Antonio Leone Carmela Gargiulo
Editors

Environmental and territorial modelling for planning and design

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4

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This book collects the papers presented at the 10th International Conference INPUT 2018 which will take place in Viterbo from 5th to 8th September. The Conferences pursues multiple objectives with a holistic, boundary-less character to face the complexity of today socio-ecological systems following a systemic approach aimed to problem solving. In particular, the Conference aims to present the state of art of modelling approaches employed in urban and territorial planning in national and international contexts.

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This book is the latest scientific contribution of the "Smart City, Urban Planning for a Sustainable Future" Book Series, dedicated to the collection of research e-books, published by FedOAPress - Federico II Open Access University Press. The volume contains the scientific contributions presented at the INPUT 2018 Conference and evaluated with a double peer review process by the Scientific Committee of the Conference. In detail, this publication, including 63 papers grouped in 11 sessions, for a total of 704 pages, has been edited by some members of the Editorial Staff of "TeMA Journal", here listed in alphabetical order:

- Rosaria Battarra;
- Gerardo Carpentieri;
- Federica Gaglione;
- Rosa Anna La Rocca;
- Rosa Morosini;
- Maria Rosa Tremiterra.

The most heartfelt thanks go to these young and more experienced colleagues for the hard work done in these months. A final word of thanks goes to Professor Roberto Delle Donne, Director of the CAB - Center for Libraries "Roberto Pettorino" of the University of Naples Federico II, for his active availability and the constant support also shown in this last publication.

Rocco Papa
Editor of the Smart City, Urban Planning for a Sustainable Future" Book Series
Published by FedOAPress - Federico II Open Access University Press

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INTRODUCTION

Between 5th and 8th September 2018 the tenth edition of the INPUT conference took place in Viterbo, guests of the beautiful setting of the University of Tuscia and its DAFNE Department.

INPUT is managed by an informal group of Italian academic researchers working in many fields related to the exploitation of informatics in planning.

This Tenth Edition pursed multiple objectives with a holistic, boundary-less character, to face the complexity of today socio-ecological systems following a systemic approach aimed to problem solving. In particular, the Conference will aim to present the state of art of modeling approaches employed in urban and territorial planning in national and international contexts.

Moreover, the conference has hosted a Geodesign workshop, by Carl Steinitz (Harvard Graduate School of Design) and Hrishi Ballal (on skype), Tess Canfield, Michele Campagna.

Finally, on the last day of the conference, took place the QGIS hackfest, in which over 20 free software developers from all over Italy discussed the latest news and updates from the QGIS network.

The acronym INPUT was born as INformatics for Urban and Regional Planning. In the transition to graphics, unintentionally, the first term was transformed into "Innovation", with a fine example of serendipity, in which a small mistake turns into something new and intriguing. The opportunity is taken to propose to the organizers and the scientific committee of the next appointment to formalize this change of the acronym.

This 10th edition was focused on Environmental and Territorial Modeling for planning and design. It has been considered a fundamental theme, especially in relation to the issue of environmental sustainability, which requires a rigorous and in-depth analysis of processes, a theme which can be satisfied by the territorial information systems and, above all, by modeling simulation of processes.

In this topic, models are useful with the managerial approach, to highlight the many aspects of complex city and landscape systems. In consequence, their use must be deeply critical, not for rigid forecasts, but as an aid to the management decisions of complex systems.

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ON RESTORING AND REVIVING LOST RELIGIOUS BUILDINGS

MULTI CRITERIA ANALYSIS TECHNIQUES TO ADDRESS AN INCREASINGLY UNDERUSED PATRIMONY

ELISABETTA POZZOBON, LUISA SANTINI
ALESSANDRO SANTUCCI

Department of Energy, Systems, Territory and Buildings (DESTeC), University of Pisa
e-mail: elisabetta.pozzobon@destec.unipi.it; luisa.santini@ing.unipi.it; santu.ale@gmail.com
URL: www.destec.unipi.it

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ABSTRACT

Historical religious heritage is vital for territorial identity. Such heritage, besides comprising most often wonderful landmarks, is a defining part of the shared identity of the population and an indispensable thread woven deep into the social fabric. In Italy, some of the buildings that once housed worship-related functions have today lost their purpose due to various causes. The conservation of these numerous historical architectures requires large amount of funds and resources. However, attempts of reviving historical sites might not succeed and consequently lead to a waste of resources. Consequently, the wise allocation of the available resources is paramount.
This work studies and proposes a MCA-based method aimed at supporting conservation designers and public decision makers in prioritizing actions and allocating resources where they can be most effective to the greatest benefit of territories and their communities.
The study area corresponds to three Italian administrative districts in the central region of Tuscany. The methodology is applied to a case-study comprised of 480 Italian architectures, including churches, oratories and chapels, which were thus further investigated. The architectures are described by a set of criteria and taken as alternatives. In order to select the ten most suitable alternatives to be used, we applied the Analytical Hierarchy Process (AHP). We chose this method because of its ability to decompose the complex decision problem involving architectural heritage into different levels of hierarchies.

KEYWORDS

Spatial Database; MCA Techniques; AH; Reuse; Religious Architectural Heritage

1 INTRODUCTION

Historical religious heritage is vital for territorial identity. Unfortunately, these days see some of the Italian worship-related buildings experiencing scarce use and maintenance problems, challenging circumstances which, in turn, can lead to abandonment (Fig. 1).

Fig. 1 Examples of underused or abandoned architectures located in the surveyed territory

The presence of religious architectural heritage is ubiquitous in Italy. Consequently, the problem of the enhancement of underused or abandoned buildings is greatly felt by anyone. However, academics think the problem is not dealt with in a sufficiently systematic way (Settis, 2011). It is common knowledge that the conservation of historical built heritage requires substantive financial resources, which are not easily available and most often dwarfed by the magnitude of the needs. Besides investigating the root causes of the problem, it is important to devise a method which can wisely and sustainably allocate the available funds in order to mitigate the failure risks being inherent to any repurposing attempt of historical sites.

Although multiple organizations such as the national or local governments have a stake in administering historical buildings, the vast majority of religious architectures devoted to worship is, in Italy, owned and managed by the Catholic Church. Given the fact that the Church's primary obligation is to provide for adequate places to hold liturgies for its communities, which sometimes may be moving away from historically relevant places following novel settlement nuclei, new, larger and brighter spaces are built to better provide for contemporary worship needs (Bartolomei, 2016), causing some of the preexisting spaces to become increasingly underused or even abandoned.

From a territorial perspective, building a strong knowledge of religious heritage, its localization and its manifold values is paramount. The Church is experiencing the same need and, through the Italian Bishops' Conference (CEI) is currently carrying out a census of all its owned built heritage. While such work is underway at the time of writing, preliminary data analysis can be found in the literature (Bartolomei et al., 2017). Thanks to their artistic and cultural status, major religious buildings are often described in books and publications. This is the case for the project named "I Luoghi della Fede" (Baldacci & Silla, 1997), which between 1995 and 2000 examined and catalogued 2527 historic religious buildings throughout Tuscany.

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This research aims at proposing a viable decision method which formulates various plausible reuse cases and checks their suitability to each of the considered buildings from a given region. The whole process then generates a hierarchy where the most promising alternatives wrt the re-purposing choices and the target territories are ranked according to both their potential value-enhancement and their impact on the local society. A general schematic for the overall process this work can be framed into is provided in Fig. 2.

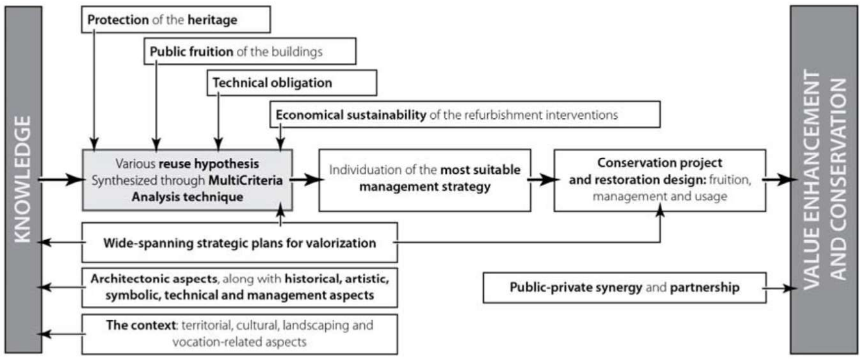

Fig. 2 The framing methodology of the whole project

Since the problem we are dealing with must drive complex decisions while considering multiple and diverse input variables, we chose to apply quantitative decision-theory tools to this particular religious-architectural-cultural field. Multi-Criteria Decision Analyses (MCDA or MCA), in fact, "involve a set of alternatives that are evaluated on the basis of conflicting and incommensurate criteria" (Malczewski, 1999).

MCA techniques represent a specific area of the Decision Analysis field (Parnell et al., 2013), which encompass every decision-making process that produces a final choice. In general, MCDA sets an articulate family of criteria, often contradicting, and assigns priorities values (called weights) to each of them. These values represent the aptness of any given criterion wrt both the driving objective of the process and the other, competing, criteria.

Various and different approaches of MCDA are presented in the literature (for a report see Figueira et al., 2005). Many of them can be applied to historical heritage (see Ferretti et al., 2014; Giove et al., 2011; Oppio et al., 2015). Following what was referred to as a "territorial approach", this study makes large use of geographical data. In fact, a large amount of the analyses of this research hinges upon a Geographical Information System (GIS), making the overall decision method a "GIS-based MCDA" (Ascough II et al., 2002; Malczewski, 1999; Malczewski & Rinner, 2015).

The entire set of surveyed architectures exceeds 2.000 religious buildings, which are situated in three Italian Provinces located in Tuscany. In the first step of the study we isolated a subset of nearly 500 architectures, which constitutes the case-study for the subsequent MCA application. In the second phase we employed the Analytic Hierarchy Process (AHP) to convey first-level overall suitability rankings and, finally, in the last phase the rankings is refined through the application of the ELECTRE III method to the ten highest scoring alternatives isolated by the AHP. So far, the research managed to complete the AHP step and set the framework of the subsequent ELECTRE III implementation. Therefore, in this contribution we will be describing the application of the AHP to the subset of alternatives extracted from the whole set of the selected architectures.

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2 MATERIALS AND METHODS

The research develops through the phases depicted in Fig. 3.

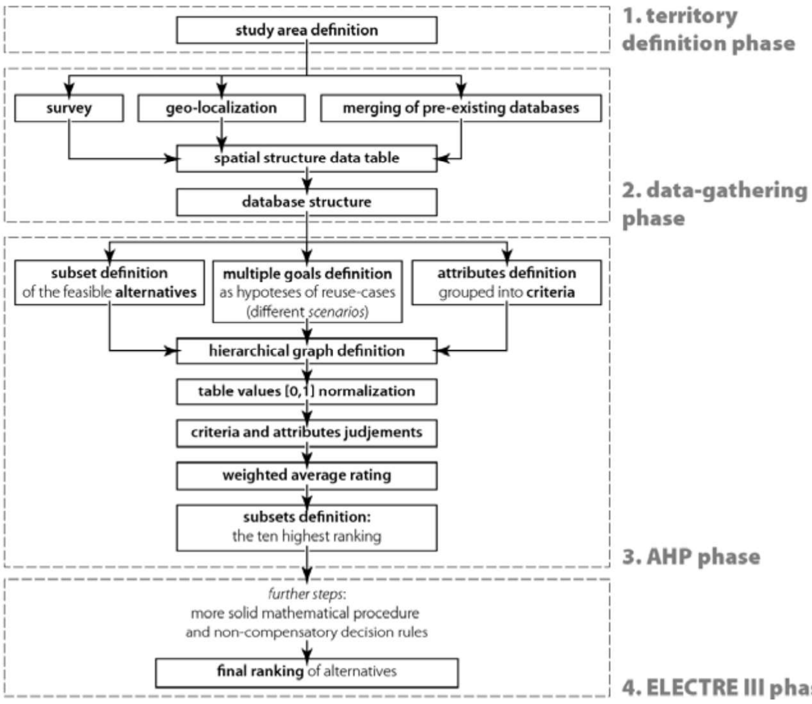

Fig. 3 The entire methodology, from the beginning of the research to the final ranking of the alternatives

2.1 STUDY AREA DEFINITION

One of the aspects that inspired the research was the recognition that nearly all studies on religious heritage begin and focus on the architectural scale, with little attention to a wider, territorial framing. Therefore, our work involves a rather extensive territorial scope. Although we want the research not to be location-specific, three Italian administrative districts are chosen as case-study territories. They are, namely, the Provinces of Pisa, Lucca and Livorno (Fig. 4). We chose these areas because of their intrinsic characteristics as well as for historic reasons: besides being inhabited since ancient times, the morphology of the three districts ranges from mountains to flatlands, from inland areas to coastal environment, offering a diverse variety of settlements to be investigated.

2.2 DATA GATHERING

Acquiring a complete and reliable dataset requires a survey, whose primary step is the rigorous geo-localization of buildings on the territory. Through the use of the opensource QuantumGIS (QGIS) software, both geographical data and attributes were handled. They were initially arranged in a geographical database, called *spatial structure data table* (Malczewski, 1999), where each row represents a particular geographical entity, in this case, a building.

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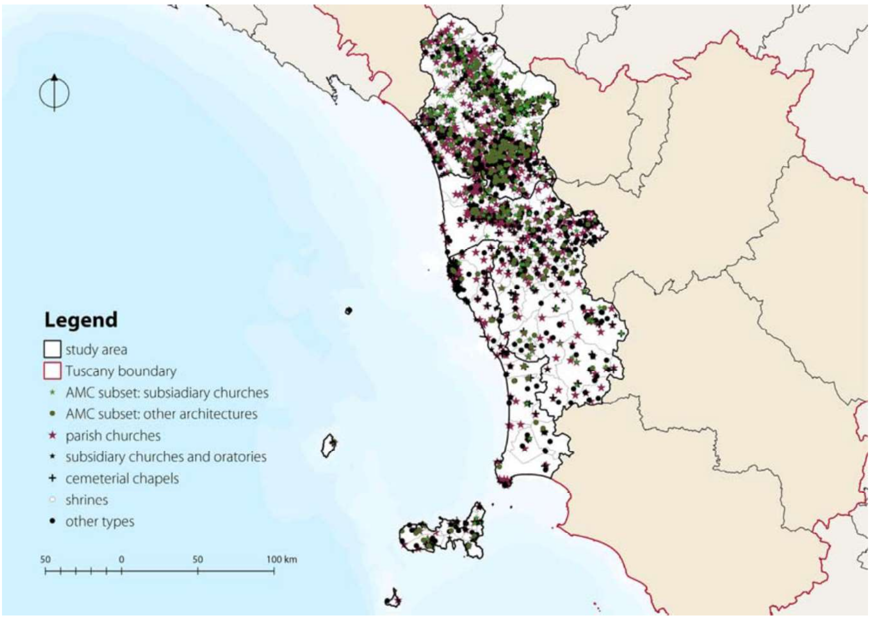

Fig. 4 The study area with geolocalised points representing religious-related buildings

Various publications were used to populate the geographical database, such as the previously mentioned lists of CEI's "The Churches of the Italian Dioceses" (CEI, 2008), the "Sacrum Luce" database, the Tuscan regional database of architectural and planning restrictions, literature from the "Places of Faith" (Baldacci & Silla, 1997) project, and the archives of the Italian National's Monuments and Fine Arts Department offices. The Tuscan Regional Technical Map (CTR) was acquired in its vector-shapefile form. It provided the essential territorial map layer into which buildings were entered but also contributed its own data by providing building locations intrinsically contained into its structure.

The CTR was subsequently enriched with several other informative layers, such as the land cover map and a road graph for the entire area. The total number of surveyed architectures is 2235, as can be seen from Fig. 5 and, visually, from Fig. 4. Gathered data was later structured into a database (Fig. 6) using PostgreSQL.

Attributes and data contained in the db comprise both quantitative and qualitative information, both a-spatial and spatial-dependant.

The most meaningful information was turned into evaluation criteria and attributes in the ensuing steps of the research for processing through MCA techniques. Among the whole dataset the case study for the subsequent MCA application was extracted (refer to the two rightmost columns of Fig. 5). It is composed of 480 architectures which:

- are not parish churches, nor cathedral churches;
- have not been previously converted;
- are scarcely used.

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	TOTAL		CEI DATABASE		SUBSET	
TYPE	number	percent.	number	percent.	number	percent.
Cathedral churches	3	0.13%	3	0.24%	-	-
Parish churches	739	33.06%	736	58.37%	-	-
Subsidiary churches	434	19.42%	430	34.10%	225	46.78%
Subsidiary oratories	54	2.42%	54	4.28%	37	7.69%
Sanctuaries	2	0.09%	2	0.16%	-	-
Convent churches and complexes	34	1.52%	6	0.48%	4	0.83%
Private chapels and oratories	182	8.14%	2	0.16%	55	11.43%
Other public religious buildings	682	30.51%	27	2.14%	155	32.22%
Disappeared buildings	11	0.49%	-	-	-	-
Multiple category	30	1.34%	-	-	4	0.83%
Stand-alone towers and bell towers	44	1.97%	-	-	-	-
Residential functional conversions	11	0.49%	-	-	-	-
Other private functional conversions	5	0.22%	-	-	-	-
Public functional conversions	4	0.18%	1	0.08%	-	-
	2235	100%	1261	100%	480	100%

Fig. 5 Composition break-down of the whole gathered dataset

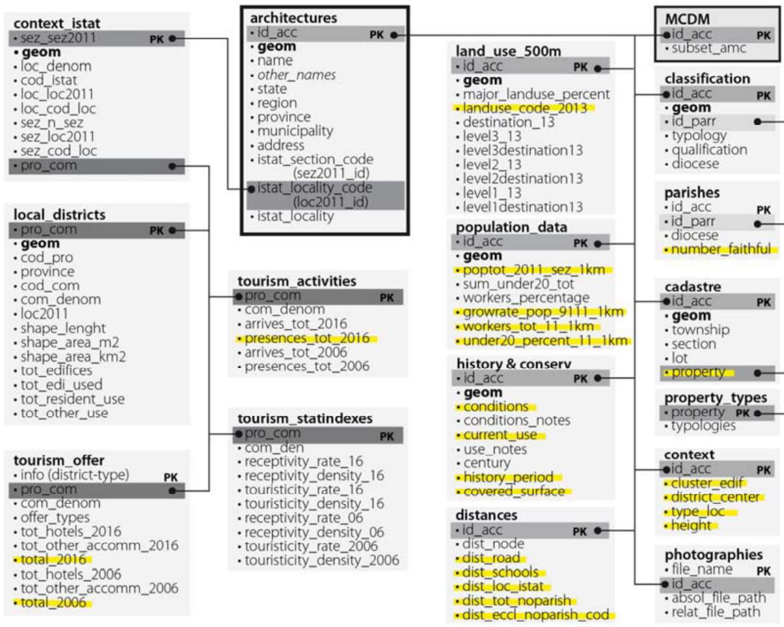

Fig. 6 The database scheme. The highlighted entries refers to the db data later turned into criteria

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2.3 THE AHP APPLICATION

The Analytic Hierarchy Process (AHP, Saaty, 1980)) is a well-established MCDA algorithm sometimes used in GIS-MCDA. Its implementation uses reciprocal paired comparisons, along with decision makers or expert judgments to prioritize both qualitative and quantitative criteria. It belongs to the set of Multi Attribute Decision Methods (MADM) and is based on the additive weighting sum. One of its peculiarities, besides its natural simplicity, resides in the weights calculation for each criterion, which is achieved using a decision matrix where each criterion is pairwise compared to each other. The AHP method is founded on the decomposition of the problem into a *hierarchy* of subcomponents which can be analyzed and judged more easily (Fig. 7 shows the research problem being subdivided into a two-layered hierarchical structure).

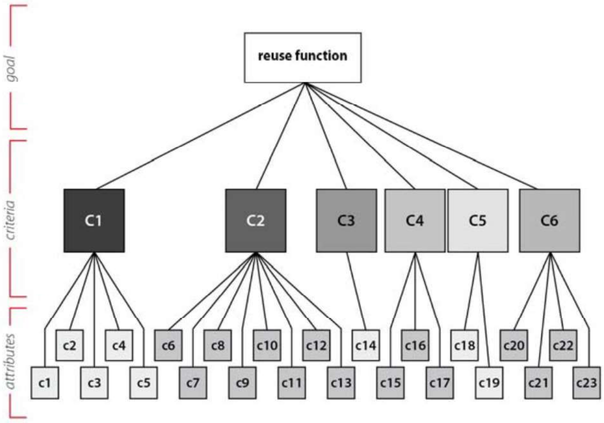

Fig. 7 The hierarchical graph. C# and c# identify the generic attributes as specified in Fig. 10

The reuse cases formulation is the starting point of the whole framework. They can be conceived and set in relation to different stakeholders available at the time. Within the scope of this research, three different categories of reuse hypotheses were conceived and further specified into 9 *scenarios* (Fig. 8). The "social" category yielded four scenarios, namely (a1) "cultural center", (a2) "parish community center", (a3) "youth center" and (a4) "scout meeting point"; the "tourism" category was specified into (b1) "info-point", (b2) "exhibition gallery and (b3) "stop of a local tourist itinerary", finally, the "economic" hypotheses include both the (c1) "business/workshop" and the (c2) "observatory" reuse cases.

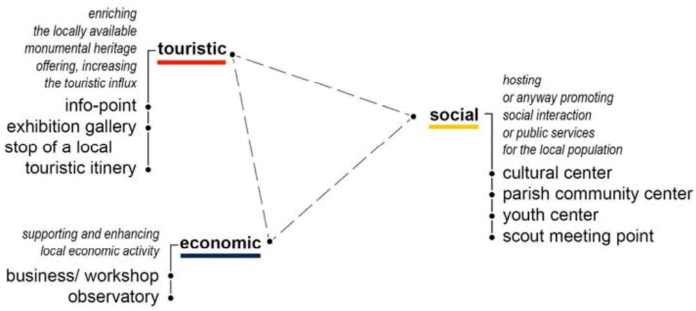

Fig. 8 Reuse-case categories and related scenarios

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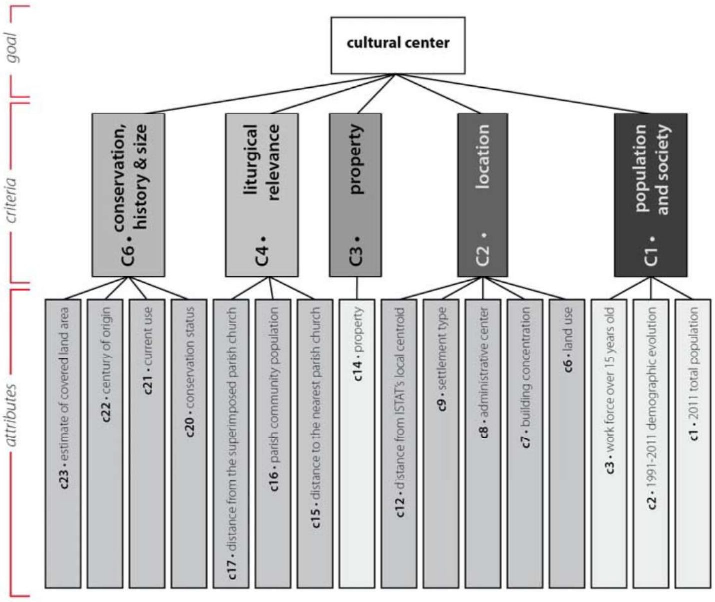

Fig. 9 Customized hierarchical scheme for the "cultural center" reuse case

Criteria	criteria weights	Attributes	attribute weights		resulting weights	TOURISTIC: Info-point	TOURISTIC: Exhibition gallery	TOURISTIC: Stop of a local touristic itinerary	SOCIAL: **Cultural center**	SOCIAL: Parish community center	SOCIAL: Youth center	SOCIAL: Scout meeting point	ECONOMIC: Business/ workshop	ECONOMIC: Observatory
C1 Population and society	0.35	**c1** 2011 total population	0.60	>	0.21	X	X	X	**X**	X	X		X	X
		c2 1991-2011 demographic evolution	0.20	>	0.07	X	X	X	**X**	X	X		X	X
		c3 work force over 15 years old	0.20	>	0.07	X	X	X	**X**	X	X		X	X
		c4 2011 population % under 20 years old	---	>	---						X	X		
		c5 distance from secondary schools	---	>	---						X	X		
C2 Location	0.35	**c6** land use	0.06	>	0.02	X	X	X	**X**	X	X	X	X	X
		c7 building concentration	0.31	>	0.11	X	X		**X**	X	X	X	X	X
		c8 administrative center	0.26	>	0.09	X	X		**X**	X	X	X	X	X
		c9 settlement type	0.28	>	0.10	X	X	X	**X**	X	X	X	X	X
		c10 distance to the nearest road	---	>	---	X	X	X					X	
		c11 distance from hiking paths	---	>	---			X				X		
		c12 distance from ISTAT's local centroid	0.09	>	0.03	X	X		**X**		X	X	X	X
		c13 altitude/height	---	>	---			X				X		X
C3 Property	0.11	**c14** property	1.00	>	0.11	X	X	X	**X**	X	X	X	X	X
C4 Liturgical relevance	0.12	**c15** distance to the nearest parish church	0.41	>	0.05	X	X	X	**X**	X	X	X	X	X
		c16 parish community population	0.26	>	0.03	X	X	X	**X**	X	X	X	X	X
		c17 distance from the superimposed parish church	0.33	>	0.04	X	X	X	**X**	X	X	X	X	X
C5 Tourism	0.00	**c18** 2016 touristic daily presences	---	>	---	X	X	X					X	
		c19 2006-2016 accommodation growth rate	---	>	---	X	X	X					X	
C6 History, conservation and size	0.08	**c20** conservation status	0.13	>	0.01	X	X	X	**X**	X	X	X	X	X
		c21 current usage	0.13	>	0.01	X	X	X	**X**	X	X	X	X	X
		c22 century of origin	0.38	>	0.03	X	X	X	**X**	X	X	X	X	X
		c23 estimate of covered land area	0.38	>	0.03	X	X	X	**X**	X	X	X	X	X

Fig. 10 6 evaluation criteria (C#) and 23 attributes (c#) are the foundation of this AHP application. The 9 columns show which of the attributes are relevant to the 9 reuse cases (right). Weights refer to the "cultural center" reuse scenario(left)

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According to Fig. 7 and Fig. 10, six criteria define the upper level of AHP hierarchical graph, describing the major investigating fields which are considered for the alternatives, namely (i) "population and society", (ii) "location", (iii) "property", (iv) "liturgical relevance", (v) "tourism", (vi) "history, conservation and size" of the architectures. They are further specified via 23 sub-criteria, also referred to as *attributes*. When defining the criteria and the attributes, both spatial related features and intrinsic/a-spatial characteristics were considered. Not all of the 23 criteria were considered altogether during each AHP application, thus criteria subsets were detailed, according to the right part of Fig. 10. This led to the definition of 9 customized hierarchical schemes (Fig. 9).

The score matrix was then defined by extracting meaningful information from the database. Some of the criteria scores directly came from database inputs, either from the survey (criteria referred to as c14, c20, c21, c22 in Fig. 10), from statistical data (c18, c19) or from ecclesiastical annals data (c16). Other criteria values required more steps to be extracted. Numerical scores could be extracted by sampling vector data (c7 is extracted from a previously interpolated criteria map, c8 and c9 are sampled from geo-localized vector data of the ISTAT census, c11 refers to different distance ranges obtained via linear buffering from Open Street Map elements, c13 is sampled from the Tuscan Digital Elevation Model raster file and c23 is extracted from the regional map vector polygonal data) or, more complexly, via SQL queries carried out in postgreSQL (c1, c2, c3, c4, c6), also in conjunction with the Dijkstra algorithm (Khan, 2016, for the c5, c10, c12, c15, c17 criteria) used to compute shortest-path distances.

As an example, the c1 criterion score values were extracted from 2011 ISTAT population tabular census data (ISTAT, 2017) linked to their pertinent reference areas. These census areas, along with the point dataset of the alternatives, were imported into postgreSQL and processed using the SQL query shown in Fig. 11.

```
DROP TABLE IF EXISTS pop.sez_11_pop4;
CREATE TABLE pop.sez_11_pop4 AS SELECT * FROM
  pop.sez_11_pop_all;
ALTER TABLE pop.sez_11_pop4 ALTER COLUMN geom
  TYPE geometry(Polygon,3003) USING ST_Geome-
  tryN(geom, 1);
ALTER TABLE pop.sez_11_pop4 ADD CONSTRAINT
  id_11_pop4_pk PRIMARY KEY (id);
DROP TABLE IF EXISTS pop.ep_alt_pop_11_4;
CREATE TABLE pop.ep_alt_pop_11_4 AS SE-
  LECT aa.id, a.sez2011, a."11_P1" AS pop1,
  a."11_P14" AS pop14, a."11_P15" AS pop15,
  a."11_P16" AS pop16, a."11_P17" AS pop17,
  a."11_P60" AS pop60, a.area_orig, st_
  area(st_intersection(a.geom, aa.geom))
  AS sup, st_intersection(a.geom, aa.geom)
  AS geom FROM pop.sez_11_pop4 a, (SELECT
  b.id_acc AS id, st_buffer(b.geom, 1000) AS
  geom FROM pop.ed_tot b) aa WHERE st_inter-
  sects(a.geom, aa.geom) ORDER BY aa.id;
ALTER TABLE pop.ep_alt_pop_11_4 ADD COLUMN
  pop_id_11_4 serial;
ALTER TABLE pop.ep_alt_pop_11_4 ADD CON-
  STRAINT pop_11_id_4_pk PRIMARY KEY (pop_
  id_11_4);
```

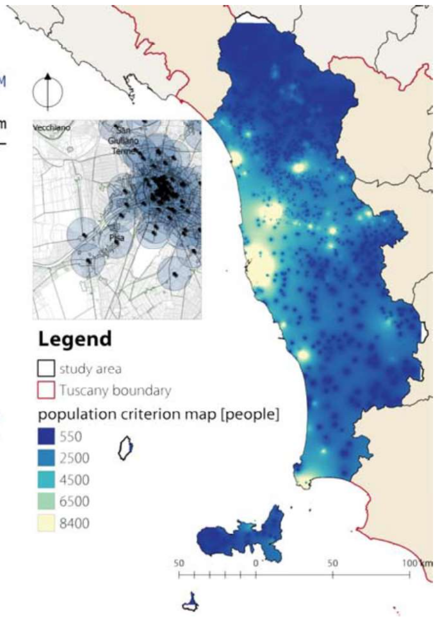

Fig. 11 SQL query example employed for the definition of the area buffers (left); population distribution of the entire study area (right); area buffers around the city center of Pisa (middle)

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Doing so, each point is evenly assigned a proportional amount of population, making it possible to compare differently located alternatives. Depending on the different reuse strategies, and within the same goal hypothesis, not all of the criteria have the same importance. Therefore, relative weights for the criteria have to be derived. Within the scope of this work, the preferences are considered *spatially homogeneous*, thus every criterion was assigned only a single-valued weight. The judgment elicitation was carried out constructing multiple preference matrices.

Like most of the other MCDA methods, AHP requires comparing and aggregating the criteria values contained into the score matrix. This can be obtained with standardization techniques, by which the value scaling into a [0.1,1] interval is carried out through customized *value functions*. Such functions transform an alternative's dimensioned raw score to a dimensionless score, between 0.1 and 1. Fig. 12 shows different application of value functions for 5 out of 23 attributes related to the "cultural center" reuse case. As a shared rule throughout the research, a minimum value of zero is avoided and replaced with 0.1, as the least desirable condition. A score of "1" indicates instead the optimum state. While c1, c2, c3 and c7 represent quantitative values, the c6 attribute, which summarizes land cover data, translates qualitative information into an ordered scale of values by pairwise comparison. Both data types are thus scaled into the universal [0.1,1] interval.

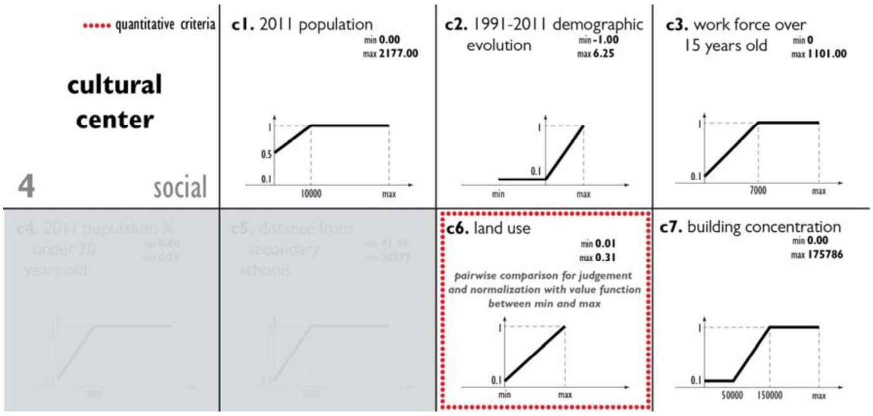

Fig. 12 Value functions used for the standardization process into the [0.1,1] interval

The overall ranking score, which express the suitability for each alternative wrt the driving decision goal, is given by:

$$A_k = \sum_{i=1}^{N} w_i a_{ki} \text{ for } k = 1,\dots,M$$

where A_k is the resulting score of the *k*-th alternative, w_i is the *i*-th weight value, *N* is the total number of criteria, a_{ki} is the score value of the *i*-th criterion wrt the *k*-th alternative and *M* is the total number of the feasible alternatives. For each scenario the equation produces a ranked list, from which the ten highest-scoring alternatives are extracted. They constitute the subset for a more mathematically solid ranking formulation. Before that, a sensitivity analysis was performed to check if and how the selection among possible alternatives would change in the case of different criteria weights.

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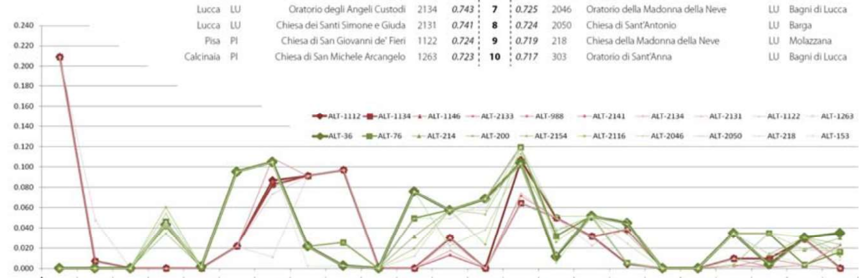
3 RESULTS AND DISCUSSION

The method is applied to each of the reuse hypotheses, resulting in 9 ranked lists. Fig. 13 shows the comparison between the AHP rankings and the score graphs for two example cases, whose results are shown in Fig. 14. Architectures connected to the "cultural center" reuse case clearly appear to be located in major city centers, such as Pisa, Lucca and Pontedera, whereas the architectures housing "scout meeting points" are quite spread over the Garfagnana territory. Unsurprisingly, such macroscopic differences are consistent with the core characteristics of the considered reuse cases.

AHP is employed in this research for choosing subsets of alternatives to be further investigated via non-compensatory decision tools, producing a more solid ranking of the architectures. However, AHP lists can be employed as final rankings, being able to give preliminary guiding orientations to stakeholders and decision makers, especially when considering all of the lists.

Cultural center						Scout meeting point				
city	province	name	ID	score	rank	score	ID	name	province	city
Pisa	PI	Chiesa di Santo Stefano dei Cavalieri	1112	0.782	1	0.782	36	Chiesa di Sant'Antonio	LU	Minucciano
Pisa	PI	Chiesa di Santa Maria dei Galletti	1134	0.770	2	0.764	76	Oratorio di San Michele	LU	Vagli Sotto
Pisa	PI	Chiesa di San Paolo all'Orto	1146	0.761	3	0.754	214	Chiesa di San Paolino Vescovo e Martire	LU	Barga
Lucca	LU	Chiesa di San Benedetto in Gottella	2133	0.759	4	0.743	200	Chiesa di Santa Maria	LU	Pieve Fosciana
Lucca	LU	Chiesa di Santa Giulia	988	0.746	5	0.738	2154	Cappella interna alla Rocca della Verruca	PI	Vicopisano
Pisa	PI	Chiesa di San Gregorio Magno	2141	0.746	6	0.731	2116	Chiesa di San Lorenzo	LI	Marciana
Lucca	LU	Oratorio degli Angeli Custodi	2134	0.743	7	0.725	2046	Oratorio della Madonna della Neve	LU	Bagni di Lucca
Lucca	LU	Chiesa dei Santi Simone e Giuda	2131	0.741	8	0.724	2050	Chiesa di Sant'Antonio	LU	Barga
Pisa	PI	Chiesa di San Giovanni de' Fieri	1122	0.724	9	0.719	218	Chiesa della Madonna della Neve	LU	Molazzana
Calcinaia	PI	Chiesa di San Michele Arcangelo	1263	0.723	10	0.717	303	Oratorio di Sant'Anna	LU	Bagni di Lucca



ALT	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23
ALT-1112	0.209	0.007	0.000	-	-	0.022	0.087	0.091	0.097	-	-	0.030	-	0.107	0.050	0.032	0.004	-	-	0.010	0.010	0.029	0.000
ALT-1134	0.209	0.007	0.000	-	-	0.022	0.083	0.091	0.097	-	-	0.030	-	0.064	0.050	0.032	0.038	-	-	0.010	0.010	0.029	0.000
ALT-1146	0.209	0.007	0.000	-	-	0.022	0.081	0.091	0.097	-	-	0.030	-	0.064	0.050	0.032	0.039	-	-	0.010	0.002	0.029	0.000
ALT-2133	0.209	0.007	0.000	-	-	0.022	0.109	0.091	0.097	-	-	0.012	-	0.064	0.050	0.031	0.039	-	-	0.002	0.002	0.003	0.023
ALT-988	0.209	0.007	0.000	-	-	0.022	0.109	0.091	0.097	-	-	0.013	-	0.064	0.050	0.031	0.039	-	-	0.002	0.010	0.003	0.000
ALT-2141	0.209	0.007	0.000	-	-	0.022	0.086	0.091	0.097	-	-	0.030	-	0.071	0.050	0.032	0.039	-	-	0.010	0.001	0.003	0.000
ALT-2134	0.209	0.007	0.000	-	-	0.022	0.109	0.091	0.097	-	-	0.018	-	0.064	0.050	0.030	0.039	-	-	0.004	0.002	0.003	0.000
ALT-2131	0.209	0.007	0.000	-	-	0.022	0.109	0.091	0.097	-	-	0.018	-	0.064	0.050	0.030	0.039	-	-	0.002	0.002	0.003	0.000
ALT-1122	0.209	0.007	0.000	-	-	0.022	0.074	0.091	0.097	-	-	0.026	-	0.074	0.050	0.032	0.004	-	-	0.010	0.001	0.029	0.000
ALT-1263	0.209	0.048	0.000	-	-	0.022	0.011	0.091	0.097	-	-	0.030	-	0.064	0.050	0.022	0.039	-	-	0.010	0.002	0.029	0.000

Fig. 13 Score matrix (bottom), score graph comparison (middle) and two AHP rankings (top) for the "cultural center" and the "scout meeting point" example cases

4 CONCLUSIONS

By making use of well-established MCDA tools, this work has proposed an algorithmic framework which is able to provide valuable guidance on reuse choices and investments, in order to assist decisions and maximize effectiveness of the available resources. In addition, based on quantitative input information describing both the buildings and their relations to the surroundings, this contribution presents, through the descriptions of 480 buildings, a real-world application example.

Once the rankings are finalized, it is important to verify the sustainability of the identified reuse hypotheses and value-enhancement strategies against the needs of the territory, both on a wide, geographical and on a narrower, local scale. Moreover, we are aware that, as much important the ranking lists may be, they are still

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meant to complement, not replace, human decisions. Finally, improving the ability of automatic algorithms to capture the full Return On Investments (ROI) value of restored buildings, both economic and social, should be the subject of future research.

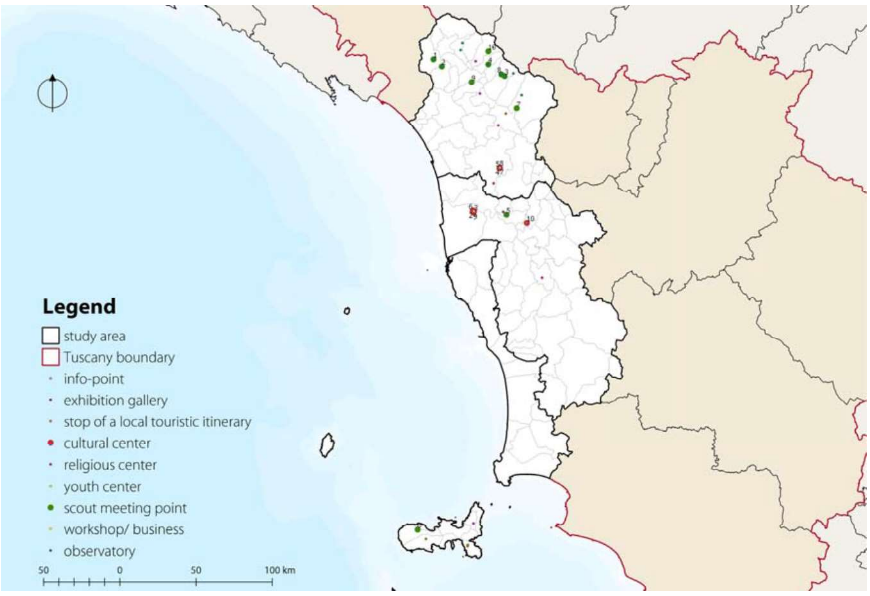

Fig. 14 Ranking results for two examples: "cultural center" and "scout meeting point"

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AUTHOR'S PROFILE

Elisabetta Pozzobon is a Ph.D. student in the DESTeC department of the University of Pisa after completing her master degree course in the same Athenaeum, Elisabetta Pozzobon is currently carrying out studies and research at the urban and territorial scale in the cultural heritage field and, in particular, in the Christian Catholic architecture, both in Italy and in Europe.

Luisa Santini teaches Urbanistic Techniques at the School of Engineering of the University of Pisa. She is an expert in urban and regional planning, urban design, environmental and strategic assessment and decision support tools

Alessandro Santucci is a researcher at LISTA (Engineering Laboratory of Territorial and Environmental System), PhD in Sciences and Methods for the City and the European Territory, University of Pisa, collaborator in the teaching of Urban Planning Technique and Modeling of the Territory. He is currently carrying out studies and research at the urban and territorial scale, in particular, in the Spatial Decision Support System (Multi Criteria Decision Analysis and GIS).

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