Chapter 11
Data Collection for Estimation of Resilience of Cultural Heritage Assets

Roko Zarnic, Vlatka Rajcic, and Barbara Vodopivec

Abstract Cultural heritage assets, the bearers of historic evidence, are under continuous pressure from change, deterioration, and destruction. Therefore, there is a need to identify and monitor the related risks and to develop appropriate measures for increasing the resilience of cultural heritage. The activities for establishing a European system for data collection and its application in the field of preventive conservation are an ongoing process, where the issue of risks and resilience is well addressed. Recently, there has been an interest in developing a model of built heritage resilience related to mitigation and reaction on sudden environmental impacts, following the resilience models of contemporary buildings. However, these models cannot be simply extended to heritage buildings because of their specific character. In this chapter, a contribution to an acceptable resilience model of heritage buildings is presented.

Keywords Cultural heritage asset • Significance • Data • Cultural heritage services • Resilience model

11.1 Introduction

Since the beginning of this century, the interest in resilience rather than in vulnerability of objects exposed to disaster came in to focus in research and mitigation activities of societies worldwide. The number of publications, documents related to

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preparedness of communities, international events, and investments in research and application of research results is increasing. This is reflected also in the field of cultural heritage safeguarding, where recently the increased interest of the EU Commission can be seen in the promotion of the research through calls in Horizon 2020. However, resilience is still a new term for those with a traditional approach to cultural heritage protection, although it is closely related to the well-established term of “preventive conservation.” Experts in the domain of risk reduction and disaster recovery are familiar with the meaning of resilience and the implementation of its idea, but a wider society of experts and stakeholders involved in heritage preservation and use still need to be better informed about it. Clear definitions contribute to a better understanding, as it has been demonstrated by an overview of definitions of resilience in [1]. However, in continuation, the recent definition of IPCC [2] will be followed: “resilience is the ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions.” Resilience applies to both people and the built and natural environment and is shaped by both physical and social factors.

A comprehensive review and discussion on heritage and resilience is presented in [3], where the role of cultural heritage in disaster risk reduction is examined. The authors quote the outcome document of the UN Conference on Sustainable Development (Rio + 20) [4]: “many people especially the poor, depend directly on ecosystems for their livelihoods, their economic, social and physical well-being, and their cultural heritage,” in order to stress the importance of heritage safeguarding not only because of its memory value but also because of its role in the economies of many countries worldwide. Cultural heritage is a powerful asset for inclusive economic development, but it is important that societies recognize its potential. The well-established term “ecosystem services” can be well applied to the cultural heritage domain by introducing the analog term “cultural heritage services,” as it will be discussed in continuation of this chapter. Introducing this term, clear links between the economic potential of ecosystems and cultural heritage can be established in order to understand the economic potential of heritage assets in particular geographic location. Identification of the economic potential of a cultural heritage asset in a certain society brings forward the awareness of its value and the need for its protection. Consequently, the attention is focused on risks and safeguarding, and the currently popular issue of resilience can serve as an inclusive framework for a new understanding of heritage in the era of climate and societal changes. In this sense, resilience is understood in a wider sense than only in technical terms of disaster risk reduction as it will be explained further in this chapter. The Thimphu Document 1 [5] points to the wider aspects of heritage protection: “the protection of cultural heritage should be promoted, not only because of its intrinsic historic or artistic value, but also because of the fundamental spiritual and psycho-social support and the sense of belonging it provides to communities during the disaster recovery phase, as well as the contribution it makes towards building resilience to the increasing frequency and intensity of disasters and adaptation to climate change". Following the idea of holistic approach to cultural heritage understanding, preservation, and usage, resilience should be understood also as the ability of cultural heritage to recover from unfavorable impacts in its total dimension, ranging from spiritual to material contents and significances.

Studies of cultural heritage engage an extremely large area of professions and activities, where a profound understanding of heritage and its significances is of primary importance. There are many definitions of cultural heritage significance based on internationally well-established doctrines developed within universities, institutions, and international organizations such as UNESCO. In this chapter, the attempt to summarize and group various significances of cultural heritage is presented in order to encompass the entire area of heritage aspects that should be considered when resilience is studied. However, the significances can be identified and studied only if appropriate and reliable data are collected, preserved, and presented in a way that can be used for various purposes, and one of them is the issue of resilience. In today's era of rapid development of IT-based techniques and tools, data collection, storage, and usage seem relatively easy tasks, but such an opinion is misleading. The large amount of available data demands systematic data management and the supporting of an entire set of activities related to cultural heritage preservation, where the increasing of resilience is an important one.

11.2 Significances of Built Heritage

11.2.1 Background of the Definition of Cultural Heritage Significances

In general, the heritage can be grouped into two categories: cultural property, including tangible and intangible objects, and natural heritage. Each of them can be further divided into subgroups, where built heritage can be one of them within the cultural property. Built heritage interacts with the surrounding natural heritage and is an environment for intangible heritage through activities performed in and around the built heritage.

Significances of heritage buildings with architectural and artistic character combine tangible and intangible aspects of cultural heritage. Interdisciplinary research resulted in the definition of significances as described in [6].

Significances were defined on the following contextual bases:

- Detailed knowledge of the research object
- Detailed knowledge of the history and the theory of conservation
- Detailed knowledge of each specific space and context

Those substantive bases determine significances such as:

- Multidisciplinary
- Descriptive (nonmaterial) and measurable (material) properties

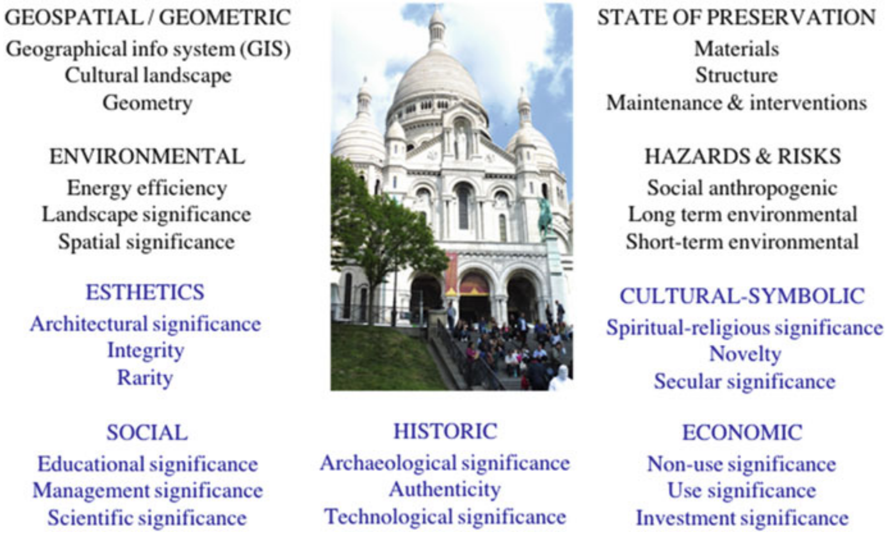

Fig. 11.1 The overview of built heritage significances

- Globally and locally defined according to the context and location
- Universal and specific according to the type of heritage

Definition of significances was carried out in five consecutive steps:

1. Identification
2. Comparative analysis
3. Semantic aggregation
4. Definition of significance
5. Significance tree modeling

Although significances were defined for the built heritage in particular (Fig. 11.1), their broad contextual basis allows them to be used also for other types of heritage. In such a case, the significance structure needs to be reconsidered and reassessed prior to its use. Since the significance scheme simplifies aspects of individual scientific disciplines that need to be addressed, an assessment of heritage significance should still be derived primarily from the evaluation process based on each discipline's methodology.

11.2.2 Definition of Cultural Heritage Significances

Geospatial/Geometric Significances

Geospatial and geometric significances are related to geographic position, cultural landscape characteristics, and geometry of asset. A geographic information system

(GIS) is a system designed to capture, store, manipulate, analyze, manage, and present all types of spatial or geographical data. A cultural landscape, as defined by the World Heritage Committee, is the cultural property that represents the combined works of nature and of man. It is a landscape designed and created intentionally by man, an organically evolved landscape that may be a relict (or fossil) landscape or a continuing landscape. Geometry of cultural heritage asset is defined by the shape of the building and includes presentation of plan, cross sections, facades, architectural details, etc.

State of Preservation

State of preservation is a condition in which cultural heritage asset has been kept by means of regular maintenance and periodic interventions. It is defined by the current condition of materials and structure. The condition of materials is defined by the current characteristics of the materials and the level of decay and damage assessed by the identification of hazards that caused the damages. Condition of structure is defined by structural assessment taking into account the level of material decay and damages of structural elements and components. Maintenance and previous interventions are defined by the assessment of the effects of regular maintenance and previous interventions (preintervention works, conservation, restoration works) on the state of preservation.

Environmental Significances

Environmental significance is related to the sustainability aspects, in particular to the environmental value in terms of protection of environment (restoration and conservation of land, reduction in pollution, and construction waste), as well as in terms of the relationship between heritage and environment/space (embedment of heritage in the space, interaction of natural and cultural heritage, restoration of heritage as a part of spatial planning). Energy efficiency defines the heritage asset in terms of sustainable use of resources in the case of its renewal (reuse of materials, the use of compatible materials), increasing the occupancy comfort by energy-efficient renovation, and the rational use of energy during the use of heritage asset. Landscape significance defines the heritage value emerging from an interaction between the cultural heritage and cultural landscape. A typical example is an environment in which palaces surrounded by gardens compose a unique space of high cultural value. Spatial significance defines spatial heritage value derived from its placement in the local environment, cityscapes, dominant urban silhouettes, etc. It defines contextual integration of a heritage asset in the area as a basis for development opportunities.

Hazards and Risks

Hazards and risks define measurable potential of harmful impacts to heritage assets. They may be natural (long term and sudden) or human induced (intentional and unintentional). They are quantifiable and can be measured or indirectly determined by their consequences. Hazards and risks can be estimated by probabilistic risk assessment, and consequently reduction measures can be undertaken. Human induced defines one or more unintended (improper decision-making, economic activities, accidents) or intended (vandalism and terrorism, riots, war) impacts induced by human activity. Long-term natural hazards are one or more environment-caused impacts, such as biodegradation, climate change, wind, water (groundwater, atmospheric water), solar radiation, particle pollution, aerosols, long-term load, and geological conditions (including local peculiarities). Short-term (sudden) natural hazards are one or more environment-induced impacts through an unexpected occurrence, such as a storm, fire, flood (flash flood, surface flooding), earthquake, landslide, avalanche, tsunami, volcano, etc.

Esthetic Significances

Esthetic significance defines the artistic features such as concept, form, color, etc., often referred to as the artistic value. It includes also the visual characteristics attributed to heritage by values assessment and interpretation, such as beauty, sublimity, esthetics of archaeological remains, etc. In the broadest sense, esthetic importance derives from the intense experience of heritage in terms of all the senses employed (smell, hearing, and touch). Architectural significance relates to the authorship [extraordinary, typical, the most valuable achievement of a certain author(s)], typology (remarkable, typical example of a certain period), and technological value or achievement (a typical example of a particular workmanship, form and style, advance in the design approach, material and structural characteristics). Integrity defines integrity, i.e., high level of preservation of those heritage values that define significance and protection regime of the asset. It is understood as the absence of adverse effects of subsequent interventions, additives, neglect, improper use, and degradation processes. Rarity defines the rareness, the exceptionality of a heritage asset. It can also be measurable, when a particular heritage asset is rare because it is a unique example of a certain historic period, culture, and author or has any other rare significance.

Cultural-Symbolic Significances

Cultural-symbolic significance defines values associated with the concept of “here” and “now”: these are the ideas, habits, actions, attitudes, and in a broader sense, cultural- and civilizational-related values. Cultural significance is sometimes associated with the term civilization and as such defines how certain features of heritage are seen and understood according to each specific context. The symbolic meaning is defined on the basis of the symbols associated with the heritage unit (legends, myths, literature, etc.). In a very broad interpretation, the cultural-symbolic significance may be associated with the feelings of attachment to the heritage site (genius loci). Spiritual-religious significance defines the value derived from religious or other sacred heritage importance. It may be linked to the practices, beliefs, and learning of a particular religion. Novelty defines stylistic unity and ideal condition of the asset (including removal of all later additions). According to novelty, the importance of heritage results from the subsequent recovery, reconstruction, and other interventions that lead to new stylistic unity or return to the previous “ideal state,” which may even never have existed. The appearance of “novelty” has priority over the appearance of “patina” in this concept. Novelty is rejected in contemporary conservation theory, but in practice the approach may still be found.

Secular significance derives from the irreligious feelings of awe, wonder, and from the respect of certain heritage asset or values associated with it. It is closely associated with the type of so-called intentional monuments.

Social Significances
Social significance defines characteristics of heritage, which create the so-called social capital: promotion and facilitation of social networking, creation of social cohesion, and sense of community (identity). It is also associated with the potential of heritage to foster development of society. Educational significance defines the potential of heritage for formal and vocational education as well as, in a wider sense, learning from the past. Management significance covers the management structure and plan of the heritage asset, as well as the protection regime including legal protection (e.g., listed asset), ownership, and accessibility. It refers to the development policy based on the heritage exploitation, including definition of its function and usage. Scientific significance defines the value and potential of heritage for the development of science. Heritage conservation can contribute to the development of new materials, techniques, tools, approaches, and research findings. Preservation process contributes to scientific advances in several disciplines; therefore, it has the potential for multi- and interdisciplinary development of science.

Historic Significances
Historic significance encompasses characteristics that bear witness to the past and illustrate a specific development of historical significance. It can be derived from the link of the asset with certain persons and/or events and for its documentary and archival value. Definition of the criteria is always a result of scientific study and consequent understanding of the heritage. Archaeological significance defines the value of the heritage, based on archaeological findings and on a definition of the archaeological importance of these findings as witnesses of a certain development. It also embraces a definition of a site's archaeological potential (defined on the previous research, confirming not yet excavated archaeological site). Authenticity defines the degree of authenticity and originality of the asset as a whole and of its elements. It is assessed on the basis of preservation level of the original shape and design, materials, purpose and use, traditions, location, as well as of resources related to heritage and defining its value. Authenticity embraces the concept of "age value" which defines evident link of the asset with the past, identifiable as a result of the natural aging cycle without apparent restoration procedures and the effects of premature aging (e.g., Patina). Technological significance defines the value of a heritage as a bearer of information about the stage of technology development. It includes craft skills and craft value associated with methods of material production and construction processes, as well as industrial and technological development (industrial, technical heritage).

Economic Significances
Economic significance defines economic value of heritage, which can be measured either with financial (expressed in money/price) or other methods (contingency

methods). Indirect development effects of heritage preservation are related to social significance. Nonuse value defines the value that cannot be offered and sold on the market and therefore cannot be expressed in financial terms. It is related to general awareness about the existence of the asset, to its availability for general public access and to conservation necessity for its preservation in order to be available to subsequent generations. The use value defines economic importance determined on the basis of the concept of utility, which can be expressed in financial terms. The market value of heritage stems from goods and services that can be offered and sold on the market (fees, wages) and are reflected in the price. Measurements can be performed with economic methods. Investment potential defines effects of investments in cultural heritage asset (reconstruction, restoration, etc.). The bases for assessment are conservation plans and feasibility studies, which include financial and economic analysis (indirect economic and developmental effects among others).

11.2.3 Cultural Heritage Services

Natural and cultural heritage are linked because the natural environment enabled development of cultures that created heritage assets. But, nature and its ecosystems also enabled survival of societies and development of their economic activities. Humans benefit from ecosystems in various ways, and these benefits are nowadays expressed by the term ecosystem services. In [7] authors explain how the new initiatives started at the end of the last century in economics to evaluate the services that nature provides. The value of these services can be broken down roughly as shown in Fig. 11.2. The authors suggest to use the same approach to evaluate the economic potential of cultural heritage by introducing the term of cultural heritage services. The idea of cultural heritage services has been introduced and discussed during the Interreg IVC project HISTCAPE—historic assets and related landscapes (http://www.histcape.eu), which outcomes are presented in publication [8]. Ecosystem services and cultural heritage services are linked through comparable values and uses that are offered both by natural environment and by human-built environment. Both environments are equally exposed to long-term environmental impacts due to climatic changes and sudden events (natural disasters). But even more dangerous are human-induced influences, among which wrong decisions are, besides war destructions, the most dangerous.

The idea of interaction of ecosystem services and cultural heritage services is put forward as an opportunity for creation of jobs and for the increase in the well-being of societies in protected areas as Natura 2000. It is closely related to important issues of sustainable reuse, assessment, and renovation of historic buildings and monuments in rural areas. For example, vernacular architecture solutions could be implemented, using local traditional materials and techniques. This, on the one hand, could be an example of nature-based solution and, on the other hand, could contextualize constructions and preserve the cultural heritage as illustrated in [9].

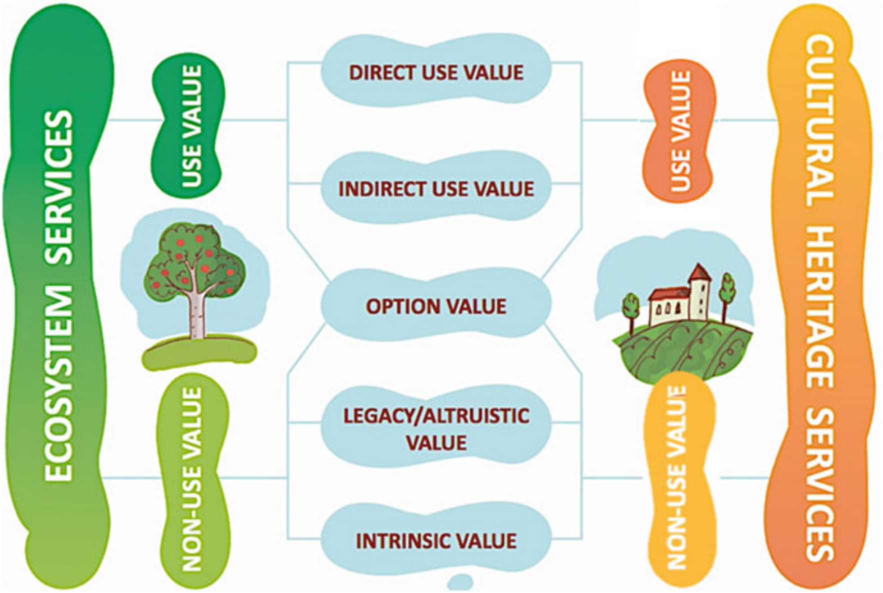

Fig. 11.2 Interconnections between ecosystem and cultural heritage services

11.3 Built Heritage Database Systems

11.3.1 Overview of Current Systems

In many countries, there are well-established systems and tools used to inventory and document cultural heritage. They reflect the tradition of cultural heritage protection, and the local approaches and understandings condition their content structure. In some countries, there are several systems for data collection, which are not connected together. Therefore, a straight comparison of data on heritage assets is not possible. The overview of currently used approaches in seven countries (Croatia, Czech Republic, Greece, Israel, Italy, Poland, and Slovenia) was presented during the 1st EU-CHIC Workshop held in Vienna in 2010 (www.eu-chic.eu) [10]. The Ad Hoc Group for Inventory and Documentation within the Technical Co-operation and Consultancy Programme related to the Integrated Conservation of the Cultural Heritage contributed the most complete effort in harmonization of approaches on at least a basic level by developing three standards related to historic buildings, monuments, archaeological sites, and heritage objects [11]. Earlier, the importance of international documenting standards for protection of cultural heritage has been recognized within the Getty art history information program [12]. The importance of establishing a systematic approach to data collection and usage in the Internet era has been clearly stated in [13]: “The great collective repository of our cultural heritage scattered around the world in libraries, museums, and archives contains vast numbers of art objects and literary works from the past and present. These are fragments of the great mosaic of human civilization. To make sure these pieces can be accessed across collections in ways that benefit our understanding of humankind and improve our quality of life, we need to work together in developing community and multi-institutional Web sites. Fortunately, a handful of models are leading the way".

Writing about the "missing grammar for the digital documentation of the past," Ioannides [14] stresses the problem of lack of standards with the following statement: "Due to unorganized and non-standardized methods of use of these IT tools, the achieved results are predominantly incompatible for different systems, presentations and future use." The most recent contribution to solving the problem of management of cultural heritage data on 3D assets and knowledge is initiated by an interdisciplinary group of professionals in the areas of 3D data acquisition, processing, modeling, archiving, and preservation of 3D cultural heritage assets led by Ioannides [15] to ICOMOS Board (2016) to establish a task force group of experts named MeSeOn (Metadata, Semantics, and Ontologies for 3D CH). The group will propose the guidelines for setting up MeSeOn standards for the tangible and intangible cultural heritage assets.

In order to contribute to the development of internationally recognized protocols for data collection, experts from fourteen European countries, Israel, and Egypt pooled their efforts in the development of the model for the so-called Cultural Heritage Identity Card. It has been developed within the EU-financed Coordinated Action EU-CHIC (FP7-ENV-2008-1 no. 226995, 2009/12). The idea of Identity Card originates from the COST Action C5: "Urban Heritage-Building Maintenance," 1996–2000 [16]. The general conclusion stressed in the final report was that there is a serious lack of reliable data on European urban heritage and a pressing need to collect it, in order to support the ongoing process of refurbishment of existing buildings. COST C5 Action concluded that there are great variations in the systems of establishing and evaluating data from buildings in the European countries. The responsibility for collecting data depends on the administrative structure in each country. Planning of broad activities, such as preventive strengthening or even post-earthquake measures in European earthquake-prone areas or energy preservation measures, can be better based on mutually developed methodology. The basic rules and approach can be developed from the existing European standards and codes. However, no generally accepted approach existed that would lead to European methodology.

The creation of a Pan-European protocol for data collection is just the first step in the ambitious process. The essential part of the data in this protocol is related to the identification of risks to which heritage assets are exposed. It is well known that the vulnerability of assets is one of the main criteria for intervention in asset management in order to increase its resilience. The final aim of the process is to develop a general approach to resilience assessment of heritage assets based on the identification of risks that can be generalized by the introduction of risk indicators.

11.3.2 European Cultural Heritage Identity Card

The main objective of the EU-CHIC Project was to develop and test guidelines that are required for the efficient compilation and storage of data pertinent to each asset under observation. Data can be collected and well maintained only if the appropriate protocols are developed and applied. The documentation protocol can be understood as an envelope with a set of rules, which establish and define the categories of data needed for achievement of a targeted goal. If the protocol for cultural heritage is defined, it can be applied to built heritage, archaeological sites, cultural landscape, heritage objects, and to collections of artifacts. A protocol can be composed of several layers regarding the type of data, their amount, and nature. During their lifetime, the heritage assets have been constantly exposed to external natural influences that increased the material and structure decay processes and to alterations of use and interventions in their structure. The necessary data for evaluation of consequences of events in the assets' lifetime can be collected from different sources and documents, but an on-site inspection is the only way to assess the current state of an asset. From the assessment of an asset under observation and knowledge gained from studying similar cases, a prediction of future behavior can be estimated. The important data for estimation, besides the ones collected by inspection, are risks resulting from events that may happen in the future life of an asset. Sufficient amount of reliable data is necessary for a basis in decision-making that determines and thus influences the future life of an asset. Those who are responsible for an asset should always be ready to answer the simple question: "What will be the consequences of my decisions?"

The collecting of detailed data on cultural heritage assets engages a significant amount of effort by professionals and researchers, which means also the engagement of a significant amount of funds. Therefore, the owners or the responsible organization of authority have property rights and can exploit the data according to their needs. However, a certain amount of data should be given to the interested public for general use (research, education, tourism, etc.). On the other hand, sensitive data that are under the owners' control are needed for management and all other decisions related to ownership of asset. As an answer to these dilemmas, a new structure of data has been developed. It was visualized in the form of an iceberg and named "EU-CHIC Iceberg" or, in short, "CHICBERG" (Fig. 11.3).

Data, which in their total volume create the Identity Card, are divided into two groups (Table 11.1). The "upper" group of data is open to general public use. The "lower" two groups of data are the sensitive ones and of high value to the owner of the asset. Therefore, these can be used only with their permission. Following this scheme, the Cultural Heritage Identity Card is not a single document of the asset but a set of documents that contains comprehensive information and is created and updated during the entire lifetime of an asset. The updating follows the changes to the asset after the initial creating of files. Therefore, the system of three levels is established as presented in Table 11.1. The first level of the Card contains data collected mainly from publicly available sources with additional information about

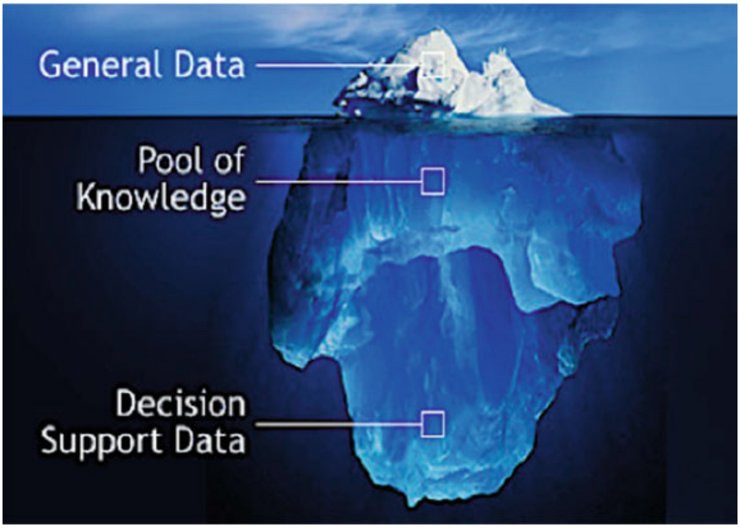

Fig. 11.3 The scheme of CHICBERG

the current physical condition and the major risks to which the asset may be exposed. The original intention of the Card was to establish a system that would enable comparison between assets of the same type across Europe and the Mediterranean countries. The first level of the Card is designed to meet this goal.

The existing standards [11] form an important, well-established system, and the intention of the EU-CHIC is not to compete or replace it but to integrate them to a wider and more ambitious system. The first level of the Card is meant as an introduction to lower, more important levels because the basic information about an asset given in the first level is elaborated in detail in the second level named Pool of Knowledge. The structured knowledge, as presented in Table 11.1, is a basis for the most important aim of the system: support for decision-making that is of crucial importance for the conservation of a cultural heritage asset. One of the most important issues is the prevention of a heritage asset from risks. Risks can be identified not only from past events in the area of heritage asset location but also from the scientific prediction of potentially harmful events. The variety of risks and concurrency of events can be managed by the introduction of risk indicators that enable good prediction of influences even when the amount of reliable data is in sufficient.

Major risks may be divided into two categories regarding their source: environmental and human induced (Table 11.2). The environmental risks are the consequences of either long-term impacts or sudden events. Long-term impacts are expressed in terms of environmental factors that affect the asset, and the results appeared over a long period of time. Sudden environmental impacts are expressed in terms of events that affect the asset in a relatively short time interval (measured in minutes or at most in hours) and its occurrence could not be foreseen in advance. The human-induced impacts might be the consequence of regular economic

Table 11.1 The content of the Cultural Heritage Identity Card

Public data General data obtained by identification	
Name, location, legal status, type, dating, function, major risks, materials, structure, state of conservation	
Owner-controlled data Detailed information on the cultural heritage asset	
Nonphysical aspects	Physical aspects
History	Geospatial aspects
Art history	Geometry of asset
Museology	Risks
Sociology	Archaeology
Ethnology	Architecture
Cultural landscape	Materials
Legal issues	Structure
Economic issues	Movable objects
Previous interventions	Current condition
Conservation	Energy efficiency
Valuation methods	Surveying techniques
Decision support Knowledge implementation procedures	
Intervention decision-making Decision impact analysis Site management	

activities, of other unintended sources of harmful influence to heritage asset, or the consequence of intended harmful influences. Among the most dangerous and relatively frequent unintended influences are improper decisions made due to the lack of knowledge or data. These are serious reasons for wrong reactions from responsible persons.

Therefore, the key target of EU-CHIC Protocol is its support to decision-making procedures. The third part of the “CHICBERG” is intended to exploit the knowledge collected and is the core of the Identity Card. Available data collected in the second section should be organized in a way that makes them suitable for various purposes of management, such as intervention decision-making, decision impact analysis, and site management. A good example is the usage of data for regular monitoring and inspection of historic buildings and monuments, as developed and applied by the “Monumentenwacht” organization in the Netherlands and in the Flanders region of Belgium.

Decision-making can be made easier if experiences gained from successful cases are exchanged and compared. The EU-CHIC aims to contribute to the simplification of comparison of general data on heritage assets and to the international exchange of knowledge and experience gained from heritage conservation. It may also be a basis for the development of a Pan-European system for regular monitoring, inspection, and maintenance of historic buildings, monuments, and sites.

Conservation of cultural heritage is related to high costs, and required interventions generally exceed available funding. It is, therefore, necessary to prioritize

Table 11.2 List of hazards to which the heritage assets are exposed

Environmental hazards	
A: Long-term influences	B: Sudden events
A1: Bio-attack	B1: Wind storm
A2: Climate condition fluctuations	B2: Fire
A3: Aeolic impact	B3: Flood
A4: Water (atmospheric, ground)	B4: Earthquake
A5: Solar radiation	B5: Landslide
A6: Particle matter and aerosols	B6: Avalanche
A7: Long-term loading	B7: Tsunami
A8: Geological and geotechnical conditions	B8: Volcano
Human-induced hazards	
C: Unintended influences	D: Intended events
C1: Economic activities	D1: Vandalisms
C2: Accidental events	D2: Riots
C3: Improper decisions	D3: Wars

renovation interventions. Multicriteria assessment can lead to scientifically sound and informed decisions about interventions. The research carried out with the purpose of establishing a multicriteria method for the assessment of architectural heritage is under progress in Slovenia. In [6] the methodology used to develop the multicriteria method is explained. Its main elements are critical content analysis of relevant literature, comparative analysis between the Slovenian and international space, and the identification of relevant criteria and sub-criteria for the decision method. The course and results of empirical research, based on interviews with selected experts, are presented together with the results of the criteria importance ranking based on the Analytic Hierarchy Process (AHP) method. The research presented in the paper is interdisciplinary and brings together the tangible and intangible aspects of cultural heritage. The obtained results confirm that rational determination of relative importance of individual criteria for the assessment of architectural heritage can help decision-makers to identify buildings with higher refurbishment priority.

11.3.3 Environmental Impact on Historic Structures

Long-term environmental factors affect both the state of preservation and structural condition of historic buildings and monuments, provoking serious decays to them. In this chapter, the impact of environmental agents to the structure of historic buildings and monuments will be presented. The examined building materials are timber, masonry, and iron cast, which are the most common in historic buildings and monuments.

Many historic structures include timber as structural elements like timber beams, roofs, pillars, or timber frames. Timber elements are usually in combination with other building materials, mostly masonry, due to their ability to enhance the stability of the structure [17]. On the other hand, masonry (limestone, marble, granite, etc.) is the most common building material in cultural heritage. From ancient times, people used masonry for the construction of monumental buildings. Even though masonry is the most durable material through time, it shows significant susceptibility to environmental factors. Cast iron became a very popular building material during the nineteenth century. Cast iron's ability to carry more loads led to its mass production and use in big structures such as columns and ornamental parts of buildings [18].

In Table 11.3, an attempt to judge the impact of long-term environmental factors to the structural properties of historic structures is presented. The judgment is provisional and illustrative and is based on the understanding of authors as generated from their professional experiences. It should be understood as a suggestion for future assessments of impact of long-term processes to resistance of structures to natural disastrous actions.

Timber is the most vulnerable among building materials. Environmental factors like the presence of insects and humidity can penetrate timber structures causing severe interior damage or aggravate already existing decays. Insolation causes brittleness, while geological conditions and loads threaten the building's stability. Regarding masonry, it shows great susceptibility to environmental impact, but the decays are mainly on the surface of the buildings or in depth of millimeters (or maximum some centimeters). Therefore, their impact leads to detachments and material loss, but these do not cause great damage to the structure. Nevertheless, the combination of long-term loads and the geological conditions with sudden events (earthquake, fire) as well as human impact (vandalism, war) could threaten the masonry structures. As far as iron cast is concerned, the environmental factors that affect it the most are its exposure to water (seawater and acid rainwater) and particle matters. Because of water's impact, phenomena like rusting (oxidation) and graphitization occur. Depending on the material's properties, components, and the grade of its exposure to these factors, rust can cause severe decay and even total loss of the materials' components. Moreover, the conversion of iron to soluble iron oxide thus causes the historic structure to be weakened.

11.3.4 Influence of Improper Decisions

The environmental impact cannot be human controlled, and the only way to mitigate it is in increasing the resilience of heritage assets. In contrast, the human-induced impacts can be controlled and limited by establishing adequate safety measures. One of the most successful and important strategies is in spreading awareness and knowledge, especially among the institutions and persons responsible for decision-making. An illustrative example of decision-making is reported in [19]. The author reports about the examination of the extent to which disaster risk reduction is considered within the management systems of various World Heritage

Table 11.3 Influence of long-term impacts on structural properties of building

Impact	High	Medium	Low
Timber			
A1	XX	X	
A2	XX		
A3		X	X
A4	XX	X	
A5	X	XX	
A6			X
A7	XX		
A8	XX		
Masonry			
A1			X
A2	X	X	X
A3			X
A4	X	XX	X
A5			X
A6			XX
A7	XX	X	
A8	XX	X	
Cast iron			
A1		X	X
A2	X	X	
A3		X	
A4	X	X	
A5		X	
A6	X		
A7	XX	X	
A8	XX	X	

X, less frequent occurrences; XX, more frequent occurrences

properties. He focused particularly on those that appear to be most exposed to disaster risks. The study surveyed 60 World Heritage properties and identified 41 properties in 18 countries as being most at risk from natural and human-induced hazards according to the World Risk Index (http://whc.unesco.org/en/soc). The source of information were UNESCO archives on the management systems established for the World Heritage properties. The aim of the research was to determine the extent to which the relevant disaster risks are identified and addressed. The research discovered the following facts:

- The risks were not identified within the management plans in 37 % of cases.
- The risks were identified, but no concrete plans or reference to mitigating them were established in management plans in 30 % of cases.
- The risks were identified, but mitigation included in management plans considered mainly visitor safety in 3 % of cases.

- The risks were identified, and plans to mitigate them were considered in management plans, but to an insufficient extent, or where there is a concern regarding their effective implementation in 20 % of cases.
- The risks and mitigation of these were presented in an effective and extensive Risk Preparedness Plan in 10 % of cases.

The results of research clearly show that in the management of World Heritage properties, risk reduction is not among the highest of priorities in spite of the vulnerability of heritage assets to hazards. Surprisingly, only in 6 out of 60 properties the risk and mitigation contingency was presented in an effective and extensive Risk Preparedness Plan. It would be interesting to study case by case and learn about the reasons for the lack of attention paid to risks. As mentioned before, human technology even nowadays cannot yet influence the occurrence of natural hazardous events, but at least decision-makers can do much more to mitigate them. In this context, the importance of reliable information supported by adequately managed data collections is of primary importance.

11.4 Resilience Model for Built Heritage

11.4.1 Resilience Model of Contemporary Buildings

The concept of resilience is developed in the domain of earthquake engineering, but earthquake is only one of the sudden environmental impacts that endanger heritage buildings. However, the knowledge developed in this area can be transferred and enlarged to all other risks to which heritage assets are exposed. As part of the conceptualization of a framework to enhance the seismic resilience of communities in the USA [20], in 2003 seismic resilience has been defined as the ability of a system to reduce the chances of a shock, to absorb such a shock if it occurs (abrupt reduction of performance), and to recover quickly after a shock (reestablish normal performance).

More specifically, a resilient system is one that shows:

- Reduced failure probabilities
- Reduced consequences from failures, in terms of lives lost, damage, and negative economic and social consequences
- Reduced time for recovery (restoration of a specific system or set of systems to their “normal” level of functional performance)

A broad measure of resilience that captures these key features can be mathematically expressed and thus calculated. Resilience depends on the quality of the asset. Specifically, performance can range from 0 to 100 %, where 100 % means no degradation in quality and 0 % means total loss. An earthquake or any other disastrous event that occurs within a short time period could cause sufficient damage to the asset such that the quality measure is immediately reduced (from

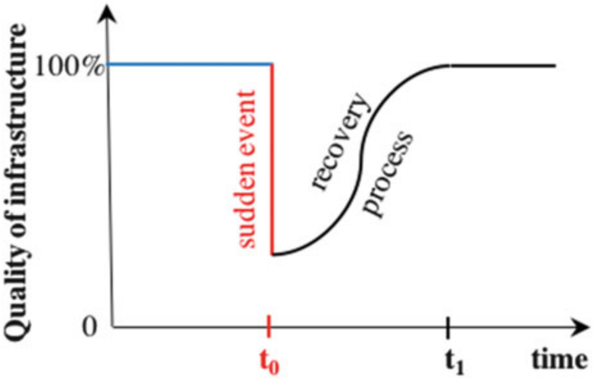

Fig. 11.4 Resilience model following [20]

100 to 50 %, or in the worst case of a collapse to 0 %). Restoration of the asset is expected to occur over a period of time to be completely repaired and become functional once again (indicated by a quality of 100 %).

When the resilience of existing, contemporary infrastructure endangered by earthquakes is observed (Fig. 11.4), the basic assumption is that the infrastructure is 100 % resilient at the time of occurrence (t_0) of earthquake and that the same resilience can be restored by appropriate intervention in a certain time period (t_1). In the case of built heritage, the situation is more complex because the resilience of heritage asset depends on the state of its preservation, including the conditions of materials, structure, maintenance, and previous interventions.

11.4.2 Proposal of Resilience Model for Built Heritage

The assumption of resilience model proposed here for cultural heritage assets (Fig. 11.5) differs from the model for contemporary structure because of the specific nature of the cultural heritage asset. It was 100 % ($R_0 = 1$) resilient at the time of its creation. Various long-term and sudden impacts occurred during its lifetime, measured in centuries or even millennia (Fig. 11.5a). In the present time (t_1), the resilience of the asset is much lower than the initial one ($R_1 < R_0$). Practically it cannot be completely restored to its original state but only to the best achievable ones ($R_1 < R_2 < R_0$). Theoretically, it would be possible to reach the initial resilience (R_0) only in cases when the complete documentation of the initial state is available and reconstruction in its parts would be allowed. Documentation is complete only if it contains both, data on tangible characteristics and intangible values of asset. The solution of the problem becomes even more demanding if in observed, present time (t_1) in (Fig. 11.5b) the additional sudden drop (R_e) of resilience occurs due to natural or human-induced impact.

Extended research is needed to quantify resilience, particularly for some types of critical assets. For critical assets for which the deliverable is not a simple engineering unit, such as for the case of a heritage endangered by human-induced hazards,

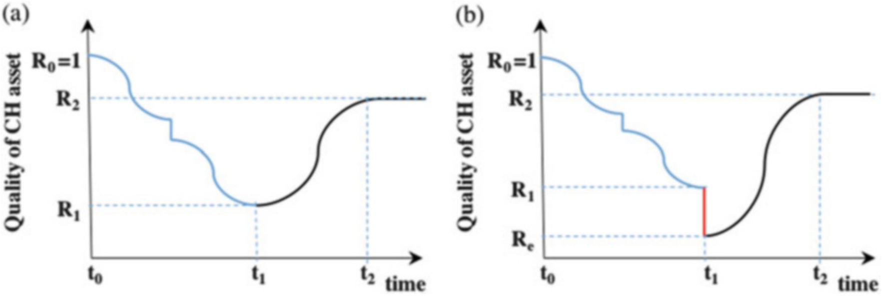

Fig. 11.5 Resilience model of cultural heritage asset in the case of long-term (**a**) and in the case of sudden (**b**) environmental or/and human-induced impacts

the quantification is almost impossible. However, it is worthwhile to start research in this area, which is completely new, though the future progress and outcomes are not very predictable.

Resilience for both physical and social systems can be further defined as consisting of the following properties [20]:

- Robustness: strength or the ability of elements, systems, and other measures of analysis to withstand a given level of stress or demand without suffering degradation or loss of function.
- Redundancy: the extent to which elements, systems, or other measures of analysis exist that are substitutable, i.e., capable of satisfying functional requirements in the event of disruption, degradation, or loss of functionality.
- Resourcefulness: the capacity to identify problems, establish priorities, and mobilize resources when conditions exist that threaten to disrupt some element, system, or other measures of analysis. Resourcefulness can be further conceptualized as consisting of the ability to apply material (i.e., monetary, physical, technological, and informational) and human resources in the process of recovery to meet established priorities and achieve goals.
- Rapidity: the capacity to meet priorities and achieve goals in a timely manner in order to contain losses, recover functionality, and avoid future disruption.
- In the specific cases of heritage assets, additional properties should be identified.

The basic idea of further research in the cultural heritage domain is to apply the theory of resilience for the development of efficient measures for preservation of cultural heritage assets. It is obvious that for each type of environmental or human-induced impact, mathematical models of resilience should be developed, but all may emerge from the above explained idea (Fig. 11.5). The main problem is not in the mathematical formulation of a model but in reliable and realistic input data for calculation of resilience. In the case of a heritage asset being exposed to several different categories of impacts, the total resilience is a combination of partial resiliencies associated with every relevant impact. And as mentioned above, an earthquake is only one of them.

The use of the risk indicators for definition and, where it is possible, quantification of input parameters for resilience assessment is crucial for practical application on a resilience model. In principle, indicators can serve many purposes, depending on the level at which they are applied, on the audience to be reached, and on the quality of the underlying data sets.

A key function of indicators is to simplify the communication process by which the results of analysis and accounting are provided to the users and to adapt information to their needs. The indicators need to be communicated in a way that is understandable and meaningful by reducing the complexity and level of detail of the original data. Due to this simplification and adaptation, the indicators may not always meet strict scientific demands to demonstrate causal chains. They rather represent trade-offs between their relevance for users and policies, their statistical quality, and their analytical soundness and scientific coherence. Indicators therefore need to be embedded in larger information systems—such as databases, accounts, monitoring systems, and models.

11.5 Conclusions

In the current era of rapid ICT development, their application in heritage conservation domain is not yet sufficient. Although the main actors in the heritage conservation discipline are still considered as one that follow the conservative principles, the use of ICT tools is well-accepted among majority of them. A very positive move in this direction has been achieved during the International Conferences on Cultural Heritage and Digital Libraries EUROMED 10, 12, and 14, where the large area of possibilities and already developed technologies and applications in the cultural heritage domain were presented. The architecture of the presented European Cultural Heritage Card (EU-CHIC) is open to further upgrading that gives the opportunity for the rising of its quality by a wide application of ICT. But the main role of ICT will be in providing data and models for resilience assessment using the risk indicators. As stressed earlier, the quality and quantity of reliable documentation is crucial for the restoring of resilience of heritage assets. The important part of documentation is the visualization of the asset as a whole and in parts, including details that may be of crucial importance in restoring monuments and historic buildings. The long-term preservation of data is another crucial issue that still needs to be addressed in a proper way. The current storage media may not be sufficiently durable and resistant to various influences. Therefore, new media should be developed and be made available in order to assure long-term preservation of stored data.

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References

1. S.B. Manyena, The concept of resilience revisited. Disasters **30**(4), 434–450 (2006)
2. C.B. Field et al. (eds.), *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: Special Report of the Intergovernmental Panel on Climate Change* (Cambridge University Press, Cambridge, 2012)
3. R. Jigyasu et al., *Heritage and Resilience: Issues and Opportunities for Reducing Disaster Risks* (UNESCO Worrld Heritage Centre, Geneva, 2013), p. 52
4. Assembly, UN General, The future we want. Resolution **66**, 288 (2012)
5. Thimphu Document 1, Outcome of the International Conference on Disaster Management and Cultural Heritage, Thimphu, Bhutan, 2010
6. B. Vodopivec et al., Renovation priority ranking by multi-criteria assessment of architectural heritage: the case of castles. Int. J. Strateg. Prop. Manag. **18**(1), 88–100 (2014)
7. I.J. Bateman, R.K. Turner, Valuation of the environment, methods and techniques: the contingent valuation method, in *Sustainable Environmental Economics and Management: Principles and Practice* (Belhaven Press, London, 1993), pp. 120–191
8. R. Eppich (ed.), *Cultural Heritage, Landscape & Rural Development: Good Practice, Methodology, Policy Recommendations and Guidelines for Rural Communities: HISTCAPE: Historic Assets and Related Landscapes* (2014), http://histcape.eu
9. V. Rajčić, Croatian traditional vernacular wooden architecture, in *HISTCAPE and Beyond*, ed. by B. Vodopivec et al. (2014), pp. 9–14
10. R. Žarnić et al., *Heritage Protection. From Documentation to Interventions* (2012), http://www.eu-chic.eu
11. Council of Europe, *Guidance on Inventory and Documentation of the Cultural Heritage, Prepared by Ad Hoc Group for Inventory and Documentation Within the Technical Co-operation and Consultancy Programme* (Council of Europe Publishing, Strasbourg, 2009), http://archives.icom.museum/object-id/heritage/core.html
12. R. Thornes, E. Fink, *Protecting Cultural Objects Through International Documentation Standards: A Preliminary Survey* (Getty Art History Information Program, Santa Monica, CA, 1995)
13. E.E. Fink, in *Sharing Cultural Entitlements in the Digital Age: Are We Building a Garden of Eden or a Patch of Weeds?* Museums and the Web Conference, pp. 5–8, 1997
14. M. Ioannides et al., in *Standards in Cultural Heritage: The Missing Grammar for the Digital Documentation of the Past*. XX CIPA Symposium, 2005
15. M. Ioannides, R. Žarnić, V. Rajčić, R. Davies, G. Papagiannakis, M. Hagedorn-Saupe, in *How to Manage (Model, Archive, Retrieve, Preserve and Exchange) Cultural Heritage Data on 3D Assets and Knowledge?* Communication to ICOMOS Board, pp. 1–3, 2016
16. F. Hofmann et al. (ed.), *COST Action C5: Urban Heritage—Building Maintenance: Final Report* (EUR 20447, EC Directorate-General for Research, Brussels, 2002), http://bookshop.europa.eu/en/cost-action-c5-pbKINA20447/?CatalogCategoryID=ANIKABstUgUAAAEjCJEY4e5L
17. M.B. Bagbancı, Examination of the failures and determination of intervention methods for historical Ottoman traditional timber houses in the Cumalıkızık Village, Bursa–Turkey. Eng. Fail. Anal. **35**, 470–479 (2013)

18. A. Davey, *Maintenance and Repair Techniques for Traditional Cast Iron-Short Guide* (Historic Scotland, 2013), pp. 2–4, 6, http://conservation.historic-scotland.gov.uk/publication-detail.htm?pubid=9908
19. P. Antoniou, in *Concern for Disaster Risk Reduction in the Management of World Heritage Properties*. A research through the archives of the World Heritage Centre, UNESCO, 2012
20. M. Bruneau et al., A framework to quantitatively assess and enhance the seismic resilience of communities. Earthq. Spectra **19**(4), 733–752 (2003)