MATHEMATICAL MODELS REPRESENTING EXPERTS' EVALUATION FOR LAYOUT OF SMALL DWELLING UNITS

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Abstract. For the purpose of automated generation of room-layouts for dwelling units, all feasible plans that are generated during the process of generation of room-layouts are to be evaluated. Selection of a layout will be done based on some mathematical models for satisfaction values of users. In this paper we have shown models to obtain satisfaction values of dwellers primarily based on the opinion of experts who have experience in successfully designing or evaluating dwelling units as a part of mass housing in Kolkata region.

1. Introduction

When the sizes of the dwelling units are very small in comparison to the available covered area the number of criteria to be considered for selecting a plan becomes very much limited. Under such cases functional layout of units becomes the most significant criterion for selection of a layout when cost and materials and method of construction to be used are standardized (Chakraborty, 2003). Satisfaction value of a layout of a plan depends broadly on three aspects of the layout. These are (i) adjacency between pairs of spaces provided, (ii) areas and dimensions of rooms provided, and (iii) different positions and orientations of windows provided to all rooms. All aspects have got two parts: (a) essential part which acts as constraints and must be satisfied to make the solution feasible and (b) qualifying part which assigns value to the layout. Out of many feasible plans one which gives maximum satisfaction to the user based on its functional layout will be considered as a quasi-optimum layout. In this paper, due to shortage of space, models are developed for aspect (i)a which is discussed in section 2 and aspect (ii)b which is detailed in section 3.

2. Allocation of Activity-Areas and their Adjacencies

2.1. ROOMS & BALANCED AREA REQUIRED FOR DIFFERENT ACTIVITIES

Once the area within which plan is to be accommodated is determined based on economic permissibility, set of required rooms will be determined subsequently to represent the social condition of the family. Investigation revealed that rooms required might be grouped into several clusters (Table 1). From each cluster at least one room is to be selected with exception for some clusters when no room may be selected. Some general rules are framed to obtain the possible set of balanced areas of rooms once the set of rooms required is finalized under given covered area. These are elaborated below.

TABLE 1. Different possible activity-areas.

Cluster No	Possible Room Types	Two sets of Balanced Areas (SqFt)		Selection Condition
I	Bed Rm 1 (main) Bed Rm 2 Bed Rm 3	70 70 65	180 165 150	At least Bed Rm 1
II	Sitting Area	65	155	Essential
III	Dining Area	65	130	Optional
IV	Kitchen	30	90	Essential
V	Toilet 1 (common) Toilet 2 Toilet 3	30 30 30	50 40 35	At least Toilet 1
VI	Balcony 1 (comn) Balcony 2 Balcony 3	20 15 15	50 40 30	Optional
VII	Store, Prayer Rm Lobby / Lobbies Garage Half Stair (either) Full Stair (or)	Area Should be Assigned by the user/architect		Optional

Remarks: When Dining is omitted Kitchen is to be made 1.5 times. When Bed Rms permitted are not sufficient Sitting can be used for sleeping during night. For Sitting cum Dining we can assume an imaginary line between the two spaces and consider both as separate rooms with full width adjacency (see Table 2).

Two sets of balanced carpet areas of rooms, one totaling 505 SqFt {L1, L2, …., Ln} and the other totaling 1115 SqFt {U1, U2, ….., Un} with actual values, are shown vertically in column 3 of Table 1. If all rooms are not required, then strike out the rooms not required. Modification of requirements may be made based on the remarks in Table 1. Let total carpet area for lower and upper sets of selected rooms are S_L and S_U respectively. Then, $\Sigma_i L_i = S_L$ and $\Sigma_i U_i = S_U$. If the total carpet area available for the proposed layout is S then balanced carpet area ($A_{i, i=1 ......}$) for any required room i can be found by linear interpolation as follows based on Eq. 1 (fig.1).

$$A_i = L_i + (U_i - L_i)(S - S_L) / (S_U - S_L), \text{[Note that } \Sigma_i A_i = S] \quad (1)$$

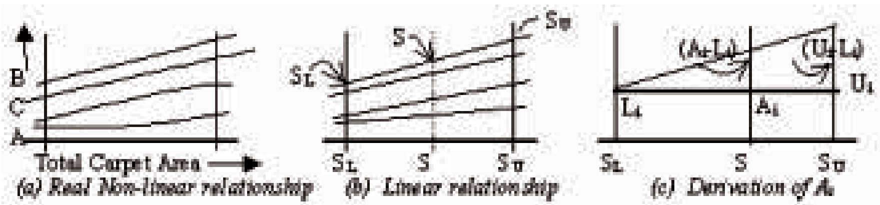

Figure 1. Relationship between Total Carpet Area and Balanced Carpet Area.

2.2. Desired adjacency matrix

After interviewing the expert architects internal adjacency matrix in Table 2 is found desirable. It is assumed here that external adjacency (like entrance to the unit) is satisfied. If this adjacency matrix is not satisfied then the plan is to be rejected. Conditions shown in the notes are also to be followed. Blank cells not shown in the

TABLE 2. Minimum internal adjacency required between two spaces if adjacent (in Ft)

Srl No.	Names of Spaces						
1	Bed Room 1	BED1	2				
2	Bed Room 2		BED2	3			
3	Bed Room 3		3	BED3	4		
4	Sitting Room				SIT	5	
5	Dining Room	3	3	3	4	DIN	6
6	Kitchen						KIT
7	Com Toilet 1					2.5	
8	Toilet 2	2.5					
9	Toilet 3		2.5				
10	Com Balcony 1				3		
11	Balcony 2	3					
12	Balcony3		3				3
13	Store					2.5	2.5

NOTES: 1) Adjacency of Bal3 may be either with Bed2 or Kitchen
2) Adjacency of Store may be either with Dining or Kitchen.
3) Adj between Sit & Din may have any value more than the minimum shown here. For Sitting and Dining adjacency will be of full length common to both rooms.

table means no adjacency is required. The table shows many activity-areas of which all may not be required for a given case. If the set of required areas of a family is a sub-set of the set of requirements given in the Table 2 then the activity-areas not required are to be deleted in the table horizontally and vertically to get the required adjacency matrix.

3. Satisfaction Values of Rooms

To know the satisfaction value of a room-layout we must know, as inputs, (i) the set of rooms required (representing social condition) and also (ii) the total covered area affordable (representing economic condition). Carpet area (not the covered area) being a factor of satisfaction we can estimate the carpet area from the given covered area. However, once the layout is given we can get the carpet area exactly. To determine the satisfaction value of the proposed layout for the given inputs a unit of measure (Guilford, 1954) for satisfaction is necessary. It is assumed that if the room areas provided are balanced (i.e. A_1, A_2, A_3,…...) and their dimensions (length and breadth (i.e. L_1 x B_1, L_2 x B_2, …….) provided are best possible for corresponding area of each room then the satisfaction value of the layout, from the point of view of room aspect (V_r) ignoring other two aspects related to doors (V_d) and windows (V_w), will be equal to 100. Some properties that are to be observed are as follows. (i) Even though by increasing any room-area we can increase the value of that room, any deviation from the balanced allocation of areas of different rooms for a fixed total area should reduce the total room--value. Similarly, (ii) any deviation from the desired dimensions of the rooms for a given area will cause reduction of total room-value. Following these properties individual rooms will be evaluated first. Then the overall value for the entire layout contributed by the room factor can be determined by summing the room values (Chakraborty, 2004).

3.1. Contribution due to Area of each Room

Let area a_i is provided to a room i in place of its balanced area A_i then the value of the room contributed by the area will be

$$V_{i\,.\,area} = A_i + b_i \log_e (a_i/A_i) \tag{2}$$

where, $\log_e (a_i/A_i)$ is 'Satisfaction Gain Factor'
Unit of the satisfaction value will be same as that of area.

Graphically the 'Satisfaction Gain Factor' ($\log_e(a_i/A_i)$) against 'Relative Carpet Area' (a_i/A_i) can be represented as in figure 2. This indicates that even though by increasing the area for a room from the balanced area we can gain satisfaction loss of same area in other rooms may result in higher loss of satisfaction finally.

Summing over all values of $V_{i\,.\,area}$ we will get total satisfaction due to room area $= \Sigma_i V_{i\,.\,area,\, i = 1\text{ to }n}$. When balanced areas, Ai, are assigned to all rooms the aggregate satisfaction value will become equal to S (total given area). This equation gives ‘absolute value’ of satisfaction in terms of effective area so that different plans of different area may be compared. To make the evaluation relative for a given area of plan ‘relative value can be obtained out of 100. The expression may be modified as $(100/S)\Sigma_i V_{i\,.\,area}$ and the value attainable when all rooms are assigned with corresponding balanced areas will be 100.

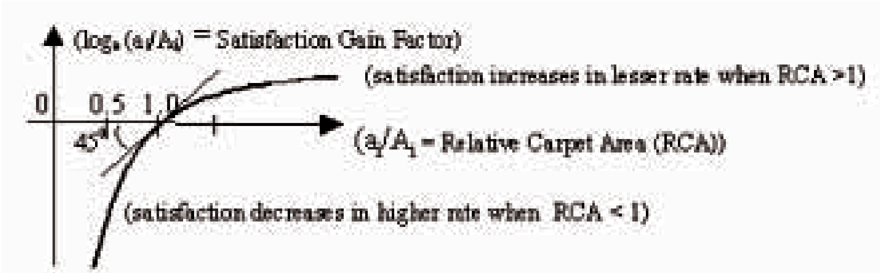

Figure 2. ‘Relative Carpet Area’ (RCA) against ‘Satisfaction Gain Factor’.

3.2. Contribution due to Dimension of each Room

Let the length, breadth and aspect ratio (= length/breadth) provided for the room$_i$ are l_i, b_i and p_i respectively, where $b_i = a_i/l_i$ and $p_i = l_i / (a_i/l_i) = l_i^2/a_i$. Also let φ_i is the aspect ratio to give the best satisfaction value when the area of the room$_i$ is a_i. Any deviation from φ_i will give lesser satisfaction for a given area a_i. It is to note that aspect ratios (= length/breadth) p_i and φ_i cannot take values less than 1. Value mentioned in eq. 2 is to be modified to give combined effect due to both area and dimension. Factor represented by eq. 3 or Figure 3 can be used for this purpose.

$$F_{i\,.\,dim} = \exp(-(k_i\,(p_i - \varphi_i))^2) \tag{3}$$

Where, k_i is a parameter to explain a specific situation.
This expression will always give a +ve value without unit ranging from 0 to 1. Maximum value of 1 is attainable when $\varphi_i = p_i$.

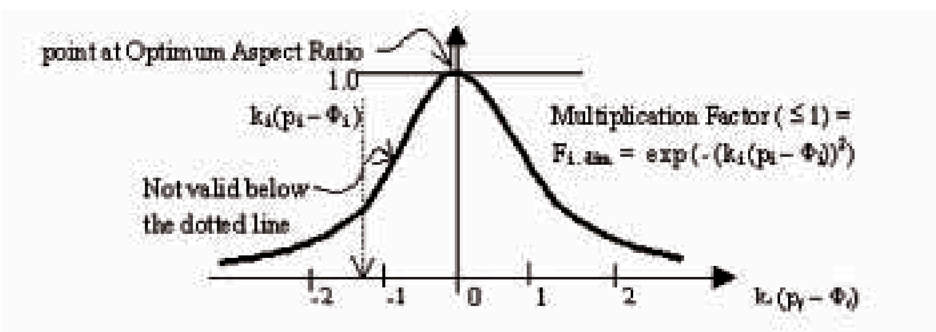

Figure 3. ‘Multiplication Factor’ due to ‘Deviation from Optimum Aspect Ratio’.

3.3. Combined Contribution due to both Area and Dimension

Overall contribution by a room i due to both area and dimension will be as follows:

$$V_i = V_{i\,.\,area} \,.\, F_{i\,.\,dim} = (A_i + b_i \log_e (a_i/A_i)) \,.\, \exp(-(k_i (p_i - \varphi_i))^2) \qquad (4)$$

Summing up the values for all rooms and standardizing the value out of 100 we will get the following expression:

$$V = \Sigma_i V_i = (100/S)\, \Sigma_i (A_i + b_i \log_e (a_i/A_i)) \,.\, \exp(-(k_i (p_i - \varphi_i))^2) \qquad (5)$$

Values of parameters A_i, φ_i, b_i and k_i are to be determined experimentally.

6. Conclusion

Methods shown here can be employed for any region and target population anywhere in the world. It will be seen that with the change of socio-economic group, geographic location and time the values and parameters of the model will change. These parameters, however, will reflect our societies' liking about different aspects of dwelling units. Therefore, the parameters can be taken as socio-architectural indices for a given location and time.

Formulating these models is nothing but an attempt to externalize the knowledge of experts who have successfully designed dwelling units for the target group under consideration. Therefore, these models will help developing 'expert system' for the purpose of architectural design. These models being the results of on-going research work may be treated as hypotheses for further investigation.

Researchers can subject these models for serious investigations and can modify or develop the models further. Statistical and psychometric methods, developed long back (Fisher, 1954) (Guilford, 1954) with high potentiality for developing models for the purpose of core of architectural design problems, are to be thoroughly explored.

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References

Chakraborty, S. 2003, Automated Generation of Room-Layout Within a Constrained Covered Area, *CAADRIA2003*, Thailand, pp. 93–100.

Chakraborty, S. 2004, Archimetrics: a necessary discipline for Obtaining Objective Values from Architectural Subjective Values, *CAADRIA2004*, South Korea, pp. 443–451.

Fisher, R. A. 1954, *Statistical Methods for Research Workers*, (12th Edn), Oliver.

Guilford, J. P. 1954, *Psychometric Methods* (2nd Edn), McGraw-Hill Book Company Inc.