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Addressing decisions about new hospitals' siting: a multidimensional evaluation approach

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Abstract

Background. Site selection for urban facilities is a crucial topic in planning decision processes for the several side effects they produce and the multiple criteria involved, especially for healthcare facilities. Nevertheless, the location problem has been ignored by most of the existing evaluation systems.
Methods. Starting from a deep literature review and the analysis of hospitals in 10 European cities, the paper proposes an evaluation system divided into four macro-areas (Functional quality, Location quality, Environmental quality, Economical aspects), each in turn composed by criteria and sub-criteria.
Results. The evaluation system has been applied for the site selection of "La Città della Salute" in Milan, Italy. Furthermore, the ShOS (Selection hospitals' Site) Evaluation Tool has been defined, with the aim of assessing the land suitability for new healthcare structures.
Conclusion. The ShOS evaluation tool improves the transparency and robustness of the decision-making process and it could be broadly applied.

Key words
- hospitals
- location
- multicriteria analysis
- evaluation tool

INTRODUCTION

The city, in its social and territorial dimension, represents, so long, a place of maximum concentration of health determinants. Some of them are positive, as the accessibility to services and health facilities, others negative as the traffic, air and noise pollution. In this context a healthcare structure is an urban element important for its direct (when health services are close and accessible) and indirect (development effects and urban regeneration of the entire area) benefits [1].

In fact, the contemporary hospital provides services not only for its users but also for the neighbourhood, fuelling social and economic regeneration of cities, moreover if it is part of a bigger urban development or renewal intervention according to new users' instances and needs [2].

Furthermore, site selection for urban facilities is a crucial topic in planning decision processes for the several side effects they produce and for the multiple conflicting criteria this kind of decisions are subjected [3, 4]. The increasing urbanization of world's population sheds light on accessibility to health care facilities. The demand of developing new healthcare and medical service centres for improving the overall quality of life and living standard should be balanced with the instance of minimizing diseconomies such as a larger exposure to new risk factors affecting the health's determinants.

Despite the site selection of healthcare facilities is of considerable importance, most of the evaluation systems as the LEED and the BREEAM Healthcare are focused on the intrinsic performances of healthcare structures [5], disregarding the extrinsic characteristics, namely related to the location [6]. The analysis of the literature *(Table 1)* shows that hospitals siting is a widespread research topic in Operational Research and more recently in Geographic Information Systems (G.I.S.). Some papers proposes an integrated approach based on spatial analysis supported by G.I.S. and Multicriteria Analysis, in order to improve the soundness of decisions by providing rational basis (Vahidnia, 2009 [7]; Soltani and Marandi, 2011 [8]; Gu *et al.*, 2012 [9]; Abdullahi *et al.*, 2013 [10]) to face the complexity due to the multidimensional nature of the siting problem. The choice of the location has been viewed under different perspectives with reference to these goals: to estimate accessibility starting from the current features of health care services; to select those locations for health facilities that maximize social welfare; to measure the

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Table 1
Literature review: Scientific domain, Evaluation method and Criteria involved [7-29]. The articles reviewed have been cited according to the publication year

Authors	Ref.	Evaluation Method	Domain	Topic	Population distribution/density	Accessibility	Proximity to services	Density of physicians	Health centre to population ratio	Physicians to population ratio	Transportation costs	Demand	Patient density	Desiderability of location	Land acquisition costs	Contamination/Pollution	Parcel area	Permeability	Compatibility	Maneuverability	Annual average households income
Hakimi	[11]	p-median	OR	Optimal location for services to minimize distance																	
Hakimi	[12]	p-median	OR	Optimum distribution of switching centers																	
Toregas *et al.*	[13]	Set covering models	OR	Location of emergency services facilities																	
Church and Revelle	[14]	Maximal covering location model	OR	Maximum possible population covered by a certain number of facilities																	
Patel	[15]	Set covering models	OR	Optimal location for services centre																	
Eaton *et al.*	[16]	Maximal covering location model	OR	Siting of ambulance bases and centre																	
Revelle and Snyder	[17]	Maximal covering location model	OR	Integrated fire and ambulance siting	x	x	x														
Shroff *et al.*	[18]	Fractional programming	OR	Long term healthcare facilities siting				x						x	x						x
Hodgson *et al.*	[19]	Covering tour model	OR	Mobile health services planning																	
Noon and Hankins	[20]	Spatial data visualization	GIS	Facility location									x								
Yasenovskiy and Hodgson	[21]	Spatial choice interaction modeling	OR	Healthcare facilities location																	
Doerner *et al.*	[22]	Multiobjective combinatorial optimization	OR	Tour planning formobile healthcare facilities	x	x	x														
Smith *et al.*	[23]	MNS model	OR	Planning of community health scheme			x					x									
Murawski and Church	[24]	Maximal covering location model	OR	Improving health services accessibility	x	x	x				x										
Vahidnia *et al.*	[7]	Fuzzy AHP	GIS, OR, MCA	Optimal location for hospitals	x	x									x	x	x				
Soltani and Marandi	[8]	Fuzzy MCDA	GIS, MCDA	Hospital site selection	x	x	x								x		x	x	x	x	
Syam and Côté	[25]	Non linear initial model	OR	Location-allocation of specialized health care services			x				x	x									
Shariff *et al.*	[26]	Genetic algorithm	OR	Healthcare facilities planning			x					x									
Lokhman *et al.*	[27]	Spatial analysis tools	GIS	Reforming Health care Facilities																	
Ebada *et al.*	[28]	Spatial analysis tools	GIS	Evacuation planning	x		x														
Gu *et al.*	[9]	Integrated Evaluation	GIS, OR	Healthcare facilities location planning	x	x	x														
Ismaila and Usul	[29]	Spatial analysis tools	GIS	Spatial Analysis of the distribution of Health care facilities	x	x	x	x	x	x											
Abdullahi *et al.*	[10]	Spatial anslysis and MCA	GIS, MCA	Site suitability assessment	x	x	x								x	x					

efficiency of the health care services' configurations in large time series (Gu *et al.*, 2012).

In these studies, the location-allocation problem is mainly solved by the use of optimization models based on different objective functions, all sharing the aim of selecting those locations able to improve the existing facilities' system and to maximize benefits for people. Since the dominant approach employed is to verify the population covered by a facility within some maximum allowable distance, the criteria mostly considered deal with population density, accessibility and proximity to services.

MATERIALS AND METHODS

In order to identify a strategy to select the site for urban healthcare facilities, the research has been divided into some consequential phases. The first phase is the analysis of the state-of-art by investigating the national and international hospitals' evaluation systems, in addition to the exam of the location strategies of European healthcare facilities. The literature review has therefore focused on the most recent and innovative evaluation techniques used for location of complex services.

The second phase of the research has been focused on the analysis of 10 contemporary hospitals (since 1990s) in the European Capital cities according to a set of location criteria. This step allows to underline the European and Italian trend of healthcare location, highlighting the real effects on the neighbouring urban context. More in deep, by the case study research it has been possible to verify whether the site selection of new healthcare facilities has been addressed by the consideration of its urban and social potentials or whether it has been based on economic or politic arguments.

After this analysis it has been possible to identify a set of prerequisites and criteria divided into four macro-areas for solving the problem of hospitals' location.

Given the multidimensional nature of the decision problem, a multi-criteria evaluation framework has been defined with the aim of providing a rationale support for selecting the most adequate location for urban healthcare facilities.

Mandatory prerequisites have been identified. If they are not respected there are no conditions to start the analysis of the area through the evaluation framework. The prerequisite *Restriction* has the aim of verifying the consistency of the new healthcare facility to the local regulations. This prerequisite is divided into the following sub-requisites: 0.1 *River banks and hydraulic and hydrological instability*, 0.2 *Companies at risk of major accident*, 03 *Urban restrictions*, aimed at analysing local regulations and constraints, and 0.4 *Proximity* to healthcare network, with the goal of verifying the presence of other healthcare facilities with the same services and performances nearby the site under investigation.

The decision problem of site selection has been hierarchically divided into four macro areas, in turn divided into sub-criteria: 1) Functional quality, that takes into account the main features of the area, as its location and degree of development (1.1 Centre of urban redevelopment), its size and flexibility (1.2 Flexibility) and taking into consideration the building density of the surrounding (1.3 Building density); 2) Location quality, that refers to the mobility system (2.1 Accessibility), the supply of services (2.2 Proximity to services), the connection to green areas (2.3 Connection to green areas) and sewerage network (2.4 Infrastructure network); 3) Environmental quality, such as promoting a quiet and healing environment (3.1 Noise pollution), reducing air pollution (3.2 Air pollution), and avoiding unpleasant accidents (3.3 Unhealthy industries); 4) Economic aspects, starting from the land value expressed in monetary terms (4.1 Economic value of the area), the ownership fragmentation (4.2 Ownership) and the interventions needed to make the area suitable for hospitals (4.3 Suitability).

A suitability score is given to each sub-criterion on the basis of a performance evaluation. The range of the scores goes from 0 to 2, where 0 corresponds to the level "Unsuitable", 1 to the "Critical", and 2 to the "Suitable" one. The performance judgements are explicit.

More in deep, the *Functional quality* takes into account the characteristics of the area, considering the promotion of the site according to its flexibility and taking into consideration the building density surrounding the site. In particular, the development of built areas is encouraged in order to avoid negative impacts, to use existing infrastructures and services, to protect green fields, habitat and natural resources. The first sub-criterion is (1.1) *Centre of urban redevelopment*, for which the requirements are to assign a preference to suburban and undeveloped areas. The benefit associated with, it is the possibility to create a new centre of urban regeneration with a positive impact on the neighbouring community. The score is assigned with reference to the distance of the area from the city centre and its level of degradation.

The goal of the (1.2) *Flexibility* [30] is to enhance the selection of an area of average size of 12-15 ha (120 000-150 000 m^2) according to the recommendations provided by the DM 12/12/00, an Italian Decalogue for designing hospitals defined by a Government Commission supported by experts. A flexibility coefficient is calculated by dividing the total GFA by the size of the area. The reference value obtained from the analysis of the Decalogue for assessing the score is 0.72 m^2/m^3, it represents the maximum admissible flexibility coefficient. The third sub-criterion covered by the criterion Functional quality is the (1.3) *Building density*, for which is suggested to select an area already built and with a building density of at least 2.5 m^3/m^2 or 0.8 m^2/m^2 (BREEAM Healthcare). The calculation doesn't include the construction site. Neighbourhood considered is in a radius of 800 m from the boundary of the area. In this way, a sustainable development and the creation of health services where they are more needed for the population are promoted and encouraged. The calculation of the density of the district, included in a radius of 800 m from the boundary of the area, will be obtained through the unit of measure m^3/m^2. The benchmark value for assigning the performance score is 2.5 m^3/m^2, that represents the minimum admissible density.

The criterion Location quality [31] considers the site's

Accessibility by private, public and alternative transport systems. Promoting public and alternative transport reduces private mobility, traffic congestion and thereby air pollution and noise. The provision of *Green areas* in the surroundings of the hospital's site is also considered for the health benefits they provide to patients, medical staff and visitors [32]. The last sub-criterion regards the *Disposal of organic waste* from health care in order to reduce hygiene problems. The (2.1) *Accessibility* [33] has been divided into (2.1.1) *Private*, according to the instance of selecting an area accessible to different kind of users, close to highways or high speed roads. Preferential accesses for ambulances or vehicles going to the hospital are encouraged in order to minimize the risk of congestion and to ensure safe distance covered in case of emergency. By analysing the mobility system before the intervention, it is possible to avoid unnecessary inconvenience. Especially the strategic choice of the location, could make more effective the definition of catchment area. The score is assigned according to the distance of travel time (maximum 15 minutes) from the boundaries of the area to high speed roads. For the (2.1.2) *Public transport system*, it is necessary to select an area where is provided a railway or a subway station within a maximum distance of 800 m from the boundary of the construction site, or bus/tram stops within the maximum distance of 200 m and served by at least two lines of bus and/or tram. The performance evaluation is obtained counting the number of public transport that serve the area and have their stop at the specified distance. For (2.1.3) *Alternative transports*, car sharing and bicycle paths are considered. Also in this case it will be evaluated the number of alternative transport systems that reach the area. It is also suggested to select an area with availability of public and private (2.1.4) existing and well distributed *Parking* in the neighbourhood. The performance score is assigned by considering the distribution of parking lots in a radius of 800 m from the boundary of the area. The last sub-criterion covered by Accessibility is the (2.1.5) *Diversification of accesses* to the area, which means multiple and different entrances for goods and people when the structure is operating. This kind of diversification, in addition to avoid any possible hygiene problems, has a positive effect on the well-being perception of the users. The differentiation of the entrances within the area is also important in order to give priority to emergency vehicles as ambulances. The score is given on the basis of the number of accesses to the area.

For the analysis of the (2.2) *Proximity to services*, it is required to select an area that has within a radius of 800 m at least 8 services among primary public health services, public (libraries, schools, churches, post offices, fire stations, parks, sport facilities, theatres) and private services (bakeries, restaurants, greengroceries, etc.). This sub-criterion aims to integrate the hospital with its surrounding areas and the everyday life of districts communities. The (2.3) *Connection to green areas* is addressed to select an area surrounded by a natural environment, with a special attention to its preservation to future changes and developments and avoiding sites with a high level of ecological value. It is also considered the connection to the existing green areas' system. These requirements may reduce, for the patients, hospital admissions, stress, depression and use of pain medication. The view of a natural landscape can also reduce stress levels in family members and medical staff. The (2.4) *Network infrastructures: sewerage* is the last sub-criterion defined for the Location Quality in order to choose an area close to an efficient sewerage system able to sustain the increased inflows produced by the hospital. The goal of this sub-criterion is to avoid hygiene problems and to minimize the loadings on the city.

The criterion *Environmental quality* refers to the main environmental issues as noise and air pollution, and the presence of unhealthy industries. As hospitals are sensitive structures, the environmental features of the area should be considered. Firstly, noise pollution is caused by excessive exposure to sounds and noises of high intensity [34]. A preliminary study on the sources of noise surrounding the area taken into consideration, can avoid and prevent problems such as mental disorders, insomnia, high blood pressure, which can cause problems even on workers. The limits established for the (3.1) *Noise pollution* are based on the standard given by the Law n. 447, DMA 29/11/2000 and the DPR 142 del 30/03/2004, that define the minimum distances from infrastructures and the limit values of noise. Buffer zones have been defined to protect sensitive structure from the possible noise of train station, subway station, road infrastructures and airports. With reference to the just mentioned laws, also a limit value of noise of 50 dB during the day and 40 dB during the night has been used for the performance scores assignment. More in deep, the scores are defined according to the difference between the benchmark value and the one surveyed in the area under investigation, with a 3 dB tolerance. For the (3.2) *Air pollution* three different pollutants have been analysed: PM_{10} with daily limit of 50 µm/m^3 and annual of 40 µm/m^3; O_3, the Italian and European laws identify three limits. They determine different kind of threshold to not exceed (Alarm threshold - time-average 240 µm/m^3; Information threshold - time-average 180 µm/m^3; Target value - calculated average 8 hours of 120 µm/m^3). As regards the target value, it should not be exceeded more than 25 days during a calendar year; NO_2, with a time limit of 200 µm/m^3 hour average not to be exceeded more than 18 times a year, an annual limit of 40 µm/m^3 average annual and an alarm threshold of 400 µm/m^3 measured on 3 consecutive hours. Each increase of pollutants is associated with an increase in adverse health events like respiratory and cardiac diseases. Scores are assigned according to the limits defined by the laws for each pollutant. (3.3) *Unhealthy industries*, defined by the Decree (DM) 05/09/1994, should not to be present in a radius of 800 m from the boundary of the hospital site. The Article 216 of the Italian Health Laws (Testo Unico delle Leggi Sanitarie) describes unhealthy industries as manufactures or factories that produce vapours, gases or other unhealthy fumes that are dangerous to the health of the inhabitants and are divided into two classes. The first includes those that have to be isolated in the countryside and kept away from the houses, the second those that require special precautions for the safety of the neighbourhood. Satisfying this law's requirements will help to avoid unpleasant incidents. The score is given according to the distance of the area from unhealthy industries.

The last criterion takes into consideration the *Economic aspects*. This thematic area aims to improve the efficiency of use of resources, with reference to the land value, the segmentation and types of land ownership and the most probable duration of the administrative process for obtaining permits and starting the construction process. About the (4.1) *Economic value of the area,* it is requested to assess the monetary value of the area per sqm. The score is assigned according to the percentage of the value of the area on the cost of construction, that should not exceed the 10%-20%. This percentage has been obtained through interviews to experts. Another important aspect to consider is the (4.2) *Ownership,* in order to analyse the types of properties, their size and level of segmentation. The presence of a high percentage of private areas, characterized by a significant fragmentation, should be carefully considered in the event of transformations of the areas due to the location of the new hospital. This type of areas is considered more critical than others. The final judgment will correspond to the identification of the percentage of public and private area, after the ownership's analysis. The final sub-criterion deals with the (4.3) *Suitability*. A deep investigation of the current situation of the area allows to understand which kind of interventions are necessary to make the area suitable and to assess the costs of interventions, usually ranging from the site reclamation, that is the most complex, time consuming and costly, to the removal of existing structures. Thus, the final judgment considers the conditions of the area and the interventions necessary to make it ready for the construction. Three levels are considered, low that corresponds to the reclamation, medium to slight modification and high when the area is already suitable or it needs minimal interventions.

Since each criterion has a different influence on the achievement of the final suitability score, weights have been assigned both at the level of criteria and sub-criteria by the use of pairwise comparison based on the Saaty semantic scale [35].

Questionnaires have been administered to different panels of experts, selected for their skills in the fields addressed by the topic under evaluation. The questionnaires are divided into two parts: the first one describes the decision problem and the second asks to the experts to express the relative importance of the criteria and sub-criteria compared two by two with respect to the goal of identifying the more suitable area at the level of criteria and to each criterion at the level of sub-criteria. Below two example of question type are explained, the first is referred to the criteria level and the second to sub-criteria level:

"Given the aim to identify a suitable area for the location of a hospital, which of the two aspects X and Y contributes most to the aim? To what extent? "

"According to the aim of the criteria 'Location quality' to identify a suitable area for the location of a hospital, which of the following sub-criteria compared, contributes most to the aim? To what extent? "

While for the first questionnaire 8 different experts have been involved and their judgments have been aggregated to reach a unique weight, the second type is more specific and only one expert, for each macro area, expressed his preference. Once the experts' preferences have been surveyed, it has been possible to achieve and display the final outcomes in a single diagram *(Figure 1)*.

The multi-criteria framework has been firstly applied for defining a performance evaluation tool, named ShOS (Selection Hospital Site) Tool, with aim of assigning a performance suitability score to different areas under evaluation and then tested for selecting the site of "Città della Salute" in Milan (Italy). The project, proposed in the early 2000s, took in consideration, in turn, six areas and for some of them agreements and feasibility studies have been made without any real decision. The aim of the program is to answer to scientific and cultural changes of contemporary medicine by combining in a unique pole healthcare services focused and specialised on research, teaching, science and training. Furthermore, it allows to relocate two existing health facilities, the Istituto Neurologico Carlo Besta and the Istituto dei Tumori, that cannot be anymore considered as adequate. This is a current issue not yet solved and there are still works on it.

The areas envisaged for siting "La Città della Salute" are: 1) Caserma Perrucchetti, an area of more than 600000 m^2 that at the moment still hosts a military complex; 2) Ortomercato, that is bounded by the outer ring road of the city and currently hosts the fish and flower market, while in the surroundings there are factories and abandoned warehouses. The size of the site is about 250000 m^2; 3) Rogoredo, an area of about 600000 m^2. Despite its high level of accessibility and being part of the urban renewal intervention of Milano Santa Giulia, actually the area is abandoned and it requires reclamation; 4) Sacco, it's an area of about 250000 m^2 that belongs to the Ospedale Luigi Sacco. It is easily accessible by car and less by the public transport system; 5) Expo, the area that has hosted from May 2015 until October 2015 the World Exposition. The area designed for "La Città della Salute" will be about 360000 m^2, that represents a third of the total; the last area under investigation is Sesto San Giovanni. The area is about 200000 m^2 and it's a brownfield with factories not active anymore.

RESULTS

The ShOS has been applied in order to find out which is the most suitable area among the six available for "La Città della Salute". The *Table 2* shows the analytical framework divided into criteria and sub-criteria, their thresholds and the performance evaluation scores assigned to the six areas. Some criteria excluded, as Flexibility, Building Density, Accessibility, Proximity to services and Environmental quality, the performances of the 6 areas with respect to the other criteria are very different.

Table 3 shows the evaluation report of one of six areas.

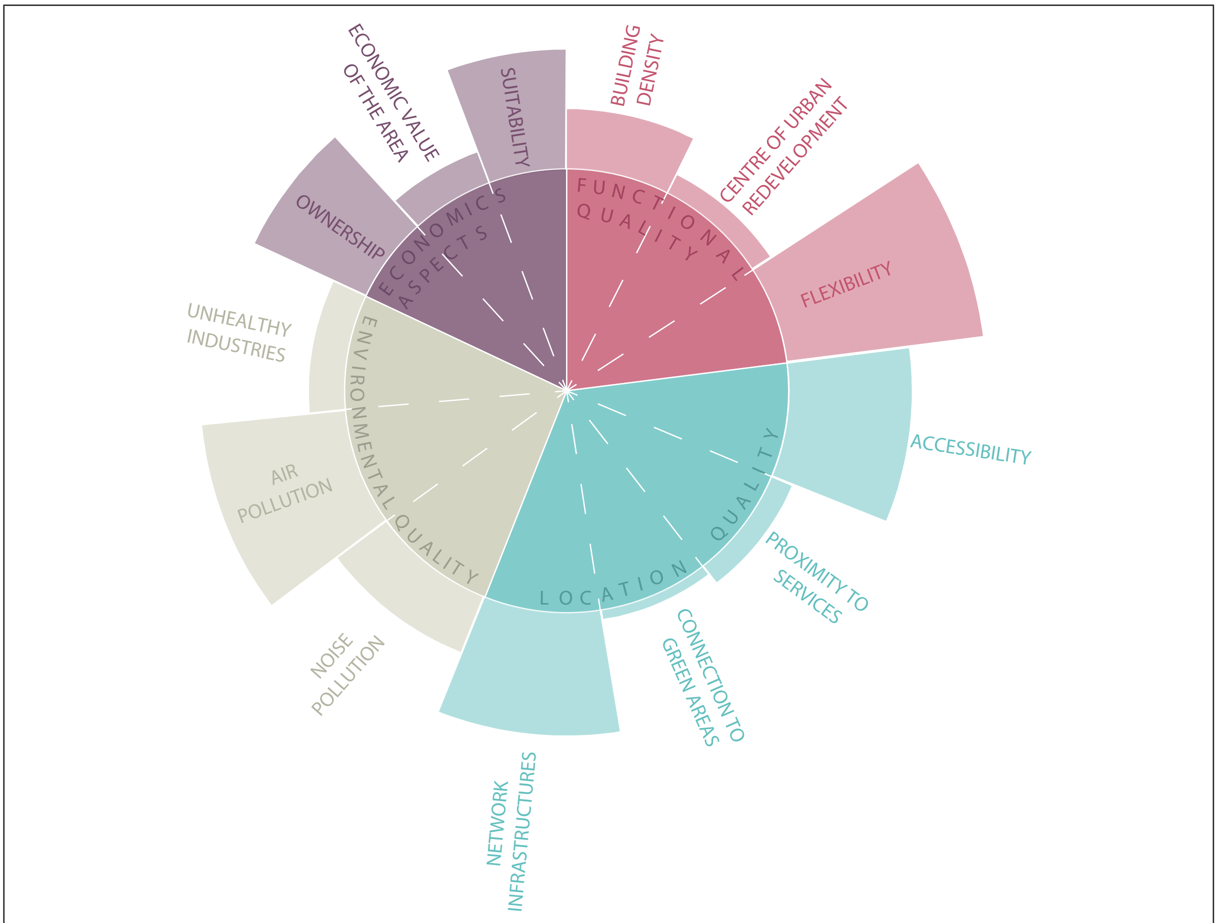

Figure 1
The hierarchical structure of the decision problem divided into four criteria, in turn divided into sub-criteria. The size and the radial depth of each segment of the circle represent the weights' system.

The ShOS tool provides an overall suitability judgement of the area under investigation and a suitability judgement at the level of criteria. More in detail, the overall is given by the weighted score obtained by the criteria. This latter score is in turn given by the weighted sum of the sub-criteria. According to the performance thresholds and to the score assigned, the weighted score of each sub-criterion is given by the performance scores, weighted according to experts' preferences.

DISCUSSION

As all the six areas have obtained a score lower than 1,50, their suitability judgement is "Critical" with minimal scores' differences: Caserma Perrucchetti = 1.39; Ortomercato = 1.36; Rogoredo = 1.34; Sacco = 1.30; Expo and Sesto San Giovanni = 1.25. Despite this homogeneous overall result, there are meaningful differences at the criteria level. For example, while for the Functional quality most of the areas are "Suitable" and for the Environmental quality all of them are "Unsuitable", for the Location quality and the Economic aspects, the results are different. This means that under the Environmental quality it is easy to understand that all the areas analysed are polluted, being in a metropolitan city, while there are other characteristics that can change according to the position of the site, as the Location quality that is evaluated according to its own sub-criteria.

The analysis of the results shows weaknesses and strengths of the areas under evaluation. On the basis of suitability scores obtained by each criterion and, especially, of the final graphs, that provide a clear synthesis of the suitability performances, the ShOS evaluation tool allows to understand, in case of mandatory choice of a specific area for the location of the health facility, the design actions to be developed for mitigate the critical issues. By taking into account the performances of four different criteria, the ShOS tool provide specific information on several aspects that are crucial for the selection of a site and it gives the possibility to the decision-maker to focus on the most critical. Thus, it should be considered not only as an evaluation tool but also as decision support tool, useful for strengthening the awareness of decision makers about advantages and disadvantages of the investigated areas.

These features of the evaluation tool increase the transparency of the decision process, making the reasons behind choices and the actions to be developed explicit.

Table 2
Performance scores assigned to each of the six areas under evaluation

Criteria	Subcriteria		Threshold	CP	O	R	S	E	SSG
Functional quality	Centre of urban redevelopment		Qualitative	0	1	2	1	2	2
	Flexibility		0,72/m^2/m^2	2	2	2	2	2	2
	Building density		x/2.50 m^3/m^2	2	2	2	1	0	1
Location quality	Accessibility	Private	Distance	2	2	2	2	2	2
		Public	x/2	2	2	2	2	2	2
		Alternative	x/2	2	2	2	2	2	2
		Parking	Qualitative	2	2	1	0	0	1
		Diversification of accesses	x/2	2	2	2	2	2	2
	Proximity to services		x/8	2	2	2	2	2	2
	Connection to green areas		x/4	1	1	1	1	0	0
	Network infrastructures		Load for the city	1	1	2	0	0	2
Environmental quality	Noise pollution		50 dB	0	0	0	0	0	0
	Air pollution	PM_{10}	annual limit 40 µg/m^3	2	2	2	2	2	2
		NO_2	annual limit 40 µg/m^3	0	0	0	0	0	0
		O_3	240 µg/m^3	2	2	2	2	2	2
	Unhealthy industries		Distance	2	0	2	1	2	0
Economic aspects	Economic value of the area		Distance	0	1	0	2	1	2
	Ownership		Level of fragmentation	2	2	0	2	2	0
	Suitability		Administrative process duration	1	1	0	2	2	0

CP = Caserma Perrucchetti; O = Ortomercato; R = Rogoredo; S = Sacco; E = Expo; SSG = Sesto San Giovanni. The range of the scores goes from 0 to 2 (0 = Unsuitable; 1 = Critical; 2 = Suitable).

Furthermore, the evaluation framework could be applied in different context by fitting existing benchmarks to new contexts.

CONCLUSIONS

A lack of transparency and efficiency in decision making processes can cause intolerable expanses and delay on the realization of healthcare facilities that represent necessary services for citizens. As example it is possible to consider the case study of "La Città della Salute" (Milan) that since 10 years, is still at the centre of politic and public discussions.

A wrong location can cause negative impacts on: the efficiency of medical service (low accessibility, no flexibility for new demands), the physical, psychological and social wellness of the users (no services and green areas [36], low air quality and noise and visual problems [37]) as well as on economic issues (extra-costs for reclamations, unforeseen environmental evaluations and mitigation interventions) [38].

Therefore it is clear that location issues affect the environmental, social and economic sustainability of healthcare structures [39, 40] and the efficiency of the health service. It means that it is necessary to start from an accurate selection of the site in order to respond to contemporary demands.

The ShOS tool proposed in the present paper can be seen as an innovative approach in the field of decision making processes regarding hospitals, since it considers simultaneously functional, locational, environmental and economical issues, providing a comprehensive overview about the areas under investigation. On one hand, the partial and the final evaluation suitability score represent a first step for clarifying the complexity of the reality in order to provide a rational basis for taking complex decisions, on the other hand, they can play the role of a common knowledge platform, useful for policymakers and urban planners. The results of the first application of ShOS tool highlight the importance of considering the suitability performances of each criterion included in the evaluation framework in addition to the overall suitability score. Furthermore, increasing the transparency of the process, by putting in evidence weaknesses and strengths imposed by the choices of the area, is consistent to the notion of constructive evaluation that expresses all its potentials when it is meant as a supporting activity of the decision making process.

Despite the first application previously discussed seems promising, there are some recommendations for developing this research. Firstly, the ShOS tool needs to be further tested in order to verify the robustness of results in different decision contexts. Secondly, as the decision problem is mostly characterized by spatial variables, the integration of spatial functions typical of Geographic Information Systems (GIS) with those of Multicriteria Analysis (MCDA) is suggested. The Multicriteria-Spatial Decision Support Systems (MC-SDSS) allow to address choices by an integrated knowl-

Table 3
The performance evaluation matrix of Caserma Perrucchetti shows the scores, the weights and qualitative judgement for each of the criteria and sub-criteria

Number	Criteria	Sub-criteria	W	Score	WS	Final score	Judgement
1.	**Functional quality**		**0.23**	4	0.42	1.8	
	In order to take into account the characteristic of the area, considering to work for the promotion of the site chosen for its flexibility and taking into consideration the building density of the surrounding					2	Suitable
1.1	Centre of urban redevelopment		0.02	0	0.00		
1.2	Flexibility		0.15	2	0.29		
1.3	Building density		0.06	2	0.12		
2.	**Locational quality**		**0.33**	6	0.51	1.5	
	In order to allow to any type of user to reach the area, promoting the public and the alternative trasnsport. Encouraging the selection af areas close to services, green areas and infrastructure network					2	Suitable
2.1	Accessibility		0.15	2	0.29		
		private		2			
		public		2			
		alterenative		2			
		parking		2			
		accesses		2			
2.3	Proximity to services		0.03	2	0.06		
2.4	Connection to green areas		0.01	1	0.01		
2.5	Network infrastructures		0.15	1	0.15		
3.	**Environmental quality**		**0.26**	3	0.24	0.9	
	Prevent further problems to patients within the hospital and don't cause them to workers and visitors. Taking into consiteration the needs of the surrounding environment					0	Unsuitable
3.1	Noise pollution		0.06	0	-		
3.2	Air pollution		0.16	1	0.16		
		PM_{10}		2			
		CO_2		0			
		O_3		2			
3.3	Unhealthy industries		0.04	2	0.07		
4.	**Economic aspects**		**0.18**	3	0.23	1.3	
	Rationalizing resources, quantifying the value of the area, understanding if we need extra money to acquire it or if the area is public and analizying the current situation of the site					1	Critical
4.1	Economical value of the area		0.03	0	-		
4.2	Ownership		0.08	2	0.15		
4.3	Suitability		0.08	1	0.08		
	Overall		1.00		1.40	**1.40**	Critical

edge about territory and by the explicit consideration of the spatial dimension of decision problems. The ability of this approach to integrate geographic data (map criteria) and stakeholders' preferences and uncertainties (value judgments) should make the ShOS evaluation tool even more suitable to deal with complex territorial problems, as hospitals' siting.

Conflict of interest statement

There are no potential conflicts of interest or any financial or personal relationships with other people or organizations that could inappropriately bias conduct and findings of this study.

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