



Architecture Algorithm for Energy Efficient Healthcare Facility

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Abstract: Design Energy efficient clinical setting is one of the fundamental criteria for healthcare project success. The focus is on creating the optimal conditions for innovation in healthcare considering the local context of Pakistan.. Concerning building form the compact geometrical form of the building is the most efficient as compared to the spread blocks plan. The accessibility is enhanced to utmost efficiency level by sculpting the entire mass of the building incorporating vehicular and pedestrian accessibility and hospital form maintaining expert care facility in centralized, collective, sheltered manner. An I- Shape plan provides central circulation core, this shows maximum healing environment of $\approx 6,240 \text{ sq.ft.}^3$ for Ziauddin Hospital 2. Since it is compact and the probability to getting lost is less therefore stress is very less. A U-Shape plan which is present in FC2 and ZH1 provides second best energy efficient solution through a grid plan $\approx 19,800 \text{ sq.ft.}^3$ and $\approx 28,800 \text{ sq.ft.}^3$ respectively are the algorithm. Since it gives more space for central connectivity and direction is easy which are key for navigation from architectural point of view.

Keywords: Healthcare care energy efficiency, compact architecture, algorithm for efficient healing environment.

1. INTRODUCTION

Various tools and techniques were also explored in this regard to evaluate the hospitals and case studies were conducted in Pakistan to see the achievement of Energy efficiency within Hospitals from early stages of design to final product. The healthcare in Pakistan is administered mainly in the private sector which accounts for approximately 80% of all outpatient visits. Keeping this aspect in consideration total nine standardized hospitals were selected with respect to size, location and character for case studies and analyzed with three variables of spatial organization, aerial distribution and design determinants. The Government hospitals include, Jinnah Postgraduate Medical Centre (JPMC) Karachi, FC Hospital Peshawar and Medical Institution Ghambat. The private sector hospitals include Agha Khan Hospital Karachi, Ziauddin Hospital Clifton Karachi; Ziauddin Hospital for low income settlements in Karachi, Indus Hospital Karachi, and OPD Nawabshah. In these case studies all three variables were analyzed with different scientific management models. For instance Spatial Organization study was based on Muda, Muri, and Mura model. The Aerial Distribution study was analyzed on 5S analysis and Design Determinant's modelling was done on Poka Yoke. The following (Table 1.1) would identify all the 9 analyzed case.

The selection of these hospital buildings were such that from two relatively backward provinces 13 hospitals of secondary and tertiary scale were studied with the lens of Energy Efficiency. The study found out that the hospitals of Pakistan have a very small percentage of places that can be termed as healing spaces.

The other issue is to document the specific conditions of hospital buildings in terms of its design determinants, spatial organization and areal distribution as there is very little unpublished information available in Pakistan concerning these aspects of hospital buildings.

2. BACKGROUND

The access to data maps and drawings concerning hospital buildings is a major constraint in Pakistan. The overall structure and nature of maintenance and management system of hospital buildings is still at its infancy level. Therefore it is a rational need to understand the types, nature and characteristics of hospital buildings in Pakistan.

At present there is no such standard method of hospital building design in Pakistan which promotes the Energy Efficiency. Neither there are any energy efficiency laws nor legislation at professional level statutes that may provide guidelines to create Energy Efficiencies in hospital buildings.

A database would be developed concerning energy efficiency of hospital buildings in Pakistan, for future researches. A documented record would be available with state institutions about nature of hospital buildings in Pakistan. With this research published information will be available in Pakistan concerning standards for hospital buildings design determinants, spatial organization and aerial distribution. The proposed research would produce maps and drawings of hospital buildings in Pakistan that may be available to professional architects with an understanding of the energy efficiency creation and improvement of hospital buildings.

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The prime objective of proposed research is “improving hospital buildings in Pakistan by adding energy efficiency based on design determinants, spatial organization, and areal distribution”. Total eight Design Determinants were investigated i.e. Entry, Parking, Waiting Area, Connectivity, Visibility, Walk Ability, Accessibility, and Way Finding. With regard to Spatial Organization, the characteristics of individual space, site allocation plan and typology of circulation was examined. Concerning Areal Distribution the total spatial sizes, standards and allocated areas to individual rooms and spaces were studied from hospital buildings in Pakistan. Three tools of analyses were also identified for analyzing data and to extract research findings from Design Determinants, Spatial Organization and the Aerial Distribution within hospital buildings in Pakistan. These tools include POKA YOKE (Zero Defect System) 3M Analysis i.e. MUDA (waste), MURI (over burden), MURA (unevenness) and 5S Analysis i.e. SEIRI (Sort), SEITON (Set in Order), SEISO (Shine), SEIKETSU (Standardize) and SHITSUKE (Sustain).

There are seven main aspects that establishes the justification for the contents of this research such as:

- i. Development of the database concerning energy efficiency in healthcare facilities of Pakistan;
- ii. Provision of published information concerning standards for healthcare facilities design;
- iii. Production of visual data, maps and drawings for professional architects to learn and develop an understanding of energy efficiency creation in hospital;
- iv. Directions for appropriate decision making by healthcare facility developers;
- v. Innovation in curative health and energy efficiency in the healthcare facilities of Pakistan;
- vi. Development of byelaws with localized standards and principles for practicing professionals; and
- vii. Development of a zero defect system for hospital buildings; and improvement in hospital buildings design.

The contents of research were outlined with a theoretical understanding about Energy Efficiency; design determinants, spatial organization and areal distribution within hospital buildings that may lead to develop a continuous improvement algorithm specific for acute care hospital.

3. LITERATURE REVIEW

By mid 1980s Roger Ulrich made first evidence based research on energy efficiency by identification of the effect of built environment on patients. This has instigated the researchers to further identify the effects of natural and built environment on patient's healing. Many architectural researches conducted in this regard

with application of different methodologies and developed an academic structure and knowledge base as intended in this research.

Currently there is a collective understanding that a energy efficiency is beneficial for patients and for healthcare staff. Healing principles (Giofrè and Zoran, 2016) and evidence based design (Royse *et al.*, 2015) are applied to augment and optimize the outcomes of care quality. The user's instinctive healing ability is developed by incorporating specified aspects of architectural design in healing spaces, as articulate by Sakallaris, *et al.*, (2015). Organization of spaces, regular maintenance and comprehensive environmental design are three significant principle components (Mourshed and Zhao, 2012) that are essential to create effective Energy Efficiency.

In order to explore the concept of hospital buildings in Pakistan a small scale reconnaissance survey of 12 hospital buildings was conducted during the year 2015. The selection of these hospital buildings were such that from each province 03 hospitals of primary, secondary and tertiary scale were studied with the lens of environmental friendly healthcare facility.

(Lindheim 1966) represented the architectural explanation of spatial organization as healthcare functionality which determines healthcare facility design in terms of acute care. Worldwide spatial organization of hospital buildings with energy efficiency was researched by a number of approaches such as discursive practice of spatial organization (Prior, 1988) where effects of knowledge was explored. Durmisevic *et al.*, (2005) explains about performance indicators for spatial organization that, access and barrier free accessibility differs from country to country with varied temporal realities. The spatial organization factors for healthcare facilities are distinct and give different sense of place, character and identity.

The site allocation plan and circulation required a functional zoning in space distribution. The utility of space and approach supports the site allocation and circulation . Bagheri *et al.*, (2005) developed the standards for site allocation plan and circulation in hospital design. He stressed on using appropriate tools i.e. Achieving Excellence Design Evaluation Tool (AEDET) which consist different models for site allocation plan and circulation in hospitals. The patients and customers' satisfaction is also depends on the allocation of appropriate site and efficient circulation with micro level design details.

The typology of circulation in hospital buildings is an especial focus in the study of circulation patterns in hospitals by Ganiyu *et al.*, (2015) and its impact on the design determinants as displayed in form of research by (Sadek and Shepley 2016). They used a matrix of cause

and effect (fishbone diagram) to evaluate the typology of circulation. (Mazlum. 2015) discussed in his work on the lean design management that typology of circulation add efficiency to hospital buildings.

It was also proved from Burgess and Radnor (2013) research case that lean principles to design determinants for healthcare facilities is also a valid application. According to World Health Organization the design determinants for a standard hospital includes an approach to enable the user to improve control of architectural determinants (WHO, 2005) as initiated by International Network of Health Promoting Hospitals (HPH). Similarly as per standards of Canadian Institute of Medical Sciences the analyses of design determinants are the sets of methods that enable a healthcare facility to be curative via accessibility to all spaces with visual control and minimum distance between different activities. The implementation of architectural design determinants involves 'connectivity' as studied by McIntyre, (2006), 'visibility' as analyzed by (Verderber, 2010) and 'accessibility' as findings in his research related to context of innovation in hospital design. Similarly 'way-finding' and its relation with 'walkability, egress and entry' i.e. relationship between vehicular and pedestrian circulation as discussed in ADA (American Disability Act) are other design determinants .

3. MATERIALS AND METHODS

The analyzed forms, shapes and circulation include E-Shape, Cross-Shape, O-Shape with Complex Interlocking and with Higher Level of Connectivity, 0-Shape Planning with Internal Triple Corridor, L-Shape Planning with Central Spine, 4-Shape Planning with L-Shape Internal Corridor System, U-Shape Planning with L-Shape Internal Corridor System, I-Shape Planning with I-Shape Internal Corridor System, Cross-Shape Planning with Central Cross-Shape Internal Corridor System, A Primary Central Hospital Street with Secondary Linking Corridor Bridges along with Triple Circulation Between Square, T-Shape with Central Pivot for Circulation Core, L+L Shape Interlocking Complex Morphology were few mentions that were used for selection of hospitals. this section, we discuss the concepts, tools and methods utilized in the proposed P-learning model.

3.1 Poka Yoke

This tool measured the Barrier Free (Visibility), Orientation (Way finding) and Vicinity (Walkability) Accessibility in Egress and Feasibility of waiting areas in hospital buildings. Muda-Mura-Muri is a tool in which wasted spaces eradicated with the application of Space Syntax; Stress from staff was eradicated by applying axial line for barrier free accessibility and way finding; whereas, the eradication of variety in spaces

that creates a puzzlement was also carried out through visibility graph.

• **5S analyses.**

The other tool was 5S analyses of Sort, Straighten, Shine, Standardize and Sustain or Seiri, Seiton, Seiso, Seiketsu and Shitsuke. With these tools spaces were aligned, visual connectivity was enhanced, and Muri spaces were standardized and connectivity labels were introduced to make circulation sustained.

The hypothesis of this research is:

Y (Improvement of Energy Efficiency) = f (Design Determinants, Spatial Organization, Areal Distribution)
Whereas,

The parameters of this research are:

Design Determinants (DD), Spatial Organization (SO), and Areal Distribution (AD)

The indicators of Design Determinants (DD) is House of Quality Matrix

The indicators of Spatial Organization (SO) is Muda, Muri, Mura

The indicators of Areal Distribution (AD) is 5S Analysis

In order to simulate the Hypothesis, Parameters and Indicators the formula applied is:

$Y = f(X_1, X_2, X_3 \dots X_n)$

Where Y is the output and f is the function of all inputs (X 's)

This formula works as follows:

Y (Improvement of Energy Efficiency) = f (Design Determinants, Spatial Organization, Areal Distribution)

$\Rightarrow Y$ (Improvement of Energy Efficiency) = f (8 Design Determinant + 3 Spatial Organization + 5 Areal Distribution)

If $Y = f(DD, SO, AD)$

Then $Y = f(8DD, 3SO, 5AD)$

The Units of Measurement in this case are:

$Y = 8DD \text{ Feet}$

$Y = 3SO \text{ Degree}$

$Y = 5AD \text{ Square Feet}$

$\Rightarrow Y = 8DD\text{feet} \times 3SO \text{ degree} \times 5AD\text{sq.ft.}$

With this particular analytical process all the selected case studies were analyzed. The data analysis via this process is a valuable methodology for identifying healing improvement opportunities in hospital.

The data-driven approach also facilitates correlation of the factors involved in the hospital's healing process and helps isolate specific inputs to expand the potential for increasing healing in hospitals. Analysis of existing hospital practices and various statistical results for hospital buildings provides a good source of future hospital project idea for Energy Efficiency.

3.1.1. A Step by Step Methodology for Improvement of Energy efficiency in Hospital buildings

- i. Application of Poka Yoke is the first step.
- ii. In order to improve energy efficiency in a hospital building this analytical process begins with the Quality Function Deployment (QFD) by the hospital project designer to determine all possible details for providing energy efficiency in hospitals.
- iii. The house of quality diagram is a useful tool in this effort.
- iv. The data generated via house of quality matrix then integrated with a statistical technique i.e. scaling in ANOVA-simultaneous where component analysis is based on quantile normalization technique in which one can construct different distributions in an identical format.
- v. Application of 5S Analysis is the second step.
- vi. After this step 5S Analysis is applied to the design which begins with 'Sort'.
- vii. The 'Sort' need to be simulated based on the user's perception of the hospital when they draw the new plans
- viii. The application of Muda, Muri, and Mura is the third step as machine learning route.
- ix. The 'Straighten' need to be simulated based on users' orientation needs, which can be quantified on the space syntax depth maps, axial line diagrams, and reassess on how users will use the designed space. This is the machine learning step.
- x. Shine refers to how easy is for the user to navigate in the space which can be simulated on questionnaire where one is the lowest and five are the highest points.
- xi. Standardize can be quantified by refereeing to bubbles diagrams which may be drawn based on 5 varying efficacies in hospital building.
- xii. After finding the data on each step finally the aforementioned equation is applied to find out the healing status of a designed hospital and suggest the improvements.
- xiii. This is the continuous energy efficiency improvement process in hospital buildings.

4. CASE STUDY

This is the live project initiated to apply the lessons learned from this entire research on improving of energy efficiency in healthcare facilities with an appropriate spatial organization, design determinants, and areal distribution.

(Fig 1). is the tabularization of the human and machine learning on all three variables and tools of space syntax software and AutoCAD software. The results of machine learning were substantiated through discussions with users.



Fig.1 The three dimensional simulation to calculate the space for energy efficiency for case one FC 1

$$\Rightarrow Y (\text{Energy Efficiency}) = 80 \text{ feet}' \times 1.3 \text{ DD degree}^\circ \times 5 \text{ AD sq.ft.}^3$$

$$\text{Energy Efficiency FC2} \propto 8 (11) \text{ feet}' \times 1.3 (3) \times 5 (5) \text{ sq.ft.}^3$$

$$\text{Energy Efficiency FC2} \propto 19,800 \text{ sq.ft.}^3$$

Their interviews and perception diagrams about the hospital building gave a clear understanding.

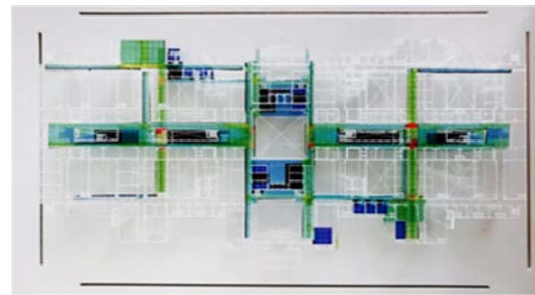


Fig. 2 The three dimensional simulation to calculate the space for energy efficiency for case 2 FC 2.

The result of spatial organization indicates minimum comfortable walking distance is 11 feet as evident from red zones in the floor plans where more used space of the hospital was circulation which makes everything and place within close proximity. The level Energy Efficiency for FC2 is calculated to be 19,800 sq.ft.³ which is evident from the 3 D model.

The window view of natural sky in day and night connects the patients and the care givers with the universe. In the day its blue sky, sunlight and clouds that are evident and in the night it is stars which are experienced by the patients and as a repercussion a natural energy efficiency is developed with the conscious effort of the architect.

$$\Rightarrow Y (\text{Energy Efficiency}) = 80 \text{ feet}' \times 1.3 \text{ DD degree}^\circ \times 5 \text{ AD sq.ft.}^3$$

$$\text{Energy efficiency FCHP} = 8 (15) \text{ feet}' \times 1.3 (2) \times 5 (8) \text{ sq.ft.}^3$$

$$\text{Energy efficiency FCHP} \propto 28,800 \text{ sq.ft.}^3$$

$$\text{Energy efficiency for GHP is simulated to be } 40,320 \text{ sq.ft.}^3$$

The analysis of spatial organization via interviews and their grading revealed that the hospital is very efficient in terms of design, circulation and connectivity for the movement of people and equipment. Thus the Energy efficiency for FCHP is $\approx 28,800$ sq.ft. as shown in the model.

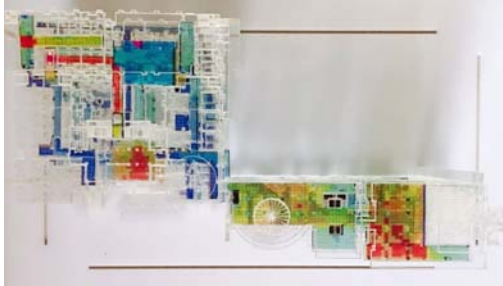


Fig. 4 The three dimensional simulation to calculate the space for energy efficiency for FCHP

The results of machine learning were substantiated through discussions with users.

$$\Rightarrow Y(\text{Energy Efficiency}) = 850 \text{ feet}^2 \times 3.33 \text{ degrees} \times 5 \text{ AD sq.ft.}$$

$$\text{Energy efficiency FC2} \approx 8 (11) \text{ feet}^2 \times 3 (3) \times 5 (5) \text{ sq.ft.}$$

$$\text{Energy efficiency FC2} \approx 19,800 \text{ sq.ft.}$$

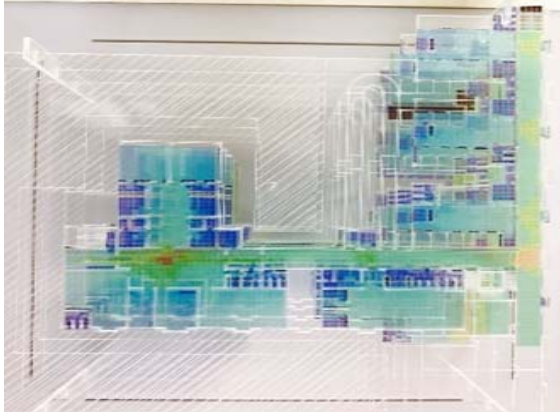


Fig. 5 The three dimensional simulation to calculate the space for energy efficiency for NGH

The (Fig 5). displayed that, the AutoCAD floor plans were converted into 3-D Model form where every floor is shown with the circulation pattern and space distribution. This 3-D Model is developed so as clear understanding can be established for the whole activity pattern and functional distribution within the hospital building.

Spatial Organization Design Determinants'
Areal Distribution

Feet 90° Normal Angle (°)
3 Nawabshah General Hospital 10 3 8

(Fig. 3.31). Simulation of NGH

$$\Rightarrow Y(\text{Energy Efficiency}) = 350 \text{ feet}^2 \times 8.33 \text{ degrees} \times 5 \text{ AD sq.ft.}$$

$$\text{Energy efficiency NGH} = 3 (10) \text{ feet}^2 \times 8 (3) \times 5 (8) \text{ sq.ft.}$$

$$\text{Energy efficiency NGH} = 28,800 \text{ sq.ft.}$$

Nawabshah General Hospital was simulated on all the aspects of energy efficiency as shown in (Fig 6).

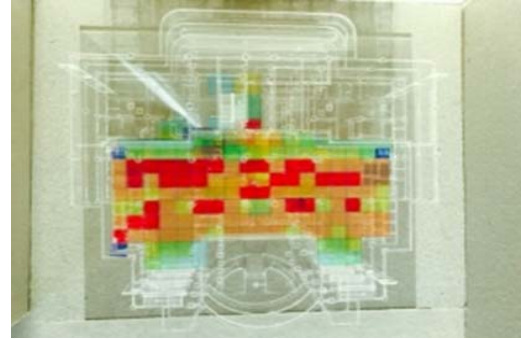


Fig. 6 The three dimensional simulation to calculate the space for energy efficiency for GGH

The aerial distribution results indicated that, within the perimeter of at least within 10 square feet one may find a sign of the intended destination within hospital. This is the highly appreciated feature of hospital which is evident from the energy efficiency simulated for the GGH as $\approx 28,800$ sq.ft. which is volume study.

Spatial Organization Design Determinants'
Areal Distribution

Feet 90° Normal Angle (°)

4 Ghambat

General Hospital 12 2 10

Fig. 3.36. All Simulations of GGH

$$\Rightarrow Y(\text{Energy Efficiency}) = 350 \text{ feet}^2 \times 8.33 \text{ degrees} \times 5 \text{ AD sq.ft.}$$

$$\text{Energy efficiency GGH} = 3 (12) \text{ feet}^2 \times 8 (2) \times 5 (10) \text{ sq.ft.}$$

$$\text{Energy efficiency GGH} = 28,800 \text{ sq.ft.}$$

The architecture mold the patients in a way that it guides the user to navigate in the space with ease and comfort.

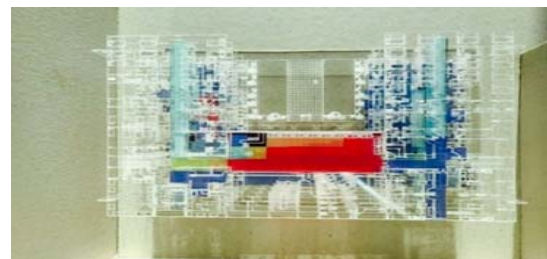


Fig.7 The three dimensional simulation to calculate the space for energy efficiency for ZHI

(Fig 7). shows the Simulation of all three variables of spatial organization, Design Determinants and Aereal Distribution at once. According to which spatial organization indicates minimum comfortable walking distance in the hospital is 16 feet.

$$\Rightarrow Y \text{ (Energy Efficiency)} = 3SO_{\text{feet}}' \times \angle 8DD_{\text{degree}}^{\circ} \times 5AD \text{ sq.ft.} \square$$

$$\text{Energy efficiency ZHI} = 3 (16) \text{ feet}' \times \angle 8 (3) \times 5 (5) \text{ sq.ft.} \square$$

$$\text{Energy efficiency ZHI} = \angle 28,800 \text{ sq.ft.}^3$$

As witnessed from more utilised space of the hospital the building has compact rectilinear plan with only 3 turns of 90° while movements within the hospital seems more contented and can be identified as an important design determinant. The aerial distribution results indicated that, within the perimeter of 5 square feet one may find indication of different zones within hospital and seems highly valued aspect of hospital.

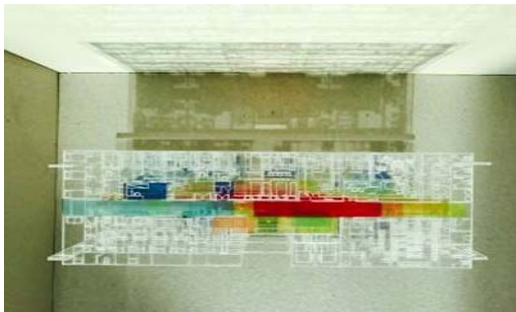


Fig.8 The three dimensional simulation to calculate the space for energy efficiency ZH 2.

(Fig 8). shows all the simulations of Ziauddin hospital on all three variables of Spatial Organization, Design Determinants and Aereal Distribution. The results indicate that, minimum comfortable walking distance in the hospital is 13 feet. Due to compact rectilinear plan the utilised space of the hospital building has no twist and turns of 90° while movements within the hospital are quite comfortable and can be recognized as the most significant design determinant. The aerial distribution results specified that, within the perimeter of 4 square feet there is indication of different zones within the hospital.

$$\Rightarrow Y \text{ (Energy Efficiency)} \propto 3SO_{\text{feet}}' \times \angle 8DD_{\text{degree}}^{\circ} \times 5AD \text{ sq.ft.} \square$$

$$\text{Energy efficiency ZHI} \propto 3 (13) \text{ feet}' \times \angle 8 (1) \times 5 (4) \text{ sq.ft.} \square$$

$$\text{Energy efficiency ZHI} \propto \angle 6,240 \text{ sq.ft.}^3$$

Their interviews and perception diagrams about the hospital building gave a clear understanding. The result of spatial organization indicates minimum comfortable walking distance is 11 feet as evident from red zones in

the floor plans where more used space of the hospital was circulation which makes everything and place within close proximity. The Energy efficiency for FC2 is calculated to be $\angle 19,800 \text{ sq.ft.}^3$ which is evident from the 3 D model.

As the building has square U shaped plan it has total 3 turns of 90° while walking within the hospital which is comfortable for the people and can be identified as a very significant design determinant. The aerial distribution result identifies that, within the perimeter of at least 5 square feet an orientation cue or way finding indicator is evident.

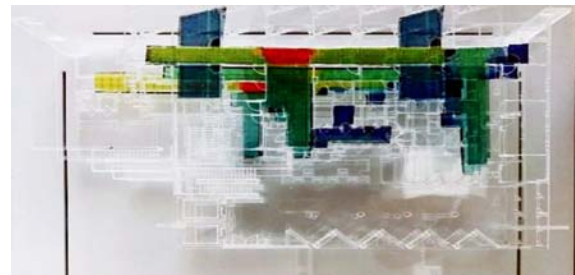


Fig. 9 The three dimensional simulation to calculate the space for energy efficiency AKU

The 3-D Model of AKU designates that the most intense circulation take place at the receptions and information desks located within the corridors and central lobby spaces.

Spatial Organization Design Determinants'
Areal Distribution
Feet 90° Normal Angle (□')
Agha Khan Hospital Karachi Fig. 9 Simulation of AKU

$$\Rightarrow Y \text{ (Energy Efficiency)} = 3SO_{\text{feet}}' \times \angle 8DD_{\text{degree}}^{\circ} \times 5AD \text{ sq.ft.} \square$$

$$\text{Energy efficiency JPMC} = 3 (17) \text{ feet}' \times \angle 8 (5) \times 5 (12) \text{ sq.ft.} \square$$

$$\text{Energy efficiency JPMC} = \angle 122,400 \text{ sq.ft.}^3$$

Spatial Organization is defined as 17 whereas the Design determinant's is simulated to be 5 whereas areal distribution is calculated to be 12 square feet.

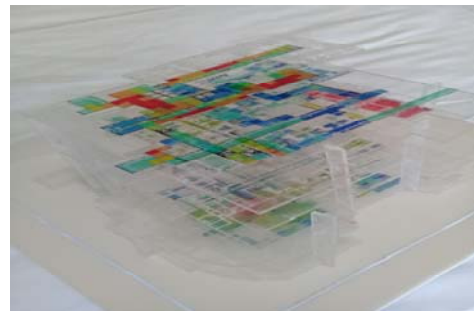


Fig.10 The three dimensional simulation to calculate the space for energy efficiency JGH

(Fig 10). indicates all the simulations of AKU hospital on all three variables of Spatial Organization, Design Determinants and Aereal Distribution. The results indicate that, minimum comfortable walking distance in the hospital is 17 feet. Due to rectilinear planning and spread nature of the building structure and used spaces of the hospital building has 5 turns of 90° while movements within the hospital. These movements are quite comfortable due to inherited natural environment which makes the building an experience of healing. The aerial distribution results quantified that, within the perimeter of 12 square feet there is clues and signs of different precincts within the hospital.

These variation diagrams are drawn to show the schematic designs. In the analysis of areal distribution of JGH feedback and opinion of concerned people and users was taken. Total 25 people were consulted and shared with them the earlier done analysis on Muda, Mura and Muri. The respondents include staff members, nurses, doctors and healthcare facility managers, and architects. The different aspects and issues on which the feedback of respondents were taken include division of spaces, space utilization, association between different spaces and their functions, most used spaces, semi used spaces and less used spaces.

Spatial Organization Design Determinants'
Aereal Distribution

feet 90° Normal Angle (□')

Jinnah General Hospital

(Fig 10). Simulation of Jinnah General Hospital

(Fig 10). designates all the simulations of Jinnah G hospital on all three variables of Spatial Organization, Design Determinants and Aereal Distribution. The results indicate that, minimum comfortable walking distance in the hospital is 15 feet. Due to rectilinear planning and compact nature of building structure and spaces it has only 3 turns of 90° while moving within the hospital. The aerial distribution results enumerated that, within the perimeter of 5 square feet there is symbol and signs of different areas within the hospital.

$\Rightarrow Y \text{ (Energy Efficiency)} \propto 3SO_{\text{feet}}' \times \text{L8DDdegree}^\circ \times 5AD \text{ sq.ft.}$

Energy efficient JGH $\propto 3 \text{ (15) feet}' \times \text{L8 (3)} \times 5 \text{ (5) sq.ft.}$

Energy efficiency JGH $\propto \text{L 27,000 sq.ft.}$

This is also done to establish the lessons learned from the case analysis and prove that these are practical principles and can be easily applied to hospital buildings to improve its Energy Efficiency.

It further establish that the principles of spatial organization, design determinants, and areal distribution may also be applied practically to a hospital project so as this research can be validated both theoretically and practically from both perspectives.

5.

DISCUSSION

The study found out that after entrance the major activity zone is the information desk and it must be located at a central place from where all the connecting roots sprung up and from that point people dispersed in every direction therefore information desk shall be centralized along with a direct access.

The synthesis of Spatial Organization is derived via application of Muda, Muri, Mura analyses via matrix are presented in (Fig 3.59). on all the nine hospitals explains the amount of efficiency achieved when simulated on space syntax, axial line and visibility graph from machine learning perspective and questionnaire and interview based from the point of view of human learning.

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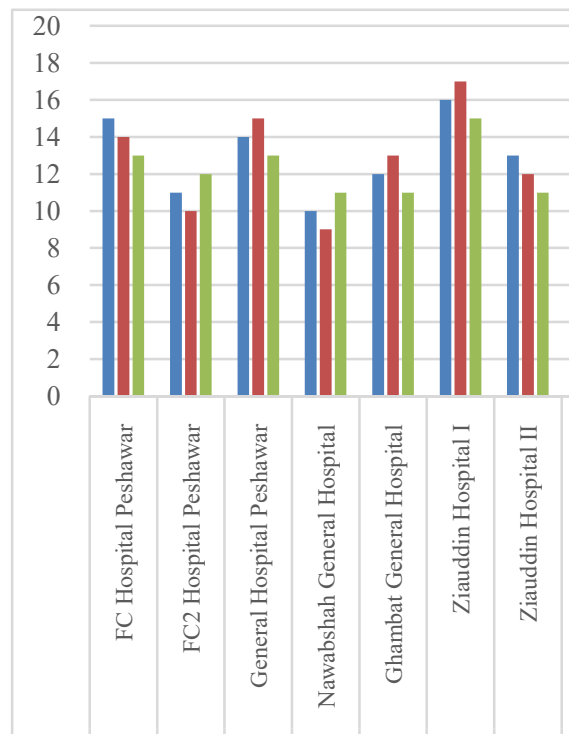


Fig.11. Bar Chart of Spatial Organization via Muda Muri Mura

Thus the corridor is designed for three movement, primarily staff movement who moves at certain pace, where we need to consider Mura that is wastage of space as presented in figure 3.64 denoted by blue colour scheme. Muri is over stressed staff denoted by red colour and green presents Muri.

All three Spatial Organization are presented in terms of feet and distance thus the maximum time in terms of distance travelled by doctors and staff in the following hospitals are denoted by Muda where redundant space is highlighted to be removed for all nine cases.

The hospital has shown more than 600 maximum limit for circulation which is the entire length of the hospital corridor along with 500 number of expected egress shall be present in all individual hospital complex, 300 or above is the number suggested by the users for labels to be present for representing maximum efficiency for way finding and barrier free zone. On the other hand the maximum number of turn's presents in the entire complex including all the departments is 800 compared to vicinity which is 600 feet as a maximum distance covered between all the proposed departments. The feasibility is calculated in terms of time thus 380 minutes is taken to take a complete tour for the entire hospital which is peripheral distance of the entire hospital. The findings concerning Areal Distribution analyses via 5S analysis presented in (Fig. 3.70) on all nine hospitals explains the number of efficiency achieved when simulated the plan and validate by on site with the aid of survey from doctors, nurses and patients.

The 3M analysis done on three variables and 5S was applied on 5 indicators. When given two variables x and y , if y is directly proportional to x , the relation is represented as, the $\propto$ or the constant ratio, where Mura is directly proportionate to sort and straight, and Muri is directly proportionate to Standardization, whereas Muda is inversely proportionate to shine. Inverse proportionality with a function of $y = 1/x$, thus Label or symbol is inversely proportionate to egress. This algorithm could be applied as a model for research for future extension.

Muda $\propto$ Visibility

Vicinity $\propto$ orientation

Since maximum visibility shows minimum stress.

On the other hand Mura is inversely proportionate to Axial Line,

Which infers standardize aids circulation and variation confused staff and visitors. FC hospital is open to sky and is using space to maximum efficiency while it is planned on grid.

Table 1. Simulation of Spatial Organization via Muda Muri Mura

S.no	Hospital Name	Spatial Organization (feet)		
		Muda	Mura	Muri
1	FC Hospital Peshawar	15	14	13
2	FC2 Hospital Peshawar	11	10	12
3	General Hospital Peshawar	14	15	13
4	Nawabshah General Hospital	10	9	11
5	Ghambat General Hospital	12	13	11
6	Ziauddin Hospital I	16	17	15
7	Ziauddin Hospital II	13	12	11
8	Agha Khan Hospital Karachi	17	18	16
9	JPMC Hospital	15	16	14

A landscape set back area in front of the main entrance to the medical center, comprises lawns and trees, it provides a buffer (separation) between the building and the street. It provides visual pleasing sitting on approaching the entrance. Staff is oriented with the procedures to follow in case of any untoward situation. Policy of TRIAGE shall be explained

6. CONCLUSION

There is now much evidence to support the hypothesis that the depth map analysis of the hospital plans directly proportionate to design determinants. The accessibility could be enhanced and upgraded to maximum utmost efficiency level by sculpting the entire mass of the building in a way that it incorporates grid design both for the exterior as well as interior of the building.

- I. This research inferred that grid orthogonal planning helps in natural navigation rather than a circular or a curved plan. Because movement becomes easy, when a person asked for directions, one is told to go straight then right.
- II. The Design Determinants is improved by application of Poka Yoke on T Q M Tool the House of Quality Matrix Formula. The algorithm driven by applying Design Determinant presented that the Vicinity $\propto$ Orientation and Corridor $\propto$ Egress-1 that refers to orientation is efficient if departmental vicinity is improved. Whereas Corridor has very less proportion with egress.
- III. An I- Shape plan is one which provides central circulation core, this shows maximum healing environment of $\approx 6,240$ sq.ft.3 for Ziauddin Hospital 2. Since it is compact and the probability to getting lost of fear therefore stress is very less.
- IV. A U-Shape plan which is present in FC 2 and ZH1 provides second best solution through a grid plan $\approx 19,800$ sq.ft.3 and $\approx 28,800$ sq.ft.3 respectively are the

calculated numerical for the healing environment . Since it gives more space for central connectivity and direction is easy which are key for navigation and healing environment from architectural point of view.

- V. The most comfortable volume of space is to have an orientation directional of space equal to $\approx 6,240$ sq.ft.3 for accessibility which rests in stress free environment also known as healing environment.
- VI. Spatial Organization is simulated by Muda Muri Mura i.e. Space Syntax, Axial Line and Visibility Graph respectively, the algorithm driven is presented as $Muda \propto \text{Visibility}$, $Mura \propto \text{Axial Line-1}$, $Muri \propto 1/\text{Space Syntax}$.
- VII. Areal Distribution is analysed by applying 5S Analysis based on Site Survey and Validation and algorithm driven is presented as $\text{Sort} \propto \text{Sustain-1}$, $\text{Shine} \propto \text{Straighten}$
- VIII. The healing environment is directly proportionate to the linearity and simplicity of the design.
- IX. A 75 % improvement was simulated when the decision of upgradation was taken and hospital space is redesigned by applying all the listed determinants for design.
- X. A 54% improvement was measured when space syntax and axial line was applied on the plan for improving Spatial organization.

The synthesized comparative and cumulative result from all nine cases of General hospitals in Pakistan on the three variables of healing environment i.e. design determinants, spatial organization and areal distribution indicated that Ziauddin Hospital 2 is best on the account of Design Determinants with 76% Poka Yoke, the FC2 hospital is best on the account of Spatial organization with 82% reduction in wastage spaces with appliance of Muda, Muri Mura and Agha Khan Hospital is best on the account of Areal distribution with 78% efficiency rate by applying principles of Seiri, Seiton, Seiso, Seiketsu and Shitsuke

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