Computational BIM design approach supporting Spatial Analysis: the case of healthcare facilities

Original

Computational BIM design approach supporting Spatial Analysis: the case of healthcare facilities / Ugliotti, Francesca Maria; Shahriari, Farzane. - In: DISEGNO. - ISSN 2533-2899. - ELETTRONICO. - DIALOGHI / DIALOGUES • visioni e visualità / visions and visuality: Testimoniare Comunicare Sperimentare / Witnessing Communicating Experimenting:(2022), pp. 2925-2936. (43° CONVEGNO INTERNAZIONALE DEI DOCENTI DELLE DISCIPLINE DELLA RAPPRESENTAZIONE CONGRESSO DELLA UNIONE ITALIANA PER IL DISEGNO / 43rd INTERNATIONAL CONFERENCE OF REPRESENTATION DISCIPLINES TEACHERS CONGRESS OF UNIONE ITALIANA PER IL DISEGNO Genova September 15th-16th-17th 2022) [10.3280/oa-832-c182].

Publisher:
FrancoAngeli

Published
DOI:10.3280/oa-832-c182

43rd International Conference
of Representation Disciplines Teachers
Congress of Unione Italiana Per Il Disegno – Proceedings 2022

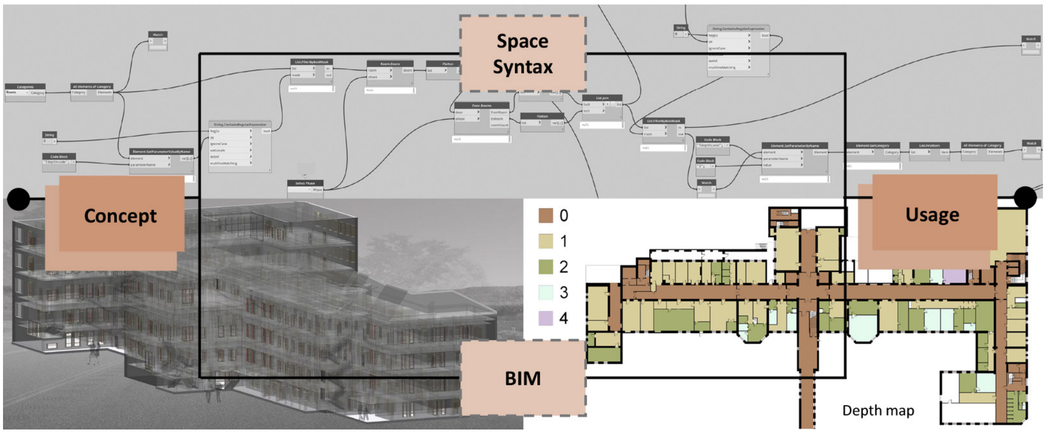
Computational BIM design approach supporting Spatial Analysis: the case of healthcare facilities

Francesca Maria Ugliotti
Farzane Shahriari

Abstract

Architectural planning and spaces organisation are primary aspects of the design of a building. Architects are constantly looking for solutions that seek to combine increasingly high-performance aesthetic and functional factors according to specific purposes of use. On the other hand, the building process has resulted from some logic that shapes the built environment, such as urban morphology, climate conditions, economic context. The interaction of specialist disciplines and among stakeholders often leads to changing the original idea of the configuration. Methodologies and tools are needed to verify that the initial requirements are met according to the social patterns. The relationship between spaces, functions, and social activities is crucial for built environment management, particularly relevant in healthcare. From the Space Syntax science-based, human-focused approach, this paper presents a methodological framework and toolkit to exploit the potential of Building Information Modelling within this field. Parametric models are used both to implement data and to automatize the evaluation of indicators based on the level of interaction and depth of spaces. The objective is to establish a database and a shared language to correlate spatial analysis with other disciplines. The proposed method can be adopted for an expeditious evaluation of the current state of the buildings, thus becoming an iterative assessment procedure of design solutions and re-functionalisation projects.

Keywords
Building Information, modelling, Visual Programming Language, Space Syntax, Graph Theory, Space Performance



From Concept to Usage with Space Syntax and BIM (author's elaboration).

doi.org/10.3280/oa-832-c182

Introduction

In the history of Architecture, many researchers have investigated dialogue between form and function from different points of view. The core of the debate is about how form influences or is affected by the function. After the radical vision against this dialogue by Modernism in the last years of the 20th century, Hillier and Hudson introduced the Space Syntax (SS) as a new terminology to explain the connection between space and its content [Forty, Mary 2000]. According to The Social Logic of Space book, the form is assumed as the configuration of spaces and functions in a specific network of social activities. The focus of the argument is the meaning of depth and its relationship with activities [Hillier, Hanson 1894]. The depth of the space is the level of being physical and functional accessibility of a certain space from a defined reference point. Against this background, special attention is given to buildings with functions that have a more complicated distribution of social activities and require a more significant study of the space configuration. In the case of the healthcare complex, the social logic of the space has a crucial part in the construction and management process. For these reasons, many authors have studied sanitary buildings [Haq, Luo 2012, pp. 98-117] to find appropriate measures and spatial plans to relate theoretical aspects with practical diagrams and methods of connection and wayfinding. In complex and large structures, the circulation path is the central element to be assessed [Ulken, Edgu 2005]. However, it is necessary to check that the space distribution meets the other construction requirements (i.e. energy efficiency, technical issues).

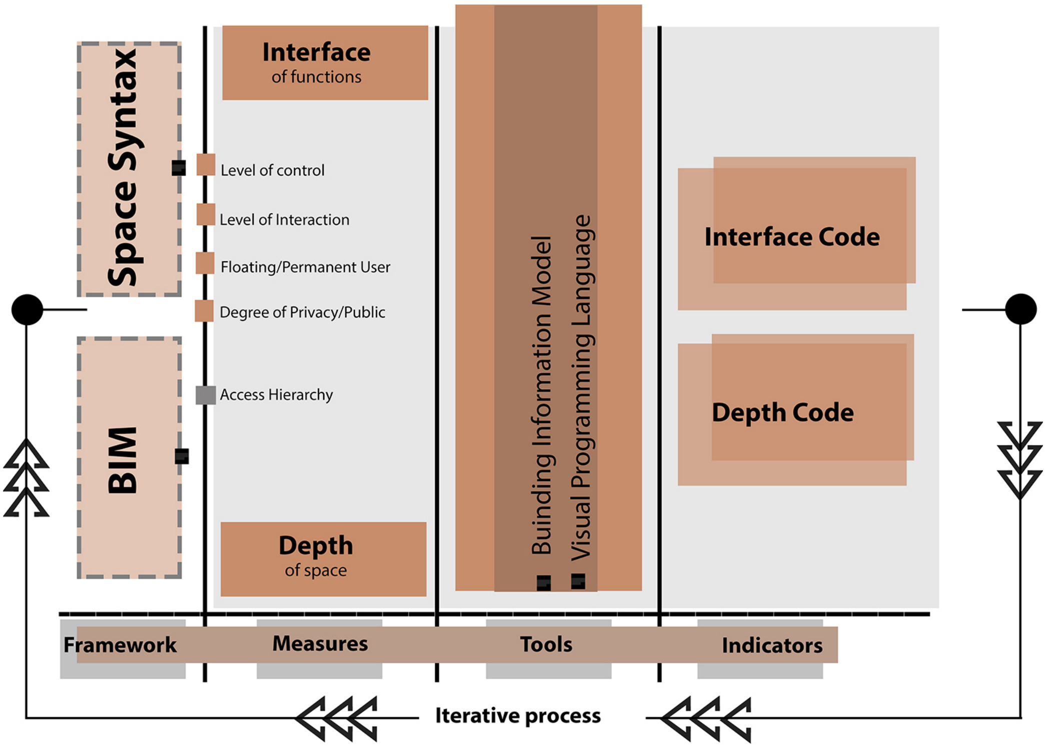


Fig. 01. Proposed methodological framework (author's elaboration).

The trend is aimed to transform information into usable data starting from a three-dimensional building representation based on objects corresponding to real components with associated relationships, attributes (e.g. materials) and properties (e.g. cost, maintenance information). All the stakeholders bring their subjects into the Building Information Modelling (BIM) system. Space and spatial configuration could be considered one [Shahriari, 2019]. Within all advantages of BIM compared with classic tools, it is considered that the design output elevates from Geometric shape to Information model [Lee, Kim 2014, pp.1-8].

Methodology

This paper explains how the SS approach and BIM can be combined to implement an innovative methodology for space analysis (fig. 01). Measurement systems are identified and analysed from the BIM perspective to set up a shared language. BIM tools can set up a consistent database relating to the spaces and ease data processing. The results are indicators that evaluate the spatial distribution compared with activities compositions and intervention scenarios. The method allows us to establish an evaluation process that becomes the basis of a re-functionalisation project, which can be verified through an iterative approach. The application is validated through a real case study. Tests described have been performed on a hospital complex of the 30s, located in Turin (Italy). It covers an area of around 140.000 sqm composed of dozens of pavilions. Buildings are designed with corridor ward style [Nazarian, Price, Demian 2011, pp. 219-231], defining a pedestrian circulation as the site's core (fig. 02). Since its foundation, several extensions have added additional height levels, new warehouses, and areas to the structures. Specifically, the data reported refer to the neurology pavilion spread over four floors above ground, including surgeries, ambulatories, recovery rooms and visit halls.

Measures

Within SS, two key concepts need to be investigated: (i) the interface of each function and (ii) the depth of the space. Related theoretical measurement systems are recalled to evaluate the main connections within the BIM context (fig. 03).

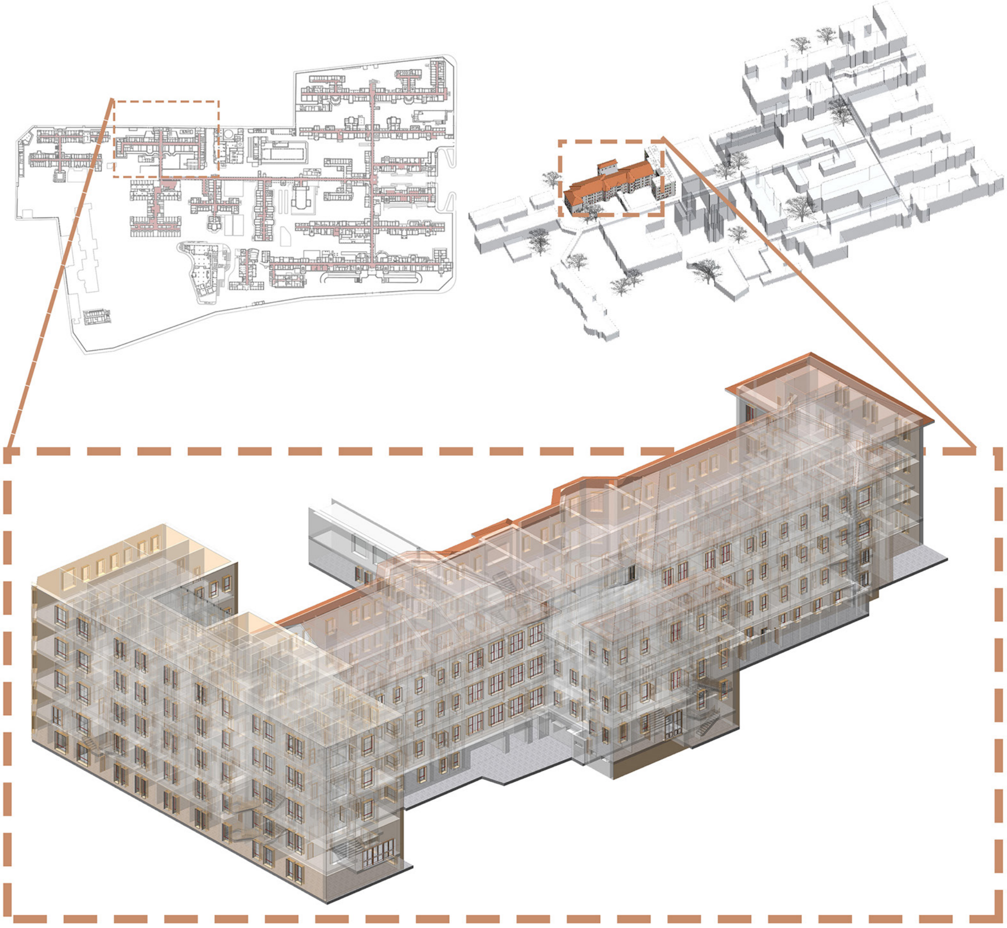


Fig. 02. Healthcare complex selected as case study (author's elaboration).

According to the literature background, the configuration of the physical environment can affect the behaviour of the users [Hillier et al. 1987, pp. 233-250] and the relationship between them. This is defined as interface and can affect the quality of the healthcare activities provided [Sailer et al. 2013]. For these reasons, the essential factor in designing or analysing a hospital is to recognise all activities expected in the structure. Within this list, it is required to stabilise the main activities compared to the secondary one and the possibility of converting the current usage to future planned activities [James, Noakes 1994]. To ensure proper caregiving activities must be located in the right position according to the space configuration [Kobus et al. 2000]. In this article, the level of the interface of activities is classified based on the following measures.

Level of Control	Some functions are created to control other spaces, for example, information points or security desks in public buildings. They required a highly accessible position to control the most possible spaces. On the contrary, some activities must be under control, i.e. waiting rooms.
Level of Interaction	Some human activities have a higher degree of interaction than others. The best access must be provided between interactive activities. On the contrary, some functions such as laundry tend to be isolated. Traditionally, the nurse station is the main argument of a sanitary building defining the style category from radial ward to corridor ward [Kobus, Skaggs, Bobrow, 2000].
Privacy/Publicity	Some activities need privacy that can be provided by enclosure or enough distance from the main access. On the other hand, some users need to run their activities within a public context. The more people can access the activity, the better the efficiency that activity can obtain. Service rooms or laundries, for example, demand fewer access degrees than others. Patient rooms in a building require a position with most silence and privacy as possible. The deeper spaces are more suitable for these rooms.
Floating/Permanent Users	Users a have a different degree of permanency in a hospital and can be considered as permanent users or inhabitants [Hillier, Hudson 1894]. This factor is much more related to the level of control.

The four mentioned measures are combined to produce a range of interaction of function subdivisions. The depth of the space is closed to the meaning of accessibility and the gradual levels from the most accessible points of the circulation system to the most remote rooms. This terminology differs from the distance, as being closed or far away are related to the dimension between two points [Davies, Jokinemi 2008].

Entrances and corridors are designed to provide access to the rooms. Rooms can in turn provide access to other rooms. In this configuration, rooms and circulation paths are classified hierarchically. A room with direct access to the circulation path is more accessible than indirect access. On the contrary, far rooms are more in-depth than rooms with no mediator space in terms of the number of spaces that must be passed to reach them. The study of space accessibility finds similarities and applications with the Graph Theory by Leonhard Euler [Trudeau 1993], used as a reference from different mathematical approaches by many researchers. The space configuration can be presented through the starting and arrival enclosed spaces as nodes and lines. The number of ramifications arising from the node can be identified, highlighting those points with as many routes as possible and reflecting greater accessibility [Hillier, Hudson 1894]. Technological development has led to other types of representation based on processing and graphical returns provided by the computer (fig. 04), including generative architectural design [Nourian et al. 2013].

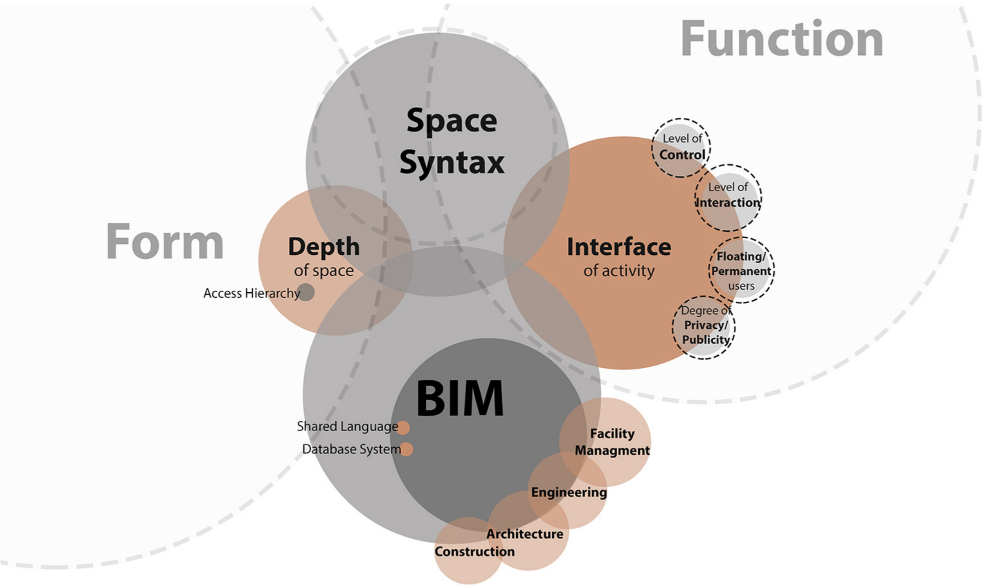
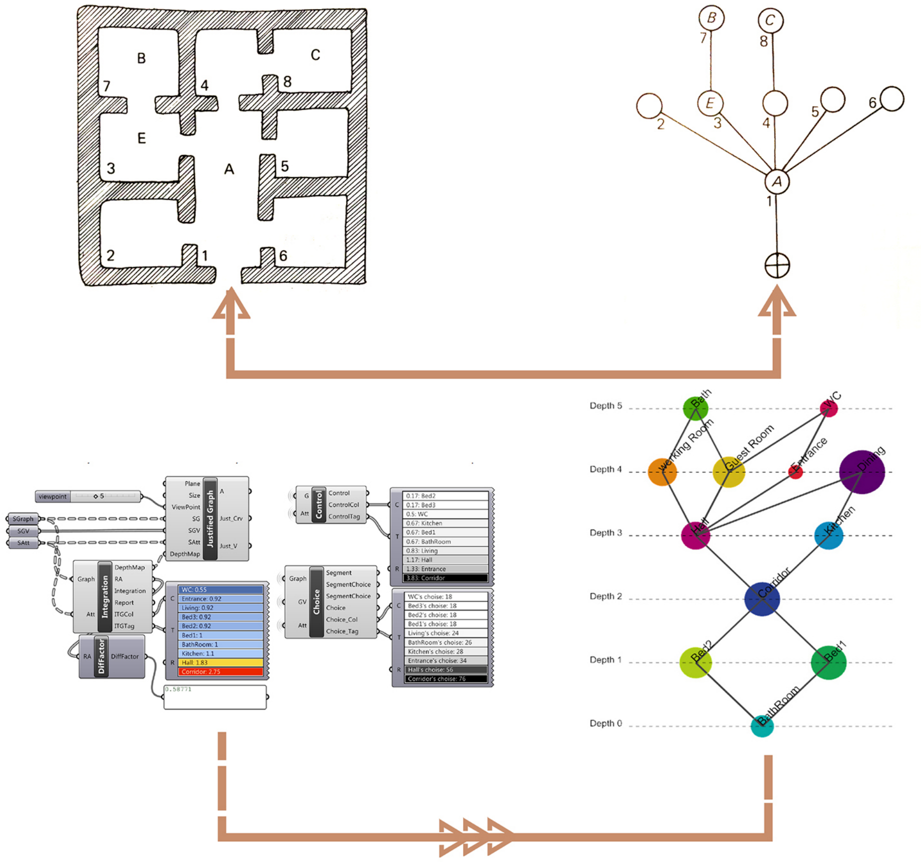


Fig. 03. Research framework (author's elaboration).



```
WC: 0.55
Entrance: 0.92
Living: 0.92
Bed3: 0.92
Bed2: 0.92
Bed1: 1
BathRoom: 1
Kitchen: 1.1
Hall: 1.83
Corridor: 2.75
```

```
0.58771
```

```
0.17: Bed2
0.17: Bed3
0.5: WC
0.67: Kitchen
0.67: Bed1
0.67: BathRoom
0.83: Living
1.17: Hall
1.33: Entrance
3.83: Corridor
```

```
WC's choise: 18
Bed3's choise: 18
Bed2's choise: 18
Bed1's choise: 18
Living's choise: 24
BathRoom's choise: 26
Kitchen's choise: 28
Entrance's choise: 34
Hall's choise: 56
Corridor's choise: 76
```

Fig. 04. Comparison between graph [Hillier, Hudson 1894] and generative depth diagrams [Nourian, Rezvani 2013]. https://www.researchgate.net/profile/Pirouz-Nourian/publication/283311205_Designing_with_Space_Syntax_A_configurative_approach_to_architectural_layout_proposing_a_computational_methodology/links/5632408508ae242468d9cfa9/Designing-with-Space-Syntax-A-configurative-approach-to-architectural-layout-proposing-a-computational-methodology.pdf?origin=publication_detail

Tools and Indicators

The starting point for spatial analysis is the collection of the existing documentation, verifying the spaces through a speditive survey [Ugliotti, 2017], and adopting a rigorous classification system. As the core of the spatial analysis is to determine the depth of each space and compare it with the requirement of the function contained by them, these aspects can be considered as BIM parameters. This concept can be transferred by assigning classes of function for each activity, codified as the Interface Code (IC). The first step is to classify the spaces of the hospital regarding their users and usage and take into consideration their level of control or interaction. Two instance parameters have been introduced to indicate the function of the space (Room Category) and the specific use (Room Type). Starting from the space typology, the interface code of activity has been evaluated, by identifying classes through conditional logic. The IC is a sum up and balances spot between the all mentioned measures in function divisions. The level of control is why a room must be closed to or far away from the main path. At the same time, it is also affected by the interaction level. If a particular activity is involved with less interaction between users, it could be placed far away from the main circulation path.

IC 0	Main entrance or public circulation path of the building. These spaces can be used by everyone, from different degrees of control or interface. It should be noted that excusive paths or elevators are not considered in this level as they are attached to the users that are exclusively using these spaces.
IC 1	Nurse station and information desk. All the spots and rooms dedicated for centralised activities of nurses are included. They have maximum interaction with other users and their activities are related to the maximum number of activities in the sanitary building. All secondary paths and accesses are classified in this class.
IC 2	Patients general care rooms. All spaces dedicated to patients in general level or general hospitalisation, such as patient or visitors waiting room and toilets, stay hall, are put into this code. General ambulatory are best example and main usage of this.
IC 3	Specific care rooms or other specific sanitary function related to the patient. Ambulatories with specific care giving role, laboratory, surgery, medicate stores, X ray are coded one degree lower as to reach to these activities a patient may need to be in general care station first.
IC 4	Administrator rooms. All rooms assigned for the head of the care-giving department, the inter-communication between caregivers or patient references for dispute resolution. They are controlling spaces characterised by a minor degree of interaction compared with nurses and caregivers.
IC 5	Staff rooms. Staff support areas such as dressing rooms and break areas. In addition, all of the private access or corridors with limited access for staff or limited persons have got this code.
IC 6	Services. All activities with the aim of providing services for other sectors and the utility rooms. Storage and storerooms for sanitary equipment are classified in this sector.

The depth of a closed room can be as well assumed as a numeric parameter, Depth Code (DC), to discretise how many doors or other spaces should be passed to reach defined rooms. The higher the code, the deeper space.

DC 0	Entrance hall and main corridors. They are all paths of the building that directly provide access to other spaces.
DC 1	Rooms level one are all the spaces adjacent to the main routes, directly connected through a door or an opening. To reach these locals you must pass through a room with code 0.
DC 2	Rooms level two can be reached after passing two doors or two other spaces (one main room with code 0 and one room with code 1. A room with code 2 is deeper compared with the space with code 1.

This sort has no limit as it is possible to have infinitive mediator rooms. In this article, the maximum obtained DC is 3. However, manual evaluation and implementation of codes is very time-consuming and can become a very complex activity in large real estate. The added value of the study is the automated calculation of these indicators exploiting the Visual Programming Language (VPL). The Dynamo script implemented aims to populate the DC of the spaces starting from identifying the main paths of circulation through their intended use and the hierarchical relationship among the spaces surrounding them. The DC of a specific room is achieved by counting the number of enclosed rooms in succession that the user must pass through to reach it. Once the user passes through a door from the main corridor (DC 0), he enters into space, for example A, immediately accessible (DC 1) as directly linked to the circulation path. If he crosses another door to enter the room next to the first one, such as B, he moves further away from the main corridor, reaching a deeper point (DC 2) of the configuration (fig. 05). According to the graph presentation, the spatial connection with the reference room is represented by three nodes and two lines. Starting from the mapping of the spaces managed through the BIM database, a script has been created to combine this logic of theory with the functional relationships between the different objects of the model. Each room is considered a space containing a function, characterised by one or more openings/doors that connect it to adjacent rooms.

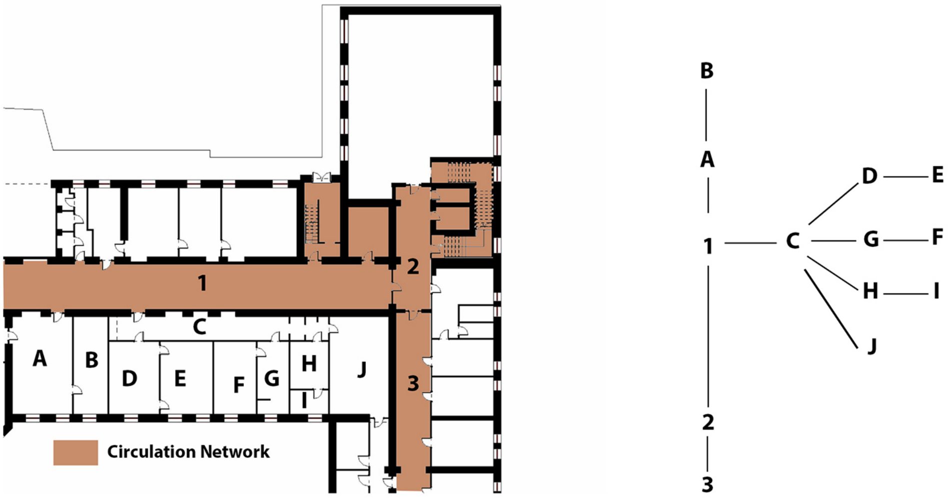


Fig. 05. Graph theory applied to a portion of the case study (author's elaboration).

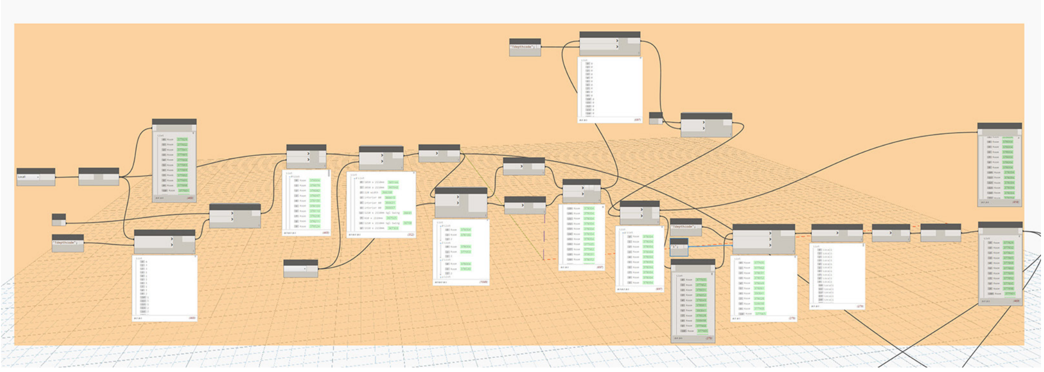


Fig. 06. Dynamo script for DC1 population (author's elaboration).

On the other hand, each door is connected to two environments, one of origin (From Room) and one of arrival (To Room). Starting from these connections between doors and rooms, a series of functions and nodes are used to automatically assign the DC of all the model spaces according to the following operations (fig. 06).

- Assignment of the DC 0 to all the rooms that have intended uses referred to the main circulation paths (Typology equal to i.e. entrance, main corridor).
- Select all rooms of the model that have DC 0.
- Identify the doors located in the selected rooms (both From Room and To Room).
- View the overall list of all rooms that have those doors in common.
- Filter the room obtained by subtracting those that have DC 0.
- Assign to the remaining rooms the DC 1.

The rooms resulting from the script are characterised by the same level of depth, i.e. the same position for the path of circulation, then the same number of doors that it is necessary to cross to reach them. These rooms are used as input data to identify those located at a subsequent level of accessibility. With the same logic, it is possible to define from time to time which are the rooms adjacent to the one considered by evaluating the rooms that have the same door in common and that are not characterised by a lower depth code previously attributed. DC 2 is given as an example.

- Select all rooms of the model that have DC 1.
- Identify the doors located in the selected rooms (both From Room and To Room)
- View the overall list of all rooms that have those doors in common
- Filter the room obtained by subtracting those that have DC 0, DC 1
- Assign to the remaining rooms the DC 2.

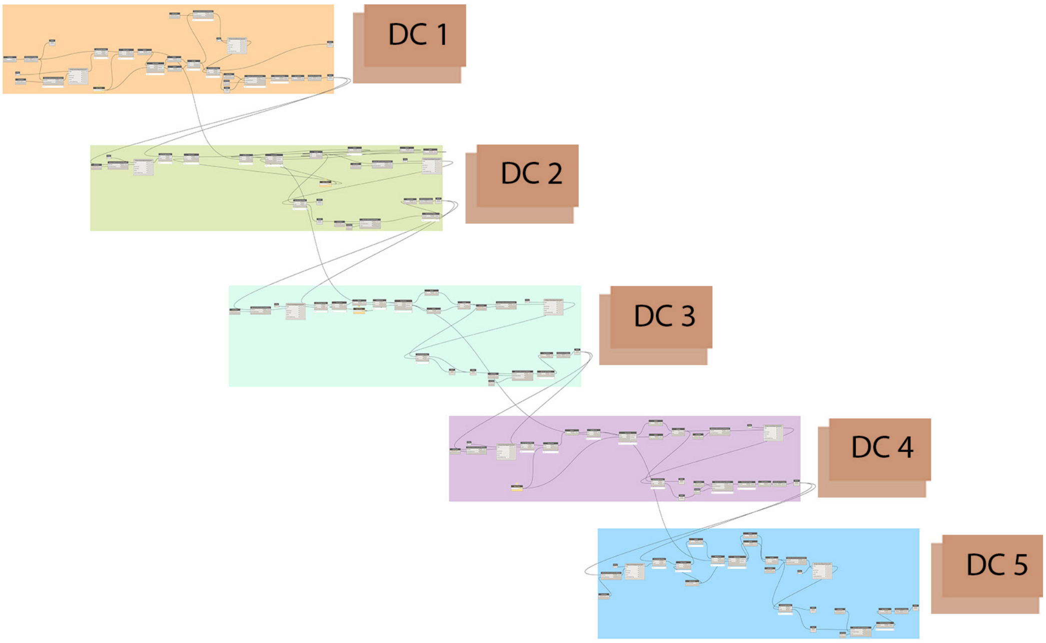


Fig. 07. Dynamo script steps for DC population (author's elaboration).

In this way, the hierarchy can be continued (fig. 07) to define rooms with an ever-increasing DC. The process can be repeated as many steps as required in the building.
The script has been designed to calculate up to 5 levels of depth. The occurrence of a room with more than 5 rooms before is rare. Once created, the script is fully automatic and can be run directly from the authoring software.

Results

Within the neurology pavilion, 469 rooms were processed, automatically assigning codes for spatial analysis. Implementing the mentioned codes for room objects has allowed using the BIM model to set representative graphic thematisations and carry out data checks. As the association is parametric, the room objects can automatically be highlighted in the floorplan views with different colours according to the value of the implemented attributes (fig. 08). In this way, it is possible to obtain a constantly updated Depth map, providing an immediate representation of the overall spatial organisation. The main factor in increasing the efficiency of many sub-functions in healthcare architecture is accessibility. The plan with less room in depth is recognised as the desirable plan. This method makes it easier to identify situations in which natural light and ventilation may not be optimal. Aside from ensuring better display, a second objective is connected to managing data in the tabular form. In the BIM schedules, it is possible to filter objects using the parameter introduced to extract a list of the elements of interest and their attributes. Furthermore, using the conditional formatting functionality, it is possible to set a cell colouring to verify the adequacy of a specific code. For example, a red highlight can be set to recognise the deeper rooms than DC 2. Due to this recognition, it became possible to compare the depth of each room with the spatial requirement of its function. The activity inside the room is labelled with IC. The conditional formula is applied to compare the DC and IC. The result of this comparison illustrated the appropriateness of the room's location in the spatial configuration and the requirements of its activity within function distribution in the plan program. In the example, the conditional formula shows the rooms possessing a depth more than DC 2, and IC less and equal 2 (fig. 09).

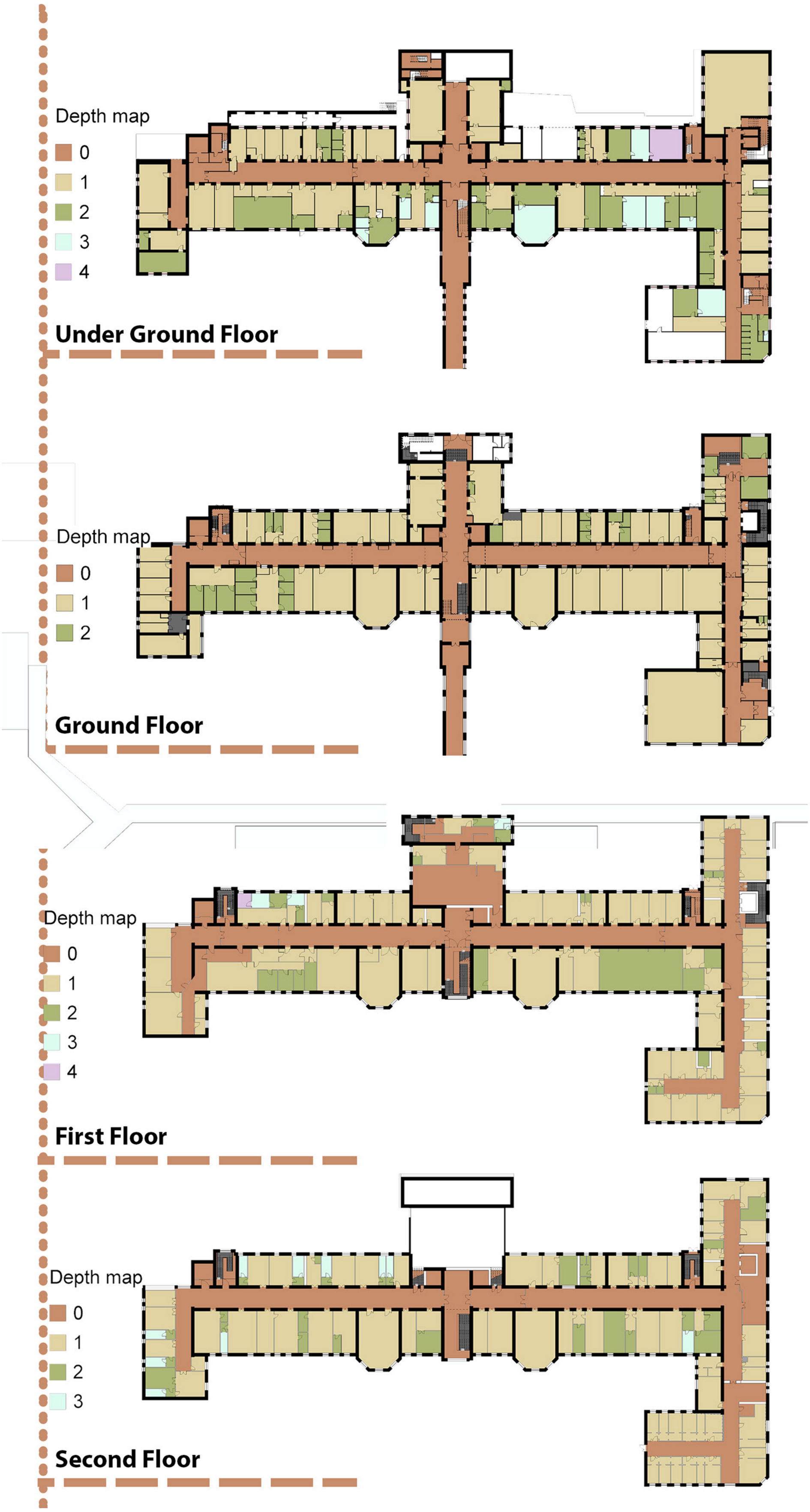
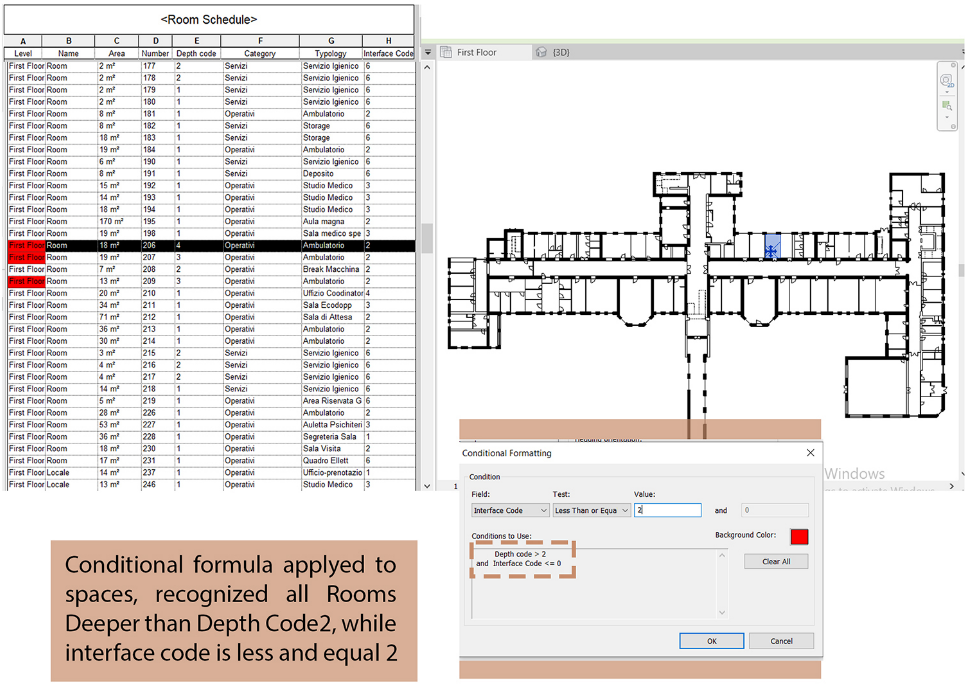


Fig. 08. BIM map of depth space (author's elaboration).

BIM and the mentioned analysis have provided a suitable sight to evaluate human activities' distribution in spatial configuration. The validation of the method on the neurology centre has allowed its applicability to the entire complex, introducing high process efficiency. Consider the time needed to associate the indicators to all the spaces and buildings characterizing the hospital. The resources saved can be invested in design and evaluation activities.

Conclusion

Through the proposed methodology and tools, spatial analysis can become an integral part of the BIM integrated digital infrastructure and revolutionise management processes and design activities. The characterisation of objects within the same data storage environment allows users to make them accessible and cross-reference information belonging to different data domains, overcoming the vision of specialist tasks. In this way, designers can have complete control over the spatial qualities of the spaces. It is possible to investigate, for example, the size, the intended use, the occupants and the affiliation structure of a room characterised by a high level of depth. In addition, the architectural component can be related to the structures and systems to make design evaluations in the case of restructuring / re-functionalisation interventions. The BIM database, powered by the potential of computing, enables the ability to manage large amounts of data and process them with great speed. This aspect is a strong point in large-scale real estate such as healthcare complexes. Once the spaces have been mapped, and the algorithm has been launched, it is possible to immediately obtain the automatic population of the depth indicator with maximum precision both for single structures and in the case of articulated complexes. Designers can benefit from this procedure as more time can be devoted to the evaluation and design activities than the effort required to represent the interconnections between spaces and functions. The BIM toolkit allows us to check the building at any time, seeing the space distribution from a different angle and using a shared language. This method can be applied to verify the design assumptions and allow continuous improvement without losing track of the functional relationships between the environments.



<Room Schedule>

A	B	C	D	E	F	G	H
Level	Name	Area	Number	Depth code	Category	Typology	Interface Code
First Floor	Room	2 m²	177	2	Servizi	Servizio Igienico	6
First Floor	Room	2 m²	178	2	Servizi	Servizio Igienico	6
First Floor	Room	2 m²	179	1	Servizi	Servizio Igienico	6
First Floor	Room	2 m²	180	1	Servizi	Servizio Igienico	6
First Floor	Room	8 m²	181	1	Operativi	Ambulatorio	2
First Floor	Room	8 m²	182	1	Servizi	Storage	6
First Floor	Room	18 m²	183	1	Servizi	Storage	6
First Floor	Room	19 m²	184	1	Operativi	Ambulatorio	2
First Floor	Room	6 m²	190	1	Servizi	Servizio Igienico	6
First Floor	Room	8 m²	191	1	Servizi	Deposito	6
First Floor	Room	15 m²	192	1	Operativi	Studio Medico	3
First Floor	Room	14 m²	193	1	Operativi	Studio Medico	3
First Floor	Room	18 m²	194	1	Operativi	Studio Medico	3
First Floor	Room	170 m²	195	1	Operativi	Aula magna	2
First Floor	Room	19 m²	198	1	Operativi	Sala medico spe	3
First Floor	Room	18 m²	206	4	Operativi	Ambulatorio	2
First Floor	Room	19 m²	207	3	Operativi	Ambulatorio	2
First Floor	Room	7 m²	208	2	Operativi	Break Macchina	2
First Floor	Room	13 m²	209	3	Operativi	Ambulatorio	2
First Floor	Room	20 m²	210	1	Operativi	Uffizio Coodinator	4
First Floor	Room	34 m²	211	1	Operativi	Sala Ecodopp	3
First Floor	Room	71 m²	212	1	Operativi	Sala di Attesa	2
First Floor	Room	36 m²	213	1	Operativi	Ambulatorio	2
First Floor	Room	30 m²	214	1	Operativi	Ambulatorio	2
First Floor	Room	3 m²	215	2	Servizi	Servizio Igienico	6
First Floor	Room	4 m²	216	2	Servizi	Servizio Igienico	6
First Floor	Room	4 m²	217	2	Servizi	Servizio Igienico	6
First Floor	Room	14 m²	218	1	Servizi	Servizio Igienico	6
First Floor	Room	5 m²	219	1	Operativi	Area Riservata G	6
First Floor	Room	28 m²	226	1	Operativi	Ambulatorio	2
First Floor	Room	53 m²	227	1	Operativi	Auletta Psichiteri	3
First Floor	Room	36 m²	228	1	Operativi	Segreteria Sala	1
First Floor	Room	18 m²	230	1	Operativi	Sala Visita	2
First Floor	Room	17 m²	231	1	Operativi	Quadro Ellett	6
First Floor	Locale	14 m²	237	1	Operativi	Ufficio-prenotazio	1
First Floor	Locale	13 m²	246	1	Operativi	Studio Medico	3

Conditional Formatting

Condition

Field: Interface Code
Test: Less Than or Equa
Value: 2 and 0

Conditions to Use:
Depth code > 2
and Interface Code <= 0

Background Color: 🟥

Conditional formula applyed to spaces, recognized all Rooms Deeper than Depth Code2, while interface code is less and equal 2

Fig. 09. Data check through the conditional formatting functionality (author's elaboration).

Acknowledgment

We would like to thank the *La Casa nel Parco CANP* Project for allowing us access to the data of our research. The research continued with the study of how the introduction of technologies can improve the quality of space and patients' lives within the realisation of the future Turin Health, Research, and Innovation Park.

References

Davies, N., Jokiniemi E. (2008). *Dictionary of Architecture and Building Construction*. Oxford: Elsevier/Architectural Press.

Forty, A., Mary, P. (2000). *Words and Buildings: a Vocabulary of Modern Architecture*. London: Thomas & Hudson.

Haq, S., Luo, Y. (2012). Space Syntax in Healthcare Facilities Research: a Review. *HERD: Health Environments Research & Design Journal*, 5(4), 98-117. https://doi.org/10.1177/193758671200500409 (consultato il 20 dicembre 2021).

Hillier, B., Hanson, J. (1984). The Social Logic of Space. Cambridge: Cambridge University Press.

Hillier, B., Burdett, R., Reponis, J. (1987). Creating Life: Or, Does Architecture Determine Anything?. Architecture et Comportement/ Architecture and Behaviour, 3(3), 233-250. https://www.epfl.ch/labs/lasur/wp-content/uploads/2018/05/HILLIER_-BURDETT_PEPONISandPENN.pdf (accessed December 20, 2021).

James, P., Noakes, T. (1994). *Hospital Architecture*. Harlow: Longman Building Studies.

Kobus, L.R., et al. (2000). *Building Type Basics for Healthcare Facilities*. New York: Stephen A. Kliment, Series and Editor.

Lee, J.K., Kim, M.J. (2014). BIM-enable Conceptual Modelling and Representation of *Building Circulation. International Journal of advanced Robotic Systems*, 11(8), 1-8. https://doi.org/10.5772/58440 (consultato il 20 dicembre 2021).

Nazarian, M., Price, A.D.F., Demian, P. (2011). A review of different approaches to access and people circulation within healthcare facilities and the application of modeling, simulation and visualisation. In *Proceedings of CIB-W096 Conference*, 219–231. Austria, 2011.

Nourian, P., Rezvani, S., Sariyildiz, S. (2013). Designing with Space Syntax A configurative approach to architecural layout, proposing a computational methodology. In Proceedings of the 31st *eCAADe Conference*, vol.1. Delft, 2013.

Sailer, K., et al. (2013). How strongly programmed is a strong programme building?: A comparative analysis of outpatient clinics in two hospitals. In Kim Y.O, Park H.T., *Seo K.W. (edited by). Proceedings of the Ninth International Space Syntax Symposium*. Seoul, 2013. Seoul: Sejong University. https://doi.org/10.13140/RG.2.1.4478.0248 (consultato il 20 dicembre 2021).

Shahriari, F. (2019). Spatial analysis of sanitary Buildings: the case study: *Molinette Hospital*. Master Thesis in Architecture, tutor prof. A. Osello. Politecnico di Torino.

Trudeau, R. (1993). *Introduction to Graph Theory*. New York: Dover Publications.

Ugliotti, F.M. (2017) *BIM and Facility Management for smart data management and visualization*. Tesi dottorale in Urban and Regional Development, tutor prof. A. Osello. Politecnico di Torino.

Ülken, G., Edgü, E. (2005). *A Space Syntax Based Model in Evacuation of Hospitals*. Fifth international Space Syntax Symposium, 162-171. Delft, The Netherlands.

Authors
Francesca Maria Ugliotti, DISEG Politecnico di Torino, francesca.ugliotti@polito.it
Farzane Shahriari, DISEG Politecnico di Torino, farzane.shahriari@yahoo.com

To cite this chapter: Ugliotti Francesca Maria, Shahriari Farzane (2022). Computational BIM design approach supporting Spatial Analysis: the case of healthcare facilitie. In Battini C., Bistagnino E. (a cura di). *Dialoghi. Visioni e visualità. Testimoniare Comunicare Sperimentare. Atti del 43° Convegno Internazionale dei Docenti delle Discipline della Rappresentazione/Dialogues. Visions and visuality. Witnessing Communicating Experimenting. Proceedings of the 43rd International Conference of Representation Disciplines Teachers*. Milano: FrancoAngeli, pp. 2925-2936.

Isbn 9788835141938