A New Integrated Computer-Aided Design System For Housing Projects

Abstract :

Egyptian experience of housing Complex projects implementation shows many positive and negative aspects which vary greatly in their degree of importance .

The subject matter of this paper deals with the problem of ignoring several design aspects in Architectural design, especially in low cost housing projects, and considering the economic issue as the most important criterion in residential projects, aimed at producing massive production of residential units with low capital cost . Virtually, the design problem rarely deals with a single view in mind.Usually design problem has a number of quite distinct and disparate aspects, each of which is important to a greater or lesser degree .

This paper is based on one of the new profound scientific approaches using the computer techniqus and the intuitive creative logic of the Architect . The aim is to obtain a flexible design that allows for dealing efficiently with the various design factors and criteria - whether physical or non-physical - in view of the integrated system so as to improve the building performance .

Consequently , this study argues the fundamentals of this new design approach through the previous literatures and attempts which are being considered uptill now . Hence this presentation and argument aim to illustrate the importance of the integrated approach in architectural problem solving and to reflect this importance on the housing projects within Egypt . Furthermore , it is essential to crystallize and develop this approach to discuss and evaluate the previous Egyptian experience , and to design and achieve a practicable design satisfying the humanistic needs and requirments of comprehensive development . To accomplish this the new integrated computer design system , we propose is configured as a structural system complying with this new design approach .

Obviously , quality of the optimal , or sub-optimal solution the proposed computerized system produces, is completely based on the quality of input data and information which are suggested and presupposed by the Architect or user.To this end , it is imperative that the experts and profissionals should contribute to prepare and design several archtectural models (Environmental, social, struchural model) .In fact, these mode will by the main subsystems to be included within the whole structural system we propose .

This paper incorporates two main topics :

1- Low cost housing project versus design factors
2- The new design approach (theoretical concept / expremiental application).

1-Low cost housing project versus design factors :

Besides the rapid growth of population, the developed countries face the high density of population as acute problems . Virtually, the increasing of population leads to increase the rate of total density versus the urban growth .This situation causes several urban and human problems such as: lack of open spaces and the urban settlements can not satisfy the humanistic needs and requirements of comprehensive development .Consequently , a new housing pattern is configured in order to satisfy the functional needs for the low income group . This pattern is known as the low-cost housing pattern .

This paper presents the low-cost housing as a general housing type that is supported and accomplished by the governments. This pattern incorporates two types. Fig. (1) . The first type is the popular sector, which provides the complete built residential units with minimum functional areas. The previous Egyptian experiences were accomplished at Embabaa and Helwan* in 1954. The second type is the public sectors resulting from the shortcoming in satisfying basic human needs and requirements of the comprehensive development. The government could not accomplish the ultimate purpose of the low-cost housing pattern. Consequently, it provides the population with the human settlements incorporating the various levels. This strategy provides a little number of units for low income group.

In fact, the private sector has accomplished the majority of housing projects before 1952 because there was not any directional housing strategy. Since 1952, the participation of government in housing projects was being developed, 31,847 units were built in the period 52/1960 (only 6% of them for low income group.) This persentage raised to 55% during 65/1970.

Obviously, there are only two or three protoypes of residential units are used in different environmental context and with various socities. In fact , each site is always unique from the others. Hence, the Egyptian strategies ignored the humanistic needs and the conditions of environmental context for each site. In addition, the worldwide prototypes of residential units could be classified into two concepts walk up gallery type and limited-wedth type.

The walk up gallery type includes one room and one living hall with 28 m2 as a total area. The limited-wedth type is appartment walk up type, slab building with length 36,48,60 meters and 14 ,.16 meters in width, one stairway serves two units, five floors , in hight equals to 15 meters, every unit has rear and front facad, with areadiffering from 32 to 48 meters square. fig (2) .
Many user-modifications are accomplished as a direct result from the Egyptian strategies. The re-modifications aim to satisfy the human needs and requirements which are igonred by the Architect. Fig (3,4,5) .

As an Examples for Some of The popula secotor projects in cairo, Egypt

Hence, it is essential to argue and evaluate all of the fundamentals, philosophies and hypotheses on which the Egyptian experience are (were) based . The aim is to revise these concepts and ideas and to configure a new integated philosophic system aimed at dealing with the design problem, especially, the housing projects, in view of the integrated harmonious whole, using the computer techniques and the artificial intellegente systems.

2. The problem solving scientific Approaches using computer techniques :

Indeed, Architectural design is a product of human consciousness. The conscious accumulation of knowledge and inheritant vocabularies conduce and influence, in different manner, the Architectural design . Virtually, Design is rarely dealt with a single view in mind. Although it is true that the design of the project may begin with a single overall direction of how to respond to the problem (that is a functional problem or that is a contextual problem), any building design, or site planning is, in fact, composed of a number of quite distinct and disparate design aspects and criteria, each of which is important to a greater or lesser degree . Even large scale projects contain a great deal of complexity and it is virtually impossible to deal with all the Universal design aspects simutaneously with a single concept. However, the traditional treatment depends partly on one of three strategyes : the first is complying with the decomposition approach, the second is complying with the theory of Evaluation and the third is the economic analysis.

2.1 Traditional design approaches :

The first strategy is based on hypothesis that it is possible and helpful to break the Design problem down into manageable number of parts .(4,6,11) Each of which could be solved separately so as to achieve the optimal or suboptimal solution. Moreover, the manner in which the problem is decmposed will vary from designer to another. Virtually although the decomposition of a design problem is useful to descride and define its main components and desful to descride and define its main components and design factors which influence the generation of from by contrast, Practically, the design aspects and factors are completely identified in a complicated and mystical manners . Each of the universal aspects has important effects on one another. In other words, the different effects of the universal aspects on the form-generation are in non-linear, relationships, because the aspects do not affect directionally on the Architectural form generation.(14)

The second strategy is based on dealing with several design aspects and criteria simultaneausly. This strategy presupposed the relative importance of each design factor or criterion in different manner.Tt, In fact, is a subjective method because the determination and designation of the different relative importance could be varied. and differed from designer to another. In addition, the scientific methodology is complying completely with the objective methods and it is almost ignoring the subjective ones . (5)

The third strategy believes that it is helpful to translate the different scales of design factors, which influence the Architectural form-generation, into one scale aimed at dealing with a single concept. Often, this scale is the money. Then the single concept may be an economic conception using the feasibility analysis.(4,6)

2.2. New Design Approach :

This study argues the fundamental of the new design approach through the previous studies which are being considered uptill nown, especially by prof. Antony, computing unit, Department of Architecture, Sydiny university. Hence, this. presentation and argument aim to illustrate the importance of the integrated approach in Architectural problem solving and to reflect this importance on the housing projects within Egypt. Furthermore,it is essential to crystallize and develop this approach to discuss and evaluate the previous Egyptian experience, and to design new buildings satisfying the humanistic needs and requirements of comprehensive development. To accomplish this the new Integrated computer design system, this study proposes is configured as a structural system complying with the scientific design approach, Antony proposed before and Conforming with The Concept of Participation between The intuitive Creative Thinking of the Architect and efficient automatic Performance of Conputer machine, Mahmoud Zaki Proposed (14) .

obviously, quality of the final solution, i.e. the optimum or sub-optimum layouts, the proposed computer system produces, is based completely on the quality and reliability of input data and information needed for computer processing. These Architectural data could be suggested and presupposed . by the Architect in different ways. To this end, it is imperative that the experts and profissionals should contribute to prepare and design several architectural models (whether they are environmental, social, or structural. In fact, these models will be the main subsystems to be included within the whole structural system this study proposes.

2.2.1 Outlines of mathematical conception of the multicriteria optimization :

Fig. (6) shows' the mathematical conception of the criteria space for a problem with two criteria. Solution set optimal performances lies along the northeastern boundary of the criteria spaces. In the general case of the "P" criteria, the solution set will lorn a surfuce in "P" dimensional space . A graphical presentation of solution set for a two criteria problem, allows easy comparison of alternatives. A similar graphical presentation of higher dimensional problems is diffecult. The method, Antony proposed, generates the solution set and designate the optimal or suboptimal solution, considering all of the objectives already defined by the Architect obviously, each design factor or objective is naturally presented on particular axis with its scale (withought conversing procedures).(14)

Besides, the outlines of mathematical conception of the multicriteria optimzation, Fig. (7) shows in abstract the mathematical conception of the other problem solving approaches.The economical methods achieve the optimal solution by moving the objective function further away from the origin in the positive quadrant. the slope of the objective function contains the cost unit for each design criteria. therefore, the objective function is an economical function. the Architectural from generation is in relationships with the economical factors apart from several design factors.

The wieghting methods achieve the optimal solution by the same manner that the economical methods used above but the slope of the objective function contains the constants.The constants are the presupposed wieghts or relative importances for each design factor. the Architectural form generation depends on the subjective methods apart from several realistic existing relationships of the various design factors (14) .

the multicriteria optimization methods achieve the optimal solution by using the objective function too. The slope of this objective function is determined by the constants. These constants are designated computerized by obtainning the optimal point of each design criterion separately and connecting them producing a natural slope. the architectural form generation is in relationships with the different design factors within various contexts .

In fact, this integrated system uses some optimization techniques in integrated manner .This paper proposes the computer program using the integrated system through the linear and non-linear programming techniques.

2.2.2.Expremental applications

This study presents two different applications . the dimensionless problem is concerned, especially in designing of residiantial units or blocks The first application considers the linear dimensionless problem by using the linear types of residensial unit or Block aimed at achieving the optimal Architectural dimensions of its components. the second application considers the non-linear dimensionless problem by using the squar types of residensial unit or block aimed at achieving the optimal architectual dimensions of its components .

Case (A) : Linear dimension less problem :

The dimensioning of floor plans, or housing block, is a prototypical design decision problem in architectural especially in the Housing projects. Consider the dimensionless floor plan of an apartment, shown in Fig. (8) ; the problem is to find the minimum length of this department, subject to constraints on the area of the rooms and on their lengths reflecting the social standard

and type of housing. In addition, several constraints can be included to produce a realisic and economic solution, i.e.a diagramatical layont. virtually, these constraints may, be addressed and defined as :

1) Areas of activities & their length.
2) Constructive constraints (e.g. the max. and min. spans of spaces and wall location restrictions).
3) Plannin constraints (e.g. the accessibility, allocation of spaces, organization laws, etc.) .

Undoubtedly, there are many other ways for defining these constraints of the diminsional problem which are equally useful . The widths of all the remaining rooms are given, and the problem becomes one of finding the length of each room. The depth of department, the ratio between the total length of department and its wedth, and the construction method, are the main factors which influence the determining and presupposing the total width of department and the rooms widths .

Formulation of Architectural constraints :

1. Area :

Room	Maximum Area (Ft^2)	(cm^2)	Minimum Area (Ft^2)	(cm^2)
Bath 1	80	744	75	698
Bed 2	180	1674	160	1488
Utility	80	744	50	465
Kitcten	200	1860	150	450
Dining	125	1163	100	930
Bed 1	200	1860	180	1674
Hall	600	5580	-	-
Living	200	1860	180	1674
Bath 2	80	744	60	558
Entrance	125	1163	100	930

2. Widths:

Hall	width	=	3.00	Ft	9.15cm
bath 1	width	=	12.00	Ft	36.6cm
bath 2	width	=	9.00	Ft	27.45cm

3. Planning :

We want the right-hand wall of bed 2 to line up with the want the right hand wall of bath 2, for structural reason.

4. Structural constraints :

left side of wall, $x_1 + x2 = x6 + x7$

right side of wall, $x\ 8 + x_9 = x3 + x4 + x5$

5. Organization laws :

suppose that the max allowable hight equals to fine Floors. On the other hand, the minimum hight should be three floors (for economic reasons).

then :	h>= 27 Ft.	82.4cm
	h<= 45 Ft	137.3cm

*** mathematical formulation of Architectural constraints**

we commonce by defining the decision variables. Here, they will be the lengths of the ten rooms. we can see, however, that the length of the hall will simply be the sum of the lengths of bath 2 and family, and we can calculate it; it is not an independent decision. This leavesus with the following nine decision variables :

Room length	variable
Bath 1	x1
Bed 2	x2
Utlity	x3
Kitchen	x4
Dining	x5
Bed 1	x6
Bath 2	x7
Entrance	x8
Living	x9

the objective function is the sum of the lengths along on side :

$Z = \min (x1 + x2\ x\ 3 + x4 + x5)$

the constraints can be represented in the mathematical form with the following :

Bath 1	12 x1 >= 75 (Ft^2)	69.8
	12 x1 <= 80	74.4
Bed2	12 x2 >= 160	14.88
	12 x2 <= 180	16.74
Utility	12 x3 >= 50	46.5
	12 x3 <= 80	74.4
Kitchen	12 x4 >= 150	45.0
	12 x4 <=200	18.60

Dining	12 x5 >=100	930
	12 x6 <= 125	1163
Bed 1	12 x6 >= 180	1674
	12 x6 <= 200	1860
Hall	3 x 7+3 x8 <= 60	558
Living	12 x9 >= 180	1674
	12 x9 <= 200	1860
Bath 2	9 x7 >= 60	558
	9 x7 <= 80	744
Entrance	9 x8 >= 100	930
	9 x8 <= 125	1163

Hight condition :

$$h >= 27$$
$$h <= 45$$

wall location constraints :

$$x1 + x2 = x6 + x7$$
$$x8 + x9 = x3 + x4 + x5 .$$

Computer model & solution

1. In fact, this problem is a linear programming problem . A problem of linear programming is one of finding nonnegative values of a number of variables for which a certain linear function of these variables assumes the greatest (or the least) possible value while the subject to certain linear constraints . Hence, the computer program, this paper presentes, is formulated using the simplex method which is the one most frequently used in solving the linear programming problems and because it guarantees to achieve the optimum solution in a fixed number of steps (12).

2.Simplex method is the most powerful technique in solving the linear programming problems because it guarantees to find the optimum solution in a fixed number of steps and because it can deal efficiently with the multicriteria optimization, especiality in the field of architecture (12) .

3.The computational procedure of the simplex method is an interactive process. It would, however, by very tedious if the problem containted several variables and constraints obviously , this type of Arch . practical problems, i . e . the dimensionless problems, have tens of variables and constraints, and it is clear that it will not be reasonable to tockle such problems by way of a hand caluculation. But the simplex is a method for a computer . Consequently, the computer model, this paper proposed

Arch . Practical problems, i . e . the dimensionless problems, have tens of variables and constraints, and it is clear that it will not be reasonable to tockle such problems by way of a hand caluculation. But the simplex is a method for a computer . Consequently, the computer model, this paper proposed , is configured based on the simplex method .

Then, the obove mathematical formulation is solved by means of the proposed computer model ; Fig. (9) presents the final computer results in the form of dimensional diagram .

Eventually , we have found both the optimal value of the objection and the values that the decision variables must take so as to achieve that oplinal .

Case (B) : Non - linear dimension less problem :

In fact, not all that many design decision problems can be formulated as linear programing problems . Sometimes, in the field of Architectures , especially in housing projects, the dimensionless problem may be nonlinear programming problem consider the dimensionless floor plan of an apartment, shown in Fig. (10) , the problems is to find the problem is to find the minimum length and wedth of this arartment, subject to several architctural constraints . The architectural constraints could be configured by the simillar manner of the case (1) .

In fact, the lengths and wedthes of all the remaining rooms are unknown, and the problem because one of finding the areas of each room, besides its length and its width , aimed to minimize the constructive cost .

Formulation of Architectural constraints :

1.Areas : table (1) present the dimensional constraints which are proposed resulting sevral housing studies .

Table (1)

room	Min length (Ft)	Max length (Ft)	Min width (Ft)	Mix area (Ft)	Min area (Ft)	Max area (Ft)	Max proportion Ratio
living room	8	20	8	20	150	300	1 . 5 : 1
kitchen	6	18	6	18	50	120	-
bathroom	5.5	5.5	8.5	5.8	-	-	-
HAll	0	15	3.5	6	0	72.0	-
bedroom 1	10	17	10	17	100	180	1 . 5 : 1
bedroom 2	8	18	8	18	100	18.0	1 . 5 : 1
bedroom 3	9	20	9	20	100	180	1 . 5 : 1
Entrance	3	4	9	18	60	60	

* Feet = 3.05 cm

2 . **Planning :**

The hall should be contralized of the apartment for the accessibility . Therefore, the length of hall should be equal to the length of bath added the length of entrance .

3 . **Structural constraints :**

Horizontal walls, the wedth of kitchen should be equal to the wedth of bed 1 .

Vertical walls : length of bed 2 should be equal to the length of bed 3 .

4 . **The organisation laws :**

Suppose that the max allowable higght equals to five floors . on the other hand, the minimum hight should be three floors .

5- **the objective functions :**

$$Z = \sum_{i=1}^{12} CI\ AI$$

Where :

Z : the value of constructive cost :

CI : the amonge of construction for one squar meter room (i) .

AI : Area of room (i) .

Table (2) Presart the amonge of constraction for one square meter of each room .

Table (2)

Room	Living	Kitchen	bath	hall	bedroom	bedroom	bedroom	entrance
Ci	1 .0	2 . 0	2 . 0	1 . 0	1 . 0	1 . 0	1 . 0	1 . 0

Mathematical formulation :

obviously, the mathematical mequalitic and equations constraints are non - linear constraints; for example :

X I * X9 > 150 Ft 458cm

X I * X9 < 300 Ft 916cm

the obve imequalities the maximum and minimum area of living room . But this mathematical formulaes includes a quadratic order the mequalities and equations one formulated to translate the architectural constraints .

Computer model & Solution :

Virtually , this problem is a non - linear programming problem. The objective function is nonlinear and the constraints are nonlinear . There is no nonlinear programming method equivalent to the simplex method exists for the solution of nonlinear programming problems because of the efficancy of the simplex method , various approaches have been developed to be converted into one or more linear programming problems .

Subprograms (CF) , this paper proposed , plays an important part in converting the non - linear programining problem to linear programining problems . In fact , this subprogram converts the nonlinear objective function and nonlinear constraints to linear equations and inequalities .

Hence , the main program can solve the above problem as a linear programming problem .Fig . (11) presents the final computer results in the form of dimensional diagram .

Event usally , we have found both the otpimum value of the constructive cost and the values that the decision variables must take so as to achieve the optimal .

3- Recommendations :

It is essential to deal completely with the Architectural design problem, especially the Arch . form generation, in view of the Integration between the various aspects and factors which influence the urban form . Furthermore , these aspects and (or) factors may be environmental , caltural, or social ones .

Virtually, the new computer - aided system , this paper proposed, is based on the Multi- criteria optimisation . Moreover , it is a structural model . consequently , this system needs for several profissional and detialed sub - systems (whether environmental , social , cultural , ... etc) so as to achieve a profound and efficient system in dealing with the varing aspects of the design problem, especially the Urban form - generation .

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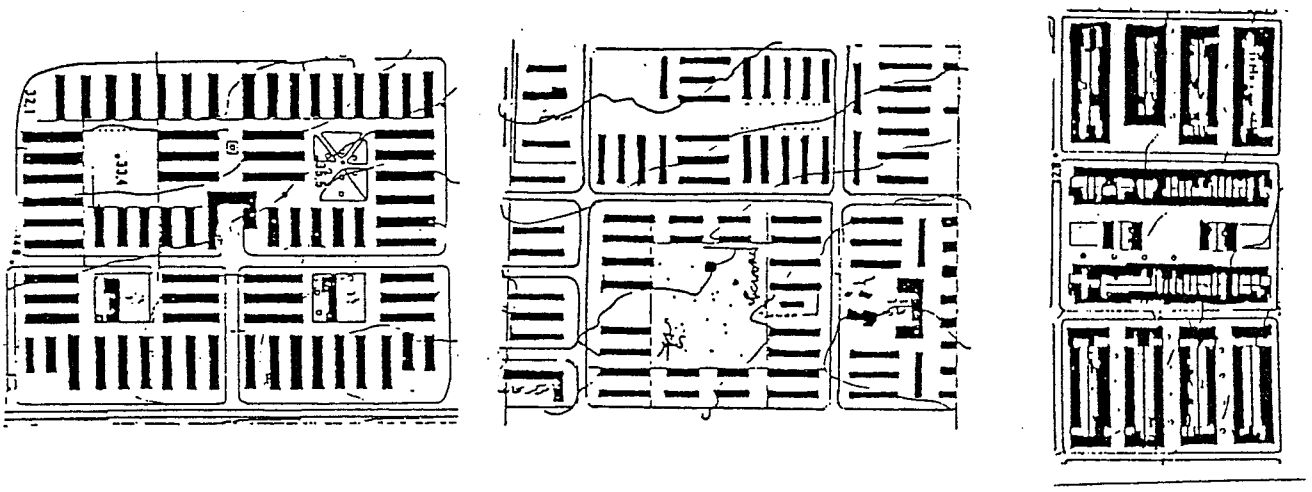


Ein - elsira Project Naser project popular Helwan Project

Fig 1 : The General public housing patterns

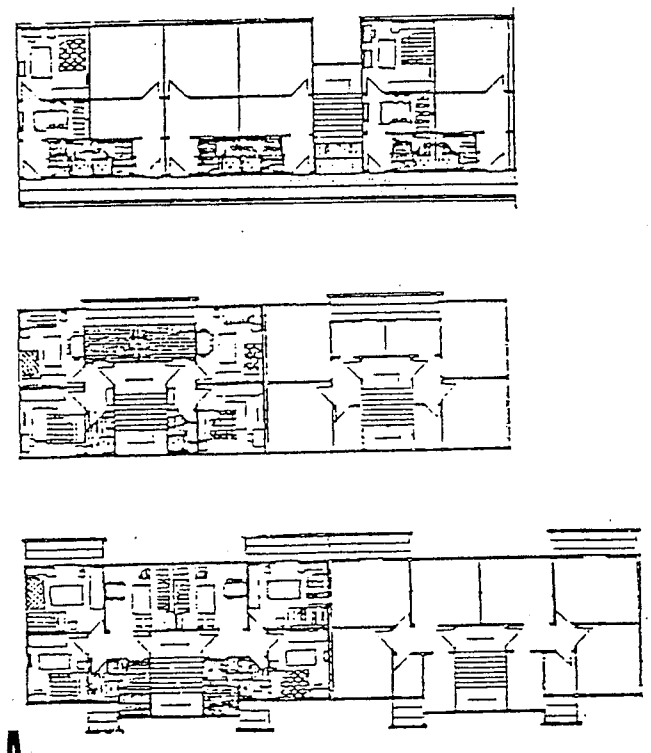
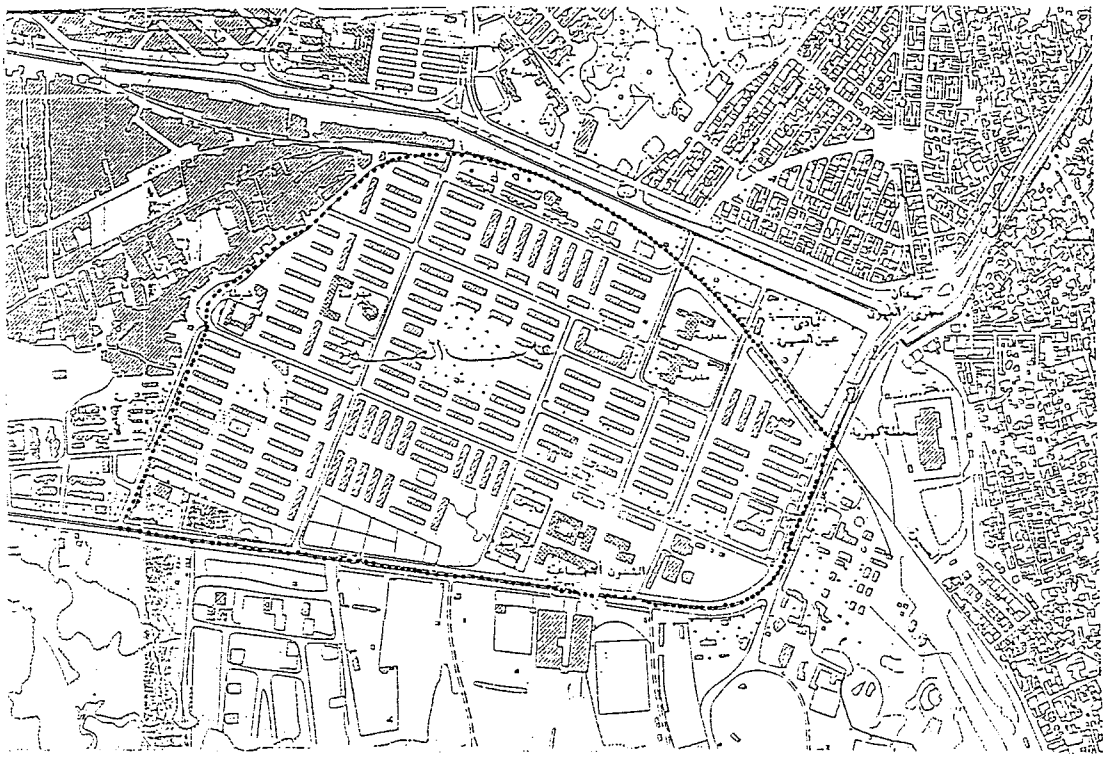


Fig 2 : Dwellings proto - types



General Layout

Fig 3 : Ein - elsira project

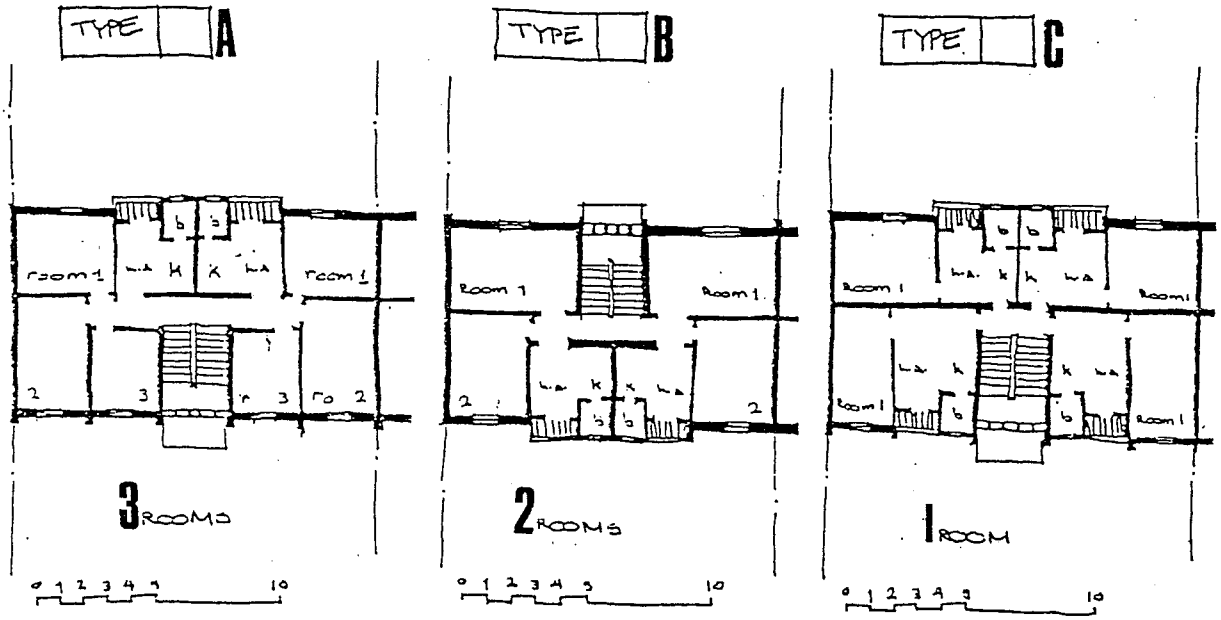


Fig 4-a : Typical floor for dwelling Proto - types

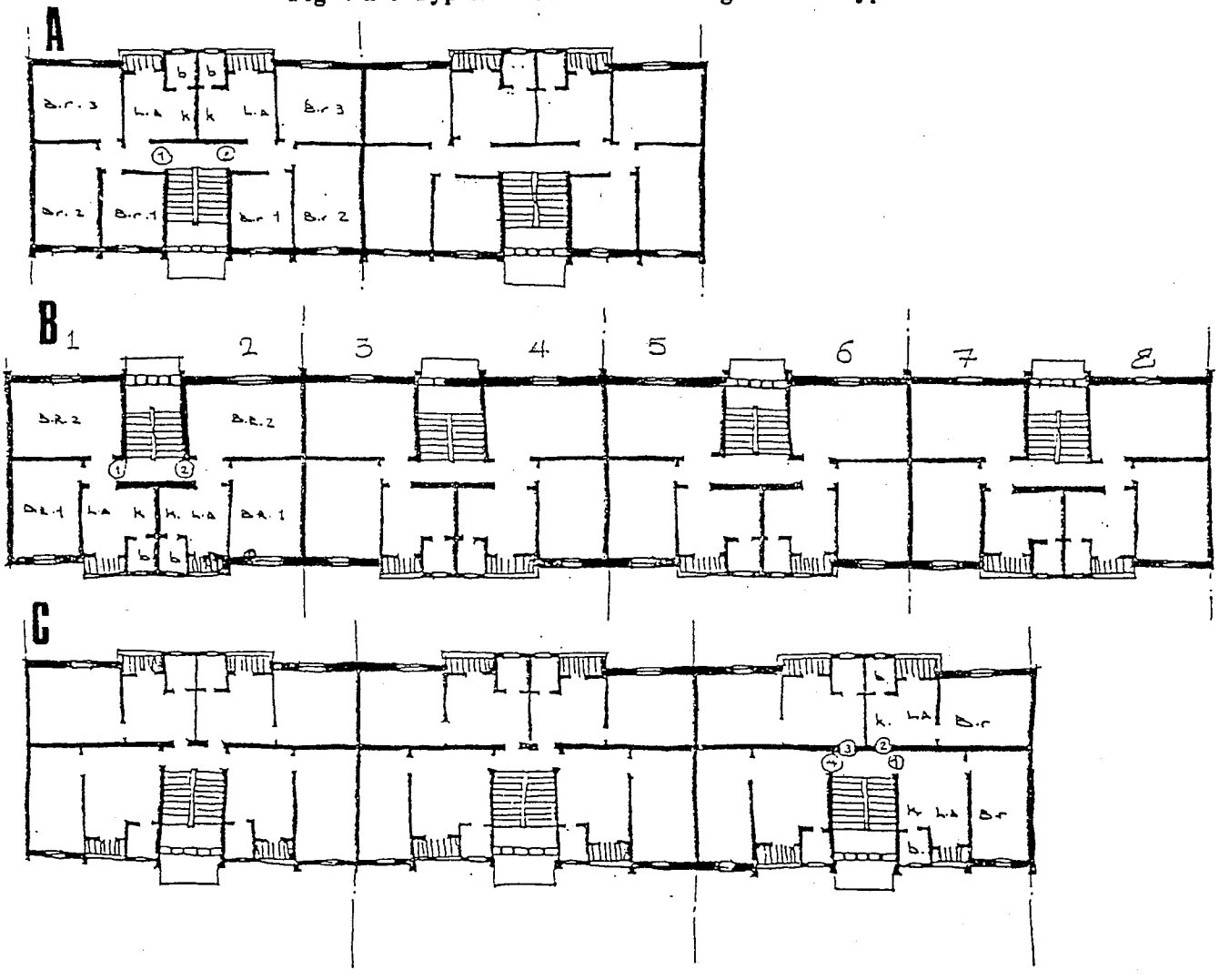
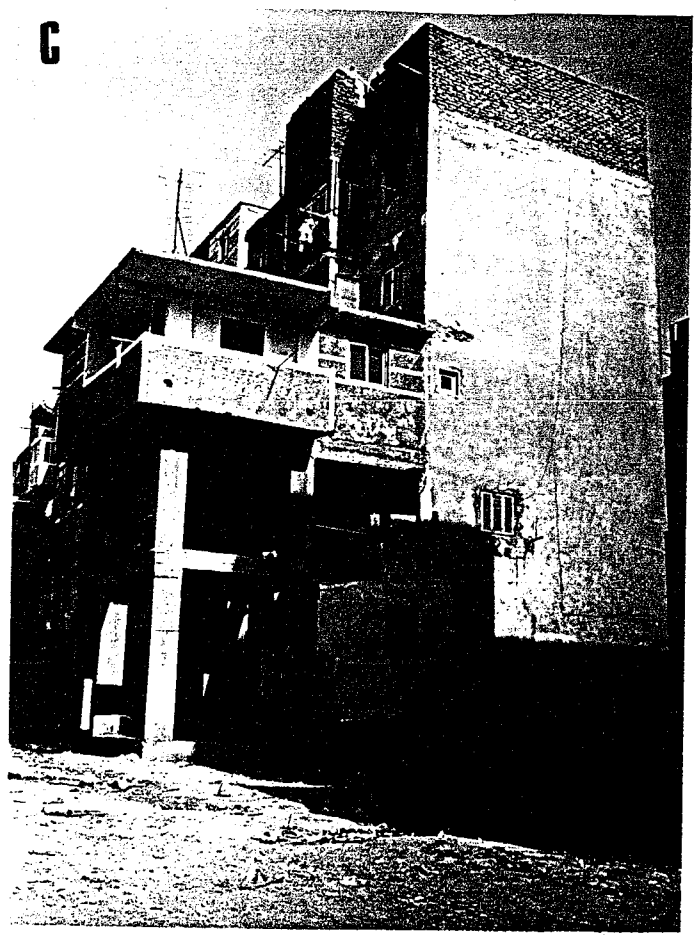
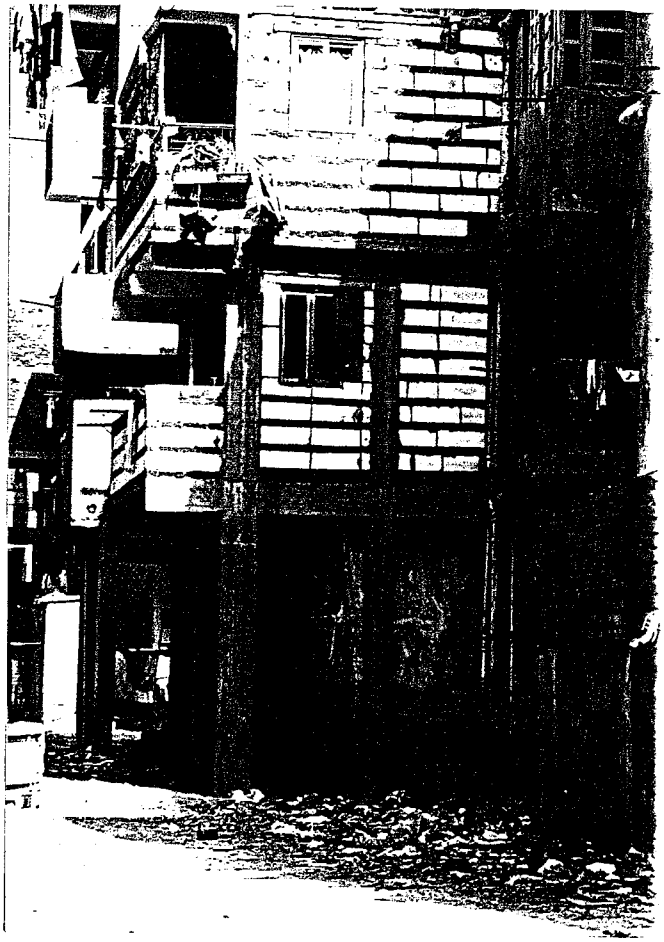
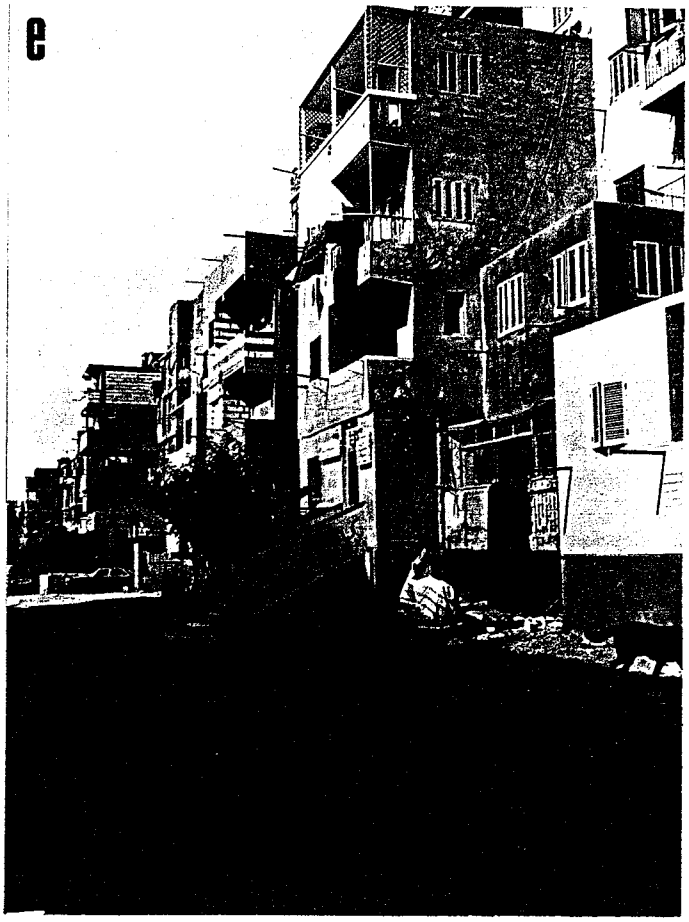


Fig 4 -b : Typicl floor for block type







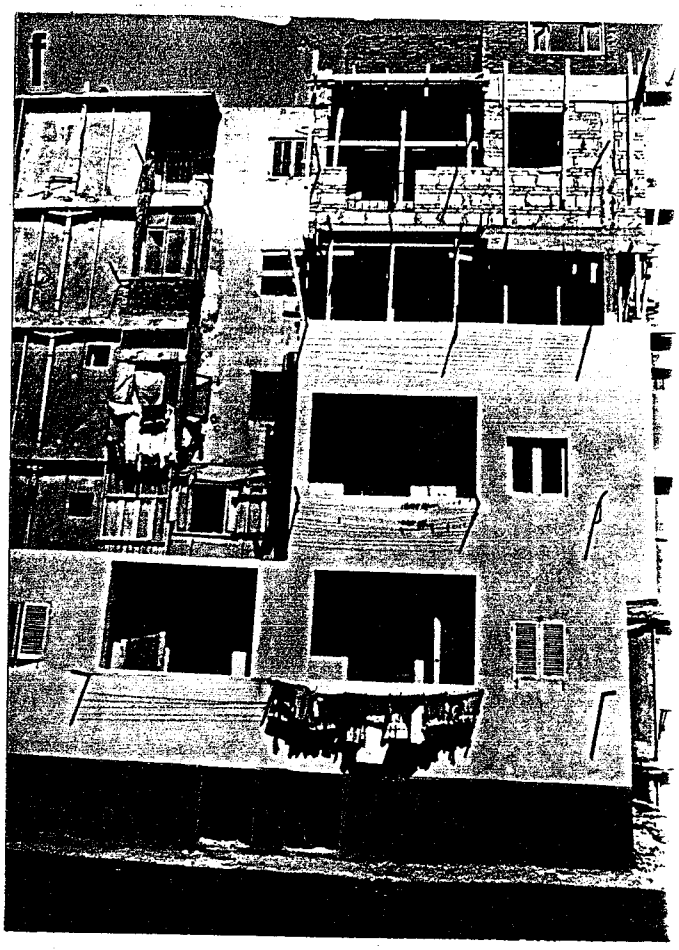
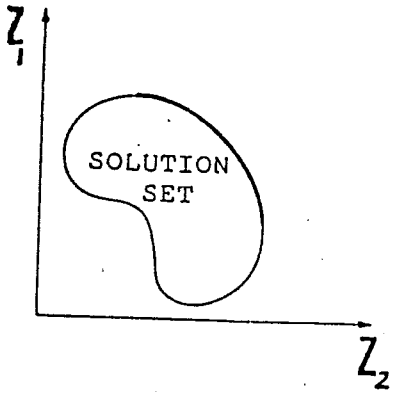
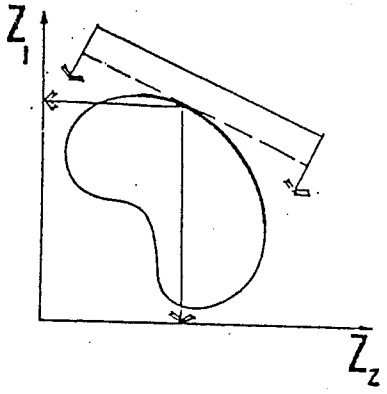


Fig 5 : User - Modifications



A graphical presentation of solution set for a two-criteria problem allows easy comparison of alternatives. It is obvious that the solution set optimal performances lies along the north-eastern boundary of the criteria space.

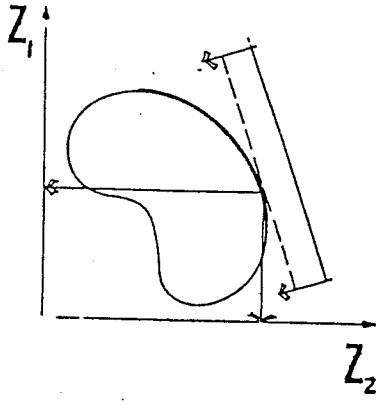
Fig 6 : Solution set for a problem with two oljectives Z1 & Z2.



1. Economical Methods

P = C1Z1 + C2Z2
Where:
P: Objective Function
C1,C2 : are the cost units of each Z1 & Z2.
Z1,Z2 : are the two design Factors or objectives.

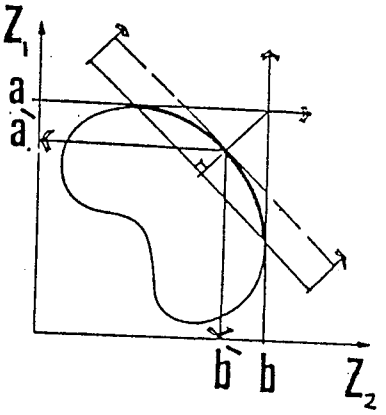
The Arch. Form Generation in relationship with the economic factors apart from any other design factors.



2. Wieghting Methods

P = W1Z1 + W2Z2
Where:
P: Objective Function
W1,W2 : are the presupposed wieghts for each the design factors Z1,Z2
Z1,Z2 : are the two design Factors or objectives.

The Arch. Form Generation depends on the intuitive creative thinking of man apart from several realistic existing relationship ips between the various design factors.



3.Multicriteria Methods

P = M1Z1 + M2z2
Where:
P: Objective Function
M1,M2 : are the two constants which are designated computerized in this case M2 =1 M2=(a-a')/(b-b')
Z1,Z2 : are the two design factors or objectives.

The Arch. Form Generation is in relationship with the different design factors with various environments.

Fig 7 : problem solving opproaches

caseA : Linear dimensionless problem

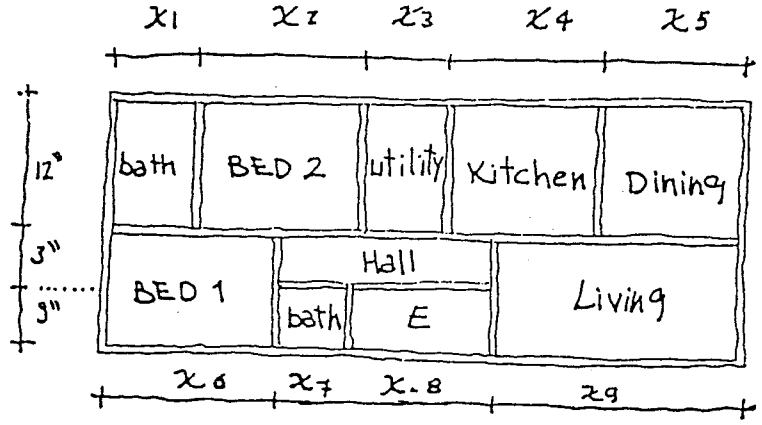


fig 8

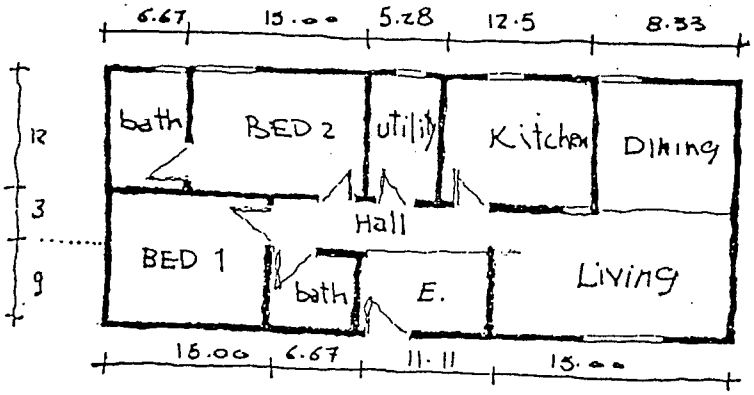


Fig 9

The final computer results in The form of dimensional diagram

case B : Non - linear dimension less problem

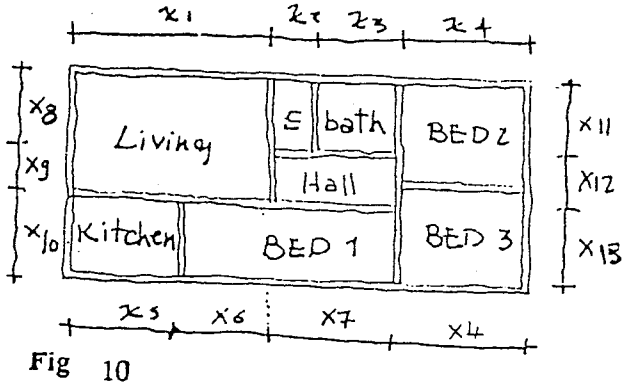


Fig 10

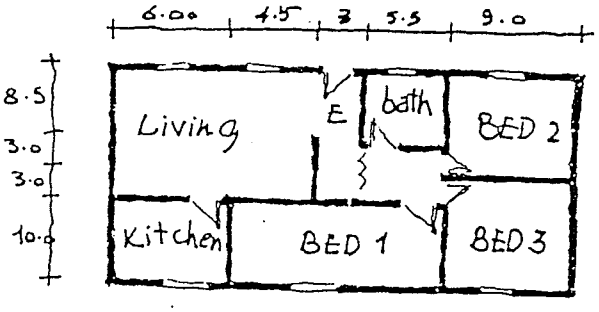


Fig 11 : The final computer results in The form of dimensional diagram

Expremental applications

بسم الله الرحمن الرحيم

جامعة عين شمس
كلية الهندسة
مكتب العميد

٢٧٨٠ ٩٢/٨/١٢
٢٨٠

السيد الدكتور/ هشام ابو سعده
الهيئة العامة لبحوث البناء والاسكان ـ شارع التحرير الدقى
تحيه طيبه وبعد :

بالاشارة الى البحث المقدم منكم لمؤتمر تطبيقات الحاسب الآلى فى العمارة والتخطيط الذى عقد بالقاهرة فى الفترة من ١ ـ ٣ مارس ١٩٩٢

اتشرف بأن أرفق طيه البحث المقدم منكم مدونا عليه ملاحظات لجنه التحكيم .
برجاء التفضل بأجراء التعديلات اللازمه طبقا للملاحظات المدونه واعادته لنا فى خلال اسبوعين من تاريخه (الاصل المدون عليه الملاحظات + عدد (٢) نسخه معدله) .
ونأمل أن يصلنا فى الموعد المحدد حتى يتسنى للكلية نشرة فى النشرة العلميه للكليه .

وتفضلوا بقبول فائق الاحترام ،،،

تحريرا فى ١٢/ ٨ / ١٩٩٢م

عميد الكلية
ورئيس المؤتمر

أ.د . محمد نبيل صالح

العنوان : ١ ش السرايات ـ العباسية ـ القاهرة
ص.ب : ١١٥١٧ العباسية
تليفون : مباشر ٢٨٢١٨٠٠ فاكس ٢٨٥٠٦١٧
سويتش : ٢٨٢٦٦٣٦/٢٨٢٦٦٣٧/٢٨٢٤٤٤٥