A New Approach to the Flows System Analysis in the Teaching Hospitals

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Abstract
The actual picture of health care building is a continuous transformation across time and space. Particularly in Italy many hospitals built in the past century are changing their image and organization. Moreover we assist to the raise of a consistent public movement inside the hospital due to a reduction of hospitalization time, an increase of the activities for outpatients and a hospital opening process to urban context. For these reasons one of the main factors that concern a hospital good design is the connection system among the different areas and spaces with specific regard to public flows.

This paper contributes to the analysis about the connection spaces identifying the relevance and the critical factors of flows and paths system from a different point of view introduced by Space Syntax methodology. The study shows the potentiality of an evidence-based approach combining both the social and spatial aspect concerning the people movement compared to the traditional functional approach. Space Syntax was chose as a possible tool to respond to the lack of means to verify the efficiency of paths in Teaching Hospital typology by blocks and under transformation. In fact the case study selected for the analysis is the Careggi University Hospital in Florence where the redevelopment works are still in progress. In this paper I describe two research phases both tested on the case-study. The first concerns the system corresponding to the whole areas of hospital and aims to show how the flows could be analyzed in according to the main principles proposed in literature through an existing analysis by people categories. The second concerns the building scale in order to analyse more deeply the effects of spatial layout on the Emergency Patient Path design and to support the design process in the choice of the spatial proximity relationships.

General aims of this study are also: contribute to the discussion about contemporary hospital typology and promotes considerations about the use of type layout in health care architecture; deliver knowledge about design and management systems of hospital complex under a flows study profile that introduces more attention to the social aspect; supply designers, planners and health trusts with tools to be used in the design and monitoring phases to compare different project proposals with regard to impact quality for hospital users.

1. Introduction

Teaching hospital complex design necessitates a cyclical process of planning, design, realisation and assessment because of the nature of health activities and technology systems. In this constantly evolving field the distinction between new building and refurbishment is negligible as designs tend to change quickly. For this reason, decision supporting tools which are able to combine both the monitoring of existing buildings and the validation of design choices for new projects are required. If we consider the current situation for health services in Italy, but also the situation in the wider European context, we can observe these societies are rich in ancient building heritage, and are characterised by large pavilion buildings.

Nowadays, this pavilion typology is a structural resource in a hospital's redevelopment overview because we have rediscovered some advantages it can offer in terms of fitting in with flexibility requirements, realisation in phases, the hospital's relationship with the city and its public spaces (Torricelli, 2006). In order not to lose any of these potential benefits, a detailed study of the connection systems between buildings is necessary.

2. The issue of flow in hospitals

In discussing this issue, we refer to the flows of information, people, and equipment in hospital complexes. In particular, the issue of 'flow management' or 'flow design' has several applications in healthcare building. These applications include: spatial proximity relationships among different functional sectors, circulation hierarchy, path differentiation, the transportation of equipment, the legibility of access, journey times and entrance control (Le Mandat, 1989 – Fermand, 1999). In this study I will deal with people flows that materialize in various spaces around the hospital. These are physically identified as corridors, tunnels, vehicular routes, pedestrian routes, stairs and elevators, and the movements of people through these spaces.

The purpose of this research is to contribute to 'flow management' and design by identifying supporting tools suitable for measuring continuous dynamic phenomena. By continuous dynamic phenomena I refer to both to the transformation of spaces in hospitals due to the development of care techniques and various spatial requirements, and real people movements into and around hospitals.

Contrary to previous studies on this subject, the basis of this study resides in the idea of a flows system as a system which is related to the humanization in hospitals.

3. Methodology

I have identified Space Syntax as a methodology and set of techniques that can provide a significant contribution in responding to the issues identified above. Space Syntax has the ability to look at complexity from a 'human point of view', as both the original way which the space is modelled in and analysed, and some aspects of cognition are implicit in Space Syntax analysis (Penn, 2003).

To illustrate where and how the use of Space Syntax can make meaningful contributions, I have chosen a case study with two application fields, which tackle 4 different flow system aspects that I have identified: at the area scale *The Outpatient System* and *Paths Among Buildings*, and at the building scale *Building Flows* and *Emergency Paths*.

The case study is the Careggi Polyclinic in Florence. It is a complex Teaching Hospital with 1600 beds and pavilions, on which extensive restructuring works have been ongoing for approximately 10 years.

3.1 The Outpatient System

An important element of the hospital to consider is the most appropriate location of outpatient services in the hospital area. To consider these issues, an outpatient axial model is required where the axial lines cover the outpatient rooms as well as corridors and halls which are accessible for members of the public. The idea of accessibility is intended neither as a set of indexes nor as matter for disabled people only, but an issue which is relevant for the reachability of a specific space in regard to its context. In light of this, from a segment analysis process I extracted Global Mean Depth as a meaningful value. I also calculated the Topological Step Depth and Metric Step Depth from public entrances to the area, from car parks, and from the bus stop. These three location groups correspond to the primary routes through which users arrive at the hospital: private cars, service vehicles and public transport. By analysing these factors it is possible to get for each room values regarding accessibility, changes of direction and distances from various origin locations in the same map.

3.2 Paths among buildings

The aim of this section is to arrange a Path Difficulty Index (D_Inx) describing space quality configurationally, in order to optimize the inpatient transport by dividing it into buildings. Just from the building *Chirurgie-PS* to 8 other blocks, there are around 1670 ambulance displacements on a monthly basis. These inpatients move through vehicular means (ambulances or medical cars).

First, it is necessary to define the concept of the difficulty of a path from a configurational point of view. I assumed this concept depends on three factors:

- Distance (the simple metric distance);
- Turns (the angular changes between segments creating the path –assuming the idea that a body or car having to travel from an origin point to a destination point, it will try to turn as little as possible) (Turner, 2000);
- Potential traffic level (the intensity of pedestrian and vehicular movement that an ambulance could meet during its journey).

The aforementioned three factors could be matched by measures deriving from a segment analysis: Metric Step Depth, Angular Step Depth, and Choice n because its properties represent the potential movement 'through' an area. The first two factors required the construction of a model which identified paths, while the last factor is derived from the whole area model previously built. The equation defining the difficulty index depending on the three variables is the following:

$$D\_Inx = p*D(md) + q*D(ad) + r*D(Ch)$$

Where *D* is the difficulty coming from Metric Step Depth (md), Angular step depth (ad), and Choice n (Ch). *p*, *q*, *r* are the weight coefficient that each variable takes. At the point where they are all assumed as equal to 1, but they still need to be verified directly with observations of ambulance movement and appropriate correlations.

3.3 Building Flows

For my study it is also significant to understand how people move around a building. To understand this issue, a VGA analysis with linked floors, restricted to the circulation spaces was conducted on the new building project *Nuove Chirurgie–PS*. Three cases were analysed: the entire functioning building (where every door on the connection spaces is assumed open), and public and health routes separated according to project plans (where closed doors separate the different routes respectively). In the last two cases the integration value shows the difference between the two systems, as in the 'public system' the ground floor is more integrated relative to every other floor, while in the 'health system' the first floor is the most integrated compared to other floors.

3.4 Emergency Paths

The concern was with finding the main health paths of the patient who moves from the Emergency Department to other services in the hospital, identifying the corresponding routes in the project map and trying to describe the nature of these spaces. I made the assumption that nurses know where the patient has to be transported, so the routes are already defined. I examined For each path –26 in total- the Step Depth and its topological, metric, and angular implications at the destination locations. Other parameters were added for a holistic evaluation, including: an examination of the floors crossed, the number of elevators, whether elevators were private or mixed, and movement numbers on the path. For each measure a threshold was set, to identify any potential critical situation.

4. Interpretation of analysis

1) In the outpatient system the segment map processed shows the main integrated routes, and their relationship with the internal corridor of buildings where there are outpatients rooms. Some of them are completely segregated (colour blue in the map), whilst others are located distant from the main accessible routes (circled in the figure). By examining the scatter diagram one can identify the points (corresponding to outpatient rooms) which have low integration and many steps from the main public park. In other words, these locations are not easily to be reachable for users.

Figure 1

1/MD in the segment map of 'outpatient's model' in the ground floor. In the scattergram the outpatient rooms Step Depth (axis y) and 1/MD (axis x) from the car park P5 by Department (a). Some outpatient rooms in building San Luca Nuovo mapped by its accessibility and Step Depth (blue) and Metric Step Depth (red) from the entrance 1 (b)

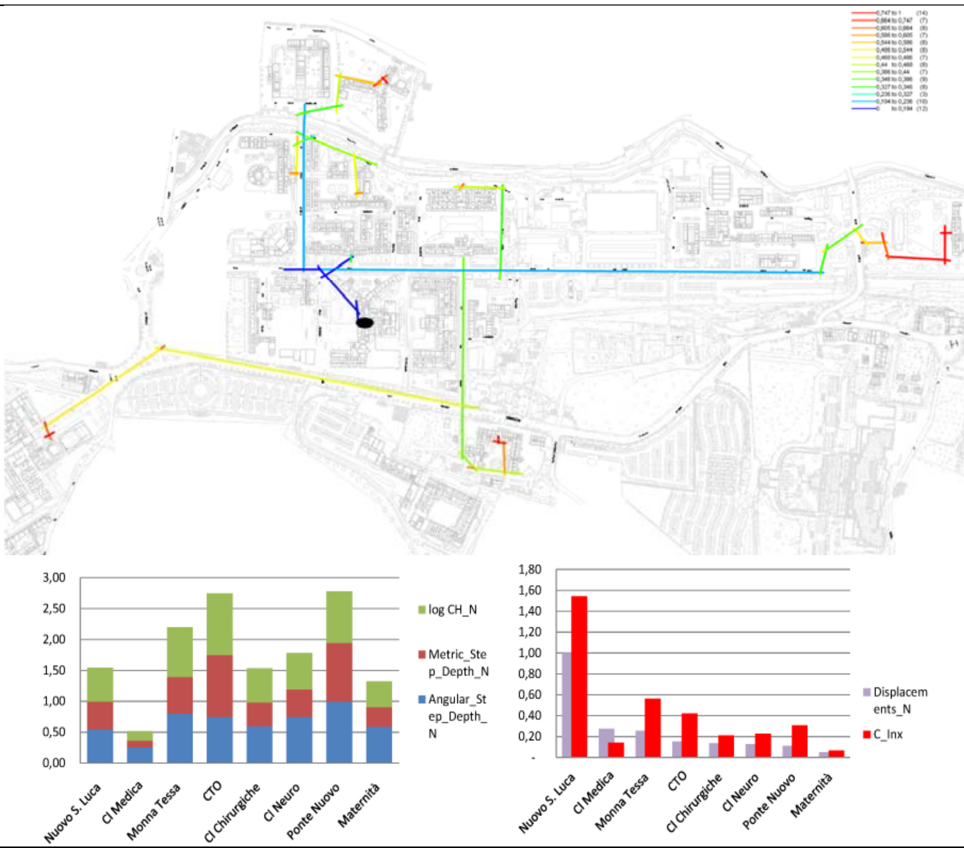

Figure 2

Angular Step Depth from the Chirurgie-PS to other buildings. In the diagrams: (a) the Difficulty Index with its different factors. (b) The Criticity Index (red) that represents the level of convenience in a link between two pavilions. It is get completing the D_Inx with the real number of monthly inpatient movement

2) The diagram of Difficulty Index indicates that there are variables other than distance and the number of displacements which affect the path's final critical status, which is contrary to one's usual expectations. Indeed, the angular changes variable is important as angular changes increase the difficulty in taking the paths that appear shorter. The comparison between the *Monnatessa* building and *CTO* is also interesting; the first has an angular value higher than *CTO* - which is further away- due to its configuration. In fact the ambulance access point is at the back of the building.

3) The VGA analysis shows the poor accessibility of vertical links for the public due to the low values of integration in their locations (elevators 1,2,4,5,9,10). Furthermore, through this one can realise a crucial subject: the location of critical points to be given special attention through both a careful management of passages and the use of clear signage. There is in fact in the project common spaces between the public and private areas (purple lines) and in these points there are high integration values. Certain reflections could be made about the suitability of the routes section in regard to the potential pedestrian flows (black arrows). Moving from the idea that clear signage alone is not sufficient to address the people flow, but that some physical or architectural barriers are needed, one may understand from the analysis some indications in regard to the permeability of architectural elements, like walls (blue arrow).

Figure 3
Integration of the 'total working' case at the ground floor of Nuove Chirurgie-PS project building. In the bar diagrams the reachability of vertical links for the public users are indicated.

4) The analysis shows there are 15 paths out of a total of 26 that are outside the threshold. Some of these are at an acceptable level relative to the threshold, whilst others are very critical, such as the path from the Emergency department to the ICCU (Intensive Care Coronary Unit). Through this analysis the designer can obtain a set of spatial and functional data in regard to path features, and he also has the opportunity to consider new proposals of distribution of functions in the building according to the potential of different spaces. For example, I have considered the path from Emergency to outpatient service, which is used by around 64,000 people per year. (FIGURE 4) The values in the destination location are high in respect of the set thresholds. Accordingly we thought about a proposal that creates a new link between the emergency corridor and the public one, and reverses the access to the outpatients services on the main public corridor. The new proposal improves the Step Depth values substantially.

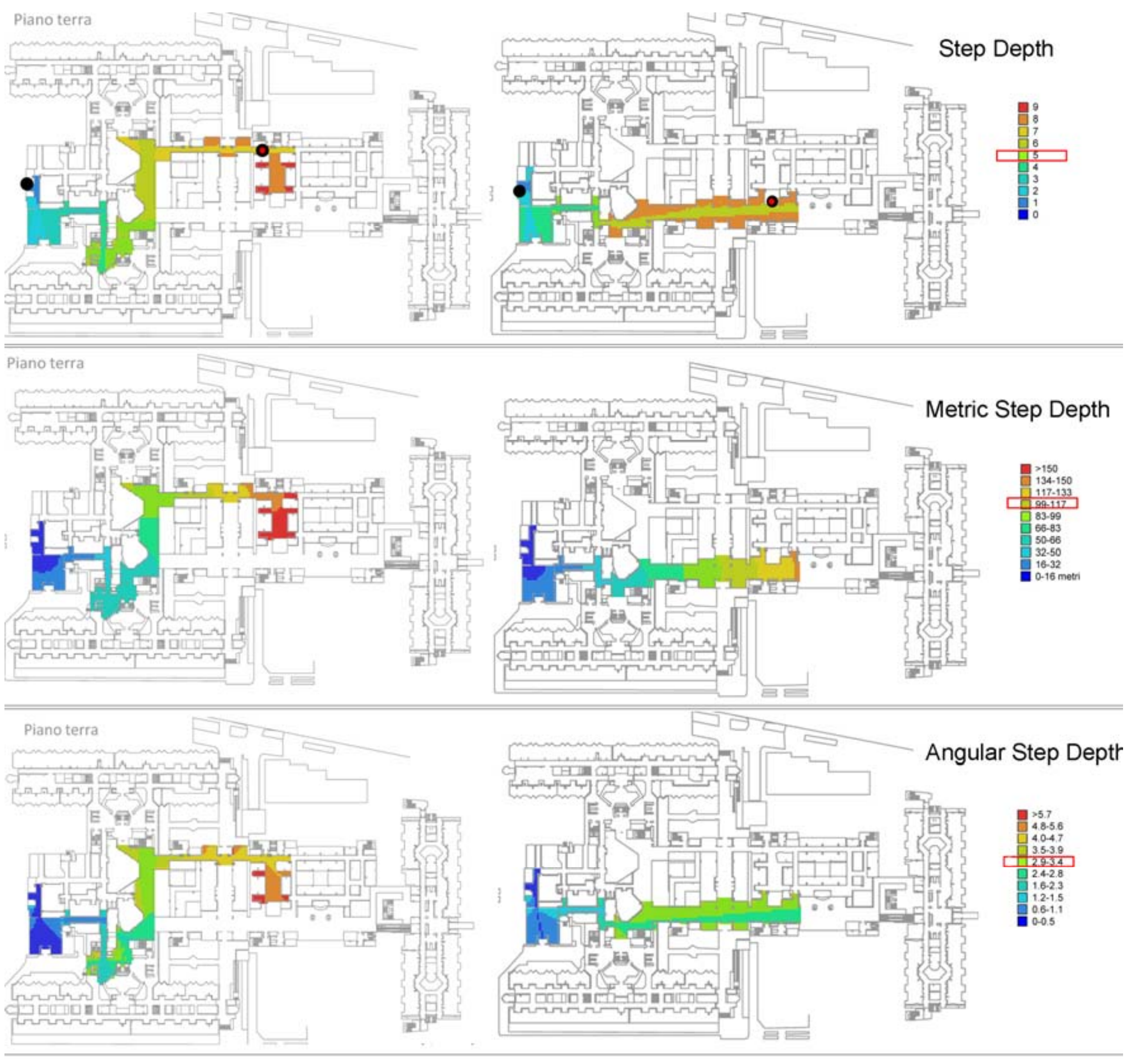

Figure 4

The path from Emergency (O) to outpatient services (D). Comparison between the original path in the first column and the new proposal in the second column. The maps show the improvement of the 3 measures in the proposal.

5. Discussion and Conclusion

The methods employed enable the understanding of the issue of flows at different scales, and at different levels of definition. One can carry out numerous comparisons between a single path and its relevance in the global system which it belongs to. A paths evaluation according to Spatial Syntax measures allows us to improve the design and quality of the hospital for users. The recommendations found in the analysis not only have the advantage of improving some project aspects, but also of helping the health trust in the management of spaces. Both of these contribute to foresee the failure risks of the project in its use phase because one can identify how people are likely to occupy the building.

In addition, medical staff can benefit as a result of behavioural protocol as the analysis indicates which path is better to use for certain trips, and how. This allows for the avoidance of congestion, reduces the distances and the angular changes.

Regarding the difficulty index, the information discovered can be also be beneficial in terms of cost savings. In fact in a transition period where demolitions are planned, but not yet executed, the saving that one could get in terms of employed resources coming from the path difficulty study could be a meaningful factor for the Health Trust.

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