

Function Efficiency Based Approach for Assessing Academic Library Space

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Abstract

Academic library (ALs) spaces are the physical spatial installation of different design ideas. Despite there are a lot of studies that improving the design of library spaces, there are no rigor results that could be implemented to understand possible effects of their design proposals and analyses AL's spaces function efficiency. The research attempts to investigate the relationship between the spatial design aspects with direct implication on function and user spatial behavior satisfaction level, aiming to develop a framework to conduct effective parameters measurements that play a role in achieving high level of function efficiency of AL's space. The proposed single framework attempts to bring spatial design, spatial configuration and spatial behavior into a single methodological framework of a function efficiency approach on the experience of professional architecture designers and Academic library's users derived from the literature review. Data about architectural space were obtained from three measurements method: 1) The Level of Importance, measuring magnitude for each variable for design process requirements using Focus group method. 2) Post Occupancy Evaluation, measuring user degree of satisfaction using Attitude survey.

The significance in such a tool works in translating the qualitative values of the design attributes to easily negotiable quantitative value.

The measurement framework of this tool was applied for its validity and reliability through investigation of an existing case study. The study brings spatial design aspects based on Focus group method and attitude survey into a single methodological framework. This framework offers significant potential for measuring spatial function efficiency of any existing academic library. It enables the designers to comprehend the relationships between their goals and their design spatial relation concept.

Keywords: Academic libraries design, spatial function and efficiency, spatial configuration, Post Occupancy Evaluation.

1. INTRODUCTION

Library spaces are transformation of different design abstract ideas into physical spatial installation. Although the architect envisions the space as a living organism during the design process and uses own personal intuition, feelings and experiences, the designer has no real way to testing its human dimensions before the design is produced and utilized [1]¹. Recently human behavior has become an important aspect in

the design process. A design that accords with scientific theories is stronger as it is supported by reliable sources [2]². Architects must proceed in a creative way by contributing scientific knowledge in architecture design process, to explore their design ideas and understand possible effects of their proposals and to analyse the true function efficiency of space. Many researches tried to study the relation between design spatial features from different approaches which means that some studied the bioclimatic dimension (lighting, acoustic, thermal, etc...), others studied aesthetical dimension (visual richness, architecture language, physical appearance, colors, material and textures), And other researches studies the function dimension (usability, accessibility and space flexibility) and this approach is the focus of this thesis regarding spatial aspects (spatial design and spatial configuration) in addition to the focus on user spatial behaviour satisfaction. Studies show that architecture program and spatial configuration affects spatial behaviour in libraries [3]³ as shown in **figure 1**.

Generally, this research links between the spatial design's aspects of academic library and user spatial behaviour satisfaction based on function and experience of users in AL's spaces into a single methodological frame work.

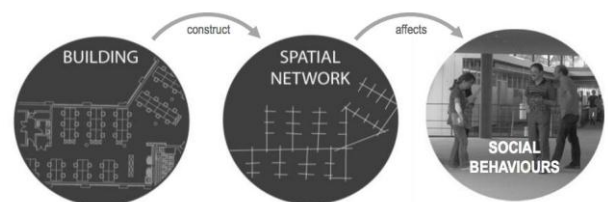


Figure 1. Co-presence patterns are affected by designs of spaces so are distinctive characteristics of spaces.

2. LITERATURE REVIEW

The research focused on the academic library's spatial transformation throughout the history, tracking the change that occurred in terms of their meaning and configuration starting from thirteen centuries till now, defining the meaning of spatial function and spatial configuration. It will shed some light on the main principles and approach of both spatial function efficiency and spatial configuration and understanding Spatial Configuration in Cognitive Studies.

Moreover the review will discuss studies on the design process definition and planning library space to classify the variety of user's activity needs.

Also discussing its importance for architects to explore their design ideas and understand possible effects of their design proposals and to analyse the true efficiency of space configuration on user spatial behavior before it has been put into use.

2.1. Academic Library Space – Short History

Libraries have had many spatial transformations throughout the history in terms of their meaning and configuration. Libraries started to be parts of churches, since the church had established domination on science and education. Libraries started to be separate buildings whereas education was still for noble people only which could read and write. However, after the invention of printing machine, number of books had increased and more people could reach books. So, a reading area started to be added to the libraries since the 17th century [4]⁴. After the democratic developments at the 19th century in France, libraries and universities started to be open to low people as well. Although the main issue based on the history of function in libraries is sheltering documents and books for noble people, today they are used as spaces of social interaction or public spaces that people can spend their leisure time with many activities inside.

Also, the shift in building technology, architectural conceptions and social structure have also changed the content, user profile, and spatial needs of libraries that all resulted in changing spatial character this offers that space should be open and functional by its flexible configuration since the beginning of the 20th century [5]⁵. Therefore, new spatial needs and new solutions have occurred in library spaces.

In addition, today libraries are classified according to their user profile and type of resources such as school libraries, public libraries, research libraries, national libraries, and university libraries. In this study, university libraries are the main topic to examine spatial usage.

Academic libraries (ALs) are libraries that are attached to higher education institution they serve two complementary purposes to support the institution's curriculum, and to support the research of the institution faculty and students.

Also, academic libraries are organized for university students and academicians with wide collections that include resources of science, literature, art and so on. Also they play now an important role in students learning experience as support the generation of new knowledge, operate as a hub of learning [6]⁶.

2.2. SIGNIFICANT STUDIES ON SPACE

Haghighi describes space as one of the main elements in a library and it can play a critical role in success or failure of plans. There is a direct relation between spaces of a library and using its service and study and research in a comfortable, calm, pleasant, attractive and accessible place, which are necessities of such a cultural and spiritual place [7]⁷.

Space is the unit within which all human activities occur. It is necessary to understand space from a functional perspective in terms of what people do and how they use it [8]⁸.

Space can be described in three geometric ideas: linearly when people move in it, convex space (in which each point can see each other) once they interact within it and finally isovist which from any point of space can be seen as a variably shaped [9]⁹. There is an expected relation between space and its use lies within the relation between configuration of people and configuration of space.

2.2.1. Spatial Function

Bustard and Hanson Define Functionality as [10,¹⁰ 11]¹¹ the ability of a complex to accommodate functions generally and therefore potentially a range of various functions, rather than any specific function. Voordet define functionality as the degree to which activities are supported by the built environment. This is related to the form of space, the spatial relation between spaces (function zoning), the routing and distribution of people through the building and service ...etc. [12]¹².

The functional considerations play an effective role within the success of the building entirely. Accordingly, the incorrect configurationally decisions give inefficient and unaccepted functions. also, the functional relationships in the space reflects the characteristics of spatial configuration of the building, depends on the way of handling the structure of spatial relation for the physical elements that separate adjacent spaces [13]¹³.

Functional factors like the relationships between spaces and activities, appropriate axes of movement, flexibility, suitability, safety...etc., are the key aspects of the building layout design. Spatial function dimension is one of the main principles that support architecture design. Both identified three variables that affect spatial function. The spatial layout is classified in terms of its: *a) Usability* (how suitable for purpose is the space considering the configurationally structure), *b) Accessibility* (circulation features and navigation - orientation and way finding - patterns) and *c) Flexibility* conditions (ability to adapt spaces when changes of use occur) [6].

2.2.2. Spatial Efficiency

The built space can be efficient when everyday users and visitors are able to participate in various activities without any difficulty.

Relevant spatial-functional features with respect to efficiency are the spatial clustering of functionally related activities, short distances (spatial depth) and the prevention of physical barriers between frequently used spaces. The degree of achieved efficiency can be read from building layouts by indicators such as the availability of interior spaces for individual and communal use, and the openness or closeness of physical partitions. In this respect, two components are important:

a) Physical efficiency: The ease with which users and visitors can reach, enter and move through a building, thus being able to use its various spaces. A focal point in particular is the integral accessibility, which means that people can also enter and move through the building independently. Spaces are usually connected together in ways that vary the distribution of integration throughout the structure, making some areas of a

building more accessible than others. Access for all can be read from floor plans by indicators such as the degree of integration of each space within the spatial layout, the depth of the space and so on. This sequence of integration serves to regulate interactions among inhabitants, and between inhabitants and visitors, which in turn makes the spatial-functional relationships more efficient and flexible. **b) Psychological efficiency:** This indicates to what extent does a building 'invite' the user or visitor to come in, use the building and the activities going on inside, also relate to a person's own feelings and his relationships with others.

Relevant spatial function orientation includes: a recognizable entrance; clear transitions and circulation from public to private; clear outline of a building layout, visual axes, points of recognition, differentiation in the use of spaces etc. [14]¹⁴.

2.2.3. Spatial Configuration

Configuration as defined in Hillier's book "space is the machine" is a set of interdependent relations in which each is determined by its relation to all the others. The arrangement of spaces in such a way influences the utilization of them consistent with how we relate these spaces to each other.

In general configuration is defined as, at least the relation between two spaces in layout taking into account the third, and at most, as the relation among spaces in the complex, taking into account all the other spaces within the complex. Spatial configuration becomes critical because it identifies flexibility and limits of space for serving users' changing needs. On the other hand, also suggests that architectural program has more significant effects on spatial preferences than spatial configuration. Hillier defines architectural program as the arrangement of relationships of activities those planned to realize. Also, architectural program is a kind of function map of space that prescribes each function/activity, which happens in a location of the related space and affected by the design concept [15]¹⁵, [16]¹⁶.

2.2.4. Understanding Spatial Configuration in Cognitive Studies

A few studies have identified the salient role of spatial configuration in human spatial experience [17]¹⁷. Many researchers address the importance of cognitive representation in spatial experience. [18]¹⁸, suggests that higher levels of configurationally understanding are generally associated with more efficient way finding performance.

Cognitive studies provide us, therefore, with a useful method, but not with a theoretical starting point for an inquiry into the human being and built environment relationship. This appears to be primarily caused by the absence of a methodological tool to describe both objective configurations in reality and subjective ones in cognitive representations. Thus there have been gaps in understanding and describing configuration as a total field of the interrelation of elements, patterns and sequences.

Hart and Moore argue that, spatial configuration is the ultimate stage of spatial cognition, configuration is perhaps the most difficult aspect of the environment to describe in an objective

and analytical manner. Thus, the cognitive approach reveals gaps in our knowledge of human spatial experience without relating the likely effect of spatial configuration on that experience. In order to describe and analyze the role of spatial configuration in the cognitive representation, a more flexible and analytic method may be needed [22]¹⁹.

2.3. STUDIES ON DESIGN PROCESS AND PLANNING LIBRARY SPACE

2.3.1 Architecture design process

Architectural design is the process of transforming abstract design ideas into physical spatial composition. The design process is a matter of synthesis of physical and mental behavior. This process is also marked by the fact that it includes the kinds of physical and mental tools that mutually trigger and shape composition.

Architectural design is a sophisticated process that advances from abstract thinking to concrete design. In this process, the designed product is created and impacted by the unique experiences, observations, perceptions and characteristics of the designer, while the design work of the architects develops through the use of varied design tools and the designer's own architectural knowledge, one that is fed from various disciplines and fields. It is this scientific knowledge that directs the innate intuitions of the designer.

Whether it is called as "image" [20]²⁰, "primary generator" [21]²¹, or "concept" [22]²², all refers to the same: the idea that makes an architectural design unique or different from all others. A design that accords with scientific knowledge is stronger as it is supported by reliable sources.

Evidence-based design is the term used for the common methodology that best enables scientific information to be transferred into design process.

Hanson emphasizes that any socially responsible architectural design effort must be supported by evidence-based research. Although the architect envisions the space as a living organism during the design process and uses his or her personal experiences to conceive of it regarding of human utilization, the architect has no real way of testing its human dimensions before the design is produced and utilized [2].

In other words, even though physical representative tests may be conducted, and mental configurations construed during the design process, the end result is a construct. That is built without human trial. It is at this confluence that the designer feels the need for methods and tools that will allow him or her to test the design suggestions. Design is about experimenting and probing. Experiments lead architects to discover something, then these help them to redefine their underlying concepts [1].

According to Ziesel, design interconnects three constituent activities: imaging, presenting and testing. Appraisals, refutations, criticism, judgments, comparisons, reflections, reviews and confrontations are all types of tests [23]²³. After presenting a design idea in whatever form, designer steps back with a critical eye and examines his/her product [24]²⁴

Ziesel, argues that designing works with two sorts of information: heuristic catalyst for imaging and a body of data for testing [23]. This means that designers rely on information to tell them how things might be, but also that they use information to tell them how well things might work [22]

2.3.2. Planning Library Spaces

The focus of designing spaces for users is far more complex as it needs to take into account the variety of user's activity needs (physical and psychosocial) and behaviour; libraries are able to accommodate students who want to work quality as well as those who prefer to work socially with others, so it is important to consider all the major factors that affect the use of the academic library space and classify space use. There are many guides to library space planning, both conceptual and practical in the library literature listed below:

Jochumsen proposes a four-space model that has been used in public libraries; a) inspiration space, b) learning space, c) meeting space, d) per formative space [25]²⁵. According to the model, the library's overall objective is to support four goals: experience; involvement; empowerment and innovation. These could also be overlapping functions that interact in library space physically and virtually.

Cunningham. H. Shares superimposes Kent's terms on Maslow's framework and provides a schema which can be used by the architects and librarians when considering user needs in libraries space design. [26]²⁶ In this schema, the lower levels of the pyramid, i.e. access and linkages (comprising location, zones, collection, information and network) and Users and activities (comprising reading, writing, collaborating, furniture, tools, equipment and flexibility) indicate the most basic needs of library users. The higher levels of the pyramid, i.e. comfort and image (comprising ambience and sense of scholarship) and sociability (comprising communal, social, quiet, noisy, independent and group) indicate the highest-level attribute of comfort and feel for an ideal learning space.

Joseph C. Rizzo Proposes four distinct levels of activity or zones of social interaction in academic library that provides recreational, study and working environment; **a)** highly active and engaging communal places, **b)** interactive collaborative places for individual research and group work, **c)** quieter places such as reading rooms, study rooms and alcoves and out of the way, **d)** Contemplative places for quiet reflection and deep thought [27]²⁷.

Beard & Dale provides five categories of various user spaces based on their observation of higher education institutional libraries in the UK. They are namely; **a)** short stay individual information gathering, **b)** open-space flexible group work, **c)** individual silent study, **d)** small-group intentional collaborative work, e) teaching and learning spaces [28]²⁸.

Choy and Goh Develop a simple frame work consists of four kinds of spaces; **a)** Collaboration (provides students with facilities and technology to work together in group), **b)** Interaction spaces (provides facilities for students to get help

from Liberians and other consult resources provided by the library), **c)** Sanctuary spaces (individual spaces of thinking, for quiet reflection and creativity), **d)** Community spaces (the social nature of student learning by providing informal seating and cafes) [29]²⁹.

2.4. LITERATURE REVIEW RESULTS

As a result of the literature review, Library spatial design features were divided and categorized by the author in three dimensions; Physical needs psychosocial needs and Movement and Circulation as shown in the previous **table 1**.

Table 1. ALs spatial design variables

Factor	Variables
Physical Needs: Those are the needs that relate to human requirements.	<ul style="list-style-type: none"> ▪ Sufficient and comfortable spaces, their area, size, height and density. ▪ Efficient space fit (furniture)
Psychosocial Needs: Those are the needs that relate to a person's own feelings and his relationships with others.	<ul style="list-style-type: none"> ▪ Concentration ▪ Space design provides the desired Personal Privacy form noise and sight.
Movement and Circulation: The physical movement of people or things.	<ul style="list-style-type: none"> ▪ The flow of people around the library spaces. ▪ Accessibility and visually appealing.

(Source: Authors)

Also as outcome of the literature review, Spaces that constitute the academic library space can be recognized into four categories shown in **table 2**.

Table2. Spaces that constitute library space planning.

Space	Description
Primary	Collaboration Highly active & engaging communal places <ul style="list-style-type: none"> ▪ Reading hall
	Individual Quietness places for thinking, for quiet reflection short stay individual information <ul style="list-style-type: none"> ▪ Studying & Research Room
Support	Interactive Provide facilities for student & technology to work <ul style="list-style-type: none"> ▪ Computer room ▪ Multimedia room ▪ Archive
	Community Social nature of students learning information <ul style="list-style-type: none"> ▪ Reception area ▪ Café

Circulation	Spaces or elements to do with movement around the space. <ul style="list-style-type: none"> ▪ Lifts and Stair cases ▪ lobbies and Corridors
Service spaces	Spaces containing functions which support an individuals or work group. <ul style="list-style-type: none"> ▪ Toilets ▪ Praying room

(Source: Authors adapted from 25, 26, 27, 28&29)

3. THE CONCEPTUAL FRAMEWORK

It was previously shown that how library space as physically designed environment is an element that contributes to the user behaviour and how different previous set of many variables or parameters are effective on space environment. This framework aims to drive the measurement process through practically applied steps that are capable of extracting meaningful data that can be used for measuring spatial function efficiency relative to user behaviour for existing library cases as shown as **figure 2**.

The outcomes needed to be identified by the following three different measurement methods each had its own approach were formed the proposed framework as a follow:

- 1- Level of Importance.
- 2- Post Occupancy Evaluation.
- 3- Syntactical Analysis Method.

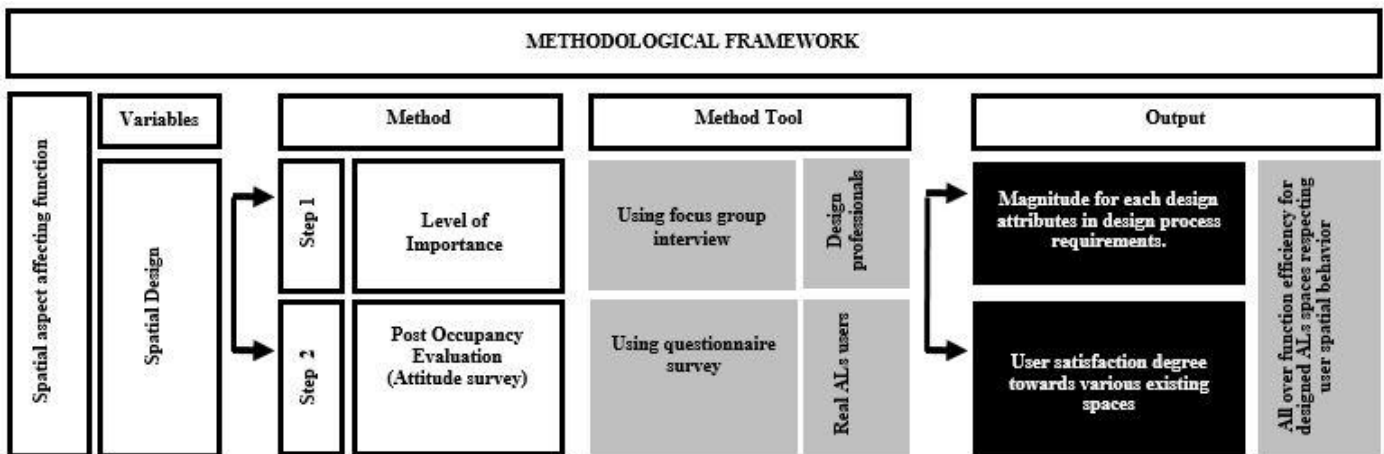


Figure 2. Proposed framework based on spatial aspects with direct implication on function and the behavior experience.
 (Source Authors)

3.1 Measuring the Level of Importance (Focus Groups Technique)

In the first step in this framework, it has been explained that design attributes impact spatial function, it's important to measure "How important need the space to achieve of this attribute?" In the design process requirements.

Level of importance are a qualitative that need to measure and evaluate the magnitude to each design attribute using focus groups data gathering technique in which a small number of participants discuss selected topics as a group for approximately one or two hours, while the interviewer focuses the discussion on to relevant subjects in a non-directive manner. This method assumes that an individual's attitudes and beliefs do not form in isolation. Participants often need to listen to other's opinions and understandings in order to form their own [30]³⁰.

In this case a group of a professional **10 architectural designers** practicing design at Egypt and Middle East with at least **15 years' experience**, then subjecting the identified

variables to several consequences for design process requirements. Therefore, any decision or ranking will be made by the author in consultation with the design professional team. A set of three factors categories namely "personal physical", "personal psychological" and "movement and circulation" which consists of 6 variables were evaluated for the purpose of assessing their importance in the design process requirement, and hence their reliability for use. These aspects were evaluated and weighted through an interview guide requesting the opinions of the participant team. To obtain the weight of each variable used in the design process; which were coded in alphabetical order from A to F.

The techniques of probability and expected value were utilized. For each variable respondent were asked to give a rating for five outcomes about its important in the design process, namely "extremely important", "major importance", "important", "minor importance" and "slightly important". Each of these outcomes was assigned a weight from 1-5, the score 5 assigned to the most important

Upon the tabulation of the various responses, the expected value [E (X)] for each variable was calculated as follows.

Step 1: The number of responses for each evaluation term was multiplied by the corresponding weight of that evaluation term.

Step 2: The sum of the products of multiplication from step 1 was divided by ten the number of respondents of the focus groups.

Step 3: assigned rank for each variable

To be able to quantify the degree of importance for each variable, the author is in consultation with the design professional team have adopted the following scaling:

If the expected value is below 1.49, then the criterion is “slightly important”; value is between 1.50 and 2.49, then the criterion is of “minor importance”; value is between 2.50 and 3.49, then the criterion is of “important”; value is between 3.50 and 4.49, then the criterion is of “major importance”; value is above 4.50, then the criterion is of “extremely important”.

3.2. Post Occupancy Evaluation (The Attitude Survey)

The second step in this framework is to measure user satisfaction of various library spaces by constructing a questionnaire survey method for academic library users to an existing case according to Churchill was carried out to determine the user satisfaction degree on academic libraries different space [31]³¹.

User perceptions experience are a significant factor in measuring the performance of a building, where the user has particular knowledge relating to the building itself or the building activities [32]³².

The process of constructing a questionnaire survey is divided into the following steps: the first step includes determining all the available concerning library space design and spatial aspect, the functional efficiency of space, identifying and categorizing those variables that affect the library spaces and have an impact on users' satisfaction. Library spatial design factors were divided and classified by the authors in three dimensions; Physical needs psychosocial needs and Movement.

To Generate the Samples of Items, a number of items were generated that represent the design variables for each of the proposed three factors

For example, in the physical needs factor, Space requirements are reviewed with a number of factors, such as, comfort space, space fit in reception space represented in the following statements; Reception area at community space is sufficient and comfortable space, Reception area is efficient space fit.

The questionnaire was built on the interval scale items and used Likert ratings scale to express the user's attitude on a five-point scale. As Likert scaling is a bipolar scaling method, measuring either positive or negative response to a statement. Finally, questions acquiring information about the respondent's gender,

age, and classification were included in the questionnaire to develop further useful statistical analysis.

3.2.1. Potential Ranking of Each Design Variable to Different Spaces

In this stage, a set of three factors categories namely “personal physical”, “personal psychological” and “movement and circulation” which consists of 6 variables were used to judge the potential of each variable to four spaces categories namely “primary”, “support”, “service” and “circulation elements” consists of 8 spaces. The eight spaces are scored on each variable.

The score scale of 1-5 is used to obtain the potential for the variables each other, the score 5 assigned to the most efficient variable in space.

Assigned ranks for each variable to the different spaces by the real users of an existing library varied between graduated and associate degree, through a survey requesting the opinions about “level of satisfaction of the space with each variable? For each variable. Which were coded in alphabetical order from A to F.

4. Case study

This part aims to apply the proposed framework to *Cairo university new central library* as an existing designed case; and present the results of the assessment and demonstrate its capability of measuring the academic library spaces design function efficiency.

The building of the case study located in Giza, and consists of five floors, with approximately area (4000) m² for each floor. It is built in 2002 using reinforced concrete construction system. The building includes several core and function spaces such as reading hall, study halls, research rooms, conference hall, meeting room, multimedia room, archives etc. The research focused on assess the primary reading zones at the ground, second and fourth floors. These floors contain the following spaces: Open reading spaces, separated study space, private research rooms and horizontal circulation and support spaces as shown in **figure 3**, other spaces on this floor but they are not included at this study.

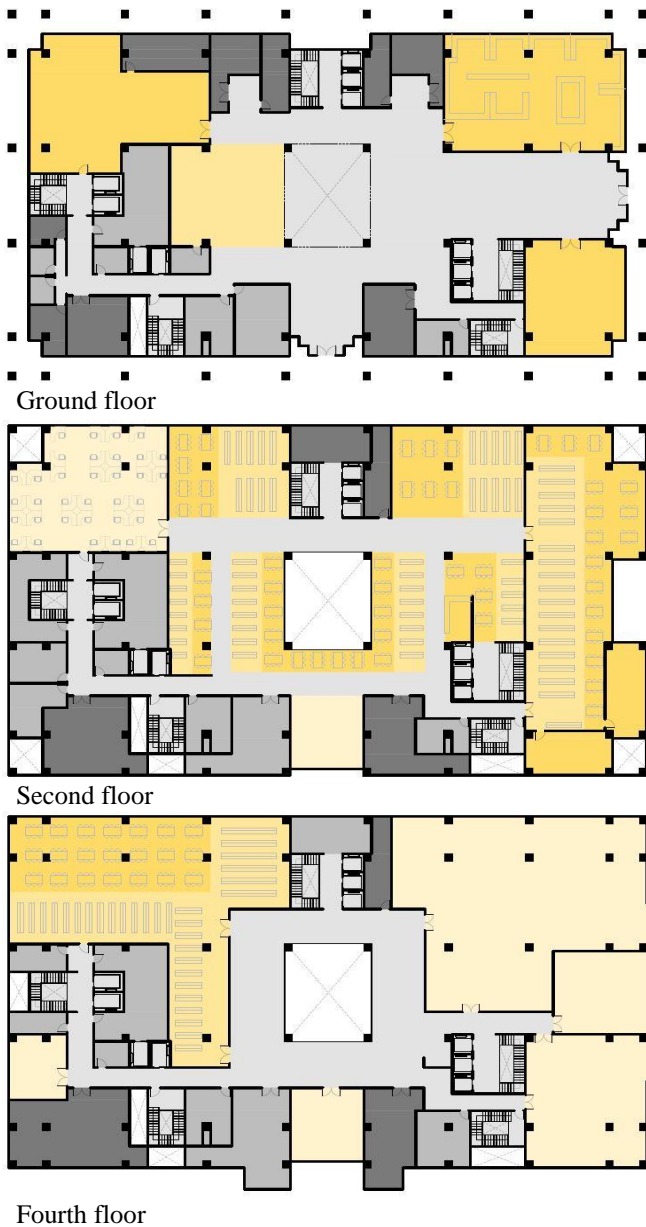


Figure 3. Simple architecture plan of the Cairo university new central library floors based on the function of spaces, Dark yellow spaces are reading zones and bookshelves (Core), yellow places are additional service for users (Function), grey spaces are (circulation), dark grey spaces are (service) and spaces not open to users. (Source: Authors)

The project inspection shows that; the open reading spaces separated from each other by bookshelves, the core and circulation atrium (flow of movement) is not physically separated from the reading zone floor. Although the atrium splits the floor into two sides but actually the two sides are connected throughout this atrium, and that is because the atrium is adjacent to the main stairs and elevators lobby which is considered the entrance of the floor. The floor includes the number of 50 users; 12 persons are in the study and research rooms, while 38 are in the open reading spaces.

Also a number of issues were detected at the first site investigation, these were; High level of distraction and noise between open reading spaces, no privacy between rooms, there are many elements that block eyes sight & obstruct movement such as book shelves as shown in **figure 4**.



Figure4. Circulation and visual obstructs; also crowded, noisy and no privacy.(Source: Authors)

4.1. Step 1: Focus Groups Results

The focus group took around two hours, the interview focuses the discussion on the important to measure “how easy can the space achieve of this attribute? in the design process requirements. Where the participants were asked to fill in the importance survey, the participants were asked to answer collectively. The benefit out of this was that any decision or ranking did not make by the author in consultation with the design professional team, until they discussed the reply and was approved by everyone for its validity and reliability, so the importance measurement was very successful in obtaining replies.

From the replies received from the interview as shown in **table 3**, some items were of high levels of importance for all the participants: **1-** Accessibility. **2-** Comfort space. **3-** Visually appealing. **4-** Personal privacy. **5-** Space fit. **6-** Concentration.

Table 3. Ranked variables importance table to Measuring the level of Importance based on the Focus Group replies

Variable		Extremely important	Major importance	Important	Minor importance	Slightly important	E (X)	Mean response	Rank
Physical	A	2	2	2	2	2	3	importance	2
	B	0	2	2	4	2	2.4	Minor importance	5
Psychosocial	C	1	2	2	1	4	2.4	Minor Important	5

Circulation	D	Personal privacy	2	2	1	0	5	2.6	Important	4
	E	Accessibility	2	5	2	1	0	3.8	Major Important	1
	F	Visually appealing	2	1	2	2	3	2.7	importance	3
<i>Where:</i>										
		Evaluation term	Strongly agree	Agree	Neutral	Disagree	Strongly disagree			
		score	5	4	3	2	1			

Source: Authors based on the focus groups replies

4.2. Step 2: The Attitude Survey Data Results

The application of the survey started in December 2019 by delivering the attitude survey to a number of 60 users by the questionnaire survey method; Diversity in age, gender and category was taken into consideration. As explained in the previous part of research, the total amount of replies received after the questionnaire process was around 32 which make the response rate 50% which better than expected.

The demographical analysis illustrated that more than (75%) of the respondents was, less than 40 years of age. The percentage of women is higher than men, as women account for (77.4%) while men are (22.6%) of library users and more than (90%) were users.

The survey variables were loaded across three spatial design factors (Dimension), with direct application on different library spaces (primary, support, service spaces and circulation elements), Behavior responses of users regarding various convex spaces as shown in **figures 5,6 and 7**

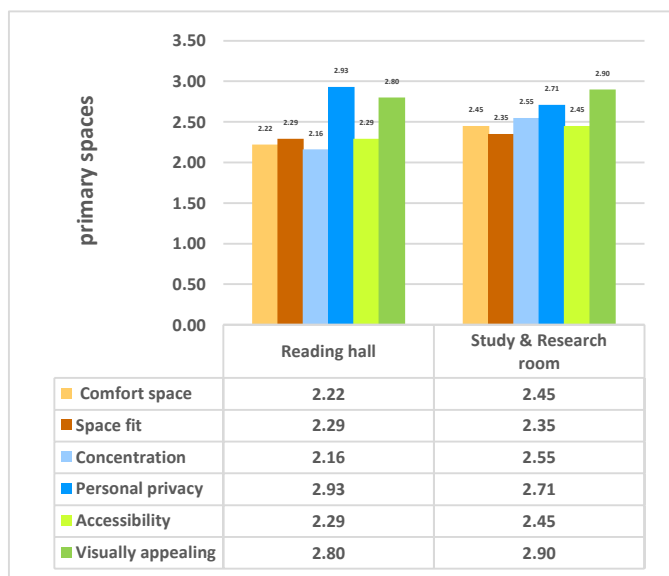


Figure 5: Behavior responses of users regarding primary.

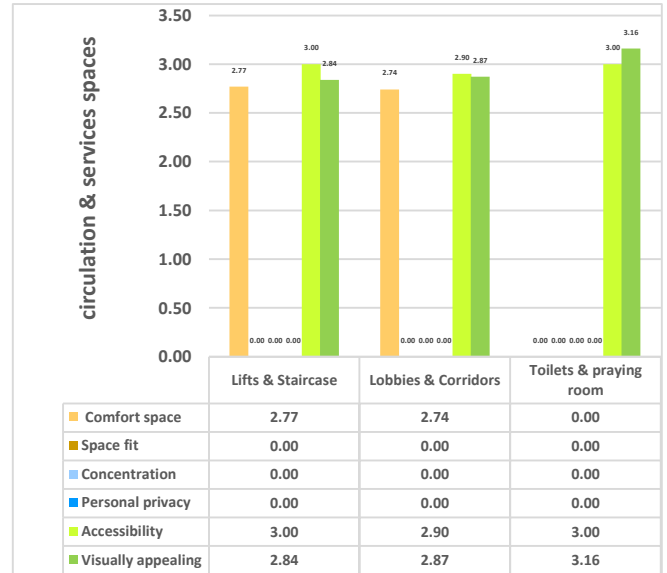


Figure 6. Behavior responses of users regarding circulation and service spaces.

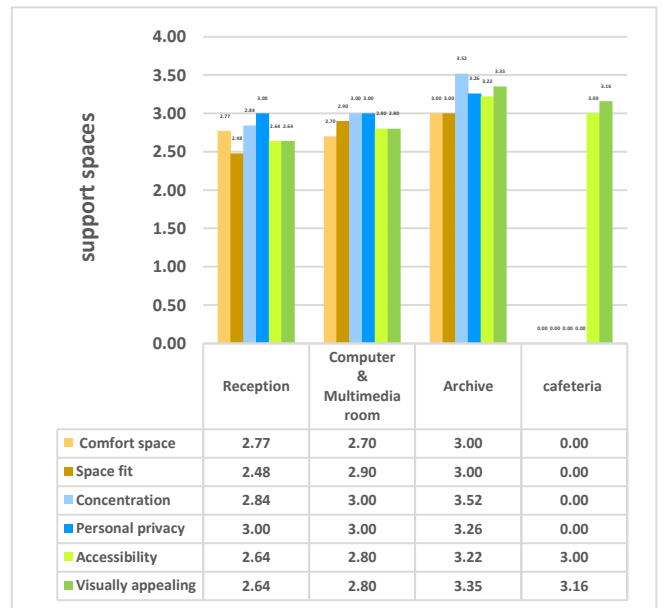


Figure 7. Behavior responses of users regarding support spaces.

The obtained results showed perception of satisfaction towards this dimension on the level of various spaces shown, it was found that those who expressed the highest levels of satisfaction were the following:

- Archive – mean value: 3.22
- Computer & multimedia room – mean value 2.86
- Reception– mean value: 2.73
- Studying hall & Research room– mean value: 2.57
- Reading hall– mean value: 2.45

While those departments that expressed the lowest levels of satisfaction were:

- Lift and stairs, lobby and corridors – mean value 1.41
- Cafeteria, toilets and prayer – mean value 1.1

Table 4. potential Rank of each spatial design variable to various floor levels

Variables alphabetical code	Spatial Design Variables "Satisfaction degree of the space with each design variable"	Floor number	Ground floor										Second floor										Fourth floor										
			primary		Support			circulation		service			primary		support			circulation		service			primary		support			circulation		service			
			Reading hall	Studying hall & Research	Reception hall	Computer & multimedia	Archive	Cafeteria	Lifts & stairs	Lobbies & corridors	Toilets & praying room	Floors mean value	Reading hall	Studying hall & Research	Reception hall	Computer & multimedia	Archive	Cafeteria	Lifts & stairs	Lobbies & corridors	Toilets & praying room	Floors mean value	Reading hall	Studying hall & Research	Reception hall	Computer & multimedia	Archive	Cafeteria	Lifts & stairs	Lobbies & corridors	Toilets & praying room	Mean value	Floors total mean value
			Space name																														
A	Comfort space			2.77	3.0	0	2.77	0	1.06	2.22	2.45		2.70	3.0	0	2.77	2.74	0	1.98	2.22						0	2.77	2.74	0	0.96	4.0		
B	Space fit			2.48	3.0	0	0	0	0.69	2.29	2.35		2.90	3.0	0	0	0	0	1.32	2.29						0	0	0	0	0.29	2.30		
C	Concentration			2.84	3.52	0	0	0	0.80	2.16	2.55		3.0	3.52	0	0	0	0	1.40	2.16						0	0	0	0	0.27	2.47		
D	Personal privacy			3.0	3.26	0	0	0	0.78	2.93	2.71		3.0	3.26	0	0	0	0	1.49	2.93						0	0	0	0	0.37	2.64		
E	Accessibility			2.64	3.22	3.0	3.0	3.0	1.86	2.29	2.45		2.80	3.22	3.0	3.0	2.90	3.0	2.83	2.29					3.0	3.0	2.90	3.0	1.77	6.46			
F	Visually appealing			2.64	3.35	3.16	2.84	3.16	1.90	2.80	2.90		2.80	3.35	3.16	2.84	2.87	3.16	2.99	2.80					3.16	2.84	2.87	3.16	1.85	6.74			
Space total mean value									1.18									2.00										0.92	4.10				

(Source: Authors based on the behaviour responses regarding various convex spaces).

Results also showed on the level of potential ranking of each spatial design variable to various floor levels as shown in table 4, it was found the following:

The Personal Physical Needs factor consists of two variables where comfort space was scored medium rate of satisfaction with mean value (4). Results showed that, four spaces were relatively satisfied with comfort space variable; archive, reading hall, lift and stairs. Two spaces were unsatisfied with this variable; studying hall, research room and reading hall, while space fit scored the lowest rate of satisfaction with mean value (2.3). Also results showed that, two spaces were relatively satisfied with this variable; archive, computer and multimedia room. Two spaces were unsatisfied with this variable; studding hall, research room and reading hall and the rest of spaces were slightly more than neutral.

The Personal Physiological Needs factor consists of two variables where concentration was scored low rate of satisfaction with mean value (2.47). Results showed that, two spaces were relatively satisfied with concentration variable; archive, computer and multimedia room. Reading hall space was only unsatisfied with this variable and the rest of spaces were slightly more than neutral, while personal privacy scored medium rate of satisfaction with mean value (2.64). Also results showed that, almost all spaces were satisfied with this variable.

Circulation and movement factor consists of two variables where accessibility was scored high rate of satisfaction with mean value (6.46). Results showed that, almost all spaces were satisfied with accessibility space variable except two spaces were relatively unsatisfied with this variable; studying hall, research room and reading hall, while visually appealing scored the highest rate of satisfaction with mean value (6.64). Also results showed that, almost all spaces were satisfied with this variable.

5. DISCUSSIONS AND CORRELATIONS

After applying the measurement tool on Cairo University New Central library and producing valid and reliable results from the level of importance, the measurement attitude survey and space syntax, these results were discussed here in this chapter. The discussion is supported by tables, comparing the quality space score evaluation as a result of rank importance of each design item multiply by the corresponding weight of the spatial design variables, to the corresponding weight of the spatial configuration variables. This correlation helps in evaluating space design function efficiency. Evaluation matrix from the first and second stage of framework will be discussed based on the syntactic values acquired with the Space Syntax Method from third step of framework as it helps in investigating problems about visual and physical relation between spaces that wouldn't show up in the survey results.

5.1. Spatial design variables relative weighted evaluation

Subjected the identified spatial design variable to several consequence process for judging, as an efficient decision making tool. This evaluation process is composed of three steps lead to the final result;

- Paired comparison of evaluated variables to each other.
- Variables weights.
- Total quality score for each method (evaluation matrix) to evaluate the relative weights of various spaces against each of the weighted aspects

5.1.1. Step1: Paired comparison variables

The method of pairwise comparison is used in the scientific study of attributes, preferences, voting system, public and social choice. This method today has been more commonly

used in market research. It has also been used in sports [33]³³, although in education performance.

Based on the work of Thurstone first introduce this scientific approach using pairwise comparison for measurement. Thurstone arguing attitudes could be measured. Thurstone developed a process and model that can be used to order items along dimension such as preference or important using an interval type scale [34]³⁴. Generally, is a process of comparing entities in pairs to judge which of each identity is preferable.

Here each variable was assigned of a letter of the alphabet then compared with other variable based on preference of participants, the value preference of one variable in relation to another can be “major preference” with three point, “minor preference with two point and “no preference” with one point. When a decision of importance between any two variables cannot be established, the two variables would be designated to have equal level of importance by using both letters in the variable scoring matrix and would be scored one point for each, as shown in **figure 8**, which explains the pair comparison of six variables to each other.

	B	C	D	E	F
A	A-3	A-3	A-2	E-2	A-2
	B	B-C	D-2	E-3	F-2
		C	D-2	E-3	F-2
			D	E-3	F-2
				E	E-2
					F

How important

Major preference (3 points)

Minor preference (2 point)

No preference (1 point each)

Figure 8. Space axial map connectivity analysis calculated by depthmapX software.

5.1.2. Step2: Variables weights

After all the comparative evaluations are made the weight of individual variable are calculated, the raw scores for each variable are adjusted to scale of 1-10, where 10 is a signed to the highest raw score variable, and the other variable adjusted correspondingly, as shown in **table 5**.

Table 5. Raw score and assigned weight for the variables.

Variables alphabetical code	Variables	Weighting	
		Row score	Assigned weight
A	Comfort space	10	7.69
B	Space fit	1	0.76
C	Concentration	1	0.76
D	Personal privacy	4	3.07
E	Accessibility	13	10
F	Visually appealing	6	4.6

5.1.3. Step3: Evaluation matrix

A Statistically reliable estimate of the consistency of the resulting weight, the potential rank of each spatial design variable for various floor levels **table 4** are multiplied by the corresponding weights of the variable **table 5**, and the resulting scores were entered into the matrix therefore the total space score were established for each space as shown in **table 6**.

Table 6: Potential rank of each spatial design variable to various floors

Based on the mentioned analysis, the second floor is considered

Variables alphabetical Code	Spatial Design Variables	Floor level		
		Ground level	Second level	Fourth level
A	Comfort space	1.06	1.98	0.96
B	Space fit	0.69	1.32	0.29
C	Concentration	0.80	1.40	0.27
D	Personal privacy	0.78	1.49	0.37
E	Accessibility	1.86	2.83	1.77
F	Visually appealing	1.90	2.99	1.85

the most efficient level, as it has obtained the highest score of (63.9), followed by the ground floor level with a total score of (39), followed by the fourth floor level with a total score of (35.4) as shown in **table 7**.

Figure 9. Floor efficiency level score.

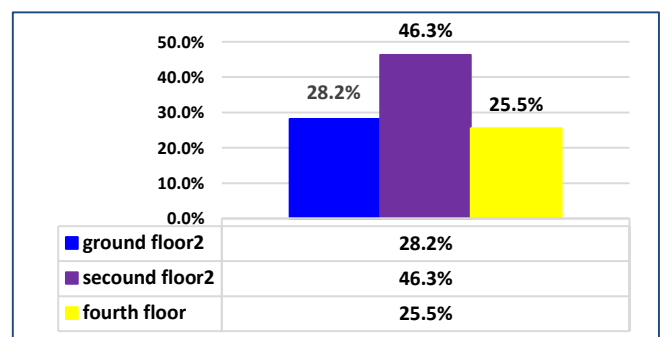


Table 7: floor score matrix evaluation

Variables alphabetical code	Variables	Ass. Weight	Floor number					
			Ground floor		Second floor		Fourth floor	
			Rank	Score	Rank	Score	Rank	Score
A	Comfort space	7.69	1.06	8.15	1.98	15.22	0.96	7.38
B	Space fit	0.76	0.69	0.52	1.32	1.00	0.29	0.22
C	Concentration	0.76	0.80	0.60	1.40	1.06	0.27	0.20
D	Personal privacy	3.07	0.78	2.39	1.49	4.57	0.37	1.13
E	Accessibility	10	1.86	18.6	2.83	28.3	1.77	17.7
F	Visually appealing	4.6	1.90	8.74	2.99	2.99	1.85	8.51
Floor efficient level score				39		63.9		35.14
		Index from 100		28.2%		46.3%		25%

6. CORRELATION OF FUNCTION EFFICIENCY AND SPATIAL CONFIGURATION

Comparing the readings of the space syntax analyses with numerical findings of function efficiency for various floor levels, many statistical results were found as shown at **figure 10**.

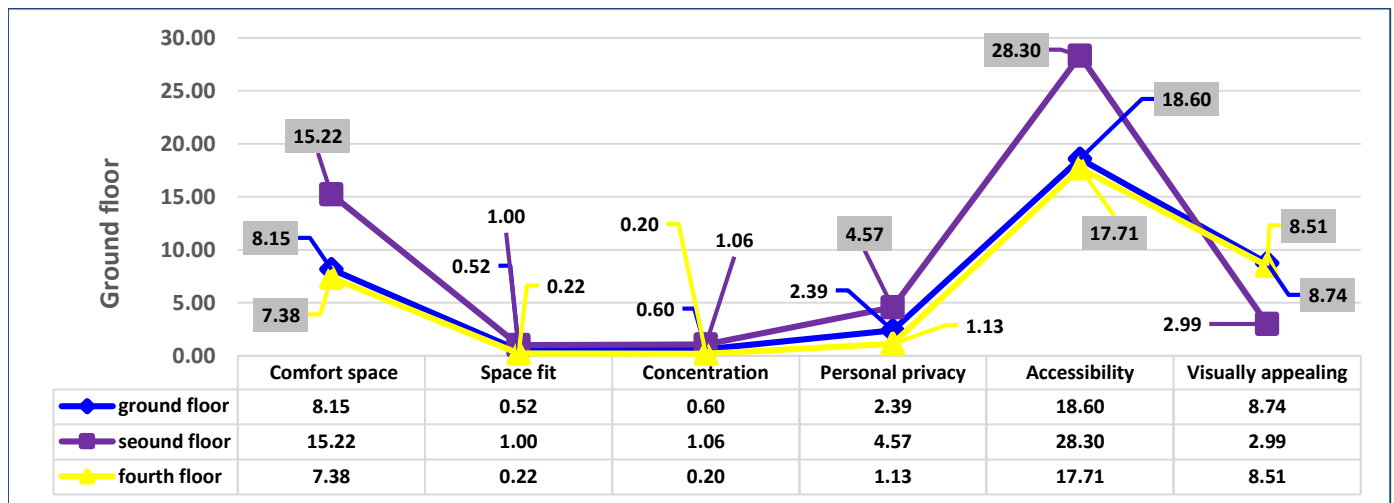


Figure 10. Floor score values regarding matrix evaluation.

In the ground floor, regarding function efficiency value, efficiency matrix evaluation results showed that, three variables were scored relatively the most efficient; accessibility, visual appealing and comfort space. While personal privacy, concentration and space fit were the lowest efficient.

Also it was found **in the second floor, regarding function efficiency value,** efficiency matrix evaluation results showed that, three variables were scored relatively the most efficient; accessibility, visual appealing and comfort space. While personal privacy, concentration and space fit were the lowest efficient.

In the fourth floor, regarding function efficiency value, efficiency matrix evaluation results showed that, three variables were scored relatively the most efficient; accessibility, visual appealing and comfort space. While personal privacy, concentration and space fit were the lowest efficient.

7. RESEARCH FINDINGS

The research intended to explore the spatial design of the experience of professional designers and the academic library users, based on a study development within the framework; using focus group method for 10 professional designers and attitude survey samples of 32 AL's user and space syntax analysis by interpreting spatial configuration from multi perspectives of built case in Egypt, were applied in order to comprehend how spatial design and spatial configuration influences the performance and use of academic library space. It was aimed to investigate and analyze to what extend the function efficiency of various spaces in academic library and spatial configuration are meets the needs and the expectations of the users.

From the analysis according to intersection of results, it has been shown that the spatial design factors expose the conflicts with existing and space-exploring principles.

All findings are integrated in an attempt to understand how the built environment influence user spatial behavior in the physical space and interact with space use pattern, in order to determine the level of function efficiency of their configuration.

Several findings representing sequential answers to these questions have been reached, supporting the main research hypothesis and validating it. These findings can be summarized as follows topics:

- **Architecture design concept affects level of user satisfaction**

Current studies showed considerable defects at the level of spatial functional relationship compared with spatial design factors and user perception, this prove the need for spatial function analysis of such academic layout to highlight this defects.

As an integrated structure Spatial configuration in itself is a means and a logical tool that reflects the state of overlap between various function activities.

- **Design implication findings**

The study found spatial axial connectivity, accessibility integration, visual integration and visual connectivity is the most affected variables is the most affected variables that are related to the way designers allocate the spatial elements are taken as an obstacle that obstruct movement or block eyesight regarding space syntax analysis.

Regarding spatial design variables: accessibility and visual appealing; the main stairs and lift located too close the primary spaces (collaborative) i.e. reading hall and support spaces (interaction and community) i.e. Computer and multimedia room, makes them high accessible and visible for the user which enable to collaborate and interact.

Regarding personal privacy and concentration; open reading hall seems not efficient to achieve this variable as easier accessibility and more visibility reduce feeling of privacy also distraction from user movement across pathways around primary or silent spaces. Also high partition avoids obstruct movement and block eyesight, help in provide privacy, while furniture arrangement and low partition oriented the space away from pathways without block eyesight. Primary individual spaces i.e. Study and reading room seems efficient in personal privacy as it is far away from stairs and lifts.

8. CONCLUSION

The primary conclusion that could be drawn out of this research work is that the academic library space design function efficiency is measurable in a number of ways and should be used in directing to understanding and testing user spatial behavior and how to analyze the true function efficiency of academic library spaces after it has been put into use.

This research has introduced an approach based on user spatial behavior and a framework that was practically applied and proving to be valid and reliable. In this general setting, a number of conclusions that relate to this subject – measuring AL's space design function efficiency – were stated in the following points:

1. A multidisciplinary approach

Since all the previous factors work collectively to examine the efficiency level of space functionality and to what extent these factors influence the physical spaces, then the process of effectively designing library space must be of a multidisciplinary approach, where not only architects are involved but also library users as the measurement approach proposed by this research was based on user satisfaction. Human behavior is a powerful factor in the formulating and directing the space organization.

2. Measurement considerations

Some points must be taken into consideration while developing a measurement approach, as following:

- The measurement tool must not isolate the physical designed environment from factors that affect spatial system; rather it will design in a way that will extract information regarding the design variables of the design environment
- There is no such thing as standard results or the ideal library design model that could be referred to when comparing the results of the measurement tool.
- The difference in awareness and experience of the library users can affect the outcome of the measuring process.

9. RECOMMENDATIONS

▪ Architect awareness

Any specialized architect in the field of library design must set a special focus on the user behavior (physical/psychosocial needs) and spatial configuration parameters to realize the important of these parameters and help them document the role of space in accommodating high level of efficiency respecting user behavior and translating the true need of users, which in turn led to the implication of suitable conventional library space planning.

▪ User participation

In measuring the academic library design performance, user participation was found to be crucial for the success of the whole process; it needs to be developed in a methodological way. Again, researchers in the field of organizational behavior are invited to participate in this area.

10. FURTHER RESEARCH WORK

Based on this study, there are a lot of aspects for improvement and further research in the study with regard to the academic library layout.

- Studies need to focus on other measurement approaches to be explored in measuring academic library function efficiency on the levels of bioclimatic dimension (lighting, acoustic, thermal, etc...), others studied aesthetical dimension (visual richness, architecture language, physical appearance ,colors, material and textures) and its implications on user satisfaction. These measurement approaches have to concentrate on translating qualitative design attributes to quantitative values.
- The possibilities of technologies, the availability of resources online and new ways of learning changed the way people use the spaces and affecting greatly the physical design of library design. This fact transferred traditional design spaces into digital environments.

REFERENCES

- [1] Sisman, M. "Searching for Possibility of Using Space Syntax as a Tool for Architectural Design". Master Thesis, ITU Graduate School of science Engineering and technology, Istanbul: **2015**.
- [2] Hanson, J. "Morphology, Design, Reconciling Intellect, and Ethics in the Reflective Practice of Architecture". Proceedings of the 3rd International Space Syntax Symposium, Georgia Institute of technology: **2001**.
- [3] Sailer, K. "The Space-Organisation Relationship: On the Shape of the Relationship between Spatial Configuration and Collective Organisational Behaviours". Faculty of Architecture, Dresden University of Technology, Dresden: **2010**.
- [4] Pevsner, N. "A History of Building Types". Princeton, N.J.: Princeton University Press: **1976**.
- [5] Edwards, B.; Fisher, B. "Libraries and Learning Resource Centres". Oxford: Architectural Press, Oxford, **2002**.
- [6] Both, K.; Heitor, T. ; Medeiros, V. "Assessing Academic Library Design: A Performance- Based Approach". Computation and Performance, Spatial Performance and Space Syntax **2013, Vol. 1**.
- [7] Haghghi, Mahmood, "Evaluation of Tehran's academic Libraries Spaces". Faculty Member of Psychology and Educational Sciences Faculty: **2009**.
- [8] Vaughan, L. "The spatial syntax of urban segregation". Progress in Planning **2007, Vol. 67, pp. 205–294**.
- [9] Benedikt, M. "To Take the Hold of Space: Isovists and Isovist Fields". Environment and Planning B: Planning and Design **1979, Vol. 6, pp. 47-65**.
- [10] Bustard, W. "Space, evolution, and function in the houses of Chaco Canyon". Environment and Planning B: Planning and Design **1999, Vol. 26 No. 2, pp. 219-240**.
- [11] Hanson, J. "Decoding Homes and Houses". Cambridge: Cambridge University Press, **2003**.
- [12] Voordt, T. ; Vrielink, D. ; & Wegen, H. Comparative floorplan-analysis in programming and architectural design. Design Studies **1997, Vol. 18 No. 1, pp. 67-88**.
- [13] Ali, F. "Spatial Configuration and Functional Efficiency of House Layouts". LAP LAMBERT Academic Publishing .Editor: eturcan: **2014**.

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- [14] Mustafa Y. A. Hassan; A. S., "Using space syntax analysis in determining level of functional efficiency: A comparative study of traditional and modern house layouts in Erbil city, Iraq" The 2nd. International Seminar on Tropical Eco-Settlements, Sanur Denpasar Indonesia Green Infrastructure: A Strategy to Sustain Urban Settlements: **2010**.
- [15] Hillier, B. "Space is the machine: A configurational theory of architecture" London: Space Syntax Laboratory: **2007**.
- [16] Hillier, B.; Hanson, J.; Graham, H., "Ideas are in things: an application of the space syntax method to discovering house genotypes Environment and Planning B", Planning and Design **1987, Vol. 14, pp. 363-385**.
- [17] Evans, G. W.; Skopanich, M. A.; Gärling, T. ; Bryant, K.J.; B. Bresolin. "The effects of pathway configuration, landmarks and stress on environmental cognition." Journal of Environmental Psychology **1984, Vol. 4 No. 4, pp.323-335**.
- [18] O'Neill, M J. "Effects of signage and floor plan configuration on way finding accuracy", Environment and Behaviour **1991, Vol. 23 No. 5, pp. 553-574**.
- [19] Hart, R.A.; Moore, G.T. "The Development of Spatial Cognition: A Review". In Downs, R.M. and Stea, D., Eds., Image and Environment, Aldine, Chicago **1973, pp. 246-288**
- [20] Alexander, C. "Notes on the Synthesis of Form", Harvard University Press, Cambridge, Mass: **1964**.
- [21] Darke, J., "The Primary Generator and the Design Process", Developments in Design Methodology, Nigel Cross, Open University, John Wiley & Sons **1984, pp.175-188**
- [22] Lawson, B., "How Designers Think", Architectural Press: **2003**.
- [23] Zeisel, J., "Inquiry by Design: Tools for Environment-Behaviour Research", Brooks/Cole, Monterey, CA: **1984**.
- [24] Hillier, B.; Leaman, A. "How Is Design Possible?" Journal of Architectural Research and Teaching **1974, Vol. 3 No. 1, pp. 4-11**.
- [25] Jochumsen, H. ; Rasmussen, C.H. ; Skot-Hansen, D. "The four spaces – a new model for the public library", New Library World **2012, Vol. 113 Nos 11/12, pp. 586-597**.
- [26] Cunningham, H.; Tabur, S. "Learning space attributes: reflections on academic library design and its use", Journal of Learning Spaces **2012, Vol. 1 No. 2**.
- [27] Joseph C., Rizzo " Finding your place in the information age library" New Library World **2012, Vol. 1182, pp. 457-466**.
- [28] Beard, J.; Dale, P. "Library design, learning spaces and academic literacy", New Library World **2010 Vol. 111 Nos 11/12, pp. 480-492**.
- [29] Choy, F. C.; Goh, S. N. A framework for planning academic library spaces. Library Management **2016, Vol. 37 Nos 1/2, pp. 13-28**.
- [30] Tynan, A.C.; Drayton, J.L. "Conducting Focus Groups: A Guide for first-time users", Marketing Intelligence & Planning **1988, Vol. 6 No. 1, pp. 5-9**.
- [31] Churchill, Gilbert A., "Jr. Marketing Research: Methodological Foundations". Hinsdale, Ill.: Dryden Press, Journal of Advertising **1976, Vol. 7 No. 1, pp. 63**.
- [32] Williams, A.M. "Obsolescence and Re-use: A study of multi-storey industrial buildings, school of land and building studies", Leicester Polytechnic, Leicester: **1985**.
- [33] Bond, T. G.; Fox, C. M. "Applying the Rasch model: Fundamental measurement in the human sciences". Mahwah, NJ: Lawrence Erlbaum Associates: **2001**.
- [34] Sandra H.; Stephen H. " Using the Method of Pairwise Comparison to Obtain Reliable Teacher Assessments", The Australian Educational Researcher **2010, Vol. 37, pp. 1-19**.