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INTRODUCTION

"Building is such a familiar activity that few people yet realise the highly divided character of knowledge of it at the level of professional competence or give much thought to the improvements than can and must be made". (1) A building is a shelter from the external environment. The external environment was originally meant to define adverse climatic conditions caused by sun, snow, wind, earthquakes etc., but it also includes in these days pollution, noise, war damage and other man made effects. The modern man also retreats to his home from the onslaught of socio-economic and psychological pressures of the surrounding society in which he is forced to earn his livelihood. It is of interest to recognize that the very house he builds as a shelter in turn affects the environment, often in an adverse manner, from which he is protecting himself. Thus the interaction between man - society - nature - shelter and networks he is using is complete. The evaluation of a housing complex shall then be based on these five fundamental aspects. Furthermore the presence of these five aspects can be recognised in a single house, a colony of houses, a town, metropolis and so on. In the final analysis the whole world is but a house in a broad sense. It was Doxiadis (2) who recognised the unifying characteristics of human settlements and it was he who once again identified the five basic interacting aspects namely Nature, Man, Society, Shelter and Networks. It is proposed to explicitly deal with these five aspects in the procedure to be developed for evaluating housing systems.

Modern advances in technology have broken the barriers of time and distance which insulated one society from another. The problems of food, clothing and shelter for the teeming millions of the world is to be analysed and solved at a global level. Piecemeal solutions for local problems shall be so integrated in a conscious manner as to add up to a final global solution. We shall restrict ourselves to <u>low-cost housing</u> since the majority of population of the world <u>who face housing</u> problems belong to the low-income group.

Analysis of any system is however restricted to the nature and extent of data that is available at any particular time. The advent of computers shows promise of an international data bank and future planning of housing systems will be based on such extensive data. For the present we shall restrict ourselves to what is feasible at sub-system level. The unit that will be undertaken for <u>realistic analysis</u> will be a <u>single house</u> situated <u>in the colony</u> of an <u>educational complex</u>.

It is in the very nature of modern analysis that the data analysed shall be in numerical form. Not all information that is available on housing, with respect to the five basic aspects outlined earlier, is in objective form. In fact most of the information available is subjective in nature. Thus an absolute measure of the efficiency of a system cannot be developed at this stage. Even for comparative study utility measures are to be established based on the designer's or professional group's preferences, experience and judgement. It is assumed that through operational gaming procedures such utility measures can be developed for all of the relevant subjective information. When in addition these measures are in non-dimensional form, it will admirably suit our purpose.

One more aspect which deserves attention is the 'curse of dimensionality'. Any attempt at unification is usually thwarted by the variety of dimensions that are associated with scientific and technical information. This is more so in the case of housing. We will use the simple process of <u>non-dimensionalising</u> each aspect <u>with respect to its own standard</u>. In essence the proposed procedures are based on the establishment of international standards for subjective and objective information. In general such standards are not readily available. However, minimum standards for permanent low-cost housing have already been worked out by the Department of Housing and Urban Development, Washington, USA. (5) The proposed procedure will be illustrated using these standards.

PROPOSED PROCEDURE FOR COMPUTING THE EFFICIENCY OF A GIVEN PROPOSAL FOR LOW-COST HOUSING

A given proposal for low-cost housing can be analysed in the sub-system level or component level. The principle used will be the same in both cases, but the details will be different in nature, composition, quality and quantity. In this paper the procedure will be explained with respect to a single house built in a colony situated in an educational complex. Two alternate schemes were used in actual construction, and a sample survey of occupant response has produced enough subjective information indicating the efficiency of each alternative. It will be shown that the proposed procedure automatically confirms this occupant response. Further extension of this procedure for evaluating the efficiency of the entire colony is in progress.

It is assumed that all relevant objective information is readily available in numerical form, and utility measures/scales for subjective information have all been worked out. It is further assumed that necessary minimum standards have been established. The proposed procedure is so simple that it is easily cast in sequential steps as shown below.

<u>Step 1</u>. The fundamental aspects of human settlements, namely Nature, Man, Society, Shelter and Networks are further subdivided into various attributes which are sufficient in number as to bring out the true nature of each aspect. Let the actuals provided for each attribute be A_i, B_j, C_k, D_e, E_m respectively for the fundamental aspects mentioned earlier. The maximum of the indices, i, j, k, e and m are not related in any manner whatsoever.

<u>Step 2</u>. Let weightages WA_i, WB_j, WC_k, WD_e and WE_m be assigned, considering the importance of each attribute in each aspect with respect to the total system.

<u>Step 3</u>. Let the corresponding standards be SA_i, SB_j, SC_k, SD_e, SE_m respectively.

<u>Step 4</u>. Let the ratios $\frac{A_i}{SA_i}$, $\frac{B_j}{SB_j}$, $\frac{C_k}{SC_k}$, $\frac{D_e}{SD_e}$, $\frac{E_m}{SE_m}$ be computed, and if any ratio is found to be greater than unity, assign unity and compute the excess provided in proper units. These excess units will be converted to 'wastage cost' eventually.

<u>Step 5</u>. Compute $(WA_i \cdot \frac{A_i}{SA_i})$, $(WB_j \cdot \frac{B_j}{SB_j})$, $(WC_k \cdot \frac{C_k}{SC_k})$, $(WD_e \cdot \frac{D_e}{SD_e})$, and $(WE_m \cdot \frac{E_m}{SE_m})$ respectively.

<u>Step 6</u>. Compute the following quantities

$$\text{Efficiency ratio } \eta_A = \frac{\Sigma(WA_i \cdot \frac{A_i}{SA_i})}{\Sigma(WA_i)}$$

$$\text{Efficiency ratio } \eta_B = \frac{\Sigma(WB_j \cdot \frac{B_j}{SB_j})}{\Sigma(WB_j)}$$

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$$\text{Efficiency ratio } \eta_D = \frac{\Sigma(WD_e \cdot \frac{D_e}{SD_e})}{\Sigma(WD_e)}$$

$$\text{Efficiency ratio } \eta_E = \frac{\Sigma(WE_m \cdot \frac{E_m}{SE_m})}{\Sigma(WE_m)}$$

Step 7. Compute the excess units provided in each attribute and multiply by the corresponding cost. Compute the sum of these wastage costs and divide by the estimated cost of the building. This number will be the 'penalty ratio', p_A, p_B, p_C, p_D and p_E for the five fundamental aspects.

Step 8. Once again weightages w_A, w_B, w_C, w_D and w_E are assigned to the efficiencies obtained in step 6 depending on the importance of the five fundamental aspects with respect to the total system.

Step 9. The final efficiency factor is obtained as,

$$\eta = \frac{w_A \eta_A + w_B \eta_B + w_C \eta_C + w_D \eta_D + w_E \eta_E}{(w_A + w_B + w_C + w_D + w_E)}$$

Step 10. Finally the penalty factor is obtained as

$$p = \frac{w_A \cdot p_A + w_B \cdot p_B + w_C \cdot p_C + w_D \cdot p_D + w_E \cdot p_E}{(w_A + w_B + w_C + w_D + w_E)}$$

The above steps appear to be cumbersome in the above descriptive form, but an illustrated example will bring out the fundamental simplicity of the procedure. While the procedure itself is simple, the value of these efficiency and penalty factors are discussed separately. It will be shown later that the success of this procedure depends on the choice of appropriate attributes for each aspect and the weightage factors assigned at several stages. It will be noticed that the principle of superposition has been assumed to be valid.

ILLUSTRATIVE EXAMPLE

Two alternate low-cost housing schemes already executed in an educational complex were evaluated by this method to check the validity of this approach with respect to occupant evaluation. The items available in the 'minimum standards' (5) motivated the choice of attributes to a certain degree; but the attributes as envisaged by Doxiadis (2) for a larger system such as a town (reproduced in Table 1) were kept as guide lines. However, the analysis of a single house requires the generation of a new table of attributes, which the authors have attempted. It will be noticed that some of the basic aspects have very little influence on the overall efficiency of various housing design alternatives for a given site.

TABLE 1: SUBDIVISION OF EKISTIC ELEMENTS (DOXIADIS)

1. Nature	Geologic resources, Topographical resources, Soil resources, Water resources, Plant life, Animal life and Climate.
2. Man	Biological Needs (space, air, temperature), Sensation and Perception (the five senses), Emotional Needs (human relations, security, beauty), Moral values.
3. Society	Population composition and Density, Social stratification, Cultural patterns, Economic development, Education, Health and Welfare, Law and Administration.
4. Shelter	Housing, Community Services (schools, hospitals), Shopping Centres and Markets, Recreational Facilities (Theatres, Museum, stadium), Civil and Business Centres (Town Halls, Law Courts), Industry and Transportation Centres.
5. Networks	Water Supply system, Power supply system, Transportation system, Communication system, Sewerage and Drainage, Physical Layout.

Step 1. Identification of attributes for each aspect is as below. Actually, an operational gaming procedure can be used to make these decisions. We shall recall at this stage that the site conditions are fixed, and we are evaluating various alternate designs. With respect to various aspects, both subjective and objective information are considered, and in the case of subjective information, utility measures are outlined in descriptive form. A scale of values ranging from zero to number 'n' may be assigned eventually. The utility measures are ordered in such a manner that the best alternative in terms of efficiency comes out uppermost.

Nature 1) Water Resources - Meager, moderate, plenty
2) Plant Life - Not possible - possible with effort - extensive
3) Animal Life - not possible - can be accommodated - provisions made
4) Climate Inside House - very hot/very cold - can be controlled-provisions made

Here is an example of subjective information and numbers 0, 1, 2 are assigned to these measures while computing efficiency.

Man 1) Biological Needs - a) Cramped, moderately free, free space
b) No air circulation, moderate, free circulation
c) Open spaces inside house absent, moderate, enough
2) Emotional Needs - a) No security, moderate security, secure
b) No privacy, adequate privacy, privacy for each occupant
c) Poor construction, good construction, excellent construction
d) Bad surface treatment of walls, floors etc., moderate, pleasant treatment of surfaces

Society 1) Population Density - a) Inadequate for five members, manageable, spacious
b) Too many families in one building, reasonable number of families, individual house
2) Cultural Patterns - families with divergent cultures, same culture, highly cultured families in the same building.

Shelter (1) Living room area (2) Bed room area (3) Bath room (4) Water closet (5) Kitchen and dining (6) Lobby and balcony and verandah (7) Storage volume (8) Counter and sink (9) Average height (10) Natural lighting area (11) Natural ventilation area (12) Staircase width.

Herein we have the entire data in objective form.

Networks 1) Water supply - Nil, moderate, abundant
2) Power supply - Nil, some lights, lights and bulk power
3) Circulation - Difficult, possible, free
4) Sewerage - Open drains, Septic tanks, Public drainage
5) Communication - Poor, good, excellent between rooms

Step 2. This and the following steps will be illustrated through a tabular statement for one aspect, say shelter. The weightages are so assigned as to reflect the importance of various attributes with respect to the aspect under consideration. It is advantageous to have the sum of these weightages as ten, hundred etc.

Step 3. The corresponding standards are written down as in Table 2.

Step 4. After computing the ratios of actuals vs standards the excess provided is recorded. This approach was found essential, since designers have a tendency to throw in the available resources on unnecessary provisions. This leads to inadequacy on the one hand and wastage on the other hand. Computation of efficiency reveals inadequacies and the 'wastage factor' in terms of total cost of building reveals the proportion of the resources that are mishandled.

Steps 5, 6 and 7 are routine computations (Table 2)

Step 8. It has already been seen that the five aspects Nature, Man, Society, Shelter and Networks do not have equal importance when alternate designs are evaluated for a given site condition. Since site conditions are fixed, the importance shifts to Shelter,

TABLE 2A: QUARTER TYPE I ANALYSIS SHELTER

Item No.	Description and Units	Cost per unit Rupees	Weight WD_e	Standard SD_e	Actuals D_e	$\frac{D_e}{SD_e}$	Penalty	$\frac{D_e}{SD_e} x WD_e$
1	Living Room - Sq. ft.	30.00	15	120	111	0.93	-	14.0
2	Bed Room - Sq. ft.	30.00	15	100	90	0.90	-	13.5
3	Bath Room - Sq. ft.	30.00	3	24	16	0.67	-	2.0
4	Water closet - Sq. ft.	30.00	8	20	13.5	0.68	-	5.4
5	Kitchen and dining - Sq. ft.	30.00	10	80	46	0.58	-	5.8
6	Lobby and Balcony and Verandah - Sq. ft.	30.00	5	75	10	0.14	-	0.7
7	Storage - cft	10.00	10	250	330	1.00	80cft	10.0
8	Counter and Sink - Sq. ft.	20.00	3	6	3	0.50	-	1.5
9	Average Height - ft.	300.00	5	8	10	1.00	2.00ft	5.0
10	Natural Lighting Area-percentage of floor area	5.00 per sq. ft.	10	10	13.5	1.00	3.5/	10.0
11	Natural ventilation area - percentage of floor area	5.00 per sq. ft.	10	5	16.0	1.00	11/	10.0
12	Stair case width - ft.	100.00	6	3	3.50	1.00	0.5ft.	5.0
*	Total area of Building - 450 sq. ft.							
			Σ100					Σ82.90

Efficiency factor $\eta_D = \frac{82.90}{100} = 0.829$

Penalty cost $= (80 \times 10) + (2 \times 300) + (\frac{3.5}{100} \times \overset{*}{450} \times 5) + (\frac{11}{100} \times \overset{*}{450} \times 5) + (0.5 \times 300) = 1875$ Rupees

Penalty ratio $p_D = 1875/13500 = 0.14$

TABLE 2B: QUARTERS TYPE II ANALYSIS SHELTER

Item No.	Description and Units	Cost per unit Rupees	Weight WD_e	Standard SD_e	Actuals D_e	$\frac{D_e}{SD_e}$	Penalty	$\frac{D_e}{SD_e} x WD_e$
1	Living Room - Sq. ft.	30.00	15	120	131	1.0	11 sq. ft.	15.0
2	Bed Room - Sq. ft.	30.00	15	100	131	1.0	31 sq. ft.	15.0
3	Bath Room - Sq. ft.	30.00	3	24	18	0.75	-	2.3
4	Water closet - Sq. ft.	30.00	8	20	12	0.60	-	4.8
5	Kitchen and dining - Sq. ft.	30.00	10	80	66	0.80	-	8.0
6	Lobby, Balcony and Verandah - Sq. ft.	30.00	5	75	100	1.0	25 Sq. ft.	5.0
7	Storage - cft	10.00	10	250	350	1.0	100 Sq. ft.	10.0
8	Counter and Sink - Sq. ft.	20.00	3	6	7	1.0	1 Sq. ft.	3.0
9	Average Height - ft.	300.00	5	8	10.5	1.0	2.5 ft.	5.0
10	Natural Lighting Area - percent of floor area	5.00 per Sq. ft.	10	10	12.6	1.0	2.6	10.0
11	Natural Ventilation area - % of floor area	5.00 per Sq. ft.	10	5	10.5	1.0	5.5	10.0
12	Staircase width - ft.	300.0	6	3	3.5	1.0	0.5 ft.	6.0
*	Total area of Building 575 sq. ft.							
			Σ100					Σ94.1

Efficiency factor $\eta_D = \frac{94.1}{100} = 0.941$

Penalty cost $= (11 \times 30) + (31 \times 30) + (25 \times 30) + (100 \times 10) + (1 \times 20) + (2.5 \times 300) + (\frac{2.6}{100} \times \overset{*}{575} \times 5) + (\frac{5.5}{100} \times \overset{*}{575} \times 5)$
$+ (0.5 \times 300) = 4165$ Rupees

Penalty Ratio $p_D = 4165/17000 = 0.230$

Networks, Man, Nature and Society, in that order. Weightages of 4, 3, 2, 1 and zero are proposed.

Steps 9 and 10 are routine computations, but numerical details are not given. This is due to the fact that the final efficiency and penalty factors have no significance as such, unless a common forum of world specialists have agreed upon the classification of subjective information and the utility measures allotted to them. Furthermore, the weightages play a central role in this procedure and require the approval of the specialists.

However the universality of this proposal and the underlying simplicity of the proposal are to be acknowledged. It is an axiom that simple concepts, even though repeated a large number of times, have more appeal to the human mind than complicated proposals which lead to the unique answer in one long-drawn step. Furthermore, freedom for adoption by various experts dealing with diverse situations within a simple framework of rules is the vital factor which renders one scheme successful with respect to others. Table 2 is self explanatory.

CRITICAL EVALUATION AND CONCLUSIONS

A procedure for evaluating alternate designs for low cost housing based on the unifying principles of human settlements discovered by Doxiadis (2) was presented. An illustrative example was given. The concept of assigning utility measures in an arbitrary scale was outlined. There are other methods of evaluating efficiencies as outlined by Sridhar Rao and Nair (3), Sridhar Rao and Mathur (4) and Mathur. (6) These are more sophisticated methods for restricted application. The proposed procedure is more global in nature. The concept of arrogating the importance of various aspects through appropriate weightages is a key concept that is central in the theme outlined. The concept of a penalty factor revealing the wastage in the use of available resources adds to the value of the proposed procedure.

The inadequacies revealed by the low efficiency factor of house Type I was confirmed from occupant response, and the wastage associated with type II house was also confirmed.

It is recognised that while proposals such as these are simple as they appear on paper, such a procedure demands on one hand extensive studies on unification of standards, and international effort on the other hand to narrow down differences in what is considered as adequate, necessary and important.

Finally the flexibility of the entire proposal in accommodating infinite variations in actual applications has its own appeal.

SUMMARY

Low cost housing systems, besides providing economical shelter for people at a desired level of performance or efficiency, should interact effectively with natural, economical and social environments. Several alternate solutions are usually conceived and one is chosen for execution based on lowest cost or some such arbitrary criteria. Subsequent evaluations of these solutions, as executed, reveal flaws and inadequacies. If such costly errors are to be avoided, the immediate task is to define the efficiencies of various competing alternatives on the basis of multiple criteria. Such an approach helps the designer to balance between designs with varied individual functional performances, aesthetic qualities and economics.

In this paper a framework for an objective measure of efficiency was developed. For those attributes of quality of housing for which the "value systems" are basically subjective in nature, utility measures on elements/subsystems based on designer's or professional group preferences were used with appropriate weightages. These were done for five conceptual aspects, (1) Nature, (2) Man (3) Society (4) Shelter and (5) Networks. The concept of minimum standards for spatial, environmental and functional aspects was next discussed. Each basic aspect was subdivided into appropriate parts and the actuals provided in a given system were rationalised with respect to corresponding standards and also assigned a weightage. The cumulative sum of these numbers further rationalised with respect to the total weightage assigned to a particular aspect defined the efficiency of that aspect, say shelter. After computing the efficiencies for the five basic aspects, weightages were once again assigned to these aspects based on the nature of the project on hand, and the overall efficiency of the system was computed. As a numerical example an existing system was evaluated and it was shown that the application of this procedure truly reflects the efficiency of the system as evaluated by the occupants in a subjective manner.

It may be argued that the proposed procedure can be used to evaluate a single house, a colony of houses, a metropolis and so on. While the basic principle hinges on non-dimensional analysis of each aspect with respect to its own standard, the assignment of weightages made this proposal rational and realistic for the analysis of housing systems built in various parts of the country for various purposes. By changing the standards, this procedure also revealed whether a system is tending towards obsolescence. Finally the concept of "penalty factor" was introduced whenever provisions were made in excess of the stipulated standards. The universal nature of the basis adopted for evaluation of building complexes made this proposal attractive even though the final number obtained as efficiency of a system had no exact physical significance as such. For comparative study of various competing alternatives the advantages of this procedure were self-evident.

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