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SPACES FOR KNOWLEDGE:
Strategies in academic library planning and design

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Abstract

Academic Libraries (ALs) design concept has been under a changing process, precipitated by both internal needs and external pressures including changes in the societal context of education, the information services and documentation storage requirements. This paper is focused on a model of form and function to assess AL' in use, in order to explore ways for better understanding their performance. The proposed model was developed within the scope of a wider research project and makes both use of Post-Occupancy Evaluation and of Space Syntax procedures in order to explore how the spatial configuration influences the performance and use of ALs space. It considers ALs building typology as spatial, physical and social systems, by: 1) measuring users satisfaction about how well the space supports their requirements; and 2) providing information on how architecture and spatial design support - enable and generate - flows of information, communication and knowledge. The analysis provides evidence suggesting that ALs' spatial system influences study performance, patterns of use and co-presence of its users. The results of data inputs point out prospective strategies about space intervention.

Keywords: *Academic libraries; functionality; users; evaluation; performance.*

Theme: *Building Morphology and Performativity*

1. Academic Libraries

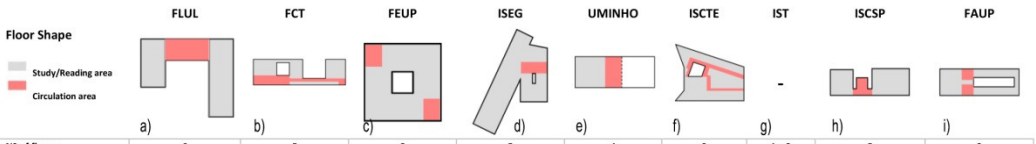
Academic libraries (ALs) are important contributors to higher education purposes being also representative of the university community (Edwards, 2011). By providing access to information resources, ALs play an important role in students learning experience as they support the generation of new knowledge (Rosa et al., 2010; Shih & Allen, 2007), operate as a hub of learning (Harrison et al., 2010) and encourage creative and independent thinking (McDonald, 2006). By embracing these distinct functions, the library as a place can foster a sense of community, and prepare the university for the future.

The organization, flexibility and adaptability strategies of ALs's to current higher education purposes and user needs have been the subject of recent investigations worldwide (Dehart, 2002; Harrison et al., 2010; Heitor, 2005; McDonald, 2006; Both, 2012). Studies consistently show that ALs are not only instrumental in establishing a new identity for the university and creating a sense of community but also their planning and design can enhance learning outcomes: they are crucial to improve the quality and effectiveness of higher education, lifelong learning and well-being. Research also reveals that ALs should provide a rich variety of opportunities for accessing information resources, for conversation and group learning. As an extension of the classroom, Library space needs to embody new pedagogies, including collaborative and interactive learning modalities. Its space must accommodate evolving information technologies and their usage, in particular, the increased use of digital technologies and the portability of technological devices, include spaces that can adapt to formal and informal learning activities as well as traditional reading rooms and silent spaces for focused individual study that inspire scholarship. As a university shared place, library space needs to offer social areas for informal reading, casual encounters as well as for temporary exhibitions and displays. At the same time, its architectural expression must continue to reflect the uniqueness of the university environment of which it is part.

Based on the assumption that ALs must be a dynamic place to support the academic community in several new ways, this paper is centered on the social and spatial dimensions of the experience of ALs' users. It is based on a study developed within the framework of IN_LEARNING research project (http://in-learning.ist.utl.pt/), using a sample of 9 AL's recently built in Portugal or being the subject of an ongoing modernization process (Figure 1). This sample is representative of different architectural approaches: 5 ALs (cases A, B, C, D, and E) occupy an entire and exclusive building (mono-functional block) with a prominent presence in the campus and a pivotal position both in functional and formal terms. Two ALs (case F and G) are integrated in multipurpose buildings without special visibility within the campus and in just one case, (H) it is not concentrated in a single area but dispersed in different spaces around the campus, close to learning spaces.

In common their design brief include a core area, consisting in general of reception area (counter service, the lending service, and a catalogue consultation and information terminal), informal reading area (periodicals), document consultation/studying area, offering individual and sometimes group work facilities, often complemented by a multimedia consultation and production area; a document management and processing area where library staff process documentation and a storage area for deposited materials; exhibition areas for temporary displays of thematic content, and multipurpose area intended for lectures and other activities were also considered in some of the case studies. In general, special attention was given to environmental comfort, particularly in terms of acoustics, to block out external noise and of lighting, excluding direct sunlight in the library space and adapting artificial lighting to the nature of functional areas. Communications network were planned in terms of functional areas,

with wireless Internet access fully available. The furniture and equipment were also tailored to the different areas and functional zones.



		FLUL	FCT	FEUP	ISEG	UMINHO	ISCTE	IST	ISCSP	FAUP
Nº of floors		6	5	8	5	4	3	1 a 2	5	2
Total área (m^2)		9426	6308	5471	4256	4024	3394	3391	2473	469
Study area (% da área total)		35%	34%	46%	38%	37%	68%	62%	56%	75%
N.º Faculty Students		-	8300	-	5242	-	8500	10936	3458	1145
Nº of seats		622	366	523	359	409	255	463	226	86
Working hours (h/Week)		70	55	55	75	79	62	45	66	53
User's Perception	Qualities	Space	Environment	Space	Lightning	Environment	Space	Envronment	Space	Environment
	Conflicts	Lack of seats	Lack of seats	Lack of seats	Noise	Lack of seats	Noise	Lack of seats	Lack of seats	Lack of seats
	Users Assessment	3,05	3,17	3,45	2,92	3,38	3,32	3,07	3,00	3,30
Assessment POE*		2,75	3,53	3,31	3,42	2,60	3,01	2,53	2,69	3,18
Final Assessment**		2,90	3,35	3,38	3,17	2,99	3,17	2,80	2,84	3,24

* The final evaluation is the arithmetic mean between the evaluation and assessment of users' aspects
** The mean assessment POE is the arithmetic mean from the functional, bioclimatic and aesthetic aspects.

Figure 1: Summary data from studied ALs and respective assessment.

2. Methodological procedure

The proposed analytical model follows the conceptual framework of a performance-based approach. It is settled on a structured data collection of design principles derived from the literature review (Federal, 2001; Hillier & Leaman, 1974; Hillier, 1996; Latimer & Niegaard, 2007; Robinson, 2008) built to describe and measure (represent, quantify, compare and analyze) spatial attributes with direct implications on function and experience in ALs buildings – use, appropriation and perception. It deals with the space both from the point of view of its *size and distribution* (occupation, dimensions), *configuration* (physical and visual relationships between spaces) and *perception of users* (students, staff, librarians) crossing diverse information in order to approach a wide spectrum of diagnostics. Thus, four main architectural dimensions – configurational, *functional, bioclimatic and aesthetical* - were selected (Holanda, 2010) to explore the complexity of space considering the diversity of both users and activities taking place in ALs.

The methodological framework is based on two complementary spatial overviews: the Post Occupancy Evaluation (Preiser et al, 1988) and Space Syntax (Hillier and Hanson 1984; Hanson, 1998). It considers the design of an exploratory mapping profile, taking into account architectural drawings (plans, sections and elevation), to record and structure information, providing a comparative spatial framework for the sample.

This mapping profile was developed making use of both high and low-tech spatial description techniques, i.e., Space Syntax synchronized with conventional measured survey involving direct data capture - photographic records and an inquiry procedure combining semi structured interviews (questionnaires) applied to a total of 565 ALs' users and space-use observations. Questionnaires focused on three themes, namely: a) *users' characteristics* – age, gender and occupation; b) *use of space* – weekly frequency, time of permanence at the library, and main activities performed; and c) *users' perception of the AL* – identification of conflicts, qualities and further improvement suggestions assessed on a scale of 0 to 4.

The spatial description of ALs was carried out in two different stages. One was focused on the syntactic description of each AL and the other on research-based fieldwork.

2.1 Functional, bioclimatic, aesthetic features

Functional, bioclimatic and aesthetic features, investigated according to their configurational perspective, are some of the highlighted principles that support architectural design. Each one is based on various specific design parameters, which in turn connect to practical options (Kohlsdorf and Kohldorf, 2005; Holanda et al., 2005; Holanda, 2010). As a consequence, this evaluation criteria applied to ALs is able to assess the space performance in a systemic way, regarding a wide range of parameters and aspects involved in their design.

Functional dimension observes the spatial layout in terms of its a) *usability* (*how suitable for purpose is the space considering the configurational structure*); b) accessibility (*circulation features and navigation - orientation and wayfinding - patterns*); and c) space flexibility conditions (*ability to adapt spaces when changes of use occur*). The configurational approach includes two focus: the global analysis (the pattern of relationship between spaces within the library, and between the library and the university precinct), and the local one (size, scale, shape, height of individual spaces), from topological to geometrical outlooks.

Bioclimatic dimension considers, based on the form-space of buildings, a) light conditions (*the sensation of daylight that supports visual comfort and facilitates visual performance*); b) acoustics (*the sound propagation conditions of wanted and unwanted sound - noise*); c) temperature/humidity (*the balance of heat gain and loss providing a comfortable level*); d) and air-quality (*artificial contaminants, odors and bacteria, etc.*).

Aesthetical dimension refers the psychological stimuli level induced by space configuration and the emotional response (symbolic included) to it from its users'. It considers space complexity, like visual richness, architectural language, physical appearance, color, materials and textures.

The functional, bioclimatic and aesthetic aspects were assessed on a scale of 0 to 4, depending on the specific evaluation criteria defined for each one. The average evaluation of ALs according to these aspects is the arithmetic mean of the quote of each aspect.

2.2 Space Syntax configurational features

Space Syntax describes the spatial layout based on its functional implications, i.e. on how configuration affects the social dynamics. It allows an understanding of principles and constraints that govern the spatial organization of the ALs by simulating part-whole relationships and exploring patterns of space use (movement and encounters). As it is well recognized in the Space Syntax literature, the spatial layout embodies the social nature of the building and by placing its users according to their roles, status and the activities they perform, modulates their interaction as well as their experience of the space. According to this approach, the spatial layout is understood as a continuous system of spaces, ordered by adjacency relationships translated into physical and visual permeability gradients (Hillier & Hanson, 1984).

ALs' configurational patterns were analyzed by means of convexity and visibility/isovists techniques (Depthmap ® software). Convexity analysis reflects the experience of those who remain static in the spatial system, (Hanson, 1998; Heitor, 2012), while visibility analysis considers the dynamic experience of space. The building plans constitute the primary source of this analysis, taking into account only physical barriers that obstruct movement and vision. Filling with points every space that can be accessed makes the graphical representation of visibility. By means of graph theory every visual field from each point of the analyzed space is calculated and the level of visibility is identified. The results obtained are represented by a color

scale ranging from red to blue. Red shades correspond to areas with highest visibility while blue corresponds to areas with more restricted visual fields.

The isovist area, visual integration and visual control of the spaces were taken in consideration in the visibility analysis. *Isovist area* represents the size of visual field or visible space area from a given point; *Visual integration* refers to the number of visual steps it takes to get from a specific point to any other point within the system, that is, the potential of a point to be seen by the users of space and *Visual control* deals with the ability of a space to visually dominate the spaces around; the visual control is higher when the visual range of the adjacent spaces has poor visibility.

Convex space analysis is based on the level of enclosure of the spatial system. Therefore, plants are decomposed into two-dimensional units, circumscribed by convex polygons, called convex spaces. These are defined as barriers to movement. Physical permeability relationships established between convex spaces establish a matrix that identifies the pattern of physical accessibility and therefore recognize which spaces are more easily reached.

The convex analysis was focused on 4 different variables: connectivity, integration HH, control and step depth from the 3 most important spaces (lobby, reading room and technical services). *Connectivity* indicates the amount of direct connections of a space with adjacent spaces; *Integration HH* refers the potential accessibility degree of an area in relation with the whole spatial system; *Control* represents the dominance of a space by requiring its obligatory crossing in order to get to other spaces of its immediate vicinity; *Step depth* from a specific location represents the distance from a given space in relation with the entire spatial system.

3. Results

The investigation of the case studies achieved a set of inferences about the configurational issues and space use of academic libraries, according to the methodological procedures.

3.1 Functional, bioclimatic, aesthetic features

The overall analysis of the 9 case studies allowed the quantification of functional sectors. The map of use of space, allowed the observation of relative occupancy of the functional areas in relation with the total area. The highest occupancy rate is dedicated to study areas emphasizing the importance of these spaces.

The vertical distribution of the functional sectors of academic libraries follows a principle of decreasing versatility of uses from the bottom to the top of the building. The multifunctional lower floors tend to assume a more private character, as they rise from the ground. Physical proximity between multifunctional areas and silent study places is a noise interference factor.

The academic libraries' technological performance is substantially prejudiced by the failures of the electric system in the reading rooms, outdated work equipment and catalogue consulting software and inadequate functioning of the wireless internet network. Given the intense computer use, for both study and research purposes, updating the academic library’s technology resources are a priority key factor for a good functional performance.

In general the physical dimension of the libraries’ spaces fits users’ requirements. However, some librarians have stated the need for space expansion due to the rapid growth of the

bibliographic collection over the past last years. Moreover, the adaptability and diversity of academic libraries' spaces are conditioned by the rigid physical structure of the space that in some cases wasn't planned to be able to respond the requirements of the diverse nature of learning methodologies (study-based and group work learning) that lead the users to spend more time in space.

On the other hand, findings have pointed a better performance according to the bioclimatic and aesthetic aspects comparing to functional features. The academic libraries' appropriate response according to these two aspects denotes the efficiency of its architectural design by optimizing both environmental conditions and enhancing the beauty and symbolic meaning of these learning spaces.

3.2 Configurational features

The analysis of convex maps indicated that the academic libraries with larger area have a higher number of convex spaces, which corresponds to higher spatial complexity of the built systems.

An overall reading of the spatial configuration of ALs indicated that *i*) the spaces with higher connectivity are the halls and circulation corridors and *ii*) libraries that are organized around a central void have higher values of connectivity homogeneously distributed, as in the case of AL of ISCTE, FEUP and FCT.

It was also observed that, the smaller the average connectivity of a library, the greater the tendency of heterogeneous distribution of connectivity values around a single core of spaces.

Figure **2** shows different distributions of connectivity among the convex spaces.

Findings concerning integration value indicated that *i*) the most integrated spaces are the corridors and circulation atriums; *ii*) the coincidence of the integration core with the reading rooms is associated with frequently incidence of noise due to the intense circulation in the space that disturbs the silence of those who are studying; *iii*) the proximity between the integration core, the main entrance of the library and the circulation spaces allows an easy access to all areas and deviates the larger flow of movement of the working areas and silence study places.

An example of a coincidence between an integration core and reading room was verified on the 1st and 2nd floors of ISEG's library (Figure 3). In addition to the intensive movement in this space, the direct connection of the stairs and elevators to the reading room is constantly committing the silence. A case where the core of the integration coincides with the circulation lobby is the UMINHO's library. In this situation, the flow of movement takes place within an area destined for circulation that is also physically separated from the reading room.

The variation of the integration mean value of the AL's depending on the number of floors and on the number of convex spaces led the investigation to a correlation between these variables. It was noted that the convex space integration of ALs simultaneously depends on the number of levels and on the number of convex spaces.

These results are relevant once they express the average level of accessibility (integration) of the spatial system of academic libraries depending simultaneously on their vertical, (for floors) and horizontal (number of convex spaces) distribution.

The average control of the studied academic libraries has a constant average value equal to 1.00.

Nevertheless, their maximum values are situated in circulation corridors and halls, a scenario which is benefic for the academic library, due to the structural nature of these spaces in the distribution of movement and connection among zones.

The step depth average analysis of the main entrance lobby, biggest reading room and technical services in relation to the libraries' system, showed which of these space typologies is the most accessible (the smaller the average step depth, the greater accessibility of the space in relation the system).

It was observed that the smaller libraries' (smaller total area) functional sectors are closely while in bigger libraries these sectors tend to assume an independent position. The lower step depth value of the technical services in relation to the library is related to an easier displacement of librarians and technical staff among the system and consequently, to a better performance and efficiency of their labor activities.

The visibility graph analysis allowed the association between the influence of configurational properties of space and the orientation, visual field amplitude, co-presence and topoception in ALs.

Therefore, by analyzing the isovist area, it was observed that *i*) the reading rooms with rectangular geometry well outlined had a greater isovist area enabling a wider visual field amplitude of space (

Figure **4**) and *ii*) the higher isovist area average of the library, the greater the tendency to appreciation of space and environment of the library by their users. It is worth to mention that the variation of isovist area value of the libraries spaces does not depend on the total area of the space, but rather, on the amplitude of the compartments.

The visual integration analysis has shown that the most visually integrated spaces of the ALS are the public areas and reading rooms with large dimensions and regular configuration. In these spaces the users have a good space perception that let them to simultaneously view several points of the system. The visual integration associated to circulation areas is fundamental for the space orientation and perception of paths. Figure 5 shows the high visual integration value of a continuous space (left) and a lower visual integration value composed by 3 shapes.

According to the comparative study of the ALs' visual integration values and to its spatial configuration, it was concluded that in libraries where the space organization is similar among the floors (in terms of functionality and structure), there is a higher visual integration. Visual integration also contributes for the user's orientation together with the isovist area and visual control area.

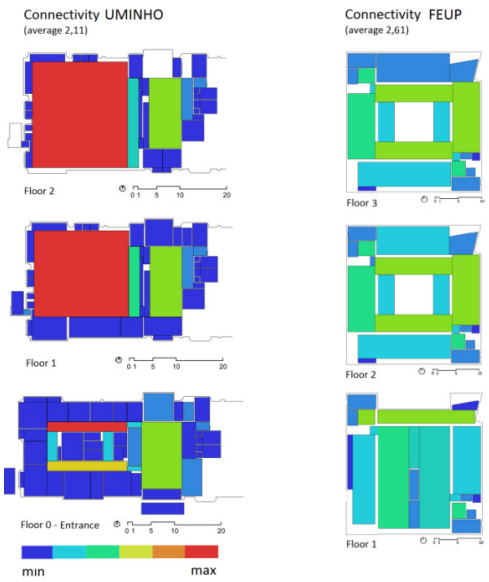


Figure 2: Space connectivity analysis of UMINHO Library (left) and FEUP Library (right) (there are not represented all the floors). It is observed that in the UMINHO Library the maximum connectivity is associated to unique space on each floor while in the FEUP Library, the spaces organized around the central atrium present homogeneous distribution of connectivity both along the floor and vertically.

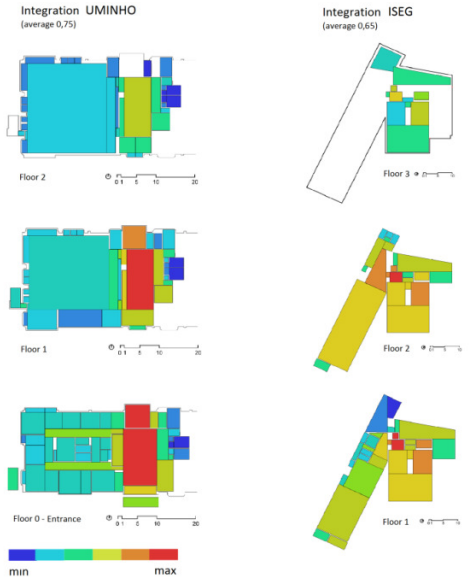


Figure 3: Space integration analysis of the UMINHO Library (left) and ISEG Library (right) (there are not represented all the floors). The high integration of the lobby and circulation atriums in the UMINHO's library facilitate the flow movement and access to all spaces. The location of the integration core in reading rooms as in ISEG's library is associated with intense circulation flows due to the high accessibility of these spaces that have a natural tendency to be used.

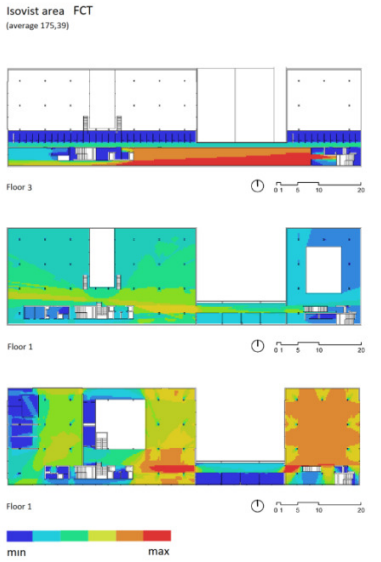


Figure 4: Isovist area analysis of FCT Library (left) and FEUP (right) (there are not represented all the floors). The negative variation isovist area occurs with the greater compartmentalization of space. The spaces with the largest isovist area are the reading rooms while individual offices/for groups tend to have lower isovist area values.

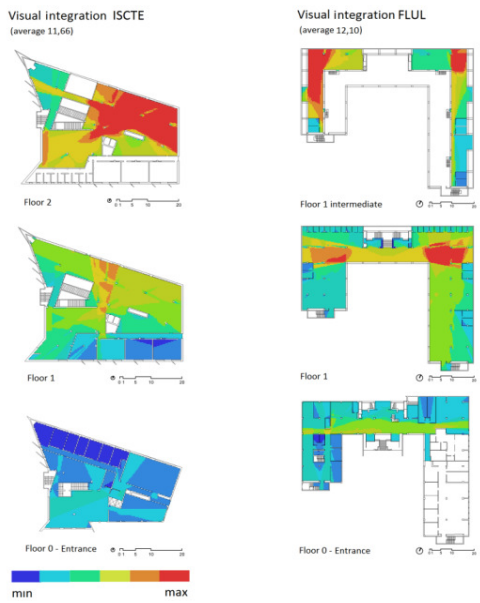


Figure 5: Visual integration analysis of ISCTE Library (left) and FLUL Library (right) (there are not represented all the floors). Note the change in visual integration assumes high values in continuous spaces and lower values in the spaces composed of several forms (the "U" form of FLUL Library has 3 rectangles).

3.3 Users' perception of space

The users surveyed in the studied academic libraries have an average age between 23 to 24 years. The majority of respondents (92%) are university students and the rest are professors or researchers. The users' frequency of academic libraries tended to increase with age growth varying between 1 to 3 times a week. User's time spent in the library ranges between 2 and more than 4 hours and the permanency in the library is also growing with age and with the weekly frequency of respondents in the library.

The main activities performed by the academic libraries main audience comprise the studying, consultation of books and group works. Given the requirements of the current education system that is increasingly based on the student's autonomy one underlines the importance of the suitability of the libraries to the study requirements of the students.

The main conflicts identified by academic libraries' users are about the lack of seating spaces, noise in the reading rooms and inadequate opening hours. In this sense, the academic libraries will have to adapt their provision with enough seats and an extended timetable to allow the use of academic libraries after school and on weekends.

The most appreciated qualities of academic libraries by their users were the study environment, the quality and extent of space, richness and timeliness of bibliographic and natural lighting. It was concluded that these aspects were the ones that best suit the needs and demands of users relatively to other spatial and functional performance factors of libraries.

The suggestions for improvement of ALs, refer primarily to the increasing number of seats, the extension of opening hours, the reorganization of space and reduction of the noise level. Therefore, these aspects are revealed of great importance to user satisfaction and can be a key factor for the proper ALs functioning.

3.4 Mathematical assessment

From the relationship between the space analysis of each ALs, the comments made by its users and the results of the objective analysis methodology of this dissertation, one may conclude that: i) the ALs with extent spaces and generous dimensions of the reading rooms were the most appreciated, ii) user satisfaction is related with choice, i.e, when designs can easily adapt to their needs or allow the possibilities for personalizing space.

Comparing the results of an objective assessment of the ALs, resulting from the proposed model and the user's perception, it appears that in most cases there is a coincidence of the results (Figure 6). This points out the reasonableness of the model and its capacity to perform a systemic analysis by interpreting spatial conditions from multiple perspectives.

It should be noted that in cases where the results do not match, although with slight deviations, stands the subjective factor of the user's satisfaction of the library, that on the one hand is dissatisfied with the number of seats, hours of operation, noise, penalizing the library's evaluation (Library of FCT, ISEG), and on the other hand enjoys the study environment above the physical conditions that space offers, overvaluing the AL (IST Libraries, UMINHO).

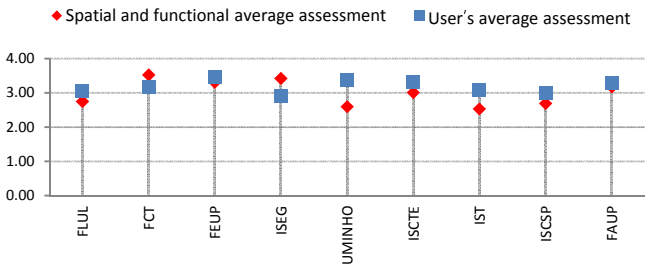


Figure 6: Comparison of objective evaluation methodology for analysis with the average assessment of users surveyed for each AL.

4. Conclusions and future developments

This paper intended to explore the social and spatial dimensions of the experience of Academic Libraries users, based on a study developed within the framework of IN_LEARNING research project (http://in-learning.ist.utl.pt/), using a sample of 9 AL's recently built in Portugal. It was aimed to investigate the strategies adopted by academic libraries to respond to new demands, analyzing to what extent the functional program and spatial configuration are developed to meet the needs and expectations of their target audience. Post-Occupancy Evaluation and Space Syntax techniques were applied in order to comprehend how the spatial configuration influences the performance and use of ALs space.

From the analysis of nine case studies and according to the intersection of the results, it has been shown that the morphological conditions of use and operation of space reveals the compatibilities and conflicts with existing functional and space-exploring principles that explain the observed phenomena.

Findings have pointed that i) the majority of academic libraries lack of reading places, mainly because of the difficulty of managing the gap between the internal college students and external students, ii) academic libraries have a deficit timetable due to lack of human resources in post-labor timetables, iii) the heavy traffic in the reading rooms to which is added the proximity of the core integration per si attracts the move, undermining the silence and concentration of users, iv) the requirement of crossing silent study areas is also a factor of attention distraction, v) the existence of multiple halls with high ceiling empowers propagation of noise and hinders air conditioning, however the organization of space around them is a factor of great appreciation of users; vi) the visual range (the area if isovist and visual integration), the dimension of space and generous natural lighting are the most valued attributes by users of academic libraries.

In general, one points out the importance of the delimitation of noisy areas (like hallways and lobbies of movement conducive to social interaction) from the silence work and study areas through the physical distancing of the spaces or change in the use of the spaces. It was found that the organization-type of academic libraries was led by a principle of hierarchy, being essential in the implementation of the strategic uses of space. It was observed that the coincidence of the nucleus of integration with the reading rooms is related to the generation of noise due to the intense motion in space. However, adapting the use of reading rooms close to the intense traffic areas to study rooms for groups allows combining the study with social interaction. Another alternative is to dedicate more accessible spaces (near the core integration) to public use for students from other universities, thus facilitating the management of places.

In the last decades ALs have been subjected to a wide range of changes that were not always sustained by the physical component of their space. Technology has enriched users space and the services for its support are increasingly rising new challenges. Spatial configuration has to be constantly explored, reinventing the concepts of flexibility and maintaining space quality and distinction, intellectually richness environment for learning, teaching, and research.

Considerable evidence shows that there is an explicit relationship between the physical characteristics of ALs, their spaces and the ability to create a positive experience reflected in the users' satisfaction.

Improving ALs called for a rethinking of the existing spatial conditions and their adaptation so as to provide a better response centered on learning and the ways in which people learn. In many existing ALs, the design approach adopted follows a “stationary” model type. Space is designed to cope with its own specific functional requirements and technical features. No extra investments were made to facilitate functional or technical adaptability in the future, limiting life expectancy. The ALs layout is organized according to a formal model, where the traditional reading room is the core unit of its spatial programming. Complementary spaces allowing other reading and learning practices are absent and support spaces are almost reduced. Such ALs are highly resistant to fit today’s higher educational needs, in particular to be reconfigured to embody collaborative and interactive learning modalities. On the contrary, when the design approach follows a more neutral non-specific layout type, ALs can be easily adapted to changing requirements over time.

In future developments, the evaluation assessment index could be optimized by using percentage weighting, wider case study samples and multidisciplinary cross information.

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