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Open building and flexibility in healthcare: strategies for shaping spaces for social aspects

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Abstract

Introduction. The fast development of technology and medicine influences the functioning of healthcare facilities as health promoter for the society, making the flexibility a fundamental requirement. Among the many ways to ensure adaptability, one that allows change without increasing the building's overall size is the Open Building approach.
Methodology. Starting from the analysis of the State-of-the-Art and many case-studies, eight parameters of evaluation were defined, appraising their relative importance through a weighting system defined with several experts. The resulting evaluation tool establishes in what measure healthcare facilities follow the Open Building principles.
Results and discussion. The tool is tested to ten case-studies, chosen for their flexible features, in order to determine his effectiveness and to identify projects' weaknesses and strengths.
Conclusions. The results suggest that many Open Building's principles are already in use but, only through a good design thinking, it will be possible to guarantee architectures for health adaptable for future social challenges.

Key words
- hospitals
- buildings
- healthcare
- flexibility

INTRODUCTION

The challenge of healthcare facilities is to face social, economic and medical changes [1]. Moreover, it is necessary to guarantee to the system, services and assets the ability to meet the constantly changing needs and the characteristics of the geolocation and organizational models [2]. In addition, hospitals are faced with a crucial task as science, technology and medicine develop at an ever-increasing pace. Hospitals have to keep up with all the new requirements and users' needs that progress involves [3]. In the last decades, healthcare has suffered major changes and the consequences are easily revealed inspecting hospitals and all the works done on them [4].

A multi-scale vision of the health topic should be included in the flexibility of operative and still in design hospitals. In fact, flexibility is connected with the network system of local services, the level of planning, health buildings where services are provided and mono-functional environmental units [5, 6]. In this way, it is possible to guarantee the actual efficiency of services delivered, taking into consideration the constant changes of the system, social and economic needs and epidemiological trends [7, 8]. An adaptive and resilient way should be evaluated for the definition of these layers considering also organizational and managerial levels [9]. In addition, important consequences when the building is operative can be produced for the management of these levels. Demands for spatial alterations, functional redistributions, substantial upgrades in the engineering plant design and adaptations, according to new regulations, have a deep impact on hospital buildings, both in economic and managing terms [10]. The more difficult and prolonged operations are the greater impact on the well-functioning of the structure and the quality of the performances provided to the patients.

For these reasons, flexibility – defined as the ability to adjust and change with few and little actions [11] – becomes one of the fundamental requirements for healthcare facilities and one of the main themes, both during the designing process and throughout the entire building's life cycle, due to a manager's careful planning [12].

It is clear that the hospital project, often unsuitable to meet the needs of the organizational complexity of a healthcare facility, is subjected to changes during the time. Therefore, it becomes necessary to define constructive and technological solutions that allow, through environmental flexibility, to guarantee future changes with minimal impact on the entire building system and

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its users. Several scholars aim to identify strategies that can provide different levels of flexibility, sub-divided into hospital systems, buildings, functional and environmental units; in particular for inpatient wards, outpatient clinics, emergency and urgent care spaces. The last ones require environments that must be carefully designed to provide relationships that enable simple processes and flows in order to cope with the varying fluxes in the demand and the increase in the use of mobile equipment, as Astley *et al*. are analysing [13].

Studies on flexibility in healthcare facilities are debated in several research works that have the common aim to find strategies and outputs on sustainability's topics. Nowadays the flexibility issue can also be encountered in relation to the environmental, economic and social aspects of the sustainability and innovation topics focused on the agenda [14].

Flexibility involves some limitations. Through studies and experiences, it is possible to manage the requirements only to a certain degree. Therefore, the building needs to be adaptable even to unpredictable changes. This can be achieved through two different kinds of design approach: variable or constant surface flexibility.

In the first case, the building can be expanded hence increasing its overall volume; some of the instruments of this kind of change are modular design that allows the easy addition of new modules, the possibility to provide new spaces by creating volumes that hang to the façade and the over sizing of the bearing structures to be ready for future upwards expansions. In the second case, constant surface flexibility is the ability to change and to adjust to new layouts without increasing the overall size of the building. Among the ways to achieve this, there are spatial and functional redistributions and the attempts to design inner spaces with a high level of adaptability. To provide the flexibility offered by the latter approach, it is necessary to apply the principles of the Open Building. This concept was developed for residential architecture by John Habraken in 1961 [15] and, according to this vision, the design of buildings involves many different levels of decision making that should be kept self-contained, but at the same time in close relation with each other. It also acknowledges that different parts of a building become obsolete in different moments and some of them needs to be frequently altered to meet people's needs.

By reducing excessive and useless dependencies and entanglements among these components of the project, it is possible to ensure their operation without interference or damage to the others. A distinction between durable elements and those that are more prone to be changed, makes for easier, quicker and low cost actions and allows a greater level of customization. Sometimes, this kind of approach can be useful when dealing with quickly changing regulations and stringent bureaucracy that does not suit the long timeframe of the designing and constructing process of complex structures, such as healthcare facilities [16, 17].

While the introduction of this distinction can have pretty straightforward benefits on the project and building phase of a hospital, the positive applications for the facility's management are perhaps less evident but nonetheless very effective. These measures can help to decrease the length, the entity and therefore costs of all the adaptations and the upgrades that will be needed in the future, enabling the quick completion of such works, with as few inconveniences to the patients as possible [2].

In the last decades, many researchers and scholars have been dealing with the subject of the flexibility of healthcare facilities: in particular, an interesting theory was introduced by one of the Working Commissions of the International Council for Research and Innovation in Building and Construction (CIB W104) in one of their annual conferences, when hospitals were one of the many possible application of the Open Building approach they considered [18].

The first step of the research work was, therefore, to fully comprehend what the Open Building approach entitled, starting with an in-depth study of the State-of-the-Art. This research revealed that the cornerstone of this approach is to operate a definite distinction among the components of a building, a distinction that is based on how long they are supposed to last and who should be able to alter them.

Generally, this distinction results in two levels of elements, Base Building and Infill [19, 20]:

- Base Building is the combination of all the long-lasting components of the building, chosen by the designer and that should not be changed. They require solidity, durability, the ability to provide the same level of performances even when the infill has to undergo profound changes. Among these elements, the most important are structure, building's envelope, locations of the access points, staircases and elevator shafts, hallways and primary plant system;
- Infill is comprised of all the frequently changing parts of the buildings, those that depend on the local needs of the inhabitants and those that are more prone to wear. For such reasons, they need to be easy to replace and totally independent from the Base Building. Among these elements, the most important are space plan configuration and elements that create it (inner partitions, floors, false ceilings), secondary plant system, furniture, fixture and equipment.

For the application of the Open Building approach to healthcare facilities though the parts that form the Infill [21, 22], it needs to be divided into two separate levels, ultimately creating three systems:

- primary system: the Structure. It can last up to more than 100 years and it includes structure, building's envelope, main distribution and building plant system;
- secondary system: the Components. They usually can last for about 20 years and among them there are inner walls, floorings, ceilings, secondary plant system and space plan configuration;
- tertiary system: the Equipment. It includes all the elements that, due to an intensive wear or to the need to be constantly upgraded, usually do not last more than 5 to 10 years.

METHODOLOGY

To better understand such a complex subject, the first step was to lead an extensive and detailed research of the national and international literature and regulations. At the same time, in order to integrate this growing theoretical knowledge, a more practical approach was introduced through the analysis of a large sample of healthcare facilities, providing a varied range of examples in typology, size, features and technical solutions. Some of the most interesting cases were better investigated by visiting them in situ. This extensive knowledge and experience led to the identification of eight evaluation parameters that can be used in the attempt to establish to what extent a building follows the principles of the Open Building approach. [23] They are:

- shape;
- structure;
- façade;
- building plant;
- expandability;
- restrictions;
- technologies;
- exchangeability of large equipment.

The shape of the building is a feature that has a deep influence on the flexibility of the project and on the possibilities of a functional and spatial reorganization: more compact is the volume, better it suits the Open Building approach. Instead, the structure is a fixed element that should be designed keeping in mind the dimensional requirements of all the hospital functions and the need to be able to easily relocate them. The regularity, the shape, the size and the modularity of the structural grid is, therefore, vital to assure that the principles of the Open Building are being followed. To that extent, it can also be very useful to employ elements able to provide for future needs, such as oversized bearing elements to support the weight of a potential new floor or hollow pillars to house the plumbing and the wiring.

The façade is an important element both aesthetically, being the image shown to the surrounding area and technologically, providing shelter and protection from the weather. It should be composed by modular panels and be as independent from the inner layout as possible, allowing modifications to the latter without having to alter the first one as well. Choices regarding the building plant should be made according to the need of adaptability to future requirements: deciding factors are the distribution, the size and placement of the technical shaft and all the features of the single elements.

Considering the fact that the Open Building approach is an example of constant surface flexibility, expandability needs to be found within the building itself, arranging spaces so that they can be able to answer to the need of change and functional reorganization in different time frames [24]. Two aspects have a deep influence on this process: the restrictions that the project presents and the technology used during the building process. The former is useful to understand how many alterations are possible to make and the latter, alongside the choice of materials, has a deep impact on how quickly and how easily these alterations can be made [25, 26]. One other crucial factor in the evaluation is the exchangeability of large equipment, because their size and the frequency with which they need to be updated can make the process really complex and expensive, sometimes even resulting in partial demolitions [27, 28].

As *Table 1* shows, the parameters were arranged into a sheet to make the evaluation tool easier to use and to fill out. The evaluation tool was provided with a handbook and each parameters had its own sheet with a basic definition and a detailed description that also listed all the possible solutions related to it that could be used in a project. These data were defined during the researching step and the case studies analysis, which were also used to rate the flexibility of each option. The grading system presents for each parameter a score between 0 and 10 points.

The output of this evaluation tool was classified in eight different marks and therefore could not be univocal or straightforward. In order to achieve that, it was essential to take into consideration that some features can be more critical and have a deeper impact on the overall flexibility of the project.

Consequently, the next step of the study was to define a weighting system that could help to give the right importance to each parameter, in relation to the others. For this reason, experts and researchers on the field of flexibility and healthcare facilities were gathered together to create a focus group. Each of them was asked to judge the influence of every parameter on the overall flexibility of a hospital building, on a scale from 1 to 10. The cultural background and the personal working experience of each member of the focus group clearly had deep impact on their opinions, leading to a very interesting and diverse debate.

Factoring together all the results, a relative value could be assigned to all the parameters, as shown in *Figure 1*.

RESULTS AND DISCUSSION

The tool was tested and its effectiveness was evaluated through the application to some case studies. Many hospitals were vetted. The structures were chosen among the ones built in the last two decades and those that appeared to be flexible, either in their entirety or simply in a few meaningful aspects, and worthy of detailed studies. The final choice settled on five Italian and five European healthcare facilities [29-31]:

- INO Hospital (1997-2012), Bern (Switzerland), Kamm and Kunding Architects, Ittenbrechbühl and Hwp Planung;
- Martini Hospital (2003-2007), Groningen (The Netherlands), Burger Grunstra Architecten;
- Gregorio Marañón Hospital (2000-2003), Madrid (Spain), R. Moneo and J. M. de la Mata;
- Barcelona Biomedical Research Park (PRBB) at the Hospital del Mar (2000-2006), Barcelona (Spain), M. Brullet Tenas, A. de Pineda Alvarez, A. de Luna X. Llambrich;
- Cancer Centre of the Guy's Hospital (2010-2016), London (United Kingdom), Rogers Stirk Harbour + Partners;
- Children's Hospital (2006-2013), Parma (Italy), Policreo and OBR Open Building Research;
- S. Stefano Hospital (2008-2013), Prato (Italy), Studio Altieri Spa and M. Cuccinella;
- Todi Marsciano Hospital (2004-2010), Todi (Italy), STS Spa;

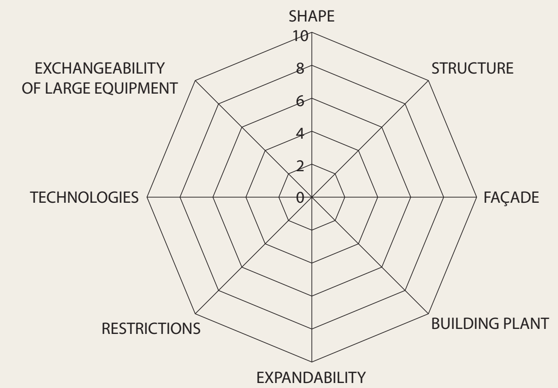
Table 1
Evaluation paper with all the tasks

	EVALUATION TOOL		
	Points	**Options**	**Score**
SHAPE	10	100% Compact	
	8	70% Compact or Vertical	
	6	50% Compact or Linear	
	4	Articulated	
	2	Horizontal	
	0	Detached buildings	
		Total score	/10
STRUCTURE	1	Span < 7 m	
	2	Span > 8 m	
	4	7 m ≤ Span ≤ 8 m or Open floor plan	
	+1	Regular	
	+1	Squared	
	+1	Oversized elements	
	+1	Concrete slabs with removable portion for vertical circulation	
	+1	Hollow pillars for wiring and plumbing	
	+1	Predalles	
		Total score	/10
FAÇADE	+6	Curtain Wall	
	+4	Modular Panels	
	0	Ventilated façade	
	0	Traditional brickwall	
		Total score	/10
BUILDING PLANT	+2*	Spread out plant infrastructure in false ceiling*	
	+1*	Condensed plant infrastructure (varying height of false ceiling)*	
	+1*	Technical Interfloor*	
	+1	Distribution in raised floors	
	+1	In view, when advisable	
	+1	Plant tower	
	+1	Size of service shafts: shafts total surface/floor surface ≥ 0,01	
	4	Distance in between service shafts: d ≤ 35 m	
	2	Distance in between service shafts: 35 m < d ≤ 70 m	
	0	Distance in between service shafts: d > 70 m	
		Total score	/10
EXPANDABILITY	+5	Internal: already equipped spaces	
	+3	Internal: shell spaces	
	+2	External: volumes "hanging" from the façade	
		Total score	/10
RESTRICTIONS	8	Only fixed vertical elements (connections and service shafts)	
	6	Up to 10%	
	4	Up to 30%	
	2	Up to 50%	
	0	Up to 50%	
	+2*	Drain pipes placed in service shafts*	
	+1*	Drain pipes run next to pillars*	
		Total score	/10
TECHNOLOGY	4	Dry assembly technique	
	2	Mixed assembly technique	
	0	Wet assembly technique	
	+2	Internal partitions: modular panels	
	+2	Internal partitions: panels set up with plant infrastructure	
	+2*	Internal partitions: prefabricated panels*	
	+1*	Internal partitions: dry walls built in situ*	
		Total score	/10
EXCHANGEABILITY OF LARGE EQUIPMENT	8	Only needs disassembly of façade panels	
	4	Disassembly of façade panels and of internal partitions	
	0	Partial demolitions	
	+2	Large equipments located on the ground floor	
		Total score	/10

* Points can be given for only one of these options

(continues)

Table 1. (Continued)



- Rapallo Hospital (2008-2013), Rapallo (Italy), Studio Strata;
- Centro Cascina Perseghetto of the Humanitas Research Hospital (2005-2007), Rozzano (Italy), Techint E&C.

By applying the evaluation tool to the ten case studies, their actual flexibility was tested, proving whether or not they could be considered Open Buildings. To better understand and simplify the final outcome of the evaluation tool, the possible result was divided into five different ranges:

- 0 to 20%: definitely not an Open Building;
- 21% to 40%: following some principles, but it cannot considered an Open Building;
- 41% to 60%: following several principles of the Open Building approach;
- 61% to 80%: it can considered an Open Building but with some aspects to be improved;
- 81% to 100%: model of Open Building.

The final results of the ten case studies are clearly presented in *Figure 2*: while none of the case studies scored higher than 80%, which was considered the ideal Open Building to aim for, four of them ranked above 60% and can be considered Open Buildings to all intents and purposes (three of them are Europeans structure and one is Italian). Four rated between 40% and 60%, following many of the principles and still lacking in some aspects. The remaining two case studies, scoring between 20% and 40%, cannot really be considered Open Buildings, even though they have a few redeeming features (usually the same that led to the choice to include them in the test in the first place).

Three of the case studies that scored higher points, INO Hospital, Martini Hospital and S. Stefano Hospital, have been operational for a few years at the moment, while the Cancer Centre was still on construction during the research and is set to open in Autumn 2016. A detailed analysis of the individual scores can permit to better understand each project and if there are some strategies for improvement.

Different kinds of shape were chosen for these projects: two are compact (INO and S. Stefano) and therefore score top marks, one was conceived with a vertical development (Cancer Centre) and one is linear (Martini): on a first analysis, the structure of INO Hospital was supposed to be one of the strong points, but the large span of the grid could prove to be a hindrance upon rearrangement of the functional layout, therefore making it earn less points than expected; instead, Martini Hospital received the same score, even if it gained it differently, particularly due to a slightly too dense structural grid.

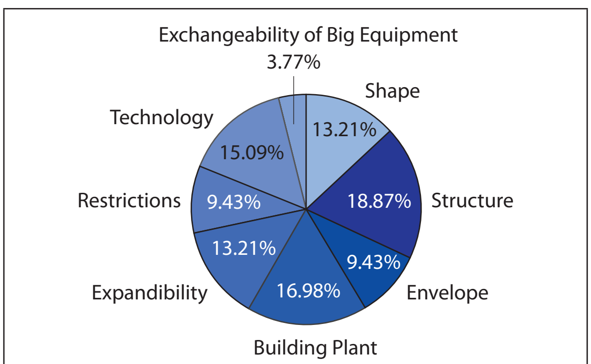


Figure 1
Weighting system: the values of the parameters.

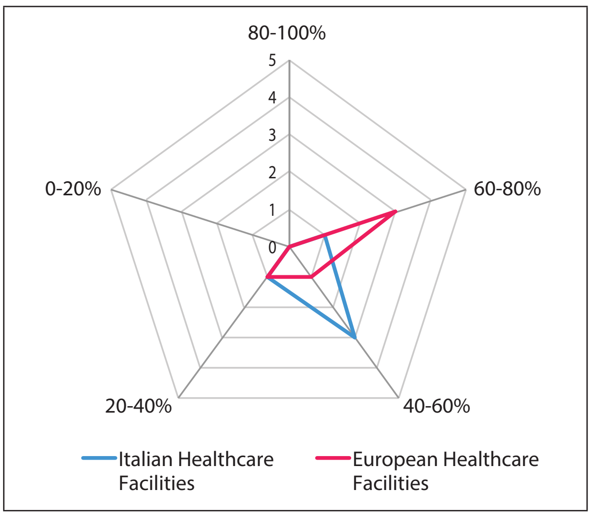


Figure 2
The results of the case studies.

A higher mark was given to S. Stefano Hospital, whose span is in the recommended range and the Cancer Centre scored last of the four cases in this parameter.

Three facilities received good marks for their façades, being them both modular and with a double layer of the envelope, at least partially. The Cancer Centre resulted again the worst of the four, gaining points only for its modularity. This facility, though, scored the highest of all the ten cases in regards to the building plant, mostly due to the large size of the service shafts in relation to the small scale of the tower's floor surface. The other three buildings received average marks, all of them because of a too rarefied distribution of the service shafts.

The highest score earned by the INO Hospital for its expandability was expected, thanks to the great care shown during the designing process that led to the creation of already equipped areas as well as shell spaces, a valid attempt to be able to answer to differently time-framed needs of room. Both the Cancer Centre and S. Stefano Hospital have sizable terraces and large verandas like areas available to the enjoyment of patients, visitors and hospital workers alike, that can be easily equipped to be used differently. Martini Hospital introduced a different approach by creating brand new surfaces thanks to quickly assembled volumes that hang from the façade.

Due to the favourable features of their projects, both the Cancer Centre and Martini Hospital earned high marks for having few restrictions against alterations. Even though they received less points, both of the scores of the other two facilities are good, ranking higher than the remaining case studies, with one exception, the PRBB.

In regards to the technology parameter, the high mark proves that the designers of Martini Hospital carefully and wisely chose both the materials and the building techniques. The Cancer Centre, still under construction, already introduced interesting solutions, receiving a high score as well. Fewer points were gained by the other two hospitals, showing room for improvement.

Lastly, all the four facilities ensure the chance to easily exchange large equipment, but the Cancer Centre and Martini Hospital score higher, due to the careful placement of the departments that avail themselves of such machines.

CONCLUSIONS

New approaches to design in the healthcare sector at different levels involved in the project have been achieved in this analysis. Strategies about the health structures, technologies, engineering plants and architectural plans are suggested to hospital planners in order to understand how it is possible to build hospitals at human scale that are able to change their internal and external services during the time [32].

The contemporary idea is to create easy and adaptable facilities, which are capable to meet new demands over time and to not influence the activities of users and medical staff. According to the State-of-the-Art, flexibility is the key deliverable of the hospital of the future and consequently designers have to ensure new needs due to technological and scientific changes [12].

While not entirely positive, these results suggest that, even if the Open Building approach is not yet common practice or even largely known, many of its principles have already been used unknowingly in many hospital projects, both in Italy and in Europe. The fact that none of the ten case studies scored higher than a 65% is a sign of how much work is yet to be done. Some of these facilities, generally considered outstanding flexible solutions, still have plenty of room for improvement.

Considering the complexity and the multidisciplinary of the topic of the healthcare facilities' flexibility, this tool is an attempt to simplify the matter. It can be used to check and evaluate different features of the projects, both in the designing process and those already in use.

In the first case, the results highlight the weaknesses and the criticalities that need further study, showing which of the many parties involved in the designing process need to be included in this phase of the work. In the second case, it can help to better understand the needs of the facility in order to improve the efficiency of the management, to reduce the costs of maintenance and to make sure that the alterations to the layout can occur as quickly and easily as possible [33, 34]. By doing that, it is possible to schedule the interventions around the regular functioning of the medical activities, also limiting the disturbance to the patients and their recovery.

The following steps of the research could be, in a first stage, to employ the evaluation tool on a larger number of healthcare facilities, mapping the flexibility of the hospitals on a regional or even national scale. In a second step, the tool could be further developed by extending the focus group that originally provided the weighting system used to obtain the final evaluation. A debate among a larger and more varied sample of professionals, other than being an exceptional chance of confrontation, could also alter the system, maybe even going as far as giving more relative importance to some of the parameters that were at first deemed as only marginal in the matter [35].

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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REFERENCES

1. Solomon NB. *Architecture: celebrating the past, designing the future*. New York: Kaplan Publishing; 2007.
2. Capolongo S. *Edilizia ospedaliera. Approcci metodologici e progettuali*. Milano: Hoepli; 2006.
3. Capolongo S, Bottero MC, Lettieri E, Buffoli M, Bellagarda A, Birocchi M, *et al.* Healthcare sustainability

challenge. In: Capolongo S, Bottero MC, Buffoli M, Lettieri E (Eds). *Improving sustainability during hospital design and operation: a multidisciplinary evaluation tool*. Cham: Springer; 2015. DOI: 10.1007/978-3-319-14036-0_1

4. Astley P, Capolongo S, Gola M, Tartaglia A. Operative and design adaptability in healthcare facilities. *Techne*, 2015;9:162-70. DOI: 10.13128/Techne-16118
5. Astley P. *Beyond estates strategy? Beyond master planning? Open planning for future healthcare environments*. Hoofdstraat, Noordwijk: Changing Roles: New Roles, New Challenges; 2009.
6. Astley P, Hind R, Mills G, Price A. *Open infrastructure planning for emergency and urgent care*. Boston: Architecture in the Fourth Dimension; 2011.
7. Buffoli M, Capolongo S, Bottero M, Cavagliato E, Speranza S, Volpatti L. Sustainable healthcare: how to assess and improve healthcare structures' sustainability. *Ann Ig* 2013;25(5):411-8. DOI: 10.7416/ai.2013.1942
8. Buffoli M, Gola M, Rostagno M, Capolongo S, Nachiero D. Making hospitals healthier: how to improve sustainability in healthcare facilities. *Ann Ig* 2014;26(5):418-25. DOI: 10.7416/ai.2014.2001
9. Buffoli M, Nachiero D, Capolongo S. Flexible healthcare structures: analysis and evaluation of possible strategies and technologies. *Ann Ig* 2012;24(6):543-52.
10. Capolongo S, Buffoli M, Oppio A, Petronio M. Sustainability and hygiene of building: future perspectives. *Epidemiol Prev* 2014;38(6):46-50.
11. Di Battista V, Fontana C, Pinto MR. *Flessibilità e riuso*. Firenze: Alinea; 1995.
12. Capolongo S. *Architecture for flexibility in healthcare*. Milano: FrancoAngeli; 2012.
13. Astley P, Mills GR, Hind R, Price ADF. Open emergency systems through acuity-adaptive design. Durban, South Africa: UIA Architecture Otherwhere Conference; 2014.
14. Capolongo S, Buffoli M, Oppio A, Nachiero D, Barletta MG. Healthy indoor environments: how to assess health performances of construction projects. *Environ Eng Manag J* 2013;12(S11):209-12.
15. Habraken J. *Supports: an alternative to mass housing*. London: Architectural Press; 1972.
16. Kendall S. Open building: a systematic approach to designing change-ready hospitals. *Healthcare Design Magazine. Healthcare Design* 2007;27-33.
17. Kendall S. *Open Building: a new paradigm in hospital architecture*. Boston: AIA Academy Journal; 2004.
18. Kendall S. Open building in health care architecture: the case of the INO Project in Bern, Switzerland. In: *Dense living urban structures, CIB W104 conference*. *Proceedings*. Hong Kong: 2014. p.106-14.
19. Kendall S, Teicher J. *Residential Open Building*. London: E & FN Spon; 2000.
20. Kendall S. Developments toward a residential fit-out industry. *Open House International* 2011;36(1):130-42.
21. Kendall S. Open Building: an approach to sustainable architecture. *J Urban Technol* 1999.
22. Eberhard JP, Rassia S, Pardalos P. *Sustainable environmental design in architecture: impacts on health*. New York: Springer Optimization and its Applications 56, Springer Science+Business Media; 2011.
23. Guenther R, Vittori G. *Sustainable healthcare architecture*. New York: John Wiley & Sons; 2008.
24. Kendall S. Hospitals on the time axis: trends in the real world and implications for architectural education. *Health Environ Res Des J* 2011;4(4):130-42.
25. Buffoli M, Bellini E, Bellagarda A, di Noia M, Nickolova M, Capolongo S. Listening to people to cure people: The LpCp – tool, an instrument to evaluate hospital humanization. *Ann Ig* 2014;26(5):447-55. DOI: 10.7416/ai.2014.2004
26. Capolongo S, Bellini E, Nachiero D, Rebecchi A, Buffoli M. Soft qualities in healthcare method and tools for soft qualities design in hospitals' built environments. *Ann Ig* 2014;26(4):391-9. DOI: 10.7416/ai.2014.1998
27. Mandolesi E. *Flessibilità interna dell'alloggio e procedimenti costruttivi in rapporto anche al contenimento dei costi*. Roma: Tipografia Leberit; 1973.
28. Origgi L, Buffoli M, Capolongo S, Signorelli C. Light wellbeing in hospital: research, development and indications. *Ann Ig* 2011;23(1):55-62.
29. Verderber S. *Innovations in hospital architecture*. New York: Routledge; 2010.
30. Masciardi I. *Ospedali in Italia*. Milano: Tecniche Nuove; 2011.
31. Buffoli M, Capolongo S, di Noia M, Gherardi G, Gola M. Healthcare sustainability evaluation systems. In: Capolongo S, Bottero MC, Buffoli M, Lettieri E (Eds). *Improving sustainability during hospital design and operation: a multidisciplinary evaluation tool*. Cham: Springer; 2015:23-30. DOI: 10.1007/978-3-319-14036-0_3
32. Bottero MC, Buffoli M, Capolongo S, Cavagliato E, di Noia M, Gola M, *et al*. A multidisciplinary sustainability evaluation system for operative and in-design hospitals. In: Capolongo S, Bottero MC, Buffoli M, Lettieri E (Eds). *Improving sustainability during hospital design and operation: a multidisciplinary evaluation tool*. Cham: Springer; 2015:31-114. DOI: 10.1007/978-3-319-14036-0_4
33. Alfonsi E, Capolongo S, Buffoli M. Evidence based design and healthcare: an unconventional approach to hospital design. *Ann Ig* 2014;26(2):137-43. DOI: 10.7416/ai.2014.1968
34. Capolongo S, Buffoli M, Oppio A, Rizzitiello S. Measuring hygiene and health perfomance of buildings: a multidimensional approach. *Ann Ig* 2013;25(2):151-7. DOI: 10.7416/ai.2013.1917
35. Capolongo S, Buffoli M, di Noia M, Gola M, Rostagno M. Current scenario analysis. In: Capolongo S, Bottero MC, Buffoli M, Lettieri E (Eds). *Improving sustainability during hospital design and operation: a multidisciplinary evaluation tool*. Cham: Springer; 2015:11-22. DOI: 10.1007/978-3-319-14036-0_2