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Flood damage estimation: knowledge gained from field surveys

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Flood damage estimation: knowledge gained from field surveys

REPORT SUBMITTED AS PART REQUIREMENT FOR THE DEGREE OF MASTER'S IN CIVIL ENGINEERING

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ABSTRACT

Flooding has been increased significantly in all over the world from the past few years because of the climate change and economic losses due to flooding have been increased more significantly from the last few decades. It is necessary to estimate the flood losses in the domain of flood risk management and to adopt the best practices for the collection, storage, and analysis of the flood damage data in order to develop the risk mitigation strategies for the severe flood events. In this study, one of the best practices has been presented for the collection and estimation of the flood damage data of the residential buildings through field surveys. In this regard, the study was divided into two phases: (1) introduction of the pilot study for the understanding of real field conditions, identifying the strengths and weaknesses in the survey questionnaire, and improving the field strategy; and (2) organization of the detailed study based on the previous experience of the pilot study and conducting field surveys on a large scale by adopting improved field strategy through a well-structured paper-based survey questionnaire.

Through field surveys, the data for socio-demographic characteristics and damage information including building features, hazard variables, building damage cost, building damage extend, financial compensation, precautionary measures, and warning systems of the population was collected. The collected flood damage data was encoded in the Moodle and the python script was used for decoding any errors between encoding and verification phases based on a timestamp and mostly graphs were generated based on readily available python scripts. The analysis and the interpretations of the graphs have been done for developing the relationships and dependencies between different variables and building features and conclusions have been drawn at the end of this study.

RÉSUMÉ

Les inondations ont augmenté de manière significative dans le monde entier au cours des dernières années en raison du changement climatique et les pertes économiques dues aux inondations ont augmenté de manière plus significative au cours des dernières décennies. Il est nécessaire d'estimer les pertes dues aux inondations dans le domaine de la gestion des risques d'inondation et d'adopter les meilleures pratiques pour la collecte, le stockage et l'analyse des données sur les dommages causés par les inondations afin de développer des stratégies de réduction des risques pour les événements d'inondation graves. Dans cette étude, l'une des meilleures pratiques a été présentée pour la collecte et l'estimation des données sur les dommages causés par les inondations aux bâtiments résidentiels par le biais d'enquêtes sur le terrain. À cet égard, l'étude a été divisée en deux phases : (1) l'introduction de l'étude pilote pour la compréhension des conditions réelles de terrain, l'identification des forces et des faiblesses du questionnaire d'enquête, et l'amélioration de la stratégie de terrain ; et (2) l'organisation de l'étude détaillée basée sur l'expérience précédente de l'étude pilote et la conduite d'enquêtes de terrain à grande échelle en adoptant une stratégie de terrain améliorée grâce à un questionnaire d'enquête papier bien structuré.

Des enquêtes sur le terrain ont permis de collecter les données relatives aux caractéristiques sociodémographiques et aux informations sur les dommages, notamment les caractéristiques des bâtiments, les variables de risque, le coût des dommages, l'étendue des dommages, les compensations financières, les mesures de précaution et les systèmes d'alerte de la population. Les données recueillies sur les dommages causés par les inondations ont été encodées dans Moodle et le script python a été utilisé pour décoder toute erreur entre les phases d'encodage et de vérification sur la base d'un horodatage et la plupart des graphiques ont été générés sur la base de scripts python facilement disponibles. L'analyse et les interprétations des graphiques ont été faites pour développer les relations et les dépendances entre les différentes variables et les caractéristiques de construction et des conclusions ont été tirées à la fin de cette étude.

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ABBREVIATIONS

ΔQ: Exterior level with respect to the street

hg: Depth of the ground floor with respect to exterior level

h1: Clear height of the cave

h2: Clear height of the ground floor

DC: Damage cost

P: Period

BM: Building Material

S: Sediments

ML1: Maintenance Level 1

ML2: Maintenance Level 2

WD1: Water depth at Level 1

WD2: Water depth at Level 2

PM1: Protective Measures at Level 1

PM2: Protective Measures at Level 2

PCA: Principal Component Analysis

NCA: Neighbourhood Component Analysis

SVM: Support Vector Machine

KNN: K-Nearest Neighbour

GIS: Geographic Information System

SPW: Service public de Wallonie

RF: Random Forest model

RGLM: Random Generalized Linear Model

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1 INTRODUCTION

1.1 Context of the Study

Floods are considered to be the most economically damaging and most devastating natural disasters in all over the world. During the past ten years, almost 80-90% of the registered disasters from the natural hazards occurred from floods, tropical cyclones, severe storms, intense heat waves and droughts. Moreover, the frequency and the intensity of the floods have been increased and the intensity of extreme rainfall precipitation is expected to increase further due to the climate change[1]. The financial loss due to the floods in recent decades has increased more significantly in many countries (A.A Komolafe, 2019; B. Jongman, 2012). According to the UN Office for Disaster Risk Reduction (UNISDR) and the Centre for Research on the Epidemiology of Disasters (CRED), the economic losses due to floods have increased to almost 43% from 1998 to 2017. Estimation of flood damage is very critical in the domain of flood risk assessment and flood risk management (Messner et al., 2007; Merz et al., 2010) because it is a significant component of flood risk vulnerability assessment including financial appraisals for budget allocation during and after the flooding event, comparison of risk analysis, generation of flood risk mapping (Qiong Li, 2012; Jianzhong Zhou, 2012). Flood damage estimation is also useful for Cost Benefit Analysis (CBA) such as financial assessment of flood mitigation measures (Elisa Oliveri, 2000; S.N. Jonkman, 2004).

After a flood event, the main objective for flood damage assessment is to collect the damage data from the field so that the reliable and consistent damage information could be given to practitioners, researchers, and public administration officials (Cammerer et al., 2013). Flood damage assessment helps us in decision making and policy making for the planning of climate change adaptation and flood risk management (B. Merz, 2010). As a part of this Master thesis, we are interested in the floods which is one of the consequences of the climate change. The floods in July 2021 which impacted Belgium, Germany and Luxembourg were unprecedented which led to the destruction of around

[1] Source was accessed on 13/07/2022 at:
https://www.who.int/health-topics/floods#tab=tab_1

26,000 houses and the lives of more than 40 people in Belgium and the total insurance losses due to the flooding in all over the Europe are estimated at more than $12 billion[2]. As an engineer, we can ask ourselves what we can contribute to the domain of flood risk management which could help us to evaluate the risk mitigation strategies and perform flood risk assessments.

1.2 Objective of the study

The Master thesis focuses on the subject of flood damage estimation based on field surveys which highlights the best practices for the collection and analysis of the flood damage data aftermaths of the flooding event that happened in the month of July 2021. This study initiated from the pilot study conducted in the district of the city of Liege (Angleur) in Belgium in November 2021. Based on the field experience and outcomes of this pilot study, field surveys on a large-scale have been conducted in which several teams of researchers, interns and Master students participated and collected field damage data through well-structured paper-based scientific questionnaires and covered severely affected municipalities located along the Vesdre River, which is one of the most impacted subcatchments in the Walloon Region by the floods in July 2021. The municipalities involved in this study are Liege, Chaudfontaine, Trooz, Pepinster, Verviers, Limbourg, Baelen and Eupen. But for this Master thesis, I have done the flood damage estimation for the municipalities of Liege, Chaudfontaine, Trooz, Pepinster, Limbourg and Eupen.

Before beginning of this research study, the desktop study has been done to find the research papers and case studies which are available on the same topic and the search was strictly restricted to the keywords. It has been found that there are limited studies conducted previously on this domain. For instance, 229 relevant articles on Google Scholar and 67 studies on Scopus are available with the keyword ***'Flood damage estimation'***. Whereas 5 studies on Google Scholar and 2 articles on Scopus are available with the keyword ***'Flood damage estimation buildings'***. However, the focus of this Master thesis is to carry out the flood damage estimation of the residential buildings based

Source assessed on 25/07/2022 at:
[2] https://www.axa.com/en/insights/the-2021-floods-in-europe-one-year-later

on field surveys, so further refining of the title was necessary, and it has been found that no relevant studies are available on the Google Scholar and Scopus with the keyword ‘Flood damage estimation residential buildings’. Whereas there are no previous studies conducted in the Belgium on the same topic. This is the reason for conducting research on this topic. Moreover, it is also necessary to investigate the actual field conditions right after the flood in order to estimate the flood damage. The statistic for the evidence of the limited research studies available on the specific domain based on the Google Scholar and Scopus is shown in the Figure 1.

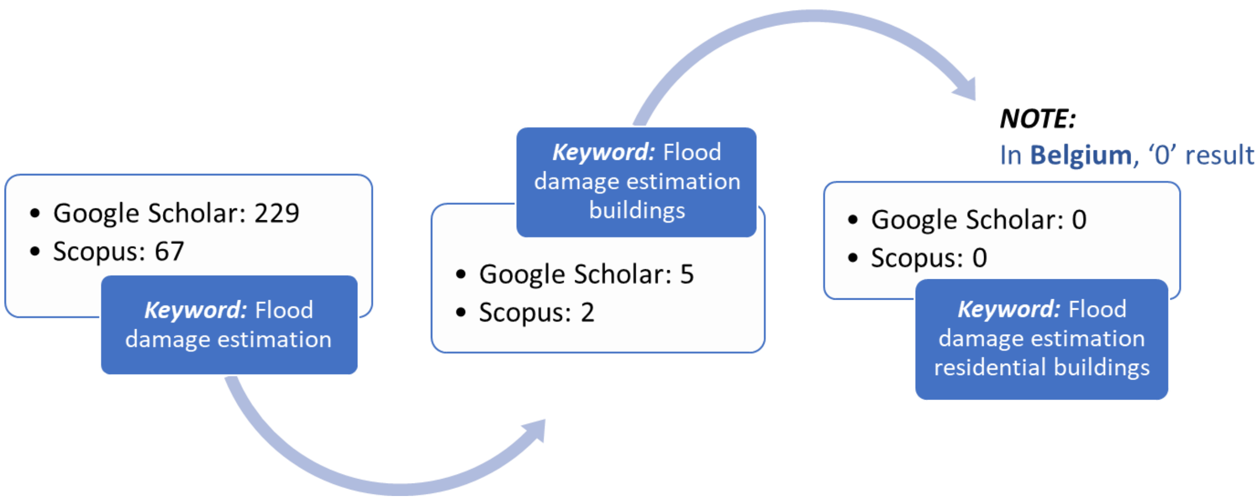


Figure 1: Scopus and Google Scholar Literature Review (Source: Own illustration)

1.3 Structure of the work

To answer the research topic, this work has been divided into 6 different parts.

1. **Literature review**

   Different case studies have been studied and relevant case studies have been extracted which are similar to the domain of our study based on these relevant case studies, understanding for the best practices of data collection, data storage and damage estimation have been developed and utilized for planning and developing the strategy of this study.

2. **Pilot study for the district of Angleur**

   Before initializing the research on a large scale, a pilot study was organized and conducted in order to evaluate the field conditions and to collect the damage information right after the flood. Based on this short study, strength, and weaknesses of the survey questionnaire was identified and improvements have been made in the detailed survey questionnaire and field strategy was developed for organizing the detailed study.

3. **Detailed study for other affected municipalities of the Walloon region**

   Based on the pilot study, detailed study was conducted with the detailed survey questionnaire and improved field strategy. All severely affected municipalities of the Walloon region were covered in this detailed study. The methodology of the study was developed and adopted for carrying out the research in order to achieve the required outcomes.

4. **Results and discussions**

   The outcomes for both field surveys (Pilot Study and detailed study) have been analysed based on different statistical techniques and interpretations have been made for the graphs which were obtained from the field data in order to justify the objectives of the research question mentioned above, while reconsidering the perspective on the methodology and the outcomes achieved. The results and explanations of both studies are discussed in separate chapters.

2 LITERATURE REVIEW

Several research studies have been found in the early stage of this thesis project, but few articles have been refined for the literature review since other articles are not particularly focused on flood damage assessment based on field surveys. The reason for the selection of field surveys instead of conducting phone-based surveys and online questionnaires was that the reliability of the data collected from the field surveys is relatively better than the data collected through virtual techniques. In this chapter, the relevant case studies have been selected and summarized based on the several parameters in Table 1 and discussed in detail in the following chapter.

Case Studies (References)	**Country**	**Sample size**	**Type of flood**	**Damage type**	**Flood duration**	**Tools for data collection, data analysis, hazard simulation and damage estimation**
INSYDE (2010 flood damage data collection by the municipality of Caldogno in the **Veneto region in north-eastern Italy**)	Italy	300 buildings	Fluvial flooding	Residential buildings	24 hrs	Explicit cost analysis based on building damage functions, In-depth synthetic model for damage estimation
RISPOSTA **(Umbria Region, Central Italy in 2012 and 2013)**	Italy	101 municipalities	Fluvial Flooding and flash floods	Residential and commercial buildings	72 hrs	Mobile application for data collection, PostGIS database for data management, Integrated web portal for data visualization

Case Studies (References)	Country	Sample size	Type of flood	Damage type	Flood duration	Tools for data collection, data analysis, hazard simulation and damage estimation
A case study in **Malmo, Sweden**	Sweden	1000 buildings	Pluvial flooding	Residential buildings	6 hrs (started at 3am)	SMLRA database for pre-processing, spatial autocorrelation analysis by Moran's **I**, linear regression analysis by MATLAB
Bago Region of **Myanmar**	Myanmar	340 households	Fluvial flooding	Residential dwellings	5 days (2011 flood)	Household questionnaire for data collection, regression model for data analysis, flood hazard simulation by Rainfall-Runoff-Inundation (RRI) model, depth-damage functions for damage estimation
Segamat town in **Johar, Malaysia**	Malaysia	50,115 units	Fluvial flooding	Residential and Commercial buildings	6 days (30th Jan till 4th Feb)	Household survey questionnaires for data collection, flood modeling by HEC-HMS/RAS, depth-damage curves for damage estimation

Case Studies (References)	**Country**	**Sample size**	**Type of flood**	**Damage type**	**Flood duration**	**Tools for data collection, data analysis, hazard simulation and damage estimation**
Urban watershed in **Hanoi, Vietnam**	Vietnam	293 responses	Fluvial (River Flooding)	Residential and Non-residential buildings	3 days	Scientific questionnaires for data collection, regression analysis for data analysis, damage estimation by depth-damage functions
August 2002 flood in **Germany**	Germany	1697 computer aided telephone interviews	Slowly rising flood water and flash floods	Private households	2 days	Data collection and management by VOXCO, principal component analysis was performed, statistical analysis by SPSS software, damage estimation by depth-damage function
Braunsbach, a small village in **Baden-Württemberg, Germany on 29 May 2016**	Germany	94 responses	Flash flooding	Residential, Commercial, mixed, and public service buildings	1 hour and 45 minutes	KoBoCollect for data collection, random forest and generalized linear model and Spearman’s rank correlation matrix for data analysis
Five major flood events in **New Zealand** between 2013 and 2017	New Zealand	674 responses	Urban stormwater, Riverine and riverine-levee breach	Residential buildings	More than 24 hours rainfall in Edgecumbe	RiACT and QField for data collection, post-hoc damage analysis, depth-damage curves for damage estimation

Table 1: Review of case studies for the collection, storage, and estimation of the flood damage data

The first case study analysed is the flood damage assessment done by the researchers of Italy in collaboration with the Joint Research Centre of the European Commission for the municipality of Caldogno located in the Veneto Region in the North-Eastern Italy in 2010. This research is limited to the flood damage estimation of the residential buildings. Several damage functions were developed based on different building components for estimating the economic losses caused by fluvial flooding. The duration of the flooding was around 24 hours. In this research, a probabilistic approach is presented for developing the synthetic damage curves for the residential buildings through a synthetic damage model named as In-depth Synthetic Model for Flood Damage Estimation **(INSYDE)** and the collected building damage data of 300 residential buildings was used in order to validate the damage model. Water depth is considered to be the most significant factor because of its direct dependency with all the other damage functions. In this case study, water quality (presence of pollutants or sediments in flood water) and the duration of the flood event were found to be the less significant event features considering the damage to most of the building damage components excluding exterior plaster, pavement, and clean-up (Francesco Dottori, 2016).

The second case study is based on the significant fluvial and flash flooding events that occurred in the Umbria Region, Central Italy in 2012 and 2013. The flooding event lasted for 72 hours and caused a significant damage mainly to the residential and commercial sectors. The damage data of the residential sector from 101 municipalities was recorded in a digital format by using prototype mobile applications. The PostGIS database was used to store the field data. Georeferenced data can be easily imported and analysed through the Database Management System (DBMS) associated with GIS (Francesco Ballio and Daniela Molinari, 2016). In this case study, the management of the damage data and data visualization was performed by using Integrated Web Portal. (Molinari et al., 2014) highlighted that the major issue is related to the management of the large amount of field data and heterogeneity of the collected damage information. In order to cope with this issue, Reliable Instruments for Post-Event Damage Assessment **(RISPOSTA)** was developed for the management of huge flood data and to perform damage evaluation which provides a way for the collection of flood damage data and helps in the development of reliable and compatible databases which could help in the risk mitigation. The establishment of reliable IT tools helps in proper data collection, storage, and spatial assessment of the records. RISPOSTA provides a platform for managing the records of physical event, costs acquired for protective measures before and during the flooding event, damage assessed, and explicative variables associated with them i.e., vulnerability and exposure (F. Ballio, 2015).

The records for the physical events are not directly interconnected with ex-post flood damage assessments. However, using aerial images or satellite, the extension of the flooded area could be derived just after the flooding event. But these tools might not be practically applied and produce unrealistic outcomes for short duration flood events i.e., in case of flash floods. In this case, field surveys are indeed necessary. Secondly, damage variables linked with hazard features such as water depth and water velocity which are complicated to record during post event damage assessment so it could be obtained through numerical modelling of that flood event. In this case study, data was collected in different time zones for capturing both direct and indirect flood damage and these records were found to be useful for administrative purposes for the damage compensation and recovery management based on National and European level. However, the conversion of physical damage data into monetary terms is still a major concern (Handmer, 2003; Downton and Pielke, 2005). Both physical and monetary data should be recorded. The sources of the data collection could be different. For instance, records for the damage to infrastructures and exposure and vulnerability could be obtained from utility companies and local authorities for the damage compensation. Whereas the information of the water depth and direct damage to buildings must be gathered through field surveys. It is also highlighted that the collected information should be georeferenced (F. Ballio, 2015).

The third case study is based on a cloudburst event which led to pluvial flooding in Malmo, Sweden in 2014. The cloudburst hit Malmo at around 3 a.m. in the morning and lasted for around 6 hours. The residential sector was targeted for the damage assessment and total 1000 records were collected for the estimation of direct damage to residential buildings. The analysis was done based on regression analysis by using MATLAB. It is also highlighted that damage to residential buildings due to the pluvial flooding creates a significant importance of direct tangible flood losses (B. Merz, 2004). Whereas the importance of urban flooding has also been increased in the recent years as the damage cost associated with it increased globally (J.I. Barredo, 2009). Reliable damage data must be required for ex-post scenarios. Whereas it is more critical for developing ex-ante flood damage modelling (Shifteh Mobini, 2021). The flood damage data commonly originated from the historical records. For instance, data from the insurance companies, field surveys, emergency departments who engage with the flood victims. The data for the building construction period has been recovered from an online mapping system which provides information for almost 87% of the cases[3]. Building construction period should be considered for the damage estimation as old buildings suffer a significant damage as compared to the new construction (Md. Nawrose Fatemi, 2020). In this case study, it has been found that the residential buildings which were connected to the combined sewer systems experienced more damage in comparison with the buildings connected with the separated sewer systems due to pluvial flooding (Shifteh Mobini and Erik Nilsson, 2021).

The fourth case study is based on the fluvial flood that happened in Myanmar which hit the Bago River in July 2018. The duration of the total precipitation was around 10 days which caused a significant damage. The descriptive household questionnaire survey was organized, and damage data was collected from 340 individual households. The field surveys were organized based on the sampling criteria which is dependent on the building characteristics by choosing households randomly i.e., selection of the households was based on the type of residential houses, number of the stories and type of the building structure. The household survey questionnaire was divided into five different categories i.e., information for house buildings, characteristics of the flood data, socio-economic data, actual and potential flood damage information. For analysing the relationship between damage and flood damage parameters along with its factors, a regression model was used. The damage functions developed for this specific case study were then compared with global flood damage functions of the past studies in order to validate them. Moreover, the damage functions were also validated with the collected field data of the 2018 flood event (Zin et al.). For estimating the flood damage, the outcomes of flood

[3] Source was accessed on 18/02/2022 at:
https://mapserver.org/

inundation analysis, flood damage functions and exposed items in flooding areas were integrated and a grid-based damage estimation model was developed on FORTRAN programming language. In this case study, damage to residential buildings and assets were estimated more accurately in economic terms with the help of new flood damage functions and these functions were developed by combining actual damage data of previous flood events and potential damage data. The method for the flood damage assessment presented in this study can be used for the evaluation of different adaptation options considering individual housing type and to analyse effectiveness of preventive investments in order to reduce the risk of flood damage in the future. Moreover, the outcomes of this case study can also be used for building resilience for flood-prone households and make it easy for policy makers for establishing adaptation measures for flood protection and policy development for flood damage reduction i.e., land use regulation and formation of guidelines for residential building construction.

The fifth case study is based on the assessment of the significant flood damage due to fluvial flooding in Segamat Town in Johar, Malaysia which is located along the Segamat River Basin in 2011. The period of the flooding event was between 30th January to 4th February 2011 and the duration of the flood was around 6 days. Field surveys were organized for residential and commercial buildings. Total 50,112 residential units and 9,318 premises were covered in this case study. Flood plain maps for different return periods were developed for residential and commercial buildings by using ArcGIS software which helped in identifying areas which are vulnerable to flood in monetary values. The maps were highlighted with realistic monetary damage information which helps government and private agencies for improving the flood management plans (Noor Suraya Romali, 2021). For monetary damage assessment, house content value was recovered from Valuation and Property Services Department (JPPH) and price (RM) per unit properties was obtained from the District and Land Office of Segamat. However, damage cost for other household items such as furniture and electrical appliances, etc. was received from the population during the field survey. Flood modelling was performed on HEC-HMS/RAS to obtain the inundation depth. Based on this cost data, inundation depth and flood duration, flood damage function curves were developed for both structural and household contents. However, flood damage estimation was done based on damage factors obtained from the damage function curves. Depth-damage curves are useful for estimating the flood damage which defines the relationship between flooding depth and economic damage for different building sectors (Noor Suraya Romali, 2021). The structural damage curve was developed for low price houses, medium price houses, and high price houses. In this case study, the flood damage estimation was performed as the product of damage factors, number of damage properties and unit property values based on damage categories (Noor Suraya Romali and Zulkifli Yusop, 2021).

However, instead of focusing on flood hazard maps, researchers are putting more attention on flood risk maps especially in Europe (De Moel et al., 2009; Velasco et al., 2015). The number of people affected by the flooding and economic damage are considered in flood risk mapping (De Moel et al., 2009). The representation of the estimated flood damage in monetary values could be achieved by flood damage mapping considering that the expected damage for specific flood-prone areas could be included into a flood risk management plan. It is also highlighted that the conversion of the available records into a reliable flood damage estimate could be done by using synthetic methods (Smith, 1981). Flood damage estimation is a collective combination of vulnerability, hazard, and exposure. For flood risk management, the distribution maps concerning damages could be a better tool following that the data from the maps could be utilized for preventing the area from flooding (Noor Suraya Romali and Zulkifli Yusop, 2021).

The sixth case study is based on the tangible direct flood damage assessment due to fluvial flooding in an urban watershed located in Lich River, Hanoi Vietnam in November 2008. The main objective of this study was to estimate the flood damage at meso-scale and assessment of future urban flood damage in the To-Lich River watershed in Hanoi. The duration of the flood was around 3 days, and 293 responses were collected from both residential and non-residential buildings. Based on the different flood characteristics which includes inundation depth, property values, land-use classes, and damage cost, the spatial analysis was performed. It is mentioned that the damage assessment was performed by using depth-damage functions based on the input data obtained through integration of hydrologic and economic data with the help of ArcGIS software (Mohamed

Kefi and Binaya Kumar Mishra, 2018). Depth-damage functions were established by performing regression analysis based on damage data collected from the field surveys. The direct damage percentage was considered as a dependent variable whereas, inundation depth was supposed to be an independent variable because flood depth was declared to be a significant variable for causing high damage. Direct flood damage could be predicted based on depth-damage functions (Aimilia Pistrika, 2014). In this study, flood damage depth was developed as a logistic function by using XLSTAT software based on two variables i.e., damage factor as a dependent variable and inundation depth as an independent variable. The findings of this case study illustrated that damage will be more significant with an increase in inundation depth (Mohamed kefi, 2018).

The seventh case study is based on the severe flooding event which occurred in Germany in August 2002. The objective of this study is to estimate the direct flood damage in monetary terms for buildings and private household contents. Total 1697 telephone interviews were conducted by SOKO-Institute, Bielefeld, Germany from the private households and data was managed and stored by using VOXCO software package. The questionnaire was composed of total 180 questions to collect information about different building features and hazard variables such as inundation depth, presence of contamination, protective measures, flood warning, evacuation, cleaning of debris, characteristics and damage of the building structure and household contents. For improving the quality of damage data, validity checks for the inputs were performed. In this case study, the researchers claimed that the damage data was reliable because most of the respondents provided damage estimates based on the amount they presented or received either from their insurance companies or from the governmental funds. The estimation of the flood damage is influenced by different factors which includes flood duration, water velocity, presence of contamination, concentration of sediments, flood warnings and external help during the flood event (Smith, 1994; Penning-Rowsell et al., 1994; USACE, 1996; Nicholas et al., 2001; Kelman and Spence, 2004).

The information regarding inundation depth and flood duration was reliably retrieved from the interviewees but respondents had no experience for estimating the flow velocity. Therefore, based on the information about deposited and transported material i.e., boulders, stones, sand etc and the corresponding inundation depth, estimates for flow velocity were derived through Shield's diagram modified by USACE in 1996. Multiple damage variables including absolute building and content damage and their corresponding loss ratios were interrelated. For investigating the correlation structure for damage influence variables, Principal Component Analysis (PCA) with varimax rotation was performed. Moreover, a statistical analysis was performed through SPSS software. The findings of this case study illustrated that the inundation depth, flood duration and sediment contamination are found to be the most significant impact variables for building and content damage. Moreover, respondents received more official flood warnings with reliable information and longer lead time but despite that high damage was experienced for both building and household contents because mostly people had no idea about protective measures concluding that flood warning itself cannot reduce flood damage especially for extreme flood events. However, the case study illustrates that the building protective measures such as building retrofitting significantly reduce the damage losses (Annegret H. Thieken and Meike Muller, 2005).

Another case study is focused on the damage assessment of Braunsbach, a small village in the district of Schwäbisch Hall in Baden-Württemberg, Germany which was severely affected by flash flooding on 29th May 2016 which led to the significant damage to buildings and infrastructure. In Braunsbach, total 96 building units were surveyed, and the estimated monetary loss was around EUR 104 million, which was more than 90% of the estimated EUR 112 million of overall flood damage in Schwäbisch Hall (Landkreis Schwäbisch Hall, 2016). The duration of the heavy rainfall event was around 1 hour, and 45 minutes. The on-site data collection was carried out right after 10 days of the flood event which was facilitated by using KoBoCollect (an open-source software bundle). The digital survey was organized by a team of 5 researchers who conducted surveys for all buildings in Braunsbach impacted by flash flooding through mobile tablets with an integrated GPS function. For deriving and validating the water depths, model Testo 876 (a thermographic camera) was used. According to the surveyors, an exact estimation of the water depth through visible marks and traces was not possible and it was estimated by visualizing the remaining moisture in the walls through differences in surface temperature. In this case study, a random forest model was used for the analysis of non-linear relationships between the variables. The field data was used to evaluate the damage driving factors through a Random Forest (RF) model and Random Generalized Linear Model (RGLM) considering the damage grade as a dependent variable. Secondly, a Spearman's rank correlation matrix was developed. The comparison between both models and correlation matrix was done. The random generalized linear model was developed for the comparison of the results obtained through random forest model (Song et al., 2013). The findings of this case study illustrate that KoBoCollect was declared to be the best flood damage data collection software which helped researchers to collect damage data in a short period of time and even with a small team of researchers. Moreover, the collected information could be further processed and assessed (Jonas Laudan and Viktor Rozer, 2016).

The last case study focuses on the post-event flood damage analysis for five flooding events that happened in New Zealand between 2013 and 2017. Christchurch City, South Dunedin, Nelson City experienced Urban stormwater flooding between 2013 and 2015. Whanganui and Edgecumbe experienced Riverine and Riverine Levee-Breach flooding between 2015 and 2017 which occurred in large river catchments due to heavy rainfall that lasted for more than 24 hours led to extra-tropical cyclones (Edgecumbe, 2017) or mid latitude low pressure systems (Whanganui, 2015). The objective of this case study was to develop an empirical residential building damage database for future building damage curve development. The duration of the field surveys was between 7 to 18 days after flooding events. The team of two or three researchers was dedicated in order to organize the field surveys. The surveyors used paper-based questionnaires for the collection of the damage data from the field. However, they shifted to open-source applications for damage data collection including RiACT (Lin et al., 2019) and QField (QField, 2020) which helped researchers in the post processing and analysis of the field data in GIS software applications. Total 674 responses of residential buildings were collected for the estimation of asset-level damage ratios for residential building typologies. For the development of flood damage curves of the buildings, water depth is considered as the flood hazard intensity parameter (Merz et al., 2010). It helps to develop depth-damage curves for post-hoc damage analysis. It is highlighted in this study that some flood characteristics including presence of sediments, contamination and water velocity are more critical to identify aftermath of the flooding events (Ryan Paulik, 2021). The findings of this case study illustrate that the information for some flood characteristics such as presence of sediments, water velocity and presence of contamination were not reliably obtained in the aftermath of flood events during field surveys. Moreover, for the conversion of component damage ratios into asset-level damage ratios, quantity survey guidelines were used. However, these ratios could be used for post-hoc analysis for developing the relationships between flood characteristics and direct tangible damage (Ryan Paulik and Kate Crowley, 2021).

To summarize all these case studies which are discussed above, we could conclude that the field data collection should be started right after the flood event depending on the accessibility of the field in order to improve the reliability of the collected data and to get the best representation of the field. In some case studies, they used software applications such as **KoBoCollect** for the collection of field data which helped researchers to collect the information in short period of time with small team of researchers which could increase the productivity of the field data collection. It is also recommended in **RISPOSTA** case study that the data should be collected in different time zones for recording both direct and indirect flood damages and this information could be useful for administrative purposes for the damage compensation and recovery management based on National and European level. In above case studies, several analysis techniques have been used by the researchers for estimating the flood damage such as **Random Forest (RF)** model which was used for the analysis of non-linear relationships between the hazard variables, **Principal Component Analysis (PCA)** with varimax rotation was used in order to develop the correlation structure for damage influence variables. The insights of these case studies conclude that **Depth-damage curves** could be helpful for estimating the flood damage which defines the relationship between the flooding depth and economic damage for different building sectors. In most of the case studies, water depth was declared to be the most critical and dominating factor for causing the high damage cost.

3 PILOT STUDY FOR ANGLEUR

3.1 Introduction

The meteorological situation from July 12 to 15, 2021 was characterized by a cut-off low pressure system over Central Europe carrying moist air to a wider region (Junghanel et al., 2021). The surface air over the Mediterranean and Northern Europe was very warm which was responsible for feeding the atmosphere's water holding capacity. This warm and humid air entered central Europe from the Mediterranean in a circulatory movement. Due to the slight damming effects in low mountain ranges of western part and force uplift, persistent heavy rainfall occurred over large areas. Due to this continuous rainfall, large rivers overflowed their riverbanks. In Belgium, the worst floods occurred in the Ardennes along the Vesdre and Ourthe rivers and then downstream along the Meuse. The flooding event happened when catastrophic flooding hit the river Meuse on July 14, 2021, caused significant damage in the Pepinster, Verviers, Chaudfontaine, Trooz, Eupen, Angleur, Esneux, Limbourg, Rochefort, Theux. The level of the river Meuse jumped from 1.2 meters to almost 4.01 meters due to the continuous rainfall event. The local precipitation reached up to more than 270 mm/ 3-day over the eastern Belgian part of the river Meuse. Based on the evaluation of two-day rainfall precipitation which was spatially averaged over this specific part of river Meuse catchment, the local precipitation was recorded as 53 mm/day for 2021 by using Belgian gridded dataset over the return period of around 1000 years.

The districts Chenee and Angleur located in the south of the city near to the region where River Ourthe meets with River Meuse experienced the worst damage due to the floods in July 2021. Angleur is a district of the city of Liège located in the province of Liège which is bordered to the Northwest by the Meuse and to the Northeast by the Ourthe. The total population of the province of the Liège is more than 1.1 million inhabitants according to statistics of Statbel updated on 1st January 2022[4]. The first study was carried out in

[4] Source was assessed on 20/05/2022 at:
https://statbel.fgov.be/en/themes/population/structure-population

Angleur after the flooding event to get the representation of the field and estimate the damage data through a short survey questionnaire. The organization of the field survey, data collection and damage data analysis are explained in detail in the following chapter.

3.2 General Research Methodology

After the flooding event in July 2021, '**SPW (Service Public de Wallonie)'** started their investigation, and some workers from SPW went to the field in order to collect the damage information and identified severely affected municipalities in the Walloon region on WalOnMap[5]. Approximately after 3 months of this flood event, the research was initiated with the '**Pilot study'** in which the Master students from UEE department conducted field surveys as a part of their course 'Water and Energy in urban environments' and covered severely affected houses in the district of city of Liege (Angleur) and collected socio-economic data and damage information from the population through a short survey questionnaire. The brief methodology of the pilot study can be seen in Chapter 3.3.

Based on this pilot study, **'Detailed study'** for other severely affected municipalities of the Walloon region was planned and started approximately after 7 months of the 2021 July flood event. To carry out this research, the field surveys were conducted in which researchers, interns and Master students participated in the field data collection through a well-structured survey questionnaire. I also contributed to the field data collection with other researchers and team members. The municipalities covered for this study includes Chaudfontaine, Pepinster, Trooz, Limbourg and Eupen. However, the research teams are still collecting data from the fields of Verviers and Baelen and flood damage estimation for these remaining municipalities will be carried out later and it is not a part of my Master Thesis. The damage analysis of both studies (pilot study and detailed study) has been done separately and discussed in detailed in Chapter 3 and Chapter 4 of this report. Whereas the brief methodology of the detailed study is presented in Chapter 4.2. The representation of the general research methodology is shown in Figure 2.

[5] Source accessed on 14/05/2022 at: https://geoportail.wallonie.be/walonmap#BBOX=230048.2844969918,262459.8076533715,130584.22080515372,145480.2922639633

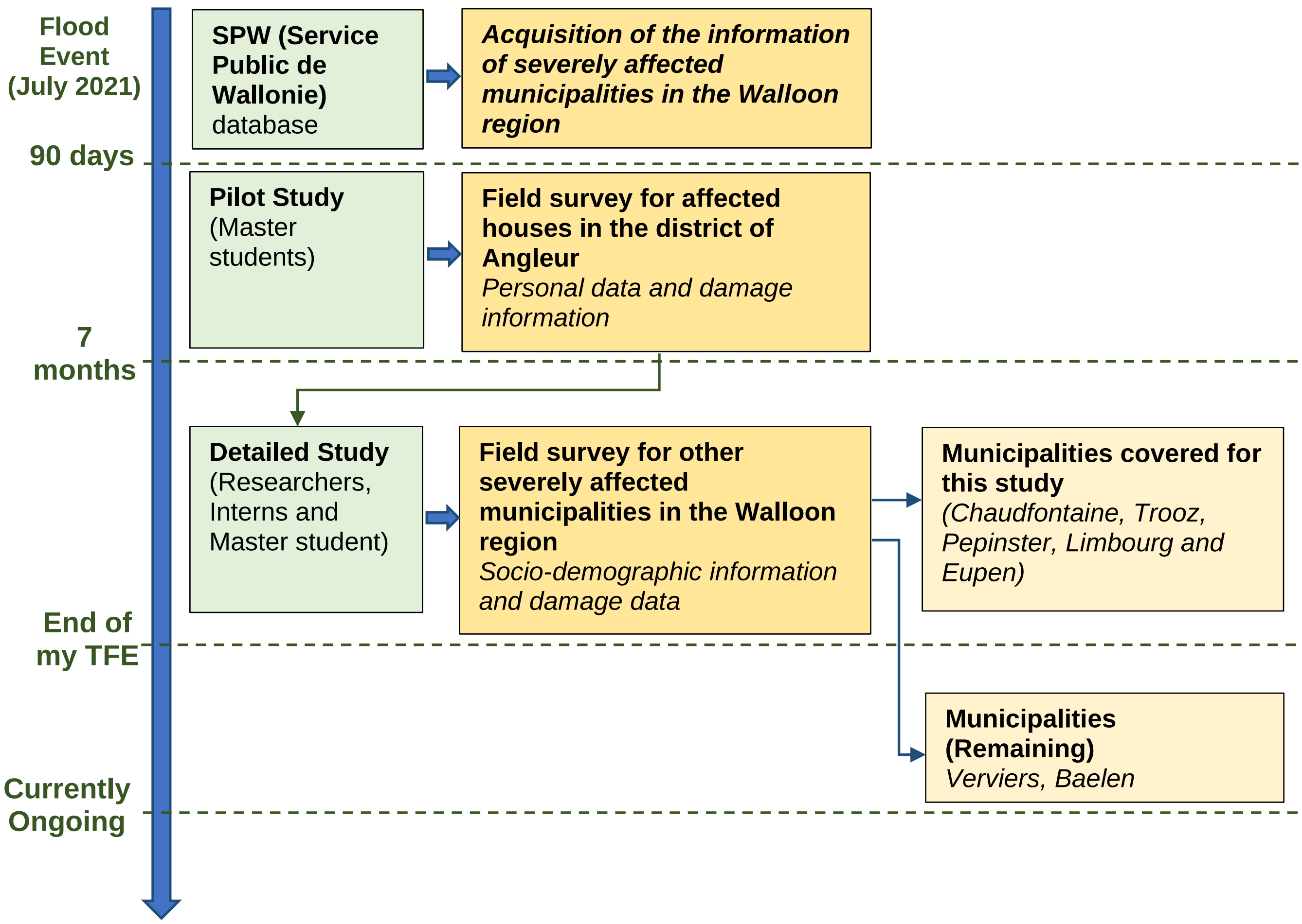


Figure 2: General methodology of the research

3.3 Methodology of the Pilot study

The brief methodology of the pilot study conducted in Angleur is represented in Figure 3. Whereas all phases of the methodology are described in detail in the following sections of this chapter.

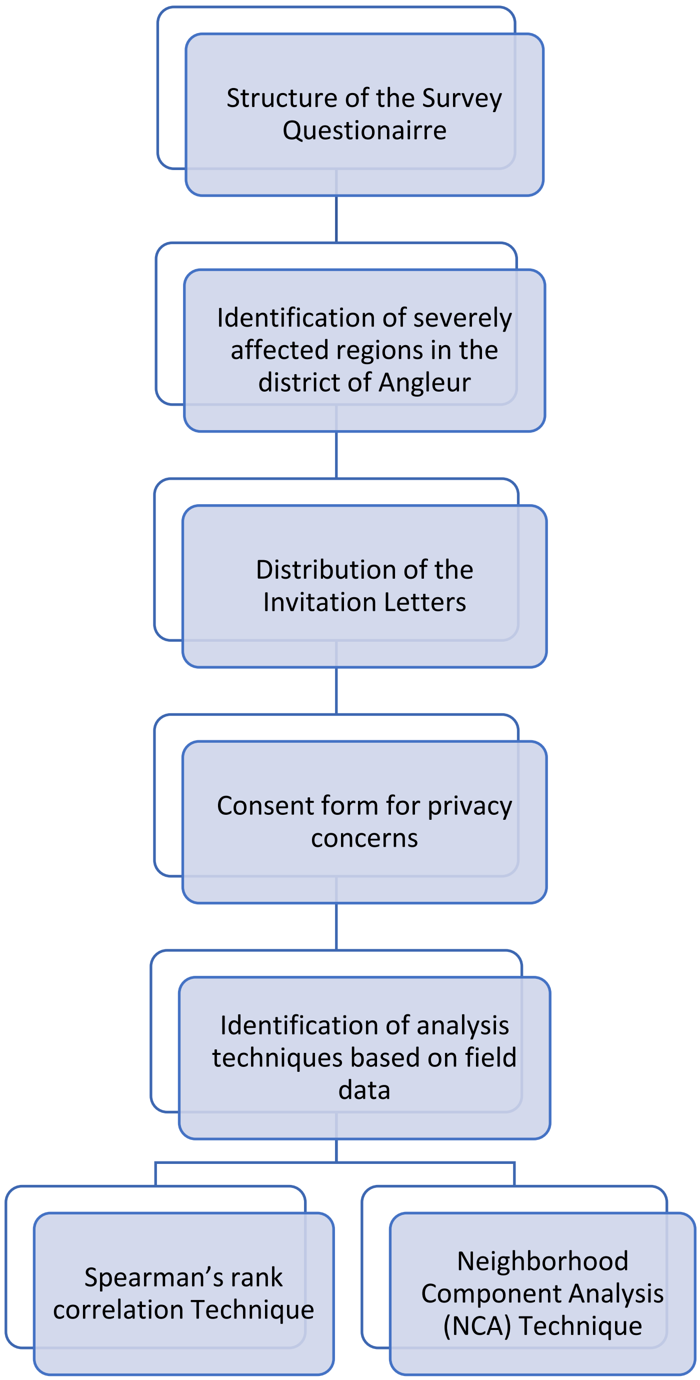


Figure 3: Methodology of the Pilot study in the district of Angleur

3.3.1 Structure of the survey questionnaire

Based on the existing literature review and field survey questionnaires for the same studies, especially RISPOSTA case study, a short questionnaire was designed for collecting the damage information from the field. The survey questionnaire was divided into two different forms i.e., form A and form B. The purpose of the form A was to collect the general information from the population such as building typology, building structure, construction period, building material, flooding depth and flood duration, presence of sediments and contamination. Whereas form B was designed to collect more detailed information regarding floor surface area, protective measures utilized before and during the flooding event as well as damage to non-structural items such as damage to doors and windows, damage to household equipment's such as refrigerators, microwave ovens, boilers, dish washers and other household electrical appliances. The survey questionnaires are attached in Appendix A.2.1 and A.2.2.

3.3.2 Identification of the severely affected houses in Angleur

Based on the **SPW (Service Public de Wallonie)** database, several streets were identified and marked on the map for field surveys. Each team was assigned to cover different streets based on the identified location on the maps. Considering the short period of time for conducting this pilot study, all affected houses in Angleur were not covered for the field survey but most of the severely affected houses were included in this pilot study. The OpenStreetMap is used for highlighting all the streets covered for this field survey and can be seen in Figure 4. All the houses along these streets were visited and further statistics of this field survey are discussed in detail in the following sections of this chapter. Whereas the more detailed information about the street name, address and postal code of the houses visited for this pilot study is provided in Appendix A.1.

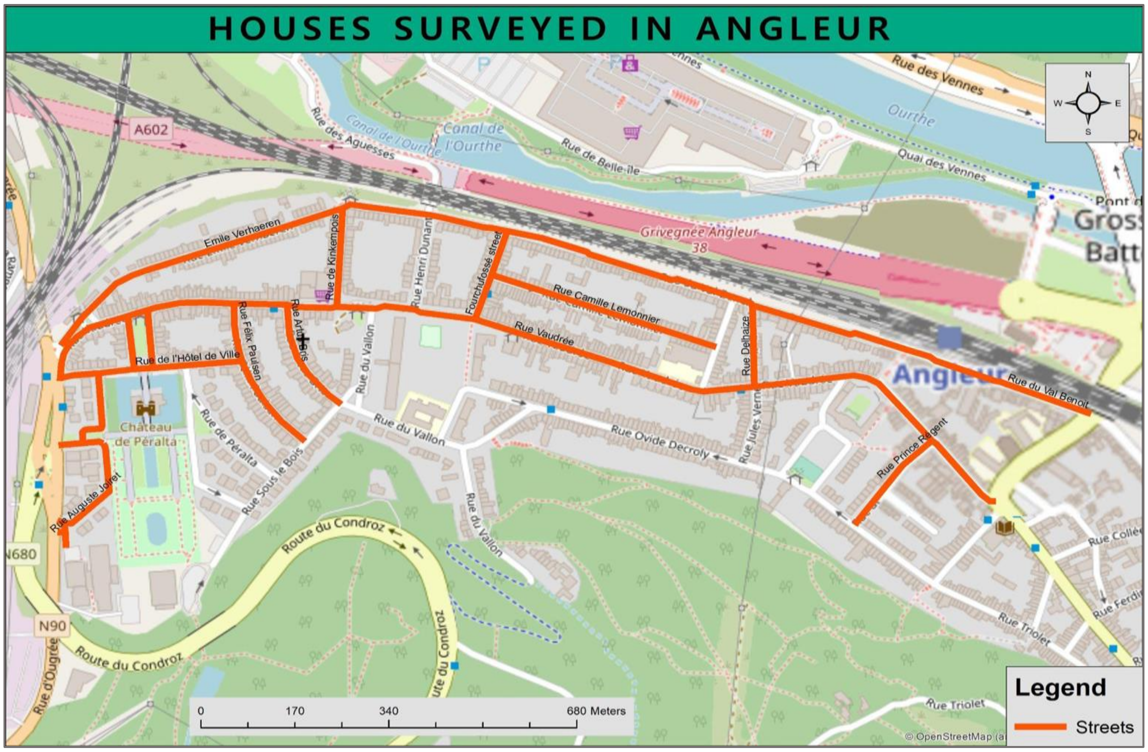


Figure 4: OpenStreetMap indicating the streets covered for field survey in Angleur

3.3.3 Distribution of the Invitation letters

Invitation letters were prepared before conducting a field survey with a brief explanation of the objectives for this study. Initially, the letters were dropped into the mailboxes of affected residents and waited for their response. Some people directly contacted the team members through an email or phone number and scheduled an appointment based on their availability for face-to-face field surveys. After a few days of dropping off invitation letters, field visits were organized, and respondents were approached door to door and requested their availability for the interview. The invitation letter can be found in Appendix A.2.3.

3.3.4 Consent form for privacy concerns

The consent form was also prepared for the respondents in order to make sure that this information will only be used by the University of Liege for scientific purposes. All private data will be kept confidential, and it will not be transmitted to the third parties. All participants were requested to read the forms carefully and sign them. The consent form for this pilot study is attached in Appendix A.2.4.

3.3.5 Identification of the analysis techniques based on our field data

Multiple analysis techniques have been studied in order to do the analysis of our field data including Principal Component Analysis (PCA), Neighbourhood Component Analysis (NCA) and Support Vector Machine (SVM). Whereas the Spearman’s rank correlation and Neighbourhood component analysis techniques were selected based on the nature and required outcomes of our field data. The description of these techniques and reason for the selection has been discussed in detail in the following sections.

3.3.5.1 Spearman’s rank correlation Technique

A non-parametric technique which is used for determining the strength and direction of a relationship between two variables that is assessed on at least an ordinal scale. The method may be used with continuous data that has failed the presumptions required to conduct the Pearson's product-moment correlation as well as with ordinal variables. For instance, you might use a Spearman's correlation to determine whether test performance and study time are related, whether depression and the length of unemployment are related, and so forth. Instead of the strength and direction of the linear relationship between your two variables, which is what Pearson's correlation decides, it additionally establishes the strength and direction of the monotonic relationship between your two variables. This technique is useful for our data in order to evaluate the dependency between different building features and is applied on both pilot and detailed studies which are discussed later in this report.

3.3.5.2 Neighbourhood Component Analysis (NCA) Technique

In contrast to the traditional Euclidean distance, Neighbourhood Components Analysis (NCA, Neighbourhood Components Analysis) is a distance metric learning technique that tries to increase the accuracy of closest neighbours’ categorization. On the training set, the technique directly maximizes a stochastic variation of the k-nearest neighbour (KNN) score with leave-one-out. Additionally, it is capable of learning a low-dimensional linear projection of the data that may be applied to quick categorization and data visualization. NCA is a supervised dimensionality reduction technique which is based on the given labels in comparison with the other methods such as Principal Component Analysis (PCA) and Support Vector Machine (SVM). It provides information about all responsible and non-responsible building features based on the feature weight which helps us to predict the damage cost. This technique is used for analysing the data of our pilot study in the field of Angleur in order to identify the building features which are responsible for predicting the damage cost and the outcomes achieved through this technique based on our collected data is discussed later in the following section.

3.4 Data collection

Field surveys were organized, and damage data was collected with the help of a scientific questionnaire. The students from Master 2 participated in the field data collection. The survey team consisted of three to four students. Each team spent almost two to three days on the field. Following the appointments arranged with the respondents or approached them directly on the field, all required damage information was collected with the help of paper-based survey questionnaires. The socio-economic information and damage data has been analysed and discussed in detail in the following sections of this chapter. However, the summary of the damage data collected on the field based on the survey questionnaire is presented in Table 2.

Variable	**Attribute or Description**
Building Typology	Residential: Detached House (1); Semi-detached house (5); Joined House (42); Apartment house (3);
Role of Respondent	Owner (31); Tenant (14); Other (3)
Construction Period	1900-1920 (9); 1920-1940 (2); 1940-1960 (8); 1960-1980 (5); 1980-2000 (1)
Type of material damage	Housing units (45); Common parts (14); Structural damage (17)
Building Material	Masonry (20), Concrete (1), Mixed (2)
External Finishes	Bricks (47); Plaster (2); Stone (3)

Variable	**Attribute or Description**
Floor Level Height	Clear height of first floor above the ground
Depth above ground	Inundation depth above the ground
Depth above floor level	Inundation depth above first floor level
Presence of sediments	Fine material (34); Coarse material (17); Garbage (14); Vegetation/Wood (15); Other (4)
Presence of contaminants	Yes (34); No (14)
Maintenance (level 01)	Good (11); Bad (1); Excellent (10)
Maintenance (level 02)	Good (7); Bad (0); Excellent (15)
Mitigation measures (Level 01)	Yes (13); No (10)
Mitigation measures (Level 02)	Yes (9); No (13)
Services Interrupted	Plumbing: Hot and cold water e.g., sanitary fittings, hot water cylinder, waste, and vent pipes Electrical and heating: all electrical appliances for heating, power, and lighting such as freezer, dryer, boiler washing machine etc.

Table 2: Residential building attributes and description of the components

3.4.1 Encoding of the field data into an Excel sheet

The collected damage information from the field surveys was encoded into the excel sheet. The encoding was done based on the type of questions in the form of numbers ranging from 0 to 2 for the damage analysis. For instance, ‘0’ for bad, ‘1’ for good and ‘2’ for excellent for the maintenance level and ‘1’ indicates Masonry, ‘2’ indicates Mixed and ‘3’ represents concrete for the building material. The encoded data in the excel sheet can be found in Appendix A.3.

3.5 Outcomes of the field survey

3.5.1 Population approached and responses received

Based on the statistics of our field survey, around 312 houses were visited. Out of these 312 houses, almost 65% of the population was absent. Whereas almost 18% of the population i.e., around 56 respondents agreed to participate in our field survey. However, almost 17% of the population i.e., around 52 people refused to participate in our field survey stating that they were not interested to discuss it anymore or some of them were busy with their house stuff or just leaving for their work. Out of 56 field surveys, 8 questionnaires were incomplete, so we did not consider those incomplete forms for our pilot study. However, out of these 48 successful field surveys, almost half of the agreed population i.e., 23 respondents provided the approximate damage cost in Euros. The summary of the people approached for this field survey is represented in Figure 5 and further information about field survey location including name, number and postal code of the streets visited are provided in Appendix A.1.

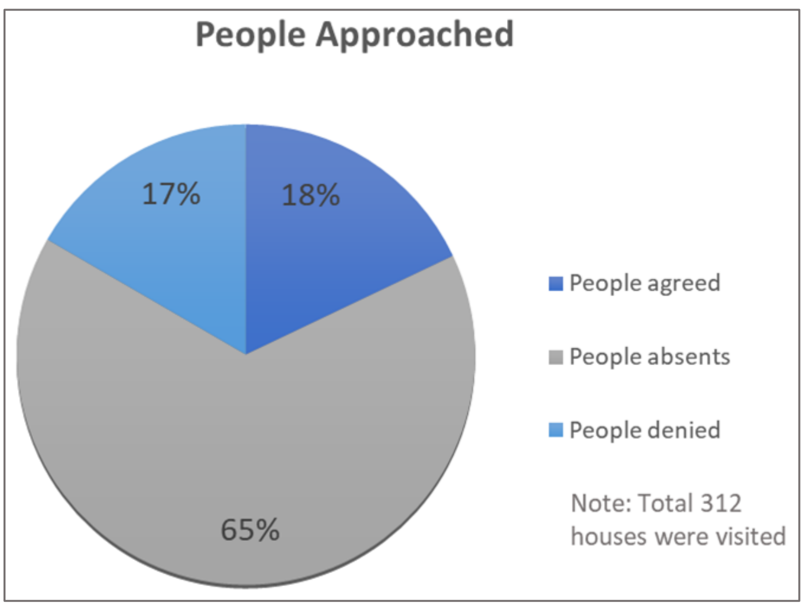


Figure 5: Summary of the people approached

3.5.2 Duration of the field survey

Based on the statistics of the field survey, almost 40% of the total population took around 40 minutes to complete the survey questionnaire. Whereas around 25% of the population took between 20 to 30 minutes for the interview. Whereas only 10% of the total population took around 1 hour for the interview and these long interviews were taken place mostly with the house owners because they had more reliable damage information of their houses in comparison with the tenants who are living there from the past few months or years. However, the average duration of the field survey was between 20 to 40 minutes. The statistics of the duration of all field surveys is shown in Figure 6.

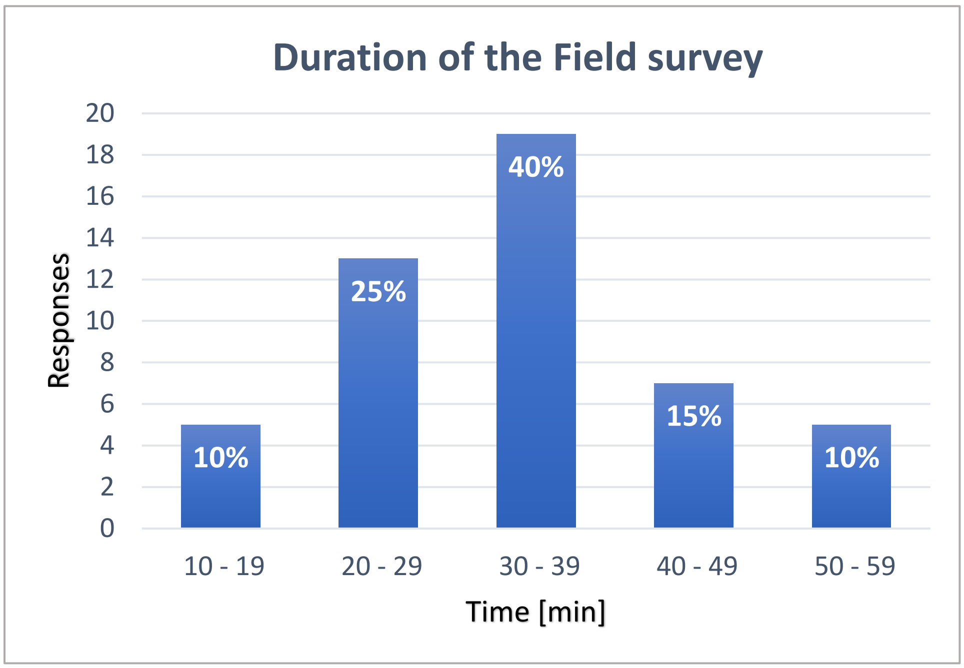


Figure 6: Duration of the field survey

3.5.3 Typology and material of the visited houses

According to the field data, 82% of the houses are characterized as Joined houses, 10% of the houses are semi-detached and very few of them are classified as detached and apartment houses. However, most of the residential buildings i.e., 76% of the total houses were constructed from the Mansory representing that it is the most dominating building material in the district of the Angleur that we particularly covered in our field survey.

Whereas 8% of the buildings were built up with concrete and 6% of the total buildings were built up with mixed i.e., both concrete and masonry and small proportion of the houses had wood as a construction material. The mean damage cost for the mixed (concrete + masonry) construction is high i.e., the difference between the mean damage cost of the houses constructed with mixed (concrete + masonry) with the houses built up with masonry is around 9,035 €. However, only one person claimed that the building material of his house is concrete, and the damage cost was reported as 70,000 €. The statistics of the building typology can been seen in Figure 7 and figures of the building material of the visited houses are represented in Figure 8.

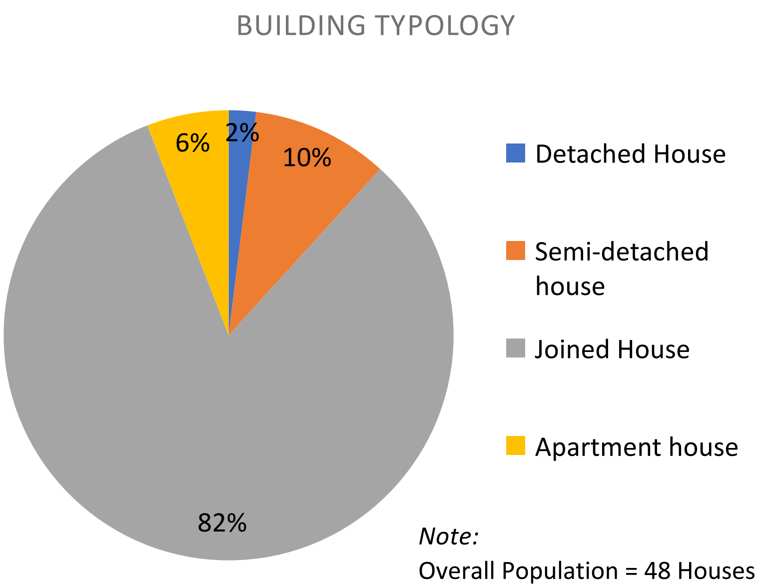


Figure 7: Building typology of the visited houses

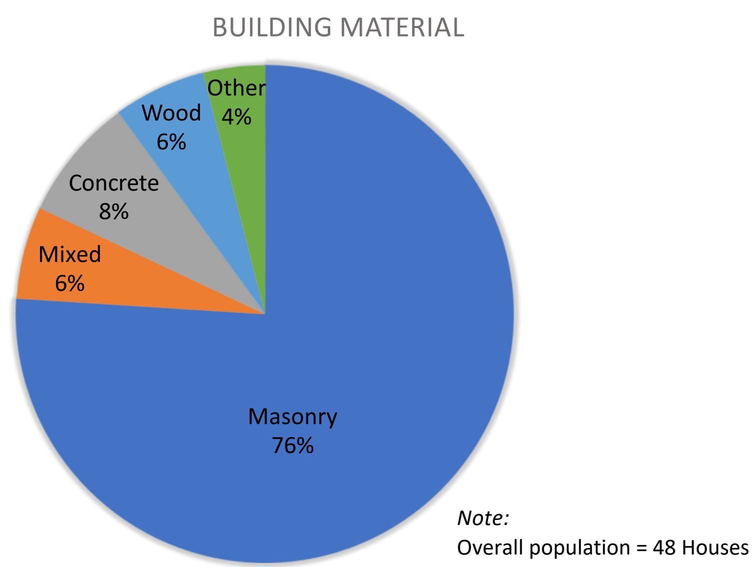


Figure 8: Building Material of the visited houses

3.5.4 Building construction Period

Most of the houses i.e., around 40% were built up in the first half of the 21st century (1919-1945) revealing that it was an old construction. Whereas almost 28% of the houses were constructed in the second half of the 21st century i.e., between 1946 and 1970 and 14% of the buildings were constructed between 1971 and 1991. However, only 2% of the residential buildings were newly constructed according to our field data. The houses which were constructed in the early nineties suffered less damage i.e., the difference between the mean damage cost of the houses constructed after 1945 with the mean damage cost for those houses built up before 1945 is around 13,358 €. However, the mean damage cost of all the houses reported by the respondents is around 55,000 €. The proportion of the visited houses based on different periods of construction is represented in Figure 9.

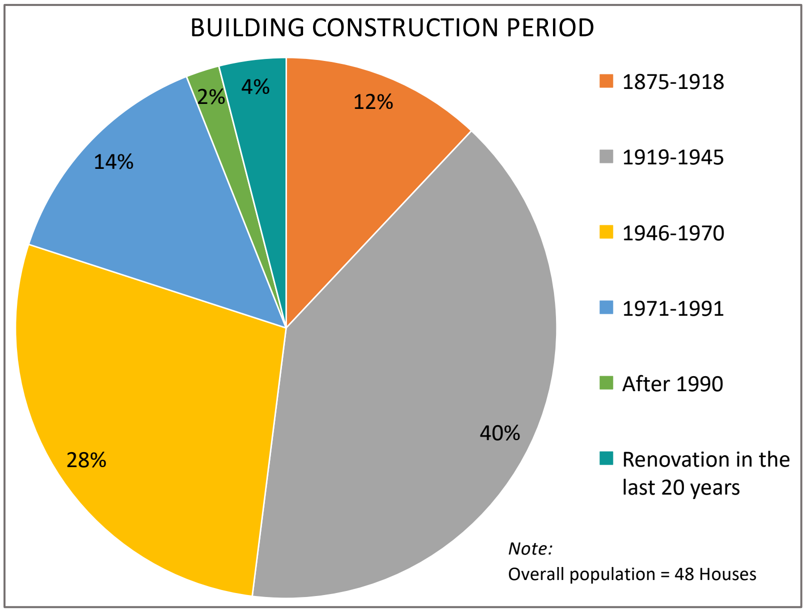


Figure 9: Building Construction Period

3.5.5 Presence of Sedimentation

The majority of the population claimed that they observed sediments in the flowing water i.e., around 40% of the population claimed that they observed fine material in the water. Whereas almost 20% of the respondents found coarse material. However, less than 20% of the total population observed vegetation, garbage, and other types of sediments in the flood water. The statistics of the composition of the sediments present in the flood water can be seen in Figure 10.

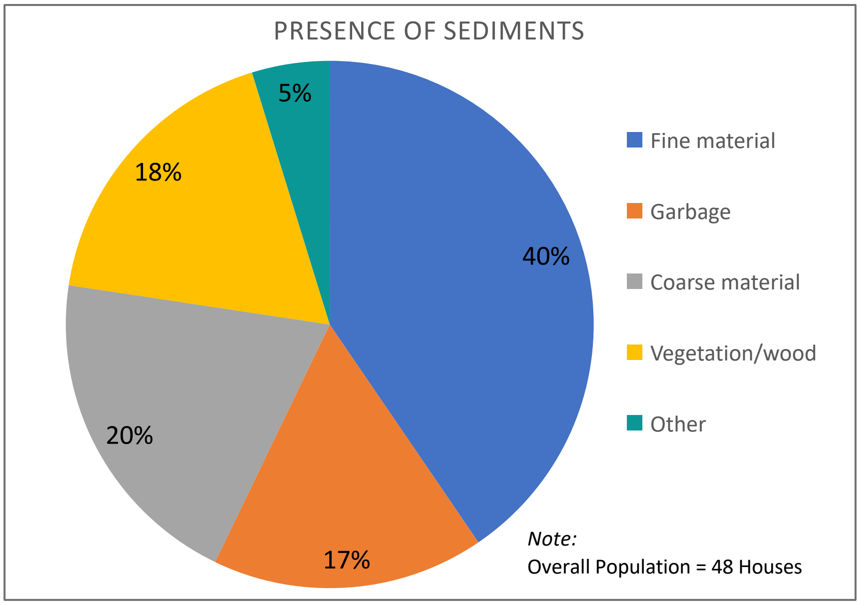


Figure 10: Presence of Sediments

3.5.6 Water depth in comparison with damage cost

According to our field data, the average water depth in the majority of the houses was between 1.5 m to 2.5 m which led to high damage cost. In very few houses, the inundation depth was greater than 2 m. We also noticed that there is a huge variation in the damage cost for the same water depth. For instance, five respondents claimed that the water depth was around 2 m in their houses. Out of these 5 respondents, 3 of them did not use any protective measures which led to high damage cost i.e., the difference between the mean damage cost of these houses with the mean damage cost of the houses with protective measures is around 64,000 €. Similarly, we can also see the huge variation in the damage cost for two other respondents who claimed the same water depth i.e., around 2.5 m because one of them utilized some mitigation measures (usage of water pumps and shutdown of electricity before the flood) which could lead them in reducing the damage cost almost half in comparison with the other respondent who did not adopt any protective measure. However, it has been illustrated that greater water depth was one of the influencing factors for causing high damage cost. The comparison of damage cost with the water depth is represented in Figure 11.

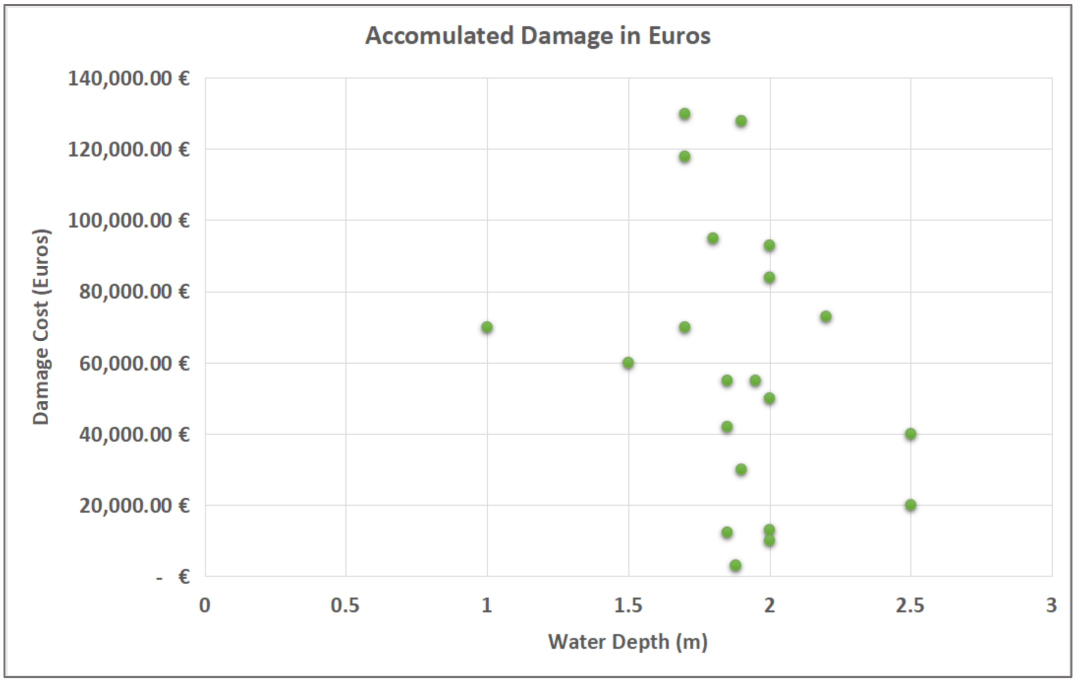


Figure 11: Comparison of water depth with the damage cost

3.5.7 Correlation between different building features

Based on the field data, the regression analysis has been performed. The strong positive correlation is obtained between protective measures of both level 1 and level 2. The second highest positive correlation is found between maintenance levels of both level 1 and level 2. However, there is a strong negative correlation between the damage cost and protective measures meaning that respondents faced less damage in terms of cost with more precautionary measures and logically it is correct. The mitigation measures utilized by the people includes shutdown of electricity before the flood event and application of water pumps during the event. Whereas the difference of the mean damage cost of the houses for which the respondents applied protective measures with those who did not apply any mitigation measures is around 7,500 €. Whereas the mean damage cost for all 23 houses is around 55,000 €. Moreover, a strong negative correlation exists between maintenance level of the houses and presence of sediments because according to the majority of the population there were sediments in the flood water including a high proportion of garbage, coarse material and vegetation which highly impacted the maintenance level of their houses which led to high damage cost. The correlation between different building features by the Spearman rank correlation matrix is represented in Figure 12.

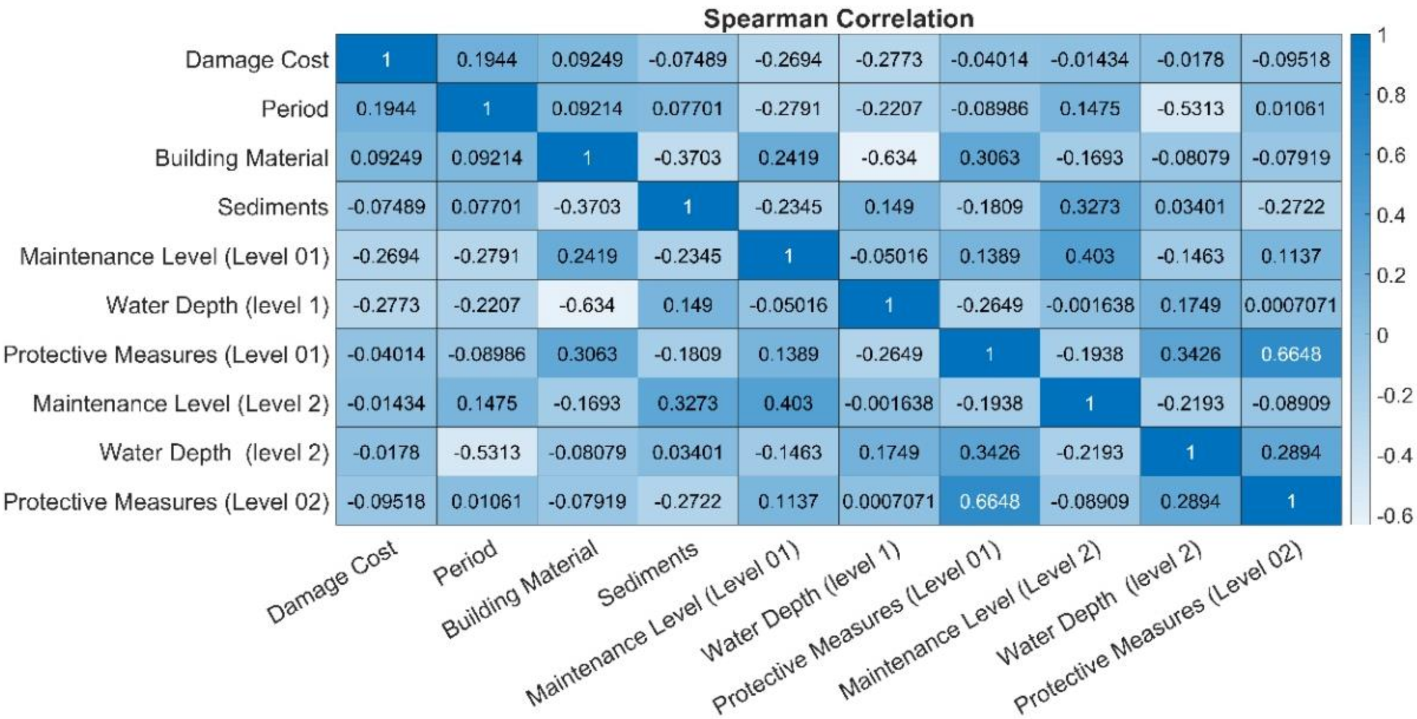


Figure 12: Spearman correlation between different building features

3.5.8 Building features responsible for the prediction of damage cost

According to neighbourhood component analysis, protective measures for level 01 have the highest feature weight, illustrating that if the respondents utilize proper measures before and during the flood event then the damage cost could be reduced up to great extent. According to our field data, almost half of the participants said that they utilized protective measures and half of them had no idea how to adopt them. Whereas the maintenance level has the second highest feature weight showing that it is strongly correlated with the damage cost. Damage analysis was performed for both level 01 and level 02 separately.

The level 01 of the well-maintained houses i.e., Excellent level of maintenance experienced less damage cost i.e., the mean damage cost is around 39,300 € in comparison with the houses having a good level of maintenance with a mean damage cost of around 75,545 €. Based on our field data, there was only one house having a bad level of maintenance which experienced a damage cost of around 30,000 €. However, considering the level 02, the majority of the houses had excellent levels of maintenance because of the presence of living areas and the mean damage cost is around 54,000 € in comparison with the mean damage cost of the houses having a good level of maintenance which is around 57,000 €. The relevant and irrelevant building features for damage cost prediction is represented in Figure 13.

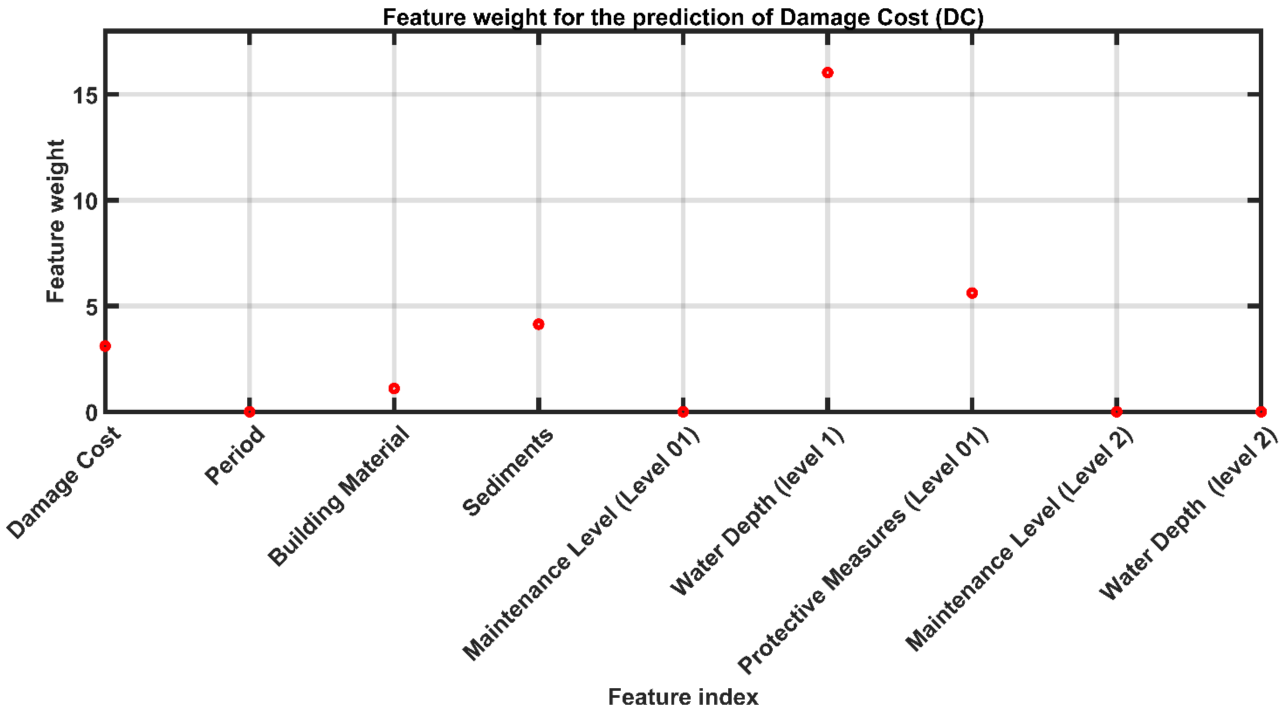


Figure 13: Building features responsible for damage cost prediction

3.6 Discussions and recommendations

3.6.1 Strengths of the field survey

Putting letters in mailboxes was one of the strengths of this field survey which helped interviewers to get more positive responses during their first contacts. Moreover, the brief explanation about the study objectives was quite impressive.

3.6.2 Weakness in the Questionnaire

The Questionnaire was repetitive. It was very difficult for the residents to estimate the damage cost by specific categories and impossible for the tenants because they did not have in-depth knowledge of the building. The teams faced difficulties measuring different heights on the field due to presence of litter and damaged household stuff. It was difficult for some of the respondents to provide an estimate for the quantity of doors and windows because they had accessibility issues in their houses due to the presence of damaged household stuff and some of them evacuated from their houses and were waiting for the municipalities if they could go inside their houses.

3.6.3 Improvements in the questionnaire

The questionnaire was not very well structured because people were explaining about the damages of caves and damages to the ground floor at the same time, it was difficult to follow the questionnaire. The information requested for level 3 was useless because it was not impacted since the average water level was around 1.90 meters so this section should be removed.

3.6.4 Improvements in strategy of the field survey

Developing a consent form must be an effective strategy for the respondents for assuring them their provided information will be kept confidential. Based on this field survey, it can be proposed that working in a team of at least 2 people would be a good strategy rather than working alone which helps surveyors to keep visual contact with the respondents while other team members write down their responses. It is always better to ask people before measuring the required parameters and capturing the pictures on site. It would be better if the interviewer asked the availability of the respondents for the next twenty minutes before starting the interview. Moreover, there is a need to include a question for asking the respondent's contact details which ensures them that they will get the return of this survey.

3.6.5 Flood Management and warnings by the authorities.

Based on the respondent’s feedback, following conclusions could be made.

- They also mentioned that the relevant information was not properly communicated about rising water levels
- People claimed that the precautionary measures were insufficient, and they had no knowledge how to adopt them
- Due to the lack of financial assistance, they experienced worst damage

- They also highlighted that they did not receive useful help from the town. However, volunteers helped the victims by their own
- The respondents highlighted that the severe effects were due to the worst management of Eupen dam
- According to respondents, they faced delays and difficulties in damage compensation from the insurance companies

3.7 Conclusions

The field surveys took a long time because most of the houses were abandoned and some of them were empty because people were working during the field survey. In some of the houses, there were accessibility issues due to the garbage and debris. Whereas some respondents refused to talk with us by giving some reasons including busy schedules, not willing to share the information, frustrated or stressed. However, almost half of the respondents agreed to share damage cost details, but the majority of the respondents had no idea about the estimation of the damage cost. Since, the houses having basements experienced significant damage because the basements were totally flooded which led to the damage of the boiler/ heating system. The dataset is very small i.e., only 23 respondents share the damage cost. However, we cannot comment on the reliability of the analysis. But this is supposed to be the benchmark of the detailed field survey which gave much useful information about this flood event and help us in order to improve the survey questionnaire based on the strengths and weaknesses identified in this study and revised the field survey for a long-scale detailed field survey.

4. DETAILED STUDY FOR SEVERELY AFFECTED MUNICIPALITIES IN THE WALLOON REGION

4.1 Introduction

Based on the previous experience and outcomes of the pilot study that was conducted in Angleur, the detailed study was planned and carried out. The severely affected municipalities along the Vesdre river, which was one of the most impacted sub catchments by the catastrophic flood event in July 2021 in the Walloon region were selected for the field surveys. There are five provinces in the Walloon Region which includes Walloon Brabant, Hainaut, Liège, Luxembourg, and Namur[6]. According to the statistics available on Statbel[7], more than 3.6 million inhabitants are living in the Walloon Region which is the least populated Region in Belgium as compared to the Brussels Capital Region and the Flemish region. The municipalities involved in this detailed study include Chaudfontaine, Trooz, Pepinster, Limbourg and Eupen.

Form the pilot study, the strengths and weaknesses in the short questionnaire were identified and the modifications have been made in the short survey questionnaire and a detailed well-structured survey questionnaire has been developed based on the outcomes of the pilot study and following the literature review of the similar case studies such as RISPOSTA for collecting more detailed information about the socio-demographic variables and flood damage data. Moreover, the field strategy has been improved and revised for this detailed study. The detailed study has been discussed in the following chapter.

[6] https://rb.gy/zubh7d
[7] Source was accessed on 10/05/2022 at: https://statbel.fgov.be/en/themes/population/structure-population

4.2 Methodology

The brief methodology of the detailed study conducted for other severely affected municipalities of the Walloon region is represented in Figure 14. Whereas the explanation of each phase of the methodology is discussed in detail in the following sections of this chapter.

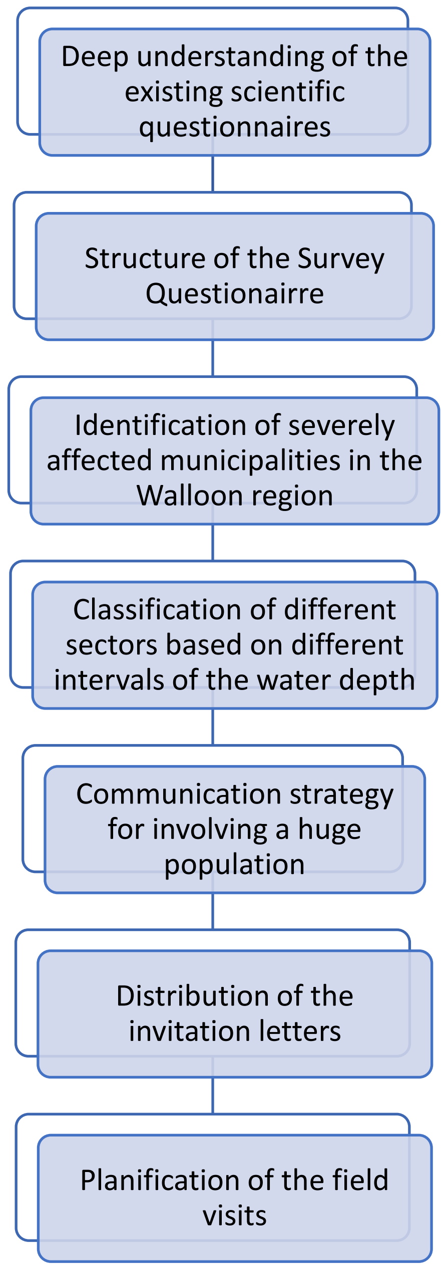


Figure 14: Methodology of the detailed study conducted for severely affected municipalities of the Walloon region

4.2.1 Deep understanding of the existing scientific questionnaires

Initially, three survey questionnaires from similar case studies of Italy, Germany and Netherlands have been reviewed and deeply evaluated. For instance, questions for general information and building characteristics were taken from the questionnaires of Italian and German studies and restructured based on the requirements of our input data. However, questions regarding the warning systems were taken from the questionnaire of the Netherlands study. Based on these previous studies, the short questionnaire which was developed for the pilot study of Angleur has been modified and a detailed scientific questionnaire has been designed for this study in order to obtain more detailed information from the participants based on their experience.

4.2.2 Structure of the survey questionnaire

The questionnaire was divided into two major parts. Part 1 of the questionnaire was designed in order to collect personal information and economic profile of the population including their street addresses and postal code, level of education, age, gender, socio-professional category and contact details of the affected respondents. Whereas Part 2 includes damage information which includes hazard variables, building features, buildings, and contents damage, building damage extent, total cost of damaged facilities, financial compensation from insurance companies, information regarding precautionary measures and warning systems. The paper-based survey methodology was selected because it is faster and easy to record other useful comments delivered by the participants and the probability of reliable information is high for field surveys. However, we could also have the chance to take pictures on the field and see the damage. The detailed questionnaires can be found in Appendix B.1.1 and B.1.2. The structure of the detailed survey questionnaire is described in Figure 15.

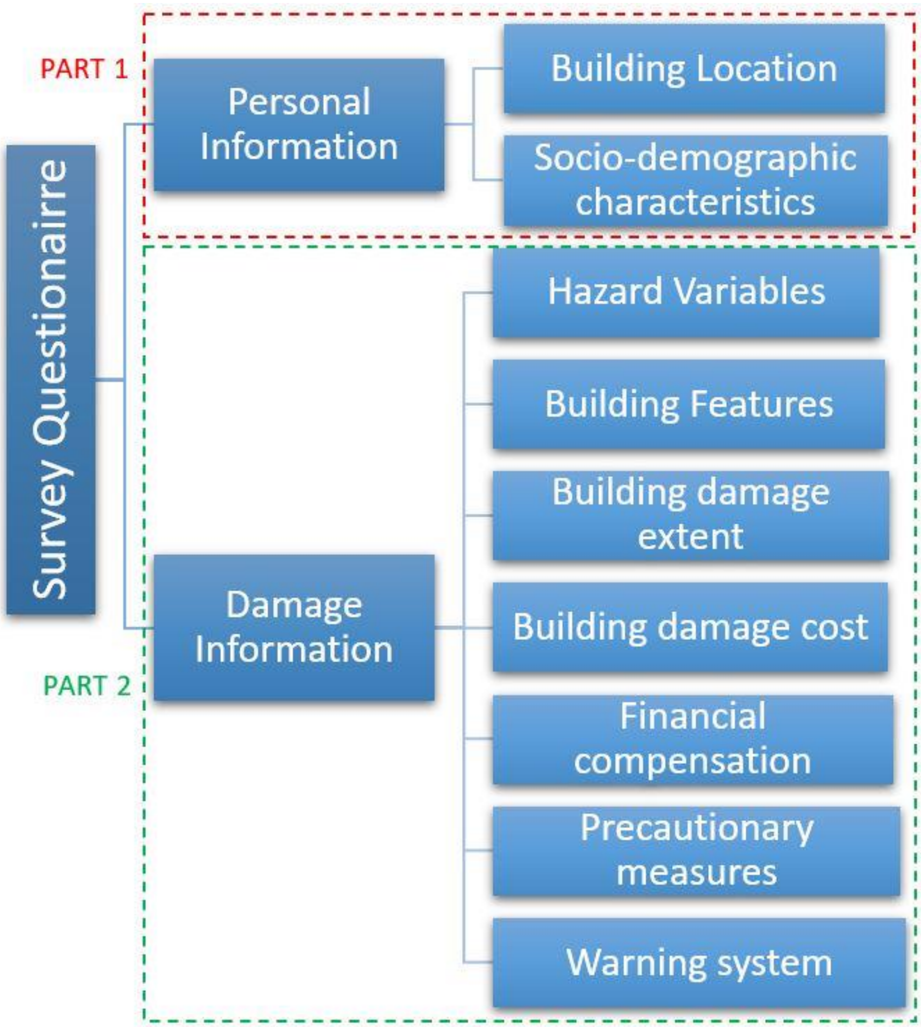


Figure 15: Structure of the detailed survey questionnaire

4.2.3 Identification of severely affected municipalities in the Walloon region

Based on the open-source information from the existing database of the **SPW (Service Public de Wallonie)** who is responsible of the policy making established by the Walloon government and primary interface between regional and citizen institutions[8], the severely affected municipalities in the Walloon region were identified along the Vesdre river which experienced huge damage. The statistics from this database illustrate that there were more than 160 buildings which were completely washed away in this flood and more than

[8]Source accessed on 25/05/2022 at: https://www.wallonie.be/fr/actualites/inondations-202-communes-wallonnes-reconnues-comme-calamites-naturelles

200 buildings need to be demolished. Whereas more than 3,000 buildings were partially damaged. The severely affected municipalities along the Vesdre River in the Walloon Region are identified in Figure 16. Whereas the municipalities that we have covered for this study are highlighted in the same figure.

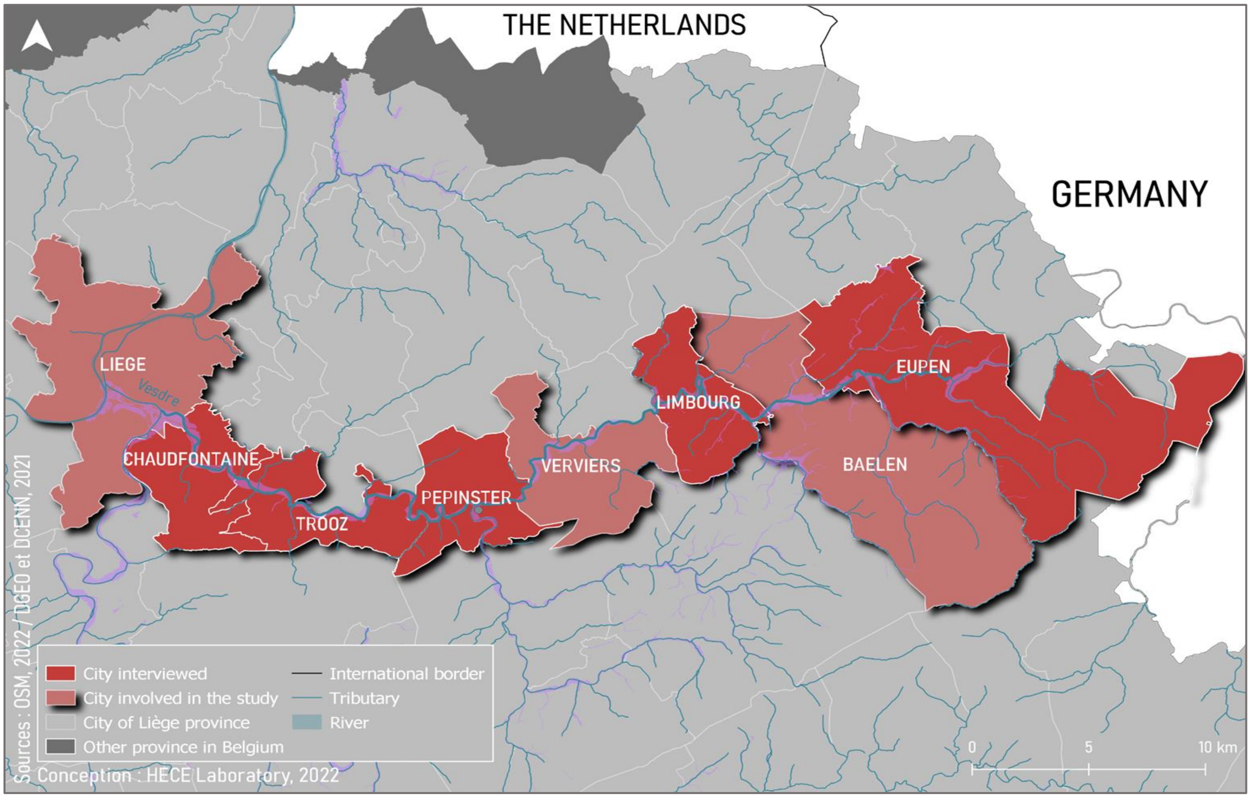


Figure 16: Severely affected municipalities in the Walloon Region

4.2.4 Classification of different sectors based on different intervals of the water depth

Before leaving for field survey, maps were created in order to locate the different intervals of the water depth for all affected municipalities and the data was retrieved from the SPW database. For instance, the map in Figure 17 represents different intervals of the water depth on the field of Pepinster. We created similar maps for all other municipalities, and we approached the population based on it. The representation of our field survey covered all the ranges of the water depth. Some are better than others. For instance, high water depth has better representation in comparison with low water depth and the comparison of the water depth obtained from the field survey and SPW database for all different ranges of water depth is discussed in detail in the following chapter.

Figure 17: Sectors characterization based on different levels of water depth (Source: SPW database)

4.2.5 Communication strategy for involving a huge population

After the identification of severely affected municipalities based on SPW database and classifications of different sectors based on the water depth, a proper communication strategy was planned and posters, invitation letters and concern forms were created. The summary of the project and the purpose of this research has been described for our population. Whereas a consent form was given to the respondents at the end of the field survey in order to read it carefully and sign it. The purpose of this consent form is to give them confidence that their privacy will be respected, and their personal information will be kept confidential and will be used only by the University of Liege for this research. The consent form for this detailed study is attached in Appendix B.1.3. The communication strategy for involving a huge number of participants from the targeted population is shown in Figure 18.

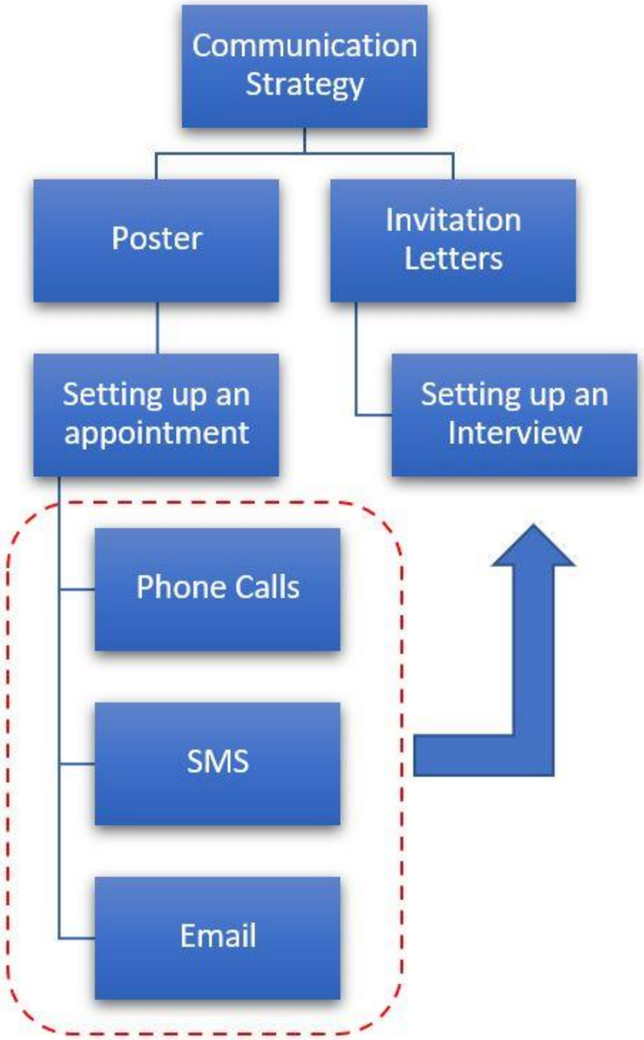


Figure 18: Communication strategy for involving huge proportion of the population

4.2.6 Dropping invitation letters into the mailboxes of the population

After identifying severely affected municipalities of the Walloon region, the invitation letters were distributed into the mailboxes of the residents. Some people contacted through emails or phone calls and gave their availability. Appointments were scheduled with those respondents. After waiting a few days, the field surveys were organized and people were already notified through invitation letters that in the following days, field surveys would be carried out to collect information of the past flood event. In addition to the invitation letters, a poster was designed and placed in the visible places of the affected municipalities in order to inform the population about this project. Moreover, the mayors of different municipalities were contacted to communicate about the project. The invitation letter is attached in Appendix B.1.4.

4.2.7 Planification of the field visits

The field surveys were planned by following the maps that we had for the severely affected municipalities in the Walloon region and the schedule of the field visits was prepared based on the availability of the team members. Each week, a team of researchers, interns and students spend approximately 2 to 3 days on the field and rest of the days of a week, the encoding of the collected field data was done. Whereas the researchers took time in order to do the encoding, verification and correction of the field data in the office. Whereas the details of the encoding data are described later in the following sections of this chapter. When we obtained a good representation of the field, we did the same procedure for other field visits.

4.3 Data Collection

The on-site data collection was started from the beginning of March 2022 by the group of researchers and students. The targeted survey locations were already identified on the maps before leaving for the field. Two teams of two people equipped with a paper map of the identified streets and common measuring devices such as measuring tape, laser distance meter and mobile phone camera. The teams spend almost the whole day from 9am till 5pm on the field following the schedule of the field visits. Almost 450 houses were approached on the field. Out of these 450 building counts, we managed to interact with almost half of the population i.e., around 200 people. We see that there is a huge difference between people approached and surveys conducted in the month of July 2022. The reason might be the summer holidays and most of the people went away from their houses in order to spend some time outside their region. The comparison between the population approached, and interviews conducted is represented in Figure 19.

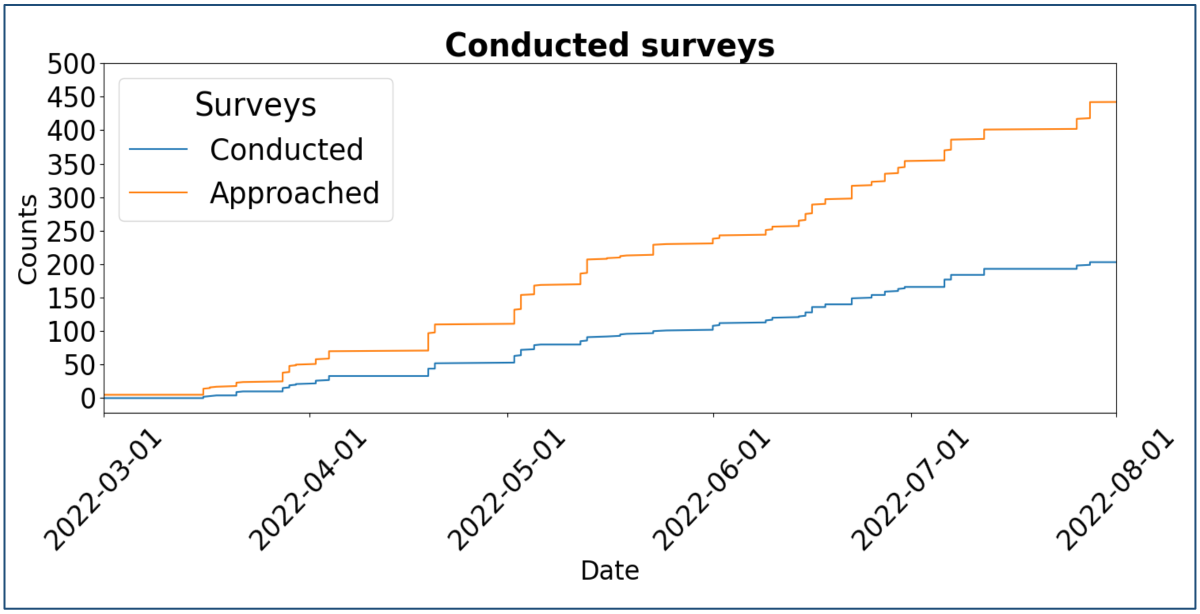


Figure 19: Comparison between approached and conducted surveys

After the flood event, the volunteers and authorities went to the field and measured the water depth and put them on GIS. The coordinates (X, Y) for all the buildings were taken from the SPW database. The location of all the buildings is taken from the ICAR database based on the building addresses and ICAR database was used in order to geo-localise the surveyed population.

4.3.1 Selection of the encoding software

'Moodle' was selected as an encoding software because it was secured by the University of Liege in order to guarantee the security and confidentiality of our collected field data. Moreover, it is free and user friendly which helps to create questions and we can easily perform the skip logic with the Moodle. We created all our questions in the Moodle and the field data was encoded in three different phases which are described later in the following sections.

4.3.1.1 Encoding of the field data

The first phase is the encoding, which allows us to store all collected field data into an excel file. After encoding of all the field data, we assigned a code '0' for encoding.

4.3.1.2 Verification of the encoded data

For the verification of the encoded data, a second person enters the data and assigned a code '-1' for the verification and correction of the data. In this way, the collected field data was cross verified two times, and the probability of the error in data storage was minimized.

4.3.1.3 Correction of encoded data

A python script was used to decode any errors between the encoding and verification phases based on a timestamp which is a unique number for each survey in order to compare each line to see if these are equal or not to reduce the human error for introducing the data. If there is an error, we correct it directly in the script. At the end, there was a file with all the corrected errors, and we created a new excel file with all the corrected data. The graphs were generated mostly with readily available python scripts and the script was modified based on the information available and the results that we need to achieve.

4.4 Results and Discussions

4.4.1 People approached and survey duration

Almost half of the respondents agreed to participate in the field survey. However, very few people contacted to schedule an appointment. According to our field data, almost 450 people were approached for the field survey. Out of these 450 people, around 200 people participated in our study and almost half of the population i.e., around 235 people rejected to participate in our field survey. Whereas a very small proportion of the population i.e., around 9 people were approached for an interview in other attempts. The average duration for the field survey was between 60 to 90 minutes. It was noticed that the longest surveys were arranged with the house owners because they had more damage information to share with us. Whereas, around 10 interviewers took more than 2 hours because those people really wanted to talk and discuss their flood experience in depth. The statistics of the population approached, and the responses received are shown in Figure 20 and figures for the total duration of the field survey can be seen in Figure 21.

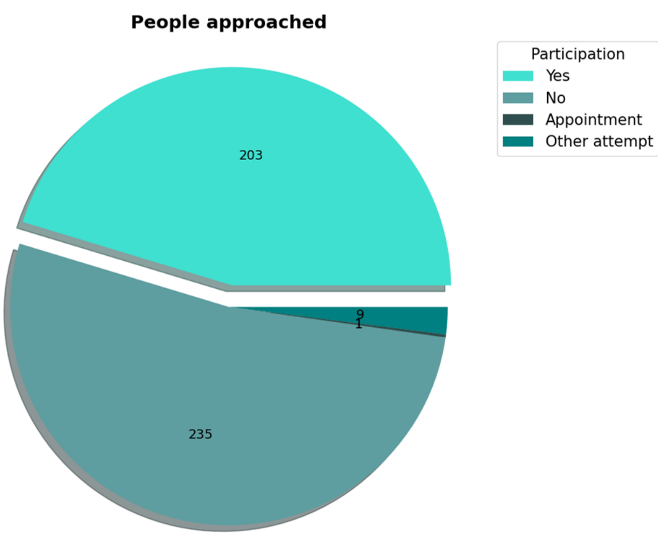


Figure 20: Population approached, and responses received

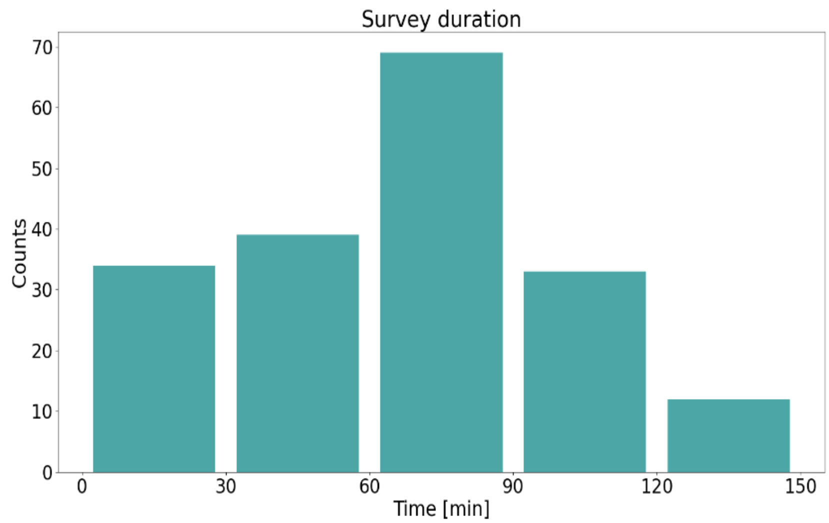


Figure 21: Duration of the field surveys for overall population

4.4.2 Comparison of socio-economic profile of the population with Statbel

According to the statistics of Statbel, almost 60% of the population have working status and around 40% of the population are unemployed or inactive. Whereas, based on the statistics of our field survey, almost 46% of the population are employed and 54% of the population is unemployed. The difference in both statistics might be due to the absence of the population who were working during our field survey. The statistics of our field data illustrates that almost half of the population were retired or inactive. Whereas 48 employees also participated in our study. The reason for less participation of the workers was due to their absence because most of them were in their workplace during the morning and afternoon. Although, we also organized some interviews during the weekends in order to approach those people who were working during the weekdays, and we also planned to approach these people through social media in order to arrange phone surveys. The figures for the socio-economic profile of the population are represented in Figure 22 and the comparison of the socio-economic profile of the people with the statistics of the Statbel (Province level) is represented in Figure 23.

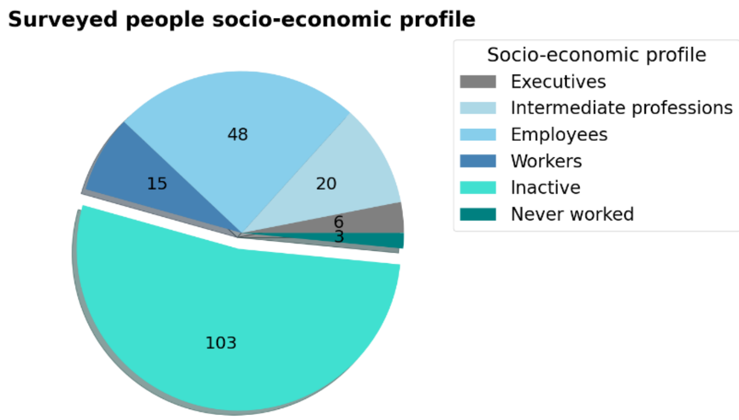


Figure 22: Socio-economic profile of the population

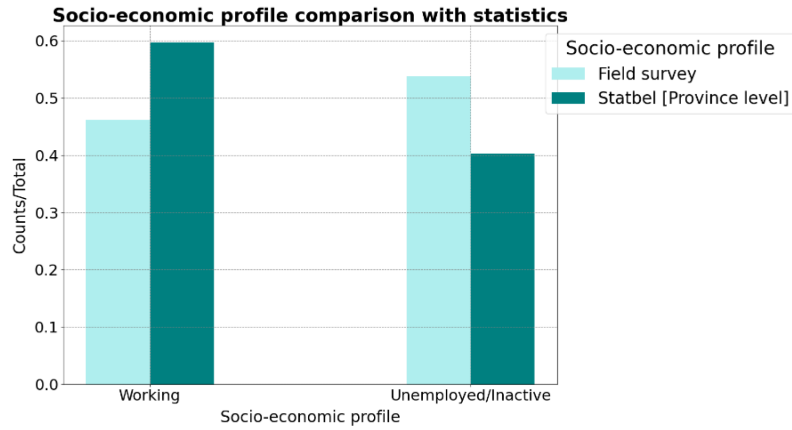


Figure 23: Comparison of socio-economic profile of the population with Statbel

4.4.3 Damage cost comparison with people's age based on their education

The statistics of field data illustrates that most of the population just hold their bachelor's diploma. Whereas the second highest proportion of the population managed to finish their high school. However, very few proportions of the population had a master's degree. Based on the statistics of our field data, most of the people who participated in our field survey was between 60 to 70 years old. Whereas the average age of the population was between 50 to 70 years. Due to the low education levels and more aged people, they did not apply proper mitigation measures and did not have sufficient knowledge about protective measures which might be one of the leading factors responsible for leading high total building damage cost. The comparison has been made between people's age and total building damage cost based on their level of education which can be seen in Figure 24.

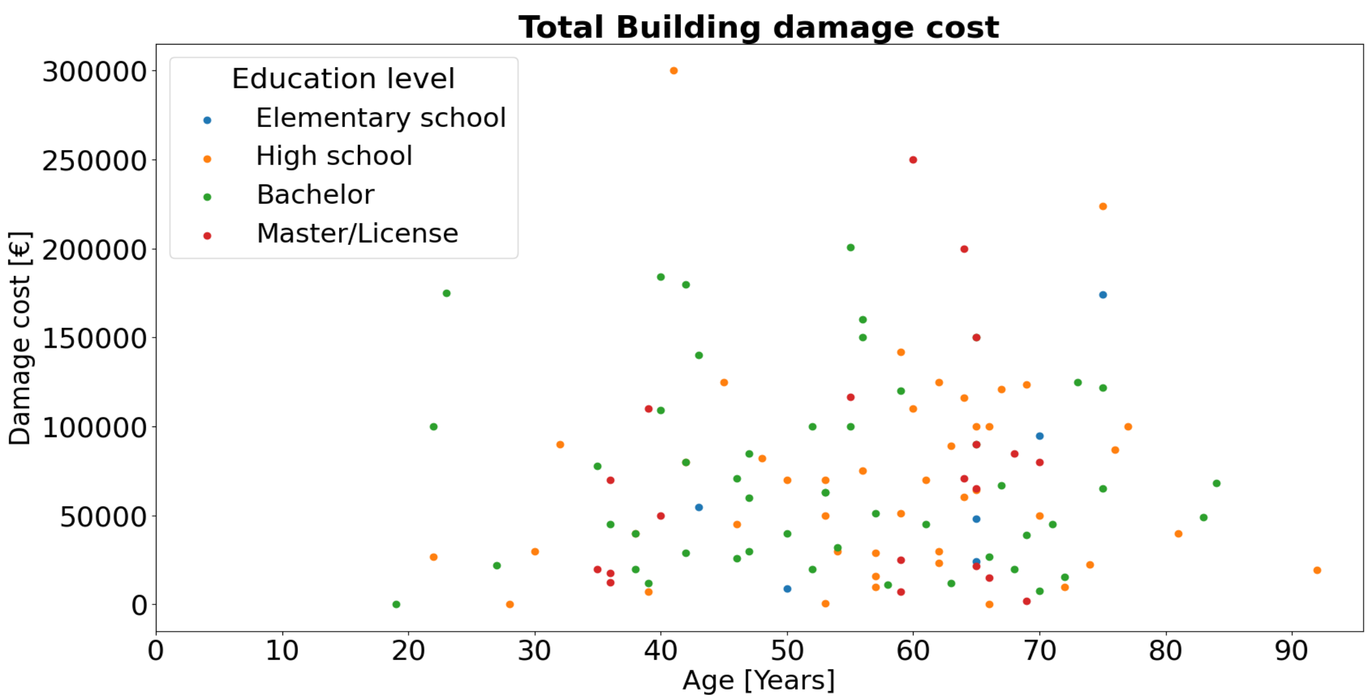


Figure 24: Comparison of damage cost with people's age based on their education

4.4.4 Evaluation of the evacuation plan and preparedness measures

Based on our collected field data, almost half of the population i.e., 91 people managed to evacuate during the flood event. Whereas one-third of the population claimed that the evacuation was not properly planned or impossible and almost 16 people evacuated after the flood event. However, the majority of the people were evacuated during the flood event. We measured the preparedness of the population based on four different preparedness measures i.e., Hazard map provides information about probability of a flood event, BE-Alert is a special alarm system used by the government of Belgium in order to alert the public for an emergency situation through an email, text message or voice message from a public service telephone line, Infocrue provides hydrological data of Walloon region including the current water status in Walloon region through all phases (Flood alert, pre flood alert, normal and low water level) and house protection with the help of protective measures utilized by the people. Based on the statistics, more than 80% of the population were not planned for both preparedness measures i.e., Infocrue and house protection showing that the respondents were not planned for this flood event which could be one of the leading factors for causing high damage cost. Whereas almost 45% of the population were not planned for both preparedness measures i.e., Be-Alert and hazard maps. Moreover, around 15% of the population adopted measures including Infocrue and house protection before the flood event. However, almost half of the population adopted measures by following the hazard maps and one fourth of the population followed Be-Alert before the flood event. The statistics of the evaluation of the evacuation plan before, during and after the flood event are shown in Figure 25 and figures of the population preparedness are represented in Figure 26.

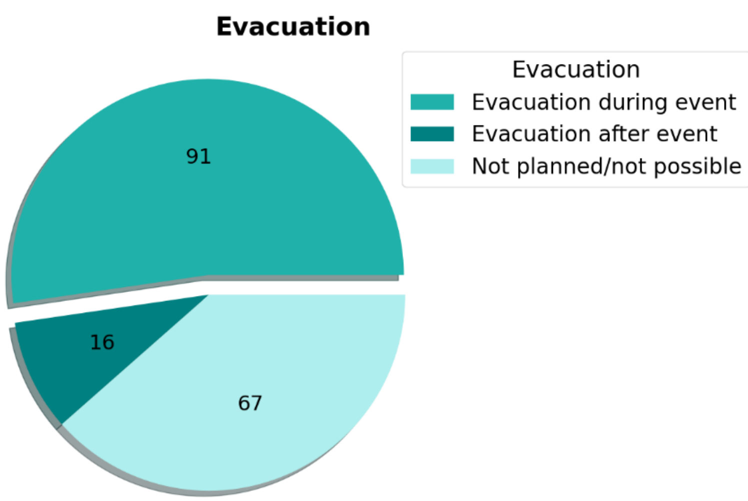


Figure 25: Evaluation of the Evacuation plan

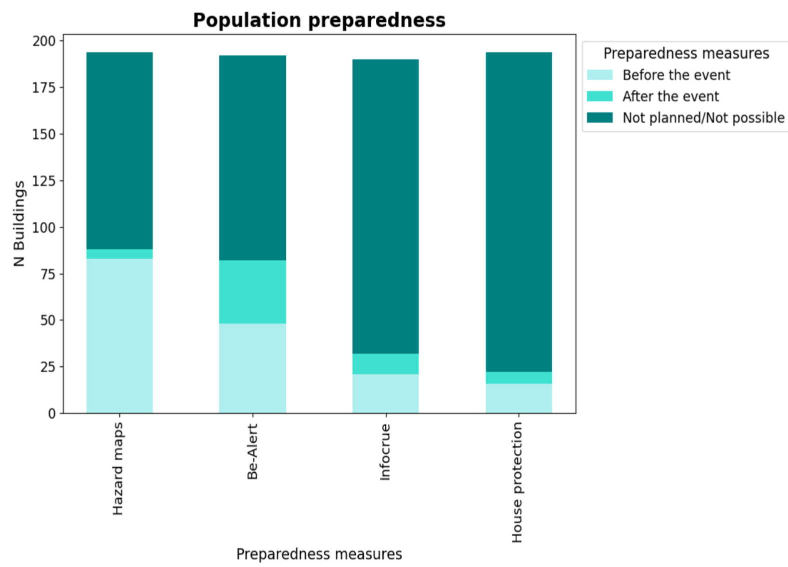


Figure 26: Preparedness measures adopted by the population

4.4.5 Comparison of water depth recorded on field with SPW data

As we already discussed before, we created maps for all affected municipalities of the Walloon region based on different levels of water depth by using the records of the SPW database. The field surveys were conducted based on different levels of water depth and comparison of the water depth is done with the one obtained from the SPW database. The statistics illustrate that the difference in both records was quite high for short intervals of the water depth. In contrast to that, large intervals of water depth have better representation because it includes more data from all the municipalities including Chaudfontaine, Trooz, Pepinster, Limbourg and Eupen representing that the large intervals of the water depth obtained from field survey is almost the same in comparison with the one obtained from the SPW database. The comparison of the different levels of water depth recorded from the field survey and SPW data outside the building is presented in Figure 27.

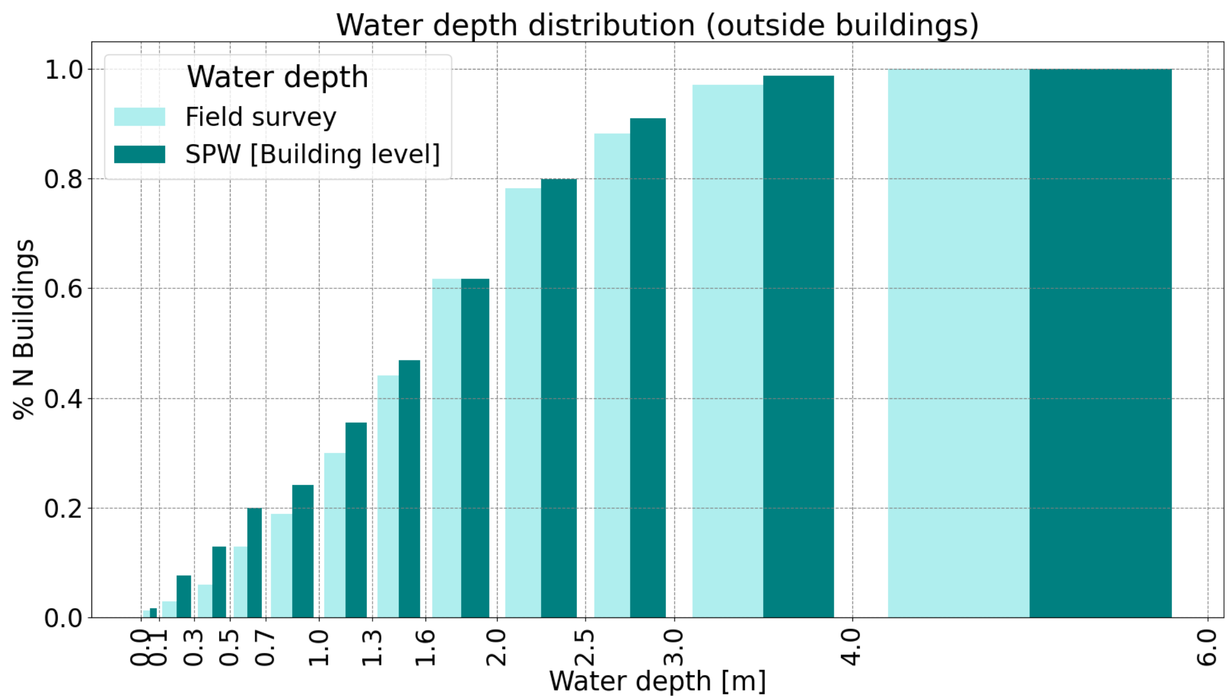
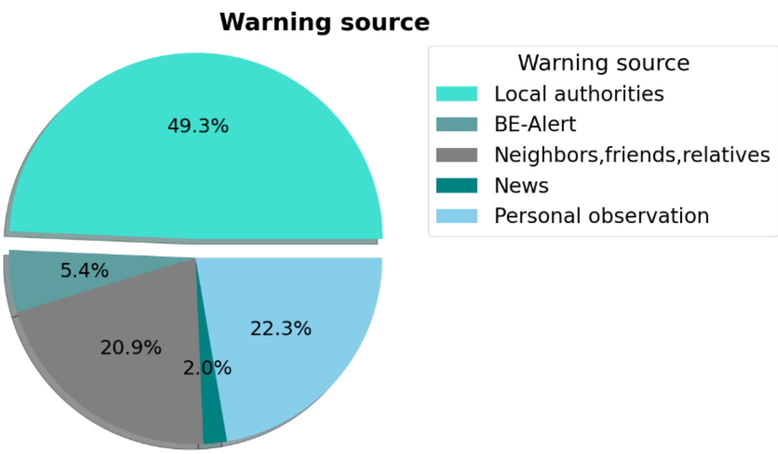


Figure 27: Water depth comparison obtained from field survey and SPW data

4.4.6 Warning sources and warning alerts

The majority of the population i.e., almost 50% of the population claimed that they heard about this flood event from the local authorities. Whereas almost 20% of the population claimed that they personally observed based on their understanding. Around 20% of the population received warnings from their friends, relatives, and neighbours. Whereas only 5% of the people received a BE-Alert before the flood event. Very few proportions of the population received warning alerts from the news. However, almost 50% of the population received alerts before the flood event. Whereas around 30% of the population claimed that they did not receive any warning from any sources for this flood event and 20% of the population said that they received warnings when it was already flooded. Whereas very few proportions of the population received warning, but they did not experience flood. The statistics of the warning alerts received by the population from the warning sources are represented in Figure 28 and figures for the warning systems are shown in Figure 29.



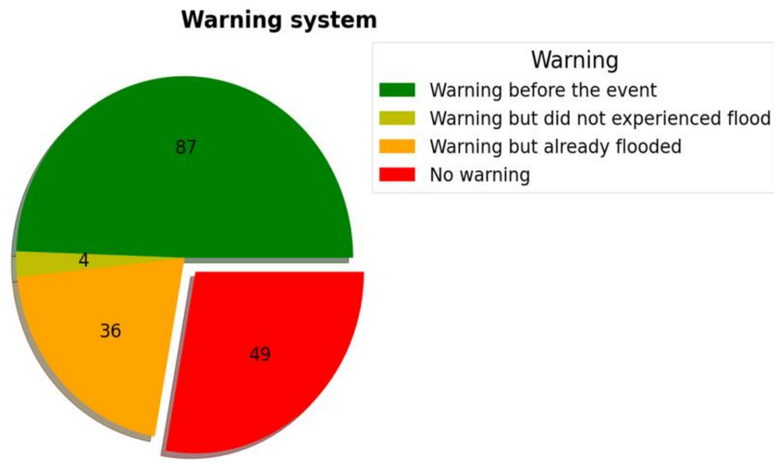


Figure 28: Warning sources of the flood received by the population

Figure 29: Warning alerts of the flood received by the population

4.4.7 Insurance coverage and financial compensation

Based on our field data, almost 85% of the population had full insurance coverage before the flood event. Whereas around 15% of the population claimed that they had no insurance coverage. According to them, they were not expecting such a destructive flood event. Moreover, almost 60% of the population completely received their financial compensation from their insurance companies. Whereas almost 35% of the population is still waiting to receive their full damage compensation. However, a very small proportion i.e., around 4% of the total population did not receive any damage compensation because some of them claimed that they had no insurance coverage before the flood event. The statistics for the insurance coverage owned by the people are represented in Figure 30 and the figures of the financial compensation received by the population can be seen in Figure 31.

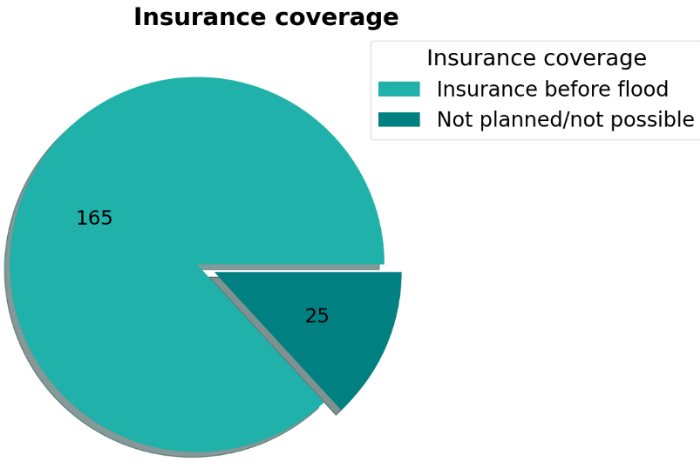


Figure 30: Insurance coverage owned by the population

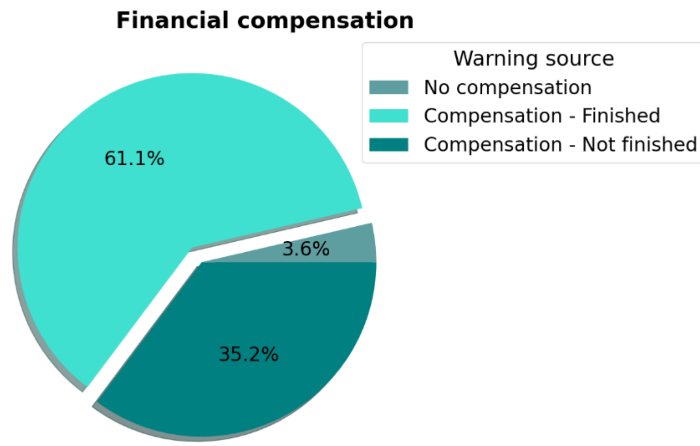


Figure 31: Financial compensation received by the population

4.4.8 Comparison of water depth distribution inside and outside the building

Based on our field survey, the water depth inside the building in majority of the houses was too high i.e, between 3m to 5m and the average water was around between 3 m to 4 m. Whereas, a very small proportion i.e, less than 10% of the houses experienced a very high water depth i.e, between 5 m to 6 m inside their buildings. Whereas most of the respondents claimed that the water depth outside their buildings was between 1 m to 2.5 m and the average water depth outside the building was between 1.5 m and 3 m. The statistics of the water depth distribution inside and outside the building are represented in Figure 32. The representation of the high water level in the field of Pepinster can be seen in Figure 33 which indicates that the water depth inside the houses was high in comparison the water depth outside the buildings. During our field survey, most of the respondents claimed that the basements of their houses were completely flooded.

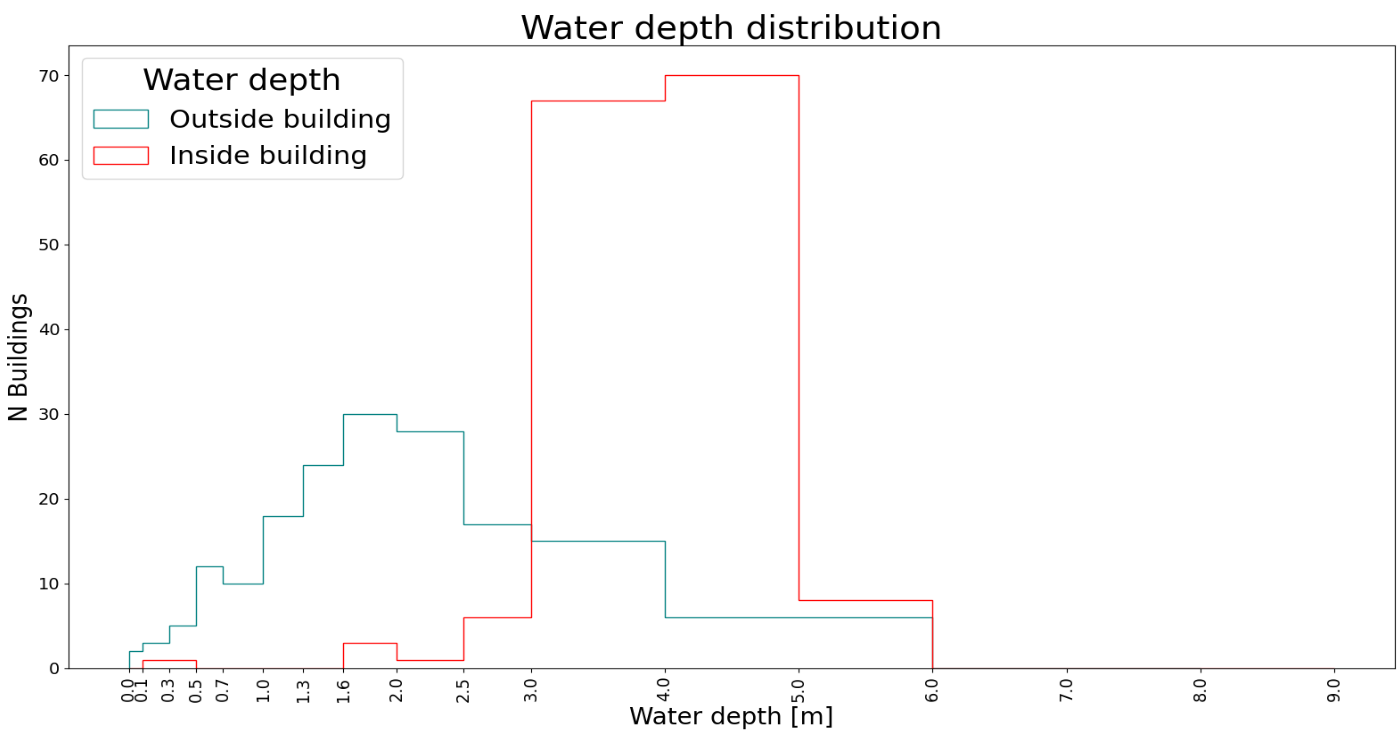


Figure 32: Water depth distribution inside and outside the building

Figure 33: Representation of the water level in the field of Pepinster (Source: RIGO & Partners)

4.4.9 Factors contributing to total building damage cost

Based on our field data, it can be illustrated that the water depth was not the only factor responsible for high damage cost. Whereas there are other factors responsible for high damage cost. For instance, most of the participants claimed that the flood velocity was very high due to which they experienced huge total building damage. According to the statistics of our field survey, the water depth in the majority of houses was between 1.5 m and 2.5 m. Whereas, the average water depth was around 2 m. The comparison between the water depth and total building damage cost based on the water velocity has been made and represented with the help of a scatter plot in Figure 34.

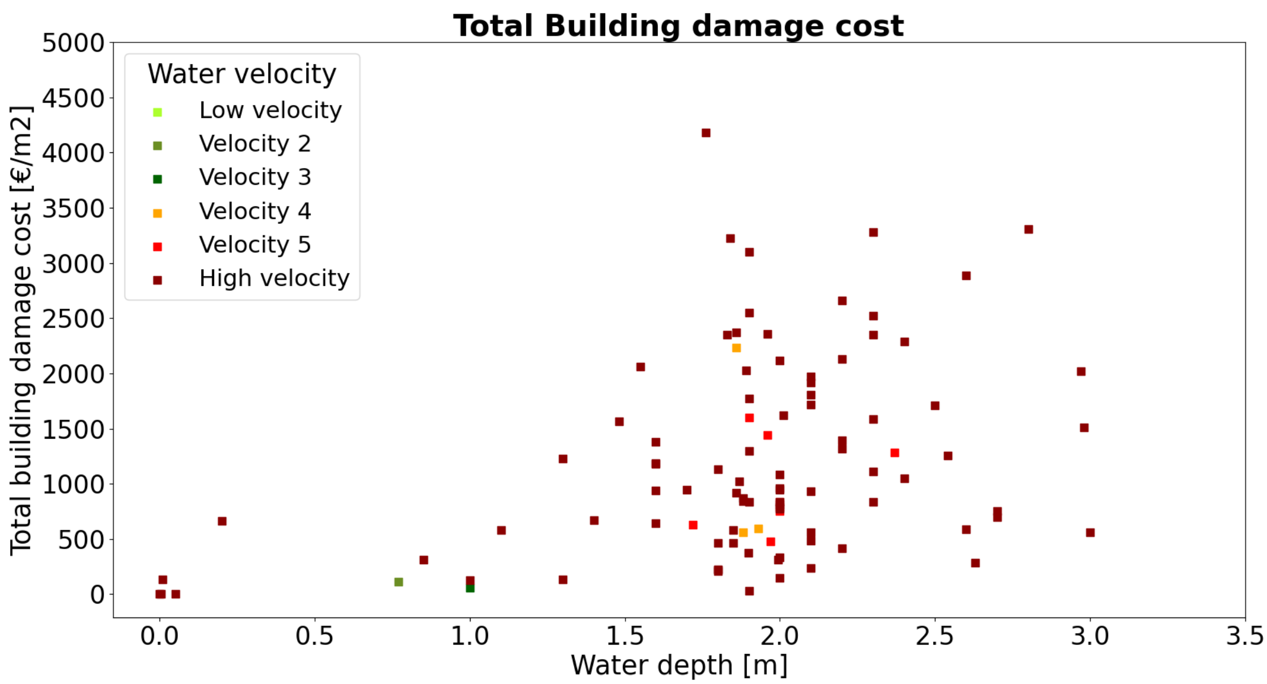


Figure 34: Total damage cost comparison with water depth based on water velocity

4.4.10 Short-term and long-term mitigation measures

In flood risk management, there are two types of mitigation measures i.e., Short-term which includes flood barriers with different elevations, usage of water pumps, moving furniture and electrical appliances to the higher levels from the ground floor and disconnecting networks etc. Whereas Long-term mitigation measures include increasing the elevation of the buildings by adapting higher levels, usage of waterproof materials, protection of the oil tanks, presence of No-return valves, improving the stability of the buildings and fixing of the networks on higher levels. Estimating the local effect might be helpful in strategic planning of the mitigation measures and integrated risk management (Viktor Rözer, 2017).

Almost 70% of the population claimed that they were not planned for any type of mitigation measures. Whereas around 20% of the population utilized some mitigation measures during the flood event and very few proportions of the population adopted measures after the event. Based on our field, on average for all four short term mitigation measures, almost 60% of the population was not planned for short mitigation measures. Out of this 60% population, a high proportion of the population had no idea about measures for water protection and usage of water pumps. Whereas almost half of the population managed to move their furniture and cut off their networks before the flood event. Whereas a small proportion of the population utilized water pumps after the flood event. The figures for the preparedness of mitigation measures can be seen in Figure 35 and the proportion of the short-term mitigation measures adopted by the population before, during and after the flood event is graphically represented in Figure 36.

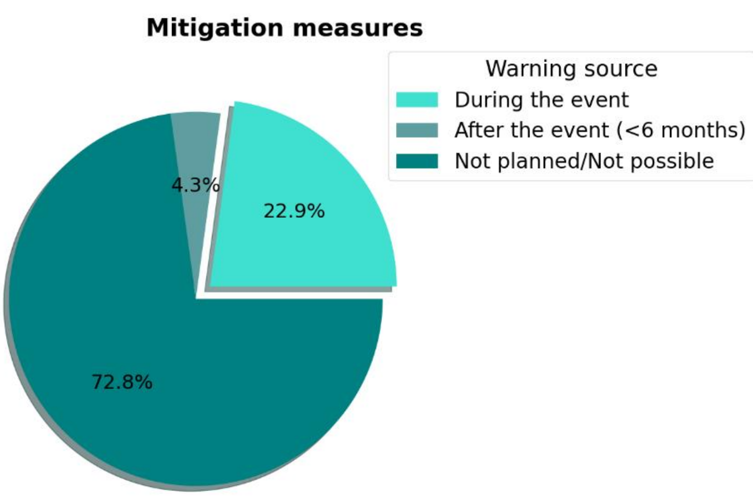


Figure 35: Adaptation of the mitigation measures by the population

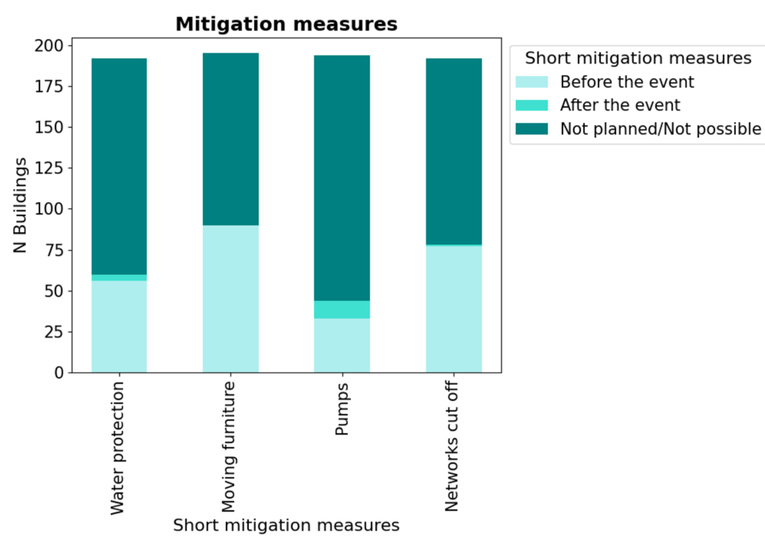


Figure 36: Short-term Mitigation measures adopted by the population

Regarding flood experience, almost 75% of the population already had previous flood experience. Whereas 25% of the population had any flood experience. It means that the majority of the population had already faced the flood situation in their past. According to our field data, more than 80% of the population was not prepared for all these long-term mitigation measures. The respondents claimed that they had no idea about waterproof products as a construction material for their houses nor did they raise high levels for the network systems. Moreover, oil tanks were not fully protected in the majority of the houses and most of the people had no return valves in their houses for maintaining the medium flow in one direction. In addition to that, a large proportion of the population did not adopt any measures for improving the stability of their houses in flood situations. However, almost 10% of the population raised high levels before the event based on their previous flood experience. The statistics of the previous and any flood experience are shown in Figure 37 and the long-term mitigation measures adopted by the population before and after the flood event can be seen in Figure 38.

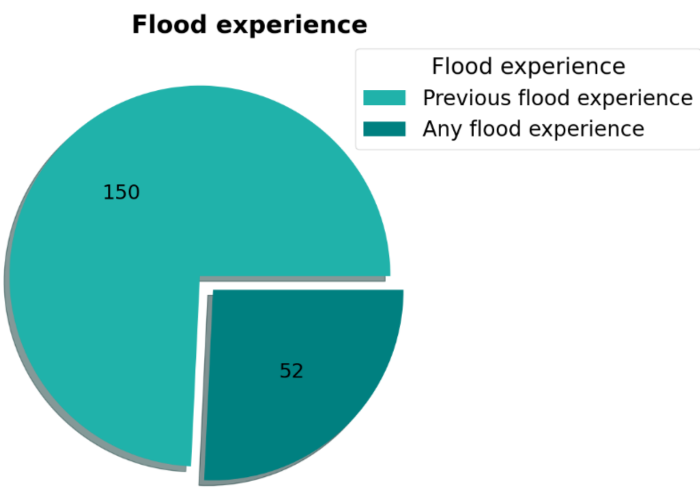


Figure 37: Flood experience of the population

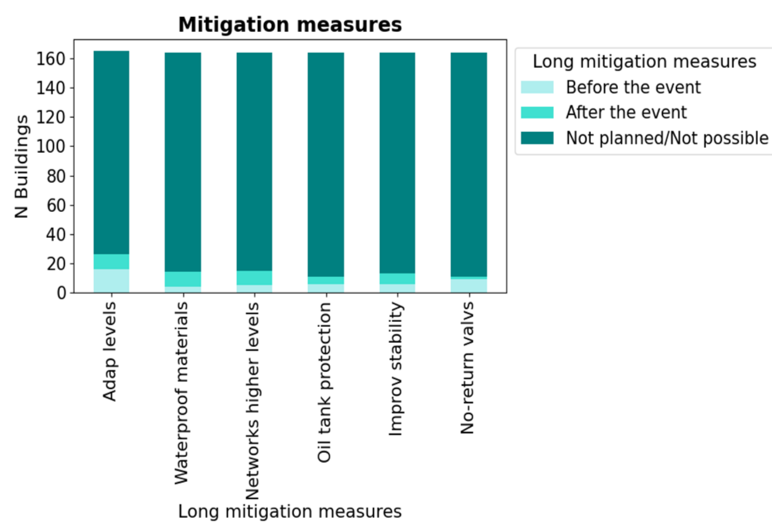


Figure 38: Long-term mitigation measures adopted by the population

4.4.11 Correlation between building features for systems damage

Based on Spearman correlation for systems damage, there is a strong positive correlation between water depth outside the building and systems damage meaning that the greater water depth outside leads to the high systems damage cost. Whereas the second highest positive correlation was found between water velocity and water depth outside illustrating that high water velocity is one of the leading factors for greater water depth outside the building. Moreover, there is also a strong positive correlation between the clay bricks material and water depth outside the building showing that clay bricks were highly affected with greater water depth outside which led to high systems damage cost. In contrast to that, there is a very strong negative correlation for apartment houses with unifamiliar houses because these are totally opposite building construction types and can never be positively correlated with each other. Moreover, there is also a strong negative correlation between clay bricks material and concrete bricks material because both materials have no independency with each other for carrying high systems damage cost. The Spearman correlation between different building features for systems damage is represented in Figure 39.

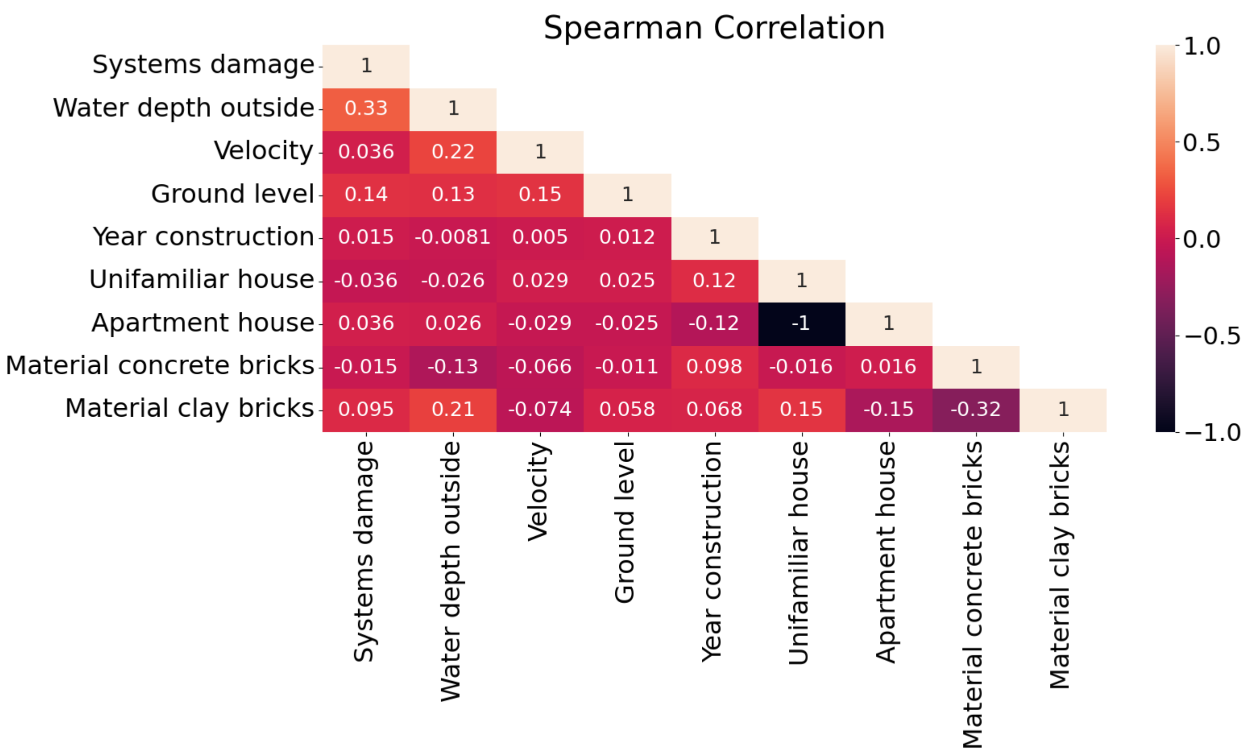


Figure 39: Spearman correlation matrix for the systems damage

4.4.12 Correlation between building features for total damage

Based on Spearman correlation for total damage, there is a strong positive correlation between water depth outside the building and total damage meaning that the greater water depth outside leads to the high total damage cost. Whereas the second highest positive correlation was found between the water velocity and total damage illustrating that high water velocity is one of the leading factors for causing a high total damage. Similarly, systems damage, there is also a high positive correlation for water velocity with water depth outside and clay bricks material with water depth outside the building. Like systems damage, there is a very strong negative correlation for apartment houses with unifamiliar houses and strong negative correlation for clay bricks material with concrete bricks material. The spearman correlation for different building features for the total damage is represented in Figure 40.

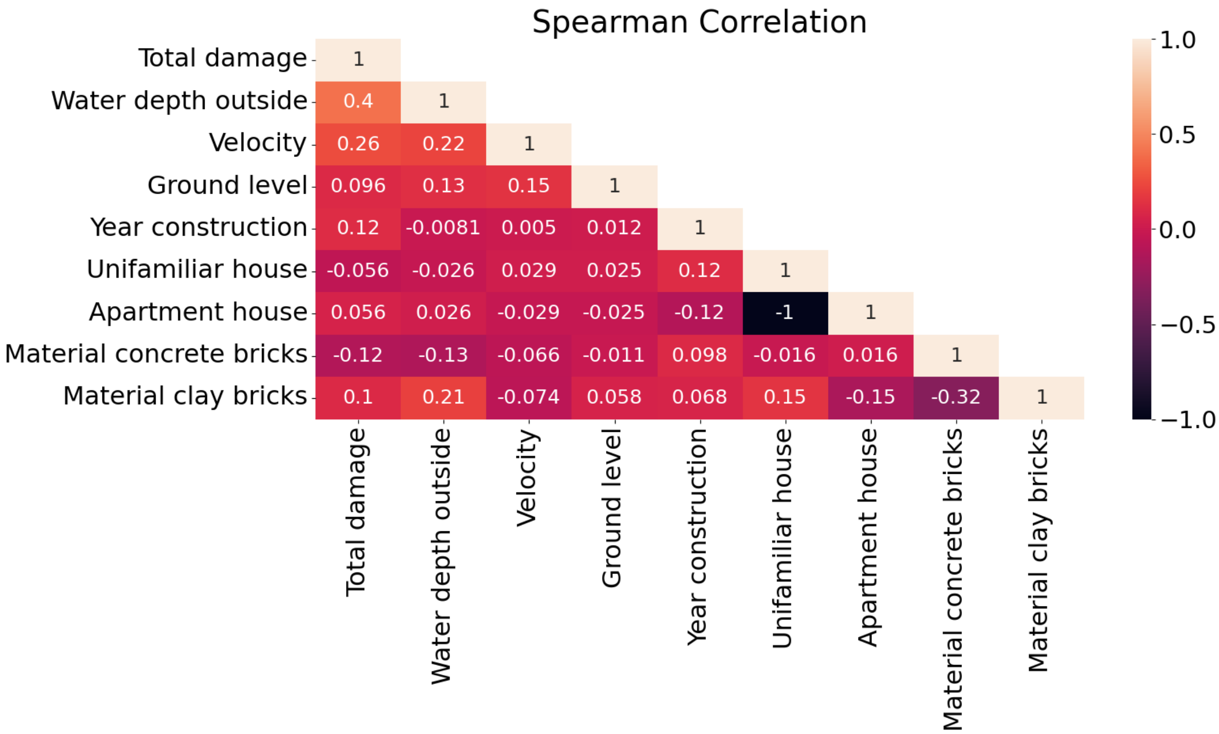


Figure 40: Spearman correlation matrix for the total damage

4.4.13 Comparison of damage cost for building components

Systems damage is one of the most influential building components which contributed a very high damage cost which is around 30,000 euros. Whereas damage to doors and windows contributed less damage cost in comparison with the damage cost of other building components and it is around 8,000 euros. However, damage to pavement is declared to be the second highest building component which contributed a huge damage cost which is around 20,000 euros.

However, 25% of the population experienced a damage cost of 6000 euros for systems damage and 3000 euros for damage to pavement. Whereas 50% of the population experienced around 10,000 euros for system damage, 7000 euros for damage to pavement and around 200 euros for damage to walls. However, 75% of the population faced around 17,000 euros for system damage, 8,000 euros for damage to walls and 10,000 euros for damage to pavements. The comparison for the damage cost of all five building components is represented with the help of a box plot in Figure 41.

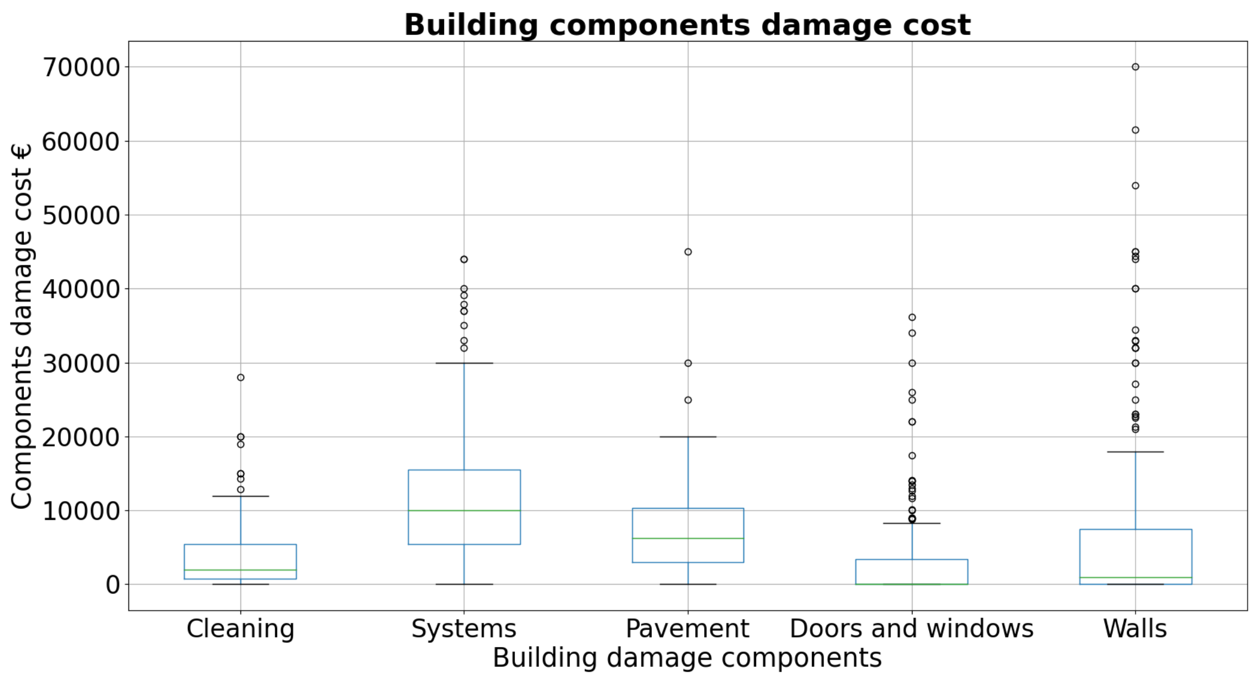


Figure 41: Comparison of damage cost of five building components

4.4.14 Influence of water velocity and water depth on cleaning component

The statistics of our field survey illustrates that velocity is another most influencing factor for high building component damage cost because the majority of the participants said that the water velocity was very high during the flood event. The cleaning component is one of the most influencing damage components for causing high systems damage cost based on high water velocity and greater water depth. The comparison of the building cleaning damage cost with water depth based on the water velocity has been made and represented in Figure 42.

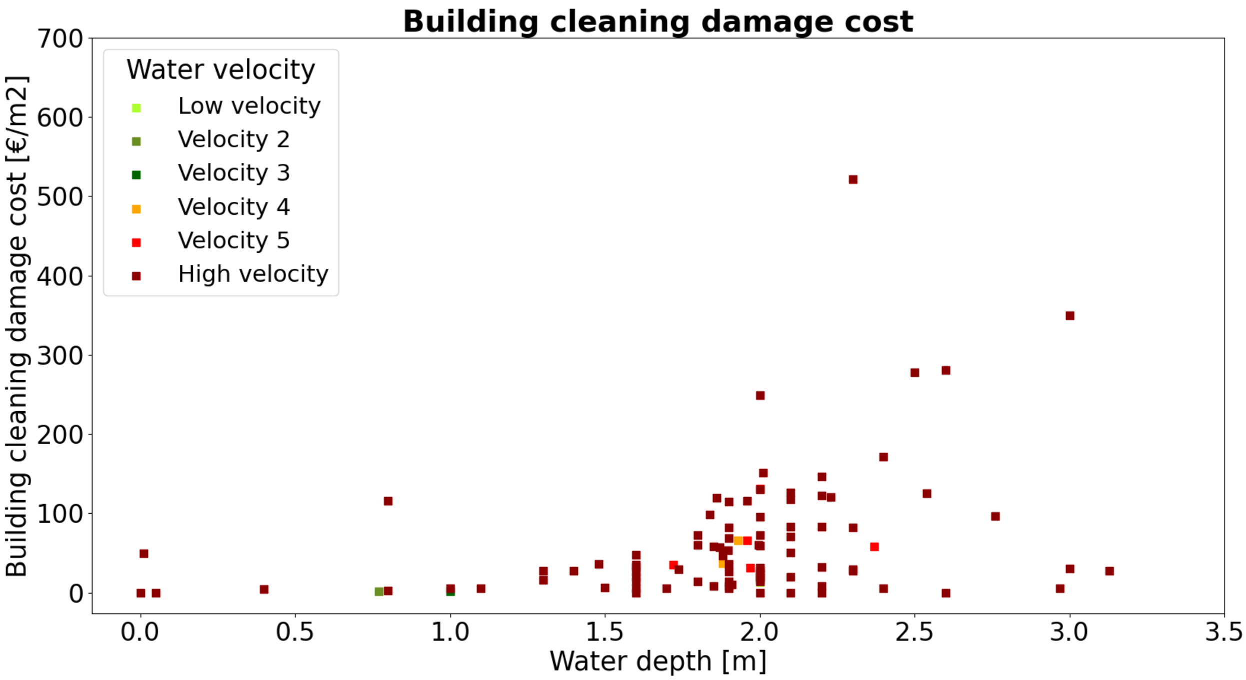


Figure 42: Influence of water velocity and water depth on cleaning component

5. CONCLUSIONS

The assessment and the data analysis in this study resulted in important information about the impacts i.e., damage to the residential buildings due to the floods in July 2021 based on different building features and hazard variables which helped to make the flood damage estimation in physical terms of the residential houses in severely affected municipalities of the Walloon Region based on field surveys through a well-structured paper-based questionnaire. This study also provided a way to develop one of the best practices for the collection and the estimation of the flood damage data. From this study, we could make several conclusions as following.

- The pilot study helped to organize the detailed study for all other severely affected municipalities in the Walloon Region. From this study, the strengths and weaknesses of the survey questionnaire were identified which helped us to modify the short survey questionnaire. Through pilot study, the field strategy for the detailed study was revised and field surveys were organized on a large-scale with the help of a well-structured detailed survey questionnaire with improved field strategy.
- This study reflects the transition phase between previous flooding events and floods in July 2021 because people did not experience this type of severe flood before in Belgium. From this study, we collected socio-demographic information and damage data of the population for this severe flooding event. Based on the outcomes of this study, we can develop the strategies for the flood risk mitigation which could help us in flood risk management for improving the management of the extreme flood events in the future.
- As we estimated from the field data that more than 80% of the population were not planned for the long-term mitigation measures. This study highlights the need to implement the long-term mitigation strategies which helps to reduce the flood damage. For instance, the authorities should specify the risk prone areas based on the field data of this severe flood event and restrict people to build their houses in these zones or enforce some regulations to relocate them in the safer regions.

5.1 Limitations of this study

- This study is limited to the residential buildings and based on field surveys. This research is restricted to only 200 responses and the analysis could be better if we have more responses. Moreover, we have not finalized the field data collection for Verviers and Baelen. We could have a better representation of the field when we have the damage data of these two remaining municipalities of the Walloon Region.
- Based on the observations during the field survey, if we have a field expert for the damage analysis during our field survey who could give technical opinions and suggestions for the precise measurements of the water depth and make critical observation of the houses then representation of the field data could be improved. For instance, it is difficult for a non-technical person to evaluate the buildings either it should be demolished, partially demolished, or need to be renovated in comparison with the field expert.
- This study was started almost after 3 months of the flood event with the pilot study. Whereas the detailed study on a large-scale started almost 7 months from the month of July 2021. The data collection should be started as early as possible aftermaths of the flood event in order to make a better representation of the field and the reliability of the field damage data could be better if we perform early field investigation.

5.2 Assumptions based on the literature review

Based on the literature review of different case studies, several assumptions have been made regarding the outcomes of our field data and the comparison of these assumptions with the real field data can be discussed as following.

- According to RISPOSTA, they shifted from paper-based questionnaire to a mobile application stating that it reduced the time for data collection and back-office work because the forms were already pre-compiled with aerial images and building coordinates. However, we had great experience with the paper-based survey questionnaire because some people shared extra information about the flood event, and we had free space to record all these useful information. Moreover, the verification and correction of the encoded data also helped us to ensure the quality of the recorded data and to reduce the human error.

- Based on most of the case studies in the literature review, water depth was found to be the most critical factor for causing the high flood damage. Whereas based on the outcomes of our field survey, water velocity is also found to be one of the dominating factors with water depth which is responsible for leading the huge flood damage.

5.3 Perspectives of this study

- The outcomes of our field surveys could be used for developing the flood damage model for Belgium such as INSYDE model after the adaptation and validation on key risk datasets such as Hazard, Vulnerability and Exposure. Based on that flood damage model, damage estimation could be performed in the monetary terms.
- This study opens the doors for other researchers who would like to contribute to the domain of flood risk management by doing cost benefit analysis in order to develop the long-term mitigation strategies for reducing the risk of such extreme flood events which also enforce the population to adopt the necessary protective measures before the flood.

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A Appendix: Pilot Study for Angleur

A.1 Summary of the field data collection

Team	Streets covered	Houses Visited	People agreed	People absents	People denied	Incomplete forms	Mean interview duration
01	Rue Vaudrée Rue Félix Paulsen Rue Auguste Joiret Rue Henri Piedboeuf Rue de l'Hôtel de Ville Avenue du Théâtre de Verdure	29	5	12	6	6	50 mints
02	Emile Verhaeren	64	7	40	17	-	40 mints
03	Rue Vaudrée (no. 20 to no. 89) Rue Jules Verne Rue Val Benoit (no. 13 to no. 28) Rue Prince Régent (no. 2 to no. 6)	56	8	36	12	-	38 mints
04	Rue du Val Benoit Rue Delhaize Rue Vaudrée	7	5	-	1	1	30 mints
05	Rue Camille Lemonnier Rue du Val Benoît	52	6	-	-	-	30 mints
06	Rue de Kinkempois Rue Vaudrée Av. Henri Piedboeuf Rue d'Hôtel de Ville	21	5	14	2	-	14 minutes
07	Rue du Val Benoit Rue de Kinkempois Rue Artus Bris	76	6	-	-	-	20 minutes
08	Vaudrée street (n°110 to n°180) Fourchufossé street (n°9 to n°17) Camille Lemonnier street (n°1 to n°99)	7	7	-	-	-	20 mints

A.2 Survey Questionnaire

A.2.1 Form A: Information générales

Localité |_ |_ |_ |_ |_ |_ |_ |_ |_ |_|

Date |_ |_ | |_ |_ | |_ |_ |

Heure de début |_ |_ | : |_ |_ |

Heure de fin d'interview |_ |_ | : |_ |_ |

Ne pas oublier de noter ceci à la fin de l'interview !

Form A index

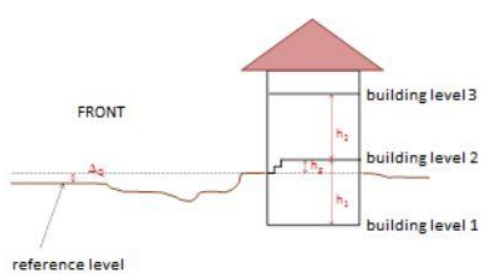
Section 1: General information

Section 2: Building features

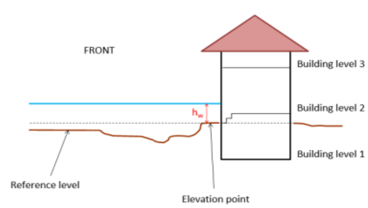
Section 3: Potential damage identification

Section 4: Event features

SECTION 1: Informations générales		
Aspect	**Data**	**Notes**
Adresse du bâtiment		
Cadastral reference		
Personne interrogée	Téléphone:_______________-__ Rôle: • Propriétaire • Locataire • Autre ______________________	

SECTION 2: Caractéristiques du bâtiment		
Aspect	**Data**	**Notes**
Type de bâtiment	• Maison 4 façades • Maison 3 façades • Maison jointive • Immeuble d'appartements Nombre de logements |_|_|_|N° • Caravane • Bâtiment public Description__________________	
Période de construction	• Avant 1875 • 1875-1918 • 1919-1945 • 1946-1970 • 1971-1990 • Après 1990 • Rénovation au cours des 2à dernières années	
Structure du bâtiment	• Maçonnerie • Mixte (maçonnerie et béton) • Béton • Acier • Bois • Autre _________________	
Parement extérieur	• Briques • Crépis • Moellons • Autre _________________	
Taille du bâtiment	Largeur |_|_ |_ |_ | m Longueur |_|_ |_ |_ | m	
Nombre de niveaux (y compris le rez-de-chaussée et le cas échéant la cave)	N° __________________	
Niveaux ΔQ = niveau extérieur (ex. trottoir) par rapport à la voirie hg = niveau de la surface habitable du rez-de-chaussée par rapport au niveau extérieur h1 = hauteur sous plafond de la cave h2 = hauteur sous plafond du rez-de-chaussée	 Δ h h h2 |_|_|_|_|_| m	

<table>
<tr><th colspan="3">SECTION 3: Identification des dommages potentiels</th></tr>
<tr><th>Aspect</th><th>Data</th><th>Notes</th></tr>
<tr><td>Types de dommages potentiels</td><td>• dommages au(x) unité(s) de logement
• dommage aux communs (dans des immeubles)
• dommages structurels</td><td></td></tr>
<tr><td>Parties du questionnaire à remplir selon les cas (1 Form B par unité de logement + 1 Form B par communs)</td><td>• Form B: caractérisation de(s) unité(s) de logement
Nombre d’unités de logement |_|_|
• Form B: caractérisation des communs
Nombre de communs |_|_|</td><td></td></tr>
</table>

<table>
<tr><th colspan="3">SECTION 4: Caractéristiques de l’événement (à ne remplir que si le bâtiment a subi des dégâts)</th></tr>
<tr><th>Data</th><th>Evaluation</th><th>Notes</th></tr>
<tr><td>Durée de l’inondation</td><td>Début:
Heure |_ |_ | |_ |_ | Date |_ |_ | |_ |_ | |_ |_ |
Fin:
Heure |_ |_ | |_ |_ | Date |_ |_ | |_ |_ | |_ |_ |
Niveau d’eau le plus élevé atteint:
Heure |_ |_ | |_ |_ | Date |_ |_ | |_ |_ | |_ |_ |</td><td></td></tr>
<tr><td>Profondeur d’eau à l’extérieur du bâtiment</td><td>hw 
</td><td></td></tr>
<tr><td>Présence de sédiments (boue …)</td><td>• Oui
• Non
Type of sédiments:
• matériaux fins (argile)
• détritus
• matériaux grossiers (sables, graviers, galets…)
• végétation/bois
• Autre ______________________</td><td></td></tr>
<tr><td>Présence de contaminants</td><td>• Oui
• Non
Spécifier le type de contaminants (ex. mazout):
_________________________</td><td></td></tr>
</table>

A.2.2 FORM B: Unité de logement OU partie commune des immeubles

Ce formulaire concerne (1 seul choix possible)

- **une unité de logement**
- **une partie commune d’un immeuble**

Information générale		
Aspect	**Data**	**Notes**
Niveaux potentiellement inondés	• Niveau 1 (cave) • Niveau 2 (rez-de-chaussée) • Niveau 3 (1st étage) • Autre	

SECTION 1: Niveau 1 (cave si existante)		
Aspect	**Data**	**Notes**
Surface au sol	|_|_|_|_| m2	
Hauteur sous plafond	|_|_| m	
Présence d’un soupirail ou une autre ouverture basse	• No • Yes	
Etat de ce niveau du bâtiment (avant inondation)	• Excellent, très bien entretenu • Normal, entretien normal • Vétuste, dégradé	
Usage	• Garage • Tavern • Logement • Stockage • Grenier • Inutilisé • Autre ______________________	

Présence d’équipements	• Equipements sanitaires, robinets, douche …(indiquer si contre le niveau de ces éléments)
	• Equipements électrique (indiquer si contre le niveau de ces éléments, en particulier celui des prises de courant)
	• Système de chauffage
	TYPE:
	    • Radiateur(s)
	    • Chauffage au sol
	    • Autre ________
	    • Type de système de chauffage
	    • Chauffage indépendants (ex. électriques)
	    • Chauffage central (relié à une chaudière)
	    • Autre ________
	• Ascenseur
	• Autre ______________________
		Décrivez ici les <u>dégâts</u> subis par ces équipements et une estimation des coûts

SECTION 1: Niveau 1 (cave si existante)		
Éléments non structurels	• Portes Nombre de portes ______________ Matériau des portes ______________ • Fenêtres Nombre de fenêtres ______________ Matériau des fenêtres ______________ Hauteur des fenêtres (par rapport au sol) _________ • Type de revêtement de sol • Carrelage • Parquet / plancher • Moquette, tapis • Béton • Autre ________________	*Décrivez ici les <u>dégâts</u> subis par ces éléments et une estimation des coûts*
Éléments non structurels	• Murs intérieurs Matériau des murs intérieures • Maçonnerie • Bois • Plaques de plâtre sur structure (bois ou métal) • Autre ________________ Finition des murs intérieurs • Peinture • Boiserie • Papier peint • Autre ________________	*Décrivez ici les <u>dégâts</u> subis par ces éléments et une estimation des coûts*
Niveau d'eau maximum à ce niveau, A L'INTERIEUR du bâtiment (à partir du niveau du sol intérieur)	|_ |_ |_ | m	*Remarques éventuelles*
Mesures de précaution mises en place lors de l'événement	• Aucune • Pompe(s) • Mise en place de plaques étanches • Coupure préventive du courant • Autre(s) _______________________	*Décrire*

<table>
<tr><th colspan="3">SECTION 2: Niveau 2 (rez-de-chaussée)</th></tr>
<tr><th>Aspect</th><th>Data</th><th>Notes</th></tr>
<tr><td>Surface au sol</td><td>|_|_|_|_|_| m2</td><td></td></tr>
<tr><td>Hauteur sous plafond</td><td>|_|_| m</td><td></td></tr>
<tr><td>Présence d’un soupirail ou une autre ouverture basse</td><td>• Yes
• No</td><td></td></tr>
<tr><td>Etat de ce niveau du bâtiment (avant inondation)</td><td>• Excellent, très bien entretenu
• Normal, entretien normal
• Vétuste, dégradé</td><td></td></tr>
<tr><td>Usage</td><td>• Garage
• Tavern
• Logement
• Stockage
• Grenier
• Inutilisé
• Autre ______________________</td><td></td></tr>
<tr><td>Présence d’équipements</td><td>• Équipements sanitaires, robinets, douche … (indiquer ci-contre le niveau de ces éléments)
• Equipements électrique (indiquer ci-contre le niveau de ces éléments, en particulier celui des prises de courant)
• Système de chauffage
TYPE:
    • Radiateur(s)
    • Chauffage au sol
    • Autre ________
    • Type de système de chauffage
    • Chauffage indépendants (ex. électriques)
    • Chauffage central (relié à une chaudière)
    • Autre ________
• Ascenseur
• Autre ______________________</td><td>Décrivez ici les <u>dégâts</u> subis par ces équipements et une estimation des coûts</td></tr>
</table>

SECTION 2: Niveau 2 (rez-de-chaussée)		
Éléments non structurels	• Portes Nombre de portes _______________ Matériau des portes _______________ • Fenêtres Nombre de fenêtres _______________ Matériau des fenêtres _______________ Hauteur des fenêtres (par rapport au sol) __________ • Type de revêtement de sol • Carrelage • Parquet / plancher • Moquette, tapis • Béton • Autre _________________	*Décrivez ici les <u>dégâts</u> subis par ces éléments et une estimation des coûts*
Éléments non structurels	• Murs intérieurs Matériau des murs intérieures • Maçonnerie • Bois • Plaques de plâtre sur structure (bois ou métal) • Autre _________________ Finition des murs intérieurs • Peinture • Boiserie • Papier peint • Autre _________________	*Décrivez ici les <u>dégâts</u> subis par ces éléments et une estimation des coûts*
Niveau d'eau maximum à ce niveau, A L'INTERIEUR du bâtiment (à partir du niveau du sol intérieur)	|_ |_ |_ | m	*Remarques éventuelles*
Mesures de précaution mises en place lors de l'événement	• Aucune • Pompe(s) • Mise en place de plaques étanches • Coupure préventive du courant • Autre(s) _________________________	*Décrire*

SECTION 3: Niveau 3 (1st étage)		
Aspect	**Data**	**Notes**
Surface au sol	|_|_|_|_|_| m2	
Hauteur sous plafond	|_|_| m	
Présence d'un soupirail ou une autre ouverture basse	• Yes • No	
Etat de ce niveau du bâtiment (avant inondation)	• Excellent, très bien entretenu • Normal, entretien normal • Vétuste, dégradé	
Usage	• Garage • Tavern • Logement • Stockage • Grenier • Inutilisé • Autre ______________________	

Présence d'équipements	• Équipements sanitaires, robinets, douche … (indiquer ci-contre le niveau de ces éléments)
	• Equipements électrique (indiquer ci-contre le niveau de ces éléments, en particulier celui des prises de courant)
	• Système de chauffage
	TYPE:
	  • Radiateur(s)
	  • Chauffage au sol
	  • Autre ________
	  • Type de système de chauffage
	  • Chauffage indépendants (ex. électriques)
	  • Chauffage central (relié à une chaudière)
	  • Autre ________
	• Ascenseur
	• Autre ______________________
		Décrivez ici les dégâts subis par ces équipements et une estimation des coûts

<table>
<tr><th colspan="3">SECTION 3: Niveau 3 (1st étage)</th></tr>
<tr><td>Éléments non structurels</td><td>Portes
Nombre de portes ______________
Matériau des portes ______________
Fenêtres
Nombre de fenêtres ______________
Matériau des fenêtres ______________
Hauteur des fenêtres (par rapport au sol) _________
Type de revêtement de sol
Carrelage
Parquet / plancher
Moquette, tapis
Béton
Autre ________________</td><td>Décrivez ici les <u>dégâts</u> subis par ces éléments et une estimation des coûts</td></tr>
<tr><td>Éléments non structurels</td><td>Murs intérieurs
Matériau des murs intérieures
Maçonnerie
Bois
Plaques de plâtre sur structure (bois ou métal)
Autre ________________
Finition des murs intérieurs
Peinture
Boiserie
Papier peint
Autre ________________</td><td>Décrivez ici les <u>dégâts</u> subis par ces éléments et une estimation des coûts</td></tr>
<tr><td>Niveau d’eau maximum à ce niveau, A L’INTERIEUR du bâtiment (à partir du niveau du sol intérieur)</td><td>|_ |_ |_ | m</td><td>Remarques éventuelles</td></tr>
<tr><td>Mesures de précaution mises en place lors de l’événement</td><td>Aucune
Pompe(s)
Mise en place de plaques étanches
Coupure préventive du courant
Autre(s) _______________________</td><td>Décrire</td></tr>
</table>

A.2.3 Invitation Letter for field surveys

LIÈGE université Sciences Appliquées		UEE Urban and Environmental Engineering

Liège, le 15 novembre 2021

Etude visant à établir un lien entre les dommages causés par les inondations et des paramètres hydrauliques et urbanistiques mesurables

Madame, Monsieur,

Les inondations catastrophiques de la mi-juillet 2021 constituent un événement extrême et inédit dans la région. Pour contribuer à améliorer la gestion du risque d'inondation dans le futur, l'Université de Liège développe des modèles destinés à mieux planifier l'aménagement des cours d'eau, l'aménagement du territoire, ou encore la gestion de crise. Ces modèles peuvent être rendus plus fiables grâce à l'utilisation de données de terrain, portant notamment sur les caractéristiques de l'inondation, celles des bâtiments soumis au risque et sur les dommages subis.
Dans ce but, l'Université de Liège réalise une enquête dans les vallées touchées par les inondations de juillet 2021 pour améliorer les connaissances actuelles sur le lien entre dommages causés par les inondations et paramètres hydrauliques et urbanistiques. Vous serez sollicité dans les prochains jours par un étudiant de l'Université de Liège, qui vous proposera de répondre à un questionnaire. Les résultats de cette enquête ne seront utilisés qu'à des fins strictement scientifiques. Aucune donnée d'identification ne sera transmise à des tiers, et votre identité ne vous sera pas demandée.
Si vous avez un créneau horaire de préférence, vous pouvez le renseigner via ce lien : XXX, ou communiquer par SMS votre adresse (rue et numéro) ainsi que la date et l'heure de rendez-vous souhaités à ce numéro : XXX.
Nous vous invitons à réserver un bon accueil à l'étudiant qui vous sollicitera et vous remercions par avance pour votre temps et votre collaboration. Si vous souhaitez davantage d'informations sur cette démarche, vous êtes invité à contacter Benjamin Dewals (b.dewals@uliege.be).

Regards,
Prof. Benjamin Dewals

Research unit Urban and Environmental Engineering
Quartier Polytech 1 - Bâtiment B52
Allée de la Découverte, 9 4000 Liège Parking P52
Tel. + 32-4-366 92 83 - b.dewals@ulg.ac.be
www.uee.ulg.ac.be - www.hece.ulg.ac.be

A.2.4 Consent form for privacy concerns

Université de Liège
Formulaire de consentement

Etude visant à établir un lien entre les dommages causés par les inondations et des paramètres hydrauliques et urbanistiques mesurables

Pour faire face au risque d'inondation, des investissements importants sont nécessaires afin de réduire la vulnérabilité (population exposée, information, alertes, publics fragiles, adaptation du bâti). Des modèles scientifiques permettant de prédire les dommages causés par les inondations sont essentiels pour orienter au mieux de tels investissements. Aujourd'hui, le principal obstacle au développement de ces modèles est un manque de données de terrain. L'Université de Liège (ULiège) effectue une collecte de telles données de dommages en lien avec des paramètres hydrauliques (ex. hauteurs d'eau) et des propriétés du bâti.
Ce document a pour but de vous fournir toutes les informations nécessaires afin que vous puissiez donner votre accord de participation à l'étude en toute connaissance de cause.
Pour participer à cette étude, vous devrez signer le consentement à la fin de ce document et nous vous en remettrons une copie signée et datée. Vous serez totalement libre, après avoir donné votre consentement, de vous retirer de l'étude.

Responsable(s) du projet de recherche

Benjamin Dewals, Professeur, Allée de la Découverte 9, 4000 - Liège, Tel. 04 366 92 83, b.dewals@uliege.be
Jacques Teller, Professeur ordinaire, Allée de la Découverte 9, 4000 - Liège, Tel. 04 366 94 99, jacques.teller@uliege.be

Description de l'étude

L'étude comporte une phase de récolte des données prévue en 2021 et en 2022 au moyen d'interviews dans les vallées affectées par les inondations de juillet 2021 dans le bassin de la Meuse. Les données seront en parallèles analysées dans le but de répondre à des questions scientifiques et améliorer des modèles.

Protection des données à caractère personnel

Le ou les responsables du projet prendront toutes les mesures nécessaires pour protéger la confidentialité et la sécurité de vos données à caractère personnel, conformément au *Règlement général sur la protection des données* (RGPD – UE 2016/679) et à la loi du 30 juillet 2018 relative à la protection des personnes physiques à l'égard des traitements de données à caractère personnel

1. Qui est le responsable du traitement ?

Le Responsable du Traitement est l'Université de Liège, dont le siège est établi Place du 20-Août, 7, B-4000 Liège, Belgique.

2. Quelles seront les données collectées ?

Les données récoltées portent notamment sur l'adresse du bâtiment concerné, les dommages subis lors d'inondations récentes, les caractéristiques de l'inondation et du bâtiment ou encore les mesures de précaution mises en œuvre.

3. À quelle(s) fin(s) ces données seront-elles récoltées ?

L'étude vise à mieux comprendre les mécanismes d'inondation et les dommages associés, dans le but d'améliorer les méthodes de modélisation et de gestion du risque d'inondation. Les données pourront être utilisées dans le cadre de la réalisation de thèses de doctorat, mémoires d'étudiants de master, rapports de stages et travaux pratiques d'étudiants de baccalauréat et master (y compris des étudiants extérieurs à

l'ULiège et venant s'y former pour une période déterminée) ; la publication d'articles présentant les résultats de l'étude dans des revues spécialisées ou de vulgarisation ; la communication des résultats de l'étude lors de congrès et/ou réalisation de toute activité permettant la leur diffusion ; l'utilisation des résultats dans le cadre d'un enseignement universitaire ; le remploi des données collectées dans le but de réaliser des études complémentaires et s'inscrivant dans le même champ de recherche.
Les résultats de cette étude seront systématiquement rendus anonymes avant toute diffusion.

4. Combien de temps et par qui ces données seront-elles conservées ?
Les données d'identification seront conservées par le(s) investigateur(s) durant l'étude. À l'issue de celle-ci, les données d'identification seront détruites (destruction de la base de données contenant ces données), avec un délai maximum de 5 ans après la fin de l'étude. Cette opération rendra les données de recherche complètement anonymes.

5. Comment les données seront-elles collectées et protégées durant l'étude ?
Lors de la phase de collecte des données, l'identification des bâtiments sera récoltée lors d'une interview avec un des investigateurs associés à l'étude. Un numéro de code spécifique à l'étude est donné pour chaque bâtiment. Lors des phases ultérieures., les données d'identification et les données de recherche seront conservées dans deux bases de données distinctes et les informations reliées entre elles au moyen de codes. Les données de recherche seront conservées sur un serveur sécurisé du SEGI (certifié ISO 27001) et sur les ordinateurs des chercheurs. Si la diffusion des résultats nécessitait de faire référence à un bâtiment participant en particulier et à certaines de ses caractéristiques, sa non-reconnaissance serait garantie.

6. Ces données seront-elles rendues anonymes ou pseudo-anonymes ?
A l'issue de la phase de récolte des données, les données de recherche seront liées à un code. La table de correspondance entre données d'identification et données de recherche sera conservée séparément.

7. Qui pourra consulter et utiliser ces données ?
Seuls les étudiants et les chercheurs de l'ULiège dont les travaux portent directement sur l'objet de l'étude auront accès aux données à caractère personnel.

8. Ces données seront-elles transférées hors de l'Université ?
Seules des données de recherche pourront être transférées à des partenaires extérieurs à des fins de recherche exclusivement. Les données d'identification ne feront l'objet d'aucun transfert vers des tiers.

9. Sur quelle base légale ces données seront-elles récoltées et traitées ?
La collecte et l'utilisation de vos données à caractère personnel reposent sur votre consentement écrit. En consentant à participer à l'étude, vous acceptez que les données personnelles exposées au point 2 puissent être recueillies et traitées aux fins de recherche exposées au point 3.

10. Quels sont les droits dont dispose la personne dont les données sont utilisées ?
Comme le prévoit le RGPD (Art. 15 à 23), chaque personne concernée par le traitement de données peut, en justifiant de son identité, exercer une série de droits:

- Obtenir, sans frais, une copie des données à caractère personnel la concernant faisant l'objet d'un traitement dans le cadre de la présente étude et, le cas échéant, toute information disponible sur leur finalité, leur origine et leur destination;
- Obtenir, sans frais, la rectification de toute donnée à caractère personnel inexacte la concernant ainsi que d'obtenir que les données incomplètes soient complétées ;
- Obtenir, sous réserve des conditions prévues par la réglementation et sans frais, l'effacement de données à caractère personnel la concernant;
- Obtenir, sous réserve des conditions prévues par la réglementation et sans frais, la limitation du traitement de données à caractère personnel la concernant;
- Obtenir, sans frais, la portabilité des données à caractère personnel la concernant et qu'elle a

fournies à l'Université, c'est - à - dire de recevoir, sans frais, les données dans un format structuré couramment utilisé, à la condition que le traitement soit fondé sur le consentement ou sur un contrat et qu'il soit effectué à l'aide de procédés automatisés ;

- Retirer, sans qu'aucune justification ne soit nécessaire, son consentement. Ce retrait entraine automatiquement la destruction, par le chercheur, des données à caractère personnel collectées ;
- Introduire une réclamation auprès de l'Autorité de protection des données (https://www.autoriteprotectiondonnees.be, contact@apd-gba.be).

11. Comment exercer ces droits ?

Pour exercer ces droits, vous pouvez vous adresser au(x) responsable(s) du projet de recherche ou au Délégué à la protection des données de l'Université, soit par courrier électronique (dpo@uliege.be), soit par lettre datée et signée à l'adresse suivante :

Université de Liège
M. le Délégué à la protection des données,
Bât. B9 Cellule "GDPR",
Quartier Village 3,
Boulevard de Colonster 2,
4000 Liège, Belgique.

Coûts, rémunération et dédommagements

Aucun frais direct lié à votre participation à l'étude ne peut vous être imputé. De même, aucune rémunération ou compensation financière, sous quelle que forme que ce soit, ne vous sera octroyée en échange de votre participation à cette étude.

Retrait du consentement

Si vous souhaitez mettre un terme à votre participation à ce projet de recherche, veuillez en informer le(s) responsable(s) du projet. Ce retrait peut se faire à tout moment, sans qu'une justification ne doive être fournie. Sachez néanmoins que les traitements déjà réalisés sur la base de vos données personnelles ne seront pas remis en cause. Par ailleurs, les données déjà collectées ne seront pas effacées si cette suppression rendait impossible ou entravait sérieusement la réalisation du projet de recherche. Vous en seriez alors averti.

Questions sur le projet de recherche

Toutes les questions relatives à cette recherche peuvent être adressées au(x) responsable(s) du projet de recherche.

Je déclare avoir lu et compris les 3 pages de ce présent formulaire et j'en ai reçu un exemplaire. Je comprends la nature et le motif de ma participation au projet et ai eu l'occasion de poser des questions auxquelles j'ai reçu une réponse satisfaisante. Par la présente, j'accepte librement de participer au projet.

Nom et prénom:
Date:
Signature:

A.3 Encoded data in Excel sheet

A.3.1 Encoding of General Information

A28 fx

A	B	C	D	E	F	G	H
FORM A	GENERAL INFORMATION						
	SECTION 1						
	Survey's mode						
	Role G0	Owner	Tenant	Other			
		31	14	3			
	SECTION 2	Building feature					
Building typology G1	Detached House	Semi-detached house	Joined House	Apartment house	Trailer home	Public building	
	1	5	42	3	0	0	
Period of construction G2	Before 1875	1875-1918	1919-1945	1946-1970	1971-1991	After 1990	Renovation in the last 20 years
		6	20	14	7	1	2
Building structure G3	Masonry	Mixed	Concrete	Steel	Wood	other	
	38	3	4		3	2	
External material G4	Bricks	Plaster	Stone	Other			
	47	2	3				
	SECTION 3						
Type of material damaged G5	Housing units	Common parts	Structural damage				
Attached documentation	45	14	17				
	SECTION 4	(Only if flooded)					
Event duration	AVERAGE	24h					
Height of water outside the building	AVERAGE	1,4 m					
Presence of sediments G6	Yes	Fine material	Garbage	Coarse material	Vegetation/wood	Other	No
	44	34	14	17	15	4	4
Presence of contaminants G7	Yes	No					
	34	14					

A.3.2 Encoding of Damage data

M29 fx

	A	B	C	D	E	F	G	H	I	J	K
1-2	Responses	Damage Cost	Period	Building Material	Sediments	Maintenance Level (Level 01)	Water Depth (level 1)	Protective Measures (Level 01)	Maintenance Level (Level 2)	Water Depth (level 2)	Protective Measures (Level 02)
3	1	42,000.00 €	1919	1	1	2	1.85	2	2	0.8	0
4	8	10,000.00 €	1919	1	1	1	2	2	1	1.15	1
5	9	73,000.00 €	1919	1	1	2	2.2	1	2	1.4	0
6	10	95,000.00 €	1971	1	1	1	1.8	2	2	1.4	1
7	11	55,000.00 €	1919	1	1	1	1.95	1	2	1.2	0
8	12	130,000.00 €	1946	1	1	1	1.7	2	2	1.3	1
9	13	118,000.00 €	1946	1	1	1	1.7	2	2	1.3	1
10	14	50,000.00 €	1971	1	1	1	2	1	2	1.4	0
11	15	70,000.00 €	1937	2	0	2	1.7	2	1	1	1
12	18	70,000.00 €	1971	3	1	2	1	2	2	0.8	0
13	19	60,000.00 €	1919	1	1	2	1.5	1			
14	22	20,000.00 €	1919	1	1	2	2.5	2	2	1.2	1
15	27	3,000.00 €	1971	1	1	2	1.88	2	2	1.25	1
16	29	30,000.00 €	1946	1	1	0	1.9	1	1	1.4	0
17	30	128,000.00 €	1956	1	1	1	1.9	2	1	1.2	0
18	31	55,000.00 €	1937	2	1	1	1.85	2	1	1.3	0
19	32	3,000.00 €	1946	1	1	2	1.88	2	2	1.25	1
20	33	13,000.00 €	1971	1	1	1	2	2	1	1	1
21	35	10,000.00 €	1919	1	1				2	1.5	0
22	36	40,000.00 €	1919	1	1	2	2.5	1	2	1.3	0
23	45	12,300.00 €	1946	1	1	2	1.85	1	2	0.4	0
24	46	93,000.00 €	1919	1	1	1	2	1	1	1.3	0
25	47	84,000.00 €	1996	1	1	1	2	1	2	0.3	0

A.3.3 Regression and Neighborhood Component analysis on MATLAB

```
clear all; clc; close all;
data = readtable('Book1.xlsx');
data = table2array(data);
data = data(: , 2:end);
dataNew = fillmissing(data,'previous');
R = corrcoef(dataNew);
figure(1)
xvalues = {'DC','P','BM','S','ML1','WD1','PM1','ML2','WD2','PM2'};
yvalues = {'DC','P','BM','S','ML1','WD1','PM1','ML2','WD2','PM2'};
h = heatmap(xvalues,yvalues,R);
h.Title = 'Correlation';

% 'Damage Cost',                       = DC
% 'Period',                            = P
% 'Building Material',                 = BM
% 'Sediments',                         = S
% 'Maintenance Level (Level 01)',      = ML1
% 'Water Depth (level 1)',             = WD1
% 'Protective Measures (Level 01)',    = PM1
% 'Maintenance Level (Level 2)',       = ML2
% 'Water Depth  (level 2)',            = WD2
% 'Protective Measures (Level 02)'     = PM2

rho = array2table(R, ...
    'VariableNames',{'DC','P','BM','S','ML1','WD1','PM1','ML2','WD2','PM2'},...
    'RowNames',{'DC','P','BM','S','ML1','WD1','PM1','ML2','WD2','PM2'});
disp('Correlation Coefficients')
disp(rho)
```

```
%% Neighborhood Component Analysis
Labels = dataNew(: , 1);
Features = dataNew(: , 2:end);
```

```
%% Apply NCA
mdl = fsrnca(Features,Labels,'Verbose',1,'Lambda',0.5/14733);
figure(2)
plot(mdl.FeatureWeights,'ro')
grid on
xlabel('Feature index')
ylabel('Feature weight')
xticks([1 2 3 4 5 6 7 8 9])
xticklabels({'P','BM','S','ML1','WD1','PM1','ML2','WD2','PM2'})
title('Feature weight for the prediction of Damage Cost (DC)')
```

```
%% Regression analysis
mdl = fitlm(Features,Labels)
mdl.Coefficients
```

B Appendix: Detailed Study for other impacted municipalities in the Walloon Region

B.1 Survey Questionnaire

B.1.1 Part 1: Personal Information

1. For each question where there is a numeric field to fill in: put 0 when the value is zero, leave the field blank when the person does not know the answer.

2. Survey taker 1

- Solène
- Imen
- Anus

3. **Survey taker 2**

- Solène
- Imen
- Anus

4. **Commune** :

- Chaudfontaine
- Esneux
- Eupen
- Liège
- Limbourg
- Pepinster
- Rochefort
- Theux
- Trooz
- Verviers

5. **Postal code**:

- 4053 - Embourg - Chaudfontaine
- 4053 - Mehagne - Chaudfontaine
- 4052 - Beaufays - Chaudfontaine
- 4050- Ninane - Chaudfontaine
- 4050 - Chaudfontaine
- 4051 - Vaux-sous-Chèvremont - Chaudfontaine
- 4130 - Tilff - Esneux
- 4130 - Esneux
- 4701 - Kettenis - Eupen
- 4700 - Eupen
- 4030 - Grivegnée - Liège

- 4000 - Liège
- 4031 - Angleur - Liège
- 4032 - Chênée - Liège
- 4020 - Liège
- 4830 - Limbourg
- 4831 - Bilstain - Limbourg
- 4834 - Goé - Limbourg
- 4860 - Pepinster
- 4860 - Wegnez - Pepinster
- 4861 - Soiron - Pepinster
- 4860 - Cornesse - Pepinster
- 4910 - La Reid - Theux
- 4910 - Theux
- 4910 - Polleur - Theux
- 4870 - Fraipont - Trooz
- 4870 - Forêt - Trooz
- 4870 - Nessonvaux - Trooz
- 4870 - Trooz
- 4801 - Stembert - Verviers
- 4800 - Petit-Rechain - Verviers
- 4802 - Heusy - Verviers
- 4800 - Polleur - Verviers
- 4800 - Lambermont - Verviers
- 4800 - Verviers
- 4800 - Ensival - Verviers
- 4802 - Heusy - Verviers

6. **Street**:

7. **Street N°**:

8. **Postal box**:

9. **Coordinates GPS** (latitude)

10. **Coordinates GPS** (longitude)

11. **Cadastral parcel number**:

12. **Interview's date**:

13. Could any contact be made?

- Yes
- No

14. We work for the University of Liège. We are conducting a research project on the consequences of the flood event in July 2021. The objective is to better understand the links between the damage suffered by flood victims and the characteristics of the flood itself, such as the water depth and flow velocities during the flood. The research results will help to create new tools to reduce buildings' vulnerability to future flooding. According to the information gathered, your street was affected by this event. We would like to ask you a few questions about what happened. Is it possible to speak with the person in your household who could best tell us about the damage caused by these floods?

- The person decides to participate
- The person refuses to be interviewed
- The person makes an appointment at a later date and time
- The person accepts another attempt to be contacted

15. Why does the person not want to participate? → END OF THE SURVEY

- No advantage in answering
- Not available
- Traumatized by the event
- Language barrier
- Not interested
- Covid-19 quarantine
    - ➔ **Question n°18 to 19**

16. Meet at a later date and time:

17. The person accepts another attempt to be contacted:

If the person does not answer:

18. Can I ask you how old are you?

Note: Enter the age in years in the input field below! Age: _ _ years

19. Please enter the gender of the person:

- Man
- Woman
- Non-binary

20. What is your level of education?

- Elementary school
- High school
- Bachelor
- Master / License

21. What socio-professional category do you belong to?

- Farmers
- Craftsman, traders, entrepreneurs
- Executives and higher intellectual professions
- Intermediate professions
- Employees
- Workers
- Inactive having already worked
- Person who has ever worked

22. Would you like to be kept informed of the progress of the study?
    - Yes → Q°23
    - No
23. Mean of contact (e-mail, phone n°…)

B.1.2 Part 2: Damage Information

1. For each question where there is a numeric field to fill in: put 0 when the value is zero, leave the field blank when the person does not know the answer.

2. Interview start time:

3. What was the **communication media** used with the resident?

- Letter
- Phone
- E-mail
- Commune
- Programs of restoration actions and management of water courses.
- Social networks
- Association of victims
- Other

4. Other communication media used with the resident:

Was the building **damaged**, externally or internally, by the July 2021 flood event? Or was the building not affected by the floods at all?

[Note: Body injuries and damage to garages, exterior installations, cars, etc. are not covered. Only damage directly on or in the building is considered in the study!]

- Yes
- No

5. Is the building used just as a **residential building**, **primarily as such**, or primarily for business purposes??

[Note: A building is primarily used for commercial purposes, if it is essentially house offices, warehouses, shops, etc.]

- Purely residential building
- Mainly residential building but also commercial
- Mainly commercial → END OF THE SURVEY

6. On which of the listed levels is the **commercial business** located?

- Basement
- Ground floor
- 1st floor
- 2nd floor
- 3rd floor (or more)

7. Are you **able to give information** about the event?

- Yes
- No → END OF THE SURVEY

Water arrival time:

8. Date and time of **water arrival**: outside the building

- Time : __________
- Date : __________

9. Date and time of **water arrival**: on the basement

- Time : __________
- Date : __________

10. Date and time of **water arrival**: on the ground floor

- Time : __________
- Date : __________

Maximum water level:

11. Date and time of reaching the **maximum water level**: outside the building

- Time : __________
- Date : __________

12. Date and time of reaching the **maximum water level**: on the basement

- Time : __________
- Date : __________

13. Date and time of reaching the **maximum water level**: on the ground floor

- Time : __________
- Date : __________

Maximum water depth:

14. **Maximum water depth** reached: outside the building

- 0 cm
- 1 to 10 cm
- 10 to 30 cm
- 30 to 50 cm
- 50 to 70 cm
- 70 cm to 1 m
- 1 m to 1,30 m
- 1.30 m to 1.60 m
- 1.60 m to 2 m
- 2 m to 2.50 m
- 2.50 m to 3 m
- 3 to 4 m
- > 4 m

15. **Maximum water depth** reached: in the basement

- 0 cm
- 1 to 10 cm
- 10 to 30 cm
- 30 to 50 cm
- 50 to 70 cm
- 70 cm to 1 m
- 1 m to 1,30 m
- 1.30 m to 1.60 m
- 1.60 m to 2 m
- 2 m to 2.50 m
- 2.50 m to 3 m
- 3 to 4 m
- > 4 m

16. **Maximum water depth** reached: in the ground floor

- 0 cm
- 1 to 10 cm
- 10 to 30 cm
- 30 to 50 cm
- 50 to 70 cm
- 70 cm to 1 m
- 1 m to 1,30 m
- 1.30 m to 1.60 m
- 1.60 m to 2 m
- 2 m to 2.50 m
- 2.50 m to 3 m
- 3 to 4 m
- > 4 m

Back to normalcy:

17. Date and time of **return to normality**: outside the building

- Time : __________
- Date : __________

18. Date and time of **return to normality**: on the basement

- Time : __________
- Date : __________

19. Date and time of **return to normality**: on the ground floor

- Time : __________
- Date : __________

20. What type(s) of damage did you suffer as a result of the July 2021 floods: **damage to the building** and/or **damage to the contents**?

[Note: Building damage means damage to masonry, windows, doors, flooring, etc.; and damage to contents means damage to furniture, electrical appliances and personal belongings. Damage not related to the building or the contents should not be taken into account (examples: damage to cars and external installations, etc.). If both types of damage are found, check the two corresponding boxes.]

- Damage to the building
- Damage to content
- No damage → END OF THE SURVEY

21. Are you a **tenant** or **owner** of the accommodation?

Note: Co-owners are considered owners (example: co-ownership of a married couple, homeowners associations, etc.)

- I am a tenant
- I own the accommodation
- I own the building

Flood event July 2021

22. To what do you attribute **the flooding of your home**?

[Note: multiple answers possible!]

- Runoff (for example, rainwater flowing down uncontrolled on the road or on neighboring land)
- Overflow of a watercourse (for example, a stream or a river having overflowed its bed)
- Saturation of the sewage system, which could no longer absorb water on the roads
- Water has entered directly into rooms below street level (e.g. backflow through drains, toilets, showers or sewage system)
- Lack of drainage on the property (overflowing depressions in the garden, overflowing manholes, faulty drainage of the gutters)
- Failure of a dyke or dam / failure of a flood retention basin
- Groundwater flood (rise of groundwater)
- I don't know
- Other cause of flooding

23. Other cause of flooding:

24. To which **watercourse** (river, stream) or which **body of water** (pond, lake) is the damage mainly attributable?

[Note: This is the stream or body of water that caused the greatest damage. Only one answer is possible.]

25. During the July 2021 floods, did water enter your **cellar**, **basement** or **ground floor**?

[Note: The water that entered the building as a result of flooding. Please do not consider water entering if it is solely from a leaky roof.]

- Yes → Q°27
- No → Q°26
- I don’t know

26. **IF NOT:** To what do you attribute the fact that the water could not enter the building?
→ Q°32

27. How did the **water enter the building**? From the outside, for example through doors, ventilation openings; from below, e.g. through toilets, sinks, traps?

[Note: only one answer possible!]

- Outside
- From below
- From the outside and from below
- The water has not reached any of the interior rooms of the house
- I don't know

28. At the peak of the event, what **levels were affected by the flooding**, including the basement? Please do not include outbuildings and detached garages.

[Note: Please mark ALL relevant levels! The attic also counts as a level, request it accordingly if necessary.]

- Basement
- Ground floor
- 1st floor
- 2nd floor
- 3rd floor
- 4th floor
- Attic
- I don't know

29. Can you determine an **approximate height of the water at the maximum level reached**, measured from the ground in meters?

- Yes → Q°30
- No → Q°31
- I don't know

30. **IF YES**, what is it?

*[Note: indicate the value **in meters** (**ex: 0.30**)]*

31. How high do you have to **climb to reach the ground floor from the street level** (sidewalk)?

*[Note: Please enter the level difference in the input field. This corresponds to steps, located both outside and inside, which you must climb from pavement level to reach the ground floor; it's not about the steps you have to climb from the basement to reach the ground floor. Indicate the value in **meters** (**ex: 0.30**)]*

32. At **what level(s)**, including the basement, was the residential **building damaged**?

[Note: Please mark ALL relevant levels!]

- Basement
- Ground floor
- 1st floor
- 2nd floor
- 3rd floor
- 4th floor
- Attic
- No financial damage in any level
- I don't know

33. Which of the **following materials** were **washed away** or **deposited by water** in the immediate vicinity of your home during the heavy rains?

[Note: Please read and mark as appropriate!]

- Mud
- Sand
- Gravel
- Stones
- Boulders
- Vegetation
- Garbage
- None
- I don't know

34. How **strong was the water flow** in the immediate vicinity of your house? Please give me a number between 1 for “calm flow”; and 6 for “torrential”. You can use the intermediate values to score your answer.

[Note: only one answer possible!]

- *1 - Calm flow*
- *2*
- *3*
- *4*
- *5*
- *6 - Torrential flow*

35. What do you think: Could an **average man have been able to stand effortlessly in the flooded street** in the immediate vicinity of your house, would he have had to **make efforts to stay upright** or would he have been **swept away**?
[Note: This is the most dangerous moment, i.e. the highest flow velocity! Please think first of all about the flow velocity, i.e. the highest flow velocity!]

- *Could have easily stood*
- *Should have make efforts to stay upright*
- *Would have been swept away by the current*
- *The water was too deep to stand*
- *I don't know*

36. Has your home been **contaminated by any of the following substances**?

[Note: read and mark as appropriate. Many possible responses!]

- *Chemicals, paints, varnishes, pesticides, small amounts of motor oil*
- *Sewage or feces*
- *Hydrocarbons (fuel, fuel oil, etc.)*
- *No, no pollution due to these substances*
- *I don't know*

Domestic damage

(damage to furniture, electrical appliances and any other movable objects in your home)

37. First of all, what is the **surface of your ground floor**

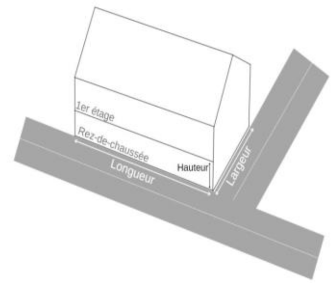
[*Note: Enter the area in square meters in the input field! If necessary, ask for a rough estimate. (Note: the number of square meters is also in the rental agreement) _ m²]*

38. What is the surface of your **1st floor**?

[Note: Enter the area in square meters in the input field! If necessary, ask for a rough estimate. (Note: the number of square meters is also in the rental agreement) _ m²]

39. What is the **ceiling height** of your **ground floor**?

40. What is the **length** and **width** of your building?



- Length: __________
- Width: __________

41. Have you had a **car or motorcycle impacted**? If yes how much:

- Car : __________
- Motorcycle : __________

42. Which of the **following items** did you need to **replace**?
[Note: Please read aloud, multiple answers are possible.]

- Washing machine; dryer
- Refrigerator; Freezer
- Boiler
- Pellet stove
- Stove / Oven
- Dishwasher
- Television, stereo
- Computer / Laptop
- Equipped kitchen
- Telephone system
- Living room furniture
- Furniture for children's bedroom(s)
- Furniture for bedroom(s), guest room
- Leisure accessories
- Tools
- Electrical appliances
- Bathroom furniture
- Personal objects such as clothing,
- Antiques and art works
- Other voluminous and expensive items → **Q°43**
- No, any valuable object
- I don't know

43. What about other voluminous and expensive items? (if yes, write it down)

44. How much do you estimate the **total cost** of **replacing** your **damaged household contents**?
[Note: Record the answer openly and make sure the amount is in EURO! Important: This is the total amount for all damaged items!]

45. What is this **value based on**?
- Receipts and invoices
- Expert advice for damage compensation, for example through insurance or financial assistance
- Own estimate
- Other document(s) used → **Q°46**

46. Other document(s) used:

47. Please compare your **household contents** BEFORE the flood and its CURRENT condition. Have you replaced the damaged household items in the meantime or do they still show obvious defects and gaps as a result of the flood?
(Please give me a number between 1 for "I have since completely replaced household items" and 6 for "Household items still have significant gaps and defects". You can use the intermediate values to score your answer)
- 1 - Fully functional → **Q°48**
- 2
- 3
- 4
- 5
- 6 - Household items still have significant defects or shortcomings
- I don't know

48. How many months after the event did it take you to **fully recover** (repair or replace) your personal household effects?

- Less than a month
- One to two months
- 3 to 6 months
- 6 to 9 months
- 9 to 12 months
- More than 12 months
- I don't know

<u>State of the house before the event</u>

49. Since we assume that household vulnerability to flooding also depends on the building itself, we would like to ask you some questions about the type and condition of the house BEFORE the event. Now think back to the type and condition of the house BEFORE the July 2021 event.
(Note: skip to the next question after reading)

50. What **type of accommodation** do you live in?

- Single family home
- Apartment building
- Other → **Q°51**

51. Other type of accommodation:

52. Which **description** best describes your home?

- Four-sided house
- Terraced or semi-detached house (three facades)
- Farm (for example, the dwelling building adjoins a barn or stable; however, the farm must no longer be used for agricultural purposes)
- Other description of the house → **Q°53**

53. Other description of your house:

54. How many **independent accommodations** does the building contain?
[Note: Enter the number of residential units in the input field! _ _ Dwellings/Apartments]

55. How many **levels** does the building have **in total**, including basement, ground floor and attic?
(Note: include the attic if it is not finished)

56. And what is the **construction method** on the **ground floor**?

(Note: Please read the text! Multiple answers possible (for mixed construction methods))

- Reinforced concrete
- Timber frame
- Masonry construction
- Clay construction
- Prefabricated construction (construction of wooden poles and prefabricated panels)
- Natural stone (sandstone, quarry stone, pumice stone, fieldstone, etc.)
- Half-timbered building
- Other construction method(s) → **Q°58**
- I don't know

57. And what is the **method of construction** on the **upper floors**?
(Note: Please read the text! Multiple answers possible (for mixed construction methods))

- Reinforced concrete
- Timber frame
- Masonry construction
- Clay construction
- Prefabricated construction (construction of wooden poles and prefabricated panels)
- Natural stone (sandstone, quarry stone, pumice stone, fieldstone, etc.)
- Half-timbered building
- Other construction method(s) → **Q°58**
- I don't know

58. Other construction method(s):

Basement:

59. Does the building have a **full or partial** basement?

[Note: a partial basement is a basement that extends over only part of the building area]

- Full basement
- Partly with basement
- Not with the basement → **Q°67**

60. What is the **approximate total area** of the house basement?

Note: Enter the area in square meters in the input field! A rough estimate is sufficient.

(About _ m²)

61. What is the **ceiling height** of the **basement**?

62. How were the **flooded basement rooms used** BEFORE the July 2021 flood?

[Note: Do not read aloud! Mark as appropriate, multiple answers are possible]

- Basement apartment
- Storage room
- Boiler room, technical installations, oil depot
- Local for the domestic fuel tank
- Sauna
- Work room, recreation room
- Laundry
- Drying room
- Living room (example: bedroom, children's room, guest room)
- Office
- Commercial shop
- Bicycle cellar
- Fitness room
- Kitchen
- Party room
- Storage room (wine cellar, food, etc.)
- Underground parking, garage
- Crawl space (used only for building maintenance)
- No use
- Other use(s) → **Q°63**

63. Other use(s):

64. Can you tell me roughly what **size basement area** is most likely to be used for **residential purposes**?
[Note: "Residential use" means basement apartments, living rooms, offices, kitchens, bathrooms, fitness rooms, party rooms, etc. Enter the area in SQUARE METERS in the input field! A rough estimate is sufficient. About _ m²]

65. What **building materials** are used for the **basement**?
(Note: We ask this question separately for basements and residential floors. It's just the basement floor! Please read carefully! Multiple answers possible (for mixed construction methods)

- Masonry construction
- Reinforced concrete
- Timber frame
- Bricks
- Other construction method(s) → **Q°66**
- I don't know

66. Other basement construction method(s):

67. Can you tell me **approximately when the building was built**?
[Note: Please read the text!]

- Before 1875
- 1875-1918
- 1919-1945
- 1946-1970
- 1971-1990
- 1991-2000
- 2001-2010
- After 2011

68. Has the building undergone a **major renovation**? If so, when was the last time?
[Note: Enter the year with 4 digits in the input field! Please note: these are "major renovations" only.]
Year: _ _ _ _

69. What is the **total usable area of the building**? (all levels together, but excluding the basement)

Note: Enter the area in square meters in the input field! A rough estimate is sufficient.

Heading system

70. Does the dwelling use **central heating**?
- Yes
- No

71. Does it have **underfloor heating**?
- Yes
- No

72. What is the **heating system** of the accommodation?
- Coal heating
- Gas heating
- Oil heating → **Q°74**
- Electric heating or night storage
- District heating
- Pellet or wood chip heating, wood heating
- Heat pump
- Other heating system(s)

73. Other heating system(s):

74. **IF OIL HEATING**: Where was the heating oil tank located at the time of the incident?
- Basement
- Ground floor
- 1st floor
- 2nd floor
- 3rd floor
- 4th floor
- Above ground, outbuilding
- Other place where the oil tank is located → **Q°72**
- Underground exterior (underground tank)
- I don't know

75. Other place where the oil tank was located:

76. At what **level** was the **heating system** at the time of the disaster?
- Basement
- Ground floor
- 1st floor
- 2nd floor
- 3rd floor
- 4th floor
- 5th floor
- Attic
- Each level, each apartment
- Dependency outside the home
- Other place where the heating
- system was → **Q°77**
- I don't know

77. Other place where the heating system was located:

78. How much do you estimate the **total cost** of repairing the **heating system**?
(Note: Record the answer openly and make sure the amount is in EURO)

79. How much do you estimate the **total cost** of repairing the **electrical system**?
(Note: Record the answer openly and make sure the amount is in EURO)

80. How much do you estimate the **total cost** of repairing the **plumbing and sanitation system**?
(Note: Record the answer openly and make sure the amount is in EURO)

81. Comment on damaged installations :

82. And how much do you estimate the **total cost** of the **damaged facilities**?
(Note: Record the answer openly and make sure that the amount is indicated in EURO)

83. Overall, how would you rate the overall condition of the building BEFORE the July 2021 event?
(Please give me a number between 1 and 3 to rate the level of maintenance of the building)

- 1 - Very good (new, very well maintained)
- 2 - Average maintenance
- 3 - Degraded, to be renovated
- I don't know

84. Overall, how would you rate the **general condition of the building BEFORE** the July 2021 event?

(Please give me a number between 1 and 3 to rate the finishing level of the building. You can use the intermediate values to score your answer.

(On request: this is the quality of the building fabric, plaster, doors, windows, etc. Important: we are talking about the state of the building BEFORE the floods!)

- 1 - Very good (luxurious)
- 2 – Intermediate
- 3 – Simple, functional
- I don't know

Flood damage to buildings

84. We now come to flood damage to buildings.

85. Please describe the **building damage** in more detail using the following list.
(Note: Please read the text! Many possible responses)

- Moisture infiltration only
- Wooden structure : expansion / contraction
- Slight cracks, damage to the exterior coating of the building (masonry, plaster) [structural and non-structural damage]
- Damage to interior linings
- Damage to the pavement (Floor covering material)
- Damage to doors
- Damage to windows
- Significant cracks or settlements, or deformations of walls and ceilings
- Collapse of construction elements (walls, ceilings)
- Building collapse
- Demolition required
- I don't know

Exterior coating

86. What **type of material** is used for the **exterior coating**?

- Brick
- Rendered, coated
- Rubble, stone
- Concrete
- Wood facing
- Other

87. Other type of material used for the exterior coating:

88. **Perimeter** of damaged exterior coating:

89. What is the approximate **damage cost** to the **exterior coating**?
(Note: record the answer openly and make sure the amount is in EURO)

<u>Internal coating:</u>

90. What is the approximate **damage cost** related to the **replacement of the interior lining** (plaster, tiles on the wall, etc.)?
(Note: record the answer openly and make sure the amount is in EURO)

<u>Damaged door(s):</u>

91. Number of **door(s) damaged**:

92. **Area** of **damaged door(s)** (in m²):

93. What is the **approximate cost of door damage**?
(Note: record the answer openly and make sure the amount is in EURO)

<u>Damaged window(s):</u>

94. Number of **window(s) damaged**:

95**. Area** of **damaged window(s)** (in m²):

96. What is the **approximate cost** of **window damage**?
(Note: record the answer openly and make sure the amount is in EURO)

<u>Flooring</u>

97. What **type of material** is used for the floor **covering the ground floor**?
- Tile
- Parquet
- Carpet, rugs
- Concrete
- Other

98. Other type of material used for floor covering the ground floor:

99. What **type of material** is used for the floor covering the **upper floors**?
- Tile
- Parquet
- Carpet, rugs
- Concrete
- Other

100. Other type of material used for floor covering the upper floors:

101. What is the **surface of the damaged floor covering**? (in m²)

102. What is the **approximate cost of the damaged floor covering**?
(Note: record the answer openly and make sure the amount is in EURO)

103. What is the **approximate cost** of **restoring the building structure**? (load-bearing walls, foundations, etc.).
[Note: record the answer openly and make sure the amount is in EURO!]

104. To what do you primarily attribute the damage to the building, water level, flow velocity or water pressure, mud and sediment deposits or impacts from floating objects, for example tree trunks or debris?
[Note: please read the text! Many possible responses!]

- Water level
- Flow velocity
- Mud and sediment deposits
- Impacts of floating objects (tree trunks, debris, washed away vehicles, etc.)
- Water pressure
- I don't know

<u>Total cost of all reparation works:</u>

105. If you **add up the costs** (material and labor) of **all necessary reparation work** on and in the **building**, what was **the total amount of damage to the building**?
(Note: give the estimate that seems most likely to you in EURO. If asked: this also includes rental costs for equipment such as dehumidifiers, space heaters, etc. Important : This is the total amount of ALL damage)

106. What is this **value based on**?
- Invoices for work carried out
- Trades quotes
- Expert estimate, for example from the insurance company
- Personal estimation
- Other source(s) → **Q°101**

107. Other source(s):

<u>Total cleaning cost:</u>

108. Can you indicate the **total amount** of the costs related to the **cleaning of the building** (water pumping, waste treatment, cleaning and dehumidification)?
(Note: in euros)

<u>Insurance:</u>

109. How much **damage** did you **declare to the insurance company**?
(Note: record the answer openly and make sure the amount is in EURO! Important: This is only the amount that was DECLARED to the insurance company as damage, not the amount that the person actually received! On request: only damage insurance to or in the house is covered; car insurance should not be taken into account! If zero euros was declared, record zero)

110. Did you have to leave your apartment or house because of the damage?
- Yes → **Q°105**
- No

111. How many days did you leave your accommodation?

112. If you **compare the building before the flood and its current condition,** can you give a number between 1 for "the building is completely restored" and 6 for "the building still has significant damage". You can use the intermediate values to score your answer.

- 1 - Completely restored → **Q°107**
- 2
- 3
- 4
- 5
- 6 - Damage still considerable
- I don't know

113. How many months were needed after the event to **completely restore** your building?

- Less than a month
- One to two months
- 3 to 6 months
- 6 to 9 months
- 9 to 12 months
- More than 12 months
- I don't know

114. In what **form** did you receive **financial compensation**?

(Note: Please read the text! Many possible responses)

- Emergency aid from the municipality or the CPAS
- Emergency aid from the Walloon Region
- Compensation from the Disaster Fund
- Private donations (e.g. friends, family, employer)
- Compensation from your insurance company
- Rent reduction; energy bills, tax breaks, etc.
- Other compensation(s) → **Q°109**
- Did not receive financial compensation → **Q°111**
- I don't know

115. Other financial compensation(s):

116. What is the **total amount of financial compensation** you have already received? (for example, donations, financial aid, insurance, etc.).
(Note: Record the answer openly and make sure the amount is in EURO! Important: We are talking about the total amount for all damages)

117. Why did you not receive financial compensation?
(Note: multiple answers possible)

- The damage is not covered by any (insurance) policy
- The administrative burden was excessive
- I do not know if I am entitled to compensation
- Did not consider compensation necessary
- Other reasons → **Q°103**
- I don't know

118. Other reason(s) for not receiving financial compensation?

119. Is the compensation **over**? (i.e. if the formalities and payments have been made or if the process is still ongoing)

- Yes → **Q°114**
- No → **Q°117**
- I don't know

120. Overall, How satisfied were you with the claim procedure?

	1 – Very satisfied	2	3	4	5	6	I don't know
Please give me a number between 1 for "very satisfied" and 6 for "very unsatisfied". You can use the intermediate values to score your answer.							

121. Why were/are you unsatisfied?

Precautionary measures

122. We would now like to ask you about any **precautionary measures** that may have been implemented, or may be implemented in the future of the floods.

123. Which of the following **precautionary measures** did you implement **during the July 2021 floods**, after this event, or you do not currently intend to implement?

(Note: Measurements that are planned for more than 6 months are considered "unplanned")

IF OWNER OCCUPANT

	In place during the event	After the event (<6 months)	Not planned / not possible
Information on flood risk (hazard maps, Be-Alert, Infocruise)			
Housing Protection Information			
Insurance			
Adaptation of the use of levels exposed to the risk of flooding			
Water-resistant or easily renewable construction and finishing materials			
Moving the heating and/or electrical system to higher levels			
Oil tank protection (prevent flotation)			
Improvement of the stability and/or the waterproof resistance of the building			
Non-return valves at the water outlets			
Water protections, fixed or mobile, which prevent water from entering the building/accommodation (such as partitions for windows and doors, sandbags, small local protection walls)			

	In place during the event	After the event (<6 months)	Not planned / not possible
Moving the furniture			
Pumps			
Preventive cut off of power, gas and water			
Don't know what to do			
Evacuating the accommodation			
Moving the house (trailer house)			

IF TENANT

	In place during the event	After the event (<6 months)	Not planned / not possible
Information on flood risk (hazard maps, Be-Alert, Infocrues)			
Housing Protection Information			
Insurance			
Adaptation of the use of levels exposed to the risk of flooding			
Watertight protections, fixed or mobile, which prevent water from entering the building/accommodation (such as partitions for windows and doors, sandbags, small local protection walls)			
Moving the furniture			
Pumps			
Preventive cut off of power, gas and water			
Don't know what to do			
Evacuating the accommodation			
Moving the house (trailer house)			

124. Before the July 2021 event, **how many times have you already been affected** by floods?

- Never before
- Once
- Twice
- Three times
- Four times
- More than four times

125. When was (the last time)?

Personal questions

126. Finally, I have a few questions **about yourself**.

127. How many people live in your household permanently, including yourself and children?

128. How many children under 14 live in your household?

129. How many people in your household are over 65?

130. Are there people with reduced mobility in your household? If yes, how much?

131. Interview end time:

Photos of the building :

Comments:

Go back to questions 18/19/20/21/22/23 of survey n°1

B.1.3 Consent Form for detailed study

LIÈGE université

Université de Liège
Formulaire de consentement

Etude visant à établir un lien entre les dommages causés par les inondations et des paramètres hydrauliques et urbanistiques mesurables

Pour faire face au risque d'inondation, des investissements importants sont nécessaires afin de réduire la vulnérabilité (population exposée, information, alertes, publics fragiles, adaptation du bâti). Des modèles scientifiques permettant de prédire les dommages causés par les inondations sont essentiels pour orienter au mieux de tels investissements. Aujourd'hui, le principal obstacle au développement de ces modèles est un manque de données de terrain. L'Université de Liège (ULiège) effectue une collecte de telles données de dommages en lien avec des paramètres hydrauliques (ex. hauteurs d'eau) et les caractéristiques du bâti.

Ce document a pour but de vous fournir toutes les informations nécessaires afin que vous puissiez donner votre accord de participation à l'étude et votre consentement pour le traitement des données récoltées.

Pour participer à cette étude, vous devrez signer le consentement à la fin de ce document et nous vous en remettrons une copie signée et datée. Vous restez libre de vous retirer de l'étude par la suite.

Responsable du projet de recherche

Benjamin Dewals, Professeur, Allée de la Découverte 9, 4000 - Liège, Tel. 04 366 92 83, b.dewals@uliege.be

Description de l'étude

L'étude comporte une phase de récolte des données prévue en 2022 au moyen d'interviews dans les vallées affectées par les inondations de juillet 2021 dans le bassin de la Meuse. En parallèle, les données seront vérifiées, anonymisées et analysées dans le but de répondre à des questions scientifiques et développer ou améliorer des modèles. Les résultats de l'étude seront publiés sous forme anonymisée.

Protection des données à caractère personnel

1.Qui est le responsable du traitement?

Le responsable du Traitement est l'Université de Liège, dont le siège est établi Place du 20-Août, 7, B- 4000 Liège, Belgique.

2.Quelles seront les données collectées ?

Les données récoltées contiennent des données de recherche et des données d'identification. Les données de recherche portent notamment sur les caractéristiques de l'inondation et du bâtiment, les dommages subis et les coûts associés, ou encore les mesures de précaution mises en œuvre. Les données d'identification contiennent l'adresse du bâtiment, des photographies des bâtiments sinistrés et, si le répondant le souhaite, des données démographiques du bâtiment et un moyen de contact (ex. e-mail).

3.À quelle(s) fin(s) ces données seront-elles récoltées ?

L'adresse est récoltée en vue de la validation de modèles hydrodynamiques. Le moyen de contact est destiné à permettre une correction des données lors de la phase de vérification de celles-ci, la fourniture au répondant d'une documentation sur les résultats de l'étude, et un éventuel suivi de l'étude. Les données de recherche visent à améliorer les connaissances scientifiques des mécanismes de dommages induits par les inondations, dans le but de faire évoluer les méthodes de modélisation et de gestion du risque d'inondation.

4.Combien de temps et par qui ces données seront-elles conservées ?

Les données d'identification seront conservées par le(s) investigateur(s) durant l'étude. À l'issue de celle-ci, les données d'identification seront détruites (destruction de la base de données contenant ces données), avec un délai maximum de 5 ans après la fin de l'étude. Cette opération rendra les données de recherche complètement anonymes.

5.Comment les données seront-elles collectées et protégées durant l'étude ?

Lors de la phase de collecte des données, l'identification des bâtiments sera récoltée lors d'une interview avec un des investigateurs associés à l'étude. Un numéro de code spécifique à l'étude est donné pour chaque bâtiment. Lors des phases ultérieures, les données d'identification et les données de recherche seront conservées dans deux bases de données distinctes et les informations reliées entre elles au moyen de codes. Les données de recherche seront conservées sur un serveur sécurisé du SEGI (certifié ISO 27001) et sur les ordinateurs des chercheurs. Si la diffusion des résultats nécessitait de faire référence à un bâtiment participant en particulier et à certaines de ses caractéristiques, sa non-reconnaissance serait garantie.

6.Qui pourra consulter et utiliser ces données ?

Seuls les étudiants et les chercheurs de l'ULiège dont les travaux portent directement sur l'objet de l'étude auront accès aux données à caractère personnel.

7.Ces données seront-elles transférées hors de l'Université ?

Seules des données de recherche pourront être transférées à des partenaires extérieurs à des fins de recherche. Les données d'identification ne feront l'objet d'aucun transfert vers ni traitement auprès de tiers.

8.Sur quelle base légale ces données seront-elles récoltées et traitées ?

La collecte et l'utilisation de vos données à caractère personnel reposent sur votre consentement écrit. En consentant à participer à l'étude, vous acceptez que les données personnelles exposées au point 2 puissent être recueillies et traitées aux fins de recherche exposées au point 3.

Questions sur le projet de recherche

Toutes les questions relatives à cette recherche peuvent être adressées au responsable du projet de recherche.Pour toute question relative à vos données à caractère personnel et au traitement qui en est fait par l'Université de Liège, vous pouvez contacter le Délégué à la protection des données (dpo@uliege.be; M. le Délégué à la protection des données, Bât. B9 Cellule "GDPR", Quartier Village 3, Boulevard de Colonster 2, 4000 Liège, Belgique). Cette adresse est également celle par le biais de laquelle vous pouvez exercer vos droits en la matière, en justifiant votre identité : accès, rectification, effacement, limitation, opposition et portabilité. Vous pouvez également introduire une réclamation auprès de l'Autorité de protection des données (https://www.autoriteprotectiondonnees.be, contact@apd-gba.be).

Retrait du consentement

Si vous souhaitez mettre un terme à votre participation à ce projet de recherche, veuillez en informer le responsable du projet. Ce retrait peut se faire à tout moment, sans qu'une justification ne doive être fournie. Sachez néanmoins que les traitements déjà réalisés sur la base de vos données personnelles ne seront pas remis en cause. Par ailleurs, les données déjà collectées ne seront pas effacées si cette suppression rendait impossible ou entravait sérieusement la réalisation du projet de recherche. Vous en seriez alors averti.

Nom et prénom :

Date :

Signature :

B.1.4 Letter for field survey invitation

LIÈGE université
Sciences Appliquées

UEE
Urban and Environmental Engineering

Recherche scientifique – Dommages liés aux inondations

Les inondations catastrophiques de la mi-juillet 2021 constituent un événement extrême et inédit dans la région. Pour contribuer à améliorer la gestion du risque d'inondation dans le futur, l'Université de Liège développe des modèles destinés à mieux planifier l'aménagement des cours d'eau, l'aménagement du territoire, ou encore la gestion de crise. Ces modèles peuvent être rendus plus fiables grâce à l'utilisation de données de terrain, portant notamment sur les caractéristiques de l'inondation, celles des bâtiments soumis au risque et sur les dommages subis.

Dans ce but, l'Université de Liège réalise une enquête dans les vallées touchées par les inondations pour améliorer les connaissances actuelles sur le lien entre dommages causés par les inondations et paramètres hydrauliques et urbanistiques. Vous serez sollicité dans les prochains jours par un chercheur de l'Université de Liège, qui vous proposera de répondre à un questionnaire. Les résultats de cette enquête ne seront utilisés qu'à des fins strictement scientifiques. Aucune donnée d'identification ne sera transmise à des tiers, et votre identité ne vous sera pas demandée.

Si vous avez une préférence en matière de créneau horaire, vous pouvez nous le communiquer :

- Soit en indiquant votre adresse (rue, numéro et localité) ainsi que la date et l'heure de rendez-vous souhaités à ce numéro par SMS : 0492/14.46.52, ou par email à l'adresse flood.survey@uliege.be.
- Soit via le formulaire de prise de rendez-vous accessible ici: https://forms.office.com/r/aMe3gFyzrQ (scanner le QR code ci-contre pour accéder directement au formulaire).

Nous vous invitons à réserver un bon accueil au chercheur qui vous sollicitera et vous remercions par avance pour votre temps et votre collaboration. Si vous souhaitez davantage d'informations sur cette démarche, vous êtes invité à nous contacter par téléphone (0492/14.46.52) ou par email (flood.survey@uliege.be).

Research unit *Urban and Environmental Engineering*
Quartier Polytech 1 - Bâtiment B52
Allée de la Découverte, 9 4000 Liège Parking P52
Tel. + 32-4-366 92 67 - flood.survey@uliege.be
www.uee.ulg.ac.be - www.hece.ulg.ac.be

Anus Muhammad – Master's Degree in Civil Engineering
2021-2022