CLIC

Circular models Leveraging Investments in Cultural heritage adaptive reuse

D3.1
CLIC Decision Support System

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CLIC Decision Support System

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Abstract

This document presents the CLIC Decision Support System that aids municipalities in making decisions on complex urban regeneration policies such as the reuse of cultural sites. For most European cities, with a centuries-long history, this issue is very important but also extremely complex. Indeed, on one hand, the urban needs and uses change over time, on the other hand, in order to preserve the city's identity, the cultural sites can only be transformed within an eligibility threshold. In addition, today, many other factors - such as resources lack, climate change and the globalization - can have a strong impact on the cultural heritage and its preservation. In this perspective, it is very important to support the decision makers that have increasingly limited resources, clarifying opportunities and risks of the transformations.

Partners involved in the document

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1 Description of the Project

The overarching goal of CLIC trans-disciplinary research project is to identify evaluation tools to test, implement, validate and share innovative "circular" financing, business and governance models for systemic adaptive reuse of cultural heritage and landscape, demonstrating the economic, social, environmental convenience, in terms of long lasting economic, cultural and environmental wealth.

The characteristics of cultural heritage and landscape pose significant challenges for its governance. Cultural heritage is a “common good”, which enjoyment cannot be denied to citizens, although many buildings and landscape structures are privately owned. Furthermore, the large economic resources needed for recovery and maintenance of heritage goods are rarely available to the private owner, often charged of the additional cost of non-use due to limited degree of transformation allowed. The existing governance arrangements currently involve limited stakeholders concerning for the historic, aesthetic or religious sociocultural values, severely restricting the use of the heritage properties, and charge the central government of conservation costs. The approach of regulatory and planning tools throughout European countries has been to preserve cultural heritage by preventing transformation of buildings or areas having historic-cultural significance.

“The current monument-based, full protection, and government-financed approach that restricts the use of protected properties and relies almost entirely on public funds is incapable of tackling the vast urban heritage of most communities and of sustaining conservation efforts in the long term” (Rojas, 2016). To turn cultural heritage and landscape into a resource, instead of a cost for the community, the structures of authority, institutions and financial arrangements should be adjusted to ensure larger stakeholders’ involvement in decision-making, attract private investments and facilitate cooperation between community actors, public institutions, property owners, informal users and producers (Rojas, 2016). The risk is that without financing channels the decay of European heritage and landscape will increase, until its irreversible loss.

Flexible, transparent and inclusive tools to manage change are required to leverage the potential of cultural heritage for Europe, fostering adaptive reuse of cultural heritage / landscape. Tools for management of change should consider costs and benefits at the local level and for all stakeholders, including future generations, and should take into account the cultural, social, environmental and economic costs of disrepair through neglect, compared to the benefits obtained through diverse scenarios of transformation / integrated conservation.

Costs and values of cultural heritage adaptive reuse have to be compared in a multidimensional space: the relationship between costs and “complex values” influences the willingness to invest in the functional recovery of cultural heritage and landscape. Therefore, it is necessary to clarify what is intended for the value of cultural heritage. The higher the perceived value for potential actors, the higher the willingness to take the risk of investment. This “complex value” of cultural heritage depends on the intrinsic characteristics, but also from extrinsic (context) characters.

Investment costs are related to the materials, technologies and techniques to be used to preserve the cultural value of the heritage / landscape, and to maintenance / management / operating costs. The willingness to invest, the same value done, increases with the reduction of costs. Then, the social cost of abandonment – and eventual irreversible loss of heritage – must be included in the investment choice.

The investment gap in cultural heritage and landscape regeneration can be addressed through careful evaluation of costs, complex values and impacts of adaptive reuse, providing critical evidence

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of the wealth of jobs, social, cultural, environmental and economic returns on the investment in cultural heritage.

CLIC Specific objectives

The scopes of CLIC project will be achieved through a set of specific, measurable, achievable, realistic and time-constrained (SMART) specific objectives:

Objective 1 – To synthesize existing knowledge on best practices of cultural heritage adaptive reuse making it accessible to researchers, policy makers, entrepreneurs and civil society organizations, also with direct dialogue with their promoters;

Objective 2 – To provide a holistic ex-post evaluation of the economic, social, cultural and environmental impacts of cultural heritage adaptive reuse, stressing on the importance of appropriate conservation and maintenance approaches able to highlight the integrity and authenticity of heritage;

Objective 3 – To provide EU-wide participated policy guidelines to overcome existing cultural, social, economic, institutional, legal, regulatory and administrative barriers and bottlenecks for cultural heritage systemic adaptive reuse;

Objective 4 – To develop and test innovative governance models and a set of evidence-based, participative, usable, scalable and replicable decision support evaluation tools to improve policy and management options/choices on cultural heritage systemic adaptive reuse, in the perspective of the circular economy;

Objective 5 – To analyse hybrid financing and business models that promote circularity through shared value creation, and assess their feasibility, bankability and robustness for cultural heritage adaptive reuse;

Objective 6 – To validate the CLIC circular financing, business and governance practical tools in 4 European cities / territories representative of different geographic, historic, cultural and political contexts;

Objective 7 – To contribute to operationalise the management change of the cultural landscape also in implementing the UNESCO Recommendation on Historic Urban Landscape;

Objective 8 – To re-connect fragmented landscapes, through functions, infrastructures, visual relations at macro and micro scale;

Objective 9 – To design and implement a stakeholders-oriented Knowledge and Information Hub to make tools and information accessible, useful and usable and test them with policy-makers, entrepreneurs, investment funds and civil society organizations;

Objective – 10 To contribute to the creation of new jobs and skills in the circular economy through cultural heritage adaptive reuse, boosting startups and sustainable hybrid businesses and empowering local communities and stakeholders through public-private-social cooperation models.

Objective 11 – To contribute to the monitoring and implementation of SDGs (especially Target 11.4) and the New Urban Agenda, creating operational synergies with global initiatives of UN-Habitat, UNESCO/ICOMOS and the World Urban Campaign.

All partners have wide experience in developing and testing CLIC proposed tools, ensuring the effective and time-constrained achievement of all the above-mentioned specific goals. The integration of sectorial knowledge, tools and methods will be achieved through a trans-disciplinary approach promoting partners and stakeholders' cooperation, co-creation of knowledge and co-delivery of outcomes.

The expected impacts of the project are the following:

- Validation of integrated approaches and strategies for cultural heritage adaptive re-use, comprising innovative finance with high leverage capacity, business models and institutional and governance arrangements that foster multi-stakeholder involvement, citizens' and communities' engagement and empowerment;
- New investments and market opportunities in adaptive re-use of cultural heritage, also stimulating the creation of start-ups;
- An enabling context for the development and wide deployment of new technologies, techniques and expertise enhancing industrial competitiveness and contributing to economic growth, new skills and jobs;
- Innovative adaptive re-use models that are culturally, socially and economically inclusive;
- Contribution to implementing the Sustainable Development Goals (SDGs) (Goals 1, 15, 11 particularly) and the United Nations New Urban Agenda.

2 Introduction

This report presents the decision support system (DSS) developed by the University of Portsmouth within the CLIC project.

In general, a decision support system is an information system that supports decision-making activities, helping the people to make decisions about problems that cannot be easily specified in advance. In the CLIC project, the problem regards the adaptive reuse of cultural heritage from the perspective of the circular economy.

Long since cultural heritage is considered a resource for local development strategies, but today its reuse takes on also new meanings related to the sustainable city paradigm. However, there are some contradictions. The sites recognized as cultural heritage are increasing; the costs for functional maintenance/reuse are growing, while public resources available are becoming scarcer, and private actors are usually focused on the short time for payback.

In the current contest, the authorities attempt to involve diverse organizations, groups, and actors interested in the re-using process. Indeed, the cultural heritage, involving a variety of values, can trigger either top-down or bottom-up actions and could lead the urban regeneration.

However, specific approaches are needed to support the local authorities in complex decision-making procedures. Indeed, qualitative and quantitative data, constraints of cultural heritage and preferences of stakeholders have to be considered, but also the interactions between the reuse actions and those with the context, as well as the optimization of available resources, the prioritization of actions.

Therefore, for supporting the decision-makers in the identification of compatible and sustainable uses, projects or project portfolios it needs to integrate different approaches. This represents one of the main contributions of the research developed for the CLIC DSS.

Document structure

This document is structured as follows chapters:

- Chapter 1 includes the description of CLIC project;
- Chapter 2 includes an introduction;
- Chapter 3 describes the decision problem;
- Chapter 4 describes the features of the CLIC Decision Support System;
- Chapter 5 describes the CLIC DSS;
- Chapter 6 includes the conclusions.

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3 Description of the decision problem

The growing attention for urban sustainability processes made the reuse of the existing heritage particularly significant for cities/landscape' regeneration. The renewed use of heritage, indeed, seems to offer opportunities to respond to the needs in cities, without increasing energy consumption, land use and waste generation.

In enhancing spaces and changing their functions, the adaptive re-use of the heritage allow obstructing buildings obsolescence, recovering economic value and draw/extract the embodied energy still available in the existing building stock. So, the adaptive reuse has potential positive economic/environmental effects, and when they involve local communities can have a very positive social impact. When the adaptive reuse regards the cultural heritage (monuments or historical buildings, complex of buildings or entire neighbourhoods such as historical centres, open spaces or historical gardens, etc.), their potentials are to be considered in terms of cultural and identity values too. It is necessary to consider tangible and intangible aspects, compatible uses or activities, sense of belonging, constraints and limitations, etc. The adaptive reuse of cultural heritage should have minimal impact on its historical significance and its setting.

For this reason, it has seemed, sometimes, more difficult to realize, requesting to consider several issues (e.g. preservation laws; contemporary expectations; adaptation of facilities; structural issues; etc.) and implication (e.g. temporary structures; removal of hazardous materials; removing and restoring foundations; etc.) (Hein and Houck, 2008).

However, in the last years, it has appeared a renewed attention for the reuse of the cultural sites. Indeed, the cultural heritage has been identified by government authorities as a tool for the sustainable development (Council of the European Union, 2014), for the economic growth, to reconvert cities, to enable integration and inclusion processes (Arfaoui and Heid 2016). Preserving and enhancing the cultural heritage is integrated into urban agendas and local development strategies in a variety of sectors such as innovation, branding, tourism and social inclusion (Blake, 2000). Although this renovated interest, in the current context, the available economic resources are rather limited and many other factors, such as climate change or the globalization, are having a strong impact on the cultural heritage and its preservation.

The Municipalities, usually the principal owners of the cultural sites, are not able to manage these sites alone. The needs and spending capacity are radically changing and the authorities, in the absence of investments, began to support the actions of organizations and groups interested in re-using abandoned property. Indeed, the cultural heritage, involving a variety of values, can trigger either top-down or bottom-up actions (Cerreta and Panaro, 2017). To achieve that, some local institutions provided the conditions for reusing abandoned public properties. This led to numerous experimentations, where more stakeholders are involved in the decision-making process (Mangialardo and Micelli, 2018).

Indeed, today it's clear that the cooperation between public, private and nongovernment sectors is important to start and carry out projects but also to sustain the places over time (Macdonald and Cheong, 2014). Several points of view need to be taken into account and integrated in order to reach an agreement among the several stakeholders involved (Fusco Girard et al., 2014). Moreover, citizens want to be fully informed of the decision to be made, therefore clear and transparent procedures must be adopted (Dutta and Husain, 2009). So, the active involvement of different actors is crucial both to start and implement the reuse of one cultural site and to develop a strategy that plans more interventions together. In general, the decision problem can be described according to two different level of analyse:

- At the local scale, the problem regards the reuse of one cultural site. Therefore, a project should be defined, recognizing the set of uses that could generate the highest benefits for the city/community without compromising the values of the heritage.

- At the global scale, the problem regards the reuse of more cultural sites altogether. Therefore, a strategy should be defined, identifying the set of projects (portfolio of projects) that could generate the highest benefits for the city/community without compromising the values of the heritage.

In both case, economic aspects need to be considered together with other elements (Wang and Zeng 2010) such as improvement of the environment and the urban landscape (Veldpaus et al., 2013), protection of place identity and heritage values, sustainability, well-being and life quality of citizens (Tweed and Sutherland, 2007). Therefore, the adaptive reuse of cultural heritage is a multi-objective problem, where different perspectives should be taken into account and it is useful to clarify the impacts and the benefits of the new uses. So, it emerges that the DSS must help:

- To involve the actors, exploring the different points of view and the preference system of different stakeholders.

- To research sustainable solutions, supporting mutual learning and the elaboration of new solutions.

- To consider the potential actions (uses or projects) as parts of a comprehensive program (e.g. reuse of a building or development of a urban strategy) to be evaluated in the whole.

- To identify actions priority to be implemented in a context marked by the lack of resources and urgent needs.

- To analyse problematic contexts marked by uncertain conditions and imperfect knowledge.

- To consider several constraints (e.g. cultural, environmental, social constraints, etc.).

4 Features of the CLIC Decision Support System

The increasing interest in enhancing the cultural heritage and the lack of public funding in the current context, request to rethink the way to deal with the issues of cultural heritage.

In this sense, emerges the possibility of supporting decision makers with appropriate methodologies that aim at classifying, prioritizing and selecting the appropriate actions to preserve and enhance cultural heritage (Fusco Girard and De Toro, 2007; Fusco Girard et al., 2014). To support such complex decisions, those methodologies need to deal simultaneously with several aspects building a participative and sharable decision.

In this sense, there emerges the possibility of using Multiple Criteria Decision Aiding (MCDA) methods (Greco et al., 2016; Ishizaka and Nemery, 2013) that can guide the Decision Makers (DMs) throughout the process.

In the past, the MCDM methods have been used in the context of cultural heritage in different case studies (e.g., Hong and Chen (2017), Dutta and Husain (2009), Giove et al. (2011)). However, given the complexity of the problem, it seems that the natural evolution of these methods is the integration of those MCDM methods in appropriate frameworks. Some attempts in this direction have been made for MCDM Methods that have been used together with GIS environment (see e.g. Tarragüel et al. (2012) or Oppio et al. (2015)).

In this perspective, a versatile framework for the evaluation and the subsequent selection of interventions for the preservation of the cultural heritage has been proposed by Ferretti and Comino (2015). They consider both qualitative and quantitative values, to help decision makers in developing urban strategies. They stress the necessity of interacting with the different stakeholders in a transparent process, to prioritize the most important elements in the context of the cultural heritage and to support the choices of public and, eventually, private stakeholders.

Recently, a further aspect has been introduced in the literature that considers the choice of the interventions in the cultural heritage context as a portfolio of choices to be made altogether in order to take into account potential synergies among the different projects to implement. An attempt in this direction has been made by (Nesticò et al., 2018) that propose to apply MCDM methods to generate a plan that chooses a portfolio of interventions to be made altogether. Indeed, the strand of methods, called portfolio decision analysis, can be integrated with many other multiple criteria methods, as in Barbati et al. (2018).

Therefore, to consider at the same time the multiple features of a complex decision problem (e.g. multiple stakeholders, objectives, criteria, restrictions, including the not economic ones), it is emerging that methodologies must be:

- More accurate, specific, and selective with respect to the characterization of the potential actions (Büyüközkan et al., 2018).
- More flexible, adaptive, and robust with respect to their implementation (Ahern, 2011).
- More pluralist and participatory, to take into account the plurality of stakeholders, experts, and policy makers (Thabrew et al., 2009).

- User friendly, taking into consideration the behavioral aspects of decision making, with the aim of defining an effective procedure of interaction with the involved actors (Abastante et al., 2018).

In this direction, it is proposed the integration of different approaches such as:

- A multi-objective approach, for considering different points of views and objectives.
- An interactive approach, for involving different stakeholders in the whole process, supporting the identification of shared decisions.
- A portfolio decision analysis approach, for considering families of actions (set of uses or projects), technically called portfolios, as feasible solutions of the problem at hand.
- A prioritization approach, for defining the priority among many uses/projects.

All these approaches together permit to take into account specific issues, stakeholders' expectations and to integrate experts' knowledge and local knowledge. So, the decision process is a learning processes, where the issues are gradually explored, and it is possible to improve or generate new solutions starting from the collected and processed information. In this perspective, the DSS can support not only the identification of the set of actions to be implemented but also their comprehensive elaboration taking into consideration constraints of different nature (urbanistic, economic, cultural and so on) and potential synergies between considered actions.

5 CLIC DSS: A user manual for different levels of analysis

According to the issues examined, the CLIC Decision Support System permits to analyse two different scales:

- **local level** - the decision problem regards the reuse of one cultural site. In particular, this could be the case of a historical building that has lost the functionalities over time and is now partially used, not used, or abandoned. To reuse this building, alternative uses should be considered according to the features of the site and the context. In this case, the DSS can support the definition of a sustainable project, identifying the set of uses that generate the highest benefits for the city/community without compromising the heritage values.

- **global level** - the decision problem regards the reuse of more cultural sites. In particular, this could be the case of a historic city centre where the density of cultural sites is considerable or the case of a regional/national park or a bigger area where it is important to consider different cultural sites together. In this case, for example, at least one project for each site should be considered, as well as, different constraints and possible synergy among projects and context. The DSS can support the definition of sustainable strategy for these sites, identifying the portfolio of projects that generates the highest benefits for the city/community without compromising the heritage values.

In the next paragraphs, the DSS is described according to two different levels.

5.1 CLIC Decision Support System at the local level

Let us consider the case of a historical building with a known surface that is now partially used, not used or abandoned. We suppose that different functions (e.g. leisure spaces, research and educational activities, commercial activities, etc.) have been thought for the reuse of the site or some of its parts.

To identify the most effective group of functions for its sustainable reuse, the CLIC DSS methodology follows the steps below:

1. Identification of elements of the decision problem.

2. Prioritization of the uses.

3. Selection of the set of uses to be implemented.

Different approaches and methods are integrated into a unique methodology. In particular, through a multi-criteria evaluation that reflects the actors' judgments, the DSS allows to identify and rank the different functionalities in order of priority. Then, taking into account the identified constraints, it enables to maximize the number of the uses that have the highest priorities without violating any constraints. In this way, the CLIC DSS supports the definition of a sustainable reuse project of site.

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5.1.1 Identification of elements of the decision problem

To specify the decision problem on the adaptive reuse of a cultural site in a given context, it needs to identify the following elements:

- The stakeholders involved in the reuse process (e.g. owners, managers, users, citizens, etc.) and their specific aims.
- The alternative uses that could be implemented (e.g. exhibitions space, workshop space, restaurant or coffee space, residential spaces, commercial spaces, hotel accommodation, enterprise, start-up or co-working spaces, sport facilities, etc.).
- The criteria to be used to assess the performance of the alternative uses (e.g. Compatibility of function with the peculiarities of heritage site, Enrichment of the cultural offerings, Creation of new jobs, etc.).
- The evaluations of each single use in terms of each criterion.
- The constraints related to the implementation of each use (e.g. budget constraints).

The identification of these elements permits to precisely define the specific decision problem in order to apply the DSS in a correct and effective way.

5.1.1.1 The criteria

Criteria should be built to make operational the different points of view that were identified from the values and concerns of the stakeholders. Therefore, the set of adopted criteria should be:

- significant in relation to the context and objectives of the problem,
- sufficient to characterize the considered situation,
- suitable to depict the preferences,
- not redundant.

According to the problem at hand, it is possible that the criteria have both a qualitative and a quantitative scales. Moreover the complexity of the problem could need/demand a hierarchical structure of criteria, that is the criteria could be articulated into smaller and manageable sub-criteria (Corrente, Greco and Slowinski 2012, 2013).

The criteria should be aggregated to compare different actions. Several methodologies have been proposed in the literature (see e.g. Greco et al., 2016; Ishizaka and Nemery, 2013). Usually multicriteria decision aiding methodologies use a univocal set of weights (an equal weight or a weighting scheme chosen by the observer or one or more experts), but this generates an issue of representation because a single weight vector is not representative of all population interested in the composite indicator. On the contrary, the recently proposed *σ-μ efficiency analysis* (Greco et al.2019) permits to take into account the whole set of feasible weight vectors compatible with the preferences expressed by the decision makers involved in the decision problem.

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5.1.2 Prioritization of the uses

5.1.2.1 Which method can we apply to identify the priority uses for a cultural site?

According to the decision problem, the prioritization of the uses could be carried out using a multiple criteria sorting method in a constructive perspective (Almeida-Dias et al., 2010). That is, the representative actors (stakeholders, experts, decision makers, etc.) are involved in the decision model building process thanks to direct interactions with the analyst.

Indeed, the choice of method to be adopted is related not only to the problem to be handled, but also to the nature of the available data/criteria.

In case of the adaptive reuse of cultural site, we propose to adopt an ELECTRE methods because of its following strength points (Figueira et al., 2013):

- The possibility of dealing with the qualitative as well as the quantitative nature of criteria.
- The possibility to handle criteria with heterogeneous of scales.
- The non-compensatory nature of the aggregation procedure, which is based on the evaluation of the advantages (reasons for) and disadvantages (reasons against) of one use over the other.
- The possibility to take into consideration imperfect knowledge of data with respect to considered criteria.

Moreover, in the ELECTRE methods, the modelling of a preference system is carried out through a systematic interaction with the actors of decision process. In particular, the ELECTRE TRI-NC method (Almeida-Dias et al., 2010) permits to identify or draw freely one or more representative reference actions for each category of priority (in our case the actions are the uses). In this way, for each criterion is defined the range of performances required to be included in a specific category of priority.

The steps to apply the ELECTRE TRI-NC are:

1. Definition of criteria weights for the stakeholders/actors involved.

2. Construction of the reference actions and the categories to which the considered actions have to be assigned.

3. Definition of indifference and preference thresholds permitting to take into account imperfect knowledge and ill determination of the performances on considered criteria.

4. Definition of the veto thresholds, representing differences of performances on considered criteria so large that if in one criterion the difference in favor of one action *a* over another action *b* overcome the threshold, then it is no more possible to state that action *b* is at least as good as action *a*.

5. Assignment of each action to a given class through the application of the ELECTRE TRI-NC ordinal classification method.

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5.1.2.2 The actors to be involved

The method considers many interactions with the actors of the process. So, it is important to identify the participants involved in each steps. The decision process depends on the decision problem and the related context, but in general:

- In *step 1*, the relevant criteria are identified and the related weights are assigned. This information is collected from the stakeholders of the process (in some cases also from the experts and decision makers). Indeed, different criteria could be interesting for different stakeholders and the same criteria could have different importance, and, consequently, different weights for different stakeholders. So, considering these different criteria and weights, it will be possible to take into account the different perspectives characterizing each stakeholder and to analyse their effects on the prioritization of the actions.

- In *step 2* and *step 4*, the reference actions and categories, and the veto thresholds are collected. This is a more technical information that, consequently, should be discussed with one or more experts. After, the proposals supplied by the experts should be presented and rediscussed with the stakeholders and/or decision makers. In this way, cognitive burden of the different participating to the discussion could be reduced without compromising the adherence to and the coherence of their preference system.

- In *step 3*, the indifference and preference thresholds are collected. In fact, these discrimination thresholds cannot be considered as preference parameters. They are related to the way in which a criterion was defined and the imperfect knowledge of the data. So, the indifference and preferences do not belong to the definition of the scale, but to the way the criterion applies actions to the scale. For this reason, to identify the discrimination thresholds of a criterion in an accurate way, it is important that the analyst has an interaction with the “author” of criterion, usually an expert that know the nature of imprecision, and/or of ill-determination, and/or of uncertainty of the criterion.

5.1.2.3 Definition of the weights for the criteria (Step 1)

The procedure applied for determining the relative importance of the criteria is the Simos-Roy-Figuiera (SRF) method, proposed in Figueira and Roy (2002).

In case of a small group of participants, the interaction can be conducted individually and subsequently in a focus group.

In case of a consistence group of participants, the interaction can be conducted in small groups, subsequently they can present and discuss altogether the different vectors of weights for the considered criteria.

The process has to be conducted in this way:

1. A deck of cards with the name of each criterion on a card has to be prepared. It is useful to add a brief description of each criterion and to provide each individual or small group with this set of cards.

2. Each individual is asked to rank order the cards according with the importance of the related criteria, from the least important to the most important. If some criteria are equally important,

the corresponding cards should be arranged together in the same line. This yields a ranking of equally important subsets or packs of criteria.

3. The difference between two successive pairs of subsets of criteria can be more or less large. When determining the weights, it is important to take into account such smaller or bigger differences of importance (or intensity).
   So, providing also a deck of blank cards, it is possible to ask the participants to insert these blank cards in the intervals between successive pairs of subsets of criteria in the ranking.
   The meaning of the blank cards is as follows: *having no blank cards means that the difference between the weights of the subsets of criteria is minimal, say one unit; one blank card means twice the unit, two blank cards means three times the unit, and so on*.

4. Each participant is asked to identify how many times the most important criterion is more important than the least important one. To simplify the question, it is possible to reason in terms of votes asking a question of this type:
   Assume the least important criterion has been given one mark, how many marks would you assign to the most important one?

In all the process it is very important to take notes of the motivations and the hesitations expressed by the participants.

Collecting all this information, one has the opportunity to perform a series of analyses considering even more than one vector of weights, defining different versions of the problem for which the solution will be acceptable, and therefore robust, even having different sets of values for the weights.

5.1.2.4 Construction of the reference actions and the categories (Step 2)

According to the method ELECTRE TRI-NC, the categories of priority and their reference actions can be defined in a co-constructive way with one or more actors. In particular:

- A category of priority is a subset that contains the actions that have a same level of priority.
- A reference actions identifies the performance that an action must have to be part of a specific category of priority.

Let us remember that in the applications we are considering an action is a given use that can be assigned to some cultural heritage building. For this reasons, since now we shall consider uses rather than, more generically, actions.

The representative reference actions for each category of priority can be identified asking the interviewed/s to draw representative use/s for each category identified. For example, if the categories of priority are four, the interviewed/s identify the performances that a use must have in relation to each criterion for being included in the following categories:

- Category C1 - subset of uses with low priority for which implementation is not advised.
- Category C2 - subset of uses with medium priority for which implementation could only be advised after significant modifications.

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- Category C3 - subset of uses with high priority for which implementation could only be advised after slight modifications.

- Category C4 - subset of uses with very high for which implementation is always advised without any reservation.

5.1.2.5 Modelling the imperfect knowledge of the data and arbitrariness (Step 3)

Frequently, the definition of criteria comprises some parts of arbitrariness. Moreover, the data used to build criteria can be imprecise, ill-determined, and uncertain. In these cases, the analyst can model the imperfect knowledge of data using indifference and preference thresholds for the performances of considered criteria. These thresholds are also called discriminating thresholds.

According to the definition in Roy, Figueira, Almeida-Dias, 2014:

- The *preference threshold*, p, between two performances, is the smallest performance difference that when exceeded is judged significant of a strict preference in favor of the action with the best performance. This difference (which is by definition non-negative) can be equal to zero.

- The *indifference threshold*, q, between two performances, is the largest performance difference that is judged compatible with an indifference situation between two actions with different performances. This difference (which is by definition non-negative) can be equal to zero and it is at most equal to the preference threshold.

The discriminating thresholds should result from an interaction between the analyst and the “author” of the criterion (for example an expert). He is the best qualified to define the part of arbitrariness, imprecision, ill-determination, or uncertainty of the data.

In particular, in presence of *variable thresholds* (thresholds that vary along the range of the scale), it is not possible to distinguish clearly between preference or indifference. In this case, the *pseudo-criterion model* (Roy et al., 2014) allows determining the preference and indifference thresholds. This model uses affine functions and, if the thresholds are defined from the worst of the two performances, it is possible to explore with the expert the following points:

1. Consider a specific criterion (for example to be maximized) and image an action (use) with a very low value of performance for this criterion. For which value another action (use) can be considered significantly better than the first one?

2. Consider the same criterion, but this time in the upper level of the scale, and image now an action (use) with high value for this criterion. For which value another action can be considered significantly better than the first one?

To simplify the understanding, in both the questions could be useful doing examples of values that could have the criterion.

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5.1.2.6 Definition of the veto thresholds (Step 4)

According to Figueira et al. 2005, *veto thresholds* express the power attributed to a given criterion to be against the assertion "a is at least as god as b", when the difference of the evaluation between *g(b)* and *g(a)* is greater than this threshold. These thresholds can be constant along a scale, but they can also vary.

The process for assessing the veto is similar to the one used for defining the discriminating thresholds.

5.1.2.7 Application of the ELECTRE TRI-NC method (Step 5)

To apply the ELECTRE TRI-NC is possible use the MCDA-ULAVAL software. This software implements the majority of the ELECTRE methods, including the ELECTRE TRI-NC method, allowing the insertion of all the data and parameters elicited. The method has to be applied for each vector of weights, according to all the parameters identified (reference actions, categories, veto thresholds, discriminating thresholds).

The results obtained for each vector of weights have to be analysed, compared and discussed. For example, one could explore if:

- the actions (uses) belong to a single category or two consecutive categories or more categories;
- the actions (uses) belong to similar categories even after changing the weights;
- the actions (uses) change the category following changes of the vector of weights;
- the actions(uses) add one or more categories following changes of the vector of weights.

The principal categorizations of the actions (uses) should be presented and discussed with the actors and the most interesting should be identified with them.

To validate the performance of the most interesting categorizations, the analyst should conduct a robustness analysis. In particular, changing some parameters, one could explore the aspects that were more uncertain or difficult to define for the actors. For example, the analyst could act on the vector of weights, the reference actions and the veto thresholds (e.g. increasing the number of cards introduced in the ranking that generated the weights of the preferred classifications, changing the veto thresholds, etc.). The effects on the categorization of the actions (uses) should be analysed and, in this way, one can verify the robustness of the results.

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5.1.3 Selection of the set of uses to be implemented

The selection of the set of uses to be implemented is identified by means of a binary linear programming model based on the following points:

- Definition of an objective function that maximizes the number of actions (uses) with the highest priority to be introduced.
- Identification of a set of constraints representing meaningful requirements to be satisfied in decisions about the adaptive reuse of a cultural site.
- Computation of the portfolio of actions to be implemented in order to optimize the objective function subject to the above constraints.

5.1.3.1 Objective function

After assigning a priority level to each use, we must construct the portfolio of uses to be proposed for implementing. This decision problem is handled by defining a *0 - 1* knapsack problem with additional logical constraints related to budget limitations and adaptive reuse requirements.

Since we cannot select all the uses at the same time due to the multiple constraints, we should start by selecting as many as possible of the uses with the highest priority, then those with the second highest priority, and so on. More precisely, we can associate a 0-1 decision variable, x_i, with each $a_i \in A$, such that $x_i = 1$ if a_i is selected, and $x_i = 0$, otherwise. Then, the number of uses in the maximal priority category C_q is maximised, solving the following optimization problem:

$$\max f_q(x) = \sum_{\{i\,:\,a_i \in C_q\}} x_i,$$

subject to all the constraints of the problem. Assume that the optimal value of this problem is $f^*_q = k_q$. Then, for the maximization of the number of artifacts in C_{q-1}, the second highest priority category, we can add the constraint $\Sigma_{\{i\,:\,a_i \in Cq\}} x_i = k_q$ to the initial set of constraints and proceed with the next optimization:

$$\max f_{q-1}(x) = \sum_{\{i\,:\,a_i \in C_{q-1}\}} x_i.$$

The process is repeated until the lowest category is explored.

This sequential process can, however, be replaced by the solution of an equivalent single optimization problem. Instead of several objective functions, we define a single objective function as follows.

$$\max f(x) = \sum_{\{i\,:\,a_i \in A\}} c_i x_i,$$

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where

$$c_i = \begin{cases} \bar{c}_h = 1 & \text{for} \quad h = 1, \\ \bar{c}_h = 1 + \sum_{k=1}^{h-1} \bar{c}_k |C_k| & \text{for} \quad h = 2, \dots, q. \end{cases}$$

We associate a coefficient $\bar{c}_h$ with each category C_h. We define also the total weight of a category by multiplying the coefficient of the category by the number of its elements, i.e. $\bar{c}_h |C_h|$.

The idea is that the coefficient of category C_h should be strictly larger than the sum of all the values $\bar{c}_h |C_h|$ associated with all the categories C_k, $k = 1, \dots, h-1$, having a lower priority.

With the proposed procedure, uses with the highest priority are selected first, unless this is not possible due to the considered constraints. In that case, the optimization process goes to the next priority level, until it reaches the lowest one.

5.1.3.2 Constraints

To have a real perspective on the considered problem of the adaptive reuse, the constraints for the problem could be discussed with the decision makers and stakeholders, and, more in general, with all the actors that have a practical knowledge on the different aspects of the problem (usually professionals or experts). In this way, the analyst can formulate coherent constraints.

For example, at the building scale, the principal constraints could regard the budget available to implement the set of new uses and/or a specific performances (e.g. related to environmental criterion, social criterion, cultural criterion, etc.) to be reached as total effect of new uses of the site.

Regarding to the budget, if each use $a_i \in A$ is associated with a cost s_i and the available budget is denoted by B, the constraint can be formulated as:

$$\sum_{\{i:\, a_i \in A\}} s_i x_i \leq B$$

Regarding a total performance to be reached for a specific criterion, the constraint can be formulated in a similar way and, if needed, changing the direction of the inequality.

5.1.3.3 Constrained optimization of the objective function

To start, one has to consider the classification of the uses supplied by ELECTRE TRI-NC taking into account the vector of weights elicited from the actors through the deck of cards methods. Then, the objective function is optimized subject to the considered constraints.

If a solution is generated, it has to be presented and discussed with the actors involved in this step. If the solution satisfies the participants, it is identified as the preferred solution. If the solution does not satisfy the participants or a solution is not feasible because the considered constraints are too restrictive, it is possible to explore and discuss with participants different budget scenarios or relaxing some constraints related to the performance of specific criteria.

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5.2 CLIC Decision Support System at the global level

For example, we consider the case of different cultural sites that have lost their functionalities over time and are now partially used, not used, or abandoned. Supposing that for each site at least one reuse project was elaborated, it is possible to define a strategy that identifies the portfolio of projects to be implement altogether.

In particular the CLIC DSS at the global analysis level aims to identify and rank different portfolios of projects and support the choice of the “best portfolio” to be implemented according to the identified criteria and constraints. In particular, the number of projects that each portfolio identifies is related to the respect of the constraints considered. Therefore, the final strategy could also affect only some of the considered sites.

The global analysis captures the multi-criteria evaluation, reflects the actors’ judgments and maximizes the number of the projects with the highest priorities to be implemented, taking into account constraints related to the specific characteristics of the decision problem. Let us observe that in the approach we are proposing, different approaches and methods have been integrated into a unique methodology, articulated in the following steps:

1. Identification of elements of the decision problem.
2. Prioritization of the projects.
3. Selection of the portfolio of projects to be implemented.

As it is possible to see, the methodology works in the same way both at the local level and the global level. The principal differences regard the elements of the decision problem, in particular, at the global scale:

- The stakeholders should be identified among those that are interested in strategy that regards the different cultural sites and a larger context.
- The alternatives are the projects of the different sites.
- The criteria to be used to assess the performance of the projects should include more aspects related to the context characteristics (e.g. accessibility, etc.).
- In addition to the constraints related to the implementation of each project (e.g. costs constraints), it could be considered also constraints related to the location of the projects, the synergies between the projects and the context, the distributions of functions on different areas/neighborhoods, etc.

Once identified the elements of the decision problem at the global scale, it is possible to apply the second step of the methodology (Prioritization of the projects) according to the stages described in paragraph 5.1.2. In this case, applying the ELECTRE TRI-NC method it will be identified the order of priority of the projects.

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To apply the third stage of the methodology (Selection of the portfolio of projects to be implemented), some specifications are needed in relation to the different constraints to be considered. They are described in the next paragraph (5.2.1).

5.2.1 Selection of portfolio of projects to be implemented

The selection of the portfolio of projects to be implemented is identified by means of a binary linear programming model based on the following points:

- Definition of an objective function that maximizes the number of actions (projects) to introduce in a portfolio with the highest priority. This point was described in the paragraph 5.1.3.
- Identification of a set of constraints representing meaningful requirements to be satisfied in a decision about the adaptive reuse of different cultural sites. Usually, at the global level, the new uses and the location of the sites are strategic elements for developing a sustainable strategy. So, often, the formulation of constraints concerns these aspects.
- Computation of the portfolio of actions to be implemented in order to optimize the objective function subject to the above constraints.

5.2.1.1 Constraints

To better understand the role of the constraints at the global scale, we use an example. Let us assume that a city wants to reuse different cultural sites and that at least one project is identified for each site. Let us also suppose that there are not sufficient resources to implement all projects . So, to identify the set of projects that maximizes the advantages and benefits in the context of a sustainable strategy, the conditions that generate positive impacts should be sought. These conditions describe specific aspects of the decision problem and can be formulated as specific constraints. In particular, according to some real situations that we have studied, we formulated the logical constraints shown below.

The **first examined aspect** regards the possibility to identify a minimum number of projects to be implemented in a specific area of the city. We suppose that in a specific area of the city different cultural sites are located and specific adaptive reuse projects $A_d = \{a_1; a_2; a_3; a_4; a_n\}$ were already defined for these sites. If this area is considered as a strategic area to be regenerated, among the projects A_d, it is possible to identify a minimum number of projects, let us say Q_d, that should be carried out.

The constraint is formulated as:

$$\sum_{\{i:\, a_i \in A_d\}} x_i \geq Q_d$$

Where Q_d represent the desired value for this condition.

The **second examined aspect** considers the possibility that the projects can create a synergy if they are located in areas very close to each other. In particular, their proximity can generate a greater

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benefit than the sum of their own benefits separately. For this reason, in some case, it could be preferred portfolios where at least a given number, called N, of those synergies will be implemented. To structure this aspect in the model, we define the areas $I = \{I_1, \ldots, I_S\}$, *such that* $I_s \in A$; $s = 1, \ldots n$, which contains all the projects in the same area and the *0-1* decision variables x_i with $a_i \in I_s$ such that $x_i = 1$ if a_i are activated and $x_i = 0$ otherwise. The following constraint, then, should be imposed:

$$\sum_{\{i:\, a_i \in I_{s,}\}} x_i \geq N \qquad \forall I_{s,} \in I$$

The constraint specifies that if two projects are located in the same area, then the variable x_i associated with that two projects should be equal to *1*. We want that at least N of the x_i variables will be equal to *1*, meaning we want at least N synergies.

The **third examined aspect** explores the set of functions that a site can have in relation to the area in which it is located. Sometime it needs to verify that a strategy sets and distributes specific uses in specific areas of the city. In these cases, it needs to identify which are the areas of the city to be considered and describe each project according to the functions that it will implement. In particular, if $K = \{1, \ldots, k\}$ indexes the set of the functions, and $U = \{1, \ldots, u\}$ the set of the areas, we can define the binary coefficients z_{iuk} as equal to *1* if the project a_i is in the area u and delivers function k, but *0* otherwise. If for a specific function a given number of projects n_k was implemented, the constraint could be modelled as:

$$\sum_{\{u \in U, a_i \in A\}} z_{iuk} x_i \geq n_k \quad \forall k \in K$$

If an equal distributions of the functions in some areas was needed, we should also define the binary variables y_u $\forall u \in U$. In this case, the constraints would be of the following type:

$$\sum_{\{i:\, a_i \in A:\, z_{iuk} = 1\}} x_i \geq 1 - M y_u \quad \forall k \in K, \forall u \in U$$

with M being a large number, and

$$\sum_{u} y_u \leq 4 - q \qquad q \in \{0, 1, 2, 3\}$$

with q being a number between *0 and 3*.

Those two constraints imply that at least one project with a given function should be open in at least *4 - q* areas. For example, if q is equal to *2*, two areas should have at least one project implemented for one of the functions defined.

5.2.1.2 Computation of the portfolio of actions to be implemented

Regarding the computation of the portfolio of actions to be implemented, to solve the binary programming model, it possible to use any linear optimization solver, for example the CPLEX 12.1 software.

To start off, one has to consider the classification of the projects supplied by ELECTRE TRI-NC, taking into account the vector of weights elicited from the actors. The process is similar to that described in the paragraph 5.1.1.3.

If a solution is generated, it has to be presented and discussed with the actors involved in this step. If the solution satisfies the participants, it is identified as the preferred solution.

If the solution doesn't satisfy the participants or a solution is not feasible because the considered constraints are too restraining, it is possible to explore and discuss with the participants different budget scenarios and/or making the constraints less binding. For example it is possible reduced:

- the number of synergies to activate,
- the number of projects that must have specific uses in a specific urban area,
- the number of projects that should be implemented in a specific urban area.

In this way the opportunities of transformation are better clarified. Indeed, the projects are explored in relation to the aims and the different points of view identified. Moreover, it is possible to identify the minimum budget needed to develop a desirable strategy.

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5.3 Validation and robustness analysis

The validation and robustness analysis permit to ensure the stability to the performances of the tool. Several forms of robustness analysis can be considered permitting the stakeholders and the policy makers to assess and test the adherence between the recommendation of the DSS and their preference systems.

In particular, it is possible to work similarly as done for the validation of the priority categories (paragraph 5.1.2.7), verifying this time that the obtained portfolio (set of uses or projects) is sufficiently stable with respect to the variations of some parameters of the model (e.g. the weights representing the importance of the criteria, the veto thresholds, the formulation of some of the constraints, etc.). In this way, several scenarios are considered, allowing to realize whether the solution is consistent and the actors still agree with it.

6 Conclusions

The methodology proposed allows to improve the use of the scarce resources available giving transparency to the choices aimed at transforming the natural, built and historic environment.

Through the interaction with different actors, it is possible to analyze the reuse of cultural heritage in terms of benefits for the city, the citizens and the stakeholders, in a process that involves a multiplicity of cultural, economic, environmental and social features.

The procedure we are proposing is strongly interactive in order to take adequately into account the heterogeneous objectives pursued by the plurality of actors involved, in the decision process.

In particular, after prioritizing the feasible actions though a sorting method (e.g. ELECTRE TRI-NC), a multiple objective optimization problem can be formulated in order to identify the most adequate portfolio of actions taking into account on one hand priorities, and on the other hand the different points of view and the specific constraints related to the policy makers and the stakeholders involved in the decision process. Along al the process a specific care is taken to permit all the actors to contribute at the design of the most appropriate solutions.

The whole procedure permits also to formulate justifications and argumentations useful to the involved actors for acknowledging the goodness of the proposed solutions, as well as to support the adopted decisions in communication towards a third party and public opinion.

More technical conclusions regard the benefits of the integration of different methods. In particular, thanks to a pilot test of the methodology (Barbati et al., 2019) it was verified its acceptability and identified the following strengths:

- The selection process has benefited by the prioritization obtained with ELECTRE TRI-NC. In particular, the integration of a ELECTRE method in a binary programming model represents the most innovative contribution of the methodology. It was defined a new interactive method to select the feasible projects, that can be easily extended to any portfolio decision problem (Salo et al., 2011).

- The formulation of constraints is very flexible and can be easily changed according to the learning process that the actors develops during the implementation of the methodology.

- The optimization model allows us to quickly show to the participants the options available, even for different parameters.

- The ELECTRE TRI-NC method leads to assigning projects to predefined classes, allowing the participants to reduce the cognitive burden necessary to choose which projects have to be prioritized.

- The methodology permits to integrate different points of view at different phases, involving different actors in a decision that they can really feel as their own decision.

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7 References

Abastante F., Corrente S., Greco S., Ishizaka A., Lami I. M. (2018). Choice architecture for architecture choices: Evaluating social housing initiatives putting together a parsimonious AHP methodology and the Choquet integral. *Land use policy*, 78, 748-762.

Ahern J. (2011). From fail-safe to safe-to-fail: Sustainability and resilience in the new urban world. *Landscape and urban Planning*, 100(4), 341-343.

Almeida-Dias, J., Figueira, J.R., Roy, B., 2010. Electre Tri-C: A multiple criteria sorting method based on characteristic reference actions. *European Journal of Operational Research*, 204(3), 565-580.

Angilella, S., Catalfo, P., Corrente, S., Giarlotta, A., Greco, S., & Rizzo, M. (2018). Robust sustainable development assessment with composite indices aggregat- ing interacting dimensions: The hierarchical-SMAA-Choquet integral approach. *Knowledge-Based Systems*, 158, 136-153.

Arfaoui, M., Heid, K. (2016). Culture, Cities and Identity in Europe. European Economic and Social Committee, Brussel. [Online] Available at: https://www.eesc.europa.eu/resources/docs/qe-01-16-463-en-n.pdf [Accessed: 5 May 2019].

Barbati, M., Figueira, J. R., Greco, S., Ishizaka, A., & Panaro, S. (2019). A multiple criteria methodology for prioritizing and selecting portfolios of urban projects. arXiv preprint arXiv:1812.10410

Barbati M., Greco S., Kadziński M., Słowiński R. (2018). Optimization of multiple satisfaction levels in portfolio decision analysis. *Omega*, 78, 192-204.

Blake J. (2000). On defining the cultural heritage. *International & Comparative Law Quarterly*, 49(1), 61-85

Büyüközkan G., Feyzioğlu O., Göçer F. (2018). Selection of sustainable urban transportation alternatives using an integrated intuitionistic fuzzy Choquet integral approach. *Transportation Research Part D: Transport and Environment*, 58, 186-207.

Cerreta M., Panaro S. (2017). From perceived values to shared values: A multi-stakeholder spatial decision analysis (M-SSDA) for resilient landscapes. *Sustainability*, 9(7), 1113.

Council of the European Union (2014). Council conclusions of 21 May 2014 on cultural heritage as a strategic resource for a sustainable Europe. [Online] Available at: http://eurlex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52014XG0614%2808%29 [Accessed: 5 May 2019].

Corrente S., Figueira J. R., Greco S., Słowiński R. (2017). A robust ranking method extending ELECTRE III to hierarchy of interacting criteria, imprecise weights and stochastic analysis. *Omega,* 73, 1-17.

Corrente, S., Greco, S. and Słowiński, R. (2012). Multiple criteria hierarchy process in robust ordinal regression. Decision Support Systems, 53(3), pp.660-674.

Corrente, S., Greco, S. and Słowiński, R. (2013). Multiple criteria hierarchy process with ELECTRE and PROMETHEE. Omega, 41(5), pp.820-846.

Dutta M., Husain Z. (2009). An application of multicriteria decision making to built heritage. The case of Calcutta. *Journal of Cultural Heritage* 10(2), 237–243.

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Grant Agr. No: 776758

Ferretti V., Comino E. (2015). An integrated framework to assess complex cultural and natural heritage systems with Multi-Attribute Value Theory. *Journal of Cultural Heritage*, 16(5), 688-697.

Figueira J., Mousseau V., Roy B. (2005). Electre Methods. In: Multiple Criteria Decision Analysis: State of the Art Surveys. International Series in *Operations Research & Management Science*, Vol 78. Springer, New York, NY, pp 133-153

Figueira J.R., Greco S., Roy B., Słowiński R., (2013). An overview of ELECTRE methods and their recent extensions. *Journal of Multi-Criteria Decision Analysis*, 20(1-2), 61-85.

Figueira J., Roy B. (2002). Determining the weights of criteria in the ELECTRE type methods with a revised Simos' procedure. *European Journal of Operational Research*, 139(2), 317-326.

Fusco Girard, L., Cerreta, M., De Toro, P. (2014). Integrated Assessment for Sustainable Choices. *Italian Journal of Regional Science*, 13, 111-142

Fusco Girard, L., De Toro, P. (2007). Integrated spatial assessment: a multicriteria approach to sustainable development of cultural and environmental heritage in San Marco dei Cavoti, Italy. *Central European Journal of Operations Research*, 15(3), 281-299.

Giove S., Rosato P., Breil M. (2010). An application of multicriteria decision making to built heritage. The redevelopment of Venice Arsenale. *Journal of Multi-Criteria Decision Analysis*, 17(3-4), 85-99.

Greco S., Figueira J., Ehrgott M., (2016). Multiple Criteria Decision Analysis: State of the Art Surveys. Springer, Berlin.

Greco S., Ishizaka A., Tasiou M., Torrisi G. (2019). Sigma-Mu efficiency analysis: A methodology for evaluating units through composite indicators. *European Journal of Operational Research*, 278(3), 942-960.

Hein, M. F., Houck, K. D. (2008). Construction challenges of adaptive reuse of historical buildings in Europe. *International Journal of Construction Education and Research*, 4(2), 115-131.

Hong Y., Chen F. (2017). Evaluating the adaptive reuse potential of buildings in conservation areas. *Facilities*, 35(3/4), 202-219.

Ishizaka A., Nemery P. (2013). Multi-criteria decision analysis: methods and software. John Wiley & Sons.

Macdonald, S., Cheong, C. (2014). The Role of Public-Private Partnerships and the Third Sector in Conserving Heritage Buildings, Sites and Historic Urban Areas. The Getty Conservation Institute, Los Angeles. [Online] Available at: https://www.getty.edu/conservation/publications_resources/pdf_publications/pdf/public_private.pdf [Accessed: 5 May 2019].

Mangialardo A., Micelli E. (2018). From sources of financial value to commons: Emerging policies for enhancing public real-estate assets in Italy. *Papers in Regional Science*, 97(4), 1397-1408.

Nesticò A., Morano P., Sica F. (2018). A model to support the public administration decisions for the investments selection on historic buildings. *Journal of Cultural Heritage*, 33, 201-207.

Oppio A., Bottero M., Ferretti V., Fratesi U., Ponzini D., Pracchi, V. (2015). Giving space to multicriteria analysis for complex cultural heritage systems: the case of the castles in Valle D'Aosta Region, Italy. *Journal of Cultural Heritage*, 16(6), 779-789.

Roy B., Figueira J. R., Almeida-Dias J. (2014). Discriminating thresholds as a tool to cope with imperfect knowledge in multiple criteria decision aiding: Theoretical results and practical issues. *Omega*, 43, 9-20.

Salo A., Keisler J., Morton, A. (2011). An invitation to portfolio decision analysis. In Salo A., Keisler J., Morton A. (Eds.), Portfolio decision analysis. Springer, New York, pp. 3-27.

Tarragüel A. A., Krol B., Van Westen C. (2012). Analysing the possible impact of landslides and avalanches on cultural heritage in Upper Svaneti, Georgia. *Journal of cultural heritage*, 13(4), 453-461.

Thabrew L., Wiek A., Ries R. (2009). Environmental decision making in multi-stakeholder contexts: applicability of life cycle thinking in development planning and implementation. *Journal of Cleaner Production*, 17(1), 67-76.

Tweed, C., Sutherland, M. (2007). Built cultural heritage and sustainable urban development. *Landscape and urban planning*, 83(1), 62-69.

Veldpaus, L., Pereira Roders, A. R., Colenbrander, B. J. (2013). Urban heritage: putting the past into the future. *The Historic Environment: Policy & Practice*, 4(1), 3-18.

Wang, H. J., Zeng, Z. T. (2010). A multi-objective decision-making process for reuse selection of historic buildings. *Expert Systems with Applications*, 37(2), 1241-1249.

8 Acronyms

[DMs]	[Decision Makers]
[DSS]	[Decision Support System]
[GIS]	[Geographic Information System]
[HUL]	[Historic Urban Landscape]
[MCDA]	[Multiple Criteria Decision Aiding]
[MCDM]	[Multiple Criteria Decision Making]
[SDGs]	[Sustainable Development Goals]