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Università degli Studi di Napoli Federico II

14

numero 2 anno 2014

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Towards an Inclusive, Safe, Resilient and Sustainable City: Approaches and Tools

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Registrazione: Cancelleria del Tribunale di Napoli, n. 5144, 06.09.2000
BDC è pubblicato da FedOAPress (Federico II Open Access Press) e realizzato con Open Journal System

Print ISSN 1121-2918, electronic ISSN 2284-4732

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EDITORIAL

Luigi Fusco Girard

1. From the city as a problem to the city as an opportunity

The city represents the place where one of the most considerable mega-trend of the new millennium is happening: the urbanization process, with its environmental, social, economic, cultural impacts. Here the national/regional wealth is produced. The city represents the engine of economic growth of a region, of a country; it is the place where productivity, capability to introduce innovations and to economize resources are higher. The city is more and more considered as the centre of national development policies: where the urban, environmental and economic issues are closely intertwined. But here previous agglomeration economies often turn into many diseconomies. The city is becoming also the place where poverty, social segregation and fragmentation of relationships are concentrated and where environmental pollution is higher. However the city is increasingly considered as an "attractor of hope". It is a "laboratory", that is the place where the future of 21st century society is going to be built: where the city capability to attract investments, creative activities, talents, people in a context of growing competition with other cities in the globalized economy appears more evident.

What future? What development? What quality of life? How to improve the existing conditions? Which strategies, approaches and tools to make more "human" the evolutionary dynamic of the city?

2. Towards a new urban paradigm

A more general question derives from the recognized unsustainability of the current city organization: what new urban paradigm to improve the quality of life, to achieve generally more desirable conditions, to make more human the evolutionary dynamic of the city?

Some general principles of the new urban paradigm are outlined by the Open Working Group on Sustainable Development Goals, appointed for reformulating the objectives of RIO + 20 - The Future We Want as the basis for the new UN Development Agenda beyond 2015. In September 2014 a totally new goal (n. 11, that is the "city goal") has been introduced in those of the post-2015, for making cities "inclusive, safe, resilient and sustainable".

Social inclusion is the capability to reduce/eliminate segregation, exclusion, marginalization, etc., forms (through the provision of specific spaces for all the subjects of the urban community, etc.); resilience is linked to the capability to regenerate significantly the resources that are used for the functioning and that the city consumes (water, energy, soil, etc.) through reuse, recycling, regeneration, transforming the linear metabolism into circular one, imitating the functioning of natural ecosystems; sustainability (in economic dynamic) is the capability to produce new economic wealth, minimizing negative impacts on the environment; safety can be interpreted from the point of view also of the health of people and environment and the security of goods.

3. Moving toward a New Urban Agenda

We are moving toward a New Urban Agenda. After the Meeting in Istanbul (1996) and the proposal of the Habitat Agenda, UN Habitat has identified a set of principles for moving towards a new urban paradigm, characterized by the "human scale" of the city development.

We can interpret this general goal as the capacity to concretely implement the human rights in the city system. Human rights to health, work, education, housing, services, good environment etc. and human scale of development are interdependent. Through human rights implementation, resilience, social inclusion, cultural identity, health, economic sustainability/prosperity are enhanced.

Are the above principles enough to give new shape to the city, and to promote the "human scale" of urbanization: to give a different form, less dis-human, to the development of the city, seen as the place where the relational dimension of humanity is achieved? To realize the "city of relations" (between centre and periphery, between built fabric and suburban territory, between inhabitants, between people and institutions, between city and nature etc.), where relations become systemic bonds able, in their turn, to generate new chains of value creation, through synergies, symbiosis and circularization processes?

4. How? Which tools?

Work is a general engine for building relations and bonds, and for making the city more inclusive, safe, resilient and sustainable.

This issue of BDC aims to promote a reflection not much on the general criteria and principles, but above all on the tools that should be acquired.

Urban planning, urban design, local finance are some examples of tools for achieving a more just, regenerative, safe and prosperous city. The city prosperity depends on its attractiveness. It can be enhanced through planning/design.

In particular, the question is: how and through which tools is it possible to move from principles to their concrete fulfilment to improve the attractiveness of the city, which depends on its infrastructure and technological, economic, social, environmental and cultural equipment in the growing shortage of local resources, due to the reduced financial/fiscal capability?

Of course, the questions multiply: for example, how to "capture" a rate of generated real estate plus values? How to integrate bottom-up, through crowd-founding processes, the local financial base in the view of specific local projects?

5. Towards operationalizing HUL to make "inclusive, safe, resilient and sustainable cities" through attractiveness capacity

The main objective of BDC issues is to document the activities of Calza Bini Research Centre - International Laboratory on Creative and Sustainable City in developing practical means to achieve sustainable and inclusive human development in cities. The entry point is here the use of historic/cultural landscape/heritage as key asset.

Currently, the Historic Urban Landscape approach is only a theoretical approach, since the proposed tools have not declined in their practical application.

The HUL approach is much focused on "what is to be managed and why" and not on "how". The "how" of the HUL approach, how it can be implemented in the cities, within their specific contexts, is the key topic of a research work, for operationalizing HUL.

HUL can help more generally to integrate urban planning with other tools of urban governance for integrating urban planning tools with local financial base.
The HUL approach is interpreted in Calza Bini research activities as an effective approach to increase the attractiveness of the city/territory system, and thus to re-generate the city/territory system, to increase productivity: to stimulate urban/territorial transformations in a more creative and desirable perspective, to make the existing system more resilient and thus more competitive for achieving new opportunities and prosperity.
The city attractiveness depends first of all on existing cultural heritage sites/landscapes and their valorization. The city attractiveness depends on the relationships between open/natural spaces and man-made capital, between nature and architectural artifice/product. These relationships have shaped the city and its history and then will be central in drawing its future. The improvement of city attractiveness depends on how it proceeds to introduce technological innovations (which allow reducing impacts of pollution/greenhouse, to conserve energy, to use renewable energy, etc.): that is, it depends on the relationship between technology and culture. The city attractiveness depends on the quality of concrete operational planning tools to combine creatively particular/specific interests and the city general interest. Improvements of the city attractiveness are linked to the existence of networks of mutual support, mutual exchange, of solidarity cooperation. They involve communication, knowledge and participatory processes, towards the self-organization, self-management, self-government. The city attractiveness is enhanced through the capacity of regeneration of natural resources. But, first of all, it needs to regenerate relationships in the city physical space: between inhabitants; between inhabitants and man-made assets; between inhabitants and earth/nature; between productive activities; between cities and economic activities; between cities and rural areas.
The new urban paradigm is based on relations and links, able to generate synergies that become symbiosis able, in turn, to trigger circular processes of organization which show how coordination and cooperation are economically, socially and environmentally convenient.

6. Conclusions

The HUL approach is here put in relation with the search of the new urban paradigm: as a tool that can contribute towards the new urban paradigm characterized by a "human scale".
HUL approach is interpreted in Calza Bini – Creative City Laboratory researches as a good one to contribute to implement the symbiosis between landscape/heritage conservation and development, producing economic, social and environmental plus-values through new relations and thus opening new opportunities. In a more general perspective HUL is considered as a good approach to address urbanization processes in a more sustainable direction: to ensure "quality" to the urbanization processes, providing new principles, new visions, approaches, methods and tools. The "good urbanization" is an urbanization that should be shaped by quality: the key role of cultural heritage/landscape is that cultural urban heritage/landscape provides quality, sense and meanings to the urbanization processes, promoting the implementation of "places" as attractive spaces in the city/metropolitan areas. Cultural heritage and landscape are the memory of the urban system: the ground of its identity. They contribute to the physical assets and to "quality of life" of people.

Cultural landscape/heritage creative use can contribute to the new urban development paradigm, based on a new city structural organization: it contributes to many SDG'S, making cities more resilient, inclusive, safe and sustainable; the reduction of poverty; the city health; the regeneration of local economy (fostering innovative activities and the local creative economy) and the local employment (in particular in sustainable tourism activities/investments); the resilience of urban system and infrastructure.

Many examples and good practices can be proposed, showing that landscape and heritage contribute to the well-being, employment, social cohesion, creative activities, etc. and more in general to enhance the city attractiveness. HUL approach offers an interesting perspective to new hybridization processes for planning and developing, but it absolutely requires specific innovative tools to be implemented.

Rigorous and innovative economic evaluation methods are required to convince private, public and social actors that the integrated conservation of the cultural urban heritage/landscape is an investment and not a cost (because benefits overcome costs), offering new arguments about the inclusion in the creative local economy; the inclusion in the sustainable tourism strategies; the inclusion in the urban resilience strategies.

Economic matrix is absolutely necessary. But it is not sufficient.

Hybrid evaluation methods are needed, able to integrate quantitative and qualitative impacts. Specific evidence based indicators are to be identified, for assessing in an operational way the changes of the city landscape. Cultural heritage/landscape should be not only protected and safeguarded, but revitalized and creatively regenerated.

Through evaluation tools, it is possible to pass from general principles to operational practices, producing empirical evidence on the economic, social and environmental benefits of HUL conservation and regeneration.

All the above (and the many others) issues refer to a common problem: how to improve decision-making processes and which evaluations should be chosen and performed at different scales? How to select an appropriate system of indicators that are actually able to verify and monitor whether and to what extent the objectives of sustainability, resilience, inclusion, safety, are achieved at their best?

Many topics emerge: the potential of hybrid landscapes in the city regeneration, in the wealth city production, in the social and cultural promotion, through many examples of good practices. Good practices offer empirical evidence of the positive multidimensional impacts. They show that integrated conservation contributes to local economic development. Here some research contributions about evaluation tools are gathered.

Joe Ravetz explores methods for valuation and evaluation, which are suitable for complex inter-connected "real" systems. Urban cultural heritage sites, or urban ecosystems, often contain multiple sources of value (economic, social cultural, ecological): such value is often generated by multiple collaborations, social learning and collective intelligence, and there are multiple policy objectives and system inter-connections to be evaluated. In contrast to the normal reductive assumptions of mainstream valuation/evaluation, such highly inter-connected situations call for new methods. This paper demonstrates the "synergistic" approach to valuation and evaluation, with a practical "evaluation template", and some examples from "Greater Manchester", UK.

Giuseppe Munda introduces the concepts of "economic democracy", political democracy and evaluation frameworks, considering that in order to formulate, evaluate and implement public projects or policies, the existence of a plurality of social actors, with interest in the

options being assessed, generates a conflictual situation. In this article, Munda shows that the compensation principle was invented by Kaldor and Hicks to achieve two clear objectives: to compare individuals' preferences according to the efficiency oriented utilitarian calculus, explicitly avoiding the principle one individual, one vote; to implement an objective evaluation criterion, that could be accepted in the framework of the dominant positivistic philosophical paradigm. In the compensation principle, there is no escape from value judgements, it is not the positivistic objective evaluation criterion. A relevant question is: are the original Kaldor-Hicks objectives still relevant in the 21st Century?

Arayeh Afsordegan, Mónica Sánchez, Núria Agell, Gonzalo Gamboa, Lázaro V. Cremades present the implementation of linguistic descriptions with multi-criteria decision aid approaches in urban energy systems, considering that Multi-Criteria Decision Aid (MCDA) methods include various collections of mathematical techniques related to decision support systems in non-deterministic environments to support such applications as facility management, disaster management and urban planning. This paper applies MCDA approaches based on qualitative reasoning techniques with linguistic labels assessment. The aim of this method is ranking multi-attribute alternatives in group decision-making with qualitative labels. Finally this method is applied to a case of urban planning in selection of the less energy consumption project in a geographical area in Catalonia.

Annalia Bernardini, Ricardo Barrero, Cathy Macharis, Joeri Van Mierlo introduce the application of the Multi-Criteria Analysis (MCA) to technological solutions aiming at recovering metro braking energy in the transport sector. Indeed, the transport sector is responsible for a large share of fossil fuels consumption and emissions, mainly CO_2, and is seeking for different ways of reducing their energy consumption and, especially, their dependency on fossil fuels. This paper presents the MCA of technological solutions recovering metro braking energy by the implementation of the MCA PROMETHEE method, endorsed to select the most suitable technological solution for the tram and metro network in Brussels. The MCA approach allowed to firstly evaluate the different technologies and afterwards to propose an individual decision to the public transport decision-maker based on the decision problem objectives and the MCA results.

The paper of Lucia Rocchi, Gianluca Massei, Luisa Paolotti, Antonio Boggia presents the topic of soil instability and agricultural management, considering that land defense from hydrogeological instability is a very important topic, at both national and international level. Every year these phenomena cause huge environmental, social and economic damages. Human activities, especially in relation to land-use change and intensification of agriculture, represent one of the main factors affecting the stability of the soil. For a proper management of territory in terms of prevention and control of hydrogeological instability, to use tools that combine support to public decision-makers with spatial analysis is essential. This paper illustrates the utility of integrating Geographic Information Systems (GIS) with Multi-Criteria Analysis (MCDA) in relation to a case study of the basin Menotre, in Umbria, proposing the use of the Dominance-based Rough Set Approach, developed in GRASS GIS 6.

Marianna D'Angiolo and Pasquale De Toro, starting from the UNESCO proposal (2011) of Heritage Impact Assessment (HIA), propose a multi-criteria approach to the evaluation of five possible alternative scenarios of intervention for the UNESCO site "Amalfi Coast". The definition of the scenarios was carried out from the higher-level planning and programming in force, as well as on the basis of a SWOT analysis. The multi-criteria

evaluation, carried out with reference to specific goals and criteria, allowed us to deduce a ranking among the scenarios proposed, in particular by applying the Regime method; also a sensitivity analysis on the results was elaborated.
Antonia Gravagnuolo introduces a metodological approach for the evaluation of landscape services in terraced cultural landscapes and the proposed methodology is applied to the case study of the UNESCO World Heritage site of the Amalfi Coast in Southern Italy too. The results show that regulation and maintenance services, as well as provisioning services, are priorities for the conservation of terraced landscapes. The terraced landscapes represent a particular type of agricultural landscapes, which are considered at risk due to economic and social transformations. Several international initiatives (UNESCO, ITLA, FAO GIAHS) highlight the need to assess, evaluate, protect and valorise the complex system of services and benefits provided by terraced landscape, in order to avoid the irreversible loss of cultural landscapes that provide an effective model of resilience built over centuries.
The paper of Bice Cavallo, Livia D'Apuzzo, Luciano Basile investigates conditions, weaker than consistency, that a pairwise comparison matrix has to satisfy in order to ensure that priority vectors proposed in literature are ordinal evaluation vectors for the actual ranking. In particular, the authors introduce a partial order on the rows of a pairwise comparison matrix; if it is a simple order, then the matrix is transitive, the actual ranking is easily established and priority vectors are ordinal evaluation vectors for the actual ranking.
Paola Carone investigates sustainable development potentialities of the ports of Tangier. Ports have always been places of the liveliness and dynamism of the cultural, economic and social development of cities, metropolitan areas and regions. The life of port areas is characterized by the flows of goods, people, languages, cultures that contribute in a way that seems intangible, but is a determining one actually, to the design of the urban context. Thinking about the potentialities of port cities in contexts related to the South of the World could be a further strategy in order to propose scenarios for really sustainable development of developing countries. The port area of Tangier in Morocco, currently characterized by two poles, the historical old port in the city center and the new one at 40 miles from the previous Tangier Med, could be an interesting laboratory for reasoning and proposing innovative strategies and plans to achieve local and global sustainable development.
The paper of Hella Ben Brahim Neji and Adel Besrour analyze students' perceptions of innovation in sustainable development technologies and their role to optimise higher education's quality. Technological innovation and scientific research have always helped industry and other economic sectors to evolve, allowing them to reduce their production, operation and maintenance costs, and in return, the fields of engineering and innovation widened increasingly. The objective of this research is to evaluate the importance technological innovations in sustainable development (especially, green energy) on the quality of higher education improvement. The study is based on a survey conducted among a sample of students from the High School of Technology and Computer Sciences (ESTI – University of Carthage, Tunisia), pointing out the need to integrate teaching staff, researcher and students, in identifying and optimization technological solutions.
Stewart Bailey, Advait Deshpande, and Alby Miller introduce the use of 3D visualisation for urban development, regeneration and smart city demonstration projects, considering the examples of Bath, Buckinghamshire, and Milton Keynes. The paper discusses three different case studies related to the use of 3D visualisation for projects focussing on urban development, regeneration, and Smart City demonstrations. With each of the case studies,

the problem statement, the approach adopted for 3D visualisation, and the outcome is covered. The paper concludes by discussing what 3D visualisation offered to each project. The paper discusses how in order to effectively use 3D visualisation the approach needs to be adapted according to the problem statement. Depending on the project requirement, 3D visualisation is likely to serve multiple purposes in urban development, regeneration, and Smart City demonstration projects. The paper suggests that the use of 3D visualisation adds an extra dimension to presenting data and also provides an effective tool for analysing the data.

VALUATION AND EVALUATION IN COMPLEX REAL SYSTEMS: A SYNERGISTIC MAPPING AND POLICY TEMPLATE

Joe Ravetz

Abstract

This paper explores methods for valuation and evaluation, which are suitable for complex inter-connected "real" systems. Urban cultural heritage sites, or urban ecosystems, often contain multiple sources of value (economic, social cultural, ecological): such value is often generated by multiple collaborations, social learning and collective intelligence, and there are multiple policy objectives and system inter-connections to be evaluated. In contrast to the normal reductive assumptions of mainstream valuation/evaluation, such highly inter-connected situations call for new methods. This paper demonstrates the "synergistic" approach to valuation and evaluation, with a practical "evaluation template", and some examples from "Greater Manchester", UK.

Keywords: synergistic approach, evaluation template, Greater Manchester

STIMA E VALUTAZIONE NEI SISTEMI REALI COMPLESSI: UNA MAPPATURA SINERGICA E UN MODELLO STRATEGICO

Sommario

Questo articolo esplora alcuni metodi per la stima e la valutazione, adatti a sistemi "reali", complessi e interconnessi. Nel patrimonio culturale urbano, o negli ecosistemi urbani, vi sono molteplici fonti di valore (economico, socio-culturale, ecologico): tale valore è spesso generato da forme molteplici di collaborazione, di apprendimento sociale e di intelligenza collettiva. Pertanto, diventa necessario valutare obiettivi politici multipli e interconnessioni sistemiche. In contrasto con le ipotesi riduttive proprie di una stima/valutazione tradizionale, queste situazioni fortemente interconnesse richiedono nuovi metodi. L'articolo presenta un approccio "sinergico" alla stima e alla valutazione, con un "modello valutativo" operativo, ed alcuni esempi sperimentati per la "Greater Manchester", nel Regno Unito.

Parole chiave: approccio sinergico, modello valutativo, Greater Manchester

1. Introduction

The word "value" might cover many possibilities: market price, or ethical principles, ecological resources, or cultural beliefs. Could it be that a "value", and its close associate "capital", is not so much an "item" or "object"? Could it be more like the inter-connection of different domains of human experience (social, technical, economic, ecological, and so on)? For instance, the value of financial "capital" is only realized through spending on goods or services; ecological "capital" is realized when mobilized by human needs and activities. Other kinds of value are about sense-making, or what can be called "boundary objects": if we ask the "value" of a Van Gogh painting, we assume that someone can pay $50 million to buy and enjoy it, whatever that means. But a unique wildlife site in Manchester, or an empty church in Naples, may be less suitable for private ownership in many ways: so the economic value might be zero or boundless, and the social or cultural value, or the market proxy for such values, might depend on many assumptions. These are often shaped by a wider system of power or ideology, which can only be understood by deliberation and negotiation (Jacobs, 1997).

All this points towards a concept of value, and a methodology of valuation, which doesn't assume that everything should be an object for sale. Such "valuation" (i.e. *"estimation of something's worth, especially one carried out by a professional appraiser*"), then extends towards "evaluation", which is more about the considered "judgement" of success, feedback to policy objectives, or "*the making of a judgement about the amount, number, or value of something*"[1]. Again we can see the contrast between a reductive approach and one which is more inter-connected or "synergistic": the first assumes that policy is like a machine, with objectives which are neutral, and outputs/outcomes which are fully predictable. The second starts from a reality where policy is more nuanced and entrepreneurial, where its objectives are often controversial, and where the outcomes depend on social learning and collaboration: all of which calls for more than a reductive approach (Ravetz, 2013). It seems more useful to work with values as human-centred combinations: not only values for the functional and material, but those which are more about capabilities and "affordances", aspirations or identities, sense-making and significance (Norman, 2103).

The reduction of values to a market price is useful for some purposes, especially where prices are the metrics for decision-making. But for social, cultural or ecological values, which are more likely to be realized and mobilized by creative collaboration and social learning, we need a more creative process of evaluation to reflect this. So, this paper demonstrates an alternative: the "synergistic" approach to working with complex, inter-connected, "real" systems, which are shaped by the human factors of collaboration and social learning. The paper is based on the "Insights" chapter of the forthcoming "Urban 3.0" (Ravetz, 2015).

2. Sustainability as capital management

Many thinkers over 20 years have looked at how "sustainability" can be identified, assessed or valued, and the direct result is often in the form of a "framework" which can be "operationalized" with "indicators" or "benchmarks" (it's interesting that artists, anthropologists and some others see it quite differently) (Graeber, 2001). One such scheme was the "5 Capitals" approach by Forum for the Future and others, looking for a practical system to account for non-monetary assets and intangibles[2] (Porritt, 2007). This provided a

way into thinking about economic systems or business models, which could take on the five capitals or five value-sets, as a kind of bottom line to be maximized or optimized. Furthermore, it aimed to make visible the transfers from one form of capital to another, which is often the effect of enterprise or business activity.

This idea of capitals and transfers seems fine, until we get to some reality checks. For instance, the calculation of proxy market value of ecosystems generally assumes that social capital or social interactions are low or zero: otherwise the calculation becomes more complex and less "tractable".

In practice the difference between high/low economic valuation is very sensitive to the social/cultural inter-connections and context. For example, as a community architect I came to specialize in feasibility studies, in which the project building "value" was at the core (Ravetz, 1995). First I learned mathematical methods of property valuation; then I realized that the whole calculation depends on the "yield factor" (ratio of capital value to revenue), and the social psychology of confidence, risk, security, cultural alignments and future expectations, of the location and surroundings, whether "prime" (5-7%) or "secondary" (8-12%). If these yield factors are agreed between all, then it's a perfect equilibrium market (where in theory there are no profits to be made). If we assume that a building is in a "good" location with expectations of rising values, its capital value will be 15 times its rental; if in a "risky" location, the capital value is half that.

For a typical ecosystem problem, if we assume that a river is mainly there to supply 1000 tonnes of water to the nearby city, then its value is low but predictable; but if people use it as a cultural landscape, or if it serves some strategic purpose, then its value can be higher, although less predictable and more negotiable.

So here synergistic thinking raises very topical questions. Firstly, what is to be valued? – this might be simple and linear, or it might be complex, self-organizing and cognitive – in which case the "value" isn't well suited to representation as a single number, more like a field of creative possibilities. And another question: who is the "subject" or user of the valuation, and what is their agenda? On one end of the range is a mythical neutral technocrat, or at the other a social/ecological entrepreneur, or a complex community in flux and development. A third question is where does this information go and for what purpose? Is it mainly technical data for a technical calculation, or more about enabling of creative collaboration in a wider community? These three questions then open the door to a more holistic and synergistic approach.

3. The synergistic approach

From global "Grand Societal Challenges" to local urban development, we can see complex inter-connected problems and opportunities. In general these are shaped not only by "linear" mechanical-type systems, but also by "cognitive" human systems of social learning and collaboration. In response the theory and practice of "synergistics" has emerged. Together with the methods of "synergistic mapping and design", we can begin to respond to these more inter-connected and co-evolutionary problems and opportunities. The method begins by drawing a concept mapping of the inter-connections of the issue, with detail as suitable (it can be started on one piece of paper), then follows a cycle of questioning, thinking and mapping:

– scoping/landscape mapping (questions: who/what is involved, what are the inter-connections?)

- scenario/change mapping (questions: what are the drivers of change, trends, alternatives?)
- synergy/idea mapping (questions: which are the most significant and creative synergies and opportunities?)
- strategy/pathway/road-mapping (questions: what to do, sooner/later, who and how?)

With this 4-stage cycle, we can explore different and parallel types of change, co-evolution and "emergence", of new patterns and new systems:

- 1.0, linear change in "functional systems", responding to direct short term change (with an image of a large and complex machine);
- 2.0, adaptive change in "complex adaptive systems", evolving with longer term changes and transitions (an image of biology wilderness or garden);
- 3.0, synergistic change in "Complex Cognitive Co-Evolutionary" systems ("C3" systems), shaped by human qualities as thinking, learning, questioning, strategy, self-awareness, shared intelligence (this is suited to an image of a human situation).

Such a "3.0" model of synergistic change helps to understand the difference between a mechanical system and a human system. It also then highlights the difference between a blind, destructive, "winner takes all" system of economic extraction or political power and a more intelligent strategic and collaborative "C3" system. The 3.0 model then can be explored in almost any kind of human domain, for example:

1. Urban 3.0: a self-organizing, responsive city or region system, which provides the physical and spatial framework to enable livelihoods for all, with responsibility for its ecological effects, and promoting a social justice and equality;
2. Economy 3.0: systems of livelihood, production, finance and overall prosperity, which include social and ecological values, responsive to global limits, creative and resilient, self-organizing and stabilizing;
3. Governance 3.0: structures for participative decision-making and collective resource management, with citizen empowerment via collaboration, based on social learning and intelligence.

4. A visual thinking framework

Visual thinking is at the core of the synergistic method, with a combination of concept diagrams, semi-figurative systems mappings, and narrative cartoons (Ravetz, 2011).

Visualization enables a direct connection to the creative thinking of stakeholders, as seen on the flip-charts used in workshops and similar deliberations. The visual thinking framework here is a kind of template, a kind of thread which runs right through each of the "insights" of the 3.0 toolkit, including evaluation, analysis, risk and resilience, innovation and transition. Each of these brings a particular angle of view for working on complex "real" systems.

The template is shown here in two parts (Fig. 1 and Fig. 2). In each, the left hand side of the picture shows the linear and adaptive (1.0-2.0) system models; the right hand side shows the "synergistic" (3.0) model.

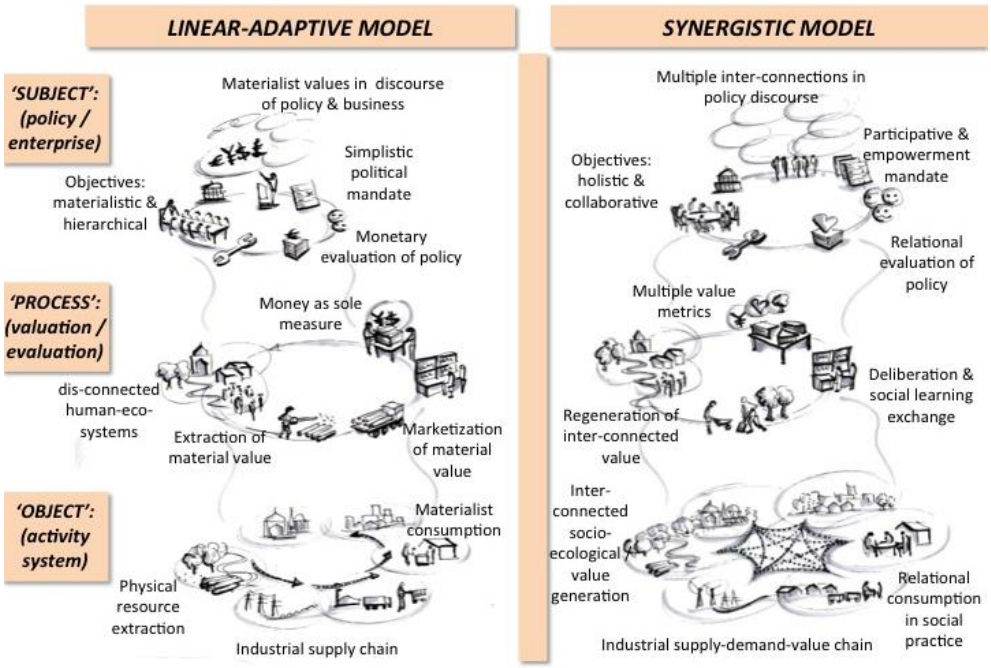
Firstly, a "semi-figurative" view shows sketches of little people, houses, cities, trees, etc., together with some of the main inter-connections, in three different layers (Fig. 1). Second, a more "analytic" view shows a concept-level flow chart: also with the main inter-connections of actors and factors, and also shown in three different layers. How to define

these layers in such complex inter-connected systems? A very practical approach is to look at the "subject-object-process" relationships.
At the top we see the "subject", the person or organization doing the valuation: the "cognitive entity" or policy system, or the business/enterprise which needs to know the value. And then below with the lower layer we see the "object": the thing being valued, the system which generates the value, or risk, or any other quality we're interested in. In the centre is the "process": the actual method of valuation/evaluation, which can be visualized as a "cycle" of generating knowledge. For instance the "process" of valuation starts with a fuzzy thing, whether a Van Gogh painting, a river, or a wasteland: then brings it into focus: and then looks for a mobilization or actualization (either taking it to an actual market to sell, or some other proxy way to define the value): and then we analyse the price, its conditions and context, leading to a final valuation, and so on. Again on the left of the picture, this "process" is focused only on material values (selling the forest for wood production): on the right hand side, the "process" is more holistic and inter-connecting of economic, social, cultural and ecological kinds of value.

5. Valuation as co-evolutionary learning

Overall this visual thinking aims to highlight the co-evolutionary shift in valuation/evaluation: from a linear model, to an adaptive/extractive model, to a synergistic model (Fig. 1).

Fig. 1 – Values, valuation and evaluation: synergistic visual thinking



Linear type valuation seems suitable for linear kinds of assets (e.g. the river supplies 1000 tonnes of water per day), linked to tangible functions, such as drinking water or irrigation. On that basis an economic valuation is simple in principle: comparing with the market price of water from other sources, or a CVM type proxy valuation, based on how much would people pay for more water, assuming it's clear which people you ask, and how the questions are framed (which in practice is often not clear).

In contrast, extractive/adaptive type valuation opens the door to more creative thinking, with feedback or circularity or "gaming", in how people value the assets, in theory or practice. For water, we could hold an auction where the most entrepreneurial could bid, and the winner will have the highest "value" business plan for selling or using the water.

This is the assumed logic of marketization programs, from cost-recovery infrastructure, to carbon markets, and "The Economics of Ecosystems and Biodiversity" (TEEB) or the UK application, "Payment for Ecosystems Services" (Defra, 2013). Such models have the promises and pitfalls of adaptive-extractive systems: strong incentives for efficiency and innovation, alongside market manipulation, speculation, extortion, polarization and vulnerability to collapse. From experience, market-based values can work well, (a) if the market is deep and liquid, and the commodities are easily tradeable; and (b) if other political, cultural or ethical value questions are agreed or with strong consensus. In practice, water in countries with 100% supply is mainly a regulator technical/market issue; in others it's the subject of power conflicts, expropriation, cultural hegemonies, and the critical perspectives of urban political ecology. So how can the synergistic approach help?

First we assume that the "thing to be valued" is inter-connected and emergent (the river is a multi-functional and multi-value resource, not only as water at 1000 tonnes/day), and then, the services provided, or "capabilities" enabled by the water, are also inter-connected and co-evolutionary (e.g. opportunities for social innovation through wetland ecologies, cultural co-creation and local enterprises, rather than linear growth projections). Then we link the valuation results with a social deliberation, capacity/collaboration building and social learning process. We look at the possibilities for multi-functional landuse, for socio-ecological enterprise, and the collaborative stewardship of the river and all of its habitats. In practice these possibilities can be challenging to political economic or ideological power: in which case, the synergistic approach to valuation helps to find "win-win-win" opportunities for collaboration.

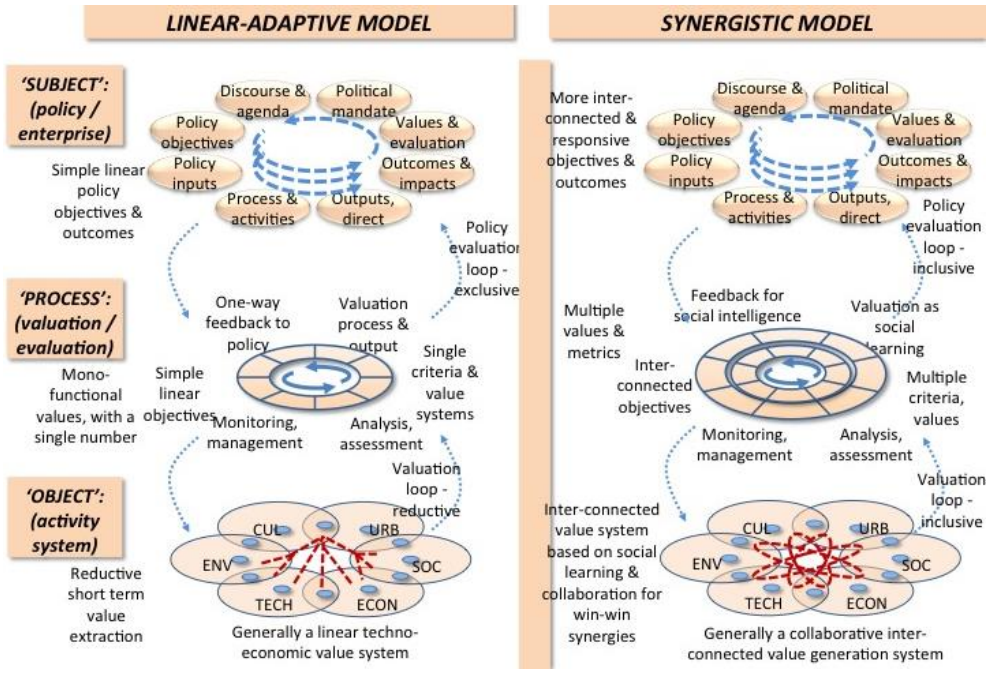
6. Evaluation as co-evolutionary learning

With a synergistic valuation on the table, we can then extend the knowledge cycle to policy evaluation. Similar thinking has emerged on evaluation of sustainability policy. For example if the policy objective is to build more roads, then it is a linear kind of task to measure the roads, the costs and performance, and provide an index or metric.

If however the policy objective is to "enhance urban accessibility and connectivity", then these are more like fuzzy, synergistic, multi-value qualities, and the outcome is not just a linear chain of policy and effect: it depends on the participation and creative thinking of users and stakeholders. Such questions emerged in a previous round of research on evaluation of "Regional Sustainable Development" (RSD), i.e. development which aims at greater integration between economic, social and environmental agendas (George, 2013; Ravetz *et al.*, 2004; Ravetz, 2007). This highlighted parallel trends, such as the rise of "rational management" and "evidence-based" policy, at every level of public governance,

even while the pressure for participation makes this task more challenging. There are trends in methods and tools, such as the extension of impact assessment to sustainability appraisal, lifecycle analysis, performance benchmarking and so on. There are technical innovations, such as remote sensing, social media and real-time databases, and in contrast there are many social innovations, in deliberative processes, community participation and organizational learning. With the benefit of recent insights from synergistic thinking, we can set out a more creative-collaborative evaluation agenda (Ravetz *et al.*, 2012): this is visualized in Fig. 2 with the "evaluation loop", which links the knowledge cycle back to policy. If we have a linear policy objective as on the left (e.g. building roads), then the system is framed as a linear system (needing materials, labour, land and money), and the evaluation is a linear calculation (measuring the inputs against outputs and targets).
If on the other hand, we have a synergistic policy objective (e.g. connectivity and accessibility), then the urban system is framed as complex, self-organizing and self-learning, in the sense that travellers "learn" about cycling or tele-conferencing, while employers "learn" that flexible working hours can increase productivity.

Fig. 2 – Values, valuation and evaluation: analytic mapping



This points towards an urban system which can be more collaborative and co-intelligent, as and where collective actions can enhance accessibility: for example, policy innovation for pedestrian zones, social innovation for "walking buses", or business innovation for employee travel budgets. Following through, the policy and governance esystem then needs

to enhance its learning and intelligence, to respond to such creative opportunities. Finally, the evaluation cycle at the centre of the picture needs to respond to this, so it can identify and promote more intelligent policy and governance approaches.

7. Towards a synergistic evaluation tool

In all this, however complex the question, we need simple practical tools. Here we demonstrate an evaluation framework which is deliberately simple: a matrix on one sheet of paper, to help the process of deliberation, visioning, analysis and evaluation.

The basic idea is to look for signs of co-evolution and social intelligence, in different domains, and also in the cross-cutting issues. Some would call for an "Urban Intelligence Index": we would crunch big datasets, and produce global league tables, with clever info-graphics and op-eds. This could be about as problematic and misleading as measuring IQ in different countries.

Recent experience with the City Prosperity Index and the City Resilience Index shows more or less the state of the art (UN-Habitat, 2012; Arup *et al.*, 2014). The first index seems to show that the hubs of former imperialism, such as Paris or Vienna, are top of the prosperity list (having expropriated vast resources from their former colonies). Meanwhile the Rockefeller City Resilience Index/Framework sets out 10 principles, which look rather similar to the sustainable city checklists of the 1990s. These again look plausible on the surface, but there is little mention of the geo-political dynamics (trade dependency, under-development policies, rapacious lending, peripherality and corruption, resource curses, etc.), which have produced such lack of resilience.

A more nuanced evaluation approach would be more useful, to take account of multiple views, boundaries, values and power structures. This could be along the lines of the EU "Open Method of Coordination", generating feedback and mutual learning, comparison and improvements, and highlighting areas of strength or weakness. In this way evaluation isn't all about "assessment" with external criteria and a surface appearance of objectivity: it's more about feedback for organizational learning and strategic intelligence.

Our evaluation template here (Table 1 and Table 2) reflects this approach. It aims to be simple and flexible to respond to almost any theme or policy question. Following the logic of the visual thinking above, it basically puts up a "linear-adaptive" model, side by side with a synergistic thinking model. The rows show the typical "domains" in the STEEP format, in a list which can be changed or extended to suit the issue. The rows also include for inter-connections of actors, inter-connection of factors, and of actions. Numbers or other metrics could be inserted if these are robust and useful knowledge, but after many experiments, we can say that most of the qualities we're looking for are highly qualitative, inter-subjective and "between the datasets". In that case, a rough "A-B-C-D-E" type rating is probably more useful than any number, however scientific its appearance. The real point is to use such a template, with any possible improvements and customizations, for continuing feedback, deliberation and learning between all concerned.

We demonstrate this evaluation template with a "home" example: the Greater Manchester Strategy (AGMA, 2013).

Greater Manchester shows a better model for city-region development and metropolitan governance, than most others in the UK: its position as the UK's (more or less) second city, and centre of Northern England is positive; its politics are generally pragmatic and collaborative (unlike for instance, Liverpool, which went through a radical socialist phase)

(Ravetz, 2014). As the world's first globalized industrial city-region, Greater Manchester (GM) was a model of free market capitalism: it was also a major hub for socialist and cooperative thinking. After a half-century of de-industrialization, (1950-2000), it's now a service and consumption-based second city to the UK. Ethnically, it's one of the most diverse: apparent unity around sport and music, but with widening gaps between the secure and precarious, the older or younger, those included or excluded from the system. Technologies and infrastructures are typical of an OECD economy, with strong science and education institutions, but the digital (IT) transition continues to disrupt everything. The economy is diverse, but polarized and under-productive, with reducing manufacturing sector, and growing debt-based consumption and property inflation.

The city-region ecology has been partly restored but now shows the challenge of affluence, by displacing its material inputs, outputs and climate emissions around the world. Governance struggles with the austerity and the public deficit, lack of public trust, and the centralizing forces of the UK (in spite of recent moves for devolution of some development budgets). Urban form and fabric is mainly old and inefficient, fragmented in ownership and investment: urban economies and urban lifestyles have taken over a wide rural area. The GM Strategy is one of a continuing series which began in this city-region format in the 1960s (Kitchen, 1997). The summary states: «This new strategy for Greater Manchester fuses together our strong plans for reforming public services with a continued drive for growth and prosperity. Our objective is to sustain progress whilst eliminating the gap between the taxes we raise and the resources we expend on public services. We want to deliver services differently, more efficiently and reduce the level of demand for those services, by bringing more people into higher quality work» (AGMA 2013, p. 6). This raises many critical issues. Firstly, it assumes that public services are in urgent need of reform by "strong plans"; secondly that the drive for "growth" must continue at all costs. Then, that "public services" are framed as for the unemployed, and as soon as people are in work the need will reduce. This is not the place for an indepth analysis of the dilemmas of the UK socio-political-economic system, or the austerity and deficit agenda. So this sample evaluation is a more strategic overview, an ongoing work in progress for debate: it was discussed in an earlier form in the GM Policy Exchange program, and now continues with the "Future of Greater Manchester" program.

The basic aim is to consider the success or otherwise, "in their own terms", of different models of strategic policy, as represented in the Greater Manchester Strategy and the discussions around it. This is not a value-judgment of whether one is better than another, as each model has a role to play: however the co-evolutionary "proposition" is that synergistic problems are likely to require synergistic responses, of social learning, creative collaboration and shared intelligence. So the rating is a simplistic indicator, where A=very good, and E=very poor, in terms of the systemic model performance in each domain (there is a further category of X=very high uncertainty). And to reflect an often complex picture, the rating can be shown in more than one level, e.g. "B/D", and so on. Again, the purpose of the rating is not to appear "scientific", but rather to generate deliberation and improvement. Where more detailed and quantitative modelling or impact assessment is feasible (more often on the 1.0-2.0 left hand side of the page), then of course this would be part of a more in-depth evaluation. The Tables 1 and 2 show the "linear/adaptive" models in terms of basic provisions or market activity, and the "synergistic" model as self-learning

feedbacks across the whole system for social intelligence. For the "subject/process/object" scheme as shown in the visual mapping above:

- the "subject" is the "evaluator" or the organization who is interested, in this case the community of policy-thinkers, academics and civil society organizations;
- the "process" is the evaluation activity, in this case an informal deliberation which feeds into various kinds of sustainability and futures studies;
- the "object" is the city-region and all its systems, as described in the rows of the matrix.

Tab. 1 – Synergistic evaluation matrix: the Greater Manchester Strategy

	"1.0-2.0" policy models: based on linear thinking	**Evaluation: GM strategy**	**Rating**	**"3.0" policy models: based on synergistic social learning**	**Evaluation: GM strategy**	**Rating**
Inter-connections of actors	Actors are mobilized via structures of power and ideology	Some actors mobilized/included in policy-making circles, others are left outside	C/D	Actors mobilized via collaboration and intelligence	Some directions for inclusion and participation: experiments in ICT platforms	D/C
Inter-connections of values	Dominant value systems are prioritized and reinforced	Neo-liberal material values of private profit, public austerity, decline of society	C/E	Diversity of value systems are included and linked	Much diversity of values and sub–cultures, but difficult to link to policy process	C/D
Social /community domains	Social and community structures are enhanced and extended	Cosmopolitization and mobility, social diversity, ageing, restructuring, skills and livelihoods shift	C/D	Social and community structures are transformed and evolved	Many aspirations, but slow progress to a more connected and inclusive society	C/D
Technical/ infrastructure domains	Technological systems are mono functional, with capacity for disempower-ment	Infrastructure is centralized and privatized. ICT transition is rapid and disruptive	B/C	Technological systems are multi-functional and empowering for all actors	ICT change is rapid and unpredictable: benefit to large corporates: potential in new social media	B/X
Economic/ employment domains	Economy and finance are materialist, extractive, monopolistic	Recent part recovery based on services, debt-based consumption, property inflation and precarious jobs with under-or mal-employment	B/D	Economy and finance are diverse, re-propriative, multi-stakeholder	GM is Cooperative movement hub: many experiments in socio-ecological enterprise, cultural creation, crowd finance, etc.	D/B

Tab. 2 – Synergistic evaluation matrix: the Greater Manchester Strategy

	"1.0-2.0" policy models: based on linear thinking	**Evaluation: GM strategy**	**Rating**	**"3.0" policy models: based on synergistic social learning**	**Evaluation: GM strategy**	**Rating**
Environment /resources domains	Environmental actions are localized, selective, externalizing	Some actors mobilized/included in policy-making circles, others are left outside	C/D	Actors mobilized via collaboration and intelligence	Some directions for inclusion & participation: experiments in ICT platforms	D/C
Policy/ governance domains	Pol. systems based on hierarchy, alienation, expropriation	Neo-liberal material values of private profit, public austerity, decline of society	C/E	Diversity of value systems are included and linked	Much diversity of values & sub – cultures, but difficult to link to policy process	C/D
Cultural domains	Cult. patterns reinforce ideological dominance & competition	Cosmopolitization & mobility, social diversity, ageing, restructuring, skills & livelihoods shift	C/D	Social and community structures are transformed and evolved	Many aspirations, but slow progress to a more connected & inclusive society	C/D
Urban-spatial domains	Spatial structures enable regimes of alienation and disempowerment	Infrastructure is centralized & privatized. ICT transition is rapid & disruptive	B/C	Technological systems are multi-functional and empowering for all actors	ICT change is rapid and unpredictable; benefit to large corporates, potential in new social media	B/X
Inter-connecting actions	Policies & actions are short-term, disconnected, mono-functional	Recent part recovery based on services, debt-based consumption, property inflation & precarious jobs	B/D	Econ. & finance are diverse, re-propriative, multi-stakeholder	GM is Cooperative movement hub: many experiments in socio-ecological enterprise, cultural creation, crowd finance etc.	D/B
Overal evaluation	Overall linear/ mechanical system: adaptive/ biological type system	Partial success on 2.0 model development, for half the people: for others, rising vulnerabiity	B/D	Overall synergistic system: based on synergy & collaboration, social learning & intelligence	GM has aspirations for a more 3.0 type model: many barriers but some signs of potential & progress	D/B

8. Urban ecosystems valuation and evaluation

Turning to other kinds of valuation and/or evaluation, urban ecosystems are a topical example. The TEEB programme aims to bridge the gap between two parallel kinds of value: the "embedded" ecological values, and "tradeable" monetary values (TEEB, 2010). But this can be problematic: in framing the "true value" as a number, whether in money or multi-criteria priorities, it bypasses the more synergistic qualities of both ecosystems and

human systems. We can start by letting economics out of its "utilitarian box"; then we can look beyond the numbers to the relationships between ecosystems and human systems, with many opportunities for synergy and self-organization on both sides.

For instance, in GM as elsewhere, the practical question comes up: how to value local ecosystems and ESS which are under pressure for development? The area of mossland and peat in the west part of GM had a valuation study for the peri-urban project PLUREL (Ravetz and Warhurst, 2013). With a review of many current studies and methods of CVM, the market value was established with a high of £300, and low of £3 per hectare, and mid-point (log-scale) of £30 per hectare. Such numbers often take a reductive and mechanistic view of social or ecological systems: as soon as policy opens the door then a development site valuation in the region of £1 million/hectare applies, and another unique ecosystem will be lost for short term development profit. Another local study looked at a semi-derelict urban parkland in north Manchester: as a magnet for crime and anti-social behaviour, with polluted water and degraded woodland, its proxy value appeared to be negative and ripe for redevelopment (Tippett *et al.* 2007; Roberts *et al.*, 2009).

In response, a low-cost community-based programme set up life-long education, healthy living, capacity building and eco-restoration activities, the park is now well loved and maintained, with a large net positive value.

Here the concept of "valuation" begins to overlap on "evaluation", where many creative possibilities emerge. A project in Australia for example, turned around the whole concept of policy evaluation: an interactive mobile exhibition/workshop process engaged stakeholders in an area of acute water shortage, enabling multi-way communication and collaboration, which in turn enabled a much more effective policy (Vanclay *et al.*, 2004). The implication is that "value" isn't just a metric of pseudo-scientific accounting, but there to be co-created, as an enabler for creative design of opportunities and synergies.

9. Urban cultural heritage valuation and evaluation

Urban cultural heritage (UCH) can be built up over hundreds or thousands of years, through the co-evolution of geographic features, cultural or political events, social or economic change, and ecological assets. Such heritage often suffers physical destruction or degradation: economic disinvestment and social dislocation, where the indigenous active users of temples, marketplaces, etc., are in decline, or displaced by higher value tourists, service industries or cultural expropriation.

Heritage valuation by rational "linear" thinking is a long running problem: trying to measure the social impact of a disused church, for example, brings on multiple layers of contingent valuation or hedonic pricing methods, resting on untested assumptions. Much of this is based on heritage valuation by "extractive/adaptive" thinking, which is more straightforward in principle: we put the church up for auction to find its market price, or construct an imaginary market to do the same, but then we discover that unique historic assets are sacrificed for short term gain. This all points to a "synergistic" thinking for valuation: not as an add-on to a linear method, but essential for cultural heritage of all kinds. How would this work?

The method starts with urban cultural heritage (UCH), not so much as an item or commodity, more of a "relational" resource and process, depending on interactions and value-chains between material objects, places, histories, narratives, worldviews, communities and individuals.

At the centre is a "relational value", not only functional/monetary, but social, ethical, political, etc., and generated by the inter-connections and relationships between these objects, places, histories and so on. As above, these "values" are less like fixed items, more like potential energy, potential innovation or potential for relational activity (for example, money in the bank, a social construction which is directly useful only when circulated). So we need a way to explore systematically, with all concerned, the synergistic potential of a cultural heritage. In this case, realizing the UCH value is not only about past history, but future opportunities. So we look for new adaptations of the built heritage emerging around new functions and services: and new patterns of creative learning and collaboration, which can emerge around the adaptations. Then we look for new socio-cultural perceptions and aspirations, which form around these collaborations. We look for socio-cultural communities forming around these perceptions and aspirations, and new financial models can form around these new communities. In turn, new functions and services can emerge around these financial models, and so on around the cycle.

The next and wider challenge is to evolve the "policy system" of urban planning, property law, public investment and policy appraisals, which can enable and promote this more creative and synergistic approach. Sometimes it happens through the contradictions and confrontations in the standard materialistic system. In many cases of social innovation, community action groups will campaign to save and re-use UCH, seeing opportunities which are missed by the mainstream (Hamdi, 2004; Wates, 2000). Or in eco-innovation, new uses are found for natural materials with a positive role and identity in the landscape. In the wider view, we can see valuation, not so much as an objective study, but more embedded in the processes of thinking, deliberation, collaboration and social learning. So the matrix summaries may be useful in transferring to other external users, but the real value is in the process of deliberation, capacity building and shared learning between all stakeholders. In that sense the heritage or ecological valuation is linked to parallel processes in economic and political self-organization.

10. Conclusion

This short exploratory paper aims to show that there is an agenda for valuation and evaluation, beyond a reductive and materialist calculus, to respond to the multiple inter-connected "value generation" which can emerge through social learning and creative collaboration. Furthermore, it shows that where the "object" of valuation/evaluation is shaped by social learning and creative collaboration, this also calls for the "subject" and the "process" of valuation/evaluation to be oriented in a similar direction. Finally, the wider role and purpose of valuation/evaluation can be seen not only as "objective" information for a technocratic governance, but as an essential feedback cycle for organizational learning and creative collaboration.

We can see numerous ways for this synergistic approach to grow and develop: one example is in policy evaluation in urban spatial planning. The conventional approach is to take high-level objectives such as fulfilment of housing need, and filter down with known parameters to numbers of housing sites. A more synergistic approach looks more widely at socio-political and institutional barriers and syndromes: explores creative and collaborative opportunities, and maps out pathways for social learning and shared intelligence which can respond. In the case of housing, this would look for opportunities with inter-generational transfers, multi-career households, young transients, under-occupation, short life licenses

and other alternative options. Similar thinking could apply in economic policy, technology policy or fiscal policy, as explored elsewhere in Urban 3.0.
In this paper we can just demonstrate a visual mapping approach, and a matrix assessment approach, with some small examples. These are not any kind of final answer, but rather the start of a new kind of journey.

Notes

1. Both definitions are from the Oxford English Dictionary online version, November 2014.
2. The "5 capitals" include: natural, social, human, manufactured and financial capital. There are loose connections to the six domains used in the "STEEPV" scheme, the five fields of the UN-Habitat City Prosperity Index, and many other systems.

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"ECONOMIC DEMOCRACY", POLITICAL DEMOCRACY AND EVALUATION FRAMEWORKS

Giuseppe Munda

Abstract

When one wishes to formulate, evaluate and implement public projects or policies, the existence of a plurality of social actors, with interest in the options being assessed, generates a conflictual situation. In this article, I show that the compensation principle was invented by Kaldor and Hicks to achieve two clear objectives: to compare individuals' preferences according to the efficiency oriented utilitarian calculus, explicitly avoiding the principle one individual, one vote; to implement an objective evaluation criterion, that could be accepted in the framework of the dominant positivistic philosophical paradigm. Here, I try to prove that in the compensation principle, there is no escape from value judgements, it is not the positivistic objective evaluation criterion. A relevant question is: are the original Kaldor-Hicks objectives still relevant in the 21st Century?

Keywords: public policy, well-being, Social Multi-Criteria Evaluation

"DEMOCRAZIA ECONOMICA", DEMOCRAZIA POLITICA E VALUTAZIONI

Sommario

Quando si vuole formulare, valutare e implementare politiche o progetti pubblici, l'esistenza di una pluralità di attori sociali, interessati alle opzioni da valutare, genera una situazione di conflitto. Come si può gestire tale conflitto? In questo articolo, dimostro che il principio di compensazione è stato inventato da Kaldor e Hicks per perseguire due chiari obiettivi: confrontare le preferenze degli individui secondo il calcolo utilitaristico orientato all'efficienza, evitando esplicitamente il principio un individuo, un voto; implementare un criterio di valutazione oggettivo, accettato nell'ambito del paradigma filosofico positivista. In questa sede, cercherò di provare che nel principio di compensazione non è possibile evitare i giudizi di valore, per cui non è il criterio di valutazione oggettivo desiderato dal positivismo. Una questione importante è: gli obiettivi originali di Kaldor-Hicks sono ancora rilevanti nel 21° secolo?

Parole chiave: politiche pubbliche, benessere, Social Multi-Criteria Evaluation

1. Introduction

Although some forms of "direct democracy" were already present in the ancient Greece, the theory of modern democracy was developed during the Age of Enlightment, when the essential elements of democracy were defined, i.e. separation of powers, basic civil rights, human rights, religious liberty and separation of church and state. "No one pretends that democracy is perfect or all-wise. Indeed, it has been said that democracy is the worst form of government except all those other forms that have been tried from time to time". This famous quote attributed to Winston Churchill synthesizes the basic issue that the perfect form of government does not exist, however any other form of government is much less desirable than democracy. This is also the main message of the so-called impossibility theorem (Arrow, 1963), which proves that a perfect voting system cannot exist. In social choice, the reaction to Arrow's theorem has been the search for less ambitious voting structures, making it necessary to retain a few basic requirements only. These basic requirements are generally threefold:

1. anonymity: all voters must be treated equally;
2. neutrality: all options must be treated equally;
3. monotonicity: more support for an option cannot jeopardize its success.

Even though human rights are calling for citizen equality and clearly anonymity should then be a fundamental column of democracy, historically this basic requirement has been implemented very recently only. Just to give a few examples, when the US electoral system started (in the 18-th century), only white male property owners (about 10 to 16 percent of the nation's population) had the right to vote. Property ownership and tax requirements were eliminated in 1850, at this stage almost all adult white males could vote. Only in 1965 the Voting Rights Act protected the rights of minority voters and eliminated voting barriers such as the literacy test. In Italy, the modern electoral system started in 1861 when the voting right was limited to male property owners; the property ownership requirement was eliminated in 1882, only in 1946 everybody could vote (including women and illiterate people). In Switzerland, only in 1971, Swiss males by a two thirds majority referendum, finally gave their female compatriots their full federal voting rights. In the UK, in 1432 it was established that only male property owners were entitled to vote in a county, and there was no major reform until the Reform Act in 1832. In 1918 all men over 21 were given the right to vote, and finally it was the Representation of the People Act in 1928 that made women's voting rights equal with men, with voting possible at 21 with no property restrictions. Obviously, the idea of equality was not really embedded in real-world democracy for a very long period; almost everywhere in the beginning voting rights were restricted to property owners, income distribution was considered the most important selection criterion.

When one wishes to implement public policies, there is a previous need of comparing different options and valuating and evaluating them to assess their social attractiveness. One of the key tasks of welfare economics is exactly this valuation and evaluation exercise (Dasgupta, 2001). Traditional welfare economics proposes the measurement of social costs and benefits made on the basis of the so called compensation principle; usually associated with the names of Kaldor (1939) and Hicks (1939). This principle can be synthesized by Kaldor's own words: he first presented Harrod's criticism to welfare economics, where equality was even considered a serious problem to be avoided when evaluating the social desirability of different policy options: «Consider the Repeal of the Corn Laws. This tended

to reduce the value of a specific factor of production-land. It can no doubt be shown that the gain to the community as a whole exceeded the loss to the landlords-but only if individuals are treated in some sense as *equal*[1].Otherwise how can the loss to some-and that there was a loss can hardly be denied-be compared with the general gain?» (Kaldor, 1939, p. 549); and then presented the solution to this "criticism": «It is only as a result of this consequential change in the distribution of income that there can be any loss of satisfactions to certain individuals, and hence any need to compare the gains of some with the losses of others. But it is always possible for the Government to ensure that the previous income-distribution should be maintained intact: by compensating the "landlords" for any loss of income and by providing the funds for such compensation by an extra tax on those whose incomes have been augmented. In this way, everybody is left as well off as before in his capacity as an income recipient; while everybody is better off than before in his capacity as a consumer. For there still remains the benefit of lower corn prices as a result of the repeal of the duty» (Kaldor, 1939, p. 550).

Hicks supported the compensation principle too because he was very attracted by its apparent objectivity. In fact Hick's was very worried by a positivist attack to normative economics, which he himself agreed with «positive economics can be, and ought to be, the same for all men; one's welfare economics will inevitably be different according as one is a liberal or a socialist, a nationalist or an internationalist, a christian or a pagan» (Hicks, 1939, p. 696). The compensation principle was a solution to this problem: «By adopting the line of analysis set out in this paper, it is possible to put welfare economics on a secure basis, and to render it immune from positivist criticism» (Hicks, 1939, p. 711). «I have accomplished my end if I have demonstrated the right of Welfare Economics – the "Utilitarian Calculus" of Edgeworth – to be considered as an integral part of economic theory, capable of the same logical precision and the same significant elaboration as its twin brother, Positive Economics, the "Economical Calculus"» (Hicks, 1939, p. 712).

In summary, we may conclude that the compensation principle was invented to achieve two clear objectives:

1. to compare individuals' preferences according to the efficiency oriented utilitarian calculus, explicitly avoiding the principle one individual, one vote;
2. to implement an objective evaluation criterion, that could be accepted in the framework of the dominant positivistic philosophical paradigm.

A relevant question now is: are these objectives still relevant in the 21st Century? In this article I argue that they are not. Section 2 will discuss the relationship between efficiency and equity in the framework of the compensation principle and Section 3 will derive some policy implications and will present an alternative evaluation methodology. In Section 4 some conclusions will be drawn.

2. Efficiency and equity in the framework of the compensation principle

The notion of individual preference that is relevant to the Kaldor-Hicks compensation principle (and cost-benefit analysis), is the preference expressed on the market place (or which would be expressed if there were a market), and not the preference expressed by a political vote (see e.g. Mishan, 1971; Pearce and Nash, 1989). This kind of "economic democracy" is preferred to classical political voting procedures for different reasons:

Political systems other than in very well-defined referenda involve voting not for issues so much as for individuals to represent the constituent's view. Market or economic voting is

considered closer to the voters' intentions: by definition if a voter, identified as a consumer, does not want something, she/he does not buy it.
Even if referenda were desirable, they cannot be held continuously on every policy decision that has to be made. To observe consumers' behaviour on the market is much cheaper, quicker and easier.
As clearly expressed by Pearce and Nash (1989, p. 7): «the use of money values permits some expression of the intensity of preference in the vote: it enables the individual to say how deeply he wants or does not want the project or good in question».
The Kaldor-Hicks principle declares a social state A "socially preferable" to an existing social state B if those who gain from the move to A can compensate those who lose and still have some gains left over. Such a situation is consistent with a Pareto improvement since we have B indifferent to A for the losers (once they are compensated) and A preferred to B for the winners (if they can over-compensate). If the monetary value of benefits exceeds the monetary value of costs, then the winners can hypothetically compensate the losers and still have some gains left over. The excess of gains over required compensation is equal to the net benefits of the project. While in political voting, minorities always loose since they have to accept "majority dictatorship", economic democracy, implemented through the Kaldor-Hicks compensation principle, always compensate losers, thus it seems to improve the fairness of the policy process.
In summary, even though Kaldor and Hicks were looking for a policy criterion implementing objective Pareto efficiency, explicitly not grounded on egalitarian considerations, finally economic democracy seems to perform much better than political democracy; in fact it is easier and cheaper to implement, it uses more information on individual's preferences (i.e. intensity of preference), and losers are always compensated. Let's then see if these arguments are correct.
The main underlying idea of using preferences expressed on the market is that individuals can be compared by means of a common property, being consumers, and one measurement unit i.e. money values measuring their willingness to pay for a good or service. One obvious consideration is that the comparison of individuals is possible according to the characteristics of this property and measurement unit only: money values are worth to be used when they are connected to one objective and one institution only, i.e. economic efficiency and markets. They fail to incorporate other objectives and values, such as fairness and equity.
Economic development implies the creation of new assets in terms of physical, social and economic structures. Within a process of "creative destruction" traditional environmental, social, and cultural assets derived from a society's common heritage may disappear. The existence of a plurality of social actors, with interest in the policy being assessed, generates a conflictual situation. «Looking at a single individual, (...) he is prevented from being better off than he is, not only because total production is limited, but also because so much of total production is at the disposal of persons other than himself. The same thing holds, of course, for any group or society of individuals, so long as that group is less than the totality of a closed community» (Hicks, 1939, p. 698-699).
I think we should take for granted the existence of a multiplicity of legitimate values in society[2]. Any social decision problem is characterised by conflicts between competing values and interests and different groups and communities that represent them. Choosing any particular operational definition for value and its corresponding valuation technique

involves making a decision about what is important and real. Any policy option always implies winners and losers, thus it is important to check if a policy option seems preferable just because some dimensions (e.g. the environmental) or some social groups (e.g. the lower income groups) are not taken into account. The fact that «one's welfare economics will inevitably be different according as one is a liberal or a socialist, a nationalist or an internationalist, a christian or a pagan» (Hicks, 1939, p. 696) is the normal state of affairs in policy decisions. I do not see any reason why this issue of existence of a plurality of values should be considered a problem that can be solved by considering consumers' preferences as the only relevant social values. Sagoff (1988) made clear the point that one's preferences as a consumer may differ from one's preferences as a citizen significantly. In my opinion, it is much more scientific an approach which deals with such a plurality of values than one which solve all conflicts by imposing a perspective considered superior on some ethical or technical grounds.

When one wishes to preserve a monument or a natural area, a fundamental question is: is there any resource which society is willing to assign to this objective? Indeed no society can avoid the economic problem of "opposition between tastes and obstacles", as Pareto made clear. To answer this question the concept of total economic value becomes immediately relevant. To attribute monetary values to e.g. historical heritage implies to capture user (actual, option and bequest) and non-user (existential, symbolic, etc.) values. Of course, to compute total economic values has nothing to do with the idea of a "true" or "correct" value. All monetary valuation attempts suffer deep philosophical problems (see e.g. Copp, 1987; Fusco Girard, 1986; Hansson, 2007; O'Neill, 1993; Sagoff, 1988; Spash, 2008) and technical uncertainties (see e.g. Aldred, 2009; Frey, 1986; Grüne-Yanoff, 2009; Hansen, 2011; Martinez-Alier *et al.*, 1998; Munda, 1996; Vatn and Bromley, 1994) such as:

- which monetary valuation technique has to be used?
- which time horizon has to be considered?
- which social discount rate?

One should remember that the market alone may be successful in efficient allocation of resources, but does not give any guarantee for preservation of the cultural or natural heritage at all nor for the fairness of the decision taken. According to the compensation principle, the social cost of a given policy option is defined as the sum of money paid as compensation to those who have been suffered damage, the level of utility that the damaged had before the event took place should determine the amount of compensation to pay[3].

In my opinion, monetary compensation is with no doubt the only possible tool when an irreparable and irreversible damage has already occurred. This way, if an accident with serious contamination occurs (e.g. in the case of Seveso in Italy (1976), of Bhopal in India (1984), of the Exxon Valdez in Alaska (1989), of the oil-tanker Prestige offshore the coasts of Galicia (2002), or more recently the BP oil spill in the Gulf of Mexico (2010) it seems correct and opportune to indemnify the victims of such contamination. But it stays to verify if, in the long run, compensation is an effective tool to prevent the appearance of enormous future social costs. Society has a much longer life expectancy than individuals, thus the value society attaches to e.g. natural resources is likely to deviate from individual values, since the simple summation of individual preferences may imply the extinction of species and ecosystems. This implies that public policy cannot be merely based upon the aggregation of individual values, and estimation of willingness to pay at any particular point of time. It is interesting to note that, Walras himself already noted that the market

cannot be used as a basis for rational collective decision-making and that «human destinies are not absolutely independent, but to some extent dependent on one another. There is a social morality which is distinct from individual morality» (cited in Burgenmeier, 1994, p. 347). Negative externalities to be internalised by monetary compensation can also be seen as "cost-shifting". In general, if the damaged people are poor (or even not yet been born), the cost of the internalization of the externality will be low. This is why a lot of multinationals locate particularly dangerous production plants in the developing countries where, in case of accidents, they are generally forced to pay monetary compensations much lower than in the western countries (see e.g. Martinez-Alier, 2002). The accident of the chemical plant of the Union Carbide in Bhopal, India, in 1984, is a sad example. Obviously, the institutional and juridical context is fundamental. In the case of oil contamination provoked by Texaco in Ecuador (with serious consequences on the human health) the fundamental point of the trial was deciding whether the competent court should have been in USA or in Ecuador. The Texaco insisted on the fact that it had to be in Ecuador.

Accepting low values for a negative externality that provokes an impact on poor community is a "political decision", far from being ethically neutral. Some years ago, an internal document of the World Bank, subsequently made public, suggested that toxic waste should be located in Africa, since the cost of the compensation was extremely low and therefore such solution has to be considered as the most efficient one. One should note that the issue of value free Science is a key issue for real-world policy and not a philosophical debate only. For example, an influential economist claimed that his work for the intergovernmental Panel on Climate Change (IPCC), where lives of people in rich countries are valued up to fifteen times higher than those in poor countries, was a matter of scientific correctness versus political correctness (New Scientist, 19 August, 1995). Is it really a matter of value free scientific correctness to use valuations based on assessments of a community's willingness and ability to pay to avoid risks of death[4]? What that economist was saying in reality was that efficiency is the only societal value according to which policy options should be evaluated; concerns on fairness and equity are not relevant.

Indeed the inseparability between efficiency and equity can be easily proved from a theoretical point of view too. The use of willingness to pay in money terms as a measure of individuals' intensity of preference would be correct only if individuals' income could be measured on a ratio scale of measurement, that is the only degree of freedom is the unit of measurement and not the origin[5]. In this measurement framework if individual X expresses the double willingness to pay for the good A than individual Z, then it is correct to derive that she/he has the double intensity of preference towards that good with respect to Z. Now, we have to consider that although it is true that zero money would be the common origin and thus money could be measured on a ratio scale logically, on the ontological side, the real origin of the scale is the true-life individuals' income, which is necessarily different across individuals. Real-world marginal utility of income across individuals is not constant clearly, thus different intensities of preference cannot be compared, on objective grounds, unless we know the exact personal distribution of income.

In empirical applications, the compensation principle is implemented by using cost-benefit analysis, where costs and benefits are aggregated linearly in a net present value (NPV) formula. The assumption underlying the NPV rule is that of an additive social welfare function, such as $SW = \sum_h U_h$ where the subscript h denotes the individual to whom the

utility function applies. Under the assumption that the marginal utility of money income (λ) is identical for all individuals, the variation of this social welfare function indicating the social worth of a project is:

$$\Delta SW = \sum_h \sum_i \frac{\partial U_{ih}}{\partial Y_{ih}} \bullet \Delta Y_{ih} = \lambda \sum_h \sum_i P_i \Delta Y_{ih} = \lambda \sum_i P_i \Delta Y_i \quad (1)$$

where *h* subscript denotes the individual to whom the utility function and quantity of the good Y_i apply. The translation into monetary terms is accomplished by the equation:

$$\lambda \frac{\partial U_i}{\partial Y_i} = P_i$$

where P_i is the (relative) price of good *i*.

Nevertheless, the assumption of the constancy of the marginal utility of income across individuals is a distributional question, and that assumption embodies particular social values.Given that society is unlikely to be indifferent among various possible distributions of income, some ways of integrating the distributional aspects into the analysis have to be found. The most popular methodology is to introduce distributional weights explicitly, by using different weights for different social groups (Bojo *et al.*, 1990). However, it is not clear how to derive such weights, since they can be based on a variety of ethical, philosophical and methodological principles and who should attach them (economists, policy-makers, society, etc.). On the other hand, one has to note that failures to use any weighting system imply making the implicit value judgement that the existing distribution of income is optimal. If, and only if, one is happy with such a value judgement, it is reasonable to use un-weighted market valuations to measure costs and benefits. Therefore, there is no escape from value judgements; the compensation principle is not the positivistic objective evaluation criterion Hicks hoped to be.On the other side it does not consider individuals as equal exactly the goal Kaldor aimed at, it can be considered a direct application of the ancient principle that property owners should count more.

A futher demonstration of the lack of concern for distributional issues embodied in this way of measuring social costs is the so-called Scitowszky paradox (Scitowszky, 1941). Real-world applications of the kaldor-Hicks test require only that gainers be able to compensate losers, it does not require actual payment to be made. But often policy decisions lead to widespread price changes, resulting in some consumers paying more for goods they purchase, and others less. Scitowszky has termed such effects pecuniary externalities. Price changes themselves redistribute income; for every consumer who pays more, a producer receives more, and vice versa. Scitowszky demonstrated that in absence of compensation, it is possible for circumstances to exist such that once the change has been implemented, a move back to the status quo could also be judged socially desirable. This because the move back could be desirable when valued at the new set of prices that emerge from the new distribution of income, resulting from the policy implementation.

3. Implications for project and policy evaluation

My main point here is the impossibility to deal with the concept of value (and connected policy instruments) as an objective value free category. Indeed, the key question is value for what and for whom? Monetary valuation methods are based on phenomena such as

consumer's surpluses, market failures, demand curves which are just a partial point of view, since connected with one institution and one objective only: markets and efficiency. From a social point of view, issues connected with actions outside of markets and behaviour of people different from the class of consumers should also be taken into account[6]. I believe that the point is not to be against giving economic value to natural resources, to human health (or even lives) or to cultural heritage. A location may be valuable for its biodiversity (measured in richness of species or genetic variety), and also as a landscape, and have also economic value (measured by the travel cost method or contingent valuation). These are different types of value. The point is that social decisions involve multiple types of values, of which economic efficiency is only one. Therefore it is misleading to make social decisions based only on that one value (Lo and Spash, 2013; Munda, 2008; O'Neill, 2001).

The classical Adam Smith's example on the value of diamonds versus water is relevant here. No doubt in a city environment everyone would prefer diamond over water, however in a different environment, e.g. a boat in the middle of the ocean, water has definitely a higher value than diamonds. Economic values depend on subjective human preferences, no discussion about this. Attempts to explain economic values through objective, context invariant categories such as energy are an obvious non-sense. On the other side, e.g. Odum's Emergy[7] measures (Odum, 1996) can be a good proxy of the ecological value of an ecosystem. Galapagos Islands have a higher ecological value than the Dutch Inside Sea surely, but the same does not necessarily apply to economic value (economic indeed would favour the Inside Sea, which, since totally eutrophised, offers an important economic service receiving all the nutrients coming from human activity). Different values, since they are related to different objectives and institutions, cannot be merged into only one metric.

Let us consider a recent real-world example, that I think synthesises well this point: Pavan Sukhdev's analysis of the Niyamgiri hill conflict between the British mining company Vedanta and the local tribal of the Dongria Kondh in Odisha, India[8]. Sukkdev was the leader of the UNEP project *The Economics of Ecosystems and Biodiversity* that collected around the world money values placed on environmental services to make the point that money valuation increases the visibility of the loss of "natural capital". However, he also acknowledges that sometimes money values are controversial; in fact while Vedanta wants to mine bauxite, the Dongria Kondh consider the hill as a deity. «Valuing these hills based on the forest resources that would be lost if mining was to proceed clearly does not, and cannot, fully account for its loss, because this is a matter of human right. The "price" of these hills, to this community, could well be infinity» (Sukhdev, 2012, p. 69).

Sukhdev does not mistake value for price, and this is why he rightly puts inverted commas on the word "price" because there cannot be infinite prices and because human rights cannot be traded off. What he may mean (although he does not say so) is that there are plural values of these hills. To Vedanta they have a value in terms of bauxite multiplied by the price of bauxite, net of costs of extraction, and brought to present value. For the community, they are immensely valued in the scale of sacredness, they are deemed to be God itself who performs divine services for the members of the tribe.

So we can see the Niyamgiri Hill as provider of environmental services (in a Millennium Ecosystem Assessment framework), including immaterial cultural services of great religious importance. Can we bring them into a single measuring rod like fictitious prices? Even fictitious prices elicited through willingness to pay or other methods of economic valuation cannot bring these different kinds of environmental services into a common

value. The problem is not (only) the technical difficulties of valuing non-market products and services, and choosing one particular discount rate to reach a NPV of the mountain (to compare to the benefits from bauxite mining). The problem is, moreover, that some of the services escape by nature from money valuation; there is value incommensurability[9].

Indeed, Hicks made very clear the point that economic welfare and social welfare are very different concepts. In fact he considered a theoretical weakness «when the reader is asked to accept a direct correlation between economic welfare and social welfare in general (whatever that may be). This is not easy to swallow; in any case it is open to the positivist objection that it reflects a particular social outlook, held by certain classes at certain times, and never likely to be acceptable universally» (Hicks, 1939, p. 697). In recent years, such a concept of social welfare, which Hicks did not appreciate so much for its subjectivity, has gained increasing popularity. A growing quantity of literature has been written about concepts such as multidimensional poverty (Sen, 1979, 1985; Duclos *et al.*, 2006), quality of life, happiness and well-being (e.g. Arrow *et al.*, 2012; Easterlin, 1995, 2001; Frey and Stutzer, 2002; Michalos, 1980, 1997). This tendency has even increased after the influential Stiglitz *et al.* (2009) report, which proposed the use of the concept of well-being as a multidimensional proxy for measuring societal prosperity and progress.

The world is characterised by deep complexity. This obvious observation has important implications on the manner in which policy problems are represented and decision-making is framed. Various authors claim that modern public economic policy needs to expand its empirical relevance by introducing more and more realistic (and of course more complex) assumptions in its models. In this context, one of the most interesting research directions in contemporary public economics, is the attempt of taking into account political constraints, interest groups and collusion effects explicitly (see e.g. Laffont, 2000, 2002; van Winden, 1999), as a consequence, transparency becomes an essential feature of public policies (Stiglitz, 2002). This implies that to reach a ranking of policy options, there is a previous need for deciding about what is important for different social actors as well as what is relevant for the representation of the real-world entity described in the model. As stated by Martinez-Alier (2002) an obvious question is then who is the one entitled to simply complexity? The new nature of the problems faced in this third millennium (e.g., food security, genetic modified organisms, climate change, ecc.), implies that very often when deciding on problems that may have long term consequences we are confronting issues "where facts are uncertain, values in dispute, stakes high and decisions urgent" (Funtowicz and Ravetz, 1991). In this case, scientists cannot provide any useful input without interacting with the rest of society and the rest of the society cannot perform any sound decision making without interacting with the scientists.

In summary, I think that instead of focusing on "missing markets" as a source of theoretical and empirical problems, or trying to explain economic values by means of energy or other common rod measures (clearly a non-sense from an economic point of view), we should focus on the creative power that missing markets have, because they push us away from commensurability towards a multidimensional evaluation of evolving realities implementing the incommensurability principle[10]. I believe we may accept as true the statement that incommensurability does not imply incomparability; on the contrary incommensurability is the only rational way to compare various objects under different methodological assumptions than maximisation or optimisation (Sen, 1997, 2000; Sen and Williams, 1982). It is in terms of incommensurability that evaluation has to take place in

practice. Evaluation of objects relative to different descriptions invokes not just different practices and perspectives, but also the different criteria and standards for evaluation associated with these. It presupposes value-pluralism. This is exactly the basic idea of multi-criteria evaluation, which can be considered a form of applied consequentialism[11]. Incommensurability can therefore be implemented by using multi-criteria evaluation. In empirical evaluations of public projects and public provided goods, multi-criteria evaluation seems to be an adequate policy tool since it allows taking into account a wide variety of evaluation criteria (e.g. environmental impact, distributional equity, and so on) and not simply profit maximisation, as a private economic agent would mainly do.

In formal terms discrete multi-criteria evaluation problems can be described in the following way A is a finite set of N feasible options; M is the number of different points of view or evaluation criteria g_m (m=1, 2, ... , M) considered relevant in an evaluation problem, where the option a is evaluated to be better than option b (both belonging to the set A) according to the m-th point of view if $g_m(a)>g_m(b)$ (Arrow and Raynaud, 1986; Figueira *et al.*, 2005; Fusco Girard and Nijkamp, 1997; Roy, 1996). This information can be synthesised in a matrix called evaluation or impact matrix. In 1986 Kenneth Arrow and Hervé Raynaud published a very influential book titled "Social choice and multicriterion decision-making", where the formal analogies between the discrete multi-criterion problem and the social choice one are analysed deeply. This book is based on the assumption that, in the case where all criteria have ordinal impact scores, if one considers the evaluation criteria as voters, a multi-criteria impact matrix and a voting matrix are identical. As a consequence all results of social choice also apply to multi-criteria decision theory fully (at least when no intensity of preference and no indifference/preference thresholds[12] are used; for a recent overview of these technical issues see Munda, 2012). However in my opinion, the relations between social choice and multi-criteria evaluation are stronger than the simple mathematical analogy. In fact I consider that multi-criteria evaluation is a type of applied democracy when it is used for evaluating policy options, this is the main idea behind Social Multi-Criteria Evaluation (SMCE) (Munda, 2004, 2008).

In a social multi-criteria evaluation framework, the pitfalls of the technocratic approach can be overtaken by applying different methods of sociological research. For example, "institutional analysis", performed mainly on historical, legislative and administrative documents, can provide a map of the relevant social actors. By means of focus groups it is possible to have an idea of people's desires and it is then possible to develop a set of policy options. Main limitations of the focus group technique are that they are not supposed to be a representative sample of the population and that sometimes people are not willing to participate or to state publicly what they really think (above all in small towns and villages). For this reason anonymous questionnaires and personal interviews are an essential part of the participatory process.

The selection of evaluation criteria has to be also based on what it is learned through the participation process. However, at this stage a problem generally arises: the evaluation criteria should come directly from the public participation process or they should be "translated" by the research team? I think that the rough material collected during interviews and focus groups could be used as a source of inspiration but the technical formulation of criteria having properties such as "non-redundancy", "legibility" and so on is a clear job of the researchers. Of course in this step, subjectivity is unavoidable, for this reason a widespread information campaign on the assumptions and conclusions of the study

including local people, regional and national authorities, international scientists and even children at school is, in my opinion, highly recommendable.

Finally one has to note that policy evaluation is not a one-shot activity. On the contrary, it takes place as a learning process which is usually highly dynamic, so that judgements regarding the political relevance of items, alternatives or impacts may present sudden changes, hence requiring a policy analysis to be flexible and adaptive in nature. This is the reason why evaluation processes have a cyclic nature. By this is meant the possible adaptation of elements of the evaluation process due to continuous feedback loops among the various steps and consultations among the actors involved.

As a tool for conflict management, SMCE has demonstrated its usefulness in many policy problems in various geographical and cultural contexts (Cerreta and De Toro, 2010; Gamboa, 2006; Garmendia and Stagl, 2010; Monterroso *et al.*, 2011; Munda and Russi, 2008; Özkaynak, 2008; Scolobig *et al.*, 2008; Soma and Vatn, 2009; Straton *et al.*, 2010; Zendehdel *et al.*, 2010). The main point of force is the fact that the use of various evaluation criteria has a direct translation in terms of plurality of values used in the evaluation exercise. From this point of view, social multi-criteria evaluation can be considered as a tool for implementing political democracy. Social multi-criteria evaluation puts its emphasis on the transparency issue; the main idea being that results of an evaluation exercise depends on the way a given policy problem is structured and thus the assumptions used, the ethical positions taken, and the interests and values considered have to be made clear. In this framework, mathematical models still play a very important role: the one of guaranteeing consistency between assumptions used and results obtained.

4. Conclusions

In this article, I showed that the compensation principle was invented by Kaldor and Hicks to achieve two clear objectives:

1. to compare individuals' preferences according to the efficiency oriented utilitarian calculus, explicitly avoiding the principle one individual, one vote;
2. to implement an objective evaluation criterion, that could be accepted in the framework of the dominant positivistic philosophical paradigm.

By using theoretical and empirical arguments I proved that in the compensation principle, there is no escape from value judgements, it is not the positivistic objective evaluation criterion Hicks hoped to be. On the other side it does not consider individuals as equal exactly the goal Kaldor aimed at.

However, monetary valuation techniques are the only ones that can answer these two questions:

- how many resources society is willing to devote to a given objective?
- how much society has to pay for compensation after e.g. an accident? Their desirability in this context is not questioned here.

Monetary valuation methods are based on one institution only: markets. From a social point of view, issues connected with actions outside of markets and behaviour of people different from the class of consumers should also be taken into account. It is misleading to take social decisions based on only one type of value. Value incommensurability is the normal state of affairs; multi-criteria evaluation can be considered a formal framework for applied consequentialism under incommensurability. In particular, social multi-criteria evaluation is proposed as a public policy framework to integrate different scientific languages, when

concerns about civil society and future generations have to be considered along with policy imperatives and market conditions. This can have beneficial consequences, not only for economic prosperity, but also when dealing with the difficult problems of our millennium.

Acknowledgements
Comments by Joan Martinez-Alier on previous drafts of this paper are gratefully acknowledged. I also thank him for providing the information on Niyamgiri hill conflict and signaling its relevance in the framework of this article. Financial support by projects HAR2013-47182-C2-1-P and 2014 SGR 591 is acknowledged.

Notes

1. Emphasis added to the original.
2. Here I disagree with Hammitt (2013, p. 200) who considers a problem the possibility that «a policy that everyone prefers may not satisfy the compensation test».
3. Although there are symbolic goods which may present difficult possibilities of transactions in actual or fictitious markets surely. How much one should receive to accept compensation for the destruction of the Big Ben, the Sagrada Familia, the Statue of Liberty or the Coliseum? Indeed Kaldor admitted the existence of such losses of a symbolic kind: «An increase in the money value of the national income (given prices) is not, however, necessarily a sufficient indication of this condition being fulfilled: for individuals might, as a result of a certain political action, sustain losses of a non-pecuniary kind- e.g., if workers derive satisfaction from their particular kind of work, and are obliged to change their employment, something more than their previous level of money income will be necessary to secure their previous level of enjoyment; and the same applies in cases where individuals feel that the carrying out of the policy involves an interference with their individual freedom. Only if the increase in total income is sufficient to compensate for such losses, and still leaves something over to the rest of the community, can it. be said to be "justified" without resort to interpersonal comparisons» (Kaldor, 1939, p. 551).
4. One has to note that the issue is not maintaining that a human life has infinite value; for example, a reduction in road accidents can be secured at some cost, but society is unlikely to devote the whole of the national income to this end. The point is that often this valuation is made implicitly and stating that is a technical issue, when it is a political one instead.
5. The word measurement is usually reserved for the situation in which a number is assigned to each observation; this number reflects a magnitude of some quantitative property (how to assign this number constitutes the so-called representation problem). The measurement procedure used constitutes a function rule $m: O \rightarrow R$, telling how to give an object o its *m(o)* value in a systematic way. Measurement operations or procedures differ in the information that the numerical measurements themselves provide about the true magnitudes. Quantitative measurement procedures associate objects $o \in O$ with a real number *m(o)* allowing much more precise statements about the true magnitudes than ordinal scale measurements. Suppose that the statement of equation (1) is true:

$$\begin{cases} m(o_1) \neq m(o_2) \text{ only if } t(o_1) \neq t(o_2) \\ m(o_1) > m(o_2) \text{ only if } t(o_1) > t(o_2) \\ t(o) = x \text{ iff } m(o) = ax + b, \text{where } a \in R^+ \end{cases} \quad (1)$$

That is, the numerical measurement m(o) is some affine function of the true magnitude x. When (1) applies, the measurement operation is called interval scaling, or measurement at the interval-scale level. When measurement is at the interval-scale level, any of the ordinary operations of arithmetic can be applied to the differences between numerical measurements, and the results can be interpreted as statements about magnitudes of the underlying property. It is sometimes possible to find measurement operations making the statement of Equation (2) true:

$$\begin{cases} m(o_1) \neq m(o_2) \text{ only if } t(o_1) \neq t(o_2) \\ m(o_1) > m(o_2) \text{ only if } t(o_1) > t(o_2) \\ t(o) = x \text{ iff } m(o) = ax, \text{where } a \in R^+ \end{cases} \quad (2)$$

When the measurement operation defines a function such as the statement contained in (2), then measurement is said to be at the ratio-scale level. For such scales, ratios of numerical measurements are unique and can be interpreted directly as ratios of magnitudes of objects.

6. For example, the European Commission White Paper on Governance (where principles such as transparency, participation and accountability are emphasized) goes in this direction (www.ec.europa.eu).
7. Emergy is the «available solar energy used up directly and indirectly to make a service or product» (Odum, 1996, p. 8).
8. The information on this example was given to me by Joan Martinez-Alier.
9. From a philosophical perspective (O'Neill, 1993), it is possible to distinguish between the concepts of strong comparability (there exists a single comparative term by which all different actions can be ranked) implying strong commensurability (a common measure of the various consequences of an action based on a interval or ratio scale of measurement, such as money or energy) or weak commensurability (a common measure based on an ordinal scale of measurement, such as consumer's utility), and weak comparability, which implies incommensurability i.e. there is an irreducible value conflict when deciding what common comparative term should be used to rank alternative options; this irreducible value conflict is unavoidable but compatible with rational choice employing, for example, practical reason or multi-criteria evaluation (Chang, 1997; Martinez-Alier *et al.*, 1998; Rabinowicz, 2012; Raz, 1986).
10. «There is great pressure for research into techniques to make larger ranges of social value commensurable. Some of the effort should rather be devoted to learning - or learning again, perhaps - how to think intelligently about conflicts of value which are

incommensurable» (Williams, 1972, p. 103). A call for dealing explicitly with incommensurability can also be found in Arrow (1997).

11. Here I disagree with Hansson (2007, p. 163) who considers cost-benefit analysis «the only well-developed form of applied consequentialism».
12. By introducing a positive constant indifference threshold q the resulting preference model is the threshold model:

$$\left\{\begin{array}{lcl} a_j P a_k & \Leftrightarrow & g_m(a_j) > g_m(a_k)+q \\ a_j I a_k & \Leftrightarrow & \left|g_m(a_j) - g_m(a_k)\right| \leq q \end{array}\right\}$$

where aj and ak belong to the set A of alternatives and gm to the set G of evaluation criteria.

The famous bold paradox in Greek philosophy (how many hairs one has to cut off to transform a person with hairs to a bold one?), later on Poincaré (1935, p. 69) and finally Luce (1956) made the point that the transitivity of indifference relation is incompatible with the existence of a sensibility threshold below which an agent either does not sense the difference between two elements, or refuses to declare a preference for one or the other. Luce was the first one to discuss this issue formally in the framework of preference modelling. Mathematical characterisations of preference modelling with thresholds can be found in Roubens and Vincke (1985).

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USING LINGUISTIC DESCRIPTIONS WITH MULTI-CRITERIA DECISION AID APPROACHES IN URBAN ENERGY SYSTEMS

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Abstract

Multi-Criteria Decision Aid (MCDA) methods include various collections of mathematical techniques related to decision support systems in non-deterministic environments to support such applications as facility management, disaster management and urban planning. This paper applies MCDA approaches based on qualitative reasoning techniques with linguistic labels assessment. The aim of this method is ranking multi-attribute alternatives in group decision-making with qualitative labels. Finally this method is applied to a case of urban planning in selection of the less energy consumption project in a geographical area in Catalonia.

Keywords: Multi-Criteria Decision Aid, qualitative labels, energy

LE DESCRIZIONI LINGUISTICHE NEGLI APPROCCI MULTICRITERIO DI AIUTO ALLA DECISIONE (MCDA) PER LA VALUTAZIONE DEI SISTEMI DI PIANIFICAZIONE ENERGETICA

Sommario

I metodi multicriterio di aiuto alla decisione includono diverse tecniche matematiche relative ai sistemi di supporto alle decisioni in ambienti non-deterministici per facilitare la gestione dei servizi, la gestione delle catastrofi e la pianificazione urbana. Questo articolo applica due approcci multicriterio basati sulla combinazione di tecniche qualitative con la valutazione di descrizioni linguistiche. Lo scopo è quello di classificare le alternative multi-attributo in processi decisionali di gruppo con descrizioni qualitative. Il metodo è stato applicato ad un caso di panificazione urbana per la selezione del progetto con il minor consumo energetico in un'area geografica della Catalogna.

Parole chiave: MCDA, descrizioni qualitative, energia

1. Introduction

Multi-Criteria Decision Aid (MCDA) approaches under uncertainty and fuzzy systems are accepted as suitable techniques to deal with conflicting problems and in particular in energy analysis and planning. The sustainable energy planning include different variables, as the decision making is directly related to the management of different type of information with different aspects such as technological, environmental, economic and social. MCDA methods include various collections of mathematical techniques related to decision support systems in non-deterministic environments to support such applications as facility management, disaster management and urban planning. (Doukas *et al.*, 2007; Figueira *et al.*, 2005; Roy and Słowiński, 2013; Słowiński and Teghem, 1990; Wang *et al.*, 2009). Urban energy systems present multiple identities with multiple criteria, which are subject to non-equivalent descriptions and the relevant aspects cannot be captured using a single perspective. For example in the case of buildings, an architect would describe the criteria in terms of volumes, shapes, materials and orientation. By contrast, sociologist would look at the people living in the building, and describe it according to demographic, cultural and socio-economic characteristics. Different persons with different backgrounds would focus on different aspects of the building according to what they consider relevant for the analysis. In order to deal with this issue, this study introduces the qualitative MCDA by using linguistic description applied to the SEMANCO (Semantic tools for carbon reduction in urban planning) project to assess the energy performance of urban plans and projects and to compare them against the baseline and against each other. In these cases, it is often difficult to obtain exact numerical values for criteria and indicators. In order to overcome this shortage, qualitative reasoning techniques integrated with MCDA, are capable of representing uncertainty, emulating skilled humans, and handling vague situations.

Frequently, this uncertainty is captured by using linguistic terms or fuzzy numbers to evaluate the set of criteria or indicators (Dubois *et al.*, 2003; Madrazo *et al.*, 2014a). Agell *et al*. (2012) proposes a qualitative reasoning technique to overcome uncertainty in human judgments that involve vague information. In a decisional process, assessment and selection of alternatives derive from complex hierarchical comparisons among them, which are often based on conflict criteria. This method can be used as a systematic tool for sustainability assessment. Several studies on energy planning have been developed to help energy planners and policy makers to design strategies for energy system models (Beccali *et al.*, 2003; Gamboa and Munda, 2007; Kaya and Kahraman, 2011; Liu, 2007; Pohekar and Ramachandran, 2004; Polatidis *et al.*, 2006; Tsoutsos *et al.*, 2009).

The aim of this paper is to analyze qualitative MCDA approaches with the distance function aggregations applied to urban energy systems. This paper considers the qualitative approach with linguistic labels for ranking multi-attribute alternatives in group decision-making. This method is applied to the real case study of the SEMANCO project to provide an appropriate energy information framework.

The paper is organized as follows: Section 2 describes some relevant MCDA methods applied to energy planning and review different policy frames for energy management. Section 3 introduces a specific MCDA method where qualitative alternatives' descriptions are considered. In Section 4, SEMANCO integrated platform application is presented in order to assess the energy performance and CO_2 emissions of projected urban plans at city level. Finally, the last section highlights some conclusions and future research directions.

2. Related works and theoretical framework

Since the 1950s and 1960s, when foundations of modern multi-criteria decision-making methods have been laid, many researches devoted their time to development of new multi-criteria decision-making models and techniques. In the past decades, research and development in the field have accelerated to continue growing exponentially. However, the methodological choices and framework for assessment of decisions are still under discussion. The general purposes of MCDA are describing trade-offs among different objectives and structuring decision process, defining and selecting alternatives, criteria and weights and finally evaluating the results to make decisions. Most of MCDA approaches which can handle both quantitative and qualitative criteria, share the common characteristics of conflict among criteria and difficulties in design or selection of alternatives (Pohekar and Ramachandran, 2004; Wang *et al.*, 2009).

A large number of multi-criteria techniques have been developed to deal with problems with different objectives such as choice, ranking and sorting or classification problems.

There are several methods base on priority, outranking, distance or mixed methods which can be applied to these problems. A decision-maker is required to choose relevant method in each problem. In the case of energy problems, multi-criteria methods should be simple to promise transparency, consider the intensity of preferences and be partially. These features are difficult to gather in one specific method simultaneously. In energy planning issue, the group of studies address to the significant potential of MCDA techniques in the urban energy systems or direct relevance to the use of energy in cities which can be found in (Blondeau *et al.*, 2002; Chang *et al.*, 2008; Dutta and Husain, 2009; Hsieh *et al.*, 2004; Keirstead *et al.*, 2012; Medineckiene *et al.*, 2014; Mosadeghi *et al.*, 2015; Qin *et al.*, 2008; Wang *et al.*, 2014; Wright *et al.*, 2002; Zavadskas and Antuchevičiene, 2004; Zavadskas and Antucheviciene, 2006).

Among all categorization in MCDA, reference point and outranking methods are widely used in the case of ranking problems (Beccali *et al.*, 2003; Loken, 2007). The study of ranking process is considered as a interest issue by computer science and artificial intelligence in the field of decision making, learning and reasoning (Belton and Stewart, 2002; Zadeh, 2001). In this case, one of the active subfield of research in artificial intelligence is Qualitative Reasoning (QR) which tries to understand and explain human beings' ability to reason without having exact information. The main objective of QR is to develop systems that permit operating in conditions of insufficient or without numerical data. Most of the selection elements cannot be given precisely and the evaluation data of the suitability of alternatives for subjective criteria are usually expressed in linguistic terms by the decision-makers preferences. There exist many different representation formats that can be used in each model, i.e., preference orderings, utility values, multiplicative preference relations and fuzzy preference relations among others.

Qualitative reasoning is able to reason at a qualitative or symbolic level directly in terms of orders-of-magnitude. To represent non-trivial domain knowledge, the patterns or alternatives to be ranked are characterized by a set of features, which are evaluated by each actor through linguistic labels corresponding to ordinal values.

Order-of-magnitude models are among the essential theoretical tools available for qualitative reasoning about real systems. They aim to capture order-of-magnitude commonsense inferences, as used by human beings in the real world. A general qualitative algebra structure was defined on the absolute order-of-magnitude model, providing a

mathematical foundation unifying sign algebra and interval algebra through a continuum of qualitative structures built from the roughest to the finest partition of the real line. Specifically, the one-dimensional absolute order-of-magnitude model works with a finite number of qualitative labels corresponding to an ordinal scale of measurement (Travé-Massuyès *et al.*, 2005).

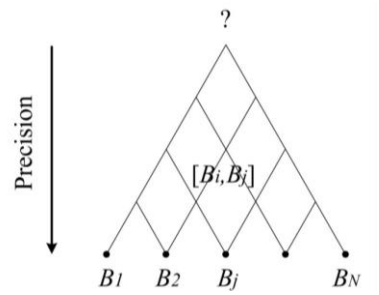
Techniques based on order-of-magnitude qualitative reasoning have provided theoretical models that can obtain results from non-numeric variables. The main advantage of this method is the capability to deal with problems in such a way that the principle of relevance is preserved, that is, each variable is valued with the level of precision required. Other advantage is that it tackles the problem of integrating the representation of existing uncertainty within the group (Forbus, 1984). In the following section we are going to introduce the algorithm description of the method in this framework.

3. A Multi-Criteria Decision Aid method

Agell et al. introduced in 2012 a qualitative approach for ranking alternatives motivated by the Reference Point Method which ranks the alternatives by using a distance function defined on the absolute order-of-magnitude qualitative space. This technique uses qualitative assessments of alternatives and minimizes the distance between them and a certain target point that models the best performance for each criterion considered. It deals with the problem in such a way that the principle of relevance is preserved. Depends on the features of each variable, the number of labels chosen to describe a real problem is not fixed.

In this method, the absolute order-of-magnitude qualitative space is used for the process of moving from the ordinal scale of the original data set to a cardinal scale by codifying the labels using location function. The space of k-dimensional vectors of labels, being k the product of the number of experts (m) by the number of criteria (r), allows the representation of alternatives from linguistic evaluations of experts by basic or non-basic labels with different granularity (Fig. 1). The basic labels, corresponding to linguistic terms, are defined by a discretization given by a set $\{a_1, \ldots, n\}$ of real numbers as landmarks, $B_i = [a_i, a_{i+1}]$ (where i= 1, …, n). The non-basic labels describing different levels of precision, are defined as $[B_i, B_j] = [a_i, a_{i+1}]$ (where i= 1, …, n).

Fig. 1 – Labels with different granularity



Source: Agell et al. (2012)

A location function introduced as an element in $\Re^2$ is defined by the addition of measures of basic label to its right and to its left (Formula 1):

$$l\left(\left[B_i, B_j\right]\right) = \left(-(i-1), n-j\right) \tag{1}$$

This function codifies each alternative via a 2-k dimensional vector of integer numbers. The vector (B_n, …, B_n) is considered as a reference label to compute distances. The location function is applied to each component of the k-dimensional vector of labels representing an alternative. As a result, each alternative is codified via a vector in $\Re^{2k}$. In order to rank the alternatives, the Euclidean distance of each alternative to this reference vector with respect to different criteria is computed. Finally alternatives are ranked according to their minimum distance to the reference label (Formula 2):

$$d\left(A, A\right) = \sqrt{\sum_{i=1}^{r} w_i \left(\sum_{j=1}^{2m} (X_{ji} - X_{ji})^2\right.} \tag{2}$$

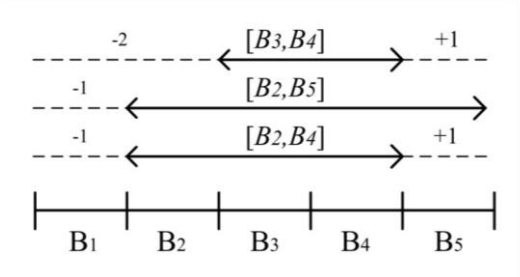
where w_i is the weight corresponding to each indicator.
Let us consider the absolute order-of-magnitude model with granularity 5 from strongly agree to strongly disagree, see Table 1.

Table 1 – Linguistic label description

Basic labels	Linguistic labels
B_1	Strongly disagree
B_2	Disagree
B_3	Neither agree nor disagree
B_4	Agree
B_5	Strongly agree

Each linguistic label corresponds to a location. For instance, the location of the non-basic label of [B_2, B_4] is the pair (−1, 1) and the reference point is B_5 defined by (−4, 0), see Fig. 2.

Fig. 2 – Locations



The following section presents one of the challenging applications and domains in which the method presented has been used in the urban energy planning area.

4. SEMANCO Integrated Platform Application

Energy is a significant factor for economic development of countries. As economy advances and human society requires more energy, the problem of reducing CO_2 emissions in cities has given rise to a serious contradiction among energy supply, environment protection and economic development. It is necessary to change the energy structure, integrating new models and modifying the way we use energy such as improving the energy efficiency of buildings by means of an urban energy system model.

The building sector has significant impacts on communities. At the same time, it is the sector with the highest cost and environmental saving potentials provided effective strategies are implemented.

Buildings are responsible for 33% of worldwide energy-related GHG emissions; also it has been identified as a sector where huge savings can be made. For example, of the 40% of energy consumed by buildings in the European Union (EU), estimates reveal that the implementation of energy-efficiency measures could lead to cost-saving of around 28% (Ekins and Lees, 2008). Therefore, the built environment is arguably a sector that can play an important role in mitigating climate change impacts, reducing energy use and natural resources (Abanda *et al.*, 2013; Robert and Kummert, 2012).

So, it is not a mistake that in small and big cities sustainability practitioners focus their attention on improving building performance.

In the SEMANCO project, semantic technologies have been used to create models of urban energy systems able to assess the energy performance of an urban area to make informed decisions about how to reduce CO_2 emissions in cities. The goal of the SEMANCO research project is to create a comprehensive framework in which semantic energy information brings the data sources at different scales from different domains.

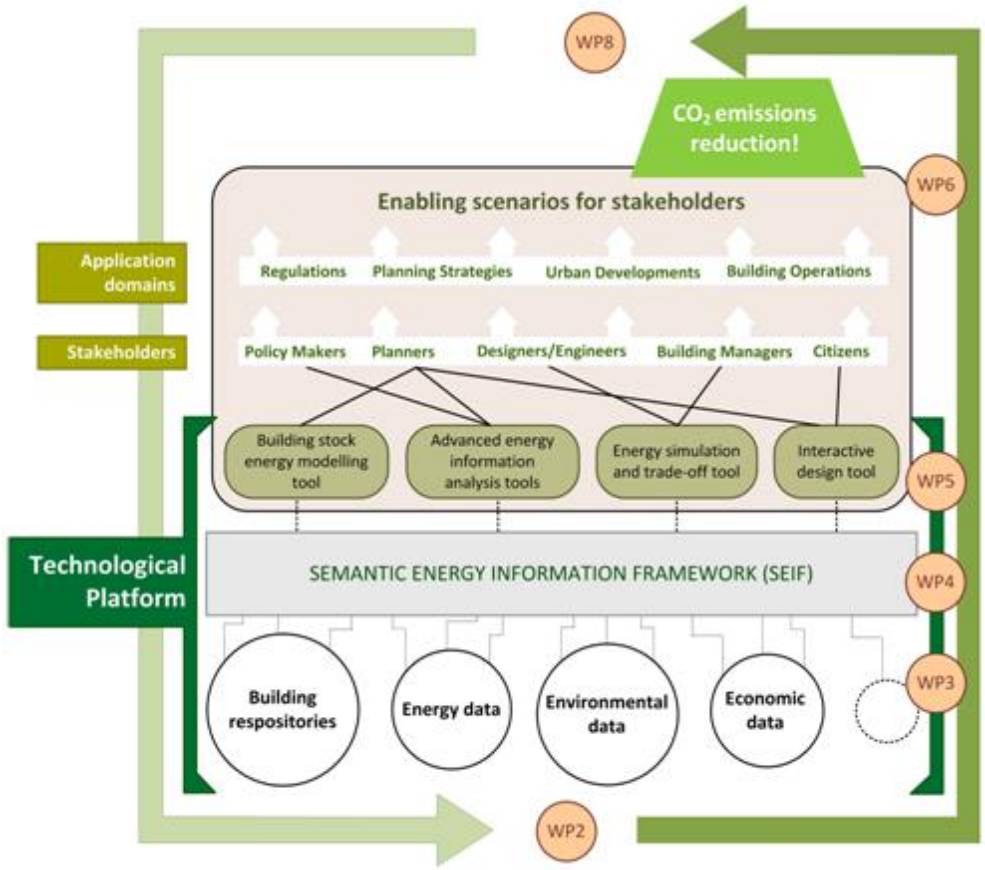
This integration of data from multiple sources with different tools is handled by a Semantic Energy Information Framework (SEIF), a key technological component developed in the project (Madrazo *et al.*, 2014a). This framework is the connection between the different data sources and the tools which use the semantically modeled data (Fig. 3).

In the integrated platform, the experts' knowledge is captured through the use case methodology, as well as the links to the external data sources which are available via the SEIF. This combination of knowledge and information constitutes the base for creating energy models for a specific urban area.

Ontology can be used to create shared vocabularies which help experts from different fields to establish relationships between certain objects of an urban energy system according to their knowledge and experience (Gruber, 1992). It can serve to promote communication between the semantically modeled data and the various software applications used by experts. This ontology has been applied to three case studies in the SEMANCO project, first at the building scale and later on at the urban level.

Different scenarios located in Copenhagen (Denmark), Manresa (Spain) and the Newcastle (United Kingdom) will enable defining the scope of the research and outlining the specifications for the tools needed by stakeholders in different domains (Fig. 4). Use cases defined by means of these templates are a foundation in the ontology building process.

Fig. 3 – Structure of SEMANCO project



Source: Madrazo et al. (2012)

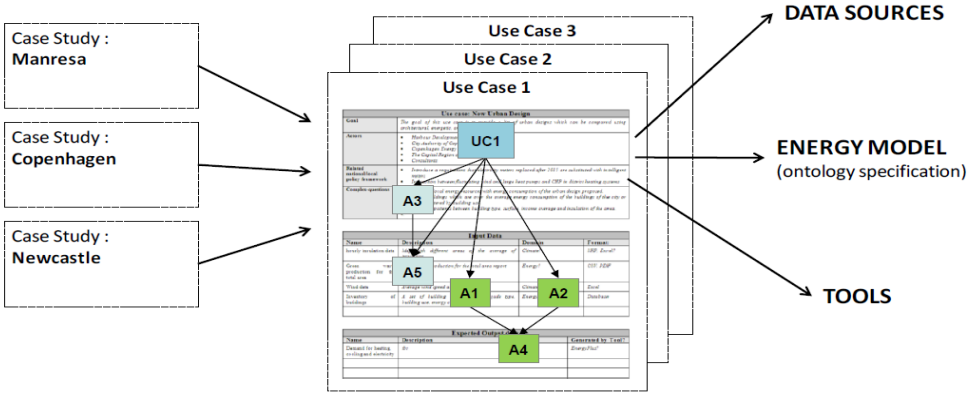
The platform shown in Fig. 5 has been designed to support services for different user groups. Real energy and different information such as socio-economic information can be obtained before and after implementation of some actions. The description of building typologies will consider the energy carriers used and final use within the building in building and neighborhood levels.

Experts can represent the existing conditions of the urban system (*descriptive model*), analyze the future evolution of the system (*predictive model*), explore different scenarios for future development (*exploratory model*) and propose improvement plans and evaluate projects to improve the performance of the urban energy system (*planning model*) using multi-criteria decision aid tools (Madrazo *et al.*, 2014b).

The MCDA tool compares alternatives in order to decide which improvements might be most suitable by generating a new plan. Figure 6 shows that each plan has a set of project attached to consider the effect of different interventions for example window improvement,

heating system improvement, roof isolation and adding renewable thermal energy supply. The user can switch back to the plan interface and use the multi-criteria tool developed to compare the interventions contained within each project. This helps them decide which project they would prefer to enact in practice.

Fig. 4 – Structure of SEMANCO project

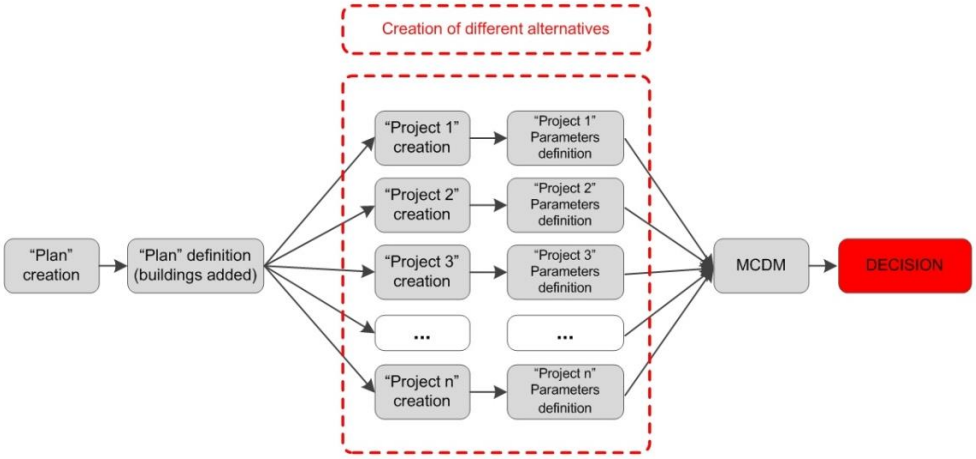


Source: Madrazo et al. (2012)

Fig. 5 – Integrated Platform and Building selection in the platform interface

Source: Madrazo et al. (2014b)

Fig. 6 – Workflow for decision making within the platform



Source: Carpenter et al. (2014)

In order to illustrate the use of the MCDA tool within the SEMANCO integrated platform, Let us consider a case where a plan has been created to refit the set of buildings and three projects proposing different ways of doing this have been created. The basic results from these can be seen in the following section.

5. Results

In this section, the results provided by qualitative MCDA applied to SEMANCO platform are presented. Indicators are crucial components in the overall assessment of progress towards sustainable development. In this study, the indicators shown in Table 2 are considered according to the calculation methods and input indeeds. On the other hand, two qualitative criteria which are ease of implementation and social acceptability are also considered to use the advantage of expert`s assessment by means of qualitative MCDA approach.

According to the given relative importance via experts, different possible improvement types (such as solar PV, heat pumps and extra insulation) for each of these indicators are defined as Project A, Project B and Project C beside the baseline (current plan), which is denoted by the plan's name Policy change, is also considered in the analysis (Fig. 7). The calculated baseline will be a reference to assess the effectiveness of the improvement plans developed for the last round of demonstration scenarios.

The steps of the qualitative MCDA algorithm, mentioned in Section 3, are executed. To this end, the highest score of each criterion are respectively considered as the reference label of the qualitative space. Table 3 shows these qualitative labels together with their locations, obtained directly from Equation 1.

Table 2 – Relevant indicators

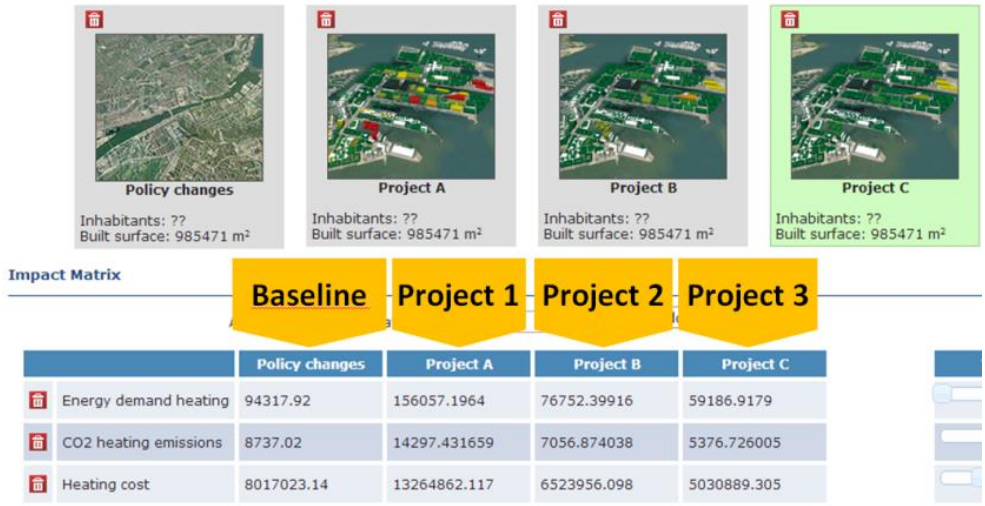
Indicators	Unit	Calculation method	Input needed
Energy demand heating	kWh/year	kWh/year = kWh/m^2 * total number of m^2 (differentiating between households and office buildings)	The total annual consumption of energy spend on heating per m^2 for households and office buildings is needed to find this indicator along with the number of m^2 in households and office buildings in the scenario.
CO_2 emission	gCO_2/MJ	Average CO_2 – factor for heat (gCO_2e/GJ) = (heat supply from grid (GJ)*CO_2 – factor heat-grid gCO2e/kWh) + Heat production in city district (GJ)*CO_2 factor city heating (gCO_2e/GJ))/[heat supply from grid (GJ) + Heat production in city district (GJ)]	Input needed is CO_2 emission-factors for heat produced, the total heat produced and total heat consumed, all within the city district, along with CO_2 emission-factors for heat produced outside the city district.
Heating cost	€/MJ	The price per kWh for the chosen heat supply solution is calculated on the basis of the combined investment costs, net present value of the operating costs over a 20 year period, including subsidies in the period in relation to the expected production. Efficient heat supply solutions could be: Conversion from natural gas to district heating. CHP based on biomass Low temperature areas. Efficient utilization of the temperatures in the district heating grid.	The total cost of supplying heat (investments, running costs, profit margin, etc.) and the total amount of heat produced from different sources.

Source: Niwas et al. (2012)

Table 3 – Different indicators with different granularity

Indicators	Granularity	Reference label locations
Energy demand heating	(B_1, …, B_{10})	(-9,0)
CO_2 emission	(B_1, …, B_8)	(-7,0)
Heating cost	(B_1, …, B_5)	(-4,0)
Ease of implementation	(B_1, …, B_7)	(-6,0)
Social acceptability	(B_1, …, B_7)	(-6,0)

Fig. 7- New plan sample platform



The first step of this algorithm is assigning qualitative labels to the quantitative scores to simplify the computation in the process of ranking. The qualitative MCDA approach considered in this example uses different basic qualitative labels with different granularity for each criterion which corresponds to several intervals whose length is defined via the distance of minimum and maximum scores (see Table 4). Then, the Euclidean distance of each alternative from two reference labels is calculated by means of Formula 2. Finally, these values are combined to give a single ranking for each improvement type. The intention is not that the output from this tool should be followed in an absolute manner but rather that it should serve to aid decision makers by clarifying their intentions. Table 5 shows the values of the distance of each alternative to the reference labels. According to the minimum distance values, the following ranking is presented: Project C > Project B > Baseline > Project A.

Table 4 – Basic linguistic labels

	Weights	**Policy change**	**Project A**	**Project B**	**Project C**
Energy demand heating	1/9	B_5	B_1	B_6	B_7
CO_2 emission	3/9	B_4	B_1	B_5	B_6
Heating cost	2/9	B_3	B_1	B_3	B_4
Ease of implementation	2/9	B_3	B_1	B_6	B_4
Social acceptability	1/9	B_3	B_4	B_3	B_2

Table 5 – Distances aggregation

Alternatives	d_i^*
Policy changes	5.34
Project A	8.70
Project B	3.9
Project C	3.82

On the basis of the current plan, Project C is better in all indicators except social acceptability which has a minimum importance among other indicators. In the comparison of best options, project C is a winner in quantitative indicators and project B in qualitative ones. So, being the weights of qualitative indicators more important can cause a ranking reversal between these two options.
The method uses for ranking these projects, does not require the handling of the previous discretization or definition of landmarks to define initial qualitative terms because the calculations are performed directly with the labels so the computations are very fast and easy. Table 6 shows the features of qualitative MCDA method.

Table 6 – MCDA ranking method features

Features	**Qualitative MCDA**
Final Scale	Qualitative labels
Granularity	Multi-granularity
Normalization	Not requiered
Weights	Trade-off
Aggregation step	Distance function
Aggregation function	Distance to the maximum

Additionally, the qualitative MCDA method can address different levels of precision, from the basic labels, which represent the most precise ones to the least precise label which can be used to represent unknown values. So, it is possible to guarantee transparency and the intensity of preferences is considered.

6. Conclusion and future work

The proposed qualitative MCDA approaches are applied to the urban energy system to help policy makers and users in choosing appropriate decisions.
Energy consumption in cities has attracted significant research in recent years. Integrated platforms, as the one considered in this paper, provide an appropriate information framework for energy planners. The case study analyzed by SEMANCO project provides access to semantically modeled energy-related data. This access is crucial for the cities decision makers to analyze and reduce carbon emission in their cities.

The study of qualitative MCDA approach using linguistic description for preference aggregations modeling in energy planning has been performed. To do so, the qualitative approach with linguistic labels introduced by Agell *et al*. (2012) for ranking multi-attribute alternatives in group decision making is considered. In the paper it is shown that the qualitative method gives the experts the ability of dealing with uncertainty, establishes an appropriate evaluation framework for group decision-making and allows considering the intensity of preferences in decision aid. However, it has been pointed out that the feature of compensation is a shortage of this method in problems where the disadvantage of one indicator cannot be compensated by the advantage of another. As future research, the role of the weights of indicators will be studied. In addition, a real case study will be performed in the city of Manresa in Catalonia, considering data gathered in SEMANCO project.

Acknowledgements

This research was partially supported by the SENSORIAL Research Project (TIN2010-20966-C02-01 and TIN2010-20966-C02-02), funded by the Spanish Ministry of Science and Information Technology. Partial support was also provided by a doctoral fellowship awarded to one of the authors at the ESADE Business School, with additional support from Ramon Llull University. Also, This work has been developed as part of the SEMANCO project (http://semanco-project.eu/), which has been co-financed by the European Commission within the 7th Framework Program of the European Union, under the coordination of the research group ARC from the School of Architecture and Engineering, Ramon Llull University, Barcelona (Spain).

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TECHNOLOGICAL SOLUTIONS AIMING AT RECOVERING METRO BRAKING ENERGY: A MULTI-CRITERIA ANALYSIS CASE STUDY

Annalia Bernardini, Ricardo Barrero, Cathy Macharis, Joeri Van Mierlo

Abstract

The transport sector, being responsible for a large share of fossil fuels consumption and emissions, mainly CO_2, is seeking for different ways of reducing their energy consumption and, especially, their dependency on fossil fuels. The purpose of this paper is to present the Multi-Criteria Analysis (MCA) of technological solutions recovering metro braking energy. The MCA PROMETHEE method endorsed to select the most suitable technological solution for the tram and metro network in Brussels. The MCA approach allowed to firstly evaluate the different technologies and afterwards to propose an individual decision to the public transport decision-maker based on the decision problem objectives and the MCA results.

Keywords: public transport, metro braking energy, PROMETHEE

SOLUZIONI TECNOLOGICHE PER IL RECUPERO DELL'ENERGIA CINETICA DI FRENATA: UN CASO-STUDIO DI ANALISI MULTICRITERIO

Sommario

Il settore dei trasporti, responsabile di un'ampia quota delle emissioni di gas serra di origine antropogenica (in particolare CO_2) e dell'utilizzo di combustibili fossili, sta individuando alternative per ridurre i consumi energetici e, soprattutto, la dipendenza dai combustibili fossili. Lo scopo di questa ricerca è di presentare un'Analisi Multi Criterio (AMC) per identificare la soluzione tecnologica che permetta di ridurre il consumo energetico, recuperando l'energia cinetica di frenata prodotta dai trasporti urbani. Tra le diverse metodologie MCA, si è scelto il metodo PROMETHEE al fine di individuare la soluzione tecnologica più efficiente da utilizzare per la rete tramviaria e metropolitana della città di Bruxelles. L'approccio AMC ha permesso di valutare in primo luogo le diverse tecnologie e, quindi, di proporre all'ente responsabile del trasporto pubblico una decisione univoca basata sugli obiettivi prescelti per il problema decisionale ed i risultati ottenuti dall'AMC.

Parole chiave: trasporto pubblico, energia cinetica di frenata, PROMETHEE

1. Introduction

In urban areas, where population density is very high and emissions present a higher risk to human health, electric powered vehicles such as trams, metros and trolley buses have already been in use for many years. These vehicles do not produce local emissions and are already efficient due to their low friction (rail vehicles) and to regenerative braking technologies that allow energy exchange among vehicles. Nevertheless, the efficiency of this system can be improved with the inclusion of energy recovery systems that capture the vehicles braking energy that could not be re-used.

When vehicles decelerate, usually an important amount of kinetic energy is lost in heat and dissipated in braking resistors. Power recovery techniques can be exploited to temporarily store this energy and use it for future accelerations or send it back to the electricity grid. Most of light rail vehicles in use of Direct Current (DC) networks nowadays are able to convert the vehicle kinetic energy into electrical energy during the braking phases of their driving cycles thanks to the dynamic braking technology, which uses the electric motor as a generator in order to stop the vehicle. One of the advantages of this system is that it avoids friction between the traditional braking pad and the wheels, reducing, thus, the wear of the braking components. In conventional DC networks, fed by irreversible rectifier substations, the braking vehicles attempt to send this energy back to the supply line. If the line is forming a hybrid train or it can be placed out of the train, connected to some part of the supply line. In this latter case, the RESS is known as wayside or stationary RESS (Rufer *et al.* 2004; Foiadelli *et al.* 2006). In both cases, several technologies could be used: batteries, Electric Double Layer Capacitors (EDLCs), flywheels, etc.

The last option is to retrofit the irreversible substation with an inverter so that they become reversible (Chuang *et al.* 2005; Han receptive at this moment, this energy will be re-used by other vehicles nearby, but if this is not the case, the vehicle voltage will increase until the maximum braking voltage is reached and this energy will be deviated to the braking resistors in the vehicle and dissipated as heat. This energy, dissipated in the braking resistors, will be the aim of different energy recovery technologies. There are several ways to re-use this energy: One of them consists in synchronizing the vehicles in such a way that when a vehicle brakes, another nearby one accelerates using that energy. This requires a very good control of the vehicles schedules and the automatization of the line and it can be altered by delays. Another option is the Rechargeable Energy Storage System (RESS) technology (also used in road hybrid vehicles) that would temporarily store this braking energy until it is needed again by the same or another vehicle. In the case of the light rail vehicles, the RESS can be installed on the vehicle (Destraz *et al.*, 2007; Hillmansen and Roberts, 2007; Allegre *et al.*, 2010) itself, Bae 2009; Cornic 2010). In this case, the energy is sent back to the network so that it can be used by any other consumer (if the transport operator owns the high voltage network, this energy could go to lighting, computers, escalators, air conditioning, other substations, etc.). This is a good solution if the transport operator is the owner of the high voltage network or if the electricity distributor is willing to buy this energy from the transport authority. These technologies have some advantages and disadvantages when compared to each other (Barrero, 2012).

The purpose of this paper is to present the Multi-Criteria Analysis of the technological energy recovery solutions, principally: EDLCs (also known commercially as supercapacitors or ultracapacitors), Flywheels and Reversible Substations, aiming at recovering metro braking energy for the public transport operator. In section two of this

paper the applied methodology for the evaluation task is introduced, section three presents the stepwise procedure of the MCA and section 4 summarize the conclusions.

2. The Multi-Criteria Analysis application

MCA is increasingly used for decision-making in environmental policy evaluation due to the complexity of issues and the inadequacies of conventional tools such as the mono-criterion Cost-Benefit Analysis (CBA) used to compare the costs and benefits of the evaluated options in order to determine its economic "efficiency". The MCA allows to capture the full range of the decision problem impacts. The objectives (criteria) and preferences of the decision-maker(s) are considered in order to assess the different options (alternatives). MCA methods can conglomerate simultaneously in the decision-making support process qualitative and quantitative objectives. In the case of a sustainable MCA decision problem all the environmental and socio-economic objectives englobed in the decision problem can be considered. For a MCA evaluation the best compromise solution(s) should emerge (Brans, 2004; Munda, 2004; Figueira *et al.*, 2005; Hayez, *et al.* 2011; Roy and Słowiński, 2013).

3. MCA method: PROMETHEE

MCA techniques can be used to identify a single most preferred option, to rank options, to short-list a limited number of options for subsequent detailed appraisal, or simply to distinguish acceptable from unacceptable possibilities. The main role of these techniques is to deal with the difficulties that human decision-makers have in handling large amounts of complex information in a consistent way. Typically, most decision problems have a multi criteria nature and refer to several concerns at the same time: technological, economical, environmental, social etc. As there is no alternative optimizing all the criteria at the same time, a compromise solution should be selected.

The MCA Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) developed by Brans (1982), further extended by Brans and Vincke (1985), Brans and Mareschal (1994), Macharis *et al.* (1998), Figueira *et al.* (2004), Brans and Mareschal (2005) has been used for this study. The PROMETHEE method has been applied successfully in several domains covering topics such as environment, hydrology and water management, business and financial management, chemistry, logistics and transportation, energy management, etc. (Behzadian *et al.*, 2010). The choice of this method was mainly made regarding its simplicity and its capacity to approximate the way human mind expresses and synthesizes preferences in front of multiple contradictory decision perspectives (Diakoulaki and Karangelis, 2007).

A typical MCA procedure consists of several steps:

1. identification of the problem and selection of the alternatives (STEP 1);
2. translation of the objectives (concerns) into several criteria (STEP 2);
3. quantification of the relative importance of each criterion (weights) (STEP 3);
4. assessment of the performance of each alternative to the identified criteria (STEP 4) and the following categorisation. Tab. 1 presents the overall performance matrix, where the aggregation of each alternative contribution to the objectives is shown. Where a_1 to an represent the potential alternatives submitted for evaluation and where f_1 to f_j are the evaluation criteria;
5. sensitivity analysis (STEP 5).

Regarding the starting step of constructing the performance matrix, there is on one side a finite set (a set that has a finite amount of components) ***A*** and on the other side a coherent set of evaluation criteria ***F***. The family of criteria must be comprehensible (usually $n \geq 2$ and $n = 7 \pm 2$) and each criterion reflects the decision-maker preferences. ***F*** needs to satisfy three axioms. All theories are based on axioms. The simpler and fewer the axioms, the more general and applicable the theory (Forman and Gass, 2001). Correspondingly ***F*** should be sufficient to compare any two alternatives $(a, b) \in \boldsymbol{A}$ without loss of meaning, if this axiom is verified, two alternatives with the same vector performance are necessarily indifferent. It must be a minimal consistency between preferences on each criterion and the overall preferences. If *a* is preferred to b on each criterion of ***F***, then *a* should be globally preferred to *b*. Deleting a criterion of ***F*** leads to a questioning of the previous two axioms' (Meyer, 2005).

$\boldsymbol{A} = \{a_1, a_2, \ldots, a_i, \ldots, a_n\}$

$\boldsymbol{F} = \{f_1, f_2, \ldots, f_i, \ldots, f_j\}$

Table 1 – Performance matrix

	$\boldsymbol{f_1}$	$\boldsymbol{f_2}$	$\boldsymbol{f_3}$	**…**	$\boldsymbol{f_j}$
$\boldsymbol{a_1}$	$f_1(a_1)$	$f_2(a_1)$	$f_3(a_1)$	…	$f_j(a_1)$
$\boldsymbol{a_2}$	$f_1(a_2)$	$f_2(a_2)$	$f_3(a_2)$	…	$f_j(a_2)$
$\boldsymbol{a_3}$	$f_1(a_3)$	$f_2(a_3)$	$f_3(a_3)$	…	$f_j(a_3)$
…	…	…	…	…	…
$\boldsymbol{a_n}$	$f_1(a_n)$	$f_2(a_n)$	$f_3(a_n)$	…	$f_j(a_n)$

The advantage of using PROMETHEE here with respect to other MCA methods is that in the end it provides an overall ranking of the different alternatives with respectively positive and negative outranking flows expressing how an alternative is outranking or outranked by the other alternatives submitted for evaluation.

The use of the PROMETHEE method requires also additional information. First, a specific preference function needs to be defined ($P_j(a,b)$) that translates the deviation between the evaluations of two alternatives (a and b) on a particular criterion (f_j) into a preference degree ranging from 0 to 1. This preference index is a non-decreasing function of the observed deviation (d) between the scores of the alternatives on the considered criterion ($f_j(a)$-$f_j(b)$), as shown in Formula 1. In order to facilitate the selection of a specific preference function, six possible shapes of preference functions are proposed to the decision-maker by Brans *et al.* (1986) (Usual shape, U-shape function, V-shape function, level function, Linear function and Gaussian function) (Turcksin *et al.*, 2011). According to Brans and Mareschal (2005) these six shapes have been satisfactory in most real-world applications. Nevertheless new preference functions could always be projected.

$$P_j(a,b) = G_j\left\{f_j(a) - f_j(b)\right\} \quad (1)$$

Another preference parameter is the calculated or direct valued weight score for each criterion. It is the task of the analyst together with the decision-maker to try to come as close as possible to the "most appropriate value weight" of each criterion. Corresponding to the weights reflects a major part of the "brain" of the decision-maker (Mareschal, 2013).

In agreement with Mareschal (2013), the set of weights $\boldsymbol{W}$ $\{w_j,\ j = 1, 2,\ldots k\}$ in PROMETHEE need furthermore to respect the following features: they should be non-negative numbers, independent from the measurement units of the criteria and the higher the weight, the more important is the criterion. Normed weights can be considered (formula 2). Several PROMETHEE software allows performing this normalization routinely adding arbitrary numbers that are then divided by their sum (Brans and Mareschal, 2005).

$$\sum_{j=1}^{k} w_j = 1 \quad (2)$$

With regard to the representation of the latters, several variations of the PROMETHEE method exist: (1) PROMETHEE I partial ranking, where both the positive and negative outranking flows are presented. The positive preference flow $\phi+(a)$ measures how much an action *a* is outranking the other *n*-1 ones. It is a global measurement of the strengths of action *a*. The larger $\phi+(a)$ the better the action. It is its power, its outranking character. The higher the flow is the better the alternative. The negative preference flow $\phi-(a)$ measures how much the other *n*-1 actions are preferred to action *a* (how alternative *a* is outranked). It is a global measurement of the weaknesses of action *a*. Its outranking character. The smaller $\phi-(a)$ the better the action. In PORMETHEE I all the actions are not necessarily compared and that the ranking can include incomparability's (Mareschal, 2013). In PROMETHEE II complete ranking, where a net outranking flow is presented based on the balance between the positive and negative outranking flows, the net preference flow $\phi(a)$ is the balance between the positive and negative preference flows:

$$\phi(a) = \phi+(a) - \phi-(a) \quad (3)$$

It thus takes into account and aggregates both the strengths and the weaknesses of the action into a single score. $\phi(a)$ can be positive or negative. The larger $\phi(a)$ the better the action (Mareschal, 2013). The global net flow of an alternative is the scalar product between the vector of the weights and the profile vector of this alternative. This property is furthermore extended in the GAIA (Geometrical Analysis for Interactive Aid) plane, which provides a graphical representation of the position of the alternatives relative to the various criteria.

A disadvantage of using PROMETHEE is that it does not provide a specific method according to which the weights are to be determined (Macharis *et al.*, 2004). But in this case this can be solved by the direct involvement of the decision-makers (as for the MCA) and their assignment of the weights.

The PROMETHEE method is one of the most intuitive and user-friendly MCA methods. This approach allowed an improved and clear gathering of the Brussels public transportation company experts pro/cons experts about the different braking energy recovery technologies (alternatives). A first step was to evaluate the effectiveness of those

alternatives on each criterion. The criteria were grouped into the following main groups: performance, implementation, reliability/maintenance and the environmental aspects.
The out coming categorisation was noticeably influenced by the established weights attributed to each criterion. Thanks to the flexibility of the MCA it is possible to measure the stability of this ranking through a sensitivity analysis for each field to see if the result significantly changes when the weights are changed, which is useful when the decision-maker has not established too rigidly weights. Furthermore preference scales and/or other characteristics were defined in straight collaboration between the decision-makers and the MCA analysts.

4. MCA software: D-Sight

D-Sight is a decision support software that helps decision-makers find the best solution to their Multi-Criteria Analysis problems. It allows them to conduct a deep but simple evaluation process. The software offers a pre-defined framework in order to structure the decision problem. The alternatives and the criteria can be simply defined. Those criteria can be gathered in different groups organized in a hierarchy tree reflecting the importance of its elements. D-Sight relies on two methodologies. The first one is PROMETHEE that is based on pairwise comparisons in order to process the alternatives evaluations. It is enhanced by its GAIA extension that offers a visual representation of the results. The second methodology is based on the Multi-Attribute Utility Theory (MAUT) that allows the decision-makers to define so-called utility functions which are used to score the alternatives on a specific basis.
Different visual tools are proposed to the decision-makers and present various aspects of the problem such as the ranking, the profiles of the alternatives (the way it is scored on all the criteria), the possible links existing among the criteria, etc. All those tools are meant to provide the decision-makers with an easy way to understand the nature of the results. It consents improving possible interactive discussion(s) of the involved stakeholders in the decision process.
D-Sight allows performing sensitivity analysis on the final results. Indeed, the software does not only provide the decision-makers with a ranking of their options, but it also offers the possibility to assess the robustness of the solution. For instance, D-Sight enables users to know in which intervals each (criterion) weight could be modified without affecting the final choice. This gives an indicator of the reliability of the solution.

5. MCA process

Step 1: Defining the problem and the alternatives

Rail vehicles have the ability to regenerate their kinetic energy into electrical energy during braking. A small portion of this regenerated energy can be reused to power vehicles auxiliaries, the remaining energy being sent back on the network to another vehicle accelerating nearby. In conventional networks, if no vehicle is located nearby, the network voltage increases due to the energy surplus and this extra energy has to be dissipated in braking resistors (Fig. 1 and Fig. 2). To avoid such energy losses, manufacturers are putting energy recovery solutions on the market, both on-board and stationary, and this for various goals: to reduce the overall energy consumption; to decrease the emissions associated to the energy generation; to stabilize the network voltage by limiting the voltage drops; to benefit from better electricity tariffs derived from lower power levels; to allow catenary-free

operations on short distances (only for on board options). The arrows in Fig. 1 point the direction of the energy flow. When the vehicle is in traction mode, the energy comes from the catenary, passes through the drivetrain to yield a torque at the wheels. This torque is used to overcome the forces acting on the vehicle and produce movement. The same energy flow direction is indicated on Fig. 2 with the arrows. The kinetic energy of the vehicle is transformed in electrical energy thanks to the electric motor acting as a generator. The energy goes from the wheels to the catenary or the braking resistors. If the network is receptive, this energy will go to the other vehicle, to an energy storage technology or will be fed back to the AC supply thanks to the reversible substation. If the network is not receptive, the energy will be dissipated in the braking resistors.

Fig. 1 – Schematic of conventional train in traction mode

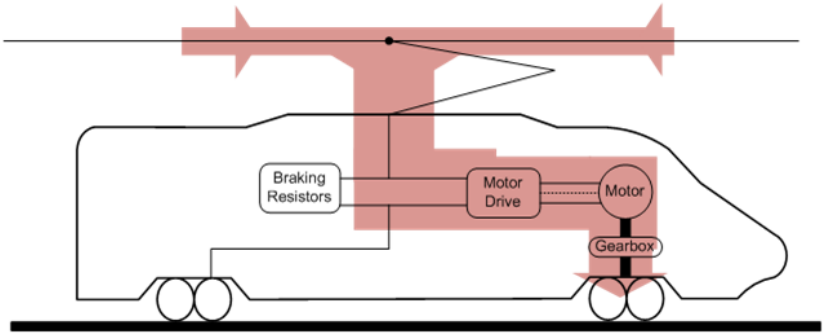
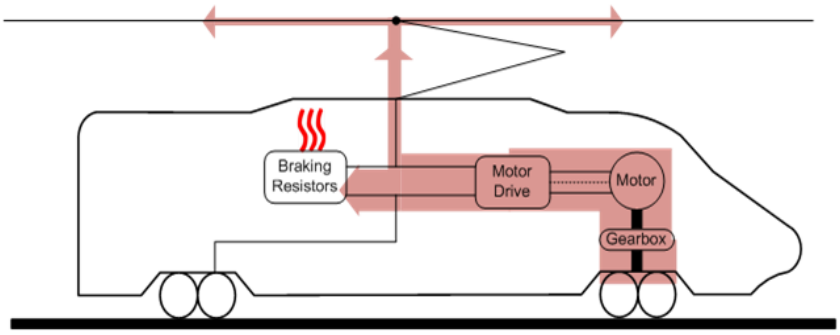


Fig. 2 – Schematic of conventional train in braking mode



In this study we focused on three energy saving methods. These three alternatives will be explained briefly in the following section.

Braking energy recovery

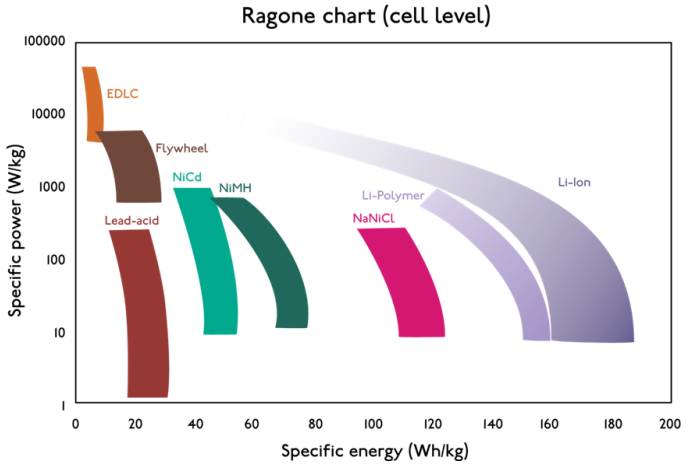
When vehicles decelerate, usually an important amount of kinetic energy is lost in heat and dissipated in braking resistors. Power recovery techniques can be exploited to temporarily

store this energy and use it for future accelerations or send it back to the electricity grid.
During the research context the public transport operator in Brussels invested in pilot installations to be put on the metro networks, on board or alongside the tracks. If the results turn out to be positive, these energy storage/recovery systems will be implemented on a broader scale, larger than the project itself.
The energy recovery technologies in DC fed rail networks can be divided in two groups:

– the first group uses Rechargeable Energy Storage Systems (RESS) to store the braking energy that will be used later. The RESS can be installed on the vehicle itself, forming a hybrid train or it can be placed out of the train, connected to some part of the supply line. In this latter case, the RESS is known as wayside or stationary RESS. In both cases, several technologies could be used: batteries, EDLCs, flywheels, etc.;
– the second group consists in sending the braking energy back to the mains electricity supply so that it can be used by any other consumer (if the transport operator owns the high voltage network, this energy could go to lighting, computers, escalators, air conditioning, other traction substations, etc.). This is a good solution if the transport operator is the owner of the high voltage network or if the electricity distributor is willing to buy this energy from the transport authority. To achieve this, reversible substations are needed.

One way to classify the different RESS technologies, and particularly interesting for portable applications, is to compare their power and energy densities, as shown by the Ragone plot in Fig. 3, where EDLCs (supercapacitors) are positioned against batteries and flywheels.

Fig. 3 – Ragone diagram (cell level). Adapted from Van Den Bossche (2009)



It is observed that EDLCs have a high power and low energy densities density in comparison to that of batteries. Flywheels have similar power density to EDLCs and are reported to benefit from higher energy densities (Vazquez *et al.*, 2010; Lukic *et al.*, 2008).

In the context of this MCA study, the following three main braking energy recovery technologies have been evaluated:
- supercapacitor based stationary RESS;
- flywheel based stationary RESS;
- reversible Substations.

These three solutions will be described more in detail in the following section.

Electric Double Layer Capacitors (Supercapacitors)
EDLCs are electrostatic storage devices that operate like large versions of common electrical capacitors where energy is stored in an electrostatic field by means of charge separation. In contrast to batteries that are charged and discharged through an internal chemical reaction, in a supercapacitor, the energy is stored as a charge or concentration of electrons on the surface of a material (NREL, 2008) and no chemical reaction occurs.
Supercapacitors bridge the gap between conventional capacitors and batteries. They have an energy density 10 to 100 times higher than conventional capacitors and a power density around 10 times higher power than most batteries of equivalent size. The main benefits of supercapacitors based ESS are a high efficiency, high peak powers and long lifetime (around one million cycles) when compared to batteries. The drawback is the low energy capacity. However, due to the characteristics of the power profile and power peaks that have to be handled, EDLCs are a good candidate to do the job.

Flywheels
A flywheel is a rotating disc spinning around an axis used for storing energy mechanically in the form of kinetic energy. The Flywheel works by accelerating a rotor to a very high speed and maintaining the energy in the system as rotational energy. Modern flywheels do not require much maintenance and also benefit from a high efficiency. Due to their mechanical nature, they can also cope with a large number of power peaks which is translated in a long lifetime, very important for braking energy recovery applications in rail transport. In specific power and energy terms, they have similar power density to EDLCs and are reported to benefit from higher energy densities (Vazquez *et al*., 2010; Lukic *et al*., 2008).
From an operational point of view, the difference among flywheels and EDLCS is that flywheels have higher energy density while EDLCs have slightly better efficiency and suffer from lower self-discharge (Haisheng *et al*., 2009). Other aspects that have to be considered when dealing with flywheels, especially for on-board applications, are the gyroscopic forces and safety enclosures (Haisheng *et al*., 2009; Bolund *et al*., 2007). High speed flywheels will need a robust a possibly bulky container for safety reasons in case of failure. The principle of operation, from the network point of view is the same as that of supercapacitor, it would store and release the braking energy when required.

Reversible substations
A substation consists in an electricity distribution system where voltage is transformed from high to low voltage (and vice-versa) using transformers. As it is more efficient to transmit electricity over long distances at very high voltages, the function of a substation is to reduce the voltage from transmission level to values suitable for local distribution. The substations used to power many conventional DC rail networks use diode rectifiers to

convert AC to DC and thus, they provide current only in one direction and are not able to absorb energy generated by the vehicles. A Reversible Substation uses an inverter to convert the rail network DC electrical energy to the mains AC and it allows the system to act in both ways.
Fig. 4 and Fig. 5 explain the difference between conventional substations and reversible substations when two distant vehicles are braking and accelerating respectively (Barrero, 2012).

Fig. 4 – Vehicle 1 braking and vehicle 2 accelerating with rectifier substation

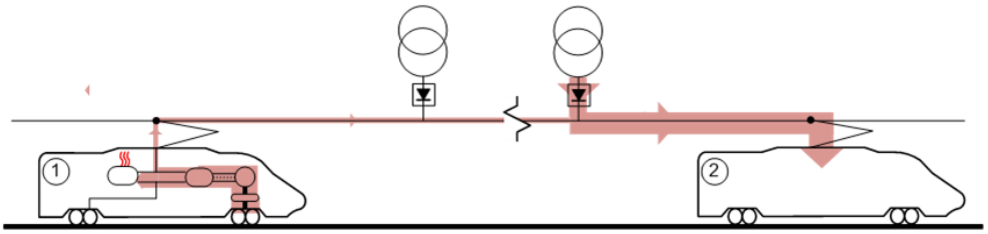
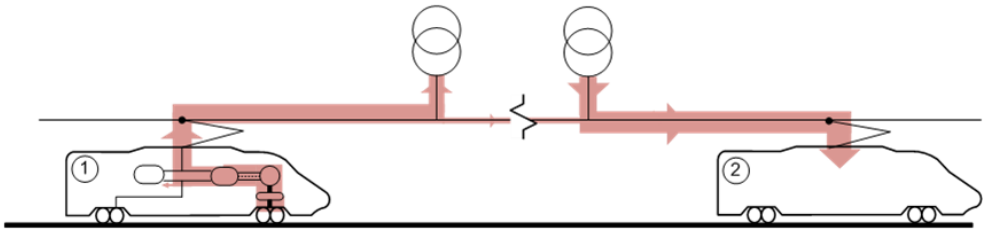


Fig. 5 – Vehicle 1 braking and vehicle 2 accelerating with reversible substation



The quantity of energy a public transport network is able to absorb is mainly conditioned by the probability of trains braking and accelerating simultaneously (UIC, 2009). This absorption phenomenon is called the receptivity of the line. The target is to improve the power line receptivity, in order to regenerate almost completely the trains braking energy. The goals are: to maximize the braking energy feedback to the upstream network, to leave priority to natural exchange of energy between trains, to reduce losses and to ensure a good quality of power supply.
From the network perspective, the operation of a reversible substation differs from that of the ESS (EDLC and flywheels) mentioned above. Reversible substations do not store the energy but they take it from the DC network, convert it to AC and send it back to the Brussels public transportation company high voltage network, where it can be consumed by other regular loads, such as lighting in buildings, computers, other substations, etc.
These systems will be less bulky than ESS and do not have the energy content limitation of

ESS, provided that all the recovered energy will be consumed. The disadvantage is that eventually they do not have the side benefits of ESS (i.e. voltage drops reduction and traffic density increase.) and that it requires the public transport operator either to own the high voltage network or to reach an agreement with the energy distributor to buy the energy sent back.

This MCA focused on two alternatives for each type of technology:

- Supercapacitors: SUPERCAP_01; SUPERCAP_02;
- Flywheels: FLYW_01; FLYW_02;
- Reversible substations: REVSUB_01; REVSUB_02.

Step 2: Defining the criteria

The choice of the criteria (and sub-criteria) was mainly defined during common meetings with the Brussels public transportation company experts and the MCA analysts. The choice of an optimal technological solution aiming at recovering the metro braking energy is interrelated to several aspects. Overall, the technologies were evaluated based on: performance, implementation, maintenance/reliability and their environmental impact.

Each criteria group has furthermore own subcriteria:

A. Performance (Technical performance of the technology).

A.1 Investment cost/Peak Power: Price per power installed.

A.2 Investment cost/Maximum energy recovery: Price per expected energy recovery.

A.3 Voltage balancing function: Is the system able to balance the voltage by avoiding voltage drops and sags?

A.4 Auxiliaries consumption/Maximum energy recovery per hour: Auxiliaries Consumption (Power) [kW] / Maximum Energy Recovery per hour (energy/time=power) [kWh/h=kW]. The energy needed to keep the system running. Used for the electronics that control the system. In voltage balancing in some cases (batteries and supercapacitors).

B. Implementation (The material and implementation characteristics of the assessed technologies).

B.1 Volume: The total space occupied by the three-dimensional technology, expressed in cubic units.

B. Mass: Mass on the ground per expected energy recovery.

B.3 Stage of development: Current status of the technology for railway applications.

B.4 Systems in service worldwide: Systems operated in railway applications.

C. Maintenance and reliability (all supply and repair actions taken to keep the technology in condition to carry out its work and the probability that the technology will perform a required function under stated conditions for a stated period of time).

C.1 Mean time between maintenance (MTBM): Systems in service worldwide: Number of times per year that maintenance events, both preventative and corrective, are needed.

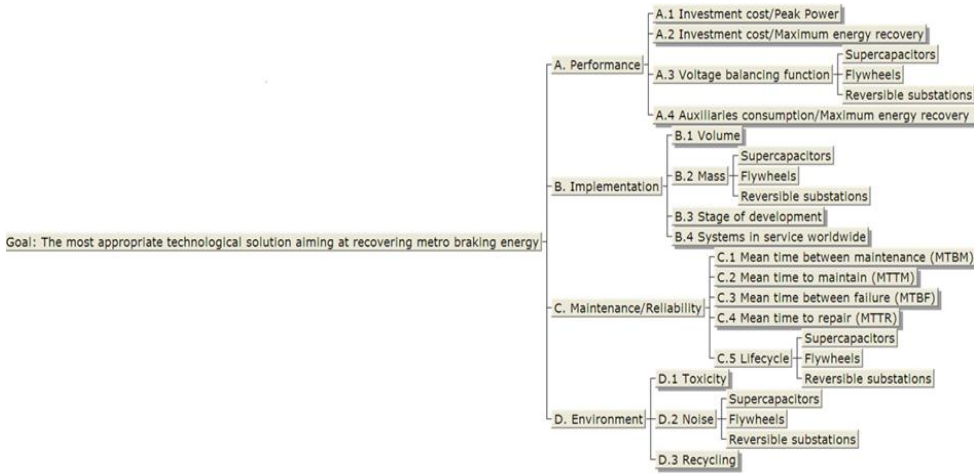
C.2 Mean time to maintain (MTTM): Average downtime for preventive maintenance. This includes any logistics delay time.

C.3 Mean time between failure (MTBF): Mean exposure time between consecutive failures of a component.

C.4 Mean time to repair (MTTR): Mean time to replace or repair a failed component.

C.5 Lifecycle: The duration in years of the technology existence from its primary development through the time of dynamic usage to ultimate end-of-life (EoL) treatment.
D. Environment (environmental effects of the technology on the environment).
D.1 Toxicity: Systems components of harmful material.
D.2 Noise: Noise measurements out of the container.
D.3 Recycling: % of material that can be recycled.
With this information, a hierarchical decision tree can be set up (Fig. 6) in which the multiple criteria and subcriteria are highlighted on which the identified technologies will be evaluated.

Fig. 6 – Hierarchy criteria tree for the Brussels public transportation company assessment



Step 3: Allocation of weights to the criteria
Table 2 gives the overall results of the weight distribution for the different criteria. For all the criteria and subcriteria the weights are determined by the importance the experts attach to each of his or her objectives. The recognition of those weights was established by the Brussels public transportation company experts during the common meetings. The sum of the weights must equal 100% at each level of the hierarchy tree. The weight of the criteria gives the importance of the sub-criteria.
This table gives also an overview of the different parameters of each criterion:
a) if the criterion has to be minimised (i.e. investment cost/peak power) or maximised (i.e. Lifecycle);
b) the used unit;
c) for some criterion also the preferences (indicates the preference threshold of the preference function, and d) if the criterion is based on a numerical scale (means that the scale is quantitative (i.e. volume) or a qualitative scale (i.e. toxicity: low/middle/high).

Table 2 – Criteria and sub-criteria weights and parameters

Code	Criteria	Weight	Min/Max	Unit	Scale numerical/ qualitative
A.1	Investment cost/Peak Power	33%	Minimize	€/MW	Numerical
A.2	Investment cost/Maximum energy recovery	40%	Minimize	€/kWh/h	Numerical
A.3	Voltage balancing function	13,3%	Maximize	Yes/No	Voltage balancing function
A.4	Auxiliaries consumption/Maximum energy recovery per hour	13,3%	Minimize	%	Numerical
		Tot. 100%			
B.1	Volume	30%	Minimize	m3	Numerical
B.2	Mass	20%	Minimize	kg	Numerical
B.3	Stage of development	30%	Maximize	Product/ Prototype	Stage of Development
B.4	Systems in service worldwide	20%	Maximize	Number	Numerical
		Tot. 100%			
C.1	Mean time between maintenance (MTBM)	20%	Minimize	Times/yea	Numerical
C.2	Mean time to maintain (MTTM)	10%	Minimize	Hours	Numerical
C.3	Mean time between failure (MTBF)	40%	Maximize	Years	Numerical
C.4	Mean time to repair (MTTR)	10%	Minimize	Hours	Numerical
C.5	Lifecycle	20%	Maximize	Years	Numerical
		Tot. 100%			
D.1	Toxicity	50%	Minimize	Low/ Middle/ High	Toxicity
D.2	Noise	25%	Minimize	dB	Numerical
D.3	Recycling	25%	Maximize	%	Numerical
		Tot. 100%			
A	Performance	40%			
B	Implementation	20%			
C	Maintenance and reliability	30%			
D	Environment	10%			
		Tot. 100%			

Step 4: Assessment of the alternatives and categorisation

Below, the functions of the different criteria that are used to evaluate the alternatives are presented; then we describe the results obtained as well as an analysis of those results.

Input parameters

The input parameters represent the way the different alternatives have been evaluated for each criterion. In this case, two methods have been considered:

– Pairwise comparisons (based on the PROMETHEE method): the alternatives are pairwise compared in order to calculate a score for a criterion.
– Utility (based on the Multi-Attribute Utility Theory): the alternatives are directly scored for a criterion using a so-called utility function.

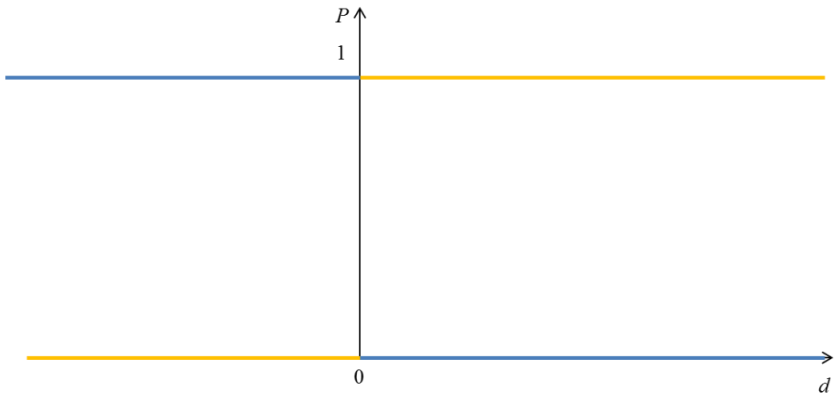
Table 3 – Sub-criteria assessment parameters

Criteria	Min/Max	Type	Function	Pair wise only	
				Indifference	Preference
Investment cost/Peak Power	Minimize	Pairwise	Linear	0	50.000
Investment cost/Max energy rec	Minimize	Pairwise	Linear	0	250
Voltage balancing function	Maximize	Utility	See below	-	-
Aux cons/Max energy rec per hour	Minimize	Pairwise	Linear	0	50
Volume	Minimize	Utility	See below	-	-
Mass	Minimize	Pairwise	Linear	0	10
Stage of development	Maximize	Utility	See below	-	-
Systems in service worldwide	Maximize	Utility	See below	-	-
MTBM	Minimize	Pairwise	Usual	0	1
MTTM	Minimize	Pairwise	Usual	0	1
MTBF	Maximize	Pairwise	Usual	0	1
MTTR	Minimize	Pairwise	Usual	0	1
Lifecycle	Maximize	Utility	See below	-	-
Toxicity	Minimize	Utility	See below	-	-
Noise	Minimize	Utility	See below	-	-
Recycling	Maximize	Pairwise	Linear	0	10

Table 3 gathers the different sub-criteria and the way they have been evaluated. The Min/Max column indicates if the criterion is to be maximized or minimized (as it was indicated in table 2). The Type column indicates whether pairwise comparisons were made or if a utility function was used. When Pairwise was chosen, the three following columns respectively indicate the PROMETHEE preference function, the indifference threshold and the preference threshold. According to Mareschal (2011) the following recommendations are to be taken into account while selecting the accurate preference function (in this case study the Usual and the Linear function). The Usual (type I) preference function is best suited for qualitative criteria. In case of a small number of levels on the criteria scale (e.g. yes/no criteria or up to 5-point scale) and if the different levels are considered quite different from each other, the Usual preference function is the good choice. While the linear (type V) preference function is best suited for quantitative criteria (i.e. prices, costs, power, etc.). All utility functions are explained afterwards. The thresholds are expressed in the unit

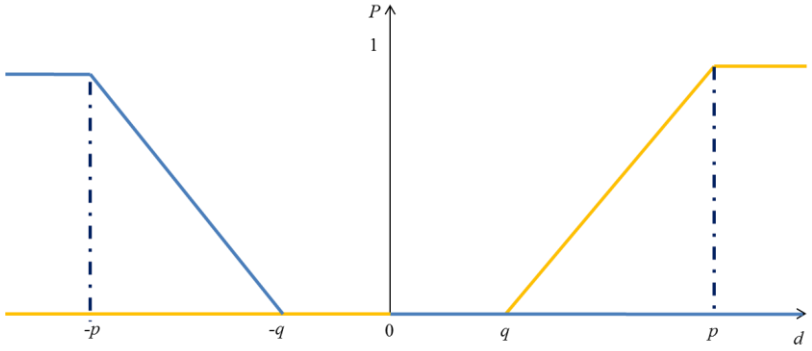
of the criterion as indicated in Table 3.
The so-called preference functions are used to make the pairwise comparisons. When comparing two alternatives *a* and *b* for a criterion *j*, they transform a difference of performance $d_j(a,b) = f_j(a)-f_j(b)$, into a preference degree of *a* over *b*, $P_j(a,b)$, for the related criterion such that $0 \leq P_j(a,b) \leq 1$. Making the comparisons for all the pairs of alternatives allows computing a score for each alternative, for the considered criterion. Six different functions are present in the PROMETHEE method. As indicated in table 3, only two of them are used in the present analysis: the linear and the usual function.
The usual function (Fig. 7) provides only two possible values of preference degrees:
– 0 when $d_j(a,b) \leq 0$;
– 1 otherwise.
There are no parameters to fix. Usual functions where used when comparing the different mean times (MTBM, MTTM, MTBF, MTTR). This typically means that if there was the slightest difference between two of the alternatives on those criteria, the alternative having the lowest (resp. highest) mean time would get a preference degree of 1 if the criteria was to be minimized (resp. maximized).

Fig. 7 – The usual function



The linear function (Fig. 8) allows more granularity by allowing having values of the preference degrees in the whole range between 0 and 1. Furthermore, two thresholds are considered when making the pairwise comparisons:
– the indifference threshold (noted *q*) below which two alternatives are considered to be indifferent;
– the preference threshold (noted p) beyond which, the preference is considered as "strong".
The preference degree is then calculated as follow:
– 0 when $d_j(a,b) \leq q$;
– $(d_j(a,b) - q) / (p - q)$ when $q < d_j(a,b) \leq p$;
– 1 when $d_j(a,b) > p$.

Fig. 8 – The linear function



A linear function was for instance used to compare the mass of the different alternatives. The indifference threshold was set to 0 (kg/kWh/h) meaning that a preference degree will be computed as soon as there is a difference between two alternatives while the preference threshold was set to 10 (kg/kWh/h) meaning that above a difference of 10 (kg/kWh/h) between two alternatives, the one with the lowest mass would be strongly preferred.
In order to illustrate this further, let's consider for instance two systems X and Y with a mass of 25 kg/kWh/h and 30 kg/kWh/h. The preference degree of *X* over *Y* is 0,5 as there is a difference of 5 kg/kWh/h and the criterion is to be minimized. For the Voltage Balancing Function, it has been decided that if the system had the functionality, it was scored to +1 for this criterion and to -1 if not. Two stages of development were here considered: prototype and product. The first one was scored to −1 and the second to +1.
Considering the Volume the alternatives were directly scored via a utility function. Having a volume under 9 m^3 is considered as "very good" and a maximal score (+1) is assigned in such cases. The score slowly decreases when the volume is over 9 m^3. Over 12 m^3 the score then goes down at a faster rate until it reaches the lowest score corresponding to a volume of 18 m^3. The Systems in service worldwide criterion has been evaluated with an increasing linear function going from 0 to 14 systems in service with respective scores of −1 and +1. For the Lifecycle the central threshold is a lifecycle of 20 years with a score of 0,7. An increase of the lifecycle brings a small increase of the score (maximum score of +1 is achieved with a lifecycle expectancy of 30 years).
On the other hand, when the lifecycle goes under 20 years, the score is strongly penalized. It decreases linearly to reach the −1 score for a lifecycle of 10 years. Regarding Noise it has been decided that the noise would be scored to +1 below 70dB and to −1 above 80dB.

Global Visual Analysis
Based on the input parameters explained above, we can now move forward and analyze the results obtained. In the following illustrations, the Reversible Substations, the Flywheels and the supercapacitor are respectively represented by green, purple and blue points. The criteria are represented by the axes. In Fig. 9, the four main categories are displayed. An axis indicates the direction of the most preferred alternatives for the related criterion. If the projection of an alternative goes far on the axis, it means that it is well scored for the criterion. One can observe that the Environment and the Performance axes are close to each other.

Fig. 9 – Global Visual Analysis of the assessed braking technologies

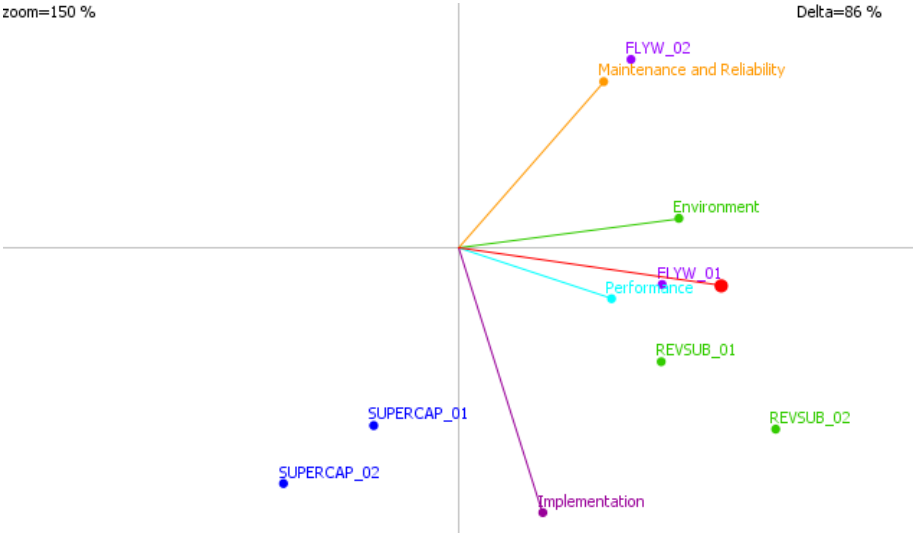
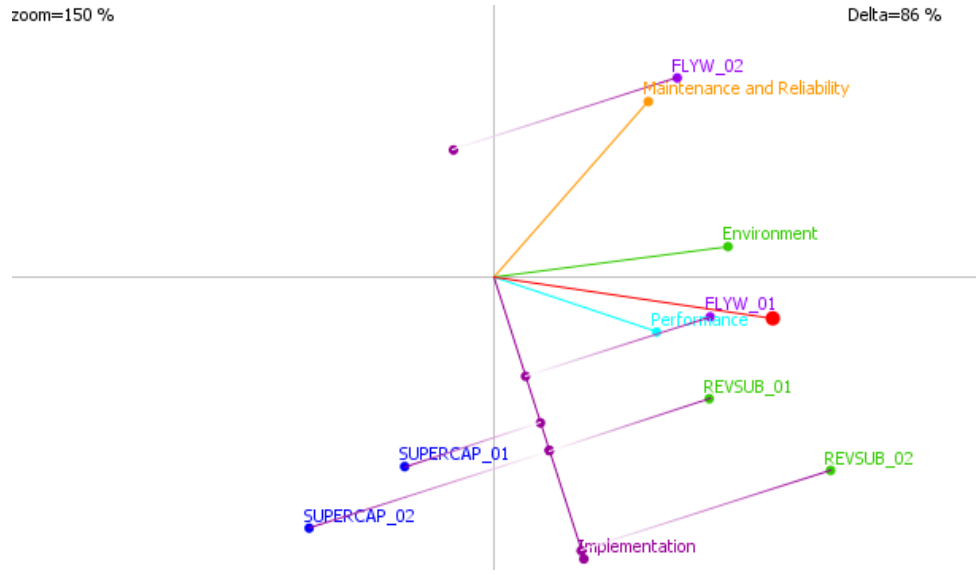


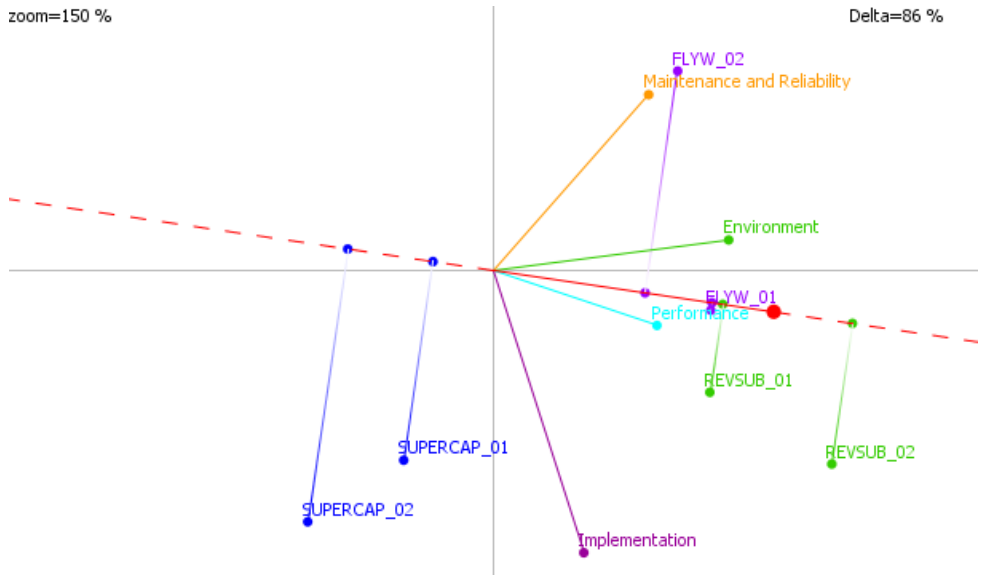
Fig. 10 – Projections of the assessed braking technologies on the Implementation axis



This means that, on average, the systems having good Performance scores also have good Environment scores. They are correlated. On the other hand, the Implementation axis goes

in a quite opposite direction of the Maintenance and Reliability. As we can observe on Fig. 10 (which is similar to Fig. 9 with additional projections on the Implementation axis), the two Supercapacitors are very attractive for the Implementation but not at all for the Maintenance and Reliability while it is the opposite for the Flywheel 2. There are three interesting alternatives. Those are the two Reversible Substations and the Flywheel 1. Indeed, none of them has negative aspects (e.g. have negative projections on the axes). They are especially well scored for the Environment and the Performances.

Fig. 11 – Complete ranking of the assessed alternatives



Ranking

The red axis is called the decision stick. It is computed with the weights given to each criterion. In Fig. 11, it is computed with the weights of the categories. As the main four axes go in the right direction of this plane, it is then logical to find a long red axis pointing to the right part of the plane as well. Projecting the alternatives on it allows us to have a visual representation of the most globally preferred alternatives. Those are the Reversible Substations, followed by the Flywheels, followed by the Supercapacitors. The global scores of the alternatives are also included between +1 and -1, +1 being the best. The ranking is represented in Fig. 12. As observed in the previous figures, the two best systems are the green ones (the reversible substations) with a score of 0,48 for Reversible Substation 02 and 0,33 for Reversible Substation 01. They are followed by the Flywheels systems with a score of 0,33 for Flywheel 01 and 0,08 for Flywheel 02. Table 4, indicates the scores of the alternatives. We can then see that Reversible Substations 01 has a score of 0,332 while Flywheel 01 has a score of 0,326. They stay very close to each other though.

Fig. 12 – Complete ranking of the assessed alternatives

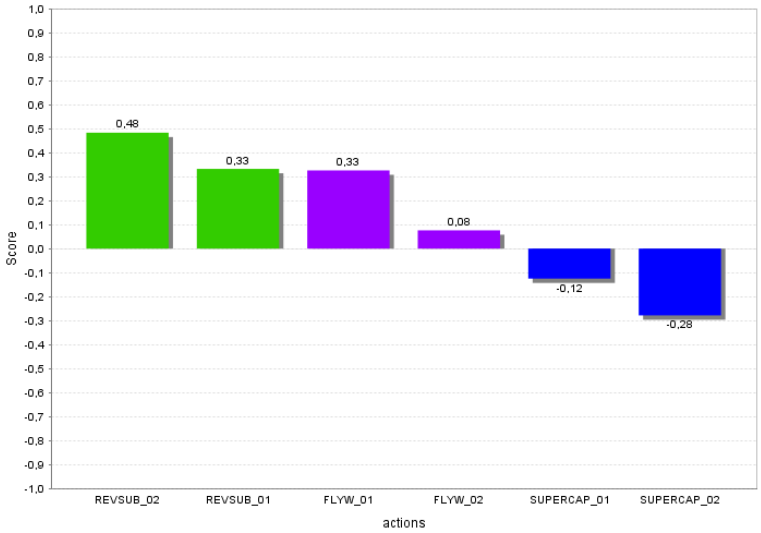


Table 4 – Scores of the assessed alternatives

Alternative	Rank	Score
Reversible Substation REVSUB_02	1	0,483
Reversible Substation REVSUB_01	2	0,332
Flywheel FLYW_01	3	0,326
Flywheel FLYW_02	4	0,076
Supercapacitor SUPERCAP_01	5	-0,125
Supercapacitor SUPERCAP_02	6	-0,278

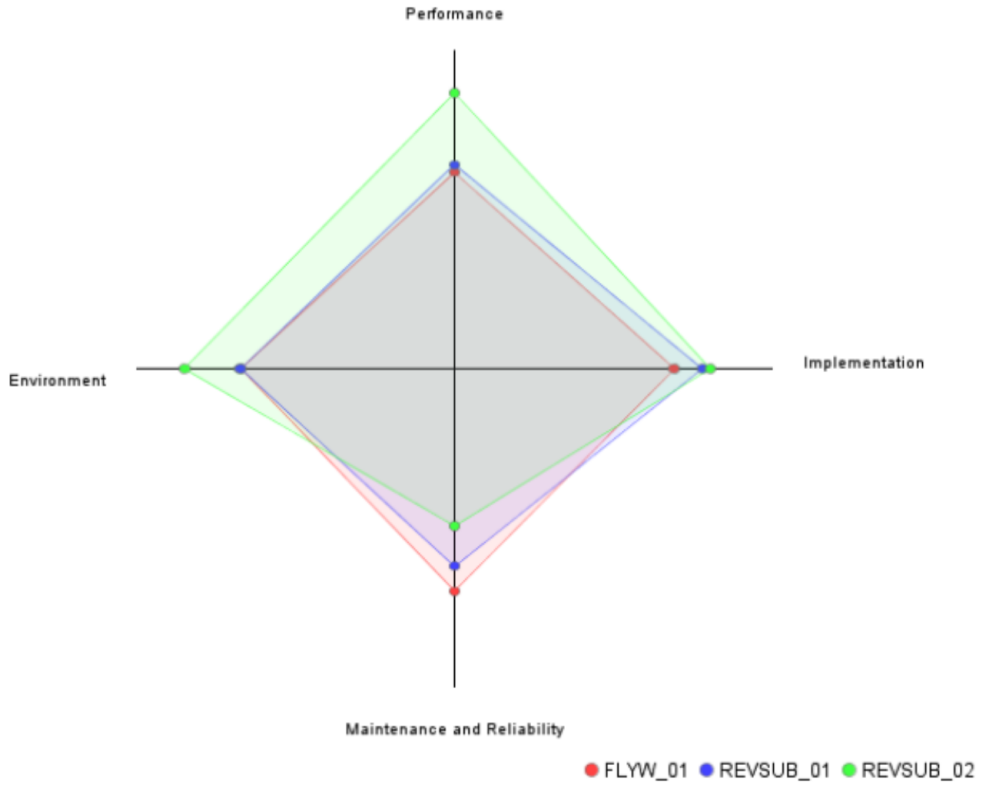
Profiles

It is interesting to compare the profiles of the three best alternatives. In Fig. 13, their scores are represented for the four main categories. Having a point on the extremity on the axis means a score of +1 while having the point on the crossing axes means a score of -1. We can observe that Reversible Substation 02 is the best on Environment, Performance and Implementation with a strong differentiation on the first two. As we have observed in the global visual analysis, it is in between of for the Maintenance and Reliability category.

Looking into this category (Fig. 14), allows us to notice that Reversible Substation 02 is average on all the sub-criteria of this category. For this alternative, there are no extreme scores for any of the sub-criteria: they are all close to 0. This means that the Maintenance and Reliability score of Reversible Substation 02 is almost not sensitive at all to the weights of the sub-criteria from this category. We can also see that Reversible Substation 01 is very

good on the Lifecycle, the MTBM and the MTTR but is not so good on the MTTM and not good at all on the MTBF.

Fig. 13 – Profiles of the three best scoring alternatives for each main category



Step 5: Sensitivity analysis

After obtaining a global ranking, it is important to perform a sensitivity analysis in order to know if Reversible Substation 02 is a robust solution or not. Indeed, as the weights of the criteria have a strong impact in the ranking of the alternatives and therefore, in the decision, we need to know if the same solution would also have been chosen for a slightly different set of weights.

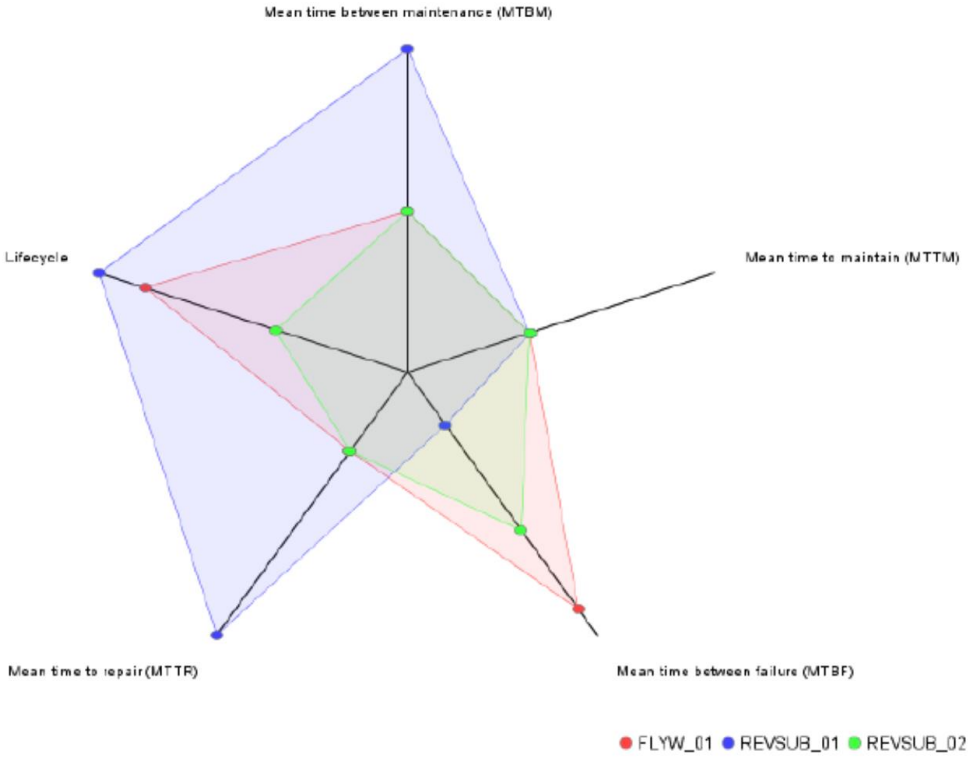
The so-called stability intervals are represented in table 5. They indicate for each criterion or category, in which interval the weight can be changed without affecting the ranking. Two important hypotheses are made here:

1. the results are here presented for the "first level". This means that the interval is computed for the stability of the first rank without taking into account rank reversal between the other ranks. This is of interest if the first alternative loses its top position,

regardless if the second, third, etc. alternatives are shifted around. Let us note that higher levels (e.g. the three first keep they rank) can also be computed;

2. when a weight is changed, the other weights change proportionally to the initial distribution.

Fig. 14 – Profiles of the three best scoring alternatives for Maintenance and Reliability



Tab. 5 – Stability intervals of the main categories

Criteria group	Min weight	Chosen weight	Max weight
Performance	12,3%	40,0%	100,0%
Implementation	0,0%	20,0%	100,0%
Maintenance and Reliability	0,0%	30,0%	49,4%
Environment	0,0%	10,0%	100,0%

We can then observe in table 5, that the result is very robust. Indeed, all the intervals are

very large. The larger is the interval, the slighter is the effect on the PROMETHEE complete classification. The weights on the Implementation and Environment criteria can even be changed from 0% to 100% without affecting the first rank of Reversible Substation 02. Let us emphasize that a complete interval (from 0% to 100%) does not mean that the related criterion does not have a role to play in the analysis.

4. Conclusion

Braking energy recovery technologies have recently become a priority for the industry and most suppliers are investing in R&D in this field. Different technologies are competing on the same segment with no clear leading technology. Each technology has advantages and drawbacks that will depend on each situation and context (Devaux and Tackoen, 2011). The Multi-Criteria Analysis turned out to be an efficient way to compare the different technologies. The MCA method PROMETHEE demonstrated the operationalization side of this assessment tool to aid the public transportation company in analysing the appropriate best compromise technology. Indeed, it allowed evaluating the different options while considering the different aspects that were important to the decision-maker. During this Multi-Criteria Analysis decision support application the following technologies: Supercapacitors, Flywheels and Reversible Substations were assessed according to the four criteria groups: Performance, Implementation, Maintenance and Reliability and Environment.

The Reversible Substation 02 was very attractive regarding the Performance, the Environment and the Implementation. On the other hand, Reversible Substation 01 and Flywheels 01 have obtained better scores for the Maintenance and Reliability. Furthermore, it gave a decisive support to take into account the various points of view of the stakeholders involved in the decision. The aim of this study was to determine which technology would fit best in the Brussels public transportation company network. As we have seen previously, all the solutions have their own strengths and weaknesses. The analysis showed that, the reversible substations were good solutions for the Brussels public transportation company with respect to their own requirements and preferences. Furthermore, the sensitivity analysis that was made reinforces the choice of the reversible substations that have been proven to be robust solutions. This research allowed the Brussels public transportation company to choose the proposed best suiting technology that was the reversible substation.

Acknowledgments

The authors acknowledge the financial support by the Brussels public transportation company. The authors would also like to thank Quantin Hayez from D-Sight for his expedient contributions.

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DISSESTO SUPERFICIALE E GESTIONE AGRICOLA DEL SUOLO: UN'APPLICAZIONE DEI *ROUGH SETS* BASATI SULLA DOMINANZA

Lucia Rocchi, Gianluca Massei, Luisa Paolotti, Antonio Boggia

Sommario

La difesa del territorio dai fenomeni di dissesto idrogeologico è un tema molto sentito e attuale sia a livello nazionale che internazionale. Ogni anno tali fenomeni provocano a livello mondiale enormi danni non solo ambientali ma anche sociali ed economici. L'attività antropica, soprattutto in relazione alla modifica dell'uso del suolo e all'intensificazione dell'agricoltura, è fra i principali fattori che incidono sulla stabilità dei suoli. Per una gestione adeguata del territorio in termini di prevenzione e controllo del dissesto idrogeologico, è fondamentale l'uso di strumenti in grado di conciliare il supporto al decisore pubblico con l'analisi territoriale. Lo scopo del presente lavoro è quello di illustrare l'utilizzo dell'integrazione tra Geographic Information Systems (GIS) e analisi multicriteri (MCDA) per un caso di dissesto superficiale relativo al bacino del Menotre in Umbria, proponendo in particolare il Dominance based Rough Set Approach, sviluppato in GRASS GIS 6.

Parole chiave: dissesto idrogeologico, DRSA, integrazione MCDA-GIS

SOIL INSTABILITY AND AGRICULTURAL MANAGEMENT: AN APPLICATION USING THE DOMINANCE-BASED ROUGH SET APPROACH (DRSA)

Abstract

Land defense from hydrogeological instability is a very important topic, at both national and international level. Every year these phenomena cause huge environmental, social and economic damages. Human activities, especially in relation to land-use change and intensification of agriculture, represent one of the main factors affecting the stability of the soil. For a proper management of territory in terms of prevention and control of hydrogeological instability, to use tools that combine support to public decision-makers with spatial analysis is essential. The purpose of this paper is to illustrate the utility of integrating Geographic Information Systems (GIS) with multicriteria analysis (MCDA) in relation to a case study of the basin Menotre, in Umbria; in particular we propose the use of the Dominance-based Rough Set Approach, developed in GRASS GIS 6.

Keywords: hydrological instability, DRSA, MCDA-GIS integration

1. Introduzione

La difesa del territorio dai fenomeni di dissesto idrogeologico, ovvero «quei processi che vanno dalle erosioni contenute e lente alle forme più consistenti della degradazione superficiale e sottosuperficiale dei versanti, fino alle forme imponenti e gravi di frana» (Commissione De Marchi, 1970, p. 40), è un tema molto sentito e attuale sia a livello nazionale che internazionale. Ogni anno tali fenomeni provocano a livello mondiale enormi danni non solo ambientali ma anche sociali ed economici, sia di tipo diretto che indiretto (Dai *et al.*, 2002). Le perdite economiche e sociali dovute ai fenomeni di dissesto possono essere ridotte solo attraverso la realizzazione di piani di gestione opportunamente realizzati, che cerchino di includere sia azioni preventive che di correzione ed emergenza (Dai *et al.*, 2002). Vista la prospettiva di un aumento di questi fenomeni a causa del perdurare dei fattori esterni di pressione antropica e dell'incremento dei fenomeni estremi, diventa fondamentale per il decisore pubblico agire in modo razionale attraverso una corretta allocazione delle risorse finanziarie e una gestione del possibile rischio (Dai *et al.*, 2002).

In Europa, l'Italia è tra i paesi maggiormente interessati da una varietà di processi naturali di tipo idrogeologico, che hanno generato nel tempo costi elevati sia in termini sociali che economici (Luino, 2005). L'ultimo rapporto del consiglio nazionale dei geologi (2010) mette chiaramente in luce come tali fenomeni in Italia siano diventati un'emergenza (Ciani *et al.* 2013; Mazzette, 2011). Tra le varie regioni italiane, le più colpite sono quelle del centro-nord. L'Umbria è una delle più interessate, essendo la quinta in Italia per densità dei fenomeni franosi (ISPRA, 2011).

Sebbene esistano delle cause naturali legate alla presenza di tali fenomeni, la pressione antropica, soprattutto in termini di modifica delle coperture e dell'uso del suolo, è da considerarsi almeno la principale concausa, con conseguenze spesso rilevanti sulla stabilità dei suoli (Chen *et al.*, 2001; Dai *et al.*, 2002; Fu *et al.*, 2000). Tali cambiamenti sono molto spesso legati ai mutamenti dell'agricoltura e alla sua intensificazione, così come all'aumento della popolazione e alla conseguente urbanizzazione (Chen *et al.*, 2001).

Appropriate pratiche agricole possono, pertanto, essere particolarmente utili per il contrasto del dissesto idrogeologico, soprattutto per quanto riguarda i fenomeni superficiali. Per poter fare ciò, però, è necessario avere una conoscenza approfondita delle realtà e dei territori, al fine di ottimizzare l'intervento. A tale scopo diventa fondamentale l'uso di strumenti in grado di conciliare il supporto al decisore pubblico con l'analisi territoriale. L'integrazione tra i *Geographic Information Systems* (GIS) e la *Multi-Criteria Decision Analysis* (MCDA) trova in tali ambiti un'applicazione naturale (Massei *et al.*, 2014).

Lo scopo del presente lavoro è quello di illustrare l'utilizzo dell'integrazione MCDA-GIS per un caso di dissesto superficiale relativo al bacino del Menotre, in Umbria. In modo particolare si proporrà l'applicazione del *Dominance-based Rough Set Approach* (DRSA) (Greco *et al.*, 2001), utilizzando specifici moduli sviluppati in GRASS GIS 6.4 (Massei *et al.*, 2014). Il contributo è organizzato come segue: dopo una rapida introduzione allo strumento operativo ed al metodo da esso applicato, si passerà ad illustrare il caso studio, per poi terminare con la discussione e le conclusioni.

2. L'integrazione MCDA-GIS

Affrontare problemi decisionali di tipo spaziale implica il dover unire l'approccio MCDA con quello territoriale, solitamente tramite GIS (Malczewski, 2006). Il vantaggio reciproco che i due approcci possono avere è enorme, tanto da essere un *hot topic* della ricerca degli

ultimi vent'anni, soprattutto per quanto riguarda una loro vera e funzionale integrazione (Chakhar e Martel, 2003; Densham, 1991; Jankowski, 1995; Laaribi *et al.*, 1996; Laskar, 2003; Malczewski, 1999, 2006; Massei *et al.*, 2012, 2014; Rahman *et al.*, 2012; Riccioli, 2009). Per poter avere una reale integrazione MCDA-GIS è necessario che, oltre a combinare giudizi di valore con dati geografici, si proceda alla trasformazione ed elaborazione dei dati (Malczewski, 2006).
Secondo alcuni autori (Chakhar e Martel, 2003; Laskar, 2003), l'integrazione MCDA-GIS può essere classificata secondo un sistema di tre livelli. Il primo livello di integrazione è quello dell'integrazione indiretta, in cui i due strumenti non condividono né lo stesso database né l'interfaccia. Per essere connessi, pertanto, è necessario che i due sistemi utilizzino un qualche strumento intermedio. Il secondo livello consiste nei cosiddetti *Built-in* MCDA-GIS: i modelli multicriteriali sono inseriti come componenti integrate nel sistema geografico, pur rimanendo indipendenti sia dal punto di vista logico che funzionale. Questo significa che l'interfaccia è la stessa (quella del software geografico) ma la parte multicriteriale utilizza un proprio database. L'ultimo livello prende il nome di integrazione completa e prevede l'uso di una sola interfaccia ed un unico database. Il contributo maggiore è dato in questo caso dalla possibilità di avere una grande efficienza applicativa, in quanto il modello o i modelli MCDA sono attivati all'interno del software GIS come fossero una delle sue tante funzioni e, pertanto, gli stessi risultati possono essere a loro volta oggetto di ulteriori elaborazioni geografiche. Per poter essere veramente flessibili e complete, inoltre, tali forme di integrazione necessitano anche della possibilità di inserire più strumenti di analisi multicriteriali, così da non limitare la loro capacità applicativa. La presenza di più metodologie permette di scegliere la più pertinente alla questione di ricerca (Massei *et al.*, 2012; 2014).
Nel presente lavoro è stata utilizzata una *suite* denominata *r.mcda* (Massei *et al.*, 2012, 2014) sviluppata dallo stesso gruppo di ricerca precedentemente in GRASS GIS 6.4 (Grass Development team, 2012a, 2012b). GRASS GIS è un avanzato software geografico open source, rilasciato sotto licenza GNU, tra i più utilizzati e diffusi per il data management, l'analisi e l'image processing, la produzione di mappe, la visualizzazione e la creazione di modelli spaziali. GRASS GIS supporta sia dati *raster* che *vector*, in due e tre dimensioni (Neteler e Mitasova, 2008). Grazie al linguaggio in cui è programmato e alla sua licenza *open*, valida anche per le sue librerie, è possibile sviluppare nuovi moduli o migliorare gli esistenti (Neteler e Mitasova, 2008; Frigeri *et al.*, 2011). Questo ha assicurato al programma, già dal suo primo rilascio, un utilizzo crescente sia in ambito accademico che professionale (Frigeri *et al.*, 2011). Nella *suite* sono presenti al momento cinque moduli diversi, ognuno dei quali integra un modello di analisi multicriteriale. I cinque metodi implementati nel sistema geografico sono: il metodo Regime (Hinloopen *et al.*, 1983; Nijkamp e Hinloopen, 1990), l'approccio Fuzzy (Yager, 1977, 1988, 1993), il metodo Electre (Roy, 1991; Vincke, 1992), l'*Analitical Hierarchical Process* (AHP) (Saaty, 1977, 1992) e il *Dominance-based Rough Set Approach* (DRSA) (Greco *et al.*, 2001). La sintassi di ogni modulo segue quella tipica di GRASS GIS ed è la seguente:

r.mcda.[algorithm].

Il prefisso "r" significa che il tipo di dati elaborati sono *raster*, mentre "mcda" è il nome dato al pacchetto; "[algorithm]" deve essere sostituito con il nome del metodo utilizzato. Nel presente lavoro è stato applicato il modulo dedicato ai *rough sets*, con approccio della

dominanza. Per questo, di seguito, viene illustrato tale metodo, tra i più innovativi in ambito multicriteriale.

Prima di descriverlo brevemente, in quanto già ampiamente presentato in letteratura, si vuole riportare la definizione data da Bernard Roy (1996) di analisi multicriteri: «un aiuto nelle decisioni e uno strumento matematico che permette la comparazione di differenti alternative o scenari rispetto a numerosi criteri, spesso contraddittori, in modo da poter guidare il decisore (i decisori) verso scelte giudiziose» (p. 10).

Un tipico problema multicriteriale si compone, perciò, di un *set* di *m* alternative $\{x_1, x_2, .. x_m\}$ che viene valutato attraverso un vettore di *n* criteri, spesso in conflitto tra loro. Il Decisore (*Decision Maker*-DM) esprime delle preferenze che vengono rappresentate da un vettore di pesi non negativi $w=[w_1,w_2,\ldots w_n]$, definiti in modo che la somma sia normalizzata a 1. La risoluzione del problema comporta l'attuazione di una scelta, una classificazione o un ranking delle alternative. Le modalità con cui viene fatto ciò dipendono dal metodo applicato. Quando si parla di multicriteri, infatti, ci si riferisce ad una famiglia di metodi con caratteristiche computazionali, però, molto varie (Figueira *et al.*, 2005) che si concretizzano poi in modalità di aggregazione differenti (Chakhar e Martel, 2003).

Rispetto agli altri metodi MCDA, il DRSA non presenta la necessità di esplicitare le preferenze del DM tramite pesi, elemento che è considerato il principale punto debole delle metodologie multicriteri. Nel DRSA si prevede che degli esperti valutino situazioni reali (o simulate se non possibile altrimenti) e che ogni criterio considerato sia semplicemente classificato come costo o beneficio, rispetto al problema oggetto di analisi (Greco *et al.*, 2001). Rispetto all'approccio originale dei *rough sets*, che non considera proprietà ordinali dell'insieme dei valori assunti dagli attributi, il DRSA per prendere in considerazione le preferenze del decisore, utilizza relazioni di dominanza invece che di indiscernibilità (Greco *et al.*, 2001). Il DRSA permette di identificare delle "regole", a partire da un caso esemplare, nella forma di frasi del tipo "se…, allora…" (Greco *et al.*, 2001), il che lo rende molto semplice ed intuitivo per il DM, nonostante sia basato su teorie matematiche molto complesse. Tre sono le tipologie di regole producibili dal DRSA: certe, possibili ed ambigue. Ogni regola decisionale deve essere essenziale, cioè non contenere elementi di ridondanza (Greco *et al.*, 2001).

L'applicazione della teoria dei *rough set* basata sulla dominanza al processo decisionale è basata su due fasi fondamentali:

1. fase di estrazione delle regole decisionali da un contesto noto;
2. fase di applicazione delle stesse regole ad un contesto non noto.

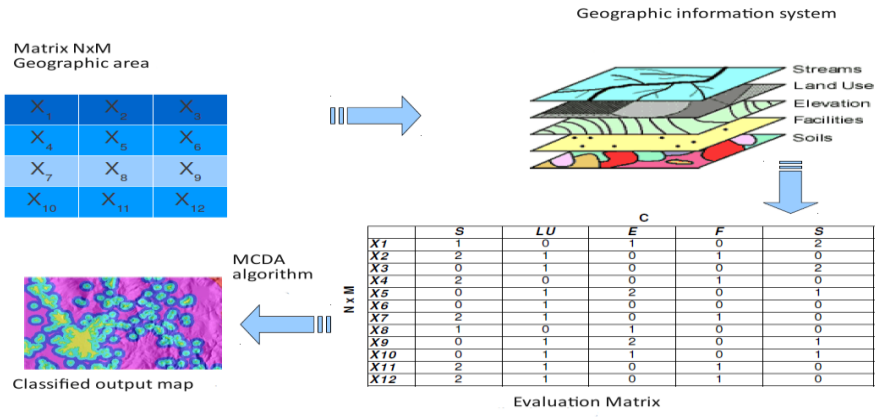
La fase di estrazione delle regole non presuppone necessariamente che tutti i criteri scelti vadano effettivamente a comporre delle regole. Questo perché può esserci l'evenienza di un criterio che il decisore ipotizza possa avere un qualche ruolo nella definizione di un fenomeno ma che poi, in realtà, non contribuisce alla formazione di alcuna regola. Questo si lega all'inquadramento originario dei *rough set* classici nell'ambito della *knowledge discovery*. La loro variante basata sul principio della dominanza, in sostituzione di quello della indiscernibilità, non muta questa loro originaria caratteristica. In concreto, è possibile che per studiare un fenomeno e per estrarne le regole si utilizzino criteri in apparente sovrabbondanza. Se così fosse, la conseguenza sarà che tali criteri non compariranno nelle regole decisionali e, quindi, non verranno utilizzati nella fase di classificazione. Si preferisce dunque non ridurre i criteri in partenza, per non ridurre le informazioni trattate dall'algoritmo. Se queste non hanno un ruolo nel processo decisionale, allora non

compariranno nelle relative regole decisionali con un livello adeguato di significatività oppure verranno "coperte" da regole più generali che emergeranno per il principio della "minimalità", che è una proprietà posseduta dall'algoritmo dei DRSA denominato DOMLEM (Greco *et al.*, 2000) applicato in questo lavoro, e che tra i tanti possibili è il più utilizzato ed applicato, nonché il migliore nel caso di grandi database, come quelli geografici. La proprietà della "minimalità" assicura, appunto, l'assenza di ridondanza nelle regole.

Il modulo r.mcda.roughset implementa per la prima volta il *Dominance-based Rough Set Approach* (DRSA) (Greco *et al.*, 2001; Mac Parthalain e Shen, 2010) in ambito geografico. Tutti i software finora sviluppati ai fini applicativi dall'Università di Poznan (si veda https://idss.cs.put.poznan.pl/site/software.html), infatti, non permettono la gestione dei dati geografici. L'implementazione del DRSA è possibile con diversi algoritmi, ma al momento il più usato e conosciuto è il DOMLEM (Greco *et al.*, 2000) e, pertanto, esso è stato utilizzato anche nel modulo r.mcda.roughset. Tale algoritmo garantisce una maggiore accuratezza rispetto ad altri sviluppati di recente, soprattutto nel caso di grandi database, il che lo fa sembrare particolarmente adatto alle applicazioni in ambito geografico (Massei *et al.*, 2014; Zurawski, 2001).

Nel modulo le regole decisionali vengono derivate dalla mappa *raster* che include la chiave tematica essenziale per le analisi, denominata *decision map*. La *decision map* è la mappa che rende possibile la fase di estrazione delle regole in un contesto noto. Anche i criteri sono rappresentati da mappe *raster*. In Grass Gis la regione di indagine, nel caso di mappe *raster*, è costituita da singole celle. Le alternative sono rappresentante proprio dalle singole celle che costituiscono la regione indagata in Grass GIS, e vengono descritte dai valori delle mappe (criteri). Per ogni cella, quindi, saranno presenti una serie di valori, ognuno descrittore del criterio *n* per l'alternativa *m.* La combinazione dei criteri dipende dal metodo, e quindi dall'algoritmo implementato, ma a livello generale vale quanto riportato dalla Fig. 1, che mostra il processo di integrazione perfetta tra la fase geografica e quella multicriteriale in un'analisi MCDA spaziale.

Fig. 1 – Il processo di integrazione MCDA- GIS



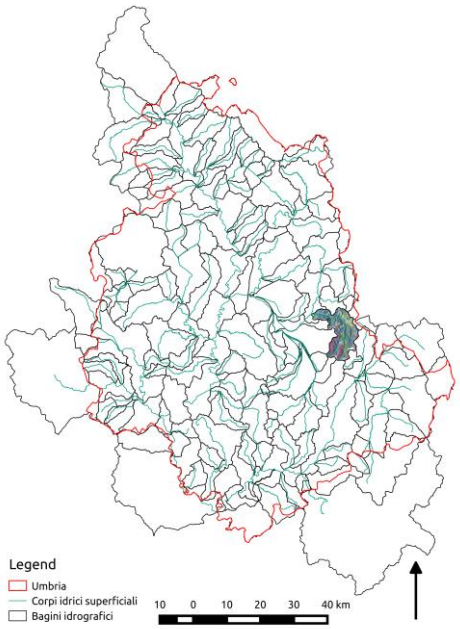
	S	LU	E	F	S
X1	1	0	1	0	2
X2	2	1	0	1	0
X3	0	1	0	0	2
X4	2	0	0	1	0
X5	0	1	2	0	1
X6	0	1	0	0	0
X7	2	1	0	1	0
X8	1	0	1	0	0
X9	0	1	2	0	1
X10	0	1	1	0	1
X11	2	1	0	1	0
X12	2	1	0	1	0

A partire dagli *input* il modulo r.mcda.roughset produce due tipologie di *output*. La prima tipologia consiste nelle mappe *raster*, che possono essere una per ogni classe identificata, oppure un'unica di sintesi. Accanto all'*output* grafico ne viene prodotto uno testuale, che permette un'analisi più approfondita, riportante le regole che sono state generate, nonché l'interconnessione con i software non geografici che applicano il DRSA, così da poter avere ulteriori elaborazioni basate, ad esempio, su algoritmi non implementati dal modulo geografico.

3. Il caso studio

Il caso studio analizzato nel presente lavoro riguarda l'area del bacino imbrifero del Menotre (Umbria) (Fig. 2). Il Menotre è un fiume di alta collina, che scorre nel territorio del comprensorio montano del folignate. La sorgente è posta a circa 800 metri sul livello del mare (m slm), nei pressi della frazione del comune di Sellano denominata Orsano e del monte Mareggia.

Fig. 2 – Inquadramento dell'area di studio



Il fiume sfocia nel Topino, a sua volta affluente di seconda del Tevere, nei pressi di Scanzano. Il tratto superiore del fiume, compreso tra i Molini e Leggiana, è un Sito di Interesse Comunitario (SIC IT5210041). In questo tratto del fiume è presente una fitta e rigogliosa vegetazione idrolitica sommersa che ricopre il letto fluviale quasi del tutto. Sulle sponde, molto strette, sono presenti numerose specie ripariali igrofile a tratti, in prevalenza salici (*Salix spp*.) e il Pioppo cipressino (*Populus nigra var. italica*).

Il bacino fluviale si estende per una superficie di circa 113 Km. L'altitudine varia tra 257 e 1419 m slm, per un'altezza media di circa 862 m slm. Anche per la presenza del SIC, la zona di monte del bacino si caratterizza per avere una destinazione dell'uso del suolo per lo più naturale o agricola, mentre la zona centrale, di valle, è quasi completamente urbanizzata. Il bacino è ampiamente interessato da instabilità di vario tipo, non uniformi all'interno del bacino stesso a causa delle diverse caratteristiche geologiche del terreno, e da una varietà di usi, e conseguentemente di coperture del suolo, nonché di diversi tipi di attività agricole (Fig. 3). Tra i fenomeni più presenti nell'area vi sono quelli di dissesto superficiale. Tale tipologia di fenomeno ha la caratteristica di essere la più facilmente controllabile e circoscrivibile attraverso interventi mirati di tipo agricolo-coltivazionale. Pertanto, l'obiettivo del lavoro è quello di identificare le aree con maggiore probabilità di accadimento di fenomeni di dissesto superficiale, in cui andare ad incentivare buone pratiche agronomiche, idonee al contenimento del fenomeno. Il concetto utilizzato in questo studio è pertanto quella della "pericolosità ambientale" che, come da indicazione ISPRA (2011), include anche le interazioni tra fattori antropici e naturali, essendo il confine tra i due non distinguibile in molte situazioni. Per effettuare l'analisi sono stati utilizzati i seguenti criteri:

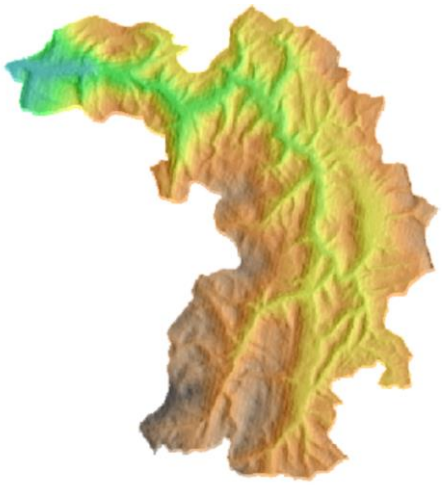
- la propensione al dissesto: misura la tendenza all'instabilità; è stata considerata un "guadagno", nel senso che maggiore è la propensione, più alto sarà il livello di pericolosità ambientale (Tyoda, 2013);
- il *Normalized Difference Vegetation Index* (NDVI): misura la produttività della vegetazione ed è un costo, perché maggiore è la vegetazione minore è la pericolosità ambientale in termini di dissesto (ISPRA, 2013; Karaburun, 2010, van der Knijff *et al.*, 1999);
- la pendenza (van der Knijff *et al.*, 1999), anche in questo caso è un guadagno;
- il fattore LS, fa riferimento all'equazione universale dell'erosione del suolo. In particolare rappresenta il prodotto di due fattori, la lunghezza e la pendenza, entrambi adimensionali (Tyoda, 2013);
- l'uso del suolo, classificato secondo il *Corinne Land Cover* 2006. Ad ogni classe di uso di suolo è stato attribuito un valore decrescente di naturalità e, quindi, crescente in termini di azione di modifica del territorio da parte dell'uomo (Minciardi e Gargini, 2003). Anche in questo caso il criterio assume un valore di guadagno (Fig. 4).

Entrando di più nel merito dei criteri scelti, è utile soffermarsi in particolare su alcuni aspetti. Ad una prima lettura potrebbe apparire esista un *double counting* tra NDVI e uso del suolo. Tuttavia si è deciso ugualmente di inserirli entrambi per due motivi. Il primo è che l'approccio consentito dai DRSA nell'estrazione delle regole non è assolutamente di tipo deterministico: è il modello a selezionare i criteri tra quelli utilizzati nell'analisi, scegliendo quelli che meglio descrivono il fenomeno osservato nella realtà.

Una volta estratte le regole, è la fase di classificazione/ordinamento ad essere fortemente deterministica. Il secondo è legato al tipo di descrizione dato dai due indici. L'indice NDVI è stato scelto perché è correlato al vigore della vegetazione, tanto da essere spesso detto anche indice di produttività vegetazionale. È, quindi, correlato alla funzione, ancorché controversa, che la vegetazione svolge nei fenomeni di dissesto superficiale e nell'azione di preservazione del suolo dall'erosione superficiale (Ispra, 2013; Tyoda, 2013; van der Knijff *et al.*, 1999). Sull'effetto della vegetazione sui fenomeni di dissesto, si trovano varie analisi che ne dimostrano l'efficacia, quali quelle riportate in ISPRA (2013), che dedica un'intera

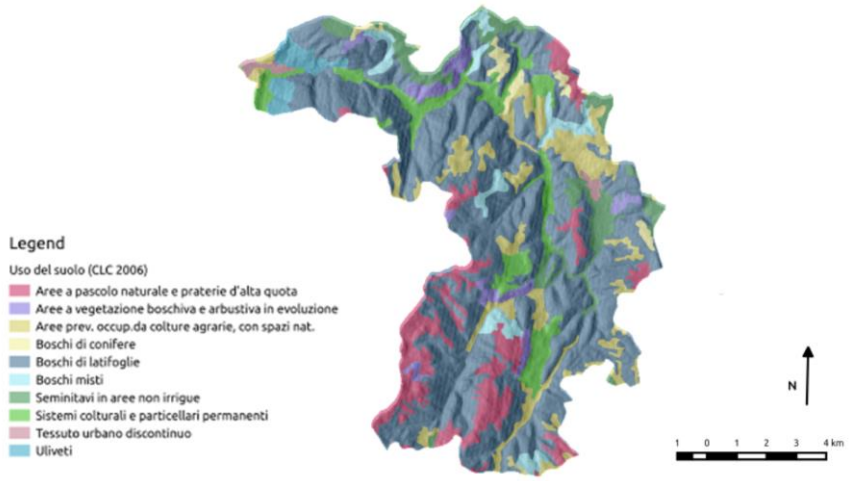
scheda di approfondimento alla tematica (pag. 79), o quelle riportate ampiamente da Tyoda (2013) che riporta una breve analisi delle valutazioni e della letteratura relativamente al ruolo della vegetazione e, successivamente, all'importanza dell'NDVI nel controllo dei fenomeni di dissesto.

Fig. 3 – Modello digitale del terreno del bacino idrografico



Fonte:www.sinanet.isprambiente.it

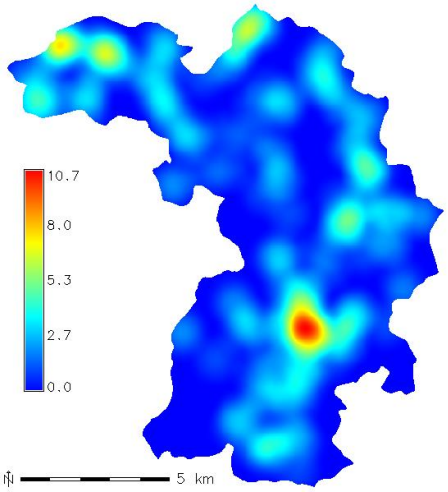
Fig. 4 – Uso del suolo *(nostra elaborazione)*



Per quanto riguarda la naturalità, si potrebbe osservare che poteva essere sostituita dall'uso del suolo riportato dal *Corine Land Cover* tal quale. Si è preferito però introdurre l'uso del suolo secondo la metodologia riportata da Minciardi e Gargini (2003) per indagare la funzione svolta nei fenomeni di dissesto superficiale secondo un "assioma" per il quale un'area non disturbata da interventi dell'uomo è di norma meno suscettibile ad eventi di dissesto. Da notare che, di nuovo, qualora tale ipotesi non fosse verificata dall'elaborazione con il modello dei DRSA si avrebbe, ancora una volta, l'assenza di regole decisionali contenenti come criterio il livello di naturalità connesso all'uso del suolo CLC. Vista la dimensione del bacino, i parametri climatici sono stati assunti come costanti e, quindi, ininfluenti ai fini dell'analisi multicriteri.

Dal momento che il concetto di pericolosità ha anche una dimensione temporale (ISPRA, 2011), come mappa delle decisioni, su cui poi costruire le regole, è stata utilizzata la mappa riportante i fenomeni di dissesto superficiale derivata dalla distribuzione spaziale delle aree inserite nel catalogo delle frane, disponibile come servizio WFS nel Portale Cartografico Nazionale del Ministero dell'Ambiente e della Tutela del Territorio e del Mare. Utilizzando tale database geografico, è stato possibile costruire una mappa *raster* in grado di rappresentare il numero di dissesti superficiali nell'area di studio (Fig. 5).

Fig. 5 – Distribuzione spaziale dei movimenti franosi superficiali *(nostra elaborazione)*



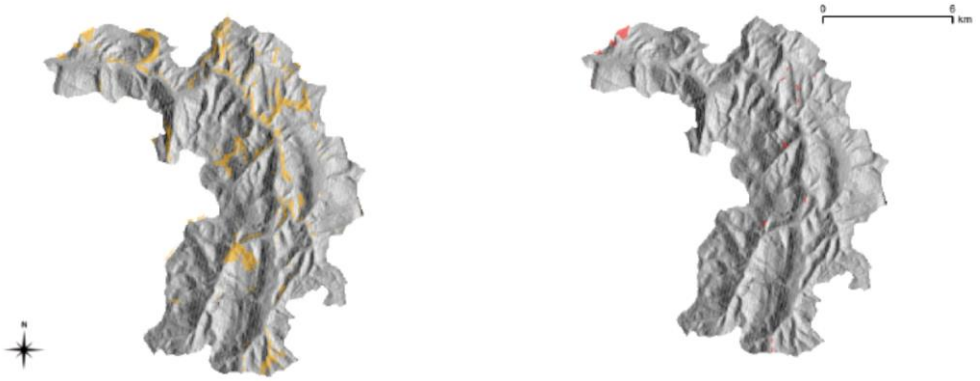
Fonte: Portale Cartografico Nazionale, servizio WFS

4. Risultati e discussione

L'applicazione del modulo r.mcda.roughset ha prodotto due tipologie di output: la mappa della pericolosità, e la lista di tutte le regole certe su cui essa è stata creata. In questo caso specifico sono state prodotte le mappe relative alle aree classificate "almeno" in una certa classe, e quelle classificate "al massimo" in una determinata classe. Va ricordato che la

parte superiore e centrale del bacino è un SIC/ZSC e, pertanto, soggetto a norme di conservazione che disciplinano i possibili interventi, tra cui quelli agricoli (Fig. 6).
In generale, il territorio analizzato presenta una certa diversità in termini di pericolosità. In modo particolare una discreta parte dell'area è nelle prime classi di pericolosità, mentre nessuna parte di essa è nella classe zero, cioè nessun livello di pericolosità. Le aree classificate come più soggette, invece, sono piuttosto concentrate e non molto estese.

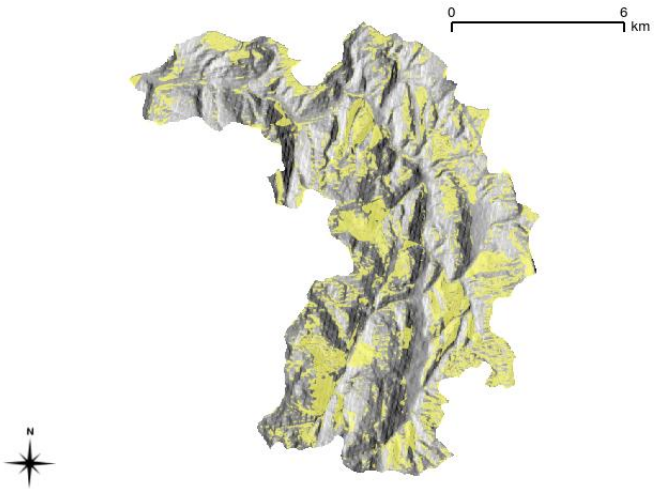
Fig. 6 – Confronto tra le classi di pericolosità "Almeno 2" (sinistra) e "Almeno 7" (destra)



La significatività delle regole non è uniforme per tutte le classi. Ad esempio, le aree appartenenti a classi di pericolosità elevata ma qualificate come "al massimo", hanno una estensione areale molto alta che le rendono difficilmente utilizzabili in ambito decisionale (Fig. 7). Le aree classificate come "almeno", invece, danno indicazioni più importanti ed estremamente puntuali per orientare le scelte del decisore proprio nelle aree di rischio più alto. Infatti, identificare in un territorio le aree che sono "almeno" in una classe di pericolosità elevata (ad esempio, classe 7) consente di orientare in modo efficace gli interventi pubblici di tipo puntuale. Classi di pericolosità più basse, invece, danno indicazioni areali meno puntuali e più estese, ma proprio per questo si prestano ad essere utilizzate per indicazioni gestionali di portata più vasta, proprie degli interventi richiesti alle imprese agricole, a tutela del territorio dalle stesse occupato e utilizzato.
In altri termini, la mappa relativa ad esempio alla classe di pericolosità "almeno in classe 2" non identifica aree puntuali su cui è necessario intervenire con opere ingegneristiche, ma delimita superfici estese dove gli agricoltori dovranno adottare particolari misure di gestione territoriale per evitare un'evoluzione negativa del contesto ambientale dal punto di vista geomorfologico. Il decisore pubblico potrà così modulare le scelte e le risorse in funzione della classe decisionale derivante dall'applicazione del modello geografico oggetto di studio.
Non è stata prodotta la mappa unica del territorio, quella contenente tutte le classi, così come derivanti dall'*overlay* delle diverse classificazioni "almeno" e "al massimo".

La scelta è stata legata alla maggiore chiarezza di analisi data dalle singole classi separate, che permettono un dettaglio decisamente maggiore rispetto all'uso di una classe unica, che tende a coprire parte dei risultati.

Fig. 7 – Mappa relativa al la classe "Al massimo 2"



Nella Fig. 8 sono, invece, riportate alcune delle regole minime prodotte dall'algoritmo. Per ognuna di esse è stato riportato il supporto, cioè il numero di esempi coperti dalla singola regola e la *Relative Strengh*, cioè quanto è forte e stabile la regola.

Fig. 8 – Alcune regole prodotte dall'algoritmo

ID		Condizione		Condizione		Condizione		Condizione		Classe	Supporto	Relative strengh
1		NDVI>=0.536500								at most 0	2	33.33%
2		NDVI>=0.484800		LS<=104.768578		prop_dissesto<=1.000000				at most 0	2	33.33%
3		(slope_class@menotre<=1.000000)		NDVI>=0.444000						at most 0	2	33.33%
5	IF	NDVI>=0.444000	&	Pendenza<=1.00000	&		&		THEN	at most 1	5	19.23%
6		NDVI>=0.436900		LS<=26.192144						at most 1	10	38.46%
22		CLC<=3112.000000		LS<=111.123863		NDVI>=0.180100				at most 3	56	52.83%
23		LS<=152.659012		NDVI>=0.370900		LS<=78.576431		prop_dissesto<=1.000000		at most 4	55	42.31%
24		CLC<=3112.000000		NDVI>=0.180100		LS<=678.36220		prop_dissesto<=4.000000		at most 4	110	84.62%

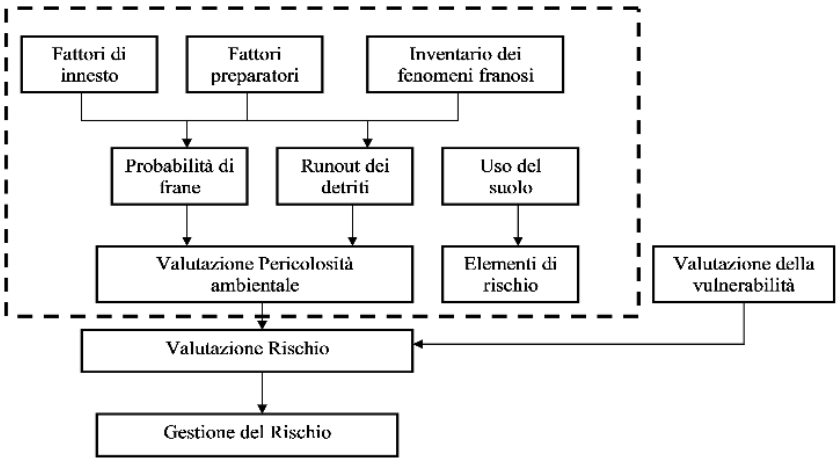
Come si può notare, le regole hanno una grande variabilità tra loro, sia in termini di criteri usati che di numero di condizioni riportate. La lettura delle regole si svolge come di seguito spiegato. Ad esempio, la regola n. 5 ci dice che se l'indicatore NDVI è superiore o uguale a 0.444000 e, contemporaneamente, la pendenza è inferiore alla classe 1, allora quella alternativa è classificabile al massimo in classe 1. La regola è supportata da solo 5 esempi ed ha una forza del 19.23%. A prescindere dalle ultime due indicazioni, più utili forse ad un analista che ad un DM, le altre sono da esso immediatamente comprensibili. Non solo: è

possibile intervenire, se lo si ritiene opportuno, al vaglio delle regole da parte di panel di esperti per valutarne effettivamente la significatività.
Le regole estratte danno indicazioni importati per la definizione delle strategie. Strategie che saranno per tanto basate su una classificazione di pericolosità e che potranno essere realizzate in zone piuttosto limitate, oppure in aree più estese, a seconda del reale uso del suolo e della proprietà dei terreni.
Vista la finalità della presente analisi, volta a studiare la pericolosità rispetto al dissesto superficiale, quello più facilmente controllabile con interventi di tipo agricolo e spesso meno studiato perché meno grave di quello profondo, un primo prodotto concreto potrebbero essere piani di tipo gestionale o piani in cui stabilire colture e interventi prioritari da realizzare in quelle aree specifiche, magari programmando anche un supporto per la loro realizzazione nell'ambito degli strumenti del nuovo periodo di programmazione comunitaria 2014-2020. Purtroppo, il *greening* propone interventi veramente minimi rispetto alle possibilità e agli orizzonti ipotizzati inizialmente ma, allo stesso tempo, attraverso un'identificazione intelligente delle aree di interesse ecologico oppure la definizioni di pratiche equivalenti nei Programmi di Sviluppo Rurale efficaci in tale direzione, è possibile creare le condizioni opportune per una vera azione di controllo.

5. Conclusioni

L'utilizzo dei metodi multicriterali è di grande supporto nell'ambito delle decisioni pubbliche. L'integrazione con i software geografici potenzia e amplifica la loro utilità.
Il lavoro presentato permette di valutare l'utilità e le potenzialità del DRSA nell'ambito della valutazione della pericolosità ambientale rispetto al dissesto superficiale. Tale metodologia MCDA in ambito geografico permette di avere una conoscenza approfondita del territorio, così da avere una classificazione spinta dello stesso.

Fig. 9 – Quadro per la valutazione del rischio l'area tratteggiata indica i confini della ricerca



Fonte: elaborazione dello schema di Dai et al. (2002)

Il doppio uso delle classi "almeno" e "al massimo" consente di avere a disposizione due approcci diversi. Uno più puntuale e uno più esteso, entrambi molto utili per determinare le aree in cui andare ad intervenire dal punto di vista delle politiche gestionali, tramite la definizione di zone prioritarie per interventi specifici in campo agricolo.
Il modulo utilizzato consente di ottenere una classificazione in base alle sole regole certe, che permette una buona affidabilità dei dati e della classificazione ottenuta. In ambito geografico la presenza di regole certe è più affidabile e preferibile, per evitare di avere un eccesso di informazioni che, invece di essere parlanti, diventerebbero di difficile interpretazione.
Il presente lavoro, come già inquadrato inizialmente, si ferma alla stima della pericolosità. La definizione della vulnerabilità e del rischio sono futuri *step* della ricerca. Benché questa prima fase possa già essere utilizzata per valutare, ad esempio, in quale aree concentrare alcuni incentivi e misure dei nuovi Programmi di Sviluppo Rurale al fine di migliorare la gestione superficiale del terreno, è solo con il completamento del quadro di analisi (Fig. 9) che si potrà arrivare a delle misure per una gestione completa e globale dell'area di studio.

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LA VALUTAZIONE PER LA VALORIZZAZIONE DEL PAESAGGIO STORICO URBANO: UNA PROPOSTA PER IL SITO UNESCO DELLA "COSTA D'AMALFI"

Marianna D'Angiolo, Pasquale De Toro

Sommario

Il presenta articolo prende spunto dalla proposta dell'UNESCO del 2011 di Valutazione di Impatto sul Patrimonio (Heritage Impact Assessment – HIA) proponendo un approccio multicriterio alla valutazione di cinque possibili scenari di intervento, tra loro alternativi, per il sito UNESCO Costa d'Amalfi. La definizione degli scenari è stata effettuata a partire dalla pianificazione sovraordinata e dalla programmazione vigente, nonché sulla base di un'analisi SWOT. La valutazione multicriterio, elaborata con riferimento a specifici obiettivi e criteri, ha consentito di dedurre una graduatoria di preferibilità tra gli scenari proposti, in particolare applicando il metodo Regime e conducendo anche una analisi di sensitività dei risultati ottenuti.

Parole chiave: Paesaggio Storico Urbano, Valutazione di Impatto sul Patrimonio, metodo multicriterio Regime

EVALUATION FOR HISTORIC URBAN LANDSCAPE VALORIZATION: A PROPOSAL FOR UNESCO "AMALFI COAST" SITE

Abstract

The UNESCO proposal (2011) of Heritage Impact Assessment (HIA) gave the cue to this article, where a multi-criteria approach to the evaluation of five possible alternative scenarios of intervention for the UNESCO site "Amalfi Coast" is applied. The definition of the scenarios derives from the higher-level planning in force, as well as from a SWOT analysis. The multi-criteria evaluation, carried out with reference to specific goals and criteria, allowed us to deduce a ranking among the scenarios proposed, in particular by applying the Regime method; a sensitivity analysis on the results was also developed.

Keywords: Historic Urban Landscape, Heritage Impact Assessment, Regime multicritera method

1. Introduzione

La *Convenzione Europea del Paesaggio* (Firenze, 2000) amplia i limiti del paesaggio verso il territorio complessivamente considerato e sollecita ad estendere l'attenzione a tutte le tipologie di paesaggio, il quale non può essere considerato la risultante della somma dei beni culturali ed ambientali esistenti, bensì un patrimonio che coinvolge in modo relazionale il territorio e che richiede strategie di intervento integrate e condivise.

La *Convenzione* propone una concezione innovativa di paesaggio relativamente a diversi aspetti correlati fra loro: una "visione dinamica" del paesaggio, sia per dimensione spaziale che temporale (manifestazione della sua complessità multidimensionale), il "significato progettuale" ed i relativi obiettivi di qualità paesaggistica, il "significato sociale" attraverso l'esplicito riferimento all'idea di una percezione sociale del paesaggio.

Il successivo *Codice dei beni culturali e del paesaggio* (D.Lgs. n. 42/2004), pur recependo la *Convenzione*, lascia trasparire ancora una concezione sostanzialmente monumentalistica del paesaggio, che tende ad enucleare dal loro contesto quei beni culturali a cui si applicano i dispositivi della tutela, non dimostrando particolare attenzione circa l'attribuzione partecipata dei valori da parte delle comunità interessate al paesaggio ed alle relative trasformazioni.

Di conseguenza l'idea del rapporto tra tutela e valorizzazione è diverso tra *Codice* e *Convenzione*. Il primo affida la tutela allo Stato centrale e la valorizzazione alle Regioni, cosicché la scomposizione dei poteri della tutela e della valorizzazione sembra contraddire il principio di unitarietà del paesaggio, affermato invece in sede comunitaria.

La *Convenzione Europea del Paesaggio*, in quanto elemento di politica territoriale, è considerata il complemento di strumenti normativi internazionali, quali la Convenzione dell'UNESCO sulla *Protezione del patrimonio mondiale, culturale e naturale dell'umanità* (Parigi, 1972). Successivamente l'UNESCO ha introdotto la categoria del Paesaggio Storico Urbano (*Historic Urban Landscape – HUL*), che rappresenta una componente essenziale nell'ambito di un processo di progressivo allargamento del concetto di paesaggio (*Recommendation on the Historic Urban Landscape*, 2011).

Il Paesaggio Storico Urbano si riferisce all'area urbana intesa come risultato di una stratificazione storica di valori e caratteri culturali e naturali che vanno al di là della nozione di "centro storico", sino a includere il più ampio contesto urbano e la sua posizione geografica. Questo contesto più ampio include, in particolare, la topografia, la geomorfologia, l'idrologia e le caratteristiche naturali del sito; il suo ambiente costruito, sia storico che contemporaneo; le sue infrastrutture sopra e sotto terra; i suoi spazi aperti e giardini, i suoi modelli di utilizzo del suolo ed l'organizzazione spaziale; percezioni e relazioni visive, così come tutti gli altri elementi della struttura urbana. Esso include anche le pratiche ed i valori sociali e culturali, i processi economici e le dimensioni intangibili del patrimonio così come collegate a diversità ed identità.

Inoltre, l'UNESCO adotta la strategia del paesaggio come approccio globale per effettuare una continua e dinamica ri-valutazione dimensionale e concettuale del patrimonio iscritto alla World Heritage List (WHL).

Nello specifico l'UNESCO definisce il sito della Costa d'Amalfi (iscritto alla WHL, Fig. 1) come "paesaggio culturale vivente o evolutivo", in quanto paesaggio che conserva un ruolo sociale attivo nella società contemporanea, strettamente associato ad un modo di vita tradizionale e nel quale il processo evolutivo continua nel tempo.

Fig. 1 – Veduta della costiera amalfitana

Foto di Anna Acampora

In virtù di tale processo evolutivo, il Piano di Gestione del sito risulta avere valenza di strumento di sviluppo, per predisporre nuove e vantaggiose possibilità di valorizzazione territoriale su più livelli ed in più direzioni. Il Piano di Gestione, in quanto strumento strategico, seleziona gli obiettivi di breve e lungo periodo, e le modalità per perseguirli, mentre in quanto strumento operativo definisce un sistema di azioni da attuare per uno sviluppo locale sostenibile.
In definitiva, è possibile affermare che il Piano di Gestione dovrebbe essere uno strumento "diagonale" tra le prescrizioni dei piani cui si raccorda e la sua natura fortemente informale, legata alle costruzioni di "visioni" e partecipativa tipica dei piani strategici (D'Auria, 2005; Ceretto Casigliano *et al*., 2002).
Rispetto alla dimensione operativa del Piano di Gestione è necessaria l'individuazione di strategie praticabili; pertanto, le strategie risulteranno fattibili o attuabili in proporzione a quanto i progetti del Piano di Gestione tenderanno a realizzare quella ipotesi di "scenario" del sito, verso cui sono protesi gli attori sociali ed istituzionali del sistema locale.
Infatti, il Piano di Gestione specifica che una delle precise finalità del progetto della conoscenza, ovvero il primo dei cinque livelli progettuali in cui si articola il Piano stesso, è quella di identificare potenzialità, ovvero di rappresentare "scenari". Essi rappresentano una

prefigurazione dell'immediato futuro, l'analisi del potenziale che permette di individuare i problemi da risolvere, le attività da sostenere, gli elementi detrattori da controllare, e soprattutto gli obiettivi che è possibile raggiungere nel medio-lungo periodo.
Il Piano di Gestione di un sito UNESCO, in quanto finalizzato a preordinare un sistema di sviluppo sulla base dei valori che hanno motivato l'iscrizione alla WHL, perviene ad un'analisi integrata dello stato dei luoghi individuandone le forze di modificazione in atto, ovvero rappresentando lo scenario esistente.
Il Piano di Gestione ha, inoltre, la funzione di "valutare" gli scenari futuri che vengono raggiunti tramite determinati progetti ed i relativi obiettivi, di cui vengono individuati gli impatti probabili sul sistema locale, affinché si scelgano i progetti strategici e le rispettive priorità per conseguire i traguardi prefissati.
Nella prospettiva di costruzione e valutazione di possibili scenari di sviluppo emerge la necessità di un approccio "multicriterio", in grado di considerare l'integrazione tra le diverse dimensioni che coesistono nel paesaggio locale e che consentono di interpretare le tendenze in atto e, nello stesso tempo, di dialogare con gli attori coinvolti.
L'approccio multidimensionale è necessario a rappresentare la complessità del paesaggio: in tal modo le molteplici dimensioni del paesaggio diventano il riferimento imprescindibile per valutare le politiche di conservazione, riqualificazione, innovazione del patrimonio culturale ed ambientale; soprattutto contribuisce alla definizione delle strategie, degli obiettivi e delle azioni di progetto, tendendo al superamento della conflittualità tra tutela e sviluppo nell'ottica della sostenibilità delle scelte territoriali.
L'approccio multicriterio è funzionale allo sviluppo del territorio e risponde di conseguenza ad esigenze fondamentali quali:

- la necessità di un processo progettuale in costante aggiornamento che consenta l'implementazione delle conoscenze acquisite, individuando un percorso che permetta di recepire i cambiamenti e rispondere a nuove esigenze;
- la necessità di indagare il contesto secondo diverse dimensioni spaziali, per cogliere relazioni e legami tra scala locale e scala territoriale, considerando che i limiti territoriali sono variabili in funzione del fenomeno considerato;
- la necessità di una costante attenzione alla molteplice dimensione temporale, che consente di leggere ed interpretare l'attuale configurazione dei luoghi come esito di un processo di lunga durata, del quale occorre cogliere permanenze e trasformazioni come premessa per l'individuazione di scenari futuri, per garantire il valore di lascito a favore delle future generazioni.

Tra le diverse percezioni del paesaggio la dissonanza che maggiormente si avverte è quella tra i tempi calzanti ed accelerati delle più recenti trasformazioni antropiche ed i tempi lenti delle stratificazioni storiche, in cui si è consolidato il rapporto uomo ed ambiente, e si è modellato un paesaggio di alta complessità e ricchezza (Balletti e Soppa, 2004).
Le valutazioni multicriterio consentono di "ri-capitalizzare" il paesaggio come patrimonio per costruire uno sviluppo etico nel rispetto delle molteplici componenti materiali ed immateriali del luogo, ovvero di valorizzare l'eredità del passato per produrre nuova ricchezza, non distruttiva dei valori consolidati, ma capace di determinare "valore aggiunto territoriale" (Balletti e Soppa, 2003).
In particolare, il presente articolo presenta la seguente struttura: al § 2 vengono brevemente presentate le caratteristiche territoriali del sito UNESCO Costa d'Amalfi, anche con riferimento alla pianificazione sovraordinata vigente e presentando i risultati di un'analisi

SWOT che è stata condotta preliminarmente alla valutazione multicriterio. L'analisi SWOT, unitamente all'analisi dei piani e programmi in atto sul territorio, ha contribuito all'elaborazione di cinque scenari di intervento, tra loro alternativi. L'analisi multicriterio è stata elaborata con riferimento a tre obiettivi e cinque criteri, deducendo una graduatoria di preferibilità tra gli scenari proposti, applicando il metodo Regime (§ 3). Nelle conclusioni (§ 4) vengono proposte delle riflessioni sulla opportunità di utilizzare un approccio di valutazione multicriterio nella conservazione e valorizzazione del Paesaggio Storico Urbano.

2. Il sito UNESCO della Costa d'Amalfi

Il sito Costa d'Amalfi è stato istituito dall'UNESCO nel 1997, in quanto eccezionale esempio di paesaggio mediterraneo, come "paesaggio culturale vivente o evolutivo". I criteri in virtù dei quali tale territorio è stato iscritto nella lista WHL sono i seguenti (Figg. 2 e 3):

- il sito mostra un importante interscambio di valori umani in un lasso di tempo o in un'area culturale del mondo, relativamente agli sviluppi dell'architettura o della tecnologia, delle arti monumentali, dell'urbanistica o della progettazione paesaggistica;
- il sito costituisce un eccezionale esempio di edificio o complesso architettonico o tecnologico o paesaggistico che illustri uno stadio significativo o stadi significativi nella storia umana;
- il sito rappresentare un esempio eccezionale di un insediamento umano tradizionale o di utilizzo del territorio che sia rappresentativo di una o più culture, specialmente se divenuto vulnerabile per l'impatto di cambiamenti irreversibili.

In particolare, il sito UNESCO Costa d'Amalfi è costituito da 15 comuni della provincia dei Salerno molto eterogenei tra loro (Amalfi, Atrani, Cetrara, Conca dei Marini, Corbara, Furore, Maiori, Minori, Positano, Praiano, Ravello, Sant'Egidio del Monte Albino, Scala, Tramonti, Vietri sul Mare), tanto per posizione ed estensione territoriale, quanto per risorse culturali ed economiche. Il territorio è caratterizzato non solo da comuni costieri per estensione molto piccoli (come Conca dei Marini e Praiano), ma anche da comuni collinari maggiormente estesi (come Sant'Egidio del Monte Albino e Tramonti), nonché da comuni (come Positano, Amalfi e Maiori) che presentano nell'ambito dello stesso territorio comunale sia un paesaggio costiero che rurale.

Le caratteristiche fondamentali da considerare ai fini del perseguimento dello sviluppo sostenibile del sistema paesaggistico della Costa d'Amalfi sono:

- l'elevato patrimonio paesaggistico, caratterizzato da elevata biodiversità e numerosi beni culturali non messi in rete tra loro;
- la fragilità dell'eterogeneo sistema territoriale;
- il rischio idrogeologico;
- l'abbandono dei terrazzamenti agricoli, componente fondamentale del sistema paesaggio culturale;
- la frammentarietà e la parcellizzazione dei terrazzamenti agricoli;
- l'eterogeneità delle attività e delle produzioni locali;
- la congestione del turismo stagionale;
- i numerosi finanziamenti comunitari spesso spesi senza un disegno integrato dei progetti.

Fig. 2 – Elementi del paesaggio culturale della Costa d'Amalfi

Foto di Anna Acampora

Per i diversi comuni della Costa d'Amalfi la programmazione della Regione Campania per il periodo 2000-2006, attuata tramite l'impiego dei fondi strutturali dell'Unione Europea, ha disposto in diverse annualità e con diverse finalità, molteplici strumenti di programmazione negoziata.
Dall'analisi degli interventi effettuati, emerge non solo l'assenza di coordinamento dei progetti nella programmazione temporale e nello spazio territoriale, ovvero tra i diversi comuni del sito UNESCO, ma anche la mancata integrazione dei progetti, rispetto alle diverse risorse e componenti paesaggistiche, nonché rispetto all'intero sistema locale. Pertanto, l'analisi di tale progettualità attuata evidenzia come in realtà i progetti afferenti alle diverse dimensioni paesaggistiche non sono realizzati in funzione del sistema paesaggio, né delle sue componenti, né delle sue dinamiche (D'Angiolo, 2011).
Inoltre, tra le principali considerazioni emerse dallo studio degli strumenti di programmazione e pianificazione in atto (Figg. 4 e 5), si rileva la carenza di una visione complessiva e unitaria dell'intero sito UNESCO Costa d'Amalfi. In ogni caso, si è proceduto all'individuazione delle linee di sviluppo esistenti che emergono dalla pianificazione vigente, al fine di comprendere l'evoluzione del sistema paesaggistico, per

proporre di conseguenza uno scenario progettuale. Infatti, esplicitare gli indirizzi in atto permette di confrontare lo stato di fatto con una visione più vantaggiosa e di definire le trattorie verso cui orientare la gestione del sito. In questa prospettiva sono stati elaborati, e quindi fatti oggetto di valutazione, cinque specifici scenari (cfr. § 3).

Fig. 3 – Particolari di Villa Ruffolo a Ravello con istallazioni artistiche

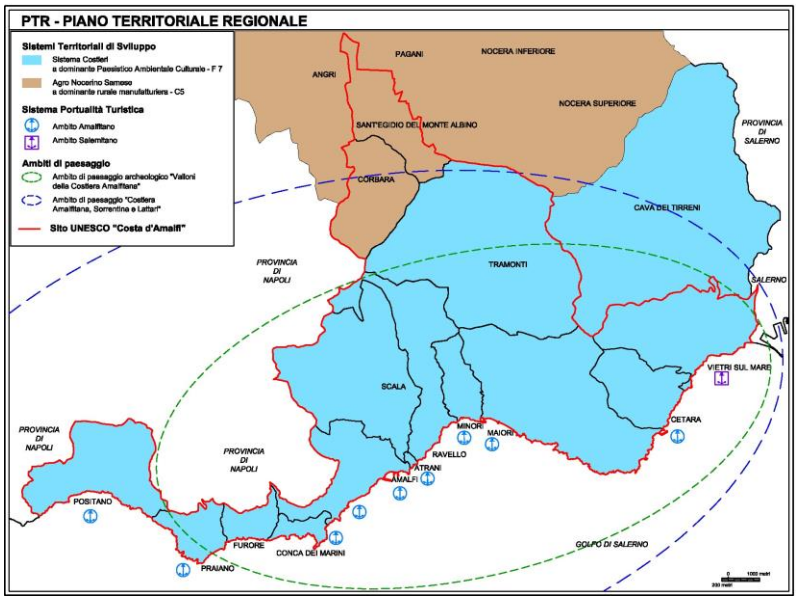
Foto di Marianna D'Angiolo

Tali "scenari" sono stati costruiti con riferimento a tre dimensioni territoriali (patrimonio culturale, patrimonio naturale, infrastrutturazione del sistema territoriale) ed esplicitati tramite "azioni strategiche" che rispondessero a tre "obiettivi" strategici, individuati

relativamente alle stesse componenti identificative del paesaggio, quali:
- tutelare e valorizzare il patrimonio culturale;
- tutelare e valorizzare il patrimonio naturale;
- migliorare e potenziare il sistema infrastrutturale.

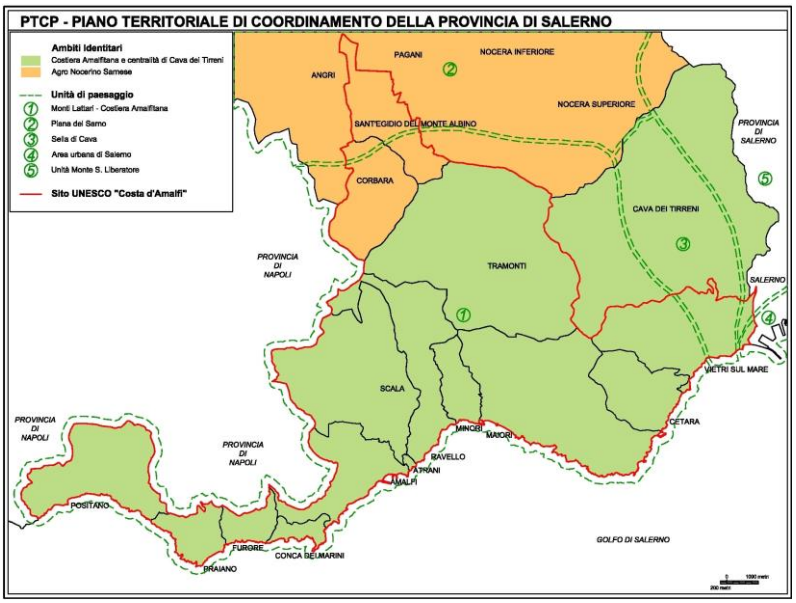
Inoltre, quale attività propedeutica alla valutazione, è risultato opportuno condurre una Analisi SWOT (Strenghs, Weakness, Opportunities, Threats), così come suggerito nel *Progetto di definizione di un modello per la realizzazione dei Piani di Gestione dei siti UNESCO* (Ministero per i Beni e le attività culturali, 2005), allo scopo di definire uno schema di sintesi che evidenzi i punti di forza e di debolezza, le opportunità e le minacce, di tutta l'area di riferimento, anche con riferimento alle possibilità di trasformazione (Tabb. 1 e 2).

Fig. 4 –Piano Territoriale Regione Campania



L'analisi SWOT ha costituito il presupposto per la elaborazione dei cinque scenari (tra loro alternativi) di possibile intervento, costituiti da un insieme di azioni strategiche tra loro integrate rispetto alle interdipendenze che caratterizzano il sistema territoriale di riferimento (Figg. 6-8). In particolare, le risorse naturalistiche e culturali sono considerate nel loro insieme come patrimonio, per cui la loro valorizzazione è strettamente legata alla cognizione di rete. Si attua, in tal modo, una maggiore strutturazione integrata e sostenibile della rete dei porti e degli approdi, delle "vie del mare", delle rotte locali, intercostiere e interregionali; si attua una maggiore integrazione rispetto al territorio ed alle relative risorse turistiche, ovvero, nel complesso, una maggiore integrazione delle infrastrutture che rende più efficaci e anche più strutturati i servizi per l'offerta turistico culturale.

Fig. 5 –Piano Territoriale di Coordinamento Provinciale



Tab. 1 – Analisi SWOT: punti di forza e di debolezza

STRENGTHS (punti di forza)
• Costa d'Amalfi: elevata presenza sul territorio di beni storico-architettonici • Costa d'Amalfi: elevata presenza di aree con elevata biodiversità • Costa d'Amalfi: elevata presenza sul territorio di sentieri • Costa d'Amalfi: presenza di diversi porti e approdi con rotte non solo locali ma anche regionali, che fanno scalo a Positano e Amalfi, che possono generare una maggiore intermodalità • Vietri sul Mare: presenza di approdo/porto funzionale ad una possibile stazione di interscambio • Vietri sul Mare: unico comune del sito UNESCO ad essere dotato di stazione ferroviaria e svincolo autostradale • Cetara: presenza di un porto di pescatori quale luogo identitario
WEAKNESSES (punti di debolezza)
• Costa d'Amalfi: i numerosi beni storico-architettonici diffusi sul territorio non sono collegati tra loro né con una rete materiale (ad esempio, di mobilità), né con una rete immateriale. • Costa d'Amalfi: diverse risorse naturalistiche sono poco valorizzate • Costa d'Amalfi: forte pressione sulla strada locale costiera (S.S.163) che percorre tutti i comuni costieri del sito UNESCO, con particolare congestione del traffico nei centri abitati • Costa d'Amalfi: la presenza sulla costa di diversi porti e approdi potrebbe generare impatti negativi relativi alla congestione sulla costa • Costa d'Amalfi: esistono solo tre strade di collegamento principale verso i comuni collinari (Ravello-Scala, Tramonti, Furore) • Corbara e Sant'Egidio del Monte Albino: poco collegati con gli altri comuni del sito UNESCO, mentre sono maggiormente collegati con i comuni dell'Agro Nocerino-Sarnese • Cetara: il porto di pescatori (luogo identitario) è soggetto agli impatti derivanti dalla vicinanza del porto di Vietri su Mare con maggiore traffico

Tab. 2 – Analisi SWOT: opportunità e minacce

OPPORTUNITIES (opportunità)
• Costa d'Amalfi: possibilità di creare una rete culturale dei numerosi beni storico-architettonici diffusi sul territorio, finalizzata ad un circuito turistico-culturale, anche di natura scolastica – Circuito di turismo religioso: Duomo ad Amalfi, Ravello, Scala; Basilica di Minori, Chiese rilevanti ad Atrani, Ravello, Scala; Convento Santa Rosa a Conca dei Marini – Circuito di turismo archeologico: siti visitabili di Villa Romana a Minori; Villa rustica (epoca romana) a Polvica-Tramonti; Villa marittima (epoca romana) a Isole de li Galli-Positano; Terme della Bagnara (epoca romana) a Vietri sul Mare; aree archeologiche indiziate: campagne di scavo archeologico, anche con eventi studio e/o workshop – Circuito museale: Museo di Amalfi, Ravello, Scala, e in altri siti minori – Circuito architetture paleoindustriali: cartiere di Amalfi, Tramonti, Maiori, Minori e Ravello; fruizione degli opifici da collegare con progetti di valorizzazione come la Cartiera-Mulino a Furore, e/o con percorsi escursionistici come nella Valle delle Ferriere; • Costa d'Amalfi: sito web della rete del patrimonio culturale e dei circuiti turistico-culturale. • Costa d'Amalfi: valorizzazione delle risorse naturalistiche, delle aree ad elevata biodiversità e delle aree naturali peri-urbane, finalizzata al turismo naturalistico, scolastico e per il tempo libero • Costa d'Amalfi: percorsi escursionistici legati ai sentieri e alle aree naturali propulsori di turismo naturalistico • Costa d'Amalfi: la presenza sulla costa di diversi porti e approdi, con rotte non solo locali ma anche regionali, potrebbe costituire un opportuno sistema di portualità in relazione alle potenzialità dei diversi comuni • Vietri sul Mare: unico comune del sito UNESCO ad essere dotato di stazione ferroviaria e svincolo autostradale, potrebbe costituire un'opportuna porta d'ingresso al sito Costa d'Amalfi, nonché un'opportuna stazione di interscambio • Cetara: presenza del porto di pescatori come opportunità di pesca-turismo, che costituisce una tipologia di turismo naturalistico in costante crescita • Vietri sul Mare: il porto potrebbe essere funzionale a stazioni di interscambio
THREATS (minacce)
• Costa d'Amalfi: i numerosi beni storico-architettonici diffusi sul territorio, soprattutto quelli minori o meno noti, sono a rischio di una conservazione inefficiente e di una gestione non volta efficacemente alla valorizzazione • Costa d'Amalfi: rischio di frammentazione ecologica del patrimonio naturale • Cetara: il potenziamento come approdo/porto turistico rischia di far perdere identità al luogo • Vietri sul Mare: se costituisse l'unica porta d'ingresso al sito Costa d'Amalfi, potrebbe rischiare la congestione della mobilità.

Nello specifico le azioni proposte, volte ad un'efficace valorizzazione integrata del territorio, costituiscono interventi specifici, puntuali e locali o relativi al sistema territoriale nel suo complesso, concepiti per innescare una dinamica di sviluppo o di gestione sostenibile, che inietti nuova linfa al fine di "ri-valutare" i valori negati del territorio e promuovere una valorizzazione effettivamente integrata del paesaggio.

Fig. 6 – Inquadramento di alcune azioni strategiche relative al patrimonio culturale

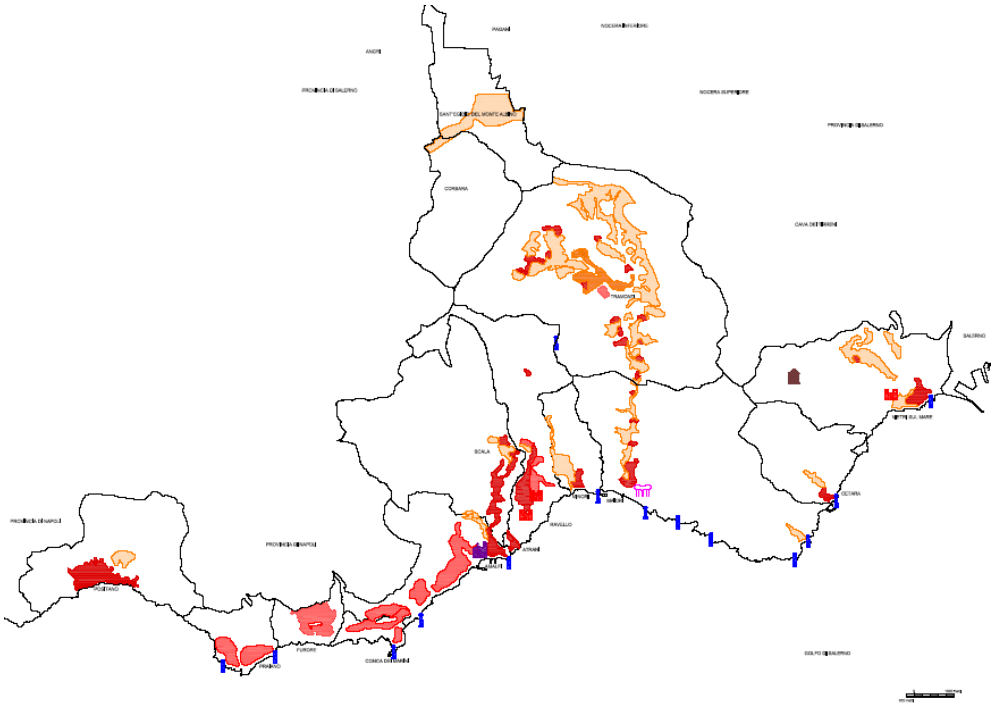
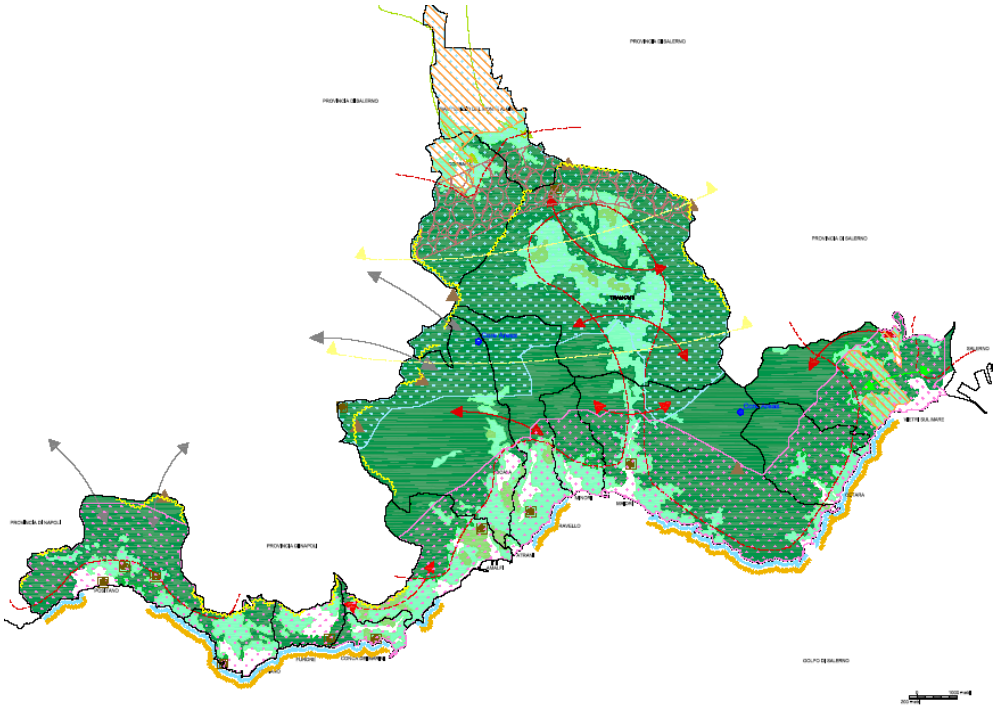


Fig. 7 – Inquadramento di alcune azioni strategiche relative al patrimonio naturale



Costruzione della rete ecologica tramite azioni di tutela e riqualificazione

- Aree ad elevata biodiversità (reale o potenziale)
- Aree di media biodiversità (reale o potenziale) e di collegamento ecologico
- Zone cuscinetto con funzione di filtro protettivo per le aree a maggiore biodiversità e naturalità
- Aree antropizzate e/o a minore biodiversità
- Aree critiche a frammentazione ecosistemica da riqualificare e riconnettere
- Ambiti di media ed elevata biodiversità caratterizzanti Insule e Core Areas della rete
- Core Areas (aree naturali di grande estensione di alto valore funzionale per la biodiversità)
- Corridoi ecologici costituiti da tutelare
- Corridoi ecologici da formare e/o potenziare
- Corridoi da realizzare per la ricucitura di aree critiche frammentate
- Corridoi di connessione con Core Areas di altre province e regioni
- Varchi, funzionali ai corridoi ecologici e di superamento delle barriere infrastrutturali

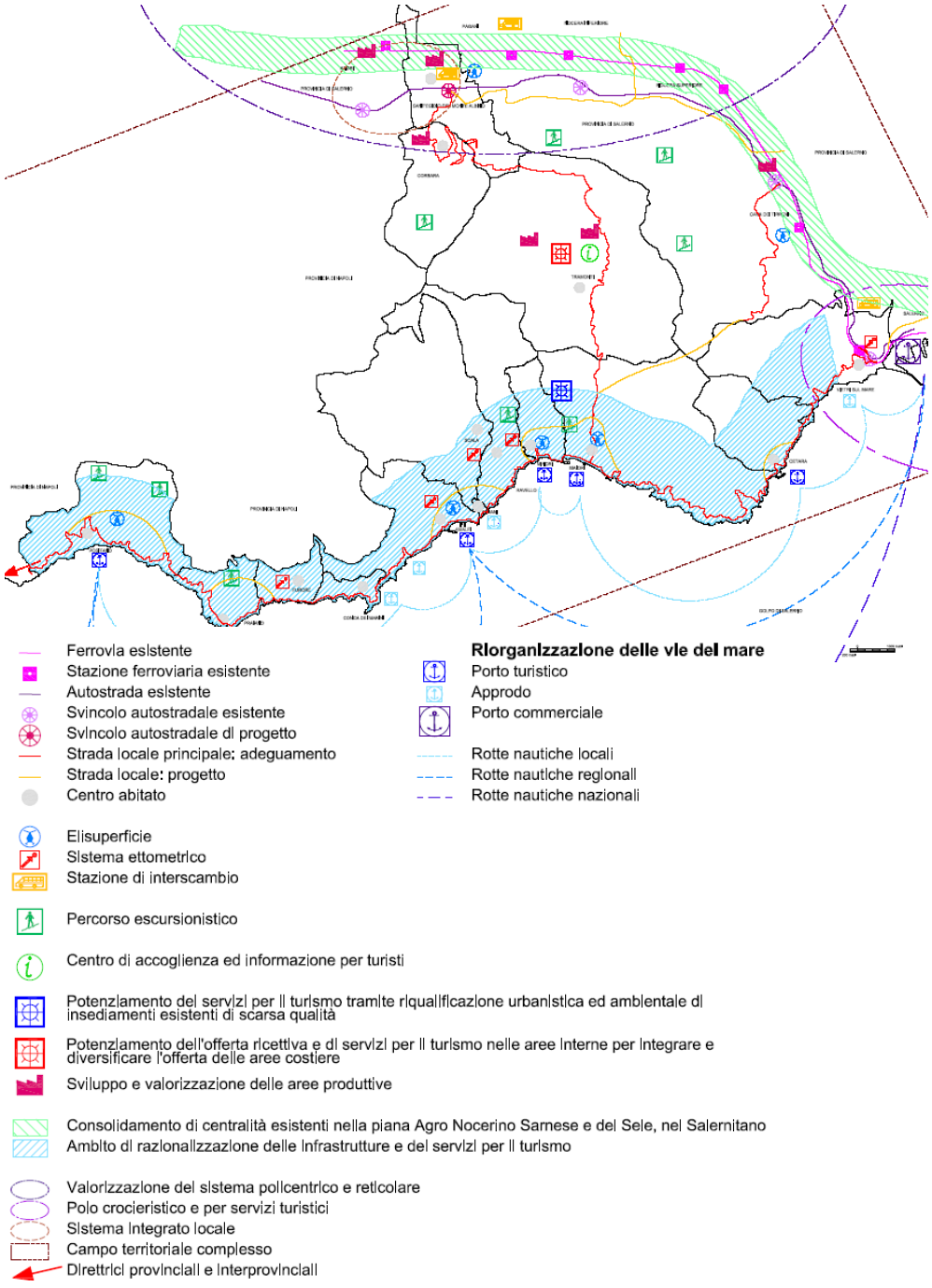
Governo del rischio ambientale

- Prevenzione, mitigazione e monitoraggio delle aree ad elevato rischio alluvione e/o frana
- Prevenzione e riduzione dell'inquinamento dei corpi idrici sotterranei
- Prevenzione dal rischio vulcanico tramite piani di emergenza comunali o intercomunali
- Prevenzione, mitigazione e monitoraggio di aree ad elevato rischio naturale ed antropico
- Difesa e/o monitoraggio delle coste per la mitigazione del fenomeno dell'erosione costiera
- Tutela e salvaguardia dell'integrità fisica delle coste alte

Tutela del patrimonio geologico

- Salvaguardia delle risorse geologiche, delle grotte
- Vette principali
- Crinali Principali

Fig. 8 – Inquadramento di alcune azioni strategiche relative al sistema infrastrutturale



3. La valutazione multicriterio

La valutazione degli scenari è stata condotta facendo riferimento alle Linee guida dall'UNESCO (2011) per la Valutazione di Impatto sul Patrimonio (*Heritage Impact Assessment – HIA*). In particolare, le Linee guida propongono una metodologia che possa consentire alla HIA di rispondere alle necessità dei i siti appartenenti alla Lista del Patrimonio Mondiale UNESCO, valutando gli impatti su beni che possiedono un Eccezionale Valore Universale (*Outstanting Universal Value – OUV*), in modo sistematico e coerente.

La Valutazione di Impatto sul Patrimonio costituisce un processo articolato in diverse fasi, tra le quali si annovera quella della definizione del modello e della valutazione degli impatti, sia diretti che indiretti. Da un punto di vista operativo, vengono proposti i seguenti riferimenti:

1. Intensità del cambiamento, che può essere valutata secondo la seguente scala:
   - nessun cambiamento;
   - cambiamento trascurabile;
   - cambiamento marginale;
   - cambiamento moderato;
   - cambiamento rilevante.
2. Effetto del cambiamento, che può essere valutato secondo la seguente scala:
   - effetto molto forte positivo;
   - effetto forte positivo;
   - effetto moderato positivo;
   - effetto debole positivo;
   - effetto nullo;
   - effetto debole negativo;
   - effetto moderato negativo;
   - effetto forte negativo;
   - effetto molto forte negativo.

Una valutazione complessiva si può ottenere combinando l'intensità del cambiamento con gli effetti prodotti, positivi o negativi; a questo scopo viene utilizzata una scala di valutazione degli impatti a cinque punti (da "molto elevato" a "trascurabile") secondo quanto riportato in Tab. 3.

Tenuto conto della proposta dell'UNESCO, per ciascuno scenario è stata definita una valutazione complessiva degli impatti con riferimento ad ogni azione strategica ed ai seguenti criteri di valutazione: patrimonio archeologico, patrimonio costruito, paesaggio storico, patrimonio naturale, sistema infrastrutturale e sistema socio-economico.

Si noti che una certa azione strategica può essere comune a più scenari (Tabb. 4-6); le caselle vuote indicano che lo scenario non è interessato dall'azione strategica corrispondente.

Poiché la valutazione degli impatti è relativa a ciascuna azione strategica, l'effetto risultante (espresso sulla scala da "molto elevato" a "trascurabile") è identico per ciascuno scenario che contiene quella azione strategica (Tabb. 7-9). Si noti che gli impatti sono tutti positivi e, per semplicità di lettura, le caselle vuote indicano impatti nulli.

Tab. 3 – Valutazione complessiva degli impatti

Valore del patrimonio	**Intensità del cambiamento**				
	Nessun cambiamento	Cambiamento trascurabile	Cambiamento marginale	Cambiamento moderato	Cambiamento rilevante
Valutazione complessiva degli impatti	**Effetto del cambiamento (positivo o negativo)**				
	Nullo	Debole	Moderato	Forte	Molto forte
Molto elevato	Nullo	Debole	Moderato/ Forte	Forte/ Molto forte	Molto forte
Elevato	Nullo	Debole	Moderato/ Debole	Moderato/ Forte	Forte/ Molto forte
Medio	Nullo	Nullo/ Debole	Debole	Moderato	Moderato/ Forte
Basso	Nullo	Nullo/ Debole	Nullo/ Debole	Debole	Debole/ Moderato
Trascurabile	Nullo	Nullo	Nullo/ Debole	Nullo/ Debole	Debole

Fonte: Adattato da ICOMOS (2011)

Per giungere ad una valutazione di sintesi si è adottato un metodo multicriterio che permette di identificare una graduatoria di preferibilità tra i diversi scenari proposti. La valutazione è stata strutturata tenendo conto dei tre obiettivi di riferimento e sei criteri (patrimonio archeologico, patrimonio costruito, paesaggio storico, patrimonio naturale, sistema infrastrutturale, sistema socio-economico) rispetto ai quali sono stati considerati gli impatti.

In particolare, gli scenari sono stati confrontati applicando il metodo multicriterio Regime (Hinloopen e Nijkamp, 1990; Nijkamp *et al*., 1990) ed utilizzando il software Definite 2.0 (DEcision on a FINITE set of alternatives) (Janssen *et al*., 2001).

In prima battuta ai tre obiettivi è stato assegnato lo stesso peso (0,33 per ciascun obiettivo, con somma dei pesi pari a 1,00) ed ai criteri è stato attribuito un peso ottenuto dividendo il peso dell'obiettivo per il numero di criteri (pari a 6), cioè assegnando il peso 0,055 a ciascun criterio di valutazione.

Sono state costruite le seguenti graduatorie di preferibilità:

1. la prima con pesi uguali per tutti gli obiettivi (Fig. 9a);
2. la seconda costituisce un insieme di graduatorie ottenute assegnando a turno a ciascun obiettivo un peso maggiore degli altri e peso uguale ai due obiettivi rimanenti; in questo modo si è effettuata un'analisi di sensitività delle graduatorie al variare dei pesi (Figg. 9b, c, d).

Tab. 4 – Azioni strategiche per il patrimonio culturale

Obiettivo 1: Tutelare e valorizzare il patrimonio culturale		**Scenari**				
N.	**Azioni strategiche**	**A**	**B**	**C**	**D**	**E**
A1.1	Restauro dei mosaici agricoli tramite supporto delle attività (agricole e non agricole) ad essi collegate	X		X	X	
A1.2	Restauro del sistema dei terrazzamenti e del relativo sistema di irrigazione e di collegamento	X		X	X	X
A1.3	Salvaguardia e recupero del sistema boschivo connesso al sistema dei terrazzamenti e della relativa filiera produttiva	X		X	X	
A1.4	Tutela degli insediamenti antichi sparsi			X	X	
A1.5	Riqualificazione insediativa ed ambientale			X	X	
A1.6	Potenziamento dell'offerta ricettiva e di servizi per il turismo nelle aree interne per integrare e diversificare l'offerta delle aree costiere, in particolare tramite l'individuazione di diversi poli attrezzati (centro di servizi di accoglienza ed informazione; promozione e vendita di prodotti locali; stazione di interscambio tra bus turistici; ecc.) a Tramonti e Maiori, in particolare presso il Valico di Chiunzi			X	X	X
A1.7	Riqualificazione integrata della rete rurale principale di mulattiere e sentieri (servizio rurale) ed infrastrutturazione complementare a quella principale (percorsi escursionistici)			X	X	X
A1.8	Tutela degli insediamenti antichi accentrati				X	
A1.9	Consolidamento ed integrazione delle polarità territoriali costituite dai beni di interesse storico architettonico: Duomo di Amalfi come grande attrattore culturale; Museo della Ceramica a Vietri sul Mare; area archeologica a Maiori			X	X	
A1.10	Tutela integrata e valorizzazione sistemica dell'architettura storica di tipo civile (quali le Ville storiche a Ravello e a Vietri sul Mare) e di tipo difensiva militare (quali le torri di guardia e di difesa lungo la costa)			X	X	
A1.11	Promozione della rete culturale costituita dai numerosi beni storico-architettonici diffusi sul territorio, finalizzata ad un circuito turistico-culturale, anche di natura scolastica			X	X	
A1.12	Valorizzazione del circuito turismo religioso: Duomo di Amalfi; Duomo di Ravello; Duomo di Scala; Basilica di Minori; Chiese rilevanti ad Atrani, Ravello e Scala; Chiesa e Convento di S. Rosa a Conca dei Marini				X	
A1.13	Valorizzazione del circuito museale: Museo del Duomo e Museo della Carta ad Amalfi; Museo del Duomo e Museo delle Antichità a Ravello; Museo della Ceramica a Vietri sul Mare; Museo della Collegiata presso la Chiesa di S. Maria a Mare a Maiori; Museo della Villa Romana a Minori				X	
A1.14	Valorizzazione del circuito turismo archeologico			X	X	
A1.15	Valorizzazione del circuito architetture paleoindustriali quali cartiere, opifici e mulini, anche tramite percorsi escursionistici	X		X	X	

Tab. 5 – Azioni strategiche per il patrimonio naturale

Obiettivo 2: Tutelare e valorizzare il patrimonio naturale		**Scenari**				
N.	**Azioni strategiche**	**A**	**B**	**C**	**D**	**E**
A2.1	Costituzione della rete ecologica allo scopo di mitigare gli effetti della frammentazione ambientale e preservare la diversità biologica	X				
A2.2	Potenziamento degli interventi di prevenzione e mitigazione dei fattori di rischio naturale ed antropico connessi a fenomeni franosi o di esondazione, nonché all'inquinamento dei corpi idrici (superficiali e sotterranei) e delle acque marine	X				
A2.3	Mitigazione del rischio ambientale, con particolare riferimento alla prevenzione ed alla riduzione dell'inquinamento dei corpi idrici superficiali e sotterranei, al monitoraggio ed alla riduzione dei fenomeni di dissesto idrogeologico	X				
A2.4	Manutenzione e ricostruzione delle necessarie sistemazioni idraulico-forestali	X				
A2.5	Salvaguardia e valorizzazione del patrimonio geologico	X				
A2.6	Messa in rete delle diverse risorse naturali ai fini del turismo naturalistico e didattico-scientifico o anche a fini ricreativi per il tempo libero	X		X	X	
A2.7	Salvaguardia della connotazione paesaggistica ed ambientale della fascia costiera tramite la salvaguardia e la valorizzazione dei fondali marini protetti di Punta Campanella e Capri (Zona di Protezione Speciale Sito di Interesse Comunitario) anche tramite attività di pesca-turismo, oltre che di escursioni marine o subacquee	X		X	X	

Tab. 6 – Azioni strategiche per il sistema infrastrutturale

Obiettivo 3: Migliorare e potenziare il sistema infrastrutturale		**Scenari**				
N.	**Azioni strategiche**	**A**	**B**	**C**	**D**	**E**
A3.1	Riorganizzazione delle "vie del mare" attraverso riqualificazione, adeguamento e potenziamento delle infrastrutture marittime, anche mediante la promozione di "taxi collettivi del mare" per collegamenti o escursioni lungo il litorale costiero		X		X	X
A3.2	Interventi specifici di sviluppo nell'ambito del sistema integrato della portualità regionale non solo turistica, anche mediante interventi puntuali		X		X	X
A3.3	Cetara: riqualificazione delle attrezzature per i servizi di approdo costiero		X		X	X
A3.4	Maiori: completamento del porto turistico e potenziamento delle attrezzature per i servizi di collegamento intercostiero		X		X	X
A3.5	Minori: riqualificazione funzionale dei servizi di approdo per i collegamenti marittimi verso la Costa d'Amalfi		X		X	X
A3.6	Positano: ripristino della banchina per l'attracco degli aliscafi ed adeguamento dei servizi per collegamenti intercostieri		X		X	X
A3.7	Vietri sul Mare: realizzazione del porto a secco e potenziamento delle attrezzature per i servizi di collegamento interregionale ai fini del trasporto pubblico e della mobilità turistica		X		X	X
A3.8	Realizzazione di un terminal intermodale (ferro-gomma-vie del mare) a Vietri sul Mare, con realizzazione di idonee aree di parcheggio destinate sia ai veicoli privati che a bus turistici di grandi dimensioni				X	X
A3.9	Realizzazione di una stazione intermodale d'interscambio tra Angri e Sant'Egidio del Monte Albino, dotata di infrastrutture di ricezione e servizio, al fine di smaltire il volume di traffico veicolare dell'area, ottimizzare i collegamenti e razionalizzare i flussi turistici del territorio				X	X
A3.10	Potenziamento integrato dei servizi per l'offerta turistica, riqualificazione e razionalizzazione nella fascia costiera dell'infrastrutturazione per la mobilità ed il turismo, potenziamento di servizi per il turismo tramite riqualificazione urbanistica ed ambientale di insediamenti esistenti di scarsa qualità			X	X	X
A3.11	Agevolazione dei flussi di traffico nelle direzioni interprovinciali e nelle zone di accesso, con l'individuazione nei punti d'ingresso alla costiera di necessarie aree di interscambio e relativi parcheggi: sulla costa a Vietri sul Mare e in area collinare a Sant'Egidio del Monte Albino, presso le zone d'ingresso e di transito interprovinciali a Positano dalla Penisola Sorrentina e a Furore da Castellammare di Stabia-Agerola				X	X
A3.12	Miglioramento della viabilità tramite le infrastrutture stradali e ferroviarie con relative aree di interscambio				X	X
A3.13	Potenziamento del sistema delle infrastrutture stradali esistenti, con la realizzazione di qualche nuovo collegamento o variante, nonché con la dotazione di nuovi parcheggi al servizio degli insediamenti storici, con aree di interscambio, percorsi pedonali, bus ecologici, vettori meccanici, ecc.				X	X
A3.14	Realizzazione di un sistema di vettori meccanici per il collegamento tra i centri costieri ed i nuclei interni, come sistema di mobilità alternativo e complementare, in particolare tra Minori e Maiori, ed eventualmente di piccoli impianti a servizio di quartieri e frazioni non servite da strade carrabili				X	X
A.3.15	Realizzazione ed adeguamento di elisuperfici per il servizio di elisoccorso e di protezione civile, e per mobilità a scopi turistici, in particolare nelle località di Positano, Amalfi, Maiori, Minori e Ravello dove è situato anche un presidio ospedaliero				X	X

Tab. 7 – Impatti per il patrimonio culturale

Azioni Strategiche	Impatti su:						Scenari				
	Patrimonio archeologico	Patrimonio costruito	Paesaggio storico	Paesaggio naturale	Sistema infrastrut-turale	Sistema socio-economico	A	B	C	D	E
A1.1			Molto forte	Forte		Forte	X		X	X	
A1.2			Molto forte	Forte		Moderato	X		X	X	X
A1.3			Forte	Molto forte		Moderato	X		X	X	
A1.4		Molto forte	Forte						X	X	
A1.5		Molto forte	Molto forte	Moderato					X	X	
A1.6					Forte	Molto forte			X	X	X
A1.7			Moderato		Moderato	Debole			X	X	X
A1.8		Molto forte	Forte							X	
A1.9	Forte	Molto forte	Moderato			Molto forte			X	X	
A1.10		Molto forte	Moderato			Moderato			X	X	
A1.11		Forte	Moderato			Moderato			X	X	
A1.12		Forte	Moderato			Forte				X	
A1.13		Forte	Moderato			Molto forte				X	
A1.14	Molto forte					Forte			X	X	
A1.15		Forte	Moderato			Moderato	X		X	X	

Tab. 8 – Impatti per il patrimonio naturale

Azioni Strategiche	Impatti su:						Scenari				
	Patrimonio archeologico	Patrimonio costruito	Paesaggio storico	Paesaggio naturale	Sistema infrastrut-turale	Sistema socio-economico	A	B	C	D	E
A2.1				Molto forte			X				
A2.2		Moderato		Molto forte	Forte		X				
A2.3		Moderato		Molto forte	Forte		X				
A2.4				Forte			X				
A2.5				Forte			X				
A2.6				Forte		Moderato	X		X	X	
A2.7				Forte		Moderato	X		X	X	

Tab. 9 – Impatti per il sistema infrastrutturale

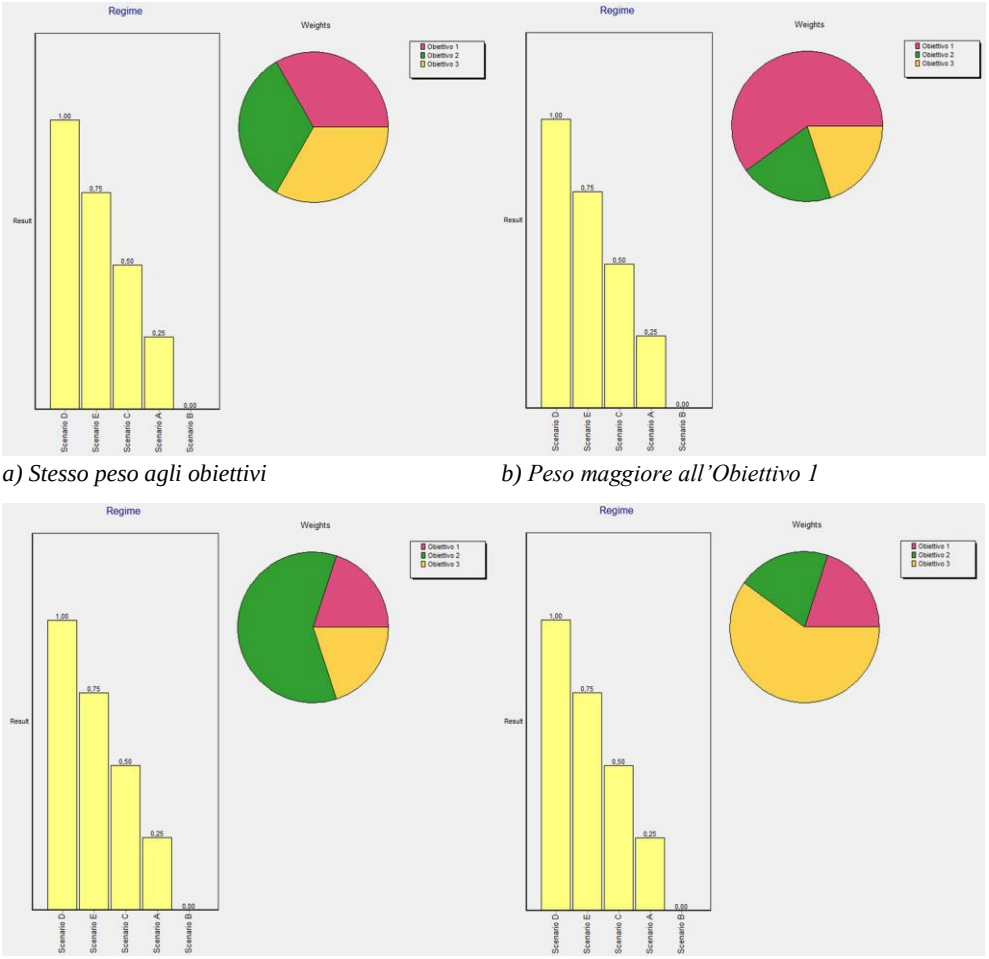
Azioni Strategiche	Impatti su:						Scenari				
	Patrimonio archeologico	Patrimonio costruito	Paesaggio storico	Paesaggio naturale	Sistema infrastrut-turale	Sistema socio-economico	A	B	C	D	E
A3.1					Molto forte	Moderato		X		X	X
A3.2					Molto forte	Moderato		X		X	X
A3.3					Molto forte	Moderato		X		X	X
A3.4					Molto forte	Moderato		X		X	X
A3.5					Molto forte	Moderato		X		X	X
A3.6					Molto forte	Moderato		X		X	X
A3.7					Molto forte	Moderato		X		X	X
A3.8					Molto forte	Moderato				X	X
A3.9					Forte	Moderato				X	X
A3.10		Moderato			Forte	Forte			X	X	X
A3.11					Forte	Moderato				X	X
A3.12					Forte	Moderato				X	X
A3.13					Molto forte	Moderato				X	X
A3.14					Forte	Debole				X	X
A.3.15					Moderato	Debole				X	X

Le graduatorie ottenute coincidono nell'individuare la seguente graduatoria di preferibilità tra gli scenari:
1ª posizione: Scenario D (punteggio 1,00);
2ª posizione: Scenario E (punteggio 0,75);
3ª posizione: Scenario C (punteggio 0,50);
4ª posizione: Scenario A (punteggio 0,25);
5ª posizione: Scenario B (punteggio 0,00).
Si evidenzia, pertanto, la "robustezza" dei risultati ottenuti che non sono sensibili alla diversa attribuzione dei pesi assegnati agli obiettivi ma alla caratteristiche proprie di ciascuno scenario in termini di performance rispetto ai criteri di valutazione.

4. Conclusioni

Le "invarianti strutturali" del paesaggio del sito UNESCO Costa d'Amalfi, in quanto risorse essenziali del territorio rappresentano i potenziali generatori di ricchezza sostenibile e durevole; che tali risorse fondamentali del territorio determinino sviluppo auto-sostenibile dipende dai progetti, ed in particolare dalla loro strategia.
Il processo di valutazione multicriterio permette così di "tenere insieme" le diverse componenti territoriali al fine di restaurare l'integrità del paesaggio e di stabilire come possa essere regolata la trasformazione del territorio (Fusco Girard e Nijkamp, 1997). Un approccio integrato ed insieme coordinato, ossia multicriterio relativo alla pianificazione strategica, possiede un elevato grado di efficacia operativa: la conservazione e la valorizzazione del paesaggio è una attività che tende per sua natura ad opporsi ai processi di semplificazione riduttiva e di omologazione che indeboliscono le identità territoriali.

Fig. 9 – Valutazione multicriterio: ordine di preferibilità degli scenari



a) Stesso peso agli obiettivi *b) Peso maggiore all'Obiettivo 1*

c) Peso maggiore all'Obiettivo 2 *d) Peso maggiore all'Obiettivo 3*

Le valutazioni multidimensionali consentono di ri-capitalizzare il "paesaggio come patrimonio" per costruire uno sviluppo etico nel rispetto delle molteplici componenti materiali ed immateriali del luogo, ovvero di valorizzare l'eredità del passato per produrre nuova ricchezza, non distruttiva dei valori consolidati, ma capace di determinare valore aggiunto territoriale (Balletti e Soppa, 2003).
Indispensabile appare, quindi, l'applicazione di metodi di valutazione multicriterio in quanto strumenti capaci di costruire partecipazione, esplicitare la trasparenza delle decisioni, ed anche di orientare decisioni "etiche" conservazione, valorizzazione e "costruzione" del Paesaggio Storico Urbano.
Risulta quindi opportuno che lo scenario strategico progettuale sia composto da progetti

fondati sul riconoscimento dei valori del patrimonio (Magnaghi, 2005). In conclusione, il processo valutativo, supportato dall'analisi SWOT, dimostra avere valenza strategica su tre diversi livelli:

- supporta la praticabilità della pianificazione paesaggistica in quanto l'approccio multicriterio è in grado di comprendere la complessità del paesaggio e di promuoverne la progettualità per la sua valorizzazione, favorendo l'attuazione di progetti integrati
- può favorire l'attuazione del Piano di Gestione, come processo progettuale rispetto alla programmazione regionale cui gli stessi progetti devono far riferimento per essere finanziati, incoraggiando in tal modo anche una coerenza nella transcalarità dei piani e programmi;
- rende operativo il perseguimento degli obiettivi di qualità paesaggistica, in virtù dei quali la Convenzione Europea mira a progettare paesaggi come espressione di valori condivisi.

Inoltre, l'approccio multicriterio contribuisce a rendere operativa la nozione Valutazione di Impatto sul Patrimonio proposta dall'UNESCO, soprattutto in presenza di diverse opzioni di intervento, valutando opportunamente gli impatti su beni che possiedono un Eccezionale Valore Universale, favorendo la loro conservazione e valorizzazione.

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UNA PROPOSTA METODOLOGICA PER LA VALUTAZIONE DEI LANDSCAPE SERVICES NEL PAESAGGIO CULTURALE TERRAZZATO

Antonia Gravagnuolo

Sommario

I sistemi terrazzati rappresentano una particolare tipologia di paesaggio culturale agricolo, considerati paesaggi a rischio a causa delle trasformazioni socio-economiche. Diverse iniziative internazionali (UNESCO, ITLA, GIAHS FAO) hanno evidenziato la necessità di conoscere, valutare, tutelare e valorizzare il sistema complesso di servizi e benefici offerti dal paesaggio terrazzato, per evitare la perdita irreversibile di sistemi che rappresentano un efficace modello di resilienza costruito nel corso dei secoli. Questo articolo propone l'approccio dei *landscape services* per la valutazione degli indicatori relativi ai servizi del paesaggio terrazzato. La metodologia viene applicata al caso studio del sito UNESCO della Costiera Amalfitana. I risultati mostrano come i servizi di regolazione, mantenimento e approvvigionamento siano prioritari per la conservazione del paesaggio terrazzato.

Parole chiave: paesaggio culturale, paesaggio terrazzato, *landscape services*

A METODOLOGICAL APPROACH FOR THE EVALUATION OF LANDSCAPE SERVICES IN TERRACED CULTURAL LANDSCAPES

Abstract

The terraced landscapes represent a particular type of agricultural landscapes, which are considered at risk due to economic and social transformations. Several international initiatives (UNESCO, ITLA, FAO GIAHS) highlight the need to assess, evaluate, protect and valorise the complex system of services and benefits provided by terraced landscape, in order to avoid the irreversible loss of cultural landscapes that provide an effective model of resilience built over centuries. This paper applies the landscape services approach for the assessment of landscape services indicators in terraced landscapes. The proposed methodology is applied to the case study of the UNESCO World Heritage site of the Amalfi Coast in Southern Italy. The results show that regulation and maintenance services, as well as provisioning services, are priorities for the conservation of terraced landscapes.

Keywords: cultural landscape, terraced landscape, landscape services

1. Introduzione

La Convenzione Europea del Paesaggio, firmata a Firenze dagli Stati Membri del Consiglio d'Europa nel 2000, offre una definizione universalmente riconosciuta del concetto di paesaggio, descrivendolo come «una determinata parte di territorio, così come è percepita dalle popolazioni, il cui carattere deriva dall'azione di fattori naturali e/o umani e dalle loro interrelazioni» (Council of Europe, 2000, art.1). La Convenzione, ratificata dallo stato italiano con la legge n.14 del 9 gennaio 2006, riconosce che il paesaggio «coopera all'elaborazione delle culture locali e rappresenta una componente fondamentale del patrimonio culturale e naturale dell'Europa, contribuendo così al benessere e alla soddisfazione degli esseri umani e al consolidamento dell'identità europea» (Council of Europe, 2000, preambolo). La qualità del paesaggio è una componente fondamentale del benessere dell'uomo, o della comunità, che fruisce di un territorio. I benefici sociali che derivano da un paesaggio di qualità sono oggetto di studi valutativi (Tempesta e Thiene, 2006) orientati alla tutela e valorizzazione di quei paesaggi riconosciuti come elementi fondanti dell'identità culturale di un territorio (Taylor *et al*., 2015). I paesaggi culturali, risultati della storica interrelazione tra l'uomo e il territorio, sono stati introdotti nella Lista del Patrimonio Mondiale UNESCO come categoria di beni culturali di eccezionale valore universale. Questi siti sono stati inseriti a partire dal 1992, quando il concetto di "paesaggio culturale" è stato incorporato nelle Linee Guida per l'Implementazione della Convenzione sul Patrimonio Mondiale, insieme ad altri siti riconosciuti come Patrimonio Mondiale naturale e misto naturale-culturale (UNESCO, 2013a).

Attualmente 85 Siti classificati come "paesaggi culturali" sono presenti nella Lista del Patrimonio Mondiale dell'UNESCO, di cui 4 transfrontalieri, che presentano un carattere di integrità e autenticità. Il paesaggio culturale deve quindi rispondere, per essere classificato come tale, ad un paesaggio integro ed autentico disegnato intensionalmente dall'uomo (i), sviluppatosi in maniera organica nel corso dei secoli, di carattere "fossile" o "vivente" (ii), oppure associativo (iii), così come indicato nell'allegato 3 delle Linee Guida (UNESCO, 2013a). L'apparente semplicità di queste tipologie nasconde un'eccezionale ricchezza, generata dalle civiltà umane che, nel corso della storia, hanno applicato principi di adattamento alle condizioni ambientali che si sono rivelati sufficientemente resilienti da arginare l'intrinseco ed inesauribile dinamismo della natura sovrapponendo ad essa una dimensione culturale che la arricchisce e la rende unica (UNESCO, 2013b).

Tra i paesaggi culturali inseriti nella Lista del Patrimonio Mondiale, il 13% dei siti hanno caratteristiche agro-pastorali, mentre il 75% di tutti i paesaggi culturali della Lista presentano alcune delle caratteristiche dei paesaggi agricoli. Dei siti in attesa di iscrizione, il 10% presenta le stesse caratteristiche. «Lo sviluppo culturale umano è inesorabilmente legato allo sviluppo dell'agricoltura» (UNESCO, 2013b), poiché sono essenzialmente le pratiche agricole ad aver storicamente conformato e generato i paesaggi attuali. I sistemi agricoli e pastorali sono caratteristici di società in cui le attività produttive e l'ambiente interagiscono. Oggi è possibile ritrovare questa caratteristica in tutti i maggiori gruppi e regioni geo-culturali, così come in altre espressioni agricole, industriali, commerciali, religiose ed artistiche. I paesaggi agricoli ed agro-pastorali sono presenti in maniera evidente nella Lista del Patrimonio Mondiale come paesaggi culturali viventi, ma anche paesaggi fossili o rappresentazioni di questa parte importante della storia dell'umanità nei siti di pitture rupestri.

Lo sviluppo di tutti questi paesaggi agricoli è stato influenzato in maniera significativa dalle sistemazioni idraulico agrarie. In molti di questi siti restano ancora oggi chiari esempi di sistemazioni agricole tradizionali e costruzioni per gli animali di allevamento, attualmente gestiti da innumerevoli piccoli proprietari, i quali riconoscono che far parte di un Patrimonio Mondiale genera valore aggiunto ai loro prodotti, specialmente quando l'utilizzo di metodi di coltivazione e sostentamento degli animali tradizionali resta una priorità. Questi paesaggi di eccezionale valore affrontano oggi numerose minacce: la perdita di conoscenze tradizionali e lavoratori specializzati associata a coltivazioni specifiche, come la vite o il riso, ma anche i cambiamenti negli stili di vita. Questi paesaggi sono anche soggetti alla industrializzazione, urbanizzazione, standardizzazione tecnica e finanziaria della produzione alimentare attuale, ed in questo senso la diversità delle espressioni culturali è a rischio. I paesaggi culturali agricoli custodiscono la conoscenza tecnica e scientifica delle generazioni passate che, nella loro apparente semplicità, contengono i principi chiave di uno sviluppo sostenibile e resiliente.

I sistemi terrazzati sono una particolare tipologia di paesaggi agricoli, considerati il più importante sistema di organizzazione del paesaggio nell'area del Mediterraneo (United Nations, 1994). Sui versanti collinari e montani conformati dall'uomo, generazioni di uomini hanno depositato il loro patrimonio "genetico" culturale sotto forma di tipologie costruttive uniche e sistemazioni idraulico-agrarie funzionali al sostentamento degli insediamenti rurali e urbani (Sereni, 1961).

I sistemi terrazzati sono classificabili nella categoria di paesaggio culturale definita "paesaggio evolutivo", risultato dell'interazione tra le esigenze sociali, economiche, amministrative e/o religiose dell'uomo in relazione all'ambiente naturale.

I paesaggi evolutivi vengono ulteriormente classificati nelle Linee Guida UNESCO in paesaggi fossili, in cui il processo evolutivo si è arrestato, e paesaggi viventi o continui, in cui rientrano i territori terrazzati, che conservano un ruolo sociale attivo nella società contemporanea, strettamente associato allo stile di vita tradizionale ed in cui il processo evolutivo è ancora in corso.

Il paesaggio terrazzato deve la sua eccezionalità alla conformazione artificiale dei versanti collinari e montuosi in terrazze coltivabili che storicamente hanno contribuito alla stabilità idrogeologica, all'accumulo idrico ed al sostentamento alimentare delle comunità locali. La ricchezza di questo patrimonio culturale, materiale e immateriale, costituisce una leva potenziale di sviluppo in grado di contribuire significativamente alla conservazione e ri-produzione di valori economici, sociali ed ambientali. Attualmente i paesaggi terrazzati sono minacciati dall'abbandono delle attività agricole tradizionali e, di conseguenza, dalla scarsa o nulla manutenzione del territorio da parte dei piccoli proprietari locali che comporta l'aumento del rischio idrogeologico (ISPRA, 2013) e la perdita di un eccezionale patrimonio di biodiversità. I costi ecologici, sociali, culturali ed economici della perdita irreversibile dei paesaggi terrazzati (Brancucci e Paliaga, 2006) richiedono nuovi strumenti metodologici e politiche pubbliche innovative verso la sua tutela attiva, manutenzione e valorizzazione (Rizzo e Bonari, 2006).

Tra i siti terrazzati presenti nella Lista del Patrimonio Mondiale, il sito della Costiera Amalfitana è stato riconosciuto nel 1997 come esempio unico di paesaggio mediterraneo dal valore scenico culturale e naturale (Fig. 1), risultato della topografia naturale e dell'evoluzione storica del territorio (Ferrigni e Sorrentino, 2013). Il sito è stato inserito nella Lista in base ai criteri (ii), (iv) e (v) indicati dalle Linee Guida per l'Implementazione

della Convenzione sul Patrimonio Mondiale (UNESCO, 2013a). L'area copre 11231 ettari in 16 comuni nella Provincia di Salerno, ed è delimitata dal profilo dei Monti Lattari, separando il Golfo di Napoli da quello di Salerno (World Heritage Centre, 2014).
L'organizzazione dell'area in terrazzamenti risale all'epoca medioevale (Caneva e Cancellieri, 2007; Pane, 1961; Pane, 1965) e risponde ad esigenze agricole ed idrauliche (Laureano, 2004). I tradizionali muri in pietra a secco (murecine o macere) e le superfici orizzontali derivanti (piazzole) sono qui associati ad un sistema di canalizzazioni e cisterne (peschiere) per l'irrigazione delle aree agricole (Maurano, 2005), la raccolta, regimentazione e conservazione delle acque meteoriche (Tarolli *et al.*, 2014). La presenza di una comunità dinamica, in grado di evolvere salvaguardando i valori identitari del paesaggio culturale e tutelando l'ambiente naturale con una manutenzione continua del territorio è il presupposto fondamentale per la conservazione del patrimonio culturale rappresentato dai terrazzamenti agricoli (Hsu e Du Guerny, 2010).

Fig. 1 – Terrazzamenti agricoli e insediamenti in Costiera Amalfitana

Foto: Ivana Carbone

Le iniziative internazionali per la tutela dei paesaggi terrazzati (Koohafkan, 2002; Fontanari e Patassini, 2008; Scaramellini e Varotto, 2008; ITLA, 2010) e per la salvaguardia della biodiversità (CBD, 2008), evidenziano l'importanza dei paesaggi culturali rurali per uno sviluppo sostenibile (Commissione Europea, 2011). I governi e le istituzioni sono chiamati ad identificare i molteplici valori del paesaggio e a valutare i benefici che da esso derivano (Altieri e Koohafkan, 2012). Gli approcci e gli strumenti sperimentati finora rappresentano una base di conoscenza fondamentale per l'individuazione e la valutazione dei valori tangibili e intangibili dei paesaggi terrazzati, per una gestione ottimale delle trasformazioni in base ad obiettivi e necessità condivise (Koohafkan e Altieri, 2012).

Questo articolo affronta il tema della valutazione del paesaggio culturale terrazzato, utilizzando l'approccio dei servizi (*landscape services*) (De Groot *et al.*, 2010). L'obiettivo di questo studio è l'elaborazione di una metodologia per l'individuazione, il *mapping* e la valutazione dei *landscape services* attribuibili ai paesaggi culturali terrazzati, con riferimento al caso studio del Sito UNESCO della Costiera Amalfitana.
Nella sezione 2 viene presentato lo stato dell'arte della letteratura sui servizi del paesaggio, e viene descritta la proposta metodologica sulla base degli studi più recenti. Nella sezione 3 vengono descritti i risultati dell'applicazione della metodologia al caso studio della Costiera Amalfitana, mentre la sezione 4 presenta un'analisi critica dei risultati. Sulla base dell'evidenza prodotta, nella sezione 5 vengono discussi i punti di forza ed i limiti della metodologia, evidenziando scalabilità, riproducibilità e utilità della stessa.

2. Servizi ecosistemici e del paesaggio

Secondo l'OECD nella valutazione del paesaggio bisogna distinguere nettamente le sue caratteristiche (*landscape character*) dal suo valore (OECD, 2011). Le caratteristiche consentono di individuare le tipologie di paesaggio (*landscape typologies*), mentre il valore deriva dalle funzioni (*functions*) che ogni tipo di paesaggio è in grado di svolgere, cioè dal tipo di bisogni che è in grado di soddisfare. Quindi, il valore del paesaggio avrà una componente oggettiva (connessa alle caratteristiche) ed una soggettiva (connessa alla percezione) (Tempesta e Thiene, 2006). I molteplici valori riscontrabili nei paesaggi terrazzati derivano quindi da funzioni e servizi che vanno identificati e valutati.
Il termine *landscape services* è stato adottato nel campo della ricerca internazionale per definire i servizi fruibili dall'uomo che derivano dalla sua interazione con il paesaggio (Limburg, 2002). A differenza degli *ecosystem services*, individuati alla scala più ampia degli ecosistemi naturali (MEA, 2005), il concetto di servizi alla scala del paesaggio sottolinea l'interazione tra un sistema fisico, dai cui dipendono i processi naturali, e la varietà di valori d'uso e indipendenti dall'uso riconosciuti dall'uomo. Quindi, sebbene le funzioni biofisiche possano continuare a perpetuarsi in assenza di persone, i servizi del paesaggio esistono solo in quanto esiste una comunità che usa e dà valore al paesaggio, in un'ottica antropocentrica (Cerreta, 2014). Il paesaggio è inteso come una categoria multifunzionale, in cui è possibile individuare aspetti propriamente naturalistici ma anche una serie di servizi, materiali e immateriali, forniti all'uomo attraverso cui rintracciare i presupposti per lo sviluppo sostenibile del territorio (Haines-Young e Potschin, 2010). Secondo De Groot (De Groot *et al.*, 2010), le comunità beneficiano solo di una parte dei servizi ecosistemici, mentre la scala paesaggistica riduce la distanza tra gli attori locali e l'ambiente, amplificando i servizi fruibili. In questa prospettiva, la categoria paesaggio può essere considerata come un sistema umano-ecologico in grado di offrire una vasta gamma di benefici, resi significativi dagli esseri umani in quanto valutati sulla base di valori ecologici, socio-culturali e economici (Chee, 2004; De Fries *et al.*, 2004; De Groot, 2006). Gli studi sui servizi degli ecosistemi sono stati approfonditi a partire dagli anni '90 (Costanza, 1997; Daily, 1997; De Groot *et al.*, 2002). Tali servizi sono stati classificati secondo categorie funzionali, categorie organizzative riferite ad entità biotiche, o categorie descrittive (Tab. 1).
Il *Millennium Ecosystem Assessment Framework* (MEA) nel 2005 individua quattro categorie di servizi, sintetizzando gli studi precedenti nell'ottica della valutazione dei benefici che l'uomo ottiene dagli ecosistemi (Tab. 2).

Tab. 1 – Classificazioni delle categorie e dei relativi servizi ecosistemici

Autori	**Categoria ecosistemica**	**Servizi ecosistemici**
Lobo (2001); De Groot *et al.* (2002)	Funzionale	Servizi di regolazione, approvvigionamento, habitat, produzione e informazione
Norberg (2009)	Organizzativa	Servizi associati a specie particolari, che regolano input esogeni specifici, o che sono correlati alla organizzazione di entità biotiche
Moberg e Folke (1999)	Descrittiva	Beni e risorse rinnovabili, beni e risorse non rinnovabili, servizi biogeochimici, servizi di informazione, servizi sociali e culturali

Tab. 2 – Classificazione dei servizi ecosistemici secondo MEA

Servizi di approvvigionamento (prodotti ottenuti dagli ecosistemi)	**Servizi di regolazione** (benefici ottenuti dalla regolazione dei processi ecosistemici)	**Servizi culturali** (benefici immateriali ottenuti dagli ecosistemi)	**Servizi di supporto** (servizi per la produzione di tutti gli altri servizi)
Produzione di alimenti	Regolazione del clima	Servizi spirituali e religiosi	Formazione del suolo
Accumulo di acqua	Regolazione di malattie	Servizi ricreativi ed ecoturismo	Cicli nutritivi
Materiali	Regolazione delle acque	Servizi estetici	Produzione di elementi primari
Fibre	Purificazione delle acque	Servizi di ispirazione	
Elementi biochimici	Impollinazione	Servizi educativi	
Risorse generiche		Senso del luogo	
		Patrimonio culturale	

Fonte: MEA (2005)

Pur individuando in maniera completa le categorie e sotto-categorie di servizi fruibili direttamente o indirettamente dall'uomo, l'approccio MEA è applicato alla scala degli ecosistemi e non rispecchia completamente i servizi fruibili alla scala del paesaggio. Gli studi sui servizi degli ecosistemi si sono diversificati recentemente sulla base delle categorie e degli indicatori forniti da MEA. L'iniziativa *The Economics of Ecosystems and Biodiversity* (TEEB), nel 2010, ha sviluppato un sistema di indicatori per la valutazione ed il monitoraggio della biodiversità a scala globale, reinterpretando le categorie di servizi. Sulla base delle definizioni di MEA, TEEB e de Groot, il recente studio di Maes (Maes, 2013) propone tre macro categorie di servizi del paesaggio al fine di uniformare le ricerche sul paesaggio a livello europeo: *provisioning* (approvvigionamento e utilizzo dell'ambiente naturale per usi antropici), *regulating and maintenance* (regolazione e mantenimento degli equilibri naturali), *cultural* (funzioni culturali materiali e immateriali).

La necessità di impiego efficace delle risorse nella pianificazione delle azioni di tutela e valorizzazione dei paesaggi culturali richiama l'esigenza di metodologie di valutazione integrate e spaziali capaci di coinvolgere le conoscenze ed esaminare i benefici dei portatori di interesse locali, relazionando ciò che viene valutato in una precisa localizzazione geografica. I processi decisionali devono essere supportati da sistemi valutativi in grado di esplicitare le complessità del paesaggio e definire in maniera trasparente ed efficace le priorità di azione.

3. Il processo di valutazione

Scopo di questo lavoro è identificare e valutare i servizi attribuibili al paesaggio terrazzato.
Sulla base della letteratura, i servizi relativi al paesaggio agricolo terrazzato sono classificabili in tre categorie: approvvigionamento, regolazione e mantenimento, servizi culturali (Maes, 2013).
In particolare, i servizi di approvvigionamento alla scala del paesaggio sono definiti come i materiali e l'energia storicamente prodotti nel paesaggio culturale. I servizi di regolazione e mantenimento sono definiti come i servizi che regolano e mantengono gli equilibri ambientali, idrogeologici e la biodiversità del paesaggio, fornendo benefici indiretti all'uomo che ne fruisce. I servizi culturali, invece, sono definiti come i servizi immateriali che derivano dall'esistenza del paesaggio culturale (TEEB, 2010).
L'obiettivo di questo lavoro è la selezione di indicatori chiave per la valutazione dei servizi del paesaggio culturale terrazzato. Sulla base della letteratura, sono stati selezionati gli indicatori associati ad ogni categoria di servizi del paesaggio e successivamente, attraverso due *focus group* con esperti e stakeholder locali, è stato attribuito un peso specifico ad ogni indicatore utilizzando il metodo *Analityc Hierarchy Process* (AHP) (Saaty, 1977; Saaty, 1980; Saaty, 1992). In questa sezione viene esplicitata la metodologia utilizzata per l'attribuzione dei pesi agli indicatori selezionati e vengono descritti i risultati della valutazione.
La metodologia proposta assume che il giudizio di esperti e stakeholder locali sia significativo per le valutazioni relative al paesaggio (Maes, 2013). Sulla base degli indicatori proposti dagli studi di riferimento relativi ai servizi del paesaggio, sono stati selezionati gli indicatori di riferimento per le tre categorie di servizi. Gli studi confrontati sono in particolare il *report* MEA, gli studi di De Groot, il sistema di classificazione TEEB ed il sistema di classificazione e valutazione denominato CICES (*Common International Classification of Ecosystem Services*), proposto recentemente al fine di uniformare le valutazioni a livello europeo (Maes, 2013).
Il *set* di indicatori risultanti dall'analisi della letteratura scientifica è stato quindi sottoposto ad un primo *screening* da cui sono stati selezionati gli indicatori specifici del paesaggio terrazzato (Tab. 3).
Nello specifico, tra gli indicatori proposti, aggregati secondo le tre categorie principali, sono stati selezionati quelli applicabili alla scala del paesaggio, tralasciando i servizi apprezzabili solo alla scala più ampia degli ecosistemi naturali, i cui benefici, pur di importanza fondamentale per la sopravvivenza delle specie viventi, non sono apprezzabili alla scala del paesaggio.
La metodologia proposta per la valutazione degli indicatori prevede una fase di conoscenza, caratterizzata dall'acquisizione di dati di tipo *hard* e *soft* (Checkland, 1981) tramite ricerche in letteratura, analisi territoriali e coinvolgimento di esperti e stakeholder locali.

Successivamente, la seconda fase prevede l'assegnazione di pesi agli indicatori, allo scopo di utilizzare il quadro risultante per il *mapping* e l'analisi spaziale dei servizi del paesaggio terrazzato con strumenti GIS (Joerin *et al.*, 2001; Marinoni, 2004; Cerreta e De Toro, 2010) (Fig. 2).

Tab. 3 – Subcategorie / Indicatori di servizi

Categoria di servizi	MEA (2005)	De Groot (2010)	TEEB (2010)	CICES (2013)	Subcategorie/ indicatori di servizi
Servizi di approvvigionamento	*	*	*	*	Produzione di alimenti
	*	*	*	*	Approvvigionamento di materiali per usi non alimentari
	*	*	*	*	Capacità di accumulo delle riserve di acqua
	*	*	*		Risorse medicinali
Servizi di regolazione e mantenimento	*	*	*	*	Qualità dell'aria e del clima
		*	*	*	Assorbimento di anidride carbonica
	*	*	*	*	Stabilità idrogeologica dei versanti
	*	*	*		Resilienza ad eventi catastrofici
	*	*	*	*	Filtrazione di agenti patogeni
	*	*	*	*	Prevenzione dell'erosione
	*	*	*	*	Mantenimento della fertilità del suolo
	*	*	*		Impollinazione
	*	*	*	*	Controllo biologico
		*	*		Habitat per flora e fauna
	*	*	*		Mantenimento della diversità genetica
Servizi culturali	*	*	*	*	Servizi ricreativi e benessere psico-fisico
	*	*	*	*	Servizi estetici e di ispirazione per arte, cultura e design
	*	*	*	*	Esperienza spirituale e senso del luogo/identità
	*				Conservazione del patrimonio di conoscenze tradizionali
	*	*			Servizi scientifici ed educativi
	*				Conservazione del patrimonio culturale materiale

Per poter procedere alla assegnazione di pesi ai criteri specifici ed alla selezione di indicatori chiave in relazione al paesaggio terrazzato, un gruppo di esperti è stato coinvolto nel processo valutativo. La prima fase di *screening* si è conclusa con l'aggregazione in gruppi di indicatori specificamente connessi al paesaggio culturale terrazzato, con l'obiettivo di ridurre le ridondanze tra gli indicatori.

Fig. 2 – Le fasi della valutazione

La fase successiva si è svolta con l'elaborazione di un questionario valutativo basato sulla metodologia AHP per l'assegnazione di pesi agli indicatori. Gli indicatori così selezionati rappresentano un input fondamentale per poter effettuare successivamente il *mapping* dei servizi del paesaggio terrazzato.

Nonostante l'ampia letteratura sul tema dei servizi ecosistemici e dei servizi del paesaggio, sono pochi gli approfondimenti metodologici sulla valutazione dei servizi e benefici del paesaggio culturale agricolo, ed in particolare del paesaggio terrazzato (Koohafkan e Altieri, 2012). In generale, gli studi esistenti si concentrano sulla valutazione dei servizi culturali, che risultano fondamentali per l'elaborazione di mappe di valore del paesaggio (Milcu *et al.*, 2013; Plieninger *et al.*, 2013; Nahuelhual *et al.*, 2014), ma che possono essere fruiti solo in relazione ed in sinergia con altre tipologie di servizi. Questo risulta particolarmente valido nel caso dei paesaggi agricoli e terrazzati, che hanno avuto storicamente funzioni di approvvigionamento, regolazione e mantenimento dell'ambiente naturale, senza le quali le civiltà locali storicamente insediate non avrebbero potuto svilupparsi (UNESCO, 2013b).

Gli indicatori sono stati quindi aggregati per tipologie funzionali, risultanti in 15 indicatori sintetici applicabili al paesaggio terrazzato (Tab. 4).

Per poter assegnare i pesi agli indicatori è stato utilizzato il metodo gerarchico AHP, tramite l'elaborazione di un questionario semi-strutturato somministrato agli esperti

coinvolti. Il metodo AHP è stato ampiamente sperimentato negli ultimi decenni, sono quindi conosciuti nel campo scientifico i vantaggi ed i limiti dello stesso. Il metodo prevede la costruzione di una struttura gerarchica, rappresentata in questo caso dalle categorie e dagli indicatori del paesaggio terrazzato, quindi il confronto a coppie tra gli elementi da valutare, assegnando una priorità relativa ad ognuno degli elementi delle coppie proposte ed elaborando i risultati ottenuti attraverso la costruzione di matrici dei confronti.

Tab. 4 – Indicatori di servizi selezionati

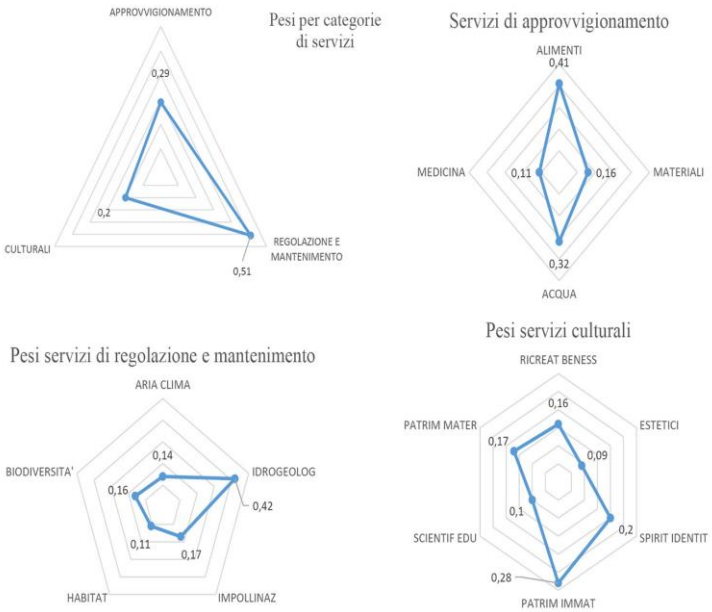
Categoria	**Gruppi di indicatori selezionati**
Servizi di approvvigionamento	1 Produzione di alimenti
	2 Approvvigionamento di materiali per usi non alimentari
	3 Capacità di accumulo delle riserve di acqua
	4 Risorse medicinali
Servizi di regolazione e mantenimento	5 Qualità dell'aria e del clima; Assorbimento di anidride carbonica
	6 Stabilità idrogeologica dei versanti; Resilienza ad eventi catastrofici; Prevenzione dell'erosione; Mantenimento della fertilità del suolo
	7 Impollinazione
	8 Habitat per Flora e Fauna
	9 Mantenimento della biodiversità agraria
Servizi culturali	10 Servizi ricreativi e benessere psico-fisico
	11 Servizi estetici e di ispirazione per arte, cultura e design
	12 Esperienza spirituale e identità culturale
	13 Conservazione del patrimonio di conoscenze tradizionali
	14 Servizi scientifici ed educativi
	15 Conservazione del patrimonio culturale materiale

Gli intervistati sono stati selezionati in modo da comprendere rappresentanti del mondo accademico ed esperti nel campo della pianificazione urbana e territoriale, valutazione ambientale strategica, scienze chimiche e biologiche e sviluppo sostenibile, inoltre sono stati selezionati amministratori e politici locali e rappresentanti di associazioni di produttori e consumatori di prodotti agricoli (gruppi di acquisto solidale) (Fig. 3). Il questionario è stato strutturato in tre sezioni: nella prima sezione introduttiva sono presentati temi e obiettivi della ricerca, sono descritte dettagliatamente le categorie di servizi e sono raccolte le informazioni personali in forma anonima; la seconda sezione comprende la valutazione delle categorie attraverso due metodi di risposta, il primo in cui si chiede di ordinare per priorità le categorie di servizi, il secondo mediante confronti a coppie tra le tre categorie; la terza sezione, infine, contiene la valutazione degli indicatori effettuata separatamente per ogni categoria, anche in questo caso attraverso due tipologie di risposta, l'assegnazione di priorità ed i confronti a coppie. L'utilizzo di due metodi di risposta congiunti permette di ridurre le possibili deformazioni dovute ad incertezze o incongruenze nella valutazione degli esperti. Gli indici di coerenza sono risultati accettabili. L'assegnazione di priorità ed il

confronto a coppie hanno permesso di attribuire un ordine di priorità alle categorie ed agli indicatori del paesaggio terrazzato (Fig. 4).

Fig. 3 – Categorie di esperti e stakeholder coinvolti

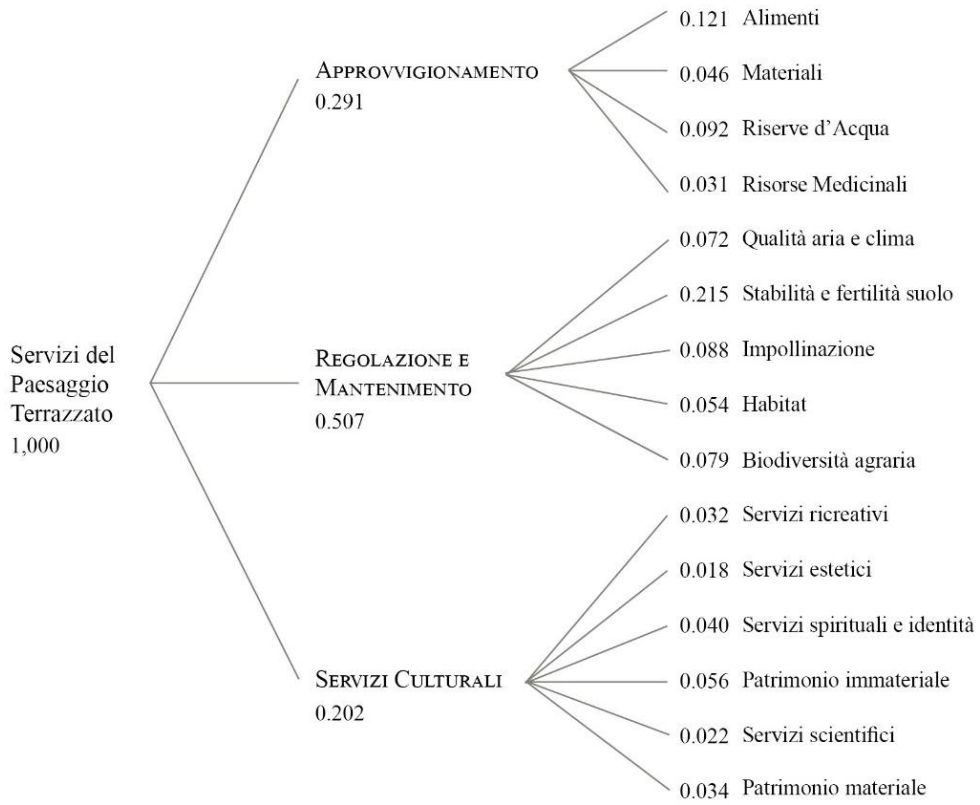
Fig. 4 – Priorità attribuite a categorie e indicatori di servizi del paesaggio terrazzato



4. Risultati

La sperimentazione ha coinvolto quattro categorie di esperti e stakeholder locali, per un totale di sei intervistati. Il numero ridotto di intervistati è da considerare accettabile per la fase preliminare di test e verifica del questionario valutativo. I risultati ottenuti hanno permesso di confrontare gli indicatori proposti ed assegnare i pesi globali considerando i valori attribuiti alle categorie di servizi del paesaggio (Fig. 5).

Fig. 5 – Pesi globali attribuiti ai servizi del paesaggio terrazzato



I valori risultanti evidenziano come i servizi di regolazione e mantenimento siano considerati prioritari rispetto alle categorie di approvvigionamento e di servizi culturali. In particolare, va notato che il mantenimento della stabilità idrogeologica e della fertilità del suolo risultano servizi prioritari per il territorio terrazzato, seguiti dall'indicatore di approvvigionamento di prodotti alimentari. Questi valori sembrano coerenti con gli studi recenti sui servizi e benefici del paesaggio terrazzato (Nahuelhual *et al.,* 2014; Tarolli *et al.,* 2014), mentre la stretta relazione tra stabilità idrogeologica e coltivazione dei terrazzamenti agricoli trova conferma nel rapporto ISPRA (2013).

In base ai pesi globali attribuiti, è stato possibile evidenziare i servizi prioritari nella valutazione dei servizi del paesaggio terrazzato (Tab. 5).

Tab. 5 – Ordine di priorità degli indicatori, relativi ai servizi ecosistemici di regolazione e mantenimento (RM), di approvvigionamento (P), culturali (C)

Indicatori	Tipologia di servizi	Peso	Totale (%)
Stabilità idrogeologica dei versanti; Resilienza ad eventi catastrofici; Prevenzione dell'erosione; Mantenimento della fertilità del suolo	RM	0,215	59,5%
Produzione di alimenti	P	0,121	
Capacità di accumulo delle riserve di acqua	P	0,092	
Impollinazione	RM	0,088	
Mantenimento della biodiversità agraria	RM	0,079	
Qualità dell'aria e del clima; Assorbimento di anidride carbonica	RM	0,072	26,8%
Conservazione del patrimonio di conoscenze tradizionali	C	0,056	
Habitat per Flora e Fauna	RM	0,054	
Approvvigionamento di materiali per usi non alimentari	P	0,046	
Esperienza spirituale e identità culturale	C	0,040	
Conservazione del patrimonio culturale materiale	C	0,034	13,7%
Servizi ricreativi e benessere psico-fisico	C	0,032	
Risorse medicinali	P	0,031	
Servizi scientifici ed educativi	C	0,022	
Servizi estetici e di ispirazione per arte, cultura e design	C	0,018	

La tabella mostra come il 60% circa dei benefici fruiti dall'uomo nel paesaggio terrazzato derivi da servizi di regolazione (RM) e approvvigionamento (P). In particolare, si nota che la capacità di accumulo delle riserve di acqua incide in maniera significativa sul totale dei pesi assegnati. Nel caso in esame della Costiera Amalfitana, il sistema capillare di canalizzazioni idriche e cisterne di raccolta delle acque connota il paesaggio terrazzato contribuendo a determinare il carattere di unicità del territorio (Laureano, 2004; World Heritage Centre, 2014). I risultati sembrano quindi coerenti con le caratteristiche e le specificità del territorio di studio.

Resta da considerare la debole priorità assegnata dal campione di esperti coinvolti alla categoria di servizi culturali (C). Tali servizi sono oggetto di numerosi studi sperimentali che ne evidenziano l'importanza in relazione al senso di identità (Fagerholm *et al.,* 2012), agli aspetti economici legati al turismo (Casado-Arzuaga *et al.,* 2014), ed alla conservazione del patrimonio culturale (Luesink, 2013), ciononostante i risultati ottenuti

sembrerebbero in contrasto con la letteratura. Allo scopo di approfondire la comprensione dei risultati, sono stati ricalcolati i valori globali assegnando uguale priorità alle tre categorie di servizi del paesaggio.
Dal confronto è emersa una possibile deformazione che è possibile attribuire al campione limitato di intervistati ed alle competenze ed interessi specifici dei rispondenti.
La maggioranza degli intervistati, infatti, possiede una conoscenza specifica del paesaggio terrazzato della Costiera Amalfitana con riferimento in particolare agli aspetti di tutela ambientale e recupero del paesaggio agricolo.
I risultati dell'analisi effettuata hanno evidenziato una relativa stabilità dei valori estremi, mentre i pesi globali assegnati agli indicatori di servizi culturali hanno mostrato una variabilità elevata (Tab. 6). I pesi globali attribuiti ad ogni indicatore derivano dalla struttura gerarchica propria della metodologia AHP. Nel secondo caso, infatti, il confronto è stato effettuato assegnando un peso pari a 0,333 ad ognuna delle categorie di servizi del paesaggio.

Tab. 6 – Assegnazione dei pesi globali assegnando valori differenziati (1) o uguali (2) al livello gerarchico delle categorie di servizi

Indicatori	**Pesi globali (1)**	**Indicatori**	**Pesi globali (2)**
Stabilità idrogeologica	0,215	Stabilità idrogeologica	0,141
Produzione di alimenti	0,121	Produzione di alimenti	0,139
Accumulo riserve di acqua	0,092	Accumulo riserve di acqua	0,106
Impollinazione	0,088	Patrimonio immateriale	0,093
Biodiversità agraria	0,079	Identità culturale	0,066
Qualità dell'aria e del clima	0,072	Impollinazione	0,058
Patrimonio immateriale	0,056	Patrimonio culturale materiale	0,056
Habitat per Flora e Fauna	0,054	Materiali non alimentari	0,053
Materiali non alimentari	0,046	Biodiversità agraria	0,052
Identità culturale	0,04	Servizi ricreativi e benessere	0,052
Patrimonio culturale materiale	0,034	Qualità dell'aria e del clima	0,047
Servizi ricreativi e benessere	0,032	Risorse medicinali	0,036
Risorse medicinali	0,031	Servizi scientifici ed educativi	0,036
Servizi scientifici ed educativi	0,022	Habitat per Flora e Fauna	0,035
Servizi estetici e di ispirazione	0,018	Servizi estetici e di ispirazione	0,03

5. Conclusioni

Le analisi svolte hanno evidenziato la praticabilità della metodologia e le implementazioni possibili allo scopo di minimizzare le deformazioni dovute alla selezione del campione di intervistati ed alla strutturazione del questionario valutativo.
La metodologia valutativa proposta è risultata attendibile nonostante il campione di esperti limitato, sembrerebbe quindi interessante la possibilità di ampliare il numero di stakeholder coinvolti per convalidare i risultati e costruire un quadro strutturato e dinamico di indicatori da utilizzare per il *mapping* ed il monitoraggio dei servizi del paesaggio culturale

terrazzato. Recenti studi ed esperienze integrano le valutazioni multicriterio all'interno dei software GIS per il *mapping* dei servizi e dei benefici del paesaggio (Cerreta e De Toro, 2010; Nahuelhual *et al.,* 2014; Ungaro *et al.,* 2014). I valori ottenuti con l'applicazione della metodologia sperimentata possono essere utilizzati per l'elaborazione di mappe di servizi del paesaggio terrazzato. L'attribuzione di pesi e priorità è un'operazione fondamentale rispetto alle fasi di *mapping* e costruzione di un quadro di monitoraggio per la valutazione degli impatti di politiche e programmi per il paesaggio terrazzato, inoltre può fornire un contributo prezioso nell'ottica della catalogazione e del confronto tra le strategie messe in campo in diversi contesti per la conservazione dei sistemi terrazzati (OECD Better Life Index, 2014a; OECD Regional Well-Being, 2014b).

E' necessario evidenziare che la metodologia proposta ha come obiettivo la valutazione dei servizi fruibili grazie all'esistenza del paesaggio terrazzato, i quali sono rilevati e mappati all'interno degli ambiti territoriali in cui esiste il paesaggio culturale, mentre il valore immateriale dello stesso deve essere rilevato anche al di fuori dei confini territoriali e valutato con tecniche in grado di rilevare e quantificare i valori indipendenti dall'uso (Navrud e Ready 2002; Nahuelhual *et al.*, 2014).

La valutazione effettuata con il coinvolgimento di esperti ha permesso di attribuire priorità e pesi agli indicatori analizzati, e di valutare gli stessi indicatori in ottica multidisciplinare. Questo processo risulta scalabile e applicabile in diversi contesti. Le sinergie o i conflitti che possono emergere dall'analisi delle preferenze per diverse categorie di stakeholder sono evidenze necessarie per la determinazione di scenari evolutivi alternativi (Attardi *et al.*, 2014; Magnaghi, 2007).

Inoltre, l'analisi delle relazioni (sinergie o conflitti) tra i servizi del paesaggio permette di evidenziare e mappare le criticità e le potenzialità del territorio nell'ottica della tutela e della valorizzazione del paesaggio culturale (Fusco Girard *et al.*, 2007; Hermann *et al.*, 2013).

La metodologia proposta, applicata su larga scala ed integrata in un quadro di monitoraggio dinamico, può configurarsi come un utile strumento per il miglioramento della trasparenza e dell'inclusione nei processi decisionali, oltre ad offrire un valido supporto per la comprensione dei processi in atto, la selezione di buone pratiche trasferibili in contesti diversi e la valutazione degli impatti delle azioni e delle decisioni sulla conservazione e valorizzazione dei paesaggi culturali terrazzati.

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INVESTIGATING CONDITIONS ENSURING RELIABILITY OF THE PRIORITY VECTORS

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Abstract

In this paper, we investigate conditions, weaker than consistency, that a pairwise comparison matrix has to satisfy in order to ensure that priority vectors proposed in literature are ordinal evaluation vectors for the actual ranking.
In particular, we introduce a partial order on the rows of a pairwise comparison matrix; if it is a simple order, then the matrix is transitive, the actual ranking is easily established and priority vectors are ordinal evaluation vectors for the actual ranking.

Keywords: pairwise comparison matrices, ordinal evaluation vectors, simple order

INDAGARE LE CONDIZIONI CHE ASSICURINO L'AFFIDABILITÀ DEI VETTORI PRIORITÀ

Sommario

In questo articolo, analizziamo le condizioni, più deboli della consistenza, che una matrice di confronti a coppie dovrebbe soddisfare affinché i vettori priorità proposti in letteratura siano vettori di valutazione ordinale.
In particolare, introduciamo una relazione di ordine parziale sulle righe di una matrice di confronti a coppie; se tale relazione rappresenta un ordine semplice, allora la matrice è transitiva, ed è possibile stabilire in maniera semplice l'effettivo ordinamento e i vettori priorità sono vettori di valutazione ordinale.

Parole chiave: matrici di confronto a coppie, vettori di valutazione ordinale, relazione di ordine semplice

1. Introduction

Most decision processes related to planning, territory government, technology transfer, transportation, conflict resolution etc. involve a multiplicity of criteria and sub-objectives (e.g. economic and social), the satisfaction of which is crucial in building the best alternative.

The pairwise comparisons are an essential tool to establish the relative importance of criteria or sub-objectives that are measurable in different scales. In fact, they constitute the crucial tool of the Analytic Hierarchy Process (AHP) (Saaty, 1977, 1980, 1986, 2008), a Multi-Criteria method introduced by Saaty (1977) for evaluating alternatives.

The AHP organizes the elements of the decision process in a hierarchy and uses the pairwise comparisons for getting a weighted ranking of the elements of a level with respect to an element in the upper level; then the local weights of the elements of each level are combined to get the global weights of the alternatives.

Unfortunately, it may happen that the methods proposed in literature for obtaining weighted rankings for alternatives/criteria are not reliable. In this paper, we focus on this problem and propose a condition that ensures the reliability of these methods.

The paper is organized as follows: in Section 2, we introduce Multiplicative Pairwise Comparison Matrices (MPCMs) and a partial order $\trianglerighteq$ on the rows of a matrix, we focus on transitive matrices and consistent matrices and show that if a matrix is transitive, but not consistent, then it may be that priority vectors proposed in literature are not reliable; in Section 3, we prove that if $\trianglerighteq$ is a simple order, then the matrix is transitive and the priority vectors provide reliable weighted ranking; in Section 4, we provide concluding remarks and directions for future work.

2. Multiplicative pairwise comparison matrices and priority vectors

Let $X = \{x_1, x_2, ..., x_n\}$ be a set of decision elements such as criteria or alternatives and

$$A = (a_{ij}) = \begin{pmatrix} 1 & a_{12} & \dots & a_{1n} \\ a_{21} & 1 & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & \dots & 1 \end{pmatrix} \tag{1}$$

the related MPCM. Thus, the entry a_{ij} is a positive number that represents the preference ratio of x_i over x_j: so $a_{ij} = 1$ if and only if there is indifference between x_i and x_j, $a_{ij} > 1$ if and only if x_i is strictly preferred to x_j, whereas $a_{ij} < 1$ expresses the reverse preference.

For an algebraic approach to pairwise comparison matrices, see Cavallo (2014), Cavallo and D'Apuzzo (2009, 2010, 2012, 2014) and Cavallo *et al.* (2012).

For MPCMs, the following condition of reciprocity:

$$a_{ji} = \frac{1}{a_{ij}} \quad \forall i, j \in \{1,2,\dots,n\} \tag{2}$$

is assumed.

Under assumption of reciprocity, we set:

$$x_i \succ x_j \Leftrightarrow a_{ij} > 1, \qquad x_i \sim x_j \Leftrightarrow a_{ij} = 1, \tag{3}$$

where $x_i \succ x_j$ and $x_i \sim x_j$ stand for "x_i is strictly preferred to x_j" and "x_i and x_j are indifferent", respectively.
Moreover, we set:

$$x_i \succsim x_j \Leftrightarrow (x_i \succ x_j \ or \ x_i \sim x_j) \Leftrightarrow a_{ij} \geq 1, \tag{4}$$

that stands for "x_i is weakly preferred to x_j".
The relation $\succ$ is asymmetric, the relation $\sim$ is reflexive and symmetric and

$$x_i \succ x_j \ \ or \ \ x_i \sim x_j \ \ or \ \ x_j \succ x_i \quad \forall i, j \in \{1,2,\ldots,n\}. \tag{5}$$

The relation $\succsim$ is strongly complete, that is:

$$x_i \succsim x_j \quad or \quad x_j \succsim x_i \quad \forall i, j \in \{1,2,\ldots,n\}; \tag{6}$$

thus, if $\succsim$ is a transitive relation, then $\succsim$ is a weak order (Roberts, 1979).
The transitivity of $\succsim$ is the minimal logical requirement and a fundamental principle that preference relations should satisfy; the transitivity is in fact acyclic about the alternatives or criteria ranking. If $\succsim$ is transitive, then there is a rearrangement $(i_1, i_2, \cdots, i_n)$ of $\{1,2,\cdots,n\}$ such that:

$$x_{i_1} \succsim x_{i_2} \succsim \ldots \succsim x_{i_n}. \tag{7}$$

We call (7) the actual ranking on X.

Order relations on the rows set of $A = (a_{ij})$

Let $\underline{a}_i = (a_{i1}, a_{i2}, \ldots, a_{in})$ be the i-th row of $A = (a_{ij})$ and $R_A = \{\underline{a}_1, \underline{a}_2, \ldots, \underline{a}_n\}$ the rows set of $A = (a_{ij})$. Then, we consider the following order relations:

– $\rhd$ the strict partial order (i.e. $\rhd$ is transitive and asymmetric; see Roberts, 1979) on R_A defined by:

$$\underline{a}_r \rhd \underline{a}_s \Leftrightarrow a_{rj} > b_{sj}, \forall j \in \{1,2,\ldots,n\}; \tag{8}$$

– $\trianglerighteq$ the partial order (i.e. $\trianglerighteq$ is reflexive, antisymmetric and transitive, see (Roberts, 1979)) on R_A defined by:

$$\underline{a}_r \trianglerighteq \underline{a}_s \Leftrightarrow \underline{a}_r \rhd \underline{a}_s \ or \ \underline{a}_r = \underline{a}_s. \tag{9}$$

We stress that if $\trianglerighteq$ is strongly complete, that is:

$$\forall \underline{a}_r, \underline{a}_s \in R_A \quad \underline{a}_r \trianglerighteq \underline{a}_s \ or \ \underline{a}_s \trianglerighteq \underline{a}_r, \tag{10}$$

then $\trianglerighteq$ is a simple order see (Roberts, 1979).

Transitive MPCMs and ordinal evaluation vectors
Cavallo and D'Apuzzo (2014) provide the notion of transitivity for a matrix defined over an abelian linearly ordered group; by considering MPCMs, we have the following definition:

Definition 1
$A = (a_{ij})$ transitive if and only

$$a_{ij} \geq 1 \quad a_{jk} \geq 1 \Rightarrow a_{ik} \geq 1. \tag{11}$$

Let $A=(a_{ij})$ be a reciprocal MPCM. By reciprocity, implication in (11) is equivalent to the following implications:

$$a_{ij}>1 \quad a_{jk}>1 \Rightarrow a_{ik}>1, \qquad a_{ij}=1 \quad a_{jk}=1 \Rightarrow a_{ik}=1. \tag{12}$$

Proposition 1
$A=(a_{ij})$ is transitive if and only $\succsim$ is a transitive relation.
Proof.
By Definition 1 and equation(4).

Thus, if $A=(a_{ij})$ is transitive, the actual ranking on X is achievable.

Definition 2 (Cavallo and D'Apuzzo, 2014)
Let $A=(a_{ij})$ be transitive. A positive vector $\underline{w}=(w_1,w_2,\ldots,w_n)$ is an ordinal evaluation vector for the ranking in (7) if and only if

$$w_i>w_j \Leftrightarrow x_i \succ x_j \quad \textit{and} \quad w_i=w_j \Leftrightarrow x_i \sim x_j,$$

or, equivalently:

$$w_i \geq w_j \Leftrightarrow x_i \succsim x_j.$$

Consistent MPCMs
In an ideal situation, in which the Decision Maker is strongly coherent when stating his/her preferences, Cavallo and D'Apuzzo (2014) provide the notion of consistency for a matrix defined over an abelian linearly ordered group; by considering MPCMs, we have the following condition:

$$a_{ij}a_{jk}=a_{ik} \quad \forall i,j,k \in \{1,2,\ldots,n\}. \tag{13}$$

Under assumption of reciprocity in (2), the consistency condition in (13) implies the transitivity condition in (11) (Cavallo and D'Apuzzo, 2014) and, as a consequence, the actual ranking is established; the reverse implication does not hold (e.g. the MPCM in Example 1 is transitive but no consistent).
Brunelli and Fedrizzi (2014) analyze some inconsistency indices for MCPMs, and Chiclana *et al.* (2009) analyze consistency of fuzzy pairwise comparison matrices.

Example 1
Let us consider the set $X=\{x_1,x_2,x_3,x_4\}$ and the related MPCM:

$$A=\begin{pmatrix} 1 & 2 & 3 & 4 \\ \frac{1}{2} & 1 & 1 & 2 \\ \frac{1}{3} & 1 & 1 & 5 \\ \frac{1}{4} & \frac{1}{2} & \frac{1}{5} & 1 \end{pmatrix}.$$

By inequality $a_{1j} > 1$, for each $j \in \{2,3,4\}$, x_1 is strictly preferred to each other x_j; by equality $a_{23} = 1$, x_2 and x_3 are indifferent; by inequalities $a_{24} > 1$ and $a_{34} > 1$, x_2 and x_3 are strictly preferred to x_4. Thus, the relation $\succsim$ is transitive (i.e. $A = (a_{ij})$ is transitive) and the actual ranking on X is $x_1 \succ x_2 \sim x_3 \succ x_4$.
However, $A = (a_{ij})$ is no consistent (e.g. $a_{13}a_{34} \neq a_{14}$).

The following proposition shows that the consistency condition is equivalent to the proportionality of the rows, and implies that $\trianglerighteq$ is a simple order on the rows.

Proposition 2
The following assertions hold:
1. $A = (a_{ij})$ is consistent if and only if

$$\underline{a}_i = a_{ij}\underline{a}_j \quad \forall i, j \in \{1,2,\ldots,n\}; \tag{14}$$

2. if $A = (a_{ij})$ is consistent, then $\trianglerighteq$ is strongly complete.

Proof.
Equation (13) is equivalent to:

$$\frac{a_{ik}}{a_{jk}} = a_{ij}, \quad \forall i, j, k \in \{1,2,\ldots,n\},$$

that is equivalent to (14).
By (14) and $a_{ij} > 0$, we have:

$$a_{ij} > 1 \Leftrightarrow \underline{a}_i \triangleright \underline{a}_j \quad a_{ij} = 1 \Leftrightarrow \underline{a}_i = \underline{a}_j \quad a_{ij} < 1 \Leftrightarrow \underline{a}_j \triangleright \underline{a}_i,$$

thus, (10) holds.

Priority vectors
In literature, several methods have been proposed to build priority vectors, that are positive vectors $\underline{w} = (w_1, w_2, \ldots, w_n)$ assigning a preference order on X by means of the relations $\succ_{\underline{w}}$ and $\sim_{\underline{w}}$ defined by the following equivalences:

$$x_i \succ_{\underline{w}} x_j \Leftrightarrow w_i > w_j \quad \textit{and} \quad x_i \sim_{\underline{w}} x_j \Leftrightarrow w_i = w_j. \tag{15}$$

Then, given a priority vector $\underline{w} = (w_1, w_2, \ldots, w_n)$, a weighting vector (providing the weights for the decision elements $x_1, x_2, \ldots, x_n$) is the following one:

$$\underline{w}^* = \frac{1}{\sum_{i=1}^{n} w_i}\underline{w}$$

obtained by normalizing $\underline{w}$ up to 1. The vector $\underline{w}^*$ is also called priority dominance vector.

Of course, whenever $A=(a_{ij})$ is transitive, a priority vector is reliable if and only if $\succ_{\underline{w}}$ and $\sim_{\underline{w}}$ coincide with $\succ$ and $\sim$, respectively.

The most used methods for deriving priority vectors from a MPCM are the eigenvector method and the geometric or arithmetic mean (Saaty, 1977; 1980; 1986; 2008; Barzilai, 1997) that provide:

- a right positive eigenvector $\underline{w}_{\lambda_{max}}$ associated with the greatest eigenvalue λ_{max} of $A=(a_{ij})$, that is a positive vector solution of equation $A\underline{w}=\lambda_{max}\underline{w}$;
- the arithmetic mean vector $\underline{w}_{am}=(\frac{1}{n}\sum_{j=1}^{n}a_{1j},\frac{1}{n}\sum_{j=1}^{n}a_{2j},\ldots,\frac{1}{n}\sum_{j=1}^{n}a_{nj})$;
- the geometric mean vector $\underline{w}_{gm}=(\prod_{j=1}^{n}a_{1j}^{\frac{1}{n}},\prod_{j=1}^{n}a_{2j}^{\frac{1}{n}},\ldots,\prod_{j=1}^{n}a_{nj}^{\frac{1}{n}})$.

Under consistency condition in (13), $\underline{w}_{\lambda_{max}}$, $\underline{w}_{am}$ and $\underline{w}_{gm}$ are reliable vectors, because provide a preference order on X equal to the actual ranking.

Unfortunately, condition (13) is hard to reach in real situations; thus, it may happen that $\underline{w}_{\lambda_{max}}$, $\underline{w}_{am}$ and $\underline{w}_{gm}$ are not reliable because they provide a preference order on X different from the actual ranking (see Example 2).

Example 2

Let us consider the MPCM in Example 1. The vectors $\underline{w}_{\lambda_{max}}=(0.82,0.36,0.43,0.15)$, with $\lambda_{max}=4.177$, $\underline{w}_{am}=(2.5,1.12,1.8,0.49)$ and $\underline{w}_{gm}=(2.13,1,1.14,0.4)$ provide the ranking $x_1\succ_{\underline{w}}x_3\succ_{\underline{w}}x_2\succ_{\underline{w}}x_4$ that does not coincide with the actual ranking; so they are not ordinal evaluation vectors.

3. Property of $\trianglerighteq$ ensuring reliability of priority vectors

At the light of the previous considerations, this section aims at establishing a condition stronger than transitivity, but weaker than consistency, under which $\underline{w}_{\lambda_{max}}$, $\underline{w}_{am}$ and $\underline{w}_{gm}$ are ordinal evaluation vectors.

Proposition 3

Let $\trianglerighteq$ be strongly complete. Then, the following equivalences hold:

$$a_{ij}>1\Leftrightarrow \underline{a}_i\triangleright\underline{a}_j \qquad a_{ij}=1\Leftrightarrow \underline{a}_i=\underline{a}_j.$$

Proof.

Let $a_{ij}>1=a_{jj}$. Then, $\underline{a}_i\neq\underline{a}_j$ and, as $\trianglerighteq$ is strongly complete, we get $\underline{a}_i\triangleright\underline{a}_j$. Viceversa, if $\underline{a}_i\triangleright\underline{a}_j$ then $a_{ik}>a_{jk}$ for each k, in particular, for $k=j$, we have $a_{ij}>a_{jj}=1$.

Let $a_{ij}=1=a_{jj}$. Then, as $\trianglerighteq$ is strongly complete, we get $\underline{a}_i=\underline{a}_j$. Viceversa, if $\underline{a}_i=\underline{a}_j$ then $a_{ik}=a_{jk}$ for each k, in particular, for $k=j$, we have $a_{ij}=a_{jj}=1$.

Theorem 1

Let $\trianglerighteq$ be strongly complete. Then, $A=(a_{ij})$ is transitive and $\underline{w}_{\lambda_{max}}$, $\underline{w}_{am}$ and $\underline{w}_{gm}$ are ordinal evaluation vectors for the actual ranking.

Proof.

Let $a_{ij}>1$ and $a_{jk}>1$. By Proposition 3 and transitivity of $\triangleright$, we get $\underline{a}_i \triangleright \underline{a}_j \triangleright \underline{a}_k$. Thus, $a_{ir}>a_{kr}$, for each $r\in\{1,\ldots,n\}$; in particular, for $r=k$, $a_{ik}>a_{kk}=1$.

Let $a_{ij}=1$ and $a_{jk}=1$. By Proposition 3, we get $\underline{a}_i=\underline{a}_j=\underline{a}_k$. Thus, $a_{ir}=a_{kr}$, for each $r\in\{1,\ldots,n\}$; in particular, for $r=k$, $a_{ik}=a_{kk}=1$.

Thus, by (12), $A=(a_{ij})$ is transitive.

Let us denote by w_i, with $i\in\{1,\ldots,n\}$, the i-th component of the vector $\underline{w}_{\lambda_{max}}$, then, by $A\underline{w}_{\lambda_{max}}=\lambda_{max}\underline{w}_{\lambda_{max}}$, we have:

$$w_i=\frac{1}{\lambda_{max}}\sum_{k=1}^{n}a_{ik}w_k. \tag{16}$$

Let us denote by v_i and u_i, with $i\in\{1,\ldots,n\}$, the i-th component of the vectors $\underline{w}_{am}$ and $\underline{w}_{gm}$, respectively.

Let $a_{ij}>1$. By Proposition 3, $\underline{a}_i \triangleright \underline{a}_j$, and as a consequence, we have:

$$\sum_{k=1}^{n}a_{ik}>\sum_{k=1}^{n}a_{jk},\quad \prod_{k=1}^{n}a_{ik}>\prod_{k=1}^{n}a_{jk};$$

thus, $v_i>v_j$ and $u_i>u_j$. Moreover, as $w_i>0$, we have:

$$\sum_{k=1}^{n}a_{ik}w_k>\sum_{k=1}^{n}a_{jk}w_k;$$

thus, by $\lambda_{max}>0$ and (16), $w_i>w_j$.

Viceversa, let $v_i>v_j$ (resp. $w_i>w_j$ and $u_i>u_j$). If ad absurdum $a_{ij}\le 1$ then, by reciprocity, $a_{ji}\ge 1$. Thus, by Proposition 3, we get $\underline{a}_j \trianglerighteq \underline{a}_i$ and, as a consequence $v_j\ge v_i$ (resp. $w_j\ge w_i$ and $u_j\ge u_i$), against the assumption.

Let $a_{ij}=1$. By Proposition 3, $\underline{a}_i=\underline{a}_j$ and, as a consequence, we have:

$$\sum_{k=1}^{n}a_{ik}=\sum_{k=1}^{n}a_{jk},\quad \prod_{k=1}^{n}a_{ik}=\prod_{k=1}^{n}a_{jk};$$

thus, $v_i=v_j$ and $u_i=u_j$. Moreover, as $w_i>0$, we have:

$$\sum_{k=1}^{n}a_{ik}w_k=\sum_{k=1}^{n}a_{jk}w_k;$$

.

thus, by $\lambda_{max} > 0$ and (16), $w_i = w_j$.

Viceversa, let $v_i = v_j$ (resp. $w_i = w_j$ and $u_i = u_j$). If ad absurdum $a_{ij} > 1$ or $a_{ij} < 1$, then, by Proposition 3, $\underline{a}_i \rhd \underline{a}_j$ or $\underline{a}_j \rhd \underline{a}_i$ and, as a consequence $v_i > v_j$ or $v_j > v_i$ (resp. ($w_i > w_j$ or $w_j > w_i$) and ($u_i > u_j$ or $u_j > u_i$)), against the assumption.

Thus, by Definition 2, $\underline{w}_{\lambda_{max}}$, $\underline{w}_{am}$ and $\underline{w}_{gm}$ are ordinal evaluation vectors for the actual ranking.

Of course, by Theorem 1 and Proposition 3, if $\trianglerighteq$ is strongly complete, then the following equivalence holds:

$$(\underline{a}_{i_1} \trianglerighteq \underline{a}_{i_2} \trianglerighteq \ldots \trianglerighteq \underline{a}_{i_n}) \Leftrightarrow (x_{i_1} \succsim x_{i_2} \succsim \ldots \succsim x_{i_n}). \tag{17}$$

Example 3

Let us consider the MPCM

$$A = \begin{pmatrix} 1 & 1 & 3 & 5 \\ 1 & 1 & 3 & 5 \\ \frac{1}{3} & \frac{1}{3} & 1 & 4 \\ \frac{1}{5} & \frac{1}{5} & \frac{1}{4} & 1 \end{pmatrix}.$$

R_A is totally ordered by $\trianglerighteq$; indeed: $\underline{a}_1 = \underline{a}_2 \rhd \underline{a}_3 \rhd \underline{a}_4$. Thus, the actual ranking is

$$x_1 \sim x_2 \succ x_3 \succ x_4.$$

Let us stress that $A = (a_{ij})$ is no consistent because (14) is not verified (e.g. the rows $\underline{a}_2$ and $\underline{a}_3$ are not proportional among them).

Finally, the vectors $\underline{w}_{\lambda_{max}} = (0.67, 0.67, 0.28, 0.11)$, with $\lambda_{max} = 4.097$, $\underline{w}_{am} = (2.5, 2.5, 1.42, 0.41)$ and $\underline{w}_{gm} = (1.97, 1.97, 0.82, 0.32)$ are ordinal evaluation vectors.

4. Conclusions and future work

We introduce a partial order $\trianglerighteq$ on the rows set of a Multiplicative Pairwise Comparison Matrix $A = (a_{ij})$; if $\trianglerighteq$ is a simple order, then $A = (a_{ij})$ is transitive and the right positive eigenvector $\underline{w}_{\lambda_{max}}$, the arithmetic mean vector $\underline{w}_{am}$ and the geometric mean vector $\underline{w}_{gm}$ are ordinal evaluation vectors for the actual ranking.

The ranking on the rows, obtained by means of $\trianglerighteq$, allows us to state the actual ranking on the set X of alternatives/criteria. Moreover, the condition of being $\trianglerighteq$ a simple order is weaker than consistency.

Our future work will be directed to investigate the existence of conditions weaker than simple order ensuring that at least one vector among $\underline{w}_{\lambda_{max}}$, $\underline{w}_{am}$ and $\underline{w}_{gm}$ is still an ordinal evaluation vector.

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I PORTI DI TANGERI: POTENZIALITÀ PER UNO SVILUPPO SOSTENIBILE

Paola Carone

Sommario

I porti costituiscono da sempre i luoghi del dinamismo e del fermento culturale, economico e sociale di città, aree metropolitane ed intere regioni. Essi sono caratterizzati da merci, persone, lingue, culture i cui flussi contribuiscono in modo, apparentemente intangibile, ma in realtà determinante al disegno del contesto urbano di riferimento. Ragionare sulle potenzialità delle città portuali in contesti legati al Sud del Mondo, potrebbe essere un'ulteriore strategia per proporre scenari di sviluppo realmente sostenibile. L'area portuale di Tangeri in Marocco, caratterizzata attualmente da due poli, il porto storico ed il nuovo a 40 km dal precedente Tangeri Med, potrebbe essere un interessante laboratorio per ragionare e proporre strategie, piani e programmi innovativi finalizzati ad uno sviluppo sostenibile a scala locale e globale.

Parole chiave: città portuali, il Mediterraneo, strategie di riqualificazione

PORTS OF TANGIER: SUSTAINABLE DEVELOPMENT POTENTIALITIES

Abstract

Ports have always been places of the liveliness and dynamism of the cultural, economic and social development of cities, metropolitan areas and regions. The life of port areas is characterized by the flows of goods, people, languages, cultures that contribute in a way that seems intangible, but is a determining one actually, to the design of the urban context. Thinking about the potentialities of port cities in contexts related to the South of the World could be a further strategy in order to propose scenarios for really sustainable development of developing countries. The port area of Tangier in Morocco, currently characterized by two poles, the historical old port in the city center and the new one at 40 miles from the previous Tangier Med, could be an interesting laboratory for reasoning and proposing innovative strategies and plans to achieve local and global sustainable development.

Keywords: port cities, the Mediterranean, renewal strategies

1. Le aree portuali come possibili catalizzatori di sviluppo sostenibile

I porti sono i luoghi dove si assiste al più grande fenomeno di osmosi in termini sociali, economici e culturali. Riconoscere, valorizzare e potenziare il rapporto d'interdipendenza tra città e porto diviene sempre più una necessità nonché esigenza. Oggigiorno si tende a proporre approcci sistemici ed innovativi che tengano conto del grandissimo potenziale economico, ambientale, culturale e paesaggistico delle aree portuali e ad analizzarne il potere rigenerativo e trasformativo.

Da sempre, infatti, lo sviluppo dei porti ha determinato oltre al benessere economico una dimensione cosmopolita della vita urbana di riferimento. Si passa dal villaggio di pescatori, come primo insediamento in prossimità dell'acqua, alle stazioni di trasbordo per il trasporto mondiale fino ai mozzi moderni di logistica in fortissima espansione, determinando così grandissime trasformazioni anche di carattere urbano. Il mare, infatti, contribuisce ad influenzare in maniera determinante la struttura economica di una regione, in quanto favorisce la nascita e lo sviluppo di attività economiche grazie al suo essere:

1. una via di comunicazione;
2. una fonte di risorse naturali;
3. la sede per la diffusione di attività turistiche e culturali.

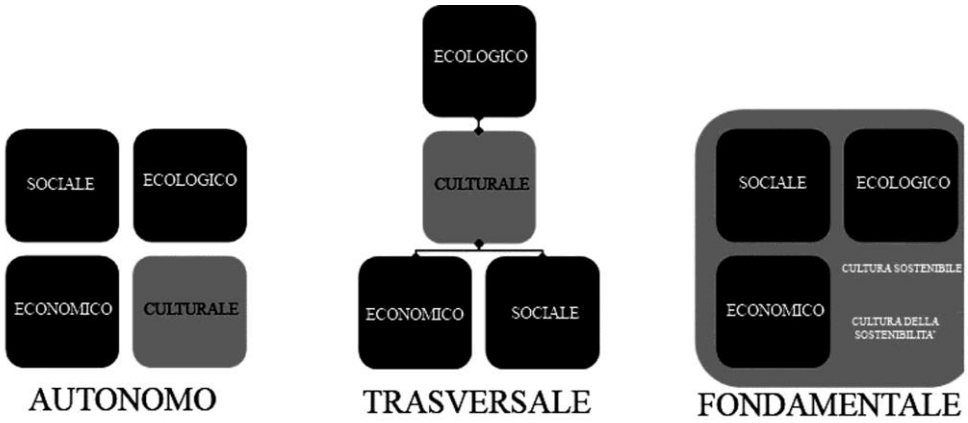
Il processo di sviluppo di vari servizi contribuisce a conferire valore aggiunto al lavoro ed alla produzione, ripercuotendosi sul benessere delle comunità, sul disegno dell'infrastruttura portuale, nonché delle aree urbane di riferimento (Bassett *et al.*, 2002).

Le regioni portuali divengono attrattori per nuove attività produttive, grazie al mercato locale, e determinano in ambito economico, per la città, un processo cumulativo o di "circolo virtuoso" (Musso, 1996). Pertanto si assiste spesso ad aumenti demografici nell'area portuale favoriti dalle attività economiche che creano virtualità localizzativa per altri settori produttivi. Tale processo di crescita demografica ed economica di questo aggregato può così dare luogo alla formazione di vere e proprie aree metropolitane. Quindi, «il porto non è solo il nodo di una rete di trasporto, è soprattutto una geocomunità: sintesi di un territorio e di una società produttrice di spazio e generatrice di relazioni. E' la sintesi tra spazio e comunità, equilibrio tra la globalità delle relazioni e la località delle funzioni. Pianificarlo vuol dire innanzitutto migliorarne la funzione di porta anzi di portale: interfaccia urbana del network di scambi, commerci, viaggi, flussi e prodotti che lo attraversano. Progettarlo significa potenziarne la funzione d'interfaccia con la città, varco attraverso cui transitano merci e persone economie e umanità, desideri e progetti» (Bruttomesso, 2006, p. 23). Ragionare con un atteggiamento creativo, che in maniera integrata paventi idee e strategie innovative, può favorire proposte e soluzioni realmente concorrenziali e vincenti in termini di sviluppo economico, ecologico e sociale. Le città, infatti, generano la più forte percentuale di prodotto interno lordo della ricchezza nazionale sia nei paesi Occidentali sia in quelli del Sud del Mondo e sono i luoghi dove si creano le più grandi opportunità in termini di sviluppo economico, ma anche sociale, ecologico e culturale. «The opportunities that individuals have in the cities to meet each other help them to get ideas and innovate» (Jacobs, 1969, p. 71).

Quelle che riescono a migliorare l'interconnettività e l'interculturalità, potenziando le infrastrutture urbane, il commercio, la mobilità, la circolarizzazione dell'economia intesa come «un acceleratore potente di cooperazione tra soggetti diversi che si scambiano risorse e servizi in modo simbiotico, partendo dal riconoscimento che i benefici riguardano tutti, in una prospettiva di gioco a somma positiva (…) con impatti anche sul piano culturale»

(Fusco Girard, 2012, p. 778) e la valorizzazione delle identità locali, riescono a creare le condizioni per migliorare la qualità della vita garantendo solidarietà e prosperità.
Al contrario le città che, nonostante il loro potenziale di generare ricchezza, non riescono a creare le condizioni per la distribuzione equa del reddito, risorse ed opportunità, rischiano di divenire città sempre più divise. «Cities are the past, the present and the future of humanity» (WUF, 2012, p.1). La recente crisi economica e finanziaria che ha investito i mercati mondiali ha portato a riflettere sempre più su quanto la sola condizione di crescita economica sia effettivamente in grado di favorire il benessere degli individui (Losasso, 2010). Pertanto prende sempre più forma la consapevolezza che l'unico sviluppo possibile risulta essere quello sostenibile, fondato su rapporti sinergici tra economia, ambiente e società e dove l'aspetto culturale risulta essere sempre più un nodo nevralgico (Fig. 1).

Fig. 1 - Schemi sull'evoluzione dell'elemento "cultura" per lo sviluppo sostenibile



Fonte: Pereira Roders (2014)

Alla base di questi concetti emerge anche l'importanza di agire in maniera locale, rispettando e migliorando le condizioni ambientali ed identitarie di un determinato contesto paesaggistico, individuando pertanto politiche e programmi culturali in grado di fornire importanti ricadute sull'occupazione e sulla qualità della vita.
Oggigiorno, tra l'altro, per paesaggio si intende un sistema frutto dell'interazione tra l'ambiente e l'intervento antropico e la sua specifica qualità deve dipendere sempre più dai caratteri oggettivi del territorio e dalle percezioni e aspirazioni della popolazione che viene a contatto con esso. Si può, quindi, introdurre il concetto di sostenibilità per il paesaggio citando «sustainable landscape is one which is able to maintain the outputs of ecosystem goods and services that people value or need, and that the key research focus for Landscape Ecology is to understand the biophysical, social and economic boundaries of the space in which this is possible» (Potschin e Haines-Young, 2006, p. 162). Sulla base delle statistiche, gli studi sulla crescita della popolazione mondiale affermano che:

1. la crescita attuale della popolazione urbana risulta senza precedenti, circa 60 milioni di persone in più ogni anno (WHO, 2014);
2. tali numeri sono destinati a raddoppiare entro il 2050 e triplicare entro il 2100 (Angel, 2012);
3. nei prossimi 30 anni la maggiore crescita della popolazione urbana si avrà nei paesi in via di sviluppo;
4. senza immigrazione (legale e illegale), la popolazione delle città nei paesi occidentali dovrebbe rimanere sostanzialmente invariata o addirittura ridursi (Pereira Roders, 2014; WHO, 2014).

La progettazione urbana nei paesi del Sud del Mondo, soprattutto in Africa e in Asia, ha bisogno di affrontare anche gli effetti della crescita non pianificata che danno luogo a condizioni di povertà diffusa, manifestate sotto il profilo urbano con la proliferazione di *slums*, d'infrastrutture inadeguate e di condizioni ambientali di forte degrado. «I problemi della città non stanno nella città, ma nella povertà di parti crescenti della popolazione urbana, nella sua marginalità sociale ed economica, nell'essere esclusi politicamente, culturalmente e fisicamente da un'idea di città fondata sul collettivo, l'integrazione, la ripartizione, la solidarietà» (Balbo, 1999, p. 16). Una città inclusiva e prospera è consapevole della sua diversità culturale e protegge i diritti di tutti i suoi abitanti. Pertanto attraverso la partecipazione ed il coinvolgimento delle parti interessate nella realizzazione di uno sviluppo urbano sostenibile si favorisce appartenenza ed identità.

Il presente articolo ha l'obiettivo di analizzare l'attuale scenario che caratterizza Tangeri, città a nord del Marocco (Fig. 2), interessante per il suo essere un'area portuale a due poli e per le potenzialità che la sua condizione geopolitica, rivela in termini di sviluppo economico, sociale, ambientale e culturale.

Fig. 2 - Panoramica di un insediamento urbano non pianificato a Tangeri

Foto: Paola Carone

La struttura dell'articolo prevede una rapida analisi delle caratteristiche del nuovo polo di Tangeri Med, al fine di analizzare il cambiamento di funzioni che riguarderà quello storico, localizzato nel centro cittadino e relativamente a quest'ultimo quanto il progetto di riqualificazione proposto possa determinare impatti e cambiamenti sul carattere ed i valori della Medina. Esso non presenta una tesi definitiva, ma descrive una realtà particolarissima nel suo genere in un contesto legato al Sud del Mondo e prova a proporre alcune linee guida per riconoscere e valorizzare gli aspetti storici, culturali, ambientali ed economici della Medina stessa nel suo rapporto con la nuova immagine di *waterfront* proposta. L'obiettivo ultimo è tentare di definire dei punti salienti per poter strutturare una metodologia in grado di analizzare gli impatti e costruire alternative possibili al progetto vincitore, secondo un processo di partecipazione e coinvolgimento della comunità locale.

2. Caso studio: il Marocco ed il suo ruolo strategico sul Mediterraneo

Il Marocco si presenta estremamente interessante sia per la sua posizione geografica, prospiciente al Mediterraneo, sia per le scelte di carattere politico ed economico che ultimamente hanno caratterizzato la nazione, proprio in un'epoca di grandi disordini e disequilibri nelle aree del Maghreb e del Medio Oriente.

A livello internazionale il Mediterraneo è però ancora percepito come un limite da controllare, una linea di confine invalicabile atta ad inibire ed ostacolare il flusso di migranti clandestini, mentre forse sarebbe ideale riproporlo come un'area strategica di collaborazione privilegiata, proprio per il suo ruolo significativo nei traffici mondiali, poiché nuovo corridoio tra la Cina, l'India, il Sud-Est asiatico e l'Europa. Attualmente esso viene definito una specie di «via della seta liquida» (Lemmi e Chieffallo, 2012, p. 21).

La conferenza di Barcellona, tenutasi il 27 e 28 novembre del 1995, infatti, si proponeva di istaurare un mercato di libero scambio tra i paesi aderenti al partenariato Euro-Mediterraneo auspicando un percorso verso una cooperazione economica e culturale tra le sue due sponde, coinvolgendo i paesi dell'Unione Europea e dodici Paesi del Sud del Mediterraneo. In tal modo sarebbe stato possibile favorire una centralità strategica rispetto alle vecchie logiche geopolitiche, sebbene l'intera regione si presentava e si presenta tuttora come un luogo molto complesso e variegato. Nello specifico si proponeva ai paesi aderenti un partenariato di carattere:

1. politico e di sicurezza;
2. economico e finanziario;
3. sociale, culturale e umano.

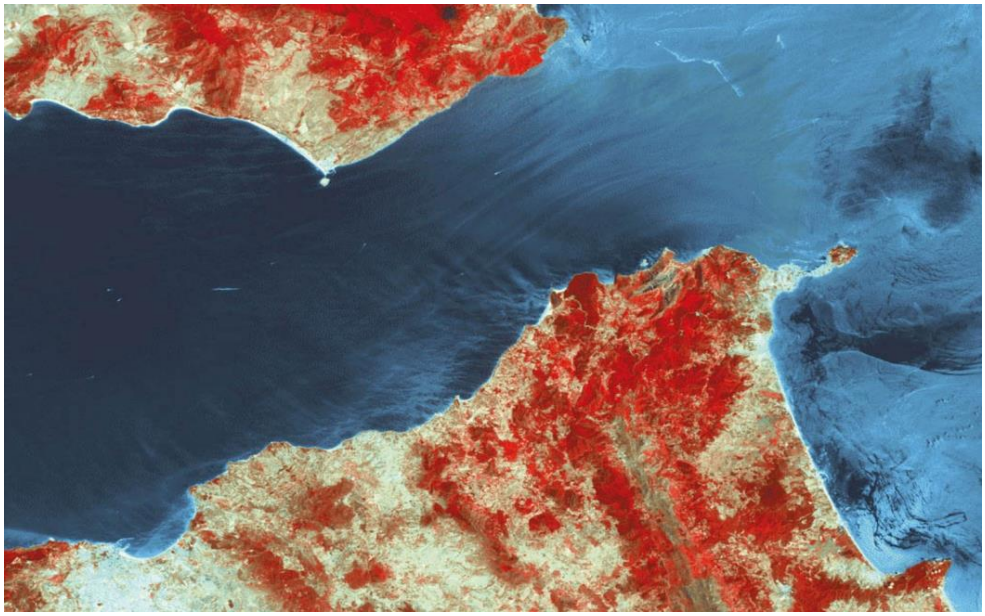
In seguito alla conferenza di Barcellona si sono verificati altri accordi di carattere bilaterale come il Vertice Euro-Mediterraneo di Barcellona 2005, che aggiunge poi il quarto capitolo relativo alla cooperazione in materia di scambi umani, le migrazioni. Altre iniziative si sono verificate nel tempo come "Orizzonte 2020", lanciata dagli stessi ministri nel 2006. Il progetto, patrocinato dall'Unione per il Mediterraneo (UpM), si propone di sviluppare e gestire tre tematiche principali:

1. sostegno all'iniziativa "Orizzonte 2020";
2. aiuto agli investimenti, finalizzati alla riduzione dell'inquinamento nelle aree portuali;
3. strutturazione di una modalità di scambio delle informazioni sul Mediterraneo (CNEL, 2008).

Per ciò che concerne il caso studio e nello specifico la regione di Tangeri-Tétuan a nord del paese (Fig. 3), si evidenzia che il numero di abitanti, secondo l'ultimo censimento

pervenuto dell'UN-Habitat del settembre 2004, è pari a 2.470.372, dato che rappresenta l'8,3 % della popolazione totale di tutto il Marocco e, quindi, una delle più densamente popolate con valori pari a 213 abitanti/km², cinque volte superiore alla media nazionale (42,1 abitanti/km²). La città di Tangeri risulta la terza città marocchina per numero di abitanti (670,000), il nome probabilmente deriva dall'arabo *Tanja* o dal latino *Tingis*, con possibile correzione berbera.

Fig. 3 - Vista aerea della regione di Tangeri Tetuan, cerniera tra Africa ed Europa



Fonte: Societé d'Amenagement pour la Reconversion de la zone Portuaire de Tanger ville (2010)

Tangeri è stata una città che, nel corso dei secoli, ha visto il susseguirsi di molteplici dominazioni: fenicia, cartaginese, romana, vandala, bizantina, araba, portoghese, spagnola e britannica; che ne hanno contribuito a caratterizzare la cultura in maniera estremamente interessante.
Nel 1912, a conclusione della seconda crisi Marocchina, Tangeri fu sottoposta a regime internazionale, che le garantiva totale neutralità politica, militare e amministrativa, quest'ultima gestita da Francia, Gran Bretagna, Spagna, Italia, Portogallo e Belgio, status che permase sino all'indipendenza del Marocco nel 1956.

3. Tangeri ed i suoi due porti, porte del Mediterraneo

Per la sua posizione strategica sul Mediterraneo, Tangeri ha conosciuto nel tempo una crescente fortuna commerciale, grazie anche al suo essere cerniera tra il continente

Africano e quello Europeo, nonché punto di riferimento per il trasporto sull'Atlantico (Fig. 4).

Fig. 4 - Individuazione del porto storico di Tangeri e del legame con la Medina e la città nuova

Foto: Paola Carone

Essa è stata definita la capitale culturale dagli artisti provenienti da tutto il mondo proprio nel periodo in cui era zona internazionale, i quali hanno provveduto con la loro arte a renderla ancora più affascinante, tra l'altro Tangeri negli anni addietro aveva incantato Matisse e Delacroix proprio per il suo forte carattere di essere città di passaggio e di attese (Fig. 5 e Fig. 6).
Paul Bowles, scrittore e compositore americano che trascorse gli ultimi cinquanta anni della sua vita a Tangeri, la definiva *the Dream City*, città del sogno. Nello specifico scriveva negli ultimi anni del secolo scorso «ancora oggi l'immagine di Tangeri resta quasi immutata. Le persone vi arrivano sognando d'immergersi nell'atmosfera fatta di eccessi che qui vi regnava negli anni '40: a volte pretendono persino che il sogno diventi realtà» (Sefrioui, 2010, p. 1).
Attualmente essa vive una rinascita sociale e culturale, dovuta sicuramente ai provvedimenti di carattere economico, urbanistico ed infrastrutturale, messi in atto.
La regista marocchina Farida Belyazid sostiene che «Tangeri sta per rinascere e ciò viene fatto dolcemente. Si vedono soprattutto il cemento, le infrastrutture, ma non ancora il risultato (…) ma oggi si respira speranza mentre 10 anni fa era disperazione» (Sefrioui, 2010, p. 3). Ed aggiunge anche che «i nostalgici sono sempre meno. Sono gli stranieri che vengono a cercare il passato. I giovani, loro vivono il loro tempo» (Sefrioui, 2010, p. 6).

Fig. 5 – Vista sul cantiere del porto storico di Tangeri dalla Kasbah

Foto: Paola Carone

Fig. 6 – Rapporto tra la Medina ed il porto storico di Tangeri

Foto: Paola Carone

Per ciò che concerne la nuova area portuale di Tangeri va sottolineato che Mohammed VI, attuale re del Marocco, con lungimiranza e perseveranza propose la costruzione di un nuovo polo a circa 40 km dal centro di Tanger da quello antico, nei pressi della Regione spagnola del Ceuta, in prossimità dei resti delle mitologiche dodici colonne di Ercole (Fig. 7). Il nuovo porto di Tangeri Med è stato inaugurato nel luglio del 2007 e continua a registrare un'interessante crescita produttiva, dato che avvalora la previsione e la lungimiranza del sovrano che aveva scommesso su questa megalitica opera.
Nello specifico si individuano due poli per la nuova infrastruttura di Tangeri Med: Tangeri Med I e Tangeri Med II. I terminali per gli idrocarburi hanno nei primi 8 mesi del 2013 registrato un flusso di 2,7 milioni di tonnellate, decuplicando in questo modo la quantità transitata da febbraio. Per le autorità portuali di Tanger Med le attività del terminal idrocarburi nella fine dell'anno potrebbero toccare i 4,3 milioni di tonnellate, contro il milione del 2012. Tale notevole incremento è conseguenza dell'avvio dell'attività di rifornimento delle navi.

Fig. 7 – Immagini degli ingressi alle due aree portuali di Tangeri

a) Ingresso del porto storico *b) Ingresso all'area portuale di Tangeri Med 1*

Foto: Paola Carone

Per ciò che concerne il traffico container, l'aumento in un anno (fine agosto 2012-fine agosto 2013) è stato del 39%, per un totale di 1,6 milioni di container. A favorire la crescita è stato, oltre al rilancio del commercio marittimo mondiale, anche il rapido risanamento dell'immagine del porto. Le attività di Tanger Med hanno evidentemente tratto beneficio anche dall'espansione dello stabilimento Renault a Tangeri, la cui produzione è integralmente destinata all'esportazione in Europa e in America.
Tanger Med si trova in prima fila nell'operazione "Marhaba 2013", iniziativa necessaria per accogliere, durante la stagione estiva, i milioni di emigrati marocchini all'estero che rientrano in patria con le famiglie per le vacanze e che vede mobilitata l'intera macchina organizzativa dello Stato. La creazione e la conseguente crescita del nuovo polo portuale di Tangeri MED, non solo ha contribuito allo sviluppo economico della città e dell'intera regione, attraverso anche la localizzazione di grandi aziende come la Renault, ma è la principale causa del progressivo mutamento funzionale dell'originario porto sito nel centro cittadino. Per quest'ultimo, essendo stato alleggerito nelle funzioni commerciali in seguito allo spostamento delle stesse a 40 km, sono previsti interventi di conversione in porto turistico e porto da pesca. Attualmente il porto storico si presenta caratterizzato da tre aree principali:

1. a nord-est si trovano le banchine utilizzate per l'attracco delle grandi navi;
2. centralmente, in prossimità della città storica, insistono gli ormeggi dei piccoli natanti turistici e per la pesca;
3. a sud-est troviamo un'area dedicata allo stoccaggio di container.

La società statale Sapt (Société d'Aménagement du port de Tanger) ha proposto un'iniziativa pubblica di 700 milioni di euro per la riqualificazione e la rifunzionalizzazione del *waterfront* della città marocchina, al fine di favorire ed innescare operazioni private legate al turismo e ad altre iniziative culturali e commerciali (Fig. 8).
Il masterplan di massima prevede tra i principi cardine:

1. il rafforzamento e mantenimento del rapporto con l'acqua;

2. la valorizzazione del porto peschereccio;
3. la definizione dei terminal per crociere.

L'area di trasformazione è stata perimetrata e suddivisa in 13 parti prevalenti e a tutti i progettisti è stata sottolineata l'importanza di ragionare sul forte legame tra città e porto e sulla progettazione di centri che valorizzino l'aspetto culturale della città stessa.

Fig. 8 – Panoramica del progetto di riqualificazione del porto storico di Tangeri

Fonte: SARPT (2010)

4. Il progetto di riqualificazione del *waterfront* di Tangeri, pre-testo di ricerca

Alla luce dell'analisi del progetto vincitore per la riqualificazione del porto storico di Tangeri un'interessante linea di ricerca potrebbe essere valutare quanto esso contribuisca a favorire realmente la valorizzazione del paesaggio e l'economica urbana in un'ottica di sviluppo sostenibile, in grado di coniugare al meglio l'aspetto energetico, economico, sociale e culturale.

E soprattutto ragionare su quanto il suddetto progetto riesca a dialogare con l'antica Medina, nucleo urbano storico, che da sempre ha avuto un rapporto forte e privilegiato con il mare (Fig. 9). Il pensare a soluzioni alternative per la riqualificazione del *waterfront* potrebbe prevedere anche l'insediamento di "industrie culturali e creative", quest'ultime sono infatti in grado di generare molteplici effetti positivi in ambito economico, sociale e culturale per la più ampia comunità urbana.

Fig. 9 – Immagine storica della Medina e del suo rapporto con il porto

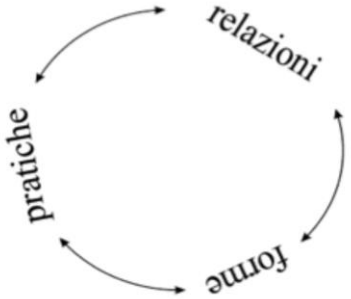
Fonte: SARPT (2010)

La definizione di "industria culturale" chiarita dall'Unesco (2011), firmata da 148 paesi all'interno della Convenzione per la Protezione e Promozione delle Espressioni Culturali, rappresenta la forma più condivisa e cita «le "industrie culturali" s'intendono le industrie che producono e distribuiscono i beni o i servizi culturali (articolo 4.5). Le "attività culturali, beni e servizi" si riferiscono a quelle attività, beni e servizi, che al momento sono considerate come un attributo specifico, un uso o uno scopo, ed incarnano o trasmettono espressioni culturali, indipendentemente dal valore commerciale che possono avere. Le attività culturali possono essere fini a se stesse, oppure possono contribuire alla produzione di beni e servizi culturali (articolo 4.5)».
Gli spazi creativi dipendono dalla realtà nella quale si opera, pertanto risulta necessario esaminare, valutare e considerare attentamente l'identità del luogo integrandola fortemente nel processo di riqualificazione e rifunzionalizzazione, dove il patrimonio passato di beni tangibili ed intangibili possa manifestarsi in maniera distintiva e caratteristica.
Con la creazione e lo sviluppo di industrie culturali e creative si favorisce la generazione di una forma di turismo anche esso culturale e creativo, in grado di agevolare l'interazione sociale e partecipativa del visitatore con il luogo e la sua vita culturale. Questa tipologia di turismo che rafforza l'identità locale e valorizza il *genius loci* in maniera autentica, favorisce l'apprendimento partecipativo alle arti, al patrimonio storico culturale e fornisce un collegamento con coloro che risiedono in un luogo, rendendo la cultura viva.
Un aspetto interessante ed innovativo per garantire autodeterminazione e maggiore condivisione nella gestione del patrimonio è il coinvolgimento della comunità locale nella definizione delle scelte di carattere urbano. La progettazione partecipata, infatti, è un potenziale esercizio per supportare le decisioni, sempre più nuove tipologie e forme di coinvolgimento degli stakeholder si stanno perfezionando, proprio per favorire una migliore condivisione delle parti interessate nella definizione delle scelte. Gli studi di Gittins (2009) e Nogué (2009), infatti, guardano al paesaggio come riferimento identitario locale per le comunità, sottolineando la necessità di considerare le specifiche preferenze quali indirizzi di intervento favorendo le pratiche partecipative nella pianificazione territoriale e paesaggistica. Tra l'altro innescare processi partecipativi, che coinvolgono le

comunità, in contesti legati ai Paesi del Sud del mondo è una sfida che UN-Habitat sta portando avanti proprio per la gestione e la valorizzazione delle città.
Come la campagna *I'm city changer* proposta al VI World Urban Forum, tenuto a Napoli nel settembre 2012, il cui slogan risulta proprio: «It is the time to change. If we work together, we can achieve better cities for all. It is the time to start changing; now is the time for city changers» (UN-Habitat, 2012, p.10) e dove tra gli obiettivi principali c'è la sensibilizzazione delle comunità su argomenti per città migliori. Nello specifico la campagna propone approfondimenti per strategie finalizzate alla costruzione di città: resilienti; inclusive; verdi; pianificate; produttive; sicure.

5. Input metodologici per la ricerca e primi risultati
La ricerca si propone di orientare azioni concrete secondo una logica di sviluppo integrato, tenendo conto della partecipazione degli abitanti e della società civile al processo di cambiamento, al fine di ottenere uno sviluppo sostenibile, che contempli fortemente le differenze culturali ed etniche. La conoscenza delle percezioni del paesaggio consente di approfondire i fattori culturali che le determinano e le relative rappresentazioni. Le aspettative dei cittadini sono un punto di partenza per una più attiva partecipazione alla costruzione di alternative di paesaggi e le analisi percettive possono aiutare a rilevare ed esplicitare i valori paesaggistici sentiti ed attribuiti dalle popolazioni stesse (Fig. 10).

Fig. 10 – Circolarità del processo creativo



Per ciò che concerne Tangeri si può senza dubbio affermare che è l'interculturalità il carattere vibrante della città e nello specifico della Medina.
L'antica città di Tangeri, come la gran parte delle Medine arabe, è caratterizzata da strade strette che s'intersecano e districano tra le case ed i bazar, cuore pulsante di un'economia che vive di turismo e di un'altra microeconomia, parallela, fatta di lavoro sommerso e di mestieri tradizionali. Il tutto contraddistinto da un fragile e delicato equilibrio che oggigiorno rischia di sparire insieme ai suoi attori (Fig. 11).
Attualmente esistono svariati programmi governativi promossi dal Ministero degli Affari Esteri Italiano in partnership con ONG italiane e marocchine (rispettivamente Cospe e Al Boughaz), finalizzati ad orientare ed aumentare la qualità della vita degli abitanti della Medina. Tali programmi si compongono di diverse azioni che interessano gli ambiti

architettonici, sociali, economici e turistici e tentano di lavorare attivamente su strumenti e metodi botton-up. Nello specifico gli obiettivi del percorso di ricerca proposto possono essere sintetizzati ed imbastiti nei due schemi delle Figg. 12 e 13.

Fig. 11 – Mercato informale nella Medina di Tangeri

Foto: Paola Carone

Dove si rafforza l'idea che le valutazioni risultano sempre più integrate e soprattutto sono il risultato di un processo di apprendimento circolare dove interagiscono indicatori economici, ecologici e sociali.
Il processo valutativo, pertanto, non si esaurisce in un semplice calcolo, ma consiste anche in una dinamica dialogico comunicativa (Fusco Girard e Nijkamp, 1997).
Al fine di raggiungere tali obiettivi (Fig. 12) si propone di lavorare all'individuazione sia di dati hard che soft, coinvolgendo gli stakeholder locali selezionati e differenziati in tre categorie prevalenti: fruitori; promotori; operatori.
La Fig. 13 individua il programma di ricerca e mette a sistema le azioni, i partner coinvolti e gli strumenti da adoperare per il conseguimento degli obiettivi sopraenunciati.
Tali strumenti e metodi, tradizionali e sperimentali, adoperati in maniera integrata, potrebbero agevolare la conoscenza e la condivisione capillare degli obiettivi proposti, secondo un processo di coinvolgimento della comunità interessata. Poiché come cita Jane

Jacobs nel suo testo *Death and life of great American cities* del 1961, ma sempre attualissimo, «Cities have the capability of providing something for everybody only because and only when they are created by everybody» (p. 27).

Fig. 12 – Obiettivi della ricerca

Una prima elaborazione principalmente dei dati soft ottenuti attraverso interviste, questionari e sondaggi sul campo, ha consentito innanzitutto di prendere atto dell'effettivo livello di conoscenza del progetto di riqualificazione dell'area portuale storica di Tangeri da parte della comunità, che la Fig. 14 sintetizza appieno.
Sempre in ambito percettivo risulta interessante l'individuazione dei caratteri principali da conservare e valorizzare per una Tangeri sempre più interculturale.
La città interculturale ha un tessuto urbano dall'aspetto di un *pacthwork* che annulla le differenze e gli antagonismi etno-sociali, con forme urbane, elementi di coesione intellettuale e impiegando le differenze di stili di vita come un potenziale motore di sviluppo sostenibile. La progettazione di una città interculturale, plurale e ospitale, deve tener conto di cinque questioni chiave relative: all'accoglienza; all'abitazione; alla partecipazione ed alla comunicazione; all'autonomia e responsabilità; e alle politiche integrate per lo sviluppo locale.
Brian K. Ray (2002) presenta dieci punti che definisce fondamentali nella gestione dell'ambiente urbano, al fine di promuovere una reale integrazione culturale e l'inclusione sociale. Esiste una carta per una città che può divenire pioniera dell'interculturalità definita «Carta dei principi per la città interetnica cablata» (Clemente e Esposito de Vita, 2008, p. 184), dove emerge che le parole chiave risultano: identità; integrazione; interazione; partecipazione; mediazione; alloggio; occupazione; accessibilità; accoglienza. Le prime cinque sono legate alla sfera sociale, le ultime ad aspetti architettonici e urbanistici.

Fig. 13 – Il programma di ricerca: le azioni, i partner e gli strumenti

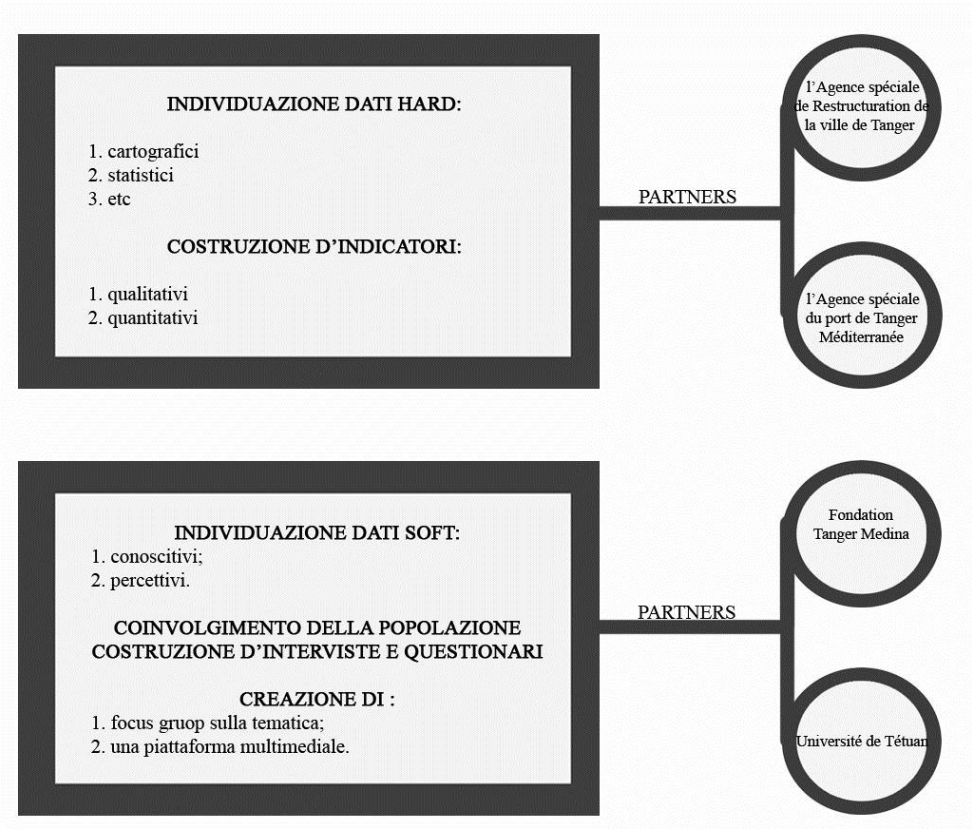


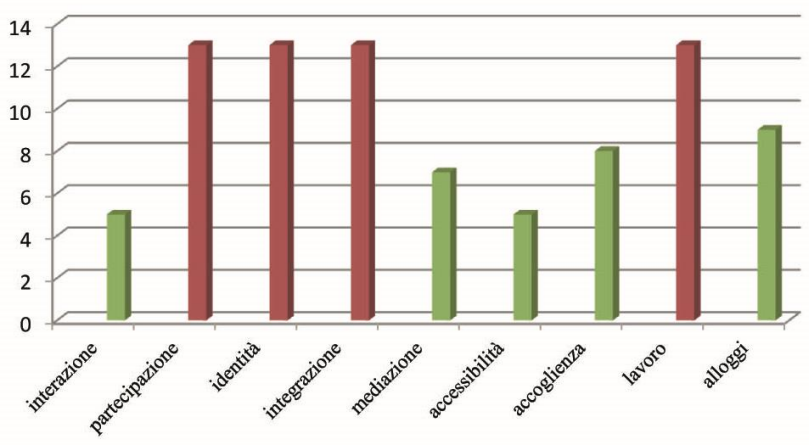
Fig. 14 –Conoscenza del progetto di riqualificazione del porto storico di Tangeri

Senza la comunità locale non è possibile né comprendere i legami e le interdipendenze tra patrimonio tangibile ed intangibile, né gestirne efficacemente il cambiamento, tale risulta l'approccio dell'Historic Urban Landscape (Unesco, 2011) che restituisce un ruolo

nevralgico alla comunità nella gestione del paesaggio, riassegnandone la responsabilità principale della conservazione e dello sviluppo.
Dalle interviste ed i sondaggi effettuati emerge che per la comunità di fruitori, operatori e promotori il livello di conoscenza del progetto di riqualificazione del porto storico di Tangeri in percentuale è abbastanza buono e che i caratteri fondamentali da preservare e potenziare per valorizzare la Medina di Tangeri risultano (Fig. 15):

- la partecipazione;
- l'identità;
- l'integrazione;
- il lavoro.

Fig. 15 – Istogramma sulle preferenze espresse dagli stakeholder per una città interculturale



Tali caratteri sottendono criteri e azioni strategiche, oggetto di future ricerche ed approfondimenti, che potenzialmente potrebbero definire delle vere e proprie linee di intervento per soluzioni programmatiche e progettuali alternative o integrate a quelle previste nel progetto di riqualificazione del porto antico, il quale inevitabilmente, per la sua forte complessità, determinerà impatti di natura economica, sociale, urbana ed ecologica, modificando l'attuale immagine della città di Tangeri e soprattutto quella interculturale, oramai stratificata e consolidata, della Medina.

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STUDENTS' PERCEPTIONS OF INNOVATION IN SUSTAINABLE DEVELOPMENT TECHNOLOGIES AND THEIR ROLE TO OPTIMISE HIGHER EDUCATION'S QUALITY

Hella Ben Brahim Neji, Adel Besrour

Abstract

Technological innovation and scientific research have always helped industry and other economic sectors to evolve, allowing them to reduce their production, operation and maintenance costs, and in return, the fields of engineering and innovation widened increasingly. The objective of this research is to evaluate the importance technological innovations in sustainable development (especially, green energy) on the quality of higher education improvement. The study is based on a survey conducted among a sample of students from the High School of Technology and Computer Sciences (ESTI – University of Carthage, Tunisia), pointing out the need to integrate teaching staff, researcher and students, in identifying and optimization technological solutions.

Keywords: Technological innovation, contingent valuation method, energy saving

LE PERCEZIONI DEGLI STUDENTI RIGUARDO L'INNOVAZIONE DELLE TECNOLOGIE SOSTENIBILI ED IL LORO RUOLO NELL'OTTIMIZZARE LA QUALITÀ DELL'ISTRUZIONE SUPERIORE

Sommario

La ricerca scientifica e l'innovazione tecnologica hanno da sempre contribuito all'evoluzione dell'industria e degli altri settori dell'economia, consentendo di ridurre i costi di produzione, esercizio e manutenzione, e di ampliare sempre di più i campi dell'ingegneria e dell'innovazione. L'obiettivo di questa ricerca è quello di valutare l'importanza delle innovazioni tecnologiche nello sviluppo sostenibile (specialmente l'energia verde) sul miglioramento della qualità dell'istruzione superiore. Lo studio si basa su di un sondaggio condotto su di un campione di studenti della Scuola Superiore di Tecnologia e Scienze informatiche (ESTI, Università di Cartagine, Tunisia), evidenziando la necessità di coinvolgere il corpo docente, ricercatori e studenti, nell'individuazione e ottimizzazione delle soluzioni tecnologiche.

Parole chiave: Innovazione tecnologica, valutazione contingente, risparmio energetico

1. Introduction

Technological innovations and scientific researches have always been the domain of higher education institutions' expertise, helping industrial and many other economic sectors to evolve. This free assistance implies for industrials a reduction of production, operation and maintenance costs. In return, science and innovation widened more and more. The development of technical solutions can be performed in situ, which is to say, developed at the company or in school of engineering and technology's institution. The work is supervised in part by field worker and secondly, by the teacher – researcher who tries to adapt, new technology and scientific methods, to the industrial organization's problem. Indeed, through the projects graduation, masters and doctoral theses, several technical solutions were presented to industry depending on the size of the problem to be studied. Among others, we can mention technical solutions developed by researchers and students to help reducing energy consumption and preserving natural resources.

In emerging countries, case of Tunisia, this interaction in research and innovation between students and professors is beneficial to all the entities, a question may arise: can we exploit these trilateral relations to help improving working conditions (ergonomics) in public higher educational institutions?

Indeed, there are several ergonomic problems that hinder the normal course of educational sessions such as heating, lighting, painting, etc. (Mokdad, 2005). It is possible to develop a number of technical solutions to these problems with the help of the teaching staff (researchers) and financial aids of industrials and other national and international agencies (Foo, 2013). These solutions would be especially relevant only if they could meet environmental standards and could allow to save energy (Multon, 2000) and therefore to reduce financial costs.

This paper is related to energy conservation and environmental needs in higher education institutions, especially in the case of an emerging country such as Tunisia. The first objective of this research is to measure the importance of teaching sustainable environmental management in higher education in general, and engineering in particular, according to students' point of view (Azapagic *et al.*, 2005; UNESCO, 1992). The second objective concerns the students' appreciation of the idea to learn in a building, respecting environment standards. Also, we'll try to introduce the idea that students can to participate in innovation of new technologies helping to reduce Energy consumption.

This research is compounded of three main parts. In the first section, we will attempt to identify the main ergonomic constraints (including energy problems) that can reduce the performance of students and teachers in classroom. This part of the article has required conducting a survey among students. In the second part, we indentified most effective technical solutions and economically profitable that solve major problems mentioned (heating, lighting, noise, etc). In this study we consider the fact that student refuses to participate in the payment of expenses (results from the analysis of data survey).

2. Context of the study and identification of ergonomic problems in classroom

This study involved the School of Technology and Computer Science (ESTI - University of Carthage), located in the industrial zone of the city of Tunis and close to the airport of Tunis-Carthage. This is a public institution: it was established in 2002 and it is divided in three departments; Electrical Engineering, Industrial Management and Computer Engineering Departments. The school currently has two joint training systems: LMD since

2007 – 2008 (last cohort is expected for 2016) and engineering fields (started in 2010). Trainings provided within this academic institution are both technical and organizational (Diplomas in automation and mechatronics engineering, logistic and management of Industrial systems engineering (production, maintenance) and Diplomas of Computer sciences.). All departments cooperate with industrial companies, thus they participate in the development of curricula, in teaching as experts and in organizing lectures. It is also conventional to conduct joint industrial projects in the final year project. In addition, mandatory training and business visits are planned as a part of the opening of the school on the social-economic environment. These training opportunities are diverse and often laid to students recruitment (see ESTI web sites, www.esti.rnu.tn, and UCAR web sites, www.ucar.rnu.tn).

Despite the vast opportunities offered by the school to its students, factors are hindering the success of teaching experience. Indeed, the number of students has actually increased at an average annual growth's rate of 28% and about 22% for lectures and professors. The school building is rented and consists of 30 classrooms, 8 computer labs, 4 laboratories of Electrical Engineering and a reading room. The evolution of student's number and teacher's one, demonstrates that classrooms' number is insufficient. As an indicative number, the expected number of students, (once the school will offer only engineering diplomas) will be about 3000 students.

Other problems can be pointed out concerning stressful working conditions in this studied case: The lack of office space for professors to supervise students, winter heating, summer cooling, lighting suited to surfaces and orientation of classrooms, lab, etc. Currently, the ministry of higher education and scientific research is planning to build a new school building. This study proposes to respect environment standards of energy economics in this new building and to integrate special courses of sustainable development in all departments.

3. Survey design, results and analysis

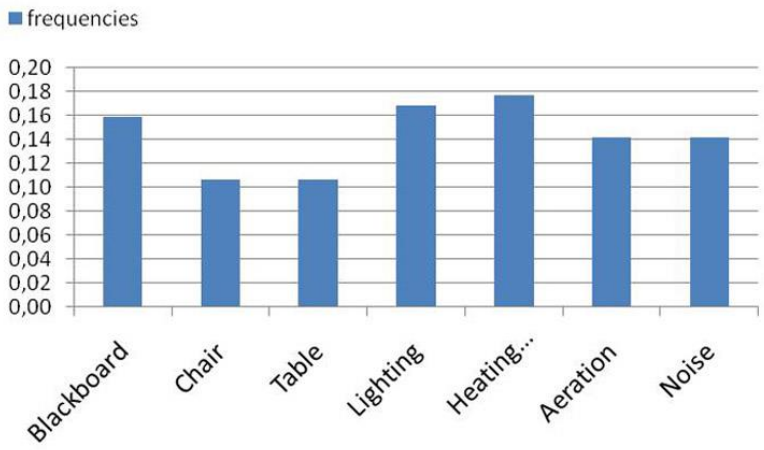
In order to rank the mentioned constraints in the last section and to determine the most important ones, a field survey was conducted among 46 students from the ESTI in 2013. In the second part of the questionnaire, a special case was advocated and that suppose that student pays monthly fees is simulated. They where guided by questions to evaluate, using contingent valuation method, the willingness to pay (WTP) for education, in an universitary building, respectful of environmental standards. Different kind of questions (direct-open, open-closed, indirect, etc.) were asked. Then, answers were used to support the introduction of environmental concerns and the need for effective technical solutions.

The ergonomic factors evaluated in this study concern the quality of tables, chairs, lighting heating, ventilation and noise. The student had to respond to the question 1 in Appendix.

Student can cross more than one case. To each case one point is attributed. By the end and for each factor, scores are aggregated and transformed on frequencies. According to students, heating and lighting represent most important discomforts in class (Fig. 1).

Recently, all blackboards in the school were changed and this problem was already resolved. The second part of the survey has guided, step by step, the student in the process of evaluating the willingness to pay (WTP) for higher education at ESTI, in an university building, respecting environment standards.

Fig. 1 – Evaluation of discomfort level (ergonomic) in university buildings' of ESTI



The first question tried to learn us if students are willing to pay for learning or not (Gourieroux, 1998; OECD, 1994). We supposed the case that university studies should become private. Only 12% of the interviewed students refused the idea to pay for education. The price estimated by 68% of students was about 20 euros/month. We went deeply in this question and we informed students about the price of private's university schools (open-ended question). The number of students accepting to pay has enhanced. However, only 20% of them accepted to pay. The expected price to be paid has varied between 100 to 150euros.

In the second step of the questionnaire, we introduced the ecological aspects. We supposed the case that the new school building of ESTI will respect environment standards and introduce green energy technologies. The refusal to pay's rate has not changed. However, we observed that only 44% of students would like to pay monthly about 200 euro/ month to have more comfortable building which uses green energy for heating and lights.

The concept of green building (Kasai and Chiappetta Jabbour, 2014) is superfluous for the interviewees, as 22% of students refuse to pay for a building complying with environmental standards. It was observed that 44% of respondents are not aware of the existence of new environmental technologies that save energy and protect the environment. The remaining students, 56% spoke either about solar and wind power. The idea of offering students the opportunity to develop new environmental technologies in their school has been well received by 89% of them.

The aim of this research isn't the popularization of the idea of private education but rather, estimating the magnitude assessment's given by students to environment technologies. It was observed that the student gives much importance to its comfort in the classroom, as he was willing to pay to have better working conditions. The fact remains, that students are not highly trained in green technologies and rarely accept to pay for green building.

4. Conclusion

Saving technologies of energy can be developed within the same institution of higher education and the benefit from this experience would be multiple. First, the institution will benefit from the establishment of techniques to preserve the environment and make significant savings. Then the student will participate in a formal way in the development of these techniques and enrich his education with the introduction of a new dimension, namely the environment.

Finally, the introduction of these technologies will develop research in the field of energy conservation and will help the industrialists to provide more efficient, reliable and profitable models. This study helped to evaluate the willingness of student to study environment technologies. Thus, their willingness to pay to have education, integrating environment studies was analyzed. In addition, we evaluated their sensitivity to ergonomic conditions in higher education buildings, especially having access to heating in winter.

Appendix

Survey

Ergonomic conditions in classes at High School of Technology and Computer Sciences (ESTI) and green energy

Name:

Age:

Class:

Department:

Identification of ergonomic problems in class (cross)

1. Classrooms and amphitheatre

BlackBoard	**Chair**	**Table**	**Light**	**Heating**	**Aeration**	**noise**	**Others**

According to you, which element mentioned in table 1 is the most uncomfortable?

2. Practical works class

Computer	**Internet**	**Software**	**Electrical engineering material**

According to you, which element mentioned in table 2 is the less modern (functional)?

3. Academic Library

Course Material	**Exercises' Material**	**Working room**	**Others (mention)**

According to you, which element mentioned in table 3 is the biggest constraint?

4. Others:

Problems linked to education

5. Availability of education material

Data show	**Course & Exercices Support**	**Interactive method used in Class**

6. Quality of education and courses in general : (A: very good)
   A B C D E

7. Does your university building respects in general environmental norms (Energy economic, water economic, cleanliness, noise, etc.)
   YES / NOT Why?

Contingent Valuation Methods to valorise a qualitative service (such as education)
Simulation

Let's suppose that education in Tunisia and especially in High School of Technology and Computer Sciences is not free of charges. Based on current prices of private education system, we try to measure the willingness to pay of students for better quality of education and ergonomic condition:

8. Considering the described scenario, if you have to pay monthly for your university education, how much you shall pay?
9. Note that prices of primary education in private institution is around 300DT/Month (M), secondary 350DT/M and Higher education is about 500DT/M, what can be your new price? (1euro=2,3 DT)
10. Note that actually, your education costs, for the national government, about 250DT/M. Considering this new information, are you willing to pay for improvement (Mobil classroom, better quality of lighting, chairs, table, etc.) or not? And if yes how much? Yes/ No
11. Private university institutions integrate high technology and good ergonomic conditions in their institution. However, Students have to pay between 400 and 700DT/M. To have same work conditions, which price are you willing to pay?
12. How much would like to pay to have a university building respecting environment?

Working at university schools implies high fees for energy (for example, water and electricity fees varies from 1 to 3 DT/student/M. This fee can reach 20 or 30DT if used technologies' are more developed in classes and practical works classes (lap tops, mobile classroom, interactive board, lighting, video projector, central heating, etc.).

13. Do you know green technologies that help reducing monetary charges and save environment?
14. Please cite someone's.
15. Suppose the scenario of paying for high education will not be applied, are you willing to pay a small monetary contribution to have green energy in your school? If yes how much?
16. Are you interested to participate in the technological development of this kind of technologies? If yes say why?

Thanks

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THE USE OF 3D VISUALISATION FOR URBAN DEVELOPMENT, REGENERATION AND SMART CITY DEMONSTRATION PROJECTS: BATH, BUCKINGHAMSHIRE, AND MILTON KEYNES

Stewart Bailey, Advait Deshpande, Alby Miller

Abstract

The aim of this paper is to discuss three different case studies related to the use of 3D visualisation for projects focussing on urban development, regeneration, and Smart City demonstrations. With each of the case studies, the problem statement, the approach adopted for 3D visualisation, and the outcome is covered. The paper concludes by discussing what 3D visualisation offered to each project. The paper discusses how in order to effectively use 3D visualisation the approach needs to be adapted according to the problem statement. Depending on the project requirement, 3D visualisation is likely to serve multiple purposes in urban development, regeneration, and Smart City demonstration projects. The paper suggests that the use of 3D visualisation adds an extra dimension to presenting data and also provides an effective tool for analysing the data.

Keywords: 3D visualisation, urban development and regeneration, Smart City

L'USO DELLA VISUALIZZAZIONE 3D PER PROGETTI DI SVILUPPO URBANO, RIGENERAZIONE E SMART CITY: BATH, BUCKINGHAMSHIRE, E MILTON KEYNES

Sommario

Obiettivo dell'articolo è presentare tre casi di studio relativi all'uso della visualizzazione 3D in progetti incentrati sui temi dello sviluppo urbano e della rigenerazione, e dimostrativi del concetto di Smart City. Per ognuno dei casi studio, sono individuati la definizione del problema, l'approccio adottato per la visualizzazione 3D ed i risultati. Nelle conclusioni viene esaminato il contributo che la visualizzazione 3D è stata in grado di offrire a ciascun progetto. L'articolo evidenzia come, per usare efficacemente la visualizzazione 3D, sia necessario adeguare l'approccio al problema in esame. In base alle esigenze del progetto, la visualizzazione 3D può servire a molteplici scopi nei progetti di sviluppo urbano, rigenerazione e Smart City. L'articolo mostra come l'utilizzo della visualizzazione 3D aggiunga una dimensione ulteriore alla presentazione dei dati e fornisca uno strumento efficace per la loro analisi.

Parole chiave: visualizzazione 3D, sviluppo urbano e rigenerazione, Smart City

1. Introduction

This paper discusses three different case studies about the use of 3D visualisation for projects concerned with urban development, regeneration, and Smart City (Caragliu *et al.*, 2009) demonstrations. The paper does not compare or debate the relative merits or demerits of various methods and technologies that rely on 3D visualisation for urban development, regeneration, and Smart City demonstration projects. The aim is to discuss Virtual Viewing's approach for utilising 3D visualisation. For this purpose, the following case studies are presented:

- an urban development housing project in Bath, United Kingdom (UK);
- the Buckinghamshire Thames Valley Local Enterprise Partnership (BTVLEP) Geographic Information System (GIS) project;
- a Smart City demonstration for Milton Keynes (MK).

For each of the above case studies, the paper covers the problem statement and the role played by 3D visualisation in the execution of the project. Although 3D visualisation formed an important part of the solution, the paper also considers how 3D visualisation was combined with other methods in order to achieve the required results. The concluding section analyses how Virtual Viewing (VV) adapted 3D visualisation to represent data in a meaningful way. The relevance of 3D visualisation for each of the projects is also discussed.

2. Urban development: Crest Nicholson Bath Riverside

This case study focuses on the requirements and the eventual solution offered to Crest Nicholson for their multi-phase real estate development project in Bath, UK. Crest Nicholson is a British house-building company listed on the London Stock Exchange and a constituent of the FTSE 250 index (London Stock Exchange, 2014). It has building operations mostly concentrated in the southern UK.

The problem statement

Crest Nicholson needed an interactive and innovative solution for their sales staff. In this case, the solution was expected to be customised for their site in Bath. This site was undergoing a multi-phase development of a riverside property including a block of flats. The work done by Virtual Viewing was specific to the second phase of this development project. Crest Nicholson expected the solution to combine animation of the actual site with real time data and live actors. To enable the sales staff to sell the houses off plan, Crest Nicholson had built a physical model (i.e. a small-scale replica) of the development site (6 ft. x 4 ft.). Crest Nicholson wanted their sales staff to interact with this physical model along with the software application to be developed.

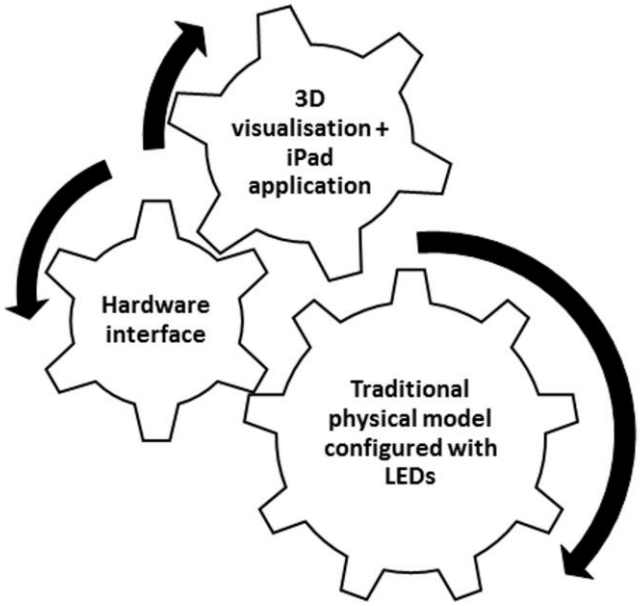
Although Crest Nicholson had previously used physical models on other developments, the interactivity between the physical models and any 3D rendering of the sites was very feature-limited. Existing systems to interact with the model had focussed on building simple functionality such as lighting up the entire model at the same time and did not offer any additional functionality. Crest Nicholson wanted a more sophisticated solution that integrated the 3D visualisation with the physical model further.

The Virtual Viewing approach

Virtual Viewing's solution combined three separate components to deliver Crest Nicholson's requirements (Fig 1):

1. an iPad application providing 3D visualisation;
2. a hardware interface to control individual model lights from the iPad application for improved demonstration capabilities;
3. a traditional physical model with embedded Light Emitting Diode (LED) lights.

Fig. 1 – VV approach for the Crest Nicholson Bath Riverside project



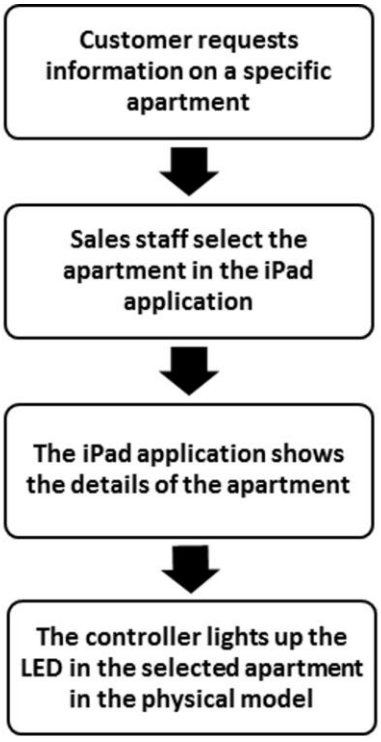
Virtual Viewing created an iPad application that provided site plans, including detailed information on each of the apartments, and a 3D flythrough of the development. This solution was created with Adobe Air and C#. C# was used to develop the web services for the application.

The hardware interface was designed to connect the iPad application with the physical model. The iPad application interacted with the hardware interface and could control parts of the physical model without direct contact. The intention was to allow the sales staff to use the iPad application during customer demonstrations to light up a specific part of the physical model. By installing LED lights inside the physical model and facilitating the hardware interface to manipulate the LED lights, the interactiveness of the demonstration was further enhanced.

The third part, the most innovative in this context, was the increased interactivity as a result of the hardware interface being linked to the iPad application. The LED lights in the

physical model could be switched on and off through the use of the iPad application and the hardware interface. These LEDs were installed on the physical model to make it stand out and add an extra layer of interactiveness as the sales staff walked the prospective customers through the physical model. With the LEDs, the sales staff could showcase the houses through 3D visualisation aided by the physical model.
Although the images from the actual project cannot be included here due to a confidentiality agreement with the client, the flowchart of Figure 2 shows the manner in which the interaction between the customers, the sales staff, and the solution developed by Virtual Viewing worked.

Fig. 2 – Flowchart for the Crest Nicholson Bath Riverside project



The outcome
The end-result with the integration of the iPad application, the hardware interface, and the LED lights in the physical model was a small scale control system. Not only did the solution fulfil the client expectations in terms of innovativeness but it also proved to be an invaluable tool for the sales staff for demonstration purposes. The fact that such an integrated software and hardware experience could be up-scaled for a more complex functionality suggests that this approach has further potential.

The strength of this approach lies in the way it combined the physical model with the 3D visualisation in the iPad application. It enhanced the sensory experience and complemented the computer-based 3D visualisation by adding a real-world 3D counterpart (real world objects are seen in 3D by default after all).

3. Urban development and regeneration: The BTVLEP GIS project

This case study is about a project executed for two stakeholders - Buckinghamshire county council and the Buckinghamshire Thames Valley Local Enterprise Partnership (BTVLEP). The Buckinghamshire county council is the governing council for the Buckinghamshire County in the Southeast of England. The county covers an estimated area of 1874 sq. km and has a population of 756,000 according to the latest census (ONS, 2011). BTVLEP is a partnership project between the local government (i.e. the Buckinghamshire county council) and the private sector intended to attract businesses and investment to the Buckinghamshire area (http://buckstvlep.co.uk/). In consequence, BTVLEP seeks out opportunities to showcase the infrastructural, commercial, and economic advantages of the Buckinghamshire area to businesses. The BTVLEP GIS project was aimed to be one such showcase.

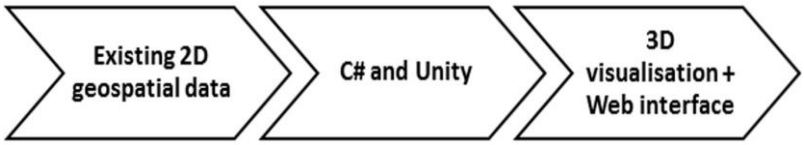
The problem statement

The main requirement was to create a platform for displaying existing 2D geospatial information held by the council in 3D format. Through this project BTVLEP aimed to demonstrate its intent about attracting investment. For the Buckinghamshire county council, the aim was to communicate data about the county in a visual, easy-to-understand manner. The data were intended to reveal various patterns and characteristics of the county such as voting patterns, woodland areas, parts that would be affected by the High Speed 2 (HS2) railway service, a planned high-speed railway between London Euston, the English Midlands, North West England, Yorkshire, and potentially North East England, and the Central Belt of Scotland, and areas of traffic congestion. The project was split into two phases. The first phase was about rendering the existing data through 3D visualisation and build a platform. The second phase was to build applications on top of the platform. This case study discusses the outcome at the end of the first phase.

The Virtual Viewing approach

At the core of Virtual Viewing's proposed solution was the position that the 2D geospatial data held by the council was of strategic importance. Instead of relying on Google Maps / Earth Application Programming Interfaces (APIs) to harness this data, the Virtual Viewing approach relied on a custom solution delivered by combining C#-based software development with Unity, developed by Unity Technologies, a cross-platform system for rendering the data (Fig. 3). Other approaches including Web Graphics Library (i.e. WebGL, a JavaScript API for rendering interactive 3D graphics and 2D graphics within any compatible web browser without the use of plug-ins, Tavares, 2012) were considered but not used after preliminary due diligence at the time of the project revealed them to be less flexible to programme in and difficult to maintain afterwards at their current state of maturity.

Fig. 3 – VV approach for the BTVLEP GIS project



The existing 2D geospatial data was held in a proprietary format for use in a desktop system. In contrast the client requirement was to render it on the web in 3D. This meant that in order to effectively harness this data, the Virtual Viewing solution needed to import, combine, and recut the aerial image data. This repurposed data then needed to be presented in a compressed form. This was done by combining the existing topographical data with aerial photos in multiple layers. The challenge lay in importing and loading the existing geospatial data into a web application. Further complexity was due to open-ended non-functional requirements and limited visibility of the kind of devices end-users may rely on to access the web-based interface.

The outcome

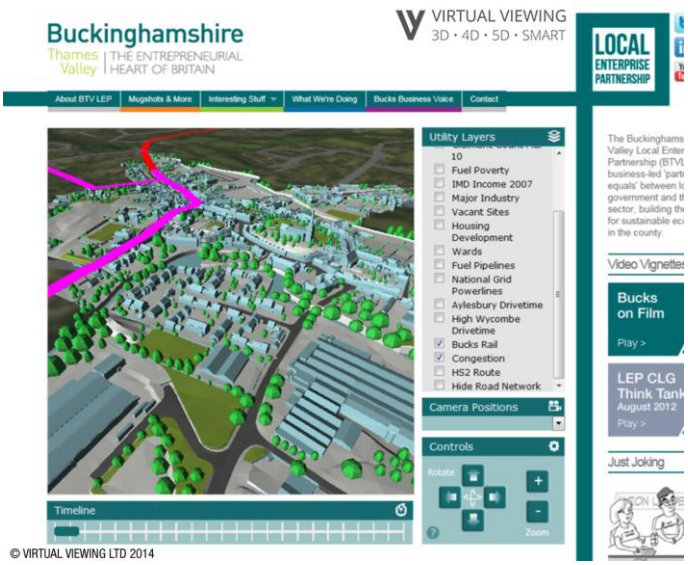
The solution developed by Virtual Viewing delivered 3D rendering of the data providing various statistics for different areas of the county. To do so 160 GB of images and topographical data was reprocessed, thinned out, and compressed to about 50 MB download size. The existing data held in PostGIS and PostgreSQL was imported for rendering it in a grid system across multiple layers.

The use of 3D provided an extra dimension to represent the existing 2D data and enabled the various data sets (including aerial images and SketchUp models of key towns in the county; SketchUp is a 3D modelling software known for its capability to work with Google Maps and Earth file formats) to be displayed simultaneously rather than requiring offline data analysis first. Given the BTVLEP's intention of demonstrating openness for business and its preparedness to embrace technology for economic revival and growth, the first phase achieved the goals defined at the outset. The following images show the final results and how the web interface conveyed the statistical data held by the council in a geospatial context. These images indicate how applying different filters enabled the results to be displayed according to the end-user's interests. As a tool for attracting investment, these images also showcase the capabilities it offered to BTVLEP when interacting with investors and businesses.

Figure 4 shows an example of the overlays for the traffic routes and congestion as rendered in the web interface.

Figure 5 provides a view of the Aylesbury area. The information specifically displayed in this image is: urban area, woodlands area, infrastructure, and voting boundaries within Aylesbury.

Fig. 4 – BTVLEP GIS, traffic routes and congestion patterns



Source: Virtual Viewing Ltd. (2014)

Fig. 5 – BTVLEP GIS – Aylesbury area

Source: Virtual Viewing Ltd. (2014)

4. Smart City demonstration: Milton Keynes

This project was intended to be a demonstration of the Smart City concept for Milton Keynes, a large town in the Buckinghamshire County with 89 sq. km area and a population of 229,411 according to the latest census (ONS, 2011).

The problem statement

The main aim of this project was to display the potential of the Smart City concept to deliver intelligent, interconnected systems and associated functionality. The demonstration was intended for a number of potential stakeholders including government institutions, property owners, and marketing agencies (Table 1). For building the demonstration, the 3D visualisation was expected to rely on an existing offline software-based model of Milton Keynes. A key characteristic of the existing offline model was that it was not connected to any geospatial data. Thus it was important to take into consideration the offline nature of the landscape being used as a baseline for the 3D visualisation.

The Virtual Viewing approach

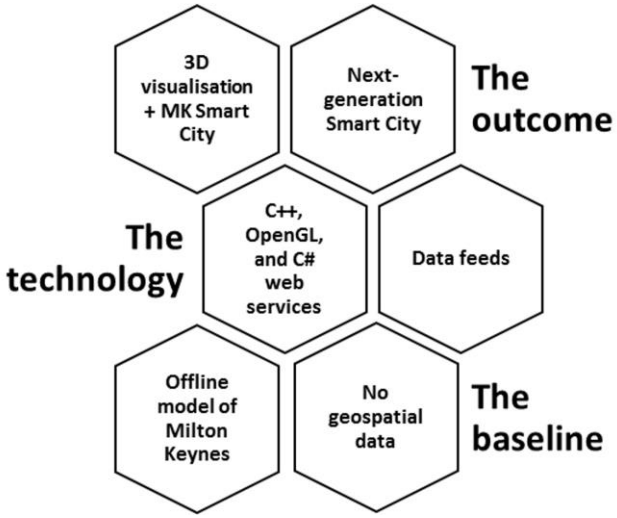
The main purpose of the project was to showcase the capabilities of Virtual Viewing vis-à-vis a Smart City demonstration. For an efficient and expedient development process, Virtual Viewing used C++, Open Graphics Library (i.e. OpenGL, a cross-language, multi-platform API for rendering 2D and 3D vector graphics, The Khronos Group, 2014), and C# web services as the development platform. The resulting Smart City demonstration was intended to facilitate further development of data driven applications and 3D models. An important consideration was for the OpenGL-based 3D visualisation to enable future dashboard application concepts and cater to a wide range of prospective end-users such as housing residents, county councils, and property developers. In doing so, the demonstration was also intended to address three potentially different markets with varying business requirements and priorities as Table 1 shows.

Table 1 – Target audience for a Smart City demonstration

Market	Business requirements and priorities
City councils and planners	Overlay general information and statistical data with cityscapes; Provide visual tools for strategic planning and management of smart cities.
Property owners	Smart managing the estate; Real-time tracking of data feeds; Identification and resolution of problems.
Marketing agencies	Create interactive marketing campaigns for a range of industries including restaurants, manufacturers, and construction companies

Figure 6 shows the building blocks of the bottom-up process used by Virtual Viewing.

Fig. 6 – VV approach for the Smart City demonstration



The time taken for development of the 3D visualisation in C++, OpenGL, and C# web services along with further updates was 18 months. The result was a desktop system capable of running on modern Windows-based platforms with support for OpenGL and hardware acceleration.

The outcome

The main strength of this Smart City demonstration was the interactive features it offered in relation to understanding, exploring, and analysing a Smart City landscape. The resulting 3D visualisation allowed multiple viewing angles combined with the ability to zoom into specific locations and retrieval of site-specific data – an indispensable feature for a Smart City demonstration. The capability to display site-specific data was made possible by allowing another application to be embedded within the 3D visualisation. By showing the capability to read data feeds available at sites equipped for transmitting them, the demonstration provided a glimpse of how real-time monitoring of sensors would function and aide decision-making, interventions for local councils and individual owners alike. For example, based on its capability to read sensor data, the demonstration could be made capable of identifying the floor(s) affected in the event of a fire. Following images show various aspects of the Smart City demonstration. Figure 7 displays energy data for the Church of Christ the Cornerstone located in Central Milton Keynes. The demonstration also showed the granularity of functionality the Smart City concept could achieve whether it was in terms of providing a panoramic aerial perspective of the city locations or focussing on a specific data set (such as power usage, fire and safety events, or live traffic data). When combined with geospatial data, this kind of Smart City demonstration offered further opportunity to understand, evaluate, and conceptualise the way planning and implementation for a Smart City could take place. More crucially however, this

demonstration also provided key inputs and techniques for the next-generation Smart City demonstration currently being developed at Virtual Viewing.

Fig. 7 – Energy data from the Church of Christ the Cornerstone

Source: Virtual Viewing Ltd. (2014)

Figure 8 shows the capability of the Smart City demonstration to geospatially link and embed an application about a specific site or location (in this case the Red Bull factory in Milton Keynes).

Fig. 8 – The Red Bull factory

Source: Virtual Viewing Ltd. (2014)

5. Discussion and conclusions

This paper has covered three different case studies related to the use of 3D visualisation for urban development, regeneration, and Smart City demonstration projects. In each case study, the approach adopted by Virtual Viewing has been discussed along with the output produced. In this section, each of these case studies, the variations in the approach taken, and the extent to which 3D visualisation was crucial to the project execution are analysed.

Different purposes converging with 3D visualisation

With each of the case studies, 3D visualisation served a different purpose:

- for the Crest Nicholson Bath Riverside project, 3D visualisation needed to be coupled with a hardware interface and a physical model to significantly augment the existing visualisation aides available to the sales staff;
- for the BTVLEP GIS project, the 3D visualisation acted as a visual filter for large amount of geospatial and statistical data. 3D visualisation was crucial to allow the data to be presented and understood quickly by third party users. With the main aim of attracting investment, the 3D visualisation also enabled BTVLEP to demonstrate its intent about emerging and advanced technologies;
- with the Smart City demonstration for Milton Keynes, 3D visualisation provided the flexibility to experiment with various ideas about how a Smart City could and should function. This is important given that the concept of a Smart City is still evolving (Zygiaris, 2013). The nature of interconnected, intelligent systems that could exist in a Smart City and the functionality that could be implemented is also part of an ongoing discussion between the industry and academia.

Despite the different purposes, 3D visualisation was a core part of the execution strategy adopted by Virtual Viewing. As the next section discusses, despite some of the technological constraints and partly due to the nature of the problem statement, Virtual Viewing employed different approaches while using 3D visualisation.

Adapting 3D visualisation to the problem statement

With the Crest Nicholson Bath Riverside project, due to the problem statement requiring an innovative solution, only presenting 3D visualisation would not have been sufficient. The existing physical models contained very rudimentary LED functionality. It was only by building a small control system with a fit-for-purpose hardware interface that the criterion for an innovative solution was fulfilled. To do so, Virtual Viewing adopted a more iterative process than most 3D visualisation projects in order to ensure seamless integration with the hardware interface and the LEDs installed in the physical model. As part of Virtual Viewing's approach, the interaction between the 3D visualisation, the hardware interface, and the physical model was central to the outcome.

With the BTVLEP GIS project, the most important requirement was to deal with a large existing data set held in a proprietary format. Given the strategic importance of the data to BTVLEP and its focus on urban development and regeneration, an additional important requirement was to do so as a web application. This required a more structured, linear approach given the complexity of the existing data set and that dictated the solution provided by Virtual Viewing. Such an approach was also important in view of the longer-term requirement to build scalable applications on top of the platform for the proposed second phase of the project. Since the end-user would only interact with the 3D

visualisation presented in web application, Virtual Viewing's approach was driven by ensuring an effective representation of the large quantity of data through 3D visualisation.
The Milton Keynes Smart City demonstration dealt with an evolving concept that could have yielded multiple implementations. To highlight the 'Smart' aspects of the demonstration, Virtual Viewing used multiple building blocks to create the 3D visualisation. The existing offline model of Milton Keynes, although it did not provide geospatial data, formed an important part of the final deliverable. The most important aspect of the 3D visualisation however was the ability to use data feeds from sensors. Coupled with the capability to zoom into any location and granularity of control vis-à-vis the sensor data, the data feeds were the most important building blocks of the final deliverable. This is reflected in Virtual Viewing's approach and also in the ongoing work about the next-generation Smart City demonstration.
Table 2 summarises the problem statement for each project and the way 3D visualisation was adapted for each project.

Table 2 – Adapting 3D visualisation according to the project requirements

Project	Problem statement	The VV approach
Crest Nicholson Bath Riverside	Create an interactive and innovative solution; Combine animation with real time data; Provide interaction with the physical model.	Iterative process; iPad application for 3D visualisation; Hardware interface between the iPad application and the physical model; Physical model configured with LEDs.
BTVLEP GIS	Use the existing 2D geospatial data; Deliver 3D visualisation for presenting statistical data and attracting investment; Create a scalable platform for further customisation.	Linear, structured process; Import, combine, and recut aerial image data; Render data in 3D in a grid system across multiple layers; Use C# and Unity for a customisable web interface.
Milton Keynes Smart City	Demonstrate the Smart City concept; Use an existing offline model of Milton Keynes as a baseline; No geospatial data.	Bottom-up process with multiple building blocks; C++, OpenGL, and C# web services; Granular functionality and capability to read data feeds from sensors; Foundation for the next-generation Smart City demonstration being built by Virtual Viewing.

3D visualisation – the extra dimension
In each of the case studies presented in this paper, 3D visualisation was required not only to provide visuals but also functioned as an important tool for marketing (Crest Nicholson), implementing a strategically important platform (BTVLEP), and conceptualisation and

analysis of an emerging, evolving concept (Milton Keynes Smart City). Although the implemented solutions differed significantly in terms of execution and technologies used, without 3D visualisation none of the projects could have achieved their stated goals. 3D visualisation not only made the projects possible, it also added an extra dimension without which their outcome would not have met the requirements set in the problem statement.

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