that the total perimeter of the pillars is equal to 15% of the external perimeter of the building and that only two sides of the building may be exposed to flow).

$$ext_{S3} = 0.5 \cdot 0.15 \cdot EP \cdot h_e \cdot (1 + s)$$

$$C_{S3} = up_{S3} \cdot ext_{S3} \cdot r_{ds}(S8)$$

<u>*Finishing*</u>

External finishing material and internal plaster replacement (F1 and F2)

The original functions have been adapted for the Walloon region

In the Walloon Region, the damage function for the replacement of the external finishing material only applies to buildings with external plaster material (i.e., EFM=1). In practice, if removed, external and internal plasters are replaced (see function R5 and R6). These costs are supposed to depend on the finishing level FL (i.e. higher quality plaster in high quality buildings). The function is probabilistic.

$$ext_{F1} = ext_{R5}$$

$$C_{F1} = up_{F1} \cdot ext_{F1} \cdot \max(r_{ds}) \cdot FL$$

$$ext_{F2} = ext_{R6}$$

$$C_{F2} = up_{F2} \cdot ext_{F2} \cdot \max(r_{ds}) \cdot FL$$

External painting (F3)

The original function has been adapted for the Walloon region

In the Walloon Region, this damage function only applies to buildings with external plaster material (i.e., EFM=1).

The extension of the external area to be repainted is considered as a function of the height of the flooded floors and the external perimeter. The costs for external painting are supposed to depend on finishing level FL (i.e. higher quality painting in high quality buildings). The function is deterministic.

$$ext_{F3} = EP \cdot N_{FF} \cdot IH$$

$$C_{F3} = up_{F3} \cdot ext_{F3} \cdot FL$$

Internal painting (F4)

The original functions have been adapted for the Walloon region

The function is deterministic. The costs for internal painting are considered to depend only on the finishing level of the building. They are calculated by considering the height of the flooded floors and the internal perimeter. Differently from

Italy, surveys revealed that plastering and painting of basement walls are not usual in the Walloon region; therefore, in the current version of the model this contribution has been not considered.

In addition, the surveys showed that wallpaper is a frequent option to decorate interior walls of Belgian houses,. This situation has been modelled in the current version of INSYDE by using the average cost between painting and wallpaper as unitary price for this component.

$ext_{F4} = IP \cdot N_{FF} \cdot IH$

$C_{F4} = up_{F4} \cdot ext_{F4} \cdot FL$

Pavement replacement (F5)

The original function has been adapted for the Walloon region

If removed, pavement (see function R2) is replaced. The function is probabilistic.

$ext_{F5} = ext_{R2}$

$C_{F5} = up_{F5} \cdot ext_{F5} \cdot r_{ds}(S1)$

Baseboard replacement (F6)

The original function is considered valid also for the Walloon region

The quantity of removed baseboard is replaced (see function R3). The function is probabilistic.

$ext_{F6} = ext_{R3}$

$C_{F6} = up_{F6} \cdot ext_{F6} \cdot r_{ds}$

<u>*Windows and doors*</u>

Doors replacement (W1)

The original function is considered valid also for the Walloon region

If removed, doors are replaced (see functions R7). When FL>1, the costs for doors and windows replacement are increased by a factor depending on FL. The function is probabilistic.

$ext_{W1} = ext_{R7}$

$$C_{W1} = \begin{cases} up_{W1} \cdot ext_{W1} \cdot \max(r_{ds}) \ , & FL \leq 1 \\ 2 \cdot up_{W1} \cdot ext_{W1} \cdot \max(r_{ds}) \ , & FL > 1 \end{cases}$$

Windows replacement (W2)

The original function has been adapted for the Walloon region

If removed, windows are replaced (see functions R8). When FL>1, the costs for doors and windows replacement are increased by a factor depending on FL. The function is probabilistic.

$ext_{W2} = ext_{R8}$

$$C_{W2} = \begin{cases} up_{W2} \cdot ext_{W2} \cdot \max(r_{ds}) \ , & FL \leq 1 \\ 2 \cdot up_{W2} \cdot ext_{W2} \cdot \max(r_{ds}) \ , & FL > 1 \end{cases}$$

Building systems

Boiler replacement (P1)

The original function has been adapted for the Walloon region

If removed, the boiler is replaced (see function R9). The function is probabilistic.

If building type is “detached” or “semi-detached” (BT=1 or BT=2), costs are increased by 25% (as the boiler is generally over dimensioned in these cases).

$$ext_{P1} = ext_{R9}$$

$$C_{P1} = \begin{cases} 1.25 \cdot up_{P1} \cdot ext_{P1}, & BT = 1 \text{ or } 2 \\ up_{P1} \cdot ext_{P1}, & BT = 3 \text{ or } 4 \end{cases}$$

Radiator painting (P2)

The original function has been adapted for the Walloon region

The virtual surveys confirmed that the original damage mechanism is also valid for the Walloon region: it is then assumed that, if the heating system type is “Radiator” (PT=1), radiator painting is required only when h>0.20 m in each flooded storey (where 0.2 m is the average height of radiators from the floor). The change in the new model is related to the assumed number of radiators per square meter, which is calculated by considering one radiator for each room and an average room size of 15 m^2, according to the results from the surveys (instead of 20 m^2 assumed for Italy). The function is deterministic.

$$ext_{P2} = N_{FF} \cdot IA/15$$

$$C_{P2} = up_{P2} \cdot ext_{P2}$$

Replacement of the underfloor heating system

The original function has been considered not valid for the Walloon region

Based on the surveys and consultation with experts, this damage subcomponent has not been considered for the Walloon region. Indeed, underfloor heating system is not conventionally used in old buildings, while it is present only in newer buildings, which nowadays are not built in the floodplains.

Electrical system replacement (P3)

The original function has been adapted for the Walloon region

Damages to the electrical system are considered exclusively dependant on water depth. From the virtual surveys, the typical heights of the different components of the system were confirmed also for the Walloon region, indicating the applicability of the thresholds adopted for Italy. However, according to the damages reported by the interviewed inhabitants, the experienced relative damage for this kind of component is generally lower than the one considered in the original INSYDE. As a consequence, the damage percentages are reduced as shown hereafter.

Four different classes are distinguished for each flooded storey:

- for h < 0.20 m, the electrical system is not damaged;
- for 0.20 m ≤ h < 1.10 m, lower sockets and cables are damaged, assuming a 30% relative damage (instead of 40% considered in the original INSYDE);
- for 1.10 m ≤ h < 1.50 m, upper sockets and cables are also damaged, assuming a 50% relative damage (instead of 70% considered in the original INSYDE);
- for h ≥ 1.50 m, control panel is also damaged, assuming a 100% relative damage.

$$ext_{P3} = \begin{cases} 0\,, & h \leq 0.2\ m \\ 0.3 \cdot IA \cdot N_{FF}\,, & 0.2 < h < 1.1\ m \\ 0.5 \cdot IA \cdot N_{FF}\,, & 1.1 \leq h < 1.5\ m \\ IA \cdot N_{FF}\,, & h \geq 1.5\ m \end{cases}$$

The function is deterministic. An incremental coefficient is introduced for FL>1, in order to account for the presence of more sophisticated systems (e.g. presence of security alarm systems, home automation systems, etc.) in high quality buildings.

$$C_{P3} = \begin{cases} up_{P3} \cdot ext_{P3}\,, & FL \leq 1 \\ 2 \cdot up_{P3} \cdot ext_{P3}\,, & FL > 1 \end{cases}$$

Plumbing system replacement (P4)

The original function has been adapted for the Walloon region

Damages to the plumbing system are supposed to occur if the sediment load is relevant (i.e. s>0.10) or if water is contaminated (q=1). Under these conditions, plumbing system is supposed be obstructed and/or damaged. The suitability of the adopted thresholds for water depth is confirmed for the new context, however, the absence of bidet in most of the Belgian houses allows the assumption of lower damages for water depths above 0.4 m. In this perspective, the damage function has been modified as:

- for h ≤ 0.15 m, the plumbing system is not damaged;
- for 0.15m < h < 0.40 m, the shower can be damaged, assuming a 10% relative damage;
- for 0.40m ≤ h < 0.90 m, toilet bowl can also be damaged, assuming a 20% relative damage (instead of 30% considered in the original INSYDE);
- for h ≥ 0.90 m, sinks can be damaged, assuming a 30% relative damage (instead of 50% considered in the original INSYDE).

$$ext_{P4} = \begin{cases} 0\,, & h \leq 0.15\ m \\ 0.1 \cdot IA \cdot N_{FF}\,, & 0.15 < h < 0.4\ m \\ 0.2 \cdot IA \cdot N_{FF}\,, & 0.4 \leq h < 0.9\ m \\ 0.3 \cdot IA \cdot N_{FF}\,, & h \geq 0.9\ m \end{cases}$$

The function is deterministic. An incremental coefficient is introduced for FL>1, in order to account for the presence of high quality components in high quality buildings.

$$C_{P4} = \begin{cases} up_{P4} \cdot ext_{P4}\,, & FL \leq 1 \\ 2 \cdot up_{P4} \cdot ext_{P4}\,, & FL > 1 \end{cases}$$

Identification of default relationships for external and internal perimeter of the building

The external perimeter of the building is considered as the sum of the length of the external building's walls that could be exposed to flood water. For this reason, a distinction is made for the different building types, i.e. detached or apartment buildings, semi-detached and attached buildings, considering the different housing units (isolated, corner and central, see Figure 8 in the main paper). As default value, the external perimeter is calculated as a function of the footprint area (Table 2), by following a synthetic approach which assumes typical layouts of the buildings (Figure 8).

A combination between an empirical and synthetic approach was instead carried out for estimating a default value for the internal perimeter for the different building typologies. The empirical data were taken from the virtual surveys, while, with respect to the synthetic analysis, different internal layouts were assumed for the different building typologies and sizes (an example for two detached buildings is shown in Figure S9).
In this analysis, an average room size of 15m^2 was considered and the number of doors (each one with a width of 0.8 m) was assumed to be equal to the number of rooms and bathrooms plus a main entrance door. In this way, the total length of the internal walls (IP) is measured and together with the empirical data, a regression analysis of IP with FA is performed, with the linear interpolation resulting as the best fit (Figure S10).

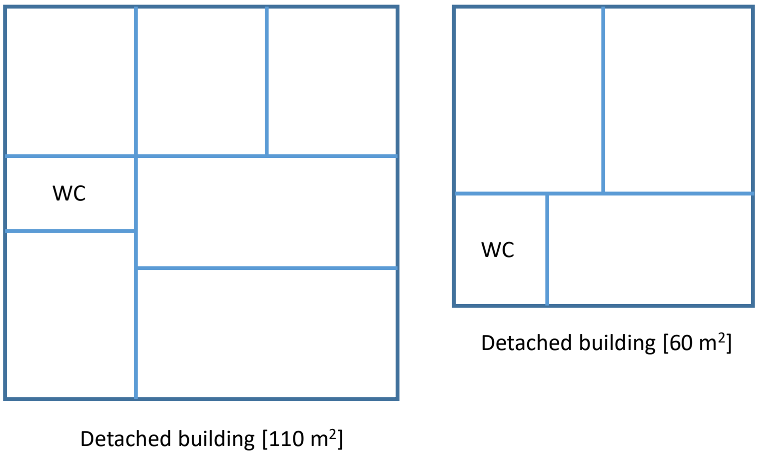


Figure S9. Examples of building layouts considered in the synthetic approach for the identifying a relationship between the internal length of the walls (IP) and the footprint area

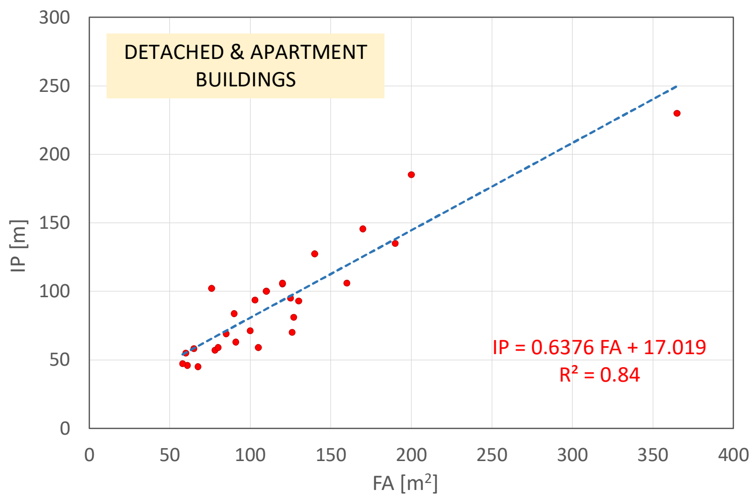
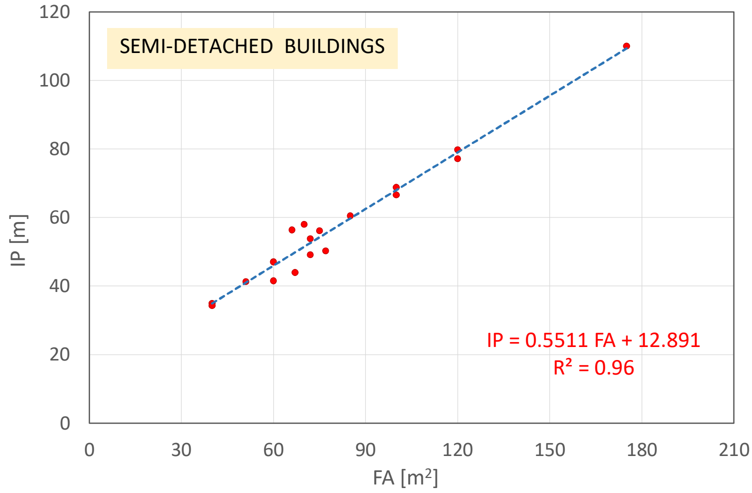


Figure S10. Results of the combined synthetic-empirical approach for the identification of a relationship between IP and FA for different building typologies (*continues in the next page*)



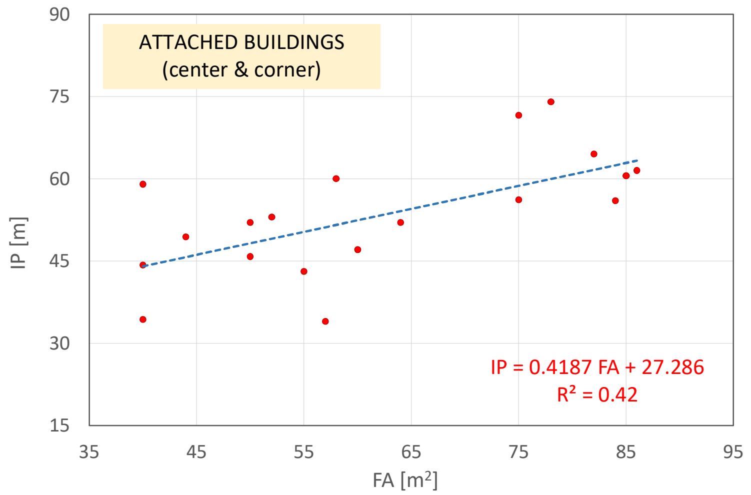


Figure S10 (continues). Results of the combined synthetic-empirical approach for the identification of a relationship between IP and FA for different building typologies

Unit Prices

Components	Subcomponents	Unit of measurement	Default value
Clean-up	C1 - Pumping of water	€/m^3 of water	2.77
	C2 -Waste disposal	€/m^3 of waste	36.69
	C3 - Cleaning	€/m^2 of surface to be cleaned	2.86
	C4 - Dehumidification	€/m^3 of building volume	2.28
Removal	R1- Flooring system	€/m^2 of building area	2.97
	R2 - Pavement	€/m^2 of building area	7.74
	R3 - Baseboard	€/m of baseboard	0.80
	R4- Plasterboard	€/m^2 of plasterboard	7.94
	R5 - Ext. finishing mat. (plaster)	€/m^2 of wall	11.34
	R6 - Internal plaster	€/m^2 of wall	11.34
	R7 - Doors	€/m^2 of door surface	21.89
	R8 - Windows	€/m^2 of window surface	23.56
	R9 - Boiler	€/m^2 of building area	0.32
Non-structural components	N1 - Flooring system replacement	€/m^2 of building area	25.00
	N2 - Plasterboard replacement	€/m^2 of plasterboard	39.43
Structural components	S1 - Soil consolidation	€/m^3 of soil	313.20
	S2 - Local repair	€/m^2 of masonry	46.51
	S3 - Pillar repair	€/m^2 of pillar surface	222.44
Finishing	F1 - Ext. finishing mat. replac. (plaster)	€/m^2 of wall	27.90
	F2 - Internal plaster replacement	€/m^2 of wall	25.76
	F3 - External painting	€/m^2 of wall	18.87
	F4 - Internal painting	€/m^2 of wall	15.85
	F5 - Pavement replacement	€/m^2 of building area	64.63
	F6 - Baseboard replacement	€/m of baseboard	4.43
Windows & doors	W1 - Doors replacement	€/m^2 of door surface	145.88
	W2 - Windows replacement	€/m^2 of window surface	364.64
Building systems	P1 - Boiler replacement	€/m^2 of building area	18.09
	P2 - Radiator painting	€/item	39.89
	P3 - Electrical system replacement	€/m^2 of building area	41.29
	P4 - Plumbing system replacement	€/m^2 of building area	29.89

Table S1. Unit of measurement and default unitary prices for damage estimation at the different building subcomponents

Assumptions on Unit Prices: economies of scale

When building type is "Apartment house" (BT=4), removal/replacement prices for the different components are reduced by 20% due to economies of scale.

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