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Methodology for damage assessment based on interior flood characteristics

Deliverable D2d1 of DEUFI reseach project

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1 Goal and structure of this deliverable

This deliverable explains the methodology followed to test the contributions of considering openings in the monetary assessment of flood damage to buildings.

The methodologies proposed link hydraulic and damage models in order to evaluate the influence of openings in the economic damage evaluation. Two different methodologies are proposed coinciding with two levels of resolution in the analysis: *district* level and *building* level.

This deliverable is organized in three sections. Section 2 outlines the methodology for damage assessment at a *district* level, while section 3 exposes the methodology for damage assessment at a *building* level.

2 Methodology for damage assessment at a *district* level

At district level, the proposed method bridges a hydraulic model, at district level, with specific tools from the *floodam* tool ecosystem[1]for economic appraisal of flood damage, in order to provide monetary estimations of flood damage at district level.

The hydraulic model represents both the street water flows using classical 2D shallow water equations and the mass conservation in each building with a reservoir model assuming no velocity in average within the building. Street shallow water equations are discretized using a classical finite volume Godunov scheme based on 2D unstructured mesh. Street and building models are computed using an Euler explicit approach such as preserving the stability and the water depth positivity. Those models are implemented in the sw2d software (https://sw2d.inria.fr/).

An opening is used to connect a cell and a building. It should be noted that each building can be connected to different cells of the mesh and conversely, a cell can be connected to several buildings. The opening discharge depends on the water level in the street and in the building allowing to represent a nil discharge if the same water level is reached on both side of an opening (see Choley et al. [2021] for more details).

To assess damages, two tools from the *floodam* tool ecosystem are mobilized: *floodam.building* and *floodam.spatial*. The *floodam* tool ecosystem is a collection of libraries written in R language, developed within the French working group "GT AMC" which aims at developing methodologies for the economic appraisal of flood management policies. The development of the *floodam* tool ecosystem has received the support of the French Ministry in charge of the Environment.

The *floodam.building* tool [Grelot and Richert, 2019, Richert et al., 2019, Grelot and Marry, 2022] produces flood damage functions for built assets, such as buildings or dwellings. To do so, the *floodam.building* tool counts on a library of elementary damage functions for each component of a building, for all possible combinations of flood duration and floodwater depth, established from expert knowledge. Thus, departing from an inventory of elementary components of a given building or dwelling –e.g. floors, ceilings, coatings, walls, etc–, the *floodam.building* tool enable us to estimate the building's damage function as a combination of the damage functions of elementary components. In addition, *floodam.building* also implements the average national french damage functions [see Rouchon et al., 2018]

The *floodam.spatial* [Grelot and Richert, 2021] tool is intended for damage estimation from spatial data. The tool enables us to transform spatialized flood parameters, such as floodwater height associated to a spatial point or polygon, into monetary estimates of the damage caused based on the assets involved.

The workflow to bridge all these tools is displayed in figure 1: on the one hand, departing from information on the built area and on the event, the hydraulic model estimates the floodwater depth in the simulation perimeter considering either porous (i.e. with openings) and nonporous (i.e. no openings) buildings. The estimation of the floodwater depth in the interior of each building in the simulation perimeter depends on whether buildings are considered porous or nonporous. In the former case, the hydraulic model is able to calculate the floodwater depth inside each building, whereas in the latter case, the floodwater depth in the interior of the building should be estimated indirectly. To do so, we follow the following procedure:

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[1] http://www.floodam.org/

1. Identification of the building
2. Identification of the grid cells adjacent to the building using a buffer around the building identified in the prior step.
3. Calculation/estimation of the potential gap between the floor level of the building and the street level
4. Estimation of the floodwater depth inside the buildings as the difference between the exterior floodwater level and the building's floor level.

On the other hand, *floodam.building* provides us with the average national french damage function for dwellings [Rouchon et al., 2018]. This function is displayed in figure 2. It links floodwater depth and flood duration with an estimation of material cost to properties per squared meter. Flood damage functions are not continuous. Instead they assign the economic damage value with a resolution of 10cm, i.e. the function considers floodwater depths belonging to the series $h = 0,\ 1,\ 15,\ 25,\ 35 \ldots$ Material costs include both structural damage and damage on furniture As it can be seen, the function showcases a direct relationship between the monetary value of the flood damage and the floodwater height: as floodwater heights increases, the monetary value of damage increases. Notwithstanding, the elasticity damage-depth is variable: in the intervals (0-0.15m] and (2-2.5m] the sensitivity of the monetary damage to changes in floodwater depth is more accentuated than in the intervals (0.15-2m] and (2.5-3m]. Furthermore, in the interval (0-0.15m] monetary damage is extremely sensitive to changes in floodwater depth.

The damage function issued from *floodam.building* and the estimates of floodwater heights within each building calculated from the hydraulic model, together with duration of the flood are fed to *floodam.spatial*. Using *floodam.spatial*, we estimate the damage endured by each building in the simulation perimeter.

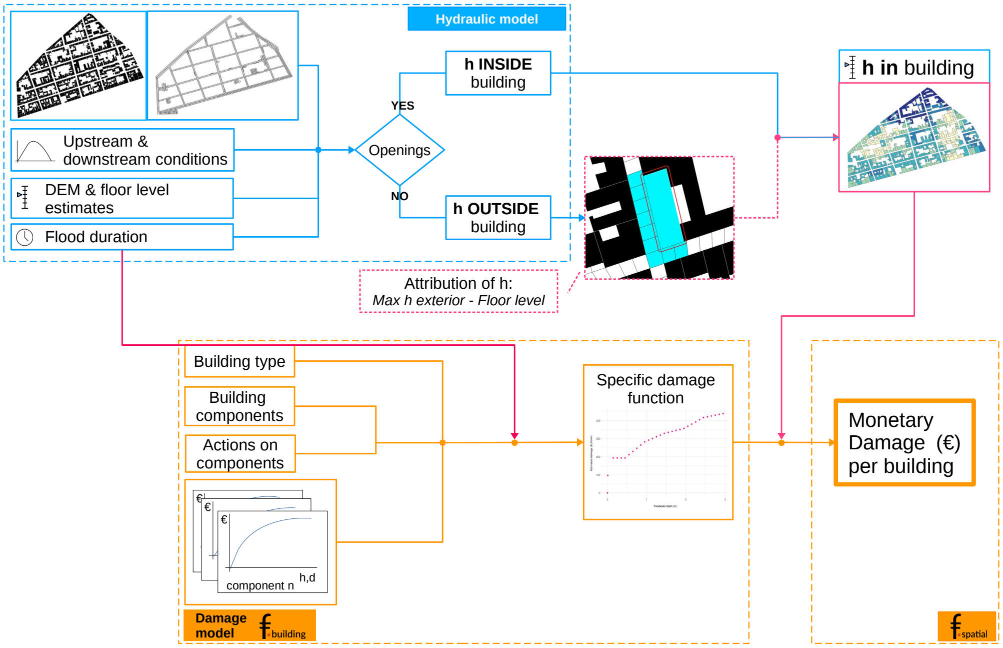

Figure 1: Bridged model flowchart

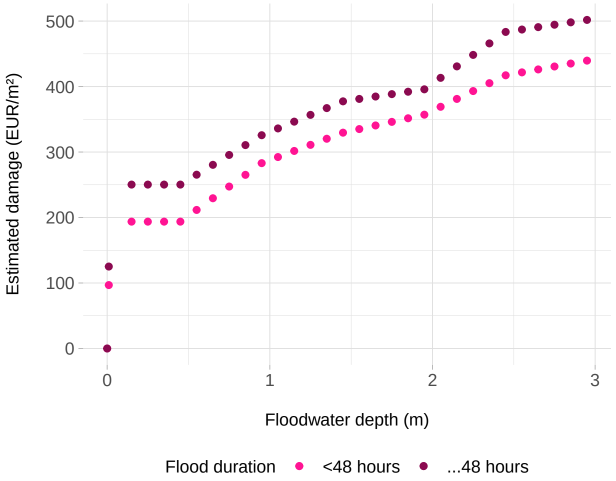

Figure 2: Damage function utilized for flood damage estimation in the simulation perimeter

3 Methodology for damage assessment at a *building* level. Fine-scale hydraulic and damage coupled model

At *building* level, the proposed method couples an ad-hoc hydraulic model, at a building level, and the *floodam.building* tool [Grelot and Richert, 2019, Richert et al., 2019, Grelot and Marry, 2022] from the *floodam* tool ecosystem[2], in order to provide damage functions that integrate the hydraulic behavior in the interior of the building.

The workflow to bridge these models (figure 3) at this level of resolution departs from a building blueprint. On the one hand, the ad-hoc hydraulic model, using the classical weir law, determines the water flow exchanges i) between the outside and the interior of a building and ii) between rooms[3]. To do so, it mobilizes the information on room surfaces and the x-y-z position of each of the openings that communicate every room with each other, and the interior of the building with the outside. The state of each opening –i.e. open, closed, half open. . . – should be declared, so the water flow that can pass through is adjusted accordingly.

The hydraulic model uses as limnigraphs as flood inputs. It needs as many limnigraphs as openings communicating the interior of the building with the outside. They provide the evolution of floodwater depth throughout time (hence depth peak and flood duration) around the building.

As output, the model returns the the evolution of the floodwater depth in the interior of the building, as well as the water speed and volume through the openings.

On the other hand, the *floodam-building* tool generates flood damage functions for built assets. As it was anticipated in the prior section, *floodam.building* is a process-driven tool that departs from a comprehensive inventory of building components (elementary components) to estimate the damage function of a building as a combination of the damage function of each component. To do so, it uses a procedure that can be summarized in four sequential steps:

1. Before any flood event, all elementary components are assumed to be in a normal state (everything works as it is supposed to).
2. When a flood hits the building, the elementary component that has been hit switches to a different state, e.g. dirty or destroyed.
3. To go back to normal, one or more actions should be taken, e.g. cleaning or reparation.

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[2] http://www.floodam.org/

[3] the hydraulic behavior of water flows outside the building is not considered in this version of the model

4. The sum of all the cost in which we should incur to get an elementary component back to its normal state is the monetary valuation of the damage to that component.
5. The process is modeled for all possible combinations of flood duration and floodwater depth

The level of detail in the input needed enables *floodam.building* to produce synthetic damage functions (i.e. based on experts knowledge) considering, not only the elementary components of the building, but also their location within the building in a three-dimensional system of coordinates.

The works at the *building* level of resolution in the frame of the DEUFI project have allowed us to develop the capabilities of *floodam.building* further. Specifically, a new procedure to calculate a damage function per room and per exterior wall based on the combination of the elementary components has been developed, tested and deployed. Furthermore, we have also added a new feature that enable us to point out to floodam which exterior walls would be eventually exposed to floods. This feature assist us in avoiding the overestimation of potential damage by including elementary components that would not be damaged (e.g. semi-detached houses).

In the context of the coupled model we are presenting here, *floodam.building* is going to use the comprehensive description of the building blueprint with exact measures and construction materials to establish the elementary components of the building. Then, using the capabilities developed in the context of the project, damage functions by room and exterior wall are going to be determined.

These damage functions, however, do not incorporate hydraulic information. To include it we proceed as follows: 1. We use the hydraulic model to determine the floodwater depth in each room of the building for a specific flood event X, characterized by its duration and depth peak outside the building, and opening state. 1. We feed the flood parameters to the damage functions by room and exterior wall generated with *floodam.building*, obtaining a level of damage that considers the hydraulic behavior of the building during a flood event with the characteristics of the flood event X. 1. Repeating systematically the two prior steps for each potential combination of flood duration and exterior floodwater depth peak, the bridged model is able to determine damage functions for the building, accounting for its specific interior hydraulic behavior.

The damage functions generated by our bridged model take into account whether openings might be open or closed, buildings can be differently exposed to floods and flood events can be sudden and violent (flash floods of very short duration and high depths) or gradual and "gentle" (slow rise floods).

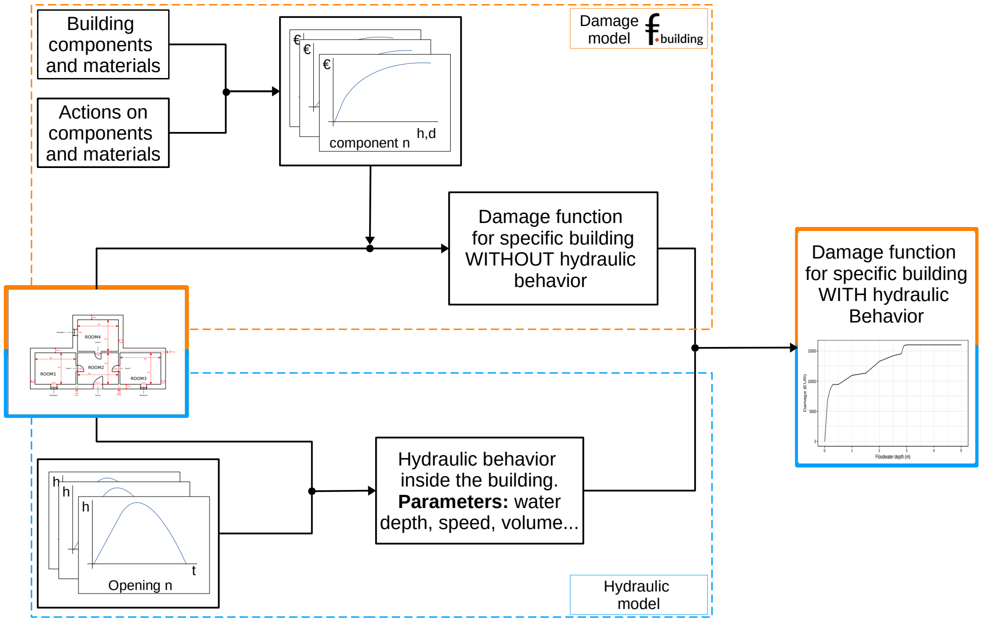

Figure 3: Bridged model flowchart

References

Cécile Choley, Pascal Finaud-Guyot, Pierre-André Garambois, and Robert Mosé. An Effective Urban Flood Model Accounting for Street-Building Exchanges. In *Simhydro 2021 - 6th International Conference Models for complex and global water issues - Practices and expectations.*, Sophia Antipolis, France, June 2021. available under request at https://hal.archives-ouvertes.fr/hal-03520964.

Frédéric Grelot and Valériane Marry. Programme pluri-annuel pour la modélisation des dommages aux logements - Rapport d'avancement 2021. techreport, INRAE, March 2022. Travaux développés dans le cadre du groupe de travail GT ACB-AMC piloté par le Ministère de la Transition Écologique.

Frédéric Grelot and Claire Richert. *Modelling Flood Damage functions of buildings. Manual for floodam v1.0.0.* Irstea, version 1.0.0.b edition, 2019. URL https://irsteadoc.irstea.fr/cemoa/PUB00061355.

Frédéric Grelot and Claire Richert. *floodam.spatial: Estimation of flood damage in a given territory*, 2021. URL http://www.floodam.org/. R package version 0.9.0.

Claire Richert, Hélène Boisgontier, and Frédéric Grelot. Economic assessment of precautionary measures against floods: insights from a non-contextual approach. *Natural Hazards and Earth System Sciences*, 19 (11):2525–2539, 2019. doi: 10.5194/nhess-19-2525-2019.

Delphine Rouchon, Natacha Christin, Cédric Peinturier, and Doris Nicklaus. Analyse multicritères des projets de prévention des inondations. guide méthodologique 2018. Théma - balises, Ministère de la Transition Écologique et Solidaire, Commissariat général au développement durable, Paris, France, mar 2018.