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Combining spatial analysis with MCDA for the siting of healthcare facilities

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ABSTRACT

Site selection of healthcare facilities is a typical ill-structured decision problem since it involves multiple criteria and sometimes conflicting stakeholders. Nowadays the site selection problem is ignored by most of the existing evaluation tools. Through a deep literature review the research proposes an evaluation system divided into four criteria (Functional quality, Location quality, Environmental quality, Economical aspects), each in turn composed by sub-criteria supported by the methodology of Multi-Criteria Decision Analysis (MCDA), with the aim of assessing the land suitability for new healthcare structures, in order to improve the transparency and robustness of the decision-making process. After that, spatial component has been added to MCDA using Geographic Information System (GIS). The Multi-Criteria-Spatial Decision Support Systems (MC-SDSS) allow to address choices by an integrated knowledge about territory and by the explicit consideration of the spatial dimension of decision problems. The case study selected to test this method is "La Città della Salute", in the city of Milan, Italy, a project aimed to answer to scientific and cultural changes of contemporary medicine. The focus of the research is to identify suitability maps able to verify the adequacy of the territory in an adaptive perspective, expanding the alternatives' domain.

1. Introduction

The location of healthcare facilities can be considered a typical ill-structured decision problem since it involves issues belonging to different fields of research and there are several and sometimes conflicting stakeholders to take into consideration. It means that, in order to solve it, it is necessary a multidisciplinary approach able to consider all these aspects and to satisfy actors affected by the hospitals' location.

According to the literature analysed on this topic, it is possible to recognize two main problems capable to influence the decision problem. The first involves the set of criteria considered that should be able to describe the complexity inherent in the problem and the second one concerns the variety of stakeholders with their own interests to fulfil and power to prioritize. In fact, first of all it is mandatory to contextualize the hospital location problem as a planning problem (Doerner et al., 2007) able to influence the access to healthcare services by all citizens (Murad, 2007).

According to the first issue, it is possible to underline how the site selection is a typical multicriteria decision making problem including both quantitative and qualitative criteria (Kahraman et al., 2003) belonging to different fields and able to move and to consider multiple resources (Murad, 2007).

Considering the second point, Burkey et al. (2012) argue how the location of healthcare facilities is also effected by many different stakeholders as patients, doctors, politicians and people that daily or rarely visit the hospital. Nowadays in particular, the population growth and the migration to urban areas (Abdullahi et al., 2014) are forcing cities to answer to primary needs such as the hospital location and choosing the right site could have significant effects on accessibility to health services (Beheshtifar and Alimoahmmadi, 2015) and to the satisfaction of stakeholders' expectation.

From this introduction it is clear the complexity of the decision problem investigated and the necessity to manage it with a decision support system based on multidimensional criteria and able to consider as much as possible the different categories of the stakeholders involved, since at the moment it is solved by a case by case process (Soltani and Marandi, 2011) and an objective methodology is still missing.

Given the above emerging research issues, the aim of the current work is to define a Decision Support System able to support the Decision-Maker (DM) and to provide information regarding all the aspects inherent to the problem and in detail, considering simultaneously functional, locational, environmental and economic issues. From the proposed evaluation framework, it is possible moreover to obtain a comprehensive overview about weaknesses and threats of the areas under investigation and, since the decision problem is characterized by

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spatial variables (Oppio et al., 2016) the combination of the Multi-Criteria Decision Analysis (MCDA) with the Geographic Information System (GIS) is suggested. In fact, the Multicriteria-Spatial Decision Support System (MC-SDSS) can provide an integrated knowledge about territory and to explicitly consider the spatial dimension of the decision problems.

The paper is divided into 4 parts. The Literature review section contextualizes the research within the existing literature about the combination of MCDA and GIS with a focus on the location of healthcare facilities. The Materials and Methods describes the case study and the evaluation framework defined to solve the decision problem under investigation, presenting the multi-methodological approach and the development of the model. The Results and Discussion section points out the main findings from its application, summarising the conclusions emerging from the analysis and highlighting strengths and weaknesses. The last section underlines future research lines and how the evaluation framework could provide an effective support to DM with respect to policy implications.

2. Literature review

MCDA and GIS are two different research fields, the first one has been defined by Roy (1985) as a revolution in the field of the operational research while the second is a set of tools able to collect, store, retrieve at will, transform and display spatial data according to a specific purpose (Borrough and McDonnell, 1998). MCDA and GIS can both benefit one of the other in order to manage and analyse spatial problem and evaluate and rank different alternatives (Densham and Goodchild, 1989; Li et al., 2004; Ferretti, 2012). In fact, the Multicriteria-Spatial Decision Support Systems (MC-SDSS) are able to support the DM in processes in the field of land management, land use planning and more in general spatial planning (Torrieri and Batà, 2017).

With the aim of investigating which fields have been explored by the combined use of MCDA and GIS and for which location problem, a literature review has been carried out with the support of the Scopus database by using the following set of keyword: "MCDA" or "Multi-Criteria Decision Analysis" and "GIS" or "Geographic Information System" and "Location". 100 documents resulted from the research. The analysis (Fig. 1) shows how the interest in combining MCDA and GIS to solve location problems is quite recent and is increased in the last years.

In particular the peak is recorded in 2016 and different research fields are investigating the topic, from the Environmental Science to the Economics, Econometrics and Finance. The investigation has been focused on the year, research areas, contexts, countries where the decision problem has been solved and whether it has been applied on real case studies. From the analysis it is clear how the research areas that mostly investigate the location problem are focused on the Energy demand, Risk assessment, Waste management, Geology and Urban planning. In fact, the decision problems solved concerns, for example, the identification of locations for the installation of wind farm (Gigović et al., 2017) or to prevent natural hazard (Tufekci et al., 2018), the landfill site selection (Mat et al., 2016), the evaluation and characterization of groundwater quality (Jhariya et al., 2017) or the rural highway route location (Abdul-Mawjoud and Jamel, 2016). It proves the important support of MC-SDSS to solve different location problems. Another important point highlighted by the research, shows how only one document analysed a case study set in Italy (Borgogno-Mondino et al., 2015) concerning the generation of maps useful for urban planners, and then, even more important is the low percentage of papers that deals with healthcare facilities. More in detail, there are two papers focused on health problems and other two concerning the location problem. Varatharajan et al. (2017) investigated this issue under an epidemiological point of view and Ho et al. (2015) aimed to reduce the mortality due to heat events. For what concern the location, the research of Hariz et al. (2017) aimed to identify the most suitable area to site an incinerator to serve healthcare facilities while in 2009, Vahidnia et al., combined the use of MCDA and in particular of the Fuzzy Analytic Hierarchy Method (FAHM) and the GIS for the hospital site selection.

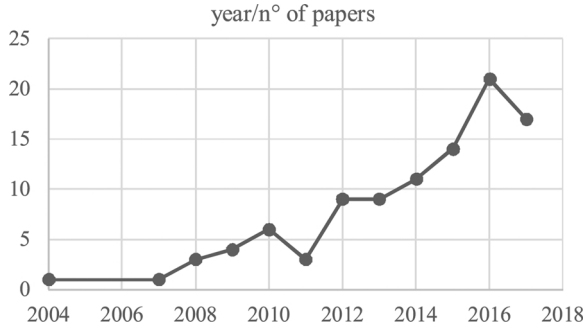

Fig. 1. Literature review: year/n° of papers.

Since only one paper was focused on the location of healthcare facilities, a further investigation has been performed stressing the decision problem with the aim to analyse how other scholars faced this challenge. In order to broaden the research but keeping the focus on the same topics, the literature review has been carried out specifying as keywords "hospital" or "healthcare facility"; maintaining "GIS" or "Geographic Information System" and "Location"; but removing "MCDA" or "Multi-Criteria Decision Analysis" since considered too narrow. 425 documents resulted from the research; a first sort has been carried out starting from the title and 23 documents resulted from the first selection. Then a second sort has been performed through the abstracts and 14 documents have been picked. Table 1 shows the results of the literature review. Even if the context of investigation and the aim of the papers are the same; what is different is the type of building/facilities to locate. In some articles it is a general hospital while in some others it is a specialized hospital for aging people (Kim et al., 2015) or a Neonatal Intensive Care Unit (Noon and Hankins, 2001).

Despite it emerges a case by case approach rather than a common methodology, the combination of georeferenced visual systems with the multicriteria analysis, able to decompose a complex problem in its elementary parts, easier to understand and to solve as the Analytic Hierarchy Method (AHP) or the Analytic network process (ANP), resulted as the favourite evaluation technique. Moreover, this further analysis confirms the previous assumptions, namely the lack of Italian case studies aimed to face this kind of decision problem and the increasing interest in the last years.

3. Material and methods

This section is divided in two paragraphs, the first one will present the Case study under investigation to test the methodology while the second one will describe the Multi-methodological framework defined to solve the decision problem and in particular its stages, namely the definition of set of criteria, the criteria weight elicitation, the standardization functions and the aggregation of the results.

3.1. Case study

In Italy, health policies and planning decisions are taken by regional bodies that have too often conflicting interests with local authorities. Considering the city of Milan, Lombardy region, where is located the pilot case study analysed by this paper, according to a morphological and spatial analysis conducted by Dell'Ovo and Capolongo (2016) on the location of existing healthcare facilities in European capitals and major Italian cities, it is possible to draw some consideration on Milanese hospitals. In detail, it is possible to count around thirty hospitals of different size, according to the number of beds available, and with different specializations. Most of them have been realized between the