ARCH D7.4

Requirements description

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Executive Summary

This deliverable has been prepared for the European Commission-funded research project ARCH: Advancing Resilience of historic areas against Climate-related and other Hazards. It is the key output of task 7.4 *"Requirements analysis"* within work package 7 *"Framework & Integration"*. The aim of task 7.4 is to get an in-depth understanding of the thematic challenges of the cities participating in the project and to ensure that the collected / generated datasets and methodologies / tools to be developed in ARCH are in line with the needs of the local end-users and the state-of-the-art. In order to achieve this, it is necessary to establish together with the end-users a systematic, structured way to elicit needs of end-users, turn them into well-defined requirements as a common basis for communication between all actors involved in the engineering process, identify which product features help to address which requirements, and which requirements cannot or will not be addressed in the ARCH project. In order to achieve this ARCH applies the Mission-Concept-Realisation-Implementation (MCRI) architecture approach for system design as elaborated by the EU FP7 projects DIESIS [1] and CIPRNet [2], which breaks system design descriptions down into

- the high-level goals (**mission**);
- the most important technical and methodological key **concepts** to be employed for reaching the goals;
- the methods for **realising** the identified key concepts; and
- the Information and Communication Technology (ICT) systems, services, and components that will be employed for **implementing** the methods identified.

Based on an initial specification of the mission and concept levels of all ARCH tools, end-user needs are elicited, recorded, analysed, and systematically transformed into well-defined requirements, which are then prioritised using the MoSCoW method [3] to guide the development process. As ARCH follows an agile co-creation approach and additional or changing end-user needs might become clear over the duration of the project, this requirements process is conducted continuously and this deliverable will be maintained as a living document after the official submission and updated whenever necessary.

This report describes this continuous requirements analysis process, the initial system specifications (mission and concepts) of all ARCH tools that will be developed during the project, and lists the initial requirements gathered between November 2019 and April 2020.

In total, 134 requirements have been collected, including 78 city case independent general requirements: 6 usability, 3 technical, 6 security, 8 organisational, and 55 functional. In addition, 56 city case specific functional requirements have been gathered: 7 for Bratislava, 12 for Camerino,

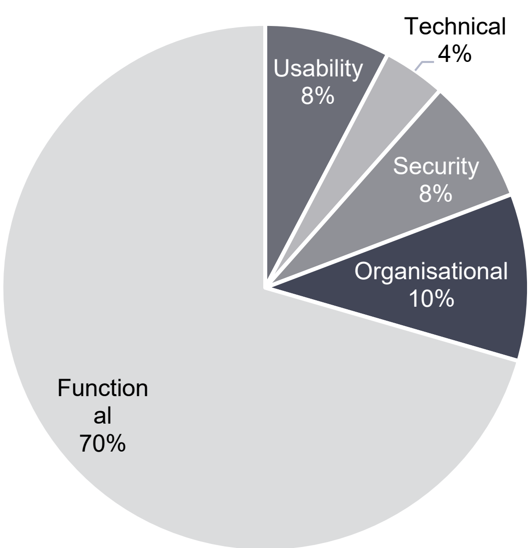

Figure 1: Percentage breakdown of city case independent requirements

13 for Hamburg, and 24 for Valencia, reflecting the progress of the co-creation processes with each city case. The gathered requirements are relevant for multiple of the technical systems developed in the ARCH project:

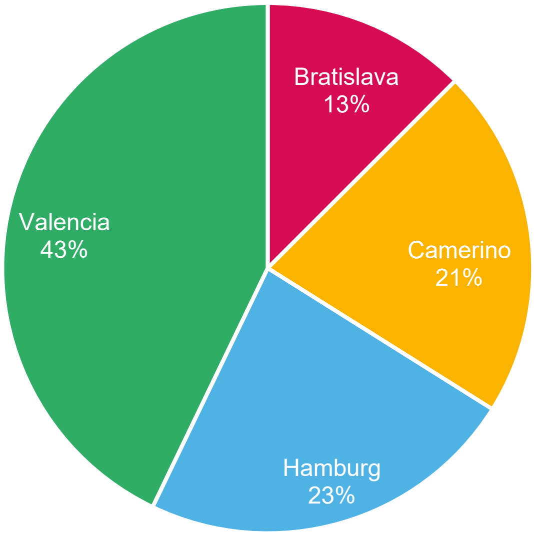

Figure 2: Percentage breakdown of city specific requirements

- 58 requirements target the Historic Area Information System developed in work package 4;
- 43 requirements target the Threats and Hazard Information System, also developed in work package 4;
- 75 requirements target the ARCH Decision Support System developed in work package 5
- 22 requirements target the Resilience Option Inventory developed in work package 6;
- 12 requirements target the Resilience Pathway Visualisation Tool, also developed in work package 6;
- 36 requirements target the ARCH Hub developed in work package 7; and
- 28 requirements target the ARCH Resilience Assessment Dashboard, also developed in work package 7.

In a next step, further features of the technical ARCH systems to cover the identified requirements will be specified.

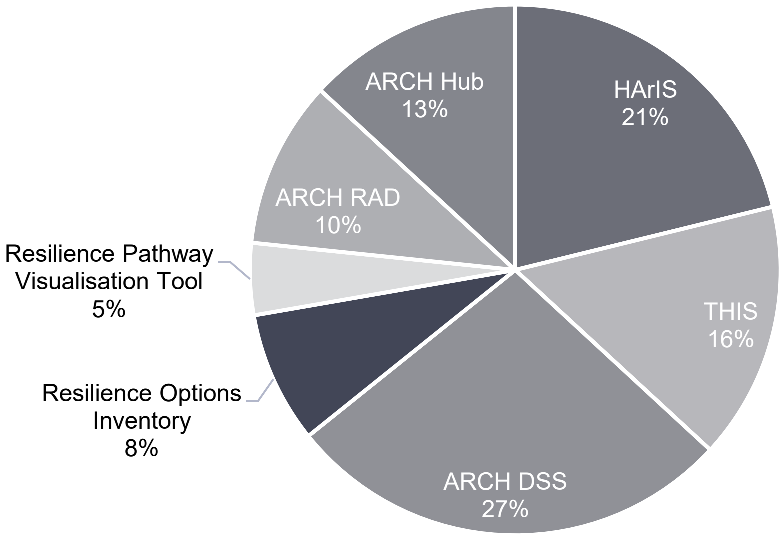

Figure 3: Percentage breakdown of requirements according to relevance for ARCH tools

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List of Abbreviations

Abbreviation	Meaning
CH	Cultural Heritage
DoA	Description of the action
DSS	Decision Support System
GA02	The second ARCH General Assembly meeting, conducted in November 2019
GIS	Geographical Information System
GMPE	Ground Motion Prediction Equations
HArIS	Historic Area Information Management System
ICT	Information and Communication Technology
MCRI	Mission-Concepts-Realisation-Implementation architecture approach
PGA	Peak Ground Acceleration
RAD	Resilience Assessment Dashboard
REST	Representational state transfer
THIS	Threats and Hazard Information Management System
WP	Work Package

1. Introduction

This deliverable has been prepared for the European Commission-funded research project *ARCH: Advancing Resilience of historic areas against Climate-related and other Hazards.* ARCH will develop decision support tools and methodologies to improve the resilience of historic areas to climate change-related and other hazards. These tools and methodologies are developed with the pilot cities of Bratislava (Slovakia), Camerino (Italy), Hamburg (Germany), and València (Spain), in a co-creative approach, including local policy makers, practitioners, and community members. The resulting solutions will be combined into a collaborative disaster risk management platform for guided resilience building, and will include

- an information management system for relevant geo-referenced properties of historic areas;
- an information management system for geo-referenced data regarding hazards and risks relevant for historic areas;
- a Decision Support System (DSS) for risk and impact analysis of historic areas;
- an inventory of resilience building measures and appropriate financing sources;
- a visual planning tool for resilience pathways; and
- a resilience assessment framework to identify resilience weak points and formulate resilience action plans.

1.1. Purpose of this report and relation to other ARCH deliverables

This report (D7.4) is the key output of task 7.4 *"Requirements analysis"* within work package 7 (WP7) *"Framework & Integration"*. The objectives of WP7 are to develop a disaster risk management framework for resilience building and assessment, operationalise this framework in a data and information platform, and integrate into this platform the datasets, tools, and methodologies from WPs 4, 5, and 6 in order to support the resilience building and assessment process.

The aim of task 7.4 is to get an in-depth understanding of the challenges of the participating cities and to ensure that the collected / generated datasets and methodologies / tools to be developed in the ARCH project are in line with the needs of the local end-users and the state-of-the-art. Therefore, WP7 collected requirements from past and ongoing research projects, relevant standards and regulations, general best practices of software development, and – most importantly – the pilot cities in the ARCH project. These initial requirements are gathered in this deliverable that is to provide ARCH project partners, who are generating / collecting datasets and adapting / developing methodologies / tools for the project, with a common basis for further development.

Subsequently, this document is relevant for all work packages that generate / collect datasets and develop methodologies / tools, specifically:

D4.2 Historic Area Information Management System (HArIS)

D4.3 Threats and Hazard Information Management System (THIS)

D4.4 Knowledge Information Management System for Decision Support

D5.1 Hazard models for impact assessment

D5.2 Handbook on Heritage Asset Vulnerability

D5.3 CIPCast DSS modification and integration

D6.1 Inventory of resilience options

D6.4 Resilience pathway visualisation tool

D7.5 Interface specification and system architecture

D7.6 System design, realisation, and integration

As ARCH follows an agile co-creation approach, additional requirements might be collected or initial requirements might be updated throughout the project. Therefore, this deliverable, which will be maintained as a living document after the official submission, also describes the process of how to continuously collect and update requirements throughout the project.

1.2. **Gender statement**

This document has been developed taking into consideration the guidance on gender in research provided in the Project Handbook (D1.2) as well as State-of-the-Art report number 5 of deliverable D7.1 on *“Gender aspects in conservation and regulation of historic areas, disaster risk management, emergency protocols, post-disaster response techniques, and techniques for building back better”.*

Following these guidelines, all needs and requirements have been and will be screened for the potential to address gender aspects (i.e. if a requirement might differ due to possible gender differences). In addition, specific initial requirements covering gender aspects have been added (e.g. the need for gender-differentiated population data when conducting risk analyses).

1.3. **Structure of this report**

The report is divided into five sections. Following this introduction, section 2 provides the process background, the methodology used for requirements analysis, and the process of continuously eliciting and analysing requirements throughout the project. Section 3 contains brief descriptions of the technical solutions that will be developed by the project as a basis for section 4, where the gathered requirements for the different solutions are listed. Finally, the document closes in section 5 with a conclusion of the conducted work.

2. Background and methodology

2.1. Background

Requirements analysis is a critical part of systems / software engineering. It has the aim to identify the most relevant actual needs of end-users and align them with specific product features in order to develop products that include all features relevant for end-users and exclude any features not wanted or needed by end-users. Requirements serve as means to guide the development process and to verify its results.

Determining the real requirements of end-users is a complicated, time-consuming task, because end-users often do not have a clear picture of their requirements before using a product, are not trained to formulated requirements, and their requirements change frequently. In addition, some end-users might never have been involved in a requirements analysis process and subsequently have to adjust to this new process and role.

In addition, the engineering process usually involves a multitude of different actors, each with their own unique backgrounds, views, and expectations. This often results in communication issues and subpar products that do not align with the needs of the end-users and subsequently are not adopted for use after the development finishes.

Therefore, it is necessary to establish a systematic, structured way to elicit needs of end-users, turn them into well-defined requirements as a common basis for communication between all actors involved in the engineering process, identify which product features help to address which requirements, and which requirements cannot or will not be addressed.

2.2. Methodology

ARCH addresses the above mentioned issues in two ways:

1. By adopting an **agile co-creation process** between project partners from the ARCH pilot cities and the technical partners, the project includes end-users in the development process from an early stage and gives them access to early product prototypes as soon as possible. As a result, the project can ensure that needs of end-users are met before rolling out a final product and is also able to incorporate changing requirements in the ongoing development process.
2. By combining the agile co-creation process with a **systematic, structured, and continuous requirements analysis process** established at the outset of the project, ARCH ensures a common understanding between all involved actors about the scope of the developed solutions and that all solutions start with a common understanding of initial needs from end-users. In addition, this ensures a better alignment between the different solutions developed within the project.

The co-creation process adopted by ARCH and the rules and guidelines that govern this process are described in deliverable D3.1. Therefore, the remained of this section focuses on describing the four pillars of the ARCH requirements analysis process: (1) the MCRI system design method for initial system specification; (2) the process of continuously obtaining requirements; (3) the MoSCoW method for prioritising requirements; and (4) guideline for writing well-defined requirements.

2.2.1. System Design – the MCRI method

In order to describe the design of the solutions developed within ARCH, we follow the top-down Mission-Concepts-Realisation-Implementation (MCRI) architecture approach elaborated in the EU FP7 projects DIESIS [1] and CIPRNet [2], and adopted by CRISMA [4] and PREDICT [5]. According to this approach, the system architecture is broken down into four conceptual levels: Mission, Concepts, Realisation, and Implementation (see Figure 4). On the **Mission** level, the high-level goals of a system are clarified. On the **Concepts** level the most important technical and methodological key concepts to be employed for reaching the goals are defined. On the **Realisation** level, the methods for realising the identified key concepts are defined. Lastly, on the **Implementation** level the ICT systems, services, and components that will be employed for implementing the methods identified at the previous level are defined.

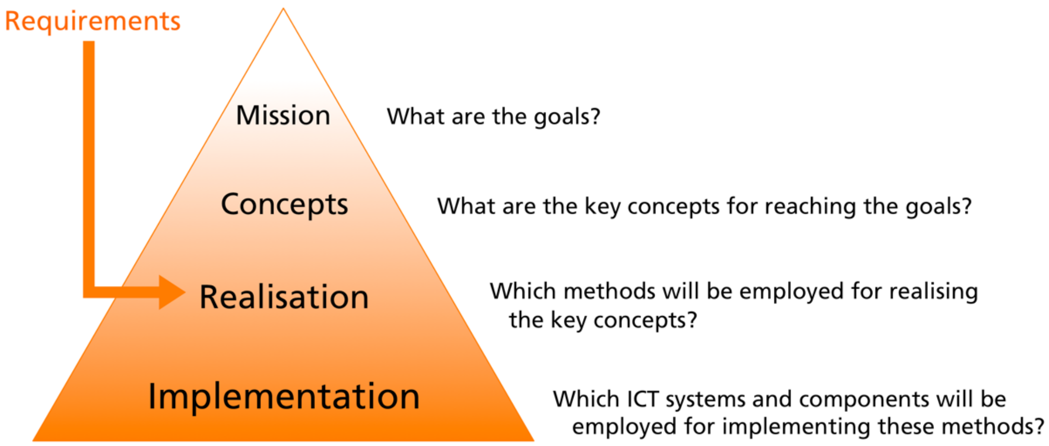

Figure 4: MCRI architecture levels (after [1] and [5])

Requirements analysis typically takes place at the realisation level and can be considered its starting point. Subsequently, the primary goal of this deliverable D7.4 is to provide an initial specification of both top levels mission and concepts for all ARCH solutions, as well as a preliminary coverage of the realisation level in form of requirements. More detailed coverage of the levels realisation and implementation are subject to forthcoming deliverables:

- D4.2, D4.3, and D4.4 will cover the information management systems developed in WP4.
- D5.1, D5.2, and D5.3 will cover the Decision Support System developed in WP5.
- D6.1 and D6.4 will cover the Resilience Option Inventory and Pathway Visualisation Tool developed in WP6.
- D7.5 and D7.6 will cover the data and information platform as well as resilience assessment dashboard developed in WP7.

2.2.2. Obtaining Requirements in ARCH

The initial set of requirements described within this report originates from three different types of sources:

(1) Public documents from previous and ongoing research projects relevant to the topics of ARCH as well as important standards and regulations in connected fields.
(2) (Semi-) structured interviews and discussions between research partners and city partners of ARCH.
(3) General discussions between project partners about (technical) standards, state of the art, and best practices.

In order to obtain requirements from source (1), desk research was conducted for relevant documents from previous and ongoing research projects connected to the topics of ARCH; these included deliverables from the already concluded projects Scan4Reco [6], RESIN [7], SMR [8], STORM [9], and HERACLES [10], as well as the ongoing projects HYPERION [11] and SHELTER [12]. These projects were funded under the same call as ARCH. Where these documents already contained requirements, these were adapted to the context of ARCH. Otherwise, information and needs relevant for ARCH were transformed into requirements as described in the subsequent sections. Documents of this type of source also include ARCH D7.1, the six State-of-the-Art reports covering topics relevant for ARCH, as well as the Description of Action [13].

Requirements from source (2) were gathered via interviews and discussions with city partners conducted by different constellations of project partners over several months. During these activities, city partners were asked to express their needs in terms of data, functionality or in general aspects and the lack thereof. These activities have been kicked off at the General Assembly meeting in Brussels in November 2019 and were further pursued in a number of bilateral and multilateral meetings of ARCH partners. Additional requirements resulted from real-world and virtual city visits of different partners (Hamburg in October 2019 and March 2020, Camerino in December 2019, Valencia in March and April 2020)[1], where city needs were expressed while technical partners offered matching expertise for creating system features. When Fraunhofer was not present at meetings to record needs, as was for example the case for multiple meetings between Camerino, UNICAM, ENEA, and INGV, minutes of those meetings have been provided that were analysed for needs, rephrased as requirements and validated with technical and city partners afterwards.

Requirements from source (3) were gathered from informal discussions between (technical) project partners about best practices and (technical) standards during meetings and conference calls, e.g. the need to comply with EU GDPR [14].

From the different sources, requirements have been initially formulated by Fraunhofer. They are managed according to a **requirement life cycle**, consisting of different maturity status. New requirements are assigned the initial status of *“suggested”*. They must always be named along with a source to make them traceable.

Through repeated review with the technical and city partners, including changing or rephrasing, the requirements are moved towards consensus, in which case they are assigned status

[1] A virtual visit to Bratislava is planned for the end of May 2020. Requirements from this meeting will be included in the next – project internal – version of the deliverable.

"*approved internally*". A requirement with pending discussion is labelled as *"to be discussed"*. All requirements presented here have been approved internally.

The review process is extended with external city stakeholders and facilitated by city partners. After passing this review, the status is set to "*fully approved*".

The workflow is visualised in Figure 5. The status of "*to be discussed*" is omitted for clarity, since it is an intermediate state of the review transitions. The management process will be continued throughout the development phase of ARCH.

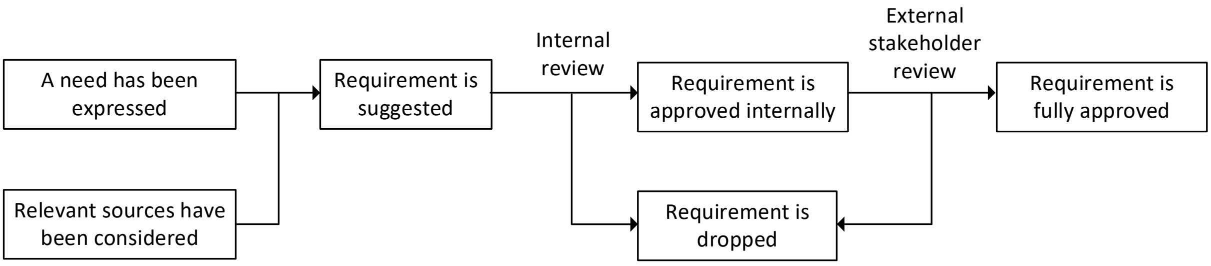

Figure 5: Process for requirement management

Requirements are mapped to ARCH solutions as well as city cases, since the solutions developed within ARCH are set out for different functional tasks and certain features may be requested by more than one city case. This results in a matrix-like dependency between requirements, ARCH solutions, and city cases.

Following the mapping between solutions, city cases, and (initial) requirements, a more detailed mapping of specific features of (prototype) solutions to single requirements should be conducted. In addition, Fraunhofer will continue to monitor and moderate the requirements analysis process across city cases and ARCH solutions to maintain a common development road map.

2.2.3. The MoSCoW method for Prioritising System Requirements

The specification of system requirements is based on the MoSCoW[2] priority classification method [3]. The method assumes an iterative development process, consisting of a number of delivery time boxes. It distinguishes four priorities:

- **Must have:** requirement is critical for the success of the system and must be delivered in the next delivery time box
- **Should have:** requirement is important or even necessary, but not as time-critical and may be realised in a later delivery time box
- **Could have:** requirement is desirable but not necessary for overall project success

[2] Abbrevation for the priorities (M)ust have, (S)hould have, (C)ould have, (W)on't have

- **Won't have:** requirement is least critical and may be realised in a later delivery time box, possibly never. Still, it is a legitimate requirement.

The method has a certain ambiguity in the *"won't have"* category, which is that without further context it can be interpreted as *"will never include",* instead of *"will likely not include*". Therefore, when phrasing requirements using the MoSCoW method, ARCH explicitly phrases requirements of the *"won't have"* priority using *"will likely not include"* to express that the requirement is still valid, despite having low priority. Furthermore, requirements that are decided to be out of scope (realised never) will not be continued in the requirements list and moved to a separate list for internal record keeping purposes.

2.2.4. Writing Good Requirements

ARCH follows established guidelines from software development and system engineering [15] to formulate requirements. A good requirement is necessary, verifiable, and attainable. Subjective statements (such as *"easy"*) are not verifiable. Requirements should also be clearly phrased and express a single thought. They should express <u>what</u> is needed, not <u>how</u> it is implemented. A way to avoid describing implementation is to ask WHY a certain requirement is needed.

When describing requirements, some terms should be avoided, including *"but not limited to"*, *"etc.", "and/or"*, which are used to cover missing knowledge but do not add more meaning. Further, a set of requirements should be self-consistent, i.e. requirements contradicting each other should not exist. Requirements are typically phrased as an active sentence using the verb "*shall*", such as "*The system shall allow the user to regain access in case of password loss*". When using the MoSCoW prioritisation, the priority can be coded into the phrase by replacing *"shall"* by the verbs "*must*", "*should*", "*could*" or "*will likely not*".

3. Introducing the ARCH solutions

This section provides an overview of the seven technical solutions that will be developed in the ARCH project. These solutions will be shaped according to the requirements described in the next section. Two of the ARCH solutions are extensions or further developments of already existing tools developed by ARCH partners in previous projects. The other five solutions are new developments within the ARCH project.

For each solution a brief overall system description as well as the method and concept levels of the MCRI architecture are provided.

3.1. The Historic Area Information System HArIS

The Historic Area Information System will be a database of geo-referenced information of historic areas based on the database developed in IT PON01 MASSIMO [16], H2020 SCAN4RECO [17], and FP7 AF3 [18].

Mission

HArIS will enable end-users to **access geo-referenced information about historic and current conditions of historic areas**. It will link both 3D geometry and material information, where possible, enabling structural resistance and simulated ageing analysis when combined with short and long term evolutions of air quality and climate data.

Key concepts

- **Storage of historic area information**
  In order to make informed decisions for resilience building, end-users need access to relevant data about historic areas. This includes descriptive, structural, architectural, and material information, as well as geo-referenced cartographic data. In addition, to support monitoring of the resilience building process, changes to the conditions of historic areas over time need to be tracked. HArIS will store such data and enable tracking of changes of the conditions of historic areas over time.
- **Electronic information sheet**
  Raw data from a database is not well-understandable for end-users. Instead, this data has to be processed into information and condensed into a format useful for end-users. HArIS will provide electronic information sheets with summaries of the main characteristics of the objects included in the database and their indicators for this purpose. The sheets will be provided in a descriptive format that allows tracking of changes over time.
- **Provision of 2D maps**
  Historic areas are spatially explicit, they are contained within a given area and single assets within them have a specific geo-location. Therefore, any information about historic areas is location specific and can be linked to a geo-position on a map. In addition, locating historic areas and specific assets within these areas on a map supports visual planning and design of resilience building measure. Therefore, HArIS will provide access to 2D thematic maps as well as 3rd-party resources including

relevant information about the historic areas relevant to their preservation and protection against adverse climate conditions.

- **Provision of 3D visualisation**
  For detailed analysis of single heritage assets, e.g. buildings, 3D visualisations are extremely helpful, as they allow experts to examine structures and identify material faults without the need to be physically present. In addition, 3D visualisations can help to preserve heritage assets digitally and help reconstruction efforts. HArIS will support such actions by allowing to acquire (both via active 3D scanning/modelling as well access to existing repositories of such data) and store 3D visualisations of (parts of) historic areas based on collected data. Furthermore, machine vision techniques shall enable automated identification of most evident physical (structural and material) deteriorations in 3D models of heritage assets, where active preservation actions are most urgently required.
- **Modularity, portability, and scalability**
  Data about the conditions of historic areas usually comes from different sources, each of which can follow different spatial and temporal resolutions. Therefore, to provide the most complete picture about the conditions of historic areas, these different sources need to be integrated. HArIS will allow the integration of multi-spatial and multi-temporal data from different sources, which will be processed through both commercial off-the-shelf and open-source products as well as novel processing algorithms to allow as much flexibility as possible in the use of different data sources.
- **Non-invasive monitoring**
  By providing electronic information about historic areas integrating data from different sources and tracking changes to this information over time, HArIS enables end-users to monitor the condition of historic areas without the need for invasive monitoring techniques. Those will include automated and autonomous imaging and 3D modelling geared to non-expert users, allowing them to easily identify issues with structures that might require urgent attention.
- **Distributed web application**
  In order to give access to the largest possible group of end-users, a software system shall be platform independent and will not require installation of specific protocols or licences. Third-party systems integrated into the ARCH solutions shall have relevant licenses and access credentials embedded into services provided to end-users, such that a single login shall be sufficient to access a range of ARCH services. Therefore, HArIS will be a distributed, web-based application accessible via service interfaces. It will be accessible from a variety of client devices and using different operating systems, ranging from desktop workstations and portables, to tablets and smartphones. It will be compatible with MS Windows, Linux, Android and iOS.

3.2. The Threats and Hazard Information System THIS

The Threats and Hazard Information System will be a database of geo-referenced environmental threat indicators.

Mission

THIS will enable end-users to **access geo-referenced information about historic and real-time environmental threat indicators** for historic areas.

Key concepts

- **Hazard indicator definition**
  In addition to having access to relevant data about the condition of historic areas (as provided by HArIS), end-users also need access to relevant information about hazards that occur in a historic area. This data needs to be measureable and compatible with the spatial and temporal resolution of other data from historic areas. Therefore, measurable indicators for the hazard assessment, such as parameters for the intensity/amount of rainfall, water levels of rivers and lakes, characteristics of expected earthquakes, air and soil temperature, and atmospheric gases, like methane, ozone, and CO_2 will be identified. Air quality parameters, apart from causing health risks to population, have also adverse effect on speed of ageing of materials of which heritage assets are build. Hence, THIS will correlate aerial pollution and climate data with object material and structural information to simulate ageing effects that might cause not only material, but also structural deteriorations.
- **Storage of historic data and hazard maps**
  The system will allow to store both data by historic events and hazard maps in order to define the hazard indicators. Hazards will include not only those directly accredited to adverse weather conditions or climatic changes, but also effects of natural and human-borne natural disasters, such as wild fires or industrial incidents impacting historic areas.
- **Integration of existing climate services**
  There exists a multitude of publicly accessible services on European, national, and local level that provide relevant hazard data, e.g. the Copernicus Climate Change Service [19] and the Copernicus Emergency Management Service [20] as well as European and National environmental agencies and authorities. Data and information from open access and participatory sensing platforms shall be also integrated, in addition to data from sensors and detectors developed in ARCH for specific needs of pilot sites.
  These services may follow different data formats, spatial and temporal resolutions, and might have different interfaces for access to them. To make as much data from these services accessible to end-users as possible, THIS will integrate them in a common database that will be used as single-point-of-access to end-users. This will also allow to provide specific interfaces for integration with local city data platforms.
- **Integration of newly deployed monitoring techniques**
  The system will allow to acquire real-time (or quasi real-time) data from monitoring techniques such as sensor networks and diffuse sensors. Moreover, data from cloud-based environmental monitoring systems will be integrated.

- **Overall integration of newly gathered and existing data in a multi-hazard model**
  A comprehensive multi-hazard model will be analysed to support the estimation of the occurrence probability of (combinations of) hazard events and their intensity.
- **Distributed web application**
  In order to give access to the largest possible group of end-users, a software system shall be platform independent and will not require installation of specific protocols or licences. Third-party systems integrated into the ARCH solutions shall have relevant licenses and access credentials embedded into services provided to end-users, such that a single login shall be sufficient to access a range of ARCH services. Therefore, THIS will be a distributed, web-based application accessible via service interfaces. It will be accessible from a variety of client devices and using different operating systems, ranging from desktop workstations and portables, to tablets and smartphones.

3.3. The ARCH Decision Support System ARCH DSS

The ARCH Decision Support System will be a web-based, geographical information system (GIS) platform for supporting risk and scenario analysis based on the CIPCast DSS [2] developed in the CIPRNet project [21].

Mission

The ARCH DSS will enable end-users to **conduct scenario and risk analyses for historic areas** with regard to natural hazards. The system will combine data gathered from different sources to allow **constant monitoring of historic areas**. Lastly, the system will allow to **predict risks and damages/impacts**.

Key concepts

- **Storage of external data**
  Scenario and risk analyses require a multitude of different data from different sources, e.g. hazard data, data about exposed elements (including population, economic sectors, built environment, etc.), and vulnerability data (e.g. risk mitigation measures already in place). While some of this data will come from HArIS and THIS, other data might come from existing data platforms of the ARCH pilot cities (e.g. the Hamburg Urban Data Hub [22]). Therefore, the ARCH DSS will provide the capability to store external data to be used for scenario and risk analyses.
- **Map-based visualisation of input and output data**
  Historic areas, related exposed elements, as well as risks faced by them due to hazards are spatially explicit. They are contained within a given area and single assets within them have a specific geo-location. Therefore, any information about historic areas is location specific and can be linked to a geo-position on a map. In addition, risk analyses need to support locating those areas with higher risk within historic areas. Therefore, the ARCH DSS will provide access to 2D maps for input and output data, wherever possible.
- **Prediction of natural events**
  Historic and current information about hazard events only allow to assess the past and current risk level of a historic area. In order to plan measures, predictions about hazard

events are necessary. The ARCH DSS will use the hazard information available to support prediction of selected natural events and estimate their intensity.

- **Prediction of damage scenarios**
  As with hazard events, past and current (physical) damage levels do not allow to predict (physical) damages of future events, which is necessary to support reliable resilience planning. Therefore, the ARCH DSS will allow to predict (physical) damage scenarios for the historic areas based on the intensity of a hazard and the vulnerability of exposed objects.
- **Prediction of impacts and consequences, including cascading effects and interdependencies**
  Besides direct (physical) damages, hazard events result in other direct and indirect impacts (e.g. loss of cultural value, loss of access, loss of revenue, etc.). In addition, hazard events might result in cascading effects to related systems (e.g. ecosystems connected to the historic areas). The ARCH DSS will allow to predict direct and indirect impacts and consequences on historic areas, also considering cascading effects and interdependencies of these areas with the natural and built environments they are embedded in.
- **Constant monitoring of heritage assets**
  By collating data on hazards, the current condition of historic areas, as well as other data from external source, the ARCH DSS will allow to constantly monitoring historic areas.
- **Support of formulation of response strategies**
  Knowing which hazards might affect a historic area and how high the risk level of different sectors within a historic area is, can only be a starting point to assess the status quo. From this point, it is necessary to be able to identify measures that reduce the risk levels of the historic areas. Therefore, the ARCH DSS will allow to formulate response and resilience strategies for given hazard scenarios and will allow to assess their effectiveness while estimating possible benefits (both tangible and intangible) and required resources.

3.4. The Resilience Options Inventory

The Resilience Options Inventory will be a library of resilience-building measures.

Mission

The Resilience Options Inventory will provide end-users with **access to harmonised information about resilience measures**. It will enable end-users to **identify suitable measures to increase resilience** for heritage areas.

Key concepts

- **Resilient measures against climate and geological hazards for historic and agricultural heritage**
  There exist a multitude of measures to build the resilience against different hazards. Analysing and including all of them in a database is out of scope of the project. Therefore, a selection of the most relevant hazards as well as type of historic area (or heritage asset) needs to be conducted. The baseline reports (D3.3) identify the most

relevant hazards for the pilot cities of ARCH and give a description of the historic areas under consideration. Following this information, the resilience options inventory will focus on measures against climate and geological hazards for historic and agricultural heritage.

- **Categorisation of resilience building measures**
  Simply listing resilience building measures is not sufficient to provide end-users with decision-making information. In order to support decision-making, resilience measures need to be categorised according to the disaster risk management phase they might be employed in, as well as which economic, environmental, and institutional benefit they might provide. This information (including an estimate on how useful this information can be for planning purposes) will be stored in the resilience option inventory.
- **Identification of funding opportunities and Linkage to resilience building measures**
  In addition to knowing which measures to implement in which sequence, it is also paramount to know how to finance these measures, preferably in a sustainable and ethical way. Therefore, sustainable, ethical, and social funding opportunities, financing models and tools, as well as fundraising approaches will be identified and linked to the resilience building measure.

3.5. The Resilience Pathway Visualisation Tool

The Resilience Pathway Visualisation Tool will be a graphical tool to design resilience implementation plans.

Mission

The Resilience Pathway Visualisation Tool will enable end-users to **graphically design resilience pathways** in order to build on resilience by **identifying, prioritising and sequencing resilience measures for implementation**.

Key concepts

- **Resilience pathway model**
  Simply knowing which measure might help to build resilience and how to finance them is not enough. In order to make a decision on which measures to implement at which time, end-users need a way to plan the implementation of measures and identify the effects they might have. The resilience pathway visualisation tool will allow to design resilience measure implementation plans using the pathway approach [23]. This will take into consideration climate change and other hazards with other risks and policy areas, focussing on acceptable / tolerable levels of risk, and prioritising decision-making by framing the issue in terms of stakeholder objectives and constraints.
- **Categorisation and sequencing of resilience measures**
  Using the pathway approach, the pathway visualisation tool will allow to choose resilience measures based on their environmental effectiveness and / or economic performance. It will allow to plan for resilience measures that are a) needed to reach the near future resilience objective, and b) needed to reach the far future resilience

objective. A sequencing of over time of these information will allow to identify implementation tipping points (or points of *"no-return"*).

- **Visualisation of resilience pathways**
  Resilience pathways can be highly complex with several different paths to take, each of which provides different effects on the resilience and other aspects (e.g. performance, effectiveness, etc.). In order to support the resilience planning, visualising of pathways is helpful. Therefore, the visualisation tool will display pathways graphically and allow end-users to easily adjust them.
- **Different levels of concretion**
  The necessary information for detailed implementation plans might not always be available. In this case, a simplified plan with less information might be required. The pathway visualisation tool will allow to take this into consideration, allowing to design resilience pathways with different levels of detail.

3.6. The ARCH Resilience Assessment Dashboard RAD

The ARCH Resilience Assessment Dashboard RAD will be a web-based implementation of the ARCH Resilience Assessment Framework. The Framework itself will be described in the forthcoming deliverable D7.3.

Mission

The ARCH RAD will enable end-users to perform **thorough or quick resilience self-assessments** for historic areas. This will be a **guided process** that will include recommendations for the use of other ARCH tools and methods suitable to support certain steps in the resilience assessment and building process.

Key concepts

- **Semi-quantitative resilience assessment**
  Resilience assessments can follow different approaches: quantitative, semi-quantitative, or qualitative [24]. Quantitative assessments measure system performance, regardless of the structure of the system and generally compare the performance of a system before and after a hazard event. Semi-quantitative assessments are designed to assess relevant "resilience system characteristics" to qualify the overall system resilience and usually employs expert opinion approaches. Qualitative resilience assessments on the other hand focus on including qualitative aspects of the resilience practices and moving to a continuous resilience management process. (see [24] and the forthcoming D7.3 for more information on different assessment approaches).
  Because ARCH wants to assess the resilience of historic areas, which include physical built infrastructure, social, cultural, environmental, and economic aspects, as well as different governance and institutional aspects that all influence resilience, <u>a quantitative system performance assessment is likely not suitable</u>. Therefore, the project already suggested in the Description of Actions (DoA) to base the resilience assessment process on the UNDRR Disaster Resilience Scorecard for Cities [25], which consists of questions directly related to the 10 Essentials for making cities resilient, which were launched as an output of the Sendai Framework for Disaster Risk Reduction (2015-

2030) [26]. Like the Scorecard, the resilience assessment of ARCH will therefore be a semi-quantitative, multi-stakeholder assessment approach based on expert judgements.

- **Guided process**
  Assessing resilience requires a lot of information from different sources (e.g. other departments / institutions, or publicly available information from different data platforms), which might need to be processed further to be usable for an assessment. In addition, the resilience assessment process usually includes a multitude of different stakeholders groups with different backgrounds and expectations. Therefore, it is essential to guide the main person (or team) responsible for the resilience assessment through this process, providing tips and support for each stage of the assessment process.
- **Link to other ARCH tools**
  The resilience assessment process might be supported by different new or existing tools (e.g. for providing information about relevant hazard scenarios or resilience building measures). RAD will directly link to other ARCH solutions at appropriate steps of the assessment process and the assessment results in order to further guide end-users through the process.
- **Identification of resilience weak points**
  The aim of resilience assessments is to identify areas within the examined system where actions are required. RAD will allow to identify such resilience weak points within the resilience scoring and list them after the assessment, allowing end-users to specifically tackle these resilience areas with dedicated actions.
- **Formulation of resilience action plans**
  Besides knowing which resilience weak points a historic area has, it is important to identify resilience measures that can help to strengthen these weak points. RAD will allow to formulate resilience action plans to address these resilience weak points, after conducting the resilience assessment. Suitable resilience measures will be identified and linked within the assessment process.
- **Multi-stakeholder process**
  As mentioned above, the resilience assessment process requires input from different sources and the assessment process needs to reflect this by being tailored to be conducted by a multi-stakeholder group. Therefore, RAD allows input from and cooperation of multiple stakeholders to conduct a joint resilience assessment based on expert judgement.
- **Adaptable to local conditions / needs and available resources**
  Local conditions and available resources differ. Not all data might be available or time / personnel to conduct an assessment might be severely restricted. The assessment procedure operationalised in RAD will be adaptable to the conditions and resources of the stakeholder group that is performing the assessment. Necessary resources to address different assessment topics will be reported.
- **Multi-level, hierarchical resilience assessment**
  Historic areas and single heritage assets are embedded within larger systems, both physically as well as in terms of governance (e.g. disaster risk management plans are often formulated on a national level). As multiple resilience aspects are directly connected to measures conducted on different hierarchical levels, resilience

assessments need to consider these hierarchical relationships. Therefore, the assessment approach of RAD will aim to cover multiple spatial / governance levels, from regional to site. These levels will be linked in a hierarchy to indicate which topics of the assessment should be answered on which governance level.

- **Web-based assessment tool**
  In order to give access to the largest possible group of end-users, a software system shall be platform independent and will not require installation of specific protocols or licences. Third-party systems integrated into the ARCH solutions shall have relevant licenses and access credentials embedded into services provided to end-users, such that a single login shall be sufficient to access a range of ARCH services. Therefore, RAD will be a distributed, web-based application. It will be accessible from a variety of client devices and using different operating systems, ranging from desktop workstations and portables, to tablets and smartphones.

3.7. The ARCH Hub

The ARCH Hub will be a collaborative, web-based data and information platform that collects and incorporates the aforementioned ARCH tools as well as the linked information, methods and datasets of ARCH.

Mission

The ARCH Hub will be the overall access point and integration platform of **all relevant ARCH solutions and information.** It will enable a **collaborative management of the resilience building process** and will allow the **sharing of best practices** by providing access to selected user groups.

Key Concepts

- **Integration of and access/link to ARCH developments**
  In order to make finding and applying the different ARCH solutions as easy as possible, a common access point is needed. The ARCH Hub will bundle all previously mentioned technical ARCH developments as well as other relevant methodologies and tools, information and data sets to give end-users a common platform for accessing them.
- **Information and guidance**
  The ARCH solutions on their own might not necessarily be self-explanatory to all audiences. In addition, how they fit together might also not be immediately obvious. Therefore, the ARCH Hub will include information and guidance for the different ARCH tools in order to provide end-users with enough information to employ these tools themselves.
- **Collaborative management**
  Resilience assessment and building is usually not done alone, but by a team of multiple stakeholders. Therefore, the ARCH Hub will allow teams of end-users to collaboratively assess the resilience of their historic areas and manage the resilience building process.
- **Sharing of best practices**
  Resilience assessment is not done in a vacuum. Other end-users might have found solutions to increase the resilience of historic areas similar to a historic area under examination by another end-user. This information should be accessible in order to

help end-users identify resilience measures for their historic areas. Therefore, the ARCH Hub will allow to share information about best-practices in resilience building with other end-users and user groups.

- **Web-based application with different user groups**
  In order to give access to the largest possible group of end-users, a software system shall be platform independent and will not require installation of specific protocols or licences. Third-party systems integrated into the ARCH solutions shall have relevant licenses and access credentials embedded into services provided to end-users, such that a single login shall be sufficient to access a range of ARCH services. Therefore, the ARCH Hub will be a distributed, web-based application. It will be accessible from a variety of client devices and using different operating systems, ranging from desktop workstations and portables, to tablets and smartphones.

4. Requirements

This section lists all requirements elicited until the end of April 2020, divided into general requirements (city case independent) and city case specific requirements.

4.1. Requirement types

ARCH currently employs a requirement classification scheme with five types based on a modified sub-set as employed in most software development projects:

- **Functional** requirements describe a functionality or service that a system should provide;
- **Organisational** requirements describe roles and responsibilities that a system should support;
- **Security** requirements describe security aspects a system should fulfill;
- **Technical** requirements describe technical aspects that a system should fulfill; and
- **Usability** requirements describe expectations and specifications that ensure that a system is easy to use.

4.2. Structure of Requirements

The tabular representation scheme for documenting requirements contains the following information:

- **Requirement ID** – is a unique identification number of the requirement, combined of the type and number of requirements (F: Functional requirement, T: Technical requirement, U: Usability requirement, S: Security requirement, O: Organisational requirement). Requirements that are specific for one city case are given an ID prefix including the first letter of the city name, such as FB, FC, FH, or FV, meaning functional requirements for Bratislava, Camerino, Hamburg or Valencia, respectively.
- **Type** – one of five types of requirements, as stated above
- **System** – an indication for which ARCH systems the requirement holds
- **City case** – describes for which city case the requirement holds (Bratislava, Camerino, Hamburg, Valencia, All)
- **Status** – the requirement life cycle status described in section 2.2.2
- **Priority** (MoSCoW) – is determined by the importance of the requirement for end-users. Priority is denoted by M(ust), S(hould), C(ould) and W(on't) tags.
- **Description** – provides explanation of the requirement.
- **Source** – indicates the origin of a given requirement (e.g. DoA, Consortium experience, end-user/stakeholder).
- **Additional information (optional)** – provides complementary information for the requirement description (e.g. web links). It may also describe assumptions.

Throughout the co-creation process, the table of requirements will be maintained and updated to account for the repeated short cycles of development, deployment and testing of the co-created technical systems. The priority will be collaboratively agreed upon among city partners and technical partners. The test and evaluation of a prototype tool may lead to changed requirements and changed priorities for the next co-creation cycle. Also, the priority may depend on available resources (workforce, remaining person months for development, availability of data and more).

In the requirement description, the term “*the system*” can either refer to the whole “system of systems” produced in ARCH, or to one or more (sub-) systems. This is indicated by an “X” in the respective system column. It is good practice to be able to trace back the source of each requirement, i.e. writing down from which document, workshop, partner or other source the requirement originates.

4.3. **General Requirements**

General requirements concern aspects of the system that are not city-specific. There are general requirements of all five types: Usability, Technical, Security, Organisational, and Functional.

4.3.1. Usability Requirements

ID	HArIS	THIS	ARCH DSS	ARCH Hub	RAD	Res. Opt. Inv.	Pathway vis.	Priority	Description	Source	Additional Information
U-01	X	X	X	X	X	X	X	M	The user interface must support the main languages spoken in the ARCH pilot cities	General considerations	The languages spoken in the ARCH pilot cities are: English, German, Italian, Spanish, and Slovak
U-02			X	X				M	The system must memorise the user's personal settings (language, notification settings, GUI settings).	General considerations	
U-03	X	X	X	X	X	X	X	S	The system should follow accessibility guidelines outlined by the W3C.	ARCH D7.1 - SotA 6, CWA 17302	https://www.w3.org/standards/webdesign/accessibility
U-04	X	X	X	X	X	X	X	S	During a session involving several ARCH tools, the user should be required to enter login credentials only once (Single Sign-On).	General considerations	
U-05			X	X	X			S	The system should be usable on smartphones and tablet computers.	General considerations	Access via browser should be supported for iOS, iPadOS, Android and Windows 10.
U-06				X				S	The system should use human-readable URLs to retrieve pages.	ARCH D7.1 - SotA 6, CWA 17302	

4.3.2. Technical Requirements

ID	HArIS	THIS	ARCH DSS	ARCH Hub	RAD	Res. Opt. Inv.	Pathway vis.	Priority	Description	Source	Additional Information
T-01	X	X	X	X	X	X	X	M	The system must be a publically available web application with a restricted section for sensitive data that requires authorisation.	General considerations	
T-02	X	X	X	X	X	X	X	S	System services that are adapted or created for ARCH should follow the representational state transfer (REST) paradigm for communication with other services (excludes already established platforms).	General considerations	https://en.wikipedia.org/wiki/Representational_state_transfer, accessed on 2020-05-05
T-03	X	X	X	X	X	X	X	C	The system could provide backend functionality to avoid entering redundant information into the databases of ARCH systems (only for data where ARCH systems are the data master)	ARCH D7.1 - SotA 6, CWA 17302	

4.3.3. Security Requirements

ID	HArIS	THIS	ARCH DSS	ARCH Hub	RAD	Res. Opt. Inv.	Pathway vis.	Priority	Description	Source	Additional Information
S-01	X	X	X	X	X	X	X	M	The hardware running the ARCH tools must be located within EU jurisdiction.	General considerations	
S-02	X	X	X	X	X	X	X	M	The system must comply with the EU GDPR.	General considerations	
S-03	X	X	X	X	X			M	Logging into the system must be protected by password.	General considerations	
S-04	X	X	X	X	X			M	The system must allow the user to re-set lost passwords.	General considerations	
S-05	X	X	X	X	X			M	The system must provide encrypted communication with the user client device (e.g. HTTPS).	General considerations	
S-06	X	X	X	X	X			M	The system must log and record access to potentially security critical data and functions.	General considerations	

4.3.4. Organisational Requirements

ID	HArIS	THIS	ARCH DSS	ARCH Hub	RAD	Res. Opt. Inv.	Pathway vis.	Priority	Description	Source	Additional Information
O-01	X	X	X	X	X			M	The system must allow new users to register.	General considerations	

O-02	X	X	X	X	X			M	The system must allow users to delete their accounts.	General considerations	
O-03	X	X	X	X	X			M	The system must provide role-based authorisation and rights management.	General considerations	A model for rights and roles has to be defined.
O-04	X	X	X	X	X			M	The system must provide the user role "system administrator" with maximum privileges.	General considerations	A model for rights and roles has to be defined.
O-05	X	X	X	X	X			M	The system must provide the user role "group user" with defined group-related privileges.	General considerations	A model for rights and roles has to be defined.
O-06	X	X	X	X	X			M	The system must provide the user role "user" as the default role for newly registered users with access only to public resources.	General considerations	A model for rights and roles has to be defined.
O-07	X	X	X	X	X			M	The system must allow the administrator to assign rights and roles to users.	General considerations	A model for rights and roles has to be defined.
O-08				X				M	The system must allow the creation of group workspaces (e.g. for each city)	General considerations	

4.3.5. Functional Requirements

ID	HArIS	THIS	ARCH DSS	ARCH Hub	RAD	Res. Opt. Inv.	Pathway vis.	Priority	Description	Source	Additional Information
F-01	X	X	X	X	X	X	X	M	The system must allow the user to export and download data sets (assuming compliance with licensing agreements and access restrictions).	City needs survey GA02	
F-02	X		X					M	The system must be able to display the location and area of CH objects on a map.	Adapted from SHELTER reqs. D6.1	
F-03	X		X					M	The system must allow selected users to update CH object / area data.	Adapted from SHELTER reqs. D6.1	Given the user has appropriate rights.
F-04	X							M	The system must include the status of a building (e.g. ruin, needs repair, …)	City needs survey GA02	
F-05	X							M	The system must include information on ownership of the building (private, public, etc.).	City needs survey GA02	
F-06	X							M	The system must contain information about material, structure and chemical properties of heritage assets.	City needs survey GA02 / ARCH DOA WP4	
F-07			X					M	The system must provide detailed information about the calculation of risks and impacts (i.e. how are values created, how does the method work).	City needs survey GA02	
F-08				X				M	The system must guide the users among the different ARCH tools.	ARCH DoA	
F-09				X				M	The system must allow to share resilience scores with other users. The default is not sharing with anybody.	City needs survey GA02	Sharing could be controlled by selecting individual users, selecting

											one or several groups, all registered users, or everybody (non-users).
F-10					X			M	The system must allow users to write suggestions and comments about issues related to CH resilience.	Adapted from SMR (Smart Mature Resilience) requirements (D2.5)	
F-11						X		M	The system must provide qualitative information on cost-effectiveness of resilience measures.	ARCH DoA WP6	
F-12						X		M	The system must provide qualitative indicators to measure the effectiveness of resilience measures.	ARCH DoA WP6	
F-13						X		M	The system must provide measures covering the whole disaster risk management cycle (before, during and after disaster)	City needs survey GA02 / ARCH DoA WP6	
F-14	X	X	X	X	X	X	X	S	The system's functions should be complementary to existing tools, indicators, policies and procedures that are currently being used for the heritage sites.	adapted from SMR (Smart Mature Resilience) requirements (D2.5)	
F-15	X		X					S	The system should allow to examine scenarios on different spatial scales.	Camerino meeting minutes 12.02.2020	
F-16	X							S	The system should interface with the SCAN4RECO database for data about the ageing process of materials.	Adapted from Scan4Reco project	Refers to metals, marbles and wood
F-17	X							S	The system should be able to integrate data from advanced sources such as sensors, drones and other live data sources.	ARCH DoA WP4 / also CWA 17302, ARCH D7.1 - SotA 6	
F-18	X							S	The system should include information on previous interventions and change of use of heritage objects.	Camerino meeting minutes 12.02.2020	

F-19	X							S	The system should contain disaggregated data on CH areas that reflects social characteristics.	ARCH D7.1 - SotA 5	
F-20	X							S	The system should use a data model following the ontology for cultural heritage information of ISO 21127.	ARCH D7.1 - SotA 6, ISO 21127	
F-21	X							S	The system should support a structured rapid damage assessment for CH buildings.	Camerino meeting minutes 12.02.2020	Such as AeDES (Agibilità e Danno nell'Emergenza Sismica), a printed Rapid Post-Earthquake Damage Evaluation form from GDNT.
F-22		X	X					S	The system should provide information on heritage assets to assess slow motions and damage progress in soils, structures and artefacts.	ARCH DoA	
F-23		X	X					S	The system should allow to download a map as displayed on screen (e.g. hazard maps, impact maps, risk maps, temperature maps).	City needs survey GA02	
F-24		X						S	The system should include Copernicus Services.	List of data services to-be-integrated, as provided by INGV	https://copernicus.eu/
F-25		X						S	The system should retrieve real-time data on weather and pollution from external sources (e.g. RFSAT sensor network, NetAtmo portal)	List of data services to-be-integrated, as provided by INGV	
F-26			X	X				S	The system should give information about which chemicals and exogenous agents have corrosive effects on the materials used in CH objects to users with appropriate security clearance.	Adapted from Hyperion D2.1; Venice case	The specific information to be stored/provided will be defined following the need-to-know principle. User security clearance levels will be controlled by (tool) administrators in collaboration with a responsible person from the pilot city.

F-27			X					S	The system should allow to adjust the thresholds for impact classification for risk analysis by authorised users.	Adapted from SHELTER reqs. D6.1	
F-28			X					S	The system should be linked to the IVAVIA process (Impact and Vulnerability Analysis of Vital Infrastructures and Built-Up Areas) from the RESIN project.	ARCH DoA	
F-29			X					S	The system should provide a damage simulation for different scenarios of extreme events and CC-induced events, accessible to users with appropriate security clearance.	Camerino meeting minutes 12.02.2020	Given that the cities provide historical data and data about physical assets. The specific information to be stored/provided will be defined following the need-to-know principle. User security clearance levels will be controlled by (tool) administrators in collaboration with a responsible person from the pilot city.
F-30			X					S	The system should support an impact assessment for different scenarios of extreme events and CC-induced events, accessible to users with appropriate security clearance.	Camerino meeting minutes 12.02.2020	The specific information to be stored/provided will be defined following the need-to-know principle. User security clearance levels will be controlled by (tool) administrators in collaboration with a responsible person from the pilot city.
F-31			X					S	The system should be able to display existing damage patterns using 3D building models for selected buildings.	Camerino meeting minutes 12.02.2020	
F-32			X					S	The system should follow the best practices reported in CEN/TR 15449-2 on Geographic information and spatial data infrastructures	ARCH D7.1 - SotA 6	

F-33			X					S	The system should calculate impacts that differentiate between social characteristics of the affected people.	ARCH D7.1 - SotA 5	Given that data on social parameters is provided for the cities and that impact indicators can be found.
F-34			X					S	The system should be able to present the source of the used data and make it traceable.	SHELTER reqs. D6.1	
F-35				X				S	The system should provide best practices for resilience building for CH.	Adapted from Hyperion D2.1; Tonsberg case	E.g. local knowledge on climate change and agriculture in case of Valencia
F-36				X				S	The system should provide an FAQ section which is editable by users with appropriate rights.	General considerations	
F-37				X				S	The system should allow users to publish information about their ongoing resilience work in the city.	Adapted from SMR (Smart Mature Resilience) requirements (D2.5)	
F-38				X				S	The system should allow users to publish best practices for their local context.	Adapted from SMR (Smart Mature Resilience) requirements (D2.5)	
F-39					X			S	The system should allow users to subscribe to ongoing resilience assessments in order to receive change notifications.	Adapted from SMR (Smart Mature Resilience) requirements (D2.5)	
F-40					X			S	The system should allow the user to enter information about the local governance and organisational structure related to CH and DRM.	ARCH D7.1 - SotA 1	This does not include personal information (e.g. names or contact details)
F-41					X			S	The system should be able to identify resilience weak points.	Technical session 16.04.2020	
F-42						X		S	The system should provide support to find suitable ways to finance resilience-building measures.	ARCH DoA WP6	

F-43						X		S	The system should provide information about finding the appropriate measures to promote resilience against specific hazards.	Adapted from SMR (Smart Mature Resilience) requirements (D2.5)	
F-44						X		S	The system should provide resilience options that distinguish impacts on population groups with regard to social characteristics, where possible.	ARCH D7.1 - SotA 5	
F-45							X	S	The system should provide a prioritisation of resilience-building measures within the roadmap.	Adapted from SMR (Smart Mature Resilience) requirements (D2.5)	
F-46	X			X				C	The system could provide access to publically available contingency plans (if existing) for securing CH in conjuction with extreme weather events.	adapted from Hyperion D2.1; Tonsberg case	
F-47	X							C	The system could support a protocol for maintenance and inspection of CH objects.	adapted from Hyperion D2.1; Granada case	A protocol has to be defined and could be integrated as an input form, feeding the HARIS system.
F-48		X	X					C	The system could allow the user to save a visualisation (e.g. a map with selected layers) under a given name, to reload it at a later point in time.	City needs survey GA02	
F-49			X			X	X	C	The system could be able to show the effects within a selected scenario, assuming that specific resilience-building measures (pathways) would be implemented (what-if scenario simulation).	adapted from SMR (Smart Mature Resilience) requirements (D2.5)	Assuming that we are able to geolocate where measures will take place and what effect that would have.
F-50			X					C	The system could provide a vulnerability classification for supported classes of CH objects.	adapted from Hyperion D2.1; Tonsberg case	Prerequisite: Cities and partners need to provide data and models for developing vulnerability attributes and indexes.

F-51				X				C	The system could allow to contact other users (e.g. cities with similar issues but better resilience score) given appropriate rights.	City needs survey GA02	
F-52				X				C	The system could provide the user with a search function to find relevant information.	general considerations	
F-53					X			C	The system's resilience assessment could be aligned with ASTM E 3032 (Standard Guide for Climate Resiliency Planning and Strategy)	SotA 6	
F-54					X			C	The system's resilience assessment could be aligned with ISO 14090 (Adaptation to Climate Change)	SotA 6	
F-55						X		C	The system could contain measures to faciliate that critical infrastructures which are linked to CH are able to deliver essential services in case of disaster.	adapted from SMR (Smart Mature Resilience) requirements (D2.5)	

4.4. City-Specific Requirements

4.4.1. Bratislava Functional Requirements

Bratislava's functional requirements are currently a few, since the co-creation processes with Bratislava was less intensive until the moment of writing this report. An extensive match-making session, which will result in additional requirements that could not be included in this report, is schedule for the end of May 2020.

ID	HArIS	THIS	ARCH DSS	ARCH Hub	RAD	Res. Opt. Inv.	Pathway vis.	Priority	Description	Source	Additional Information
FB-01			X					M	The system must provide pluvial flood maps for Bratislava.	ARCH DoA	
FB-02	X		X					S	The system should provide data on surface permeability for Bratislava.	ARCH D3.3 - Bratislava baseline report	
FB-03	X							S	The system should retrieve ownership information on buildings from the Bratislava cadastre map (cadastre web portal).	City needs survey at GA02	https://www.katasterportal.sk/kapor/informacie.do https://www.geoportal.sk/en/kataster/
FB-04			X					S	The system should provide visitor statistics for CH buildings in Bratislava.	City needs survey GA02	
FB-05			X					S	The system should provide city heat maps (temperature) for Bratislava.	City needs survey GA02	

FB-06						X		S	The system should include adaptation measures related to pavement materials with different water permeability.	ARCH D3.3 - Bratislava baseline report	
FB-07		X	X					C	The system could provide a warning when monitored parameters exceed normal or critical thresholds. (E.g. an ozone warning when the concentration of ozone over the city surpasses 180 µg/m^3)	City needs survey GA02	The exact number of the threshold remains to be determined.

4.4.2. Camerino Functional Requirements

Camerino's functional requirements were gathered from the city needs survey conducted at the second General assembly meeting (GA02) in November 2019 as well as from city partner meetings. Several external sources have already been pre-selected for implementation by the project partners.

ID	HArIS	THIS	ARCH DSS	ARCH Hub	RAD	Res. Opt. Inv.	Pathway vis.	Priority	Description	Source	Additional Information
FC-01	X							M	The system must allow to manage information about movable heritage objects including storage location, original location and guidelines for the managing and securing of artefacts and artwork after seismic events.	City needs survey GA02	A data model for storage deposits needs to be defined. Actions: 1) Mapping of cultural heritage goods in the Old Town, providing a database system with information about exhibition and preservation criteria, major

											vulnerabilities and traceability measures. 2) Analysis of suitable and effective sites for the recovery in case of disasters. 3) Assessment model for the historic-economic-social value of the existing cultural heritage giving priority ranks.
FC-02		X						M	The system must be able to use the data provided by the Real-time Urban Seismic Network (RUSN) to be deployed in Camerino.	ARCH DoA	Monitoring of cultural heritage with a significant value in order to provide alerts and real-time information about damage due to natural hazards and degradation
FC-03	X	X	X					S	The system should allow to monitor characteristic parameters of building vibrations (using sensor data for modelling the dynamic vibration).	Camerino meeting minutes 12.02.2020	
FC-04	X	X	X					S	The system should allow to monitor material degradation using sensor data.	Camerino meeting minutes 12.02.2020	
FC-05	X							S	The system should incorporate data from cadastral maps of Camerino.	Camerino meeting minutes of 11.03.2020	
FC-06	X							S	The system should retrieve LIDAR data and interferometric data for Camerino.	List of data services to-be-integrated, as provided by INGV	
FC-07	X							S	The system should contain building footprints of the historic areas in Camerino from the town management plan.	List of data services to-be-integrated, as provided by INGV	.DXF provided by Camerino
FC-08	X							S	The system should provide data from MEMS installed at the Palazzo Ducale and Santa Maria in Via Church.	Camerino meeting minutes 12.02.2020	Installation and evaluation of a permanent monitoring-alert system for two case studies: Santa Maria in Via Church and the Ducal Palace, to support the decision making about retrofit and preservation actions,

											including collection of information for improving the efficiency of emergency actions (e.g. rescue of artworks).
FC-09		X						S	The system should retrieve information on environmental risks and hazards (incl. Hydrogeological risks) for Camerino.	List of data services to-be-integrated, as provided by INGV	http://www.pcn.minambiente.it/mattm/en/services/
FC-10		X						S	The system should retrieve earthquake and seismic data from external sources.	List of data services to-be-integrated, as provided by INGV	https://earthquake.usgs.gov/
FC-11			X					S	The system should provide Peak Ground Acceleration (PGA) and spectral acceleration shake maps using Ground Motion Prediction Equations (GMPE).	Camerino meeting minutes 12.02.2020	https://www.researchgate.net/publication/226610764_Ground_motion_prediction_equations_derived_from_the_Italian_strong_motion_database
FC-12			X					S	The system should include economic and social maps on building level, including visitor numbers for CH buildings.	Camerino meeting minutes of 11.03.2020	

4.4.3. Hamburg Functional Requirements

Hamburg's functional requirements have mainly been assessed from the city needs survey conducted at the second General assembly meeting (GA02) in November 2019 and during a virtual visit with Hamburg stakeholders on 04.03.2020, resulting in a down-priorisation of initially stated requirements (won't have) due to stakeholder interests.

ID	HArIS	THIS	ARCH DSS	ARCH Hub	RAD	Res. Opt. Inv.	Pathway vis.	Priority	Description	Source	Additional Information
FH-01	X	X	X					M	The system must interface with the Hamburg Urban Data Hub.	City needs survey GA02	
FH-02	X	X	X					M	The system must interface with the Hamburg ATLAS system.	City needs survey GA02	
FH-03	X		X					S	The system should include 3D models of selected buildings within the Speicherstadt.	Hamburg city visit w. stakeholders 04.03.2020	
FH-04	X		X					S	The system should be able to exchange building information (including 3D models) compatible with Hamburg's BIM (building information model).	Hamburg city visit w. stakeholders 04.03.2020	The Hamburg systems using BIM are the Urban Data Hub and Urban Data Platform. This shall support the long-term strategy of digitising object management in the city.
FH-05	X		X					S	The system should provide construction parameters for bricks (including carrying capacity, action of frost) used in the quay walls and selected Speicherstadt buildings (German: "Backsteinkataster")	Hamburg city visit w. stakeholders 04.03.2020	
FH-06		X	X					C	The system could include hazard maps for floods for the Hamburg heritage area.	City needs survey GA02	
FH-07			X					C	The system could provide a model for heat impact to copper roofs.	City needs survey GA02	

FH-08				X				C	The system could include methdological descriptions about chemical examinations of wooden poles.	Hamburg city call	Might require additional work, e.g. actual extraction of samples from wooden poles for a trial run
FH-09	X							W	The system will likely not offer underwater imaging for Hamburg canals using UUS drones on demand.	RFSAT	
FH-10	X							W	The system will likely not include chemical data of wooden poles for monitoring purposes	City needs survey GA02	
FH-11		X						W	The system will likely not provide data for modelling prolonged intervals of low water levels.	General considerations / Hamburg city case	
FH-12						X		W	The system will likely not include measures on applying absorbents/protectors/plasters to walls and surfaces for protection.	Adapted from Hyperion D2.1; Venice case	
FH-13	X	X	X					W	The system will likely not allow to assess the risk posed by microorganisms and climate change to the wooden poles beneath the Speicherstadt.	Hamburg city visit w. stakeholders 04.03.2020	

4.4.4. Valencia Functional Requirements

The requirements for Valencia mainly stem from the city needs survey at the second General Assembly meeting in November 2019, two online match-making sessions on 31.03.2020 and 01.04.2020, as well as a technical session on 16.04.2020. Some rather advanced features were gathered as requirements, resulting in a low priority.

ID	HArIS	THIS	ARCH DSS	ARCH Hub	RAD	Res. Opt. Inv.	Pathway vis.	Priority	Description	Source	Additional Information
FV-01		X						M	The system must provide information on seasonal weather patterns.	City needs survey GA02	
FV-02	X							S	The system should interface with the Valencia Geoportal.	List of data services to-be-integrated, as provided by INGV	https://geoportal.valencia.es/home/
FV-03	X							S	The system should include elevation model-based products (e.g. slope, morphology) for La Huerta and Albufera.	Technical session 16.04.2020	
FV-04	X							S	The system should include sensor data (climate, weather and air quality) from open-access platforms and newly deployed platforms for La Huerta and Albufera.	Technical session 16.04.2020	
FV-05		X	X					S	The system should provide temperature maps from satellite sensors for La Huerta and Albufera.	City needs matrix V4, Technical session 16.04.2020	
FV-06		X	X					S	The system should be able to show burned areas on a map for selected parts of Albufera.	Technical session 16.04.2020	

FV-07		X						S	The system should provide climate projections for Valencia from Copernicus.	List of data services to-be-integrated, as provided by INGV	
FV-08		X						S	The system should retrieve geographic data for Valencia from external sources.	List of data services to-be-integrated, as provided by INGV	http://centrodedescargas.cnig.es/CentroDescargas/index.jsp
FV-09			X					S	The system should allow to assess the cooling effect of La Huerta and Albufera through thermal modelling.	Technical session 16.04.2020	
FV-10			X					S	The system should provide risk calculations for forest fire hazards in the Devesa de Saler area, accessible to users with appropriate security clearance.	City needs matrix V3 from 31.03.2020	"The specific information to be stored/provided will be defined following the need-to-know principle.
FV-11			X					S	The system should provide data on surface soil moisture, land use, vegetation indices and morphology change from satellite imaging for La Huerta and Albufera.	City needs matrix V3 from 31.03.2020	
FV-12			X					S	The system should support indicator-based climate change risk analysis for La Huerta and Albufera.	Technical session 16.04.2020	
FV-13						X		S	The system should include cooling measures for the city of Valencia.	Technical session 16.04.2020	
FV-14	X	X	X					C	The system could be able to simulate forest fire propagation under estimated weather and environmental conditions.	Technical session 16.04.2020	
FV-15	X		X					C	The system could provide soil moisture and fertilisation monitoring using ground sensors for selected parcels of La Huerta and Albufera.	Technical session 16.04.2020	
FV-16	X		X					C	The system could allow to analyse crop growth, ground envelope and structures	Technical session 16.04.2020	

									using 3D modelling for selected parcels of La Huerta and Albufera.		
FV-17			X			X		C	The system could provide potential changes in fire risk assuming changes in agricultural residual burning practices in the Devesa de Saler area.	City needs matrix V3 from 31.03.2020	
FV-18			X					C	The system could display the state of crops via use of satellite images	City needs survey GA02	
FV-19			X					C	The system could provide low-altitude, close-proximity aerial multispectral imaging for crop health monitoring.	Technical session 16.04.2020	
FV-20			X					W	The system will likely not provide a model to calculate CC-induced impacts on crops	City needs survey GA02	
FV-21			X					W	The system will likely not provide hydraulic modelling for irrigation channels in La Huerta.	Technical session 16.04.2020	
FV-22			X					W	The system will likely not allow to assess water run-off for selected parts of La Huerta via modelling.	Technical session 16.04.2020	
FV-23			X					W	The system will likely not provide water system modelling on catchment level for selected parts of Albufera.	Technical session 16.04.2020	
FV-24			X					C	The system could allow to assess water quality in the Albufera lagoon based on satellite imagery.	Technical session 16.04.2020	

5. Conclusions

This deliverable provides an introduction of the continuous requirements analysis process of the ARCH project as well as an initial collection and classification of the up-to-now identified requirements for the technical ARCH tools that will be created throughout the project. These tools are

- the Historic Area Information System HArIS;
- the Threats and Hazard Information System THIS;
- the ARCH Decision Support System ARCH DSS;
- the Resilience Option Inventory;
- the Resilience Pathway Visualisation Tool;
- the ARCH Resilience Assessment Dashboard RAD; and
- the ARCH data and information platform ARCH Hub.

The requirements for these tools were collected and prioritised by combining an **agile co-creation process** between project partners from the ARCH pilot cities and the technical partners with a **systematic, structured, and continuous requirements analysis process**. The former ensures that the project includes end-users in the development process from an early stage and that their needs are met before rolling out a final product. The latter ensures a common understanding between all involved actors about the scope of the developed solutions and that all solutions start with a common understanding of initial needs from end-users.

Furthermore, this deliverable introduces the Mission-Concepts-Realisation-Implementation (MCRI) architecture approach used to describe the design of the ARCH tools that will be developed over the course of the project and provides initial high-level specifications of these tools by describing their goals (**mission**) and the most important technical and methodological key **concepts** to be employed for reaching the goals. The actual requirements for each tool provide an initial step into the **realisation** level of the system design description.

In total, 134 requirements have been collected, including 78 city case independent general requirements: 6 usability, 3 technical, 6 security, 8 organisational, and 55 functional (see Figure 6). In addition, 56 city case specific functional requirements have been gathered: 7 for Bratislava, 12 for Camerino, 13 for Hamburg, and 24 for Valencia (see Figure 7), reflecting the progress of the co-creation processes with each city case. The gathered requirements are relevant for multiple of the technical systems developed in the ARCH project (see Figure 8):

- 58 requirements target HArIS developed in work package 4;

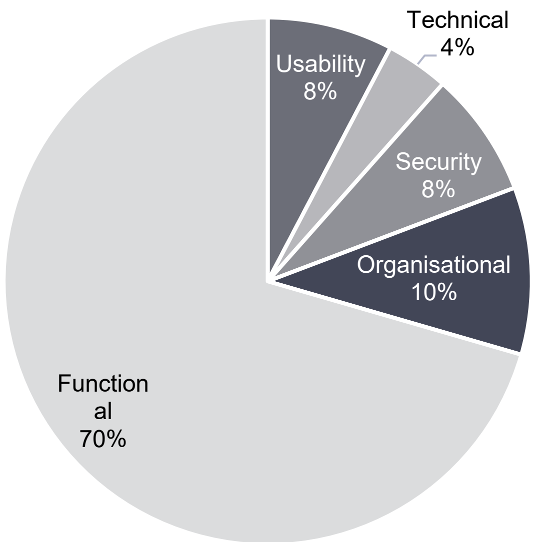

Figure 6: Percentage breakdown of city case independent requirements

- 43 requirements target THIS, also developed in work package 4;
- 75 requirements target the ARCH DSS developed in work package 5;
- 22 requirements target the Resilience Option Inventory developed in work package 6;
- 12 requirements target the Resilience Pathway Visualisation Tool, also developed in work package 6;
- 36 requirements target the ARCH Hub developed in work package 7; and
- 28 requirements target ARCH RAD, also developed in work package 7.

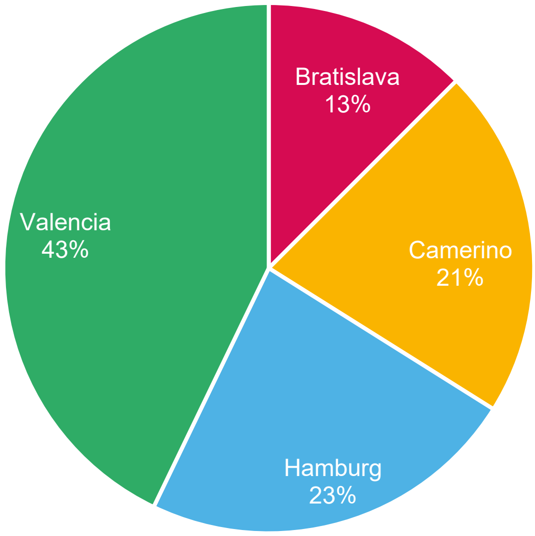

Figure 7: Percentage breakdown of city specific requirements

In addition to categorising the requirements into city case independent and specific requirements, as well as identifying the targeted technical systems, all requirements have been prioritised using the MoSCoW method [3] to guide the development process. In a next step, further features of the ARCH tools to cover the identified requirements will be specified.

In order to account for the agile co-creation process followed by ARCH, this document will be maintained as a living document after submission.

In the upcoming ARCH deliverables of work packages 4, 5, 6, and 7 the specific implementation of the requirements will be documented.

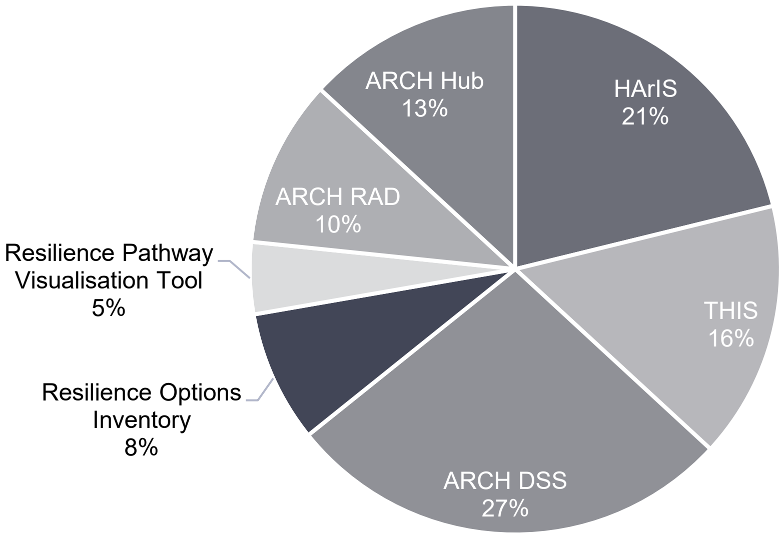

Figure 8: Percentage breakdown of requirements according to relevance for ARCH tools

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