# A BUILDING SYSTEM OF URBAN HOUSING, WITH SPECIAL REFERENCE TO IRAN

by

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1. Introduction

1.1 Background

Iran's rapid rate of growth in industrialization, the increasing independence of young people,[1] the flow of migrants into cities in search of jobs and the ever-growing western influences are inevitably changing living patterns in this culturally rich country rapidly. There is a distinct change in the traditional family structure: the emergence of nuclear families in urban areas is in contrast to the traditional extended family structure found in rural areas.

The government's policy of encouraging apartment living and of trying to provide a dwelling unit for every nuclear family in Iran are also strong factors in altering the traditional family lifestyle of two or three generations living in the same house.[2]

The nation's fifth development plan states that Tehran will require 700,000 new dwelling units over the next five years. The traditional hand-built, brick-by-brick method of construction is still employed today. Lower middle and lower income housing is most urgently needed.[3]

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[1] Art & Architecture, International Edition, #20, January - March, 1974, p. 92, (Printed in Tehran, Iran).

[2] Art & Architecture, International Edition, #18-19, June - November, 1973, (Printed in Tehran, Iran).

[3] Ibid, p. 99.

## 1.2 Objective

The objective of this thesis is to develop a large-scale, prefabricated, precast concrete building system that can meet the ever increasing housing needs in urban Iran, while maintaining an efficient use of materials and labor. The incentive for developing such a plan is to offer as much flexibility as possible, while still remaining within the framework of a highly developed cultural tradition which emphasizes family solidarity and communication.

## 1.3 Scope

The building system developed in this thesis is restricted to large-scale compact urban housing for middle income groups.

## 1.4 Product

The result of this work is a compact scheme reflecting the need for strong family privacy while responding to a severe, hot and dry climate.

The prefabricated building system provides for one through four bedroom housing units. A visual transition is created by combining high and low rise units. Functionally, this transition occurs with the provision of roof spaces of the lower units as balconies/terraces for the units above. This functional utilization of the roof area corresponds to that of the traditional courtyards of conventional single story town houses.

## 1.5 Methodology

### 1.5.1 Analysis

The information for analysis has been obtained through an examination of the design parameters in Iran. These parameters include socio-cultural, economic and the climatic factors. The analysis should be based on sociological to technological considerations.

Furthermore, the parameters range from micro to macro levels of analysis. The micro level of concern defines the problem in its immediate context; i.e., the analysis of the existing housing indicates the traditional, spatial organization. The macro level of consideration *defines the problem in its larger context which may include the matter* of housing in groups and neighborhoods. The information obtained from such analyses will delimit the ways by which the urban fabric is structured.

### 1.5.2 Objective

The objective is to state design criteria within the context of the parameters given above. The scope of the criteria is dependent upon the range of parameters. Goals and/or directions are then stated to improve the present design standards. This is a strategy that should be responsive to increasingly changing needs of urbanites. The new designs should respond to this condition by providing flexibility and option.

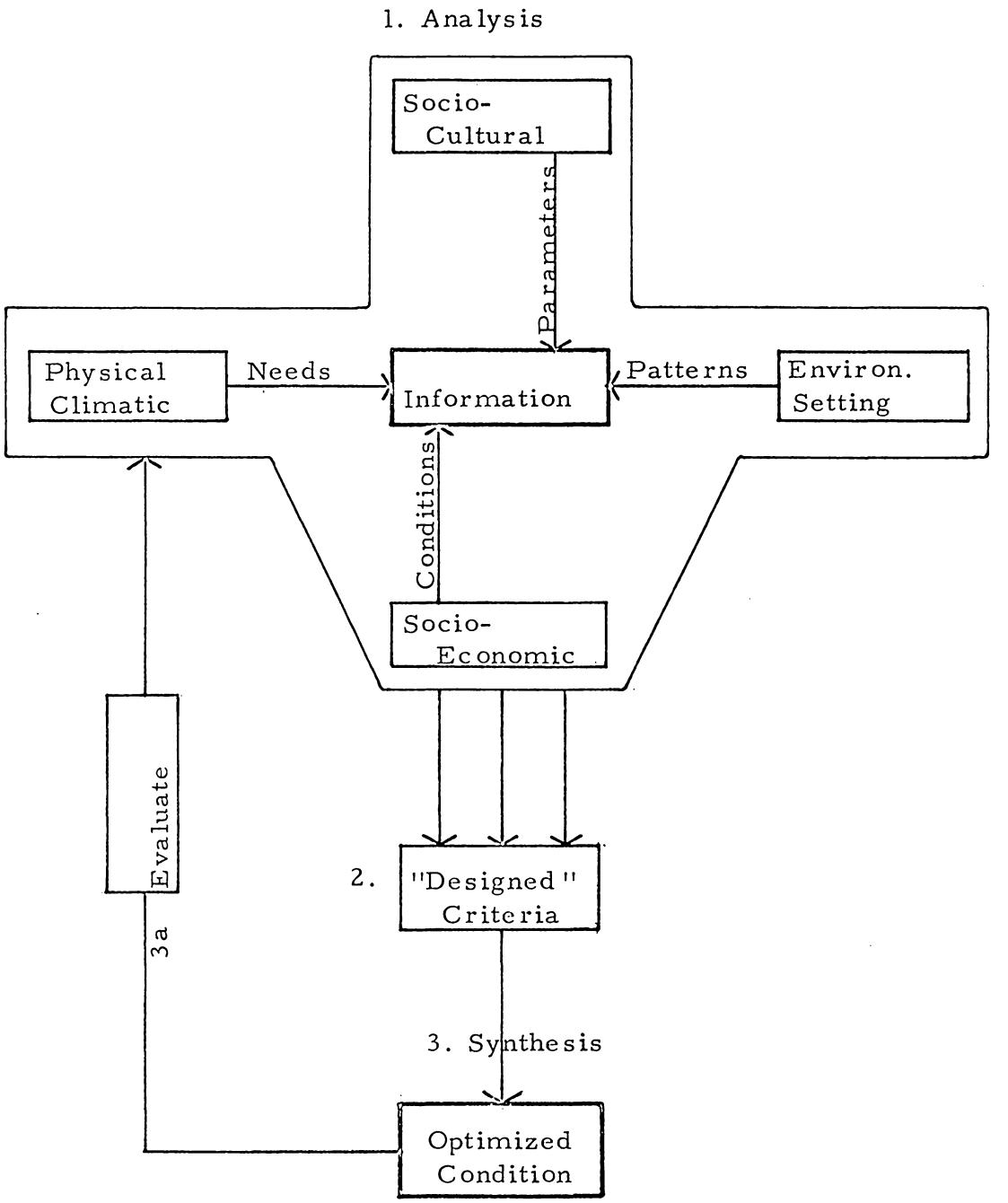



Fig. 1. Thesis Methodology

1.5.3 Synthesis

Synthesis is the optimized condition (solution) that has met the designed criteria within the context of the parameters.

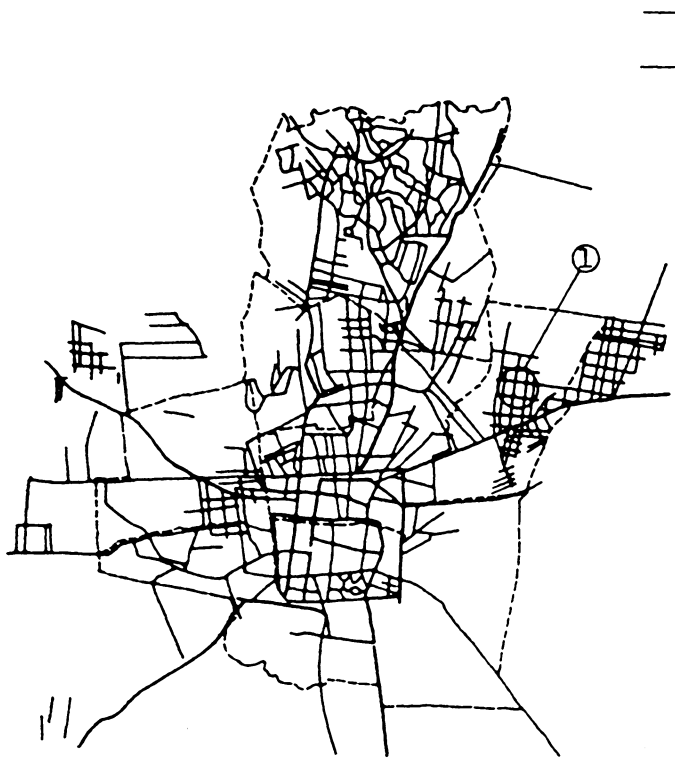
1.5.4 Test

The evaluation of the solution is in terms of the stated parameters and the designed criteria.

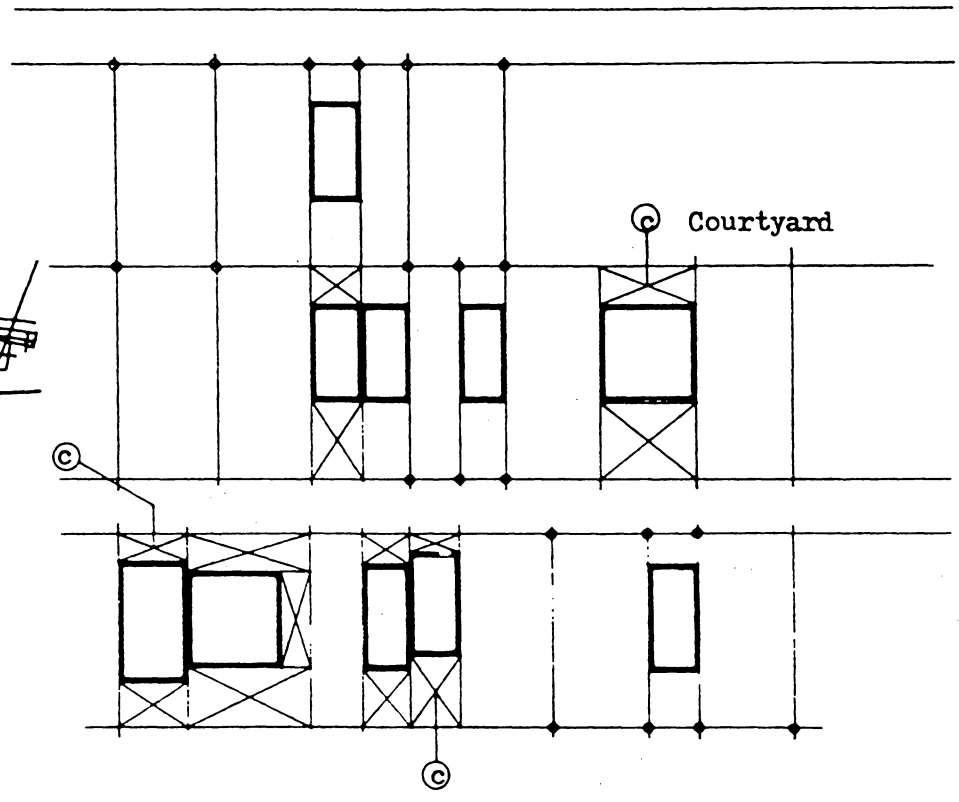
2. Traditional Planning and Design

Traditionally Iranian cities, suburbs and smaller communities have grown in an unplanned, spontaneous fashion. Fig. 2 . The city has an integrated network of functions. But, in particular, the residential aspect is the most distinct, giving the city a unique residential image. Although there has been no master plan for most Iranian cities, the urban fabric has maintained its rich texture.

Traditionally houses are built in a row, thus creating private enclosed shaded courtyards. Fig. 2 . For security and privacy, these houses are oriented inward towards the courtyard and have a southern exposure. These individual family-size courtyards function as outdoor extensions of the interior living areas; thus, individual family activities take place within these courtyards. The houses or apartments are placed next to one another, forming a continuous east to west axis that minimizes the exposure to the sun and the resultant heat gain.




City Plan




1. Typical Grid

Fig. 2. Urban Pattern

## 2.1 Analysis of the Existing Housing

### Siting

The traditional (individual) sites, unique in urban Iran, are typically rectangular with varying dimensions (30 by 120 to 60 by 120 ft., approx.). The sites are back-to-back, with their smaller dimension facing the access street. Fig. 3 . In various stages of this study the relationship of each existing housing unit (a house or an apartment) to its individual site has been examined. The analysis ranges from one- to two-story town houses to the scale of three- to four-story apartments.

### Case One. Fig. 3.1

The housing unit is placed in such a way that two separate passages are created which link entry courtyard (a) to the larger courtyard (b). The advantage is that these side yards function as buffer zones separating H.U. (Housing Unit) from the adjacent ones, enhancing accoustical privacy. A disadvantage is that an already limited site has been divided up into too many small areas.

### Alternative One. Fig. 3a

This illustrates the possibility of combining the two pathways into a more distinct one. It also indicates the possibility of incorporating the entrance courtyard (a) into the pathway itself.

Alternative Two. Fig. 3b

By placing the housing unit in position 1.b of Fig. 3, entrance courtyard (a) and the passageway can be incorporated into one space, creating a larger and perhaps more usable courtyard (b).

Case Two. Fig. 3.2

Here the typical site may be even further divided into two smaller lots. Typically, three- to four-story apartments[4] (one apt. unit/floor) have been placed on the two created sites. One disadvantage is that the entrance courtyard (a) does not meet the space requirements for adequate and maneuverable parking space. Secondly, although courtyard (a) may be very useful in the case of a town house, it is both too substantial for the ground level apartment and inaccessible for upper level apartments.

Alternative One. Fig. 3a

This shows the possibility of incorporating the two divided and less usable courtyards (a) and (b) of (2.) into a more spacious one (ab). It also provides for a more efficient courtyard (c) to be accessible at every level for each apartment.

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[4]Art & Architecture, International Edition, #18-19, June - November, 1973, p. 53, (Printed in Tehran, Iran).

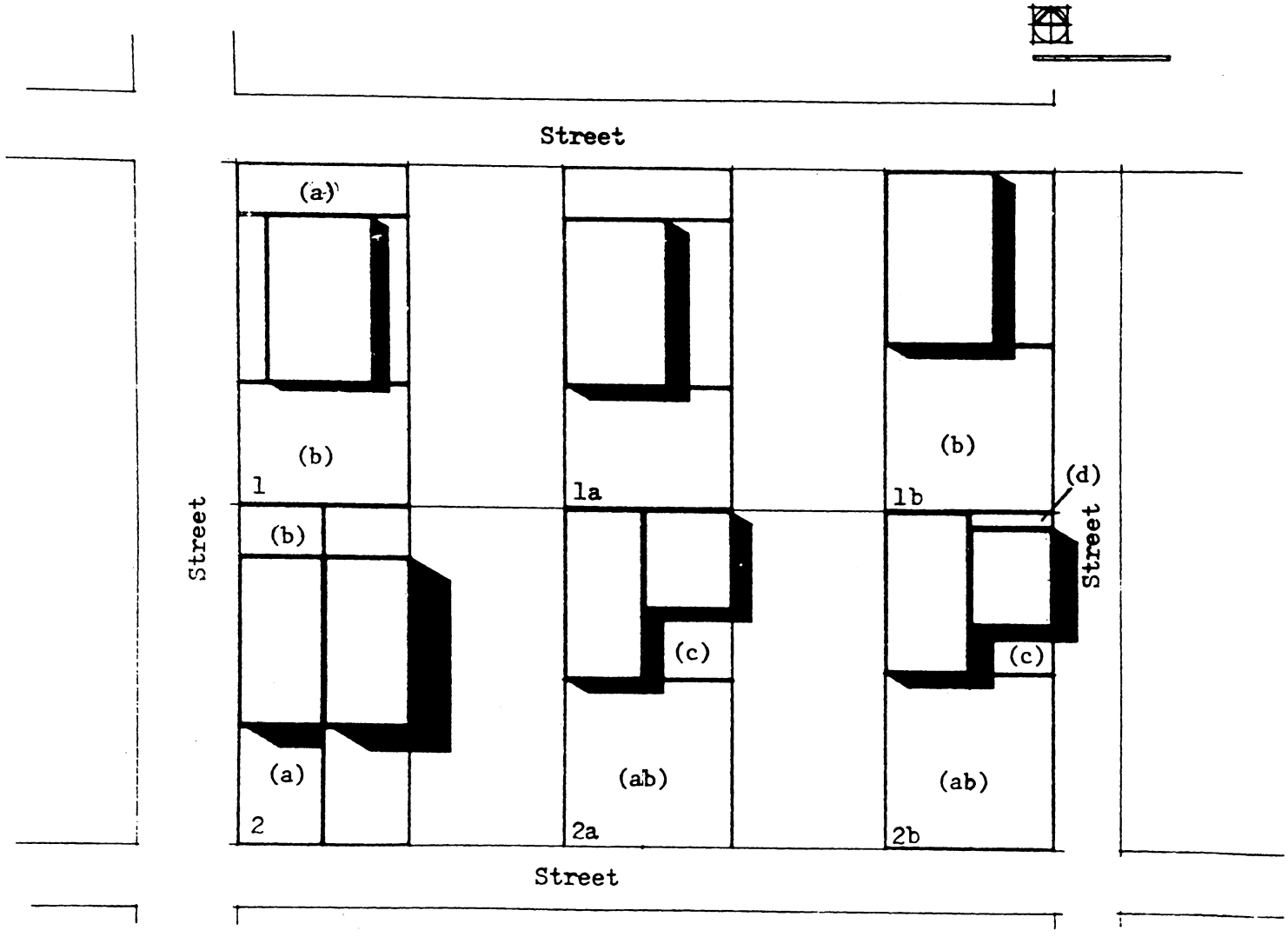



Fig. 3. Analysis of Housing

Alternative Two. Fig. 3b

By staggering apartment units, a sense of individuality is given to every housing unit. This arrangement introduces outdoor areas (c & d) that are immediately accessible from the housing units at every level. In addition, such three-dimensional courtyards (c) or (d) may be oriented towards the communal courtyards (ab) on the ground level for further visual access.

At a large scale, the space (ab) has the potential for integration with all contiguous sites (Fig. 5 , p. 19 ). This arrangement is possible even within the context of the traditional back-to-back sites.

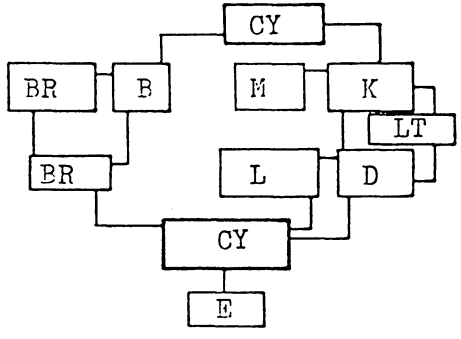
2.2 Internal Organization

Existing Housing: (Micro Scale), Fig. 4

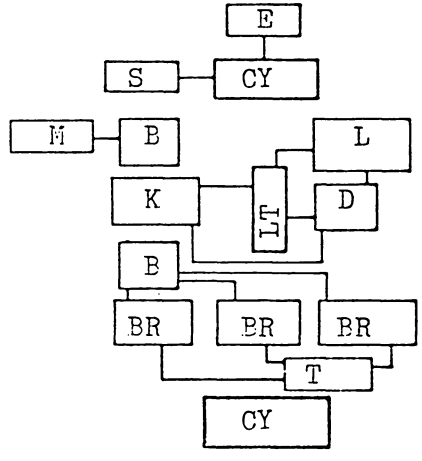
Courtyards, as outdoor living spaces, reflect the predominant aspect of the cultural structure of the traditional houses on both the micro and the macro scales.

Virtually, any other internal spaces depend on these courtyards for light and ventilation or for basic primary orientation. Two kinds of courtyards are often found in the same housing unit with two distinct functions. The primary one is larger and has a southern orientation; the secondary courtyard serves as either the entrance or the back yard area, depending upon the location of its site. Fig. 4.1.

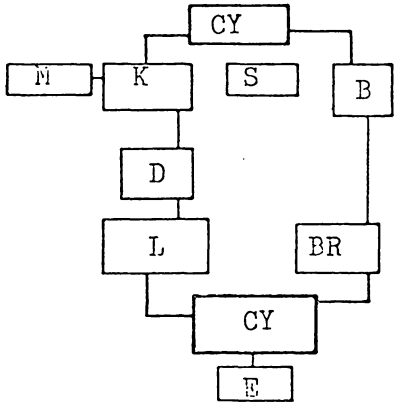
4.1 Town House




4.2 Apartment




4.3 Town House; floor one




B - bath
BR - bedroom
CY - Courtyard
D - Dining
E - entrance
L - Living Room
LT - light shaft
M - mechanical
S - stairs
T - terrace
U - utility

4.4 Town House; floor two

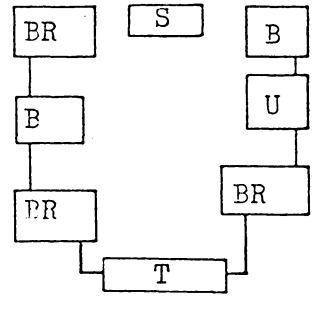



Fig. 4. Existing Housing

In a case of a typical two-story town house, the living, dining, kitchen and bathroom areas are on the same level with the courtyard, whereas the bedroom and bathroom areas, with access to the terrace, are on the upper floor. Fig. 4.3.

For a typical apartment building with a limited front lot dimension, the bedrooms are generally found on the south side. On the other hand, the living room, dining room and kitchen areas have a northern exposure. Fig.4.2. The courtyards are not readily accessible spaces for apartments on the upper floor. In addition, for most of the three- to four-story apartment buildings, the floor plans are identical on every floor, allowing for no variation in living room size or number of bedrooms. Obviously, this means that there is no consideration for families with different spacial needs.

## 2.3 Design Considerations

The proposed scheme should respond to the socio-cultural, economic and climatic parameters of Iran. In particular, it is important that viable characteristics of traditional housing be incorporated in new designs. These features include the compact configuration of urban fabric, the courtyard as an extension of interior living areas, and the desire for individual family privacy regardless of size.

The option of having several generations living in close proximity - a socio-cultural tradition of the past - should be provided for in the

housing design of today. The design proposals should accommodate both the large, traditional, as well as the increasingly more prevalent nuclear family structures. In addition, new proposals should provide means for achieving accoustical privacy during early design stages.

3. Housing Groups

Traditionally, three- to four-story apartment buildings have been placed on typically rectangular back-to-back sites, adjoining town houses in blocks. A residential street extends the length of each block and the entrance to each housing unit is through the facade of the courtyard.

At present, groups of residential streets typically extending the length of each block from east to west, define the boundaries of each neighborhood.

Because of limited site conditions in the urban areas, houses are built right next to each other. The net result is that there is little individuality to the houses. Viewing the over all pattern in which houses are located on the individual sites, it becomes apparent that many spaces surrounding the housing units are not fully utilized. It is evident, then, that the high cost and scarcity of urban land calls for not only a more economical way of constructing individual housing units and multiple dwelling units, but also a method of design which optimizes the space in accordance with the socio-cultural patterns.

3.1 Planning Goals

The criteria outlined in this thesis is to respond to the architectural needs of a growing nuclear, lower middle and middle income family structure that has deviated from the traditional lifestyle of the Iranian family. Hence, the growing concern for privacy, a sense of individuality within the context of community living, and protection from extreme climatic conditions should be relevant factors in the design process.

Since there is a lack of available land for more suitable housing in urban Iran, one possible solution to the problem would be to reclaim land used for other purposes. For example, if a mass rapid transit system were introduced, less space would be needed for automobiles and more could be given over to housing projects. In the process, the already congested traffic problem in urban areas could be relieved.[5]

It should be noted that the concentration of the professionally educated is greater in Tehran than in other urban areas of Iran. Table 1. Thus, it would be reasonable to implement new design concepts among those who would be more amenable to change, given a greater appreciation for aesthetic qualities of design. Where there is a heavy population

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[5]Art & Architecture, International Edition, #18-19, June - November, 1973, p. 73, (Printed in Tehran, Iran).

Table 1
% Educated City Dwellers of Tehran
Compared with Total Population of All Urban Centers

| Job Classification | % |
|---|---|
| Human Science | 40.1 |
| Education | 46.9 |
| Fine Arts | 79.9 |
| Law | 63.3 |
| Social Science | 61.7 |
| Natural Science | 45.3 |
| Engineering | 52.2 |
| Medicine | 53.1 |
| Agriculture | 26.1 |

NOTE: For example, 53.1% of all city doctors of the whole nation live in Tehran.

Source: Art & Architecture, #21, March-April, 1974, p. 48, (Printed in Tehran, Iran).

concentration and a hot-dry climate, such as in Tehran, there is the need for open spaces. It is also important to provide a variety of designs, siting layouts, and community outdoor spaces that enhance the dynamic qualities of urbanism and is compatible with the existing urban fabric. Individual identity to each housing unit can avoid the uniformity of such units and the continuous wall of rows of apartments. Thus, a design goal is to create a staggering progression of entrance conditions into each housing unit. There should also be a transition from street to housing unit by providing distinct spacial sequences. Moreover, a transition space which serves several units offers the potential for social interaction.

The housing should be oriented to provide cool, outdoor areas on the site so that the cool summer breezes can naturally ventilate the housing units and their exterior spaces. Such exterior spaces should also have protection from winter winds.

## 3.2 Design Approach

### Macro Scale

In an attempt to achieve higher density of housing, the siting of a typical town block has already been studied. This includes the study of the relationship between the existing individual town houses and their sites. Secondly, an investigation of the ways in which some important

characteristics of the existing town houses (such as the private courtyards) may be maintained and incorporated into the design of cluster housing at a much higher density.

With the proposed siting, certain conditions will be altered to allow for a higher density of dwelling units within the fabric of the existing neighborhoods. Fig. 5 . Existing street patterns will remain unchanged, thereby delimiting the context in which large-scale housing can be sited. These streets will serve as access and entrance points for designated parking areas located near the housing units. In conditions where there are high rises without adequate parking, additional parking will be designated adjacent to the high rise.

By staggering the rows of housing units at the site plan and varying the height of the buildings gradually, alternative massing solutions can be created. Also, see Fig. 7 . In summary, such variations should eliminate linearity, define entry configurations, and increase individual identification within clusters.

Another way of achieving alternative massing configurations is by stepping up portions of the housing units. Fig. 8 . A visual transition is created symbolically, offering a continuity between the high and low rise units. Portions of the roof of the lower units can be used as small, protected private courtyards. This is a functional utilization within the revised scheme that carries the traditional concept of

courtyards and ensures that revered traditions of the past can be integrated into new designs.

The walls of the traditional courtyards can also be utilized in various configurations with clusters of housing to enclose outdoor community spaces. The outdoor community space (ab), Fig. 5 has been confined by the walls and a limited number of clusters. The size of the outdoor communal spaces (such as ab) is flexible and its scale would depend upon the density of the surrounding clusters.

Site planning should be implemented to provide an enclosed communal entrance with spacial sequences for groups of housing on a neighborhood block. A transitional space (enclosed staircase) placed in between housing units would facilitate the access from the street or parking area to the individual units. Such a staircase would provide direct access from any unit to the typical outdoor space (ab). The use of outdoor areas would thereby increase. The circulation access from the center offers flexibility in terms of the design of each unit. The aspect can be seen in the organizational relationship of Fig. 12.

Although the thesis primarily deals with high density housing, the option of providing town houses has also been considered. Planning concepts for such town houses should be compact in response to the scarcity and the high cost of urban land.

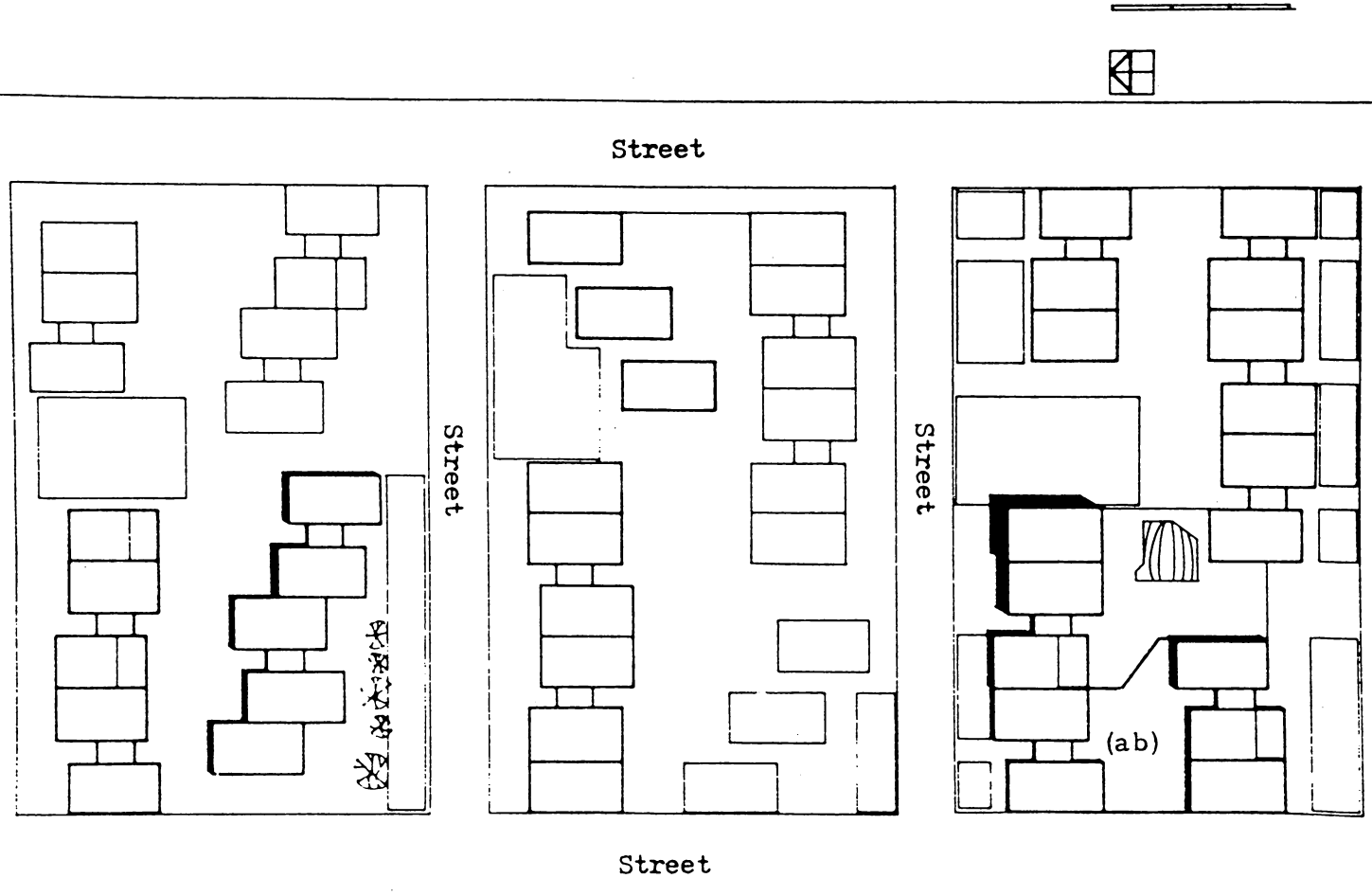


Fig. 5. Variation in Siting

4. Physical Environment

Iran consists of three distinct geographical regions. The North, bounded by the Caspian Sea, and a mountainous terrain is sub-tropical with hardwood forests. The Iranian plateau region to the South with its barren mountains is characterized by long periods of heat and dryness. In contrast, the Persian Gulf coastal is a humid, sandy region studded with date palms.[6]

Mean Annual Precipitation (in inches):[7]

| | |
|---|---|
| Coastal North and West | - 20-30 |
| Central and East | - 4-8 |
| South | - 8-12 |

Mean Temperature (in fahrenheit):

Upper Range - Over 86°
Lower Range - below 50°

Mean Humidity (in MM. of H. G.):

Under 15

The capital city of Tehran has a latitude of 35.4° North and a longitude of 51.26 East. More detailed climatic data for Tehran are

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[6]"Environment - Iran", Art & Architecture, International Edition, #18-19, June-November, 1973, p. 67, (Printed in Tehran, Iran).

[7]The Times Atlas of the World, Comprehensive Edition, World Climatology, 1972, p. 4, (John Bartholomew & Son, Ltd.).

Table 2
Climate Data for Tehran

| | | JAN | FEB | MAR | APR | MAY | JUN | JULY | AUG | SEP | OCT | NOV | DEC | TOT | MEAN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp. | Max. | 48.2 | 51.8 | 59 | 71.6 | 82.4 | 91.4 | 96.8 | 95 | 87.8 | 75.2 | 59 | 50 | | |
| | Min. | 30.2 | 32 | 39.2 | 50 | 59 | 62.2 | 71.6 | 71.6 | 64.4 | 53.6 | 37 | 32 | | |
| Rain Fall | | 31 | 29 | 35 | 35 | 14 | 3 | 0 | 2 | 2 | 8 | 38 | 24 | 224 | |
| Rainy Days | | 4 | 4 | 5 | 3 | 2 | 1 | 0 | 1 | 1 | 1 | 3 | 4 | 29 | |
| % R. Humidity | | 76 | 64 | 44 | 46 | 51 | 50 | 47 | 49 | 50 | 54 | 66 | 77 | | |
| Cloudiness | | 4 | 5 | 4 | 4 | 4 | 1 | 1 | 1 | 1 | 2 | 4 | 4 | | 3 |

Rainfall is in milimeter
Cloudiness is in tenth of sky covered

Source: Fisher, W.B., The Middle East, 1961 and 1971, p. 280-281, Butler and Tanner, Ltd., London.

listed in Table 2 . Also, refer to 7.2.1 for a discussion of design criteria for comfort systems as correlated with the physical environmental factors.

4.1 Interpretation of the Climatic Data

Clear skies, relatively long over-heated diurnal periods with a wide range of temperatures and dryness characterize the environment of the arid climate. Dryness is typical throughout most months of the year. Thus, it is important that water be conserved and rainfall collected. Low humidity conditions are conducive to the application of evaporative cooling principles. The design temperatures should be based upon the peak summer and lowest winter data.

4.2 Functional Response

Large spaces (such as living rooms) should have a southern exposure to gain the maximum amount of solar heat during the winter when the sun is at a low position (35° latitude). Fig. 21 . The rays of the summer sun coming from a much higher altitude may be blocked so that spaces are maintained at a comfortable temperature.

The flat roof in Iran is a space to be used during summer months for sleeping or entertaining purposes. Its form also responds to the limited rainfall that occurs in a dry climate. Fig. 6 . Maximum heat radiation, from ground to sky, occurs on clear nights and creates a cooling effect.

The western sun intensity creates critical heating loads in the summer for spaces that have major western exposures. To minimize heat gain, protective devices may be used on the western sides. Cross ventilation is also desirable to maintain comfortable temperatures within the dwelling units.

4.2.1 Town Structure

The walls of housing units should provide shade for outdoor living areas. Unit dwelling or groups should create courtyard-like areas in the shade (notice the orientation and design sketch of Fig. 7 ). Because concentration is desired, the town structure should respond to severe heat with a shaded and dense layout,[8] so that heat loss, rather than heat gain, should be the objective. Therefore, compact building arrangements around green areas utilizing evaporative cooling effects are preferred. Group arrangements should be continuous from east to west to create a volumetric effect.[9] The same conditions are optimal during the winter to prevent heat loss in buildings.

4.2.2 Public spaces

Pools of water and green spaces create a much more pleasant environment for outdoor activity than do paved surfaces. Fig. 5.

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[8]Victor Olgay, General Objectives in the Hot-Arid Region, Design with Climate, p. 167.

[9]Ibid.

Where vegetation is scarce, grass-covered and floral areas should be developed. These should provide shade in the summer and not block the sunshine in the winter. Vegetation is desirable for its radiation absorbancy, its evaporative characteristics and the shade it provides.

4.2.3 Orientation

Considering the above climatic factors, all exposures from south to 35° south east[10] are therefore desirable. In the summer, deep spaces offer a cool alternative to the intense outdoor heat. Accumulated hot air should be released through openings that are placed at ceiling heights. Spaces that are adjacent to courtyards are cooled by the summer breezes. Roof spaces should not be used as attics in hot climates.[11] Fig. 6.

Bright surfaces are appropriate when high reflection is needed to prevent heat from penetrating in the space. In contrast, dark surfaces may be used to absorb the sun's rays for winter heating.

4.2.4 Capacity Insulation

The principle is that protection from heat gain in the summer is equally as important as that of heat loss in the winter. Heat storage

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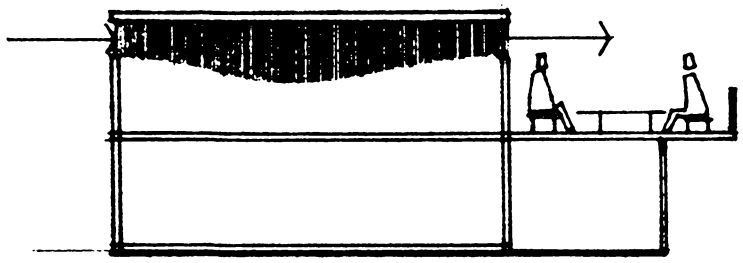
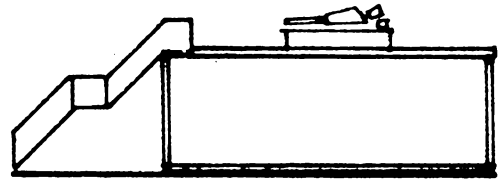
[10]Victor Olgay, General Objectives in the Hot-Arid Region, Design with Climate, p. 167.

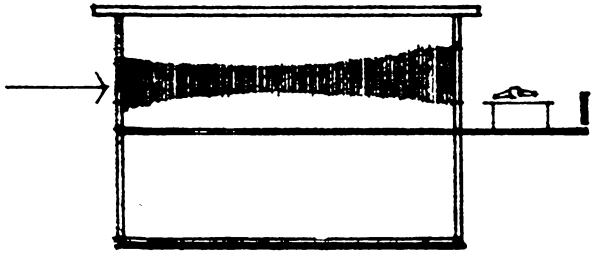
[11]"Housing as Climatic Protection in Hot-Dry Environments", Physiological Objectives in Hot Weather Housing, p. 43.



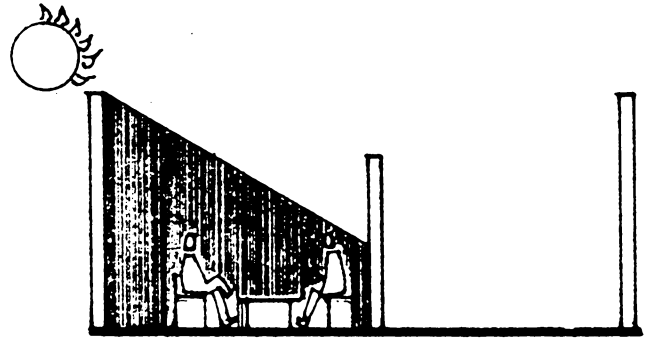
(1) Reducing human heat production; terraces function as outdoor living spaces.



(2) Radiation to dark sky is condusive to sleeping outdoors.



(3) Balconies are as effective when accessible from the bedrooms



(4) West wall shades the courtyard.

Fig. 6. Functional Response

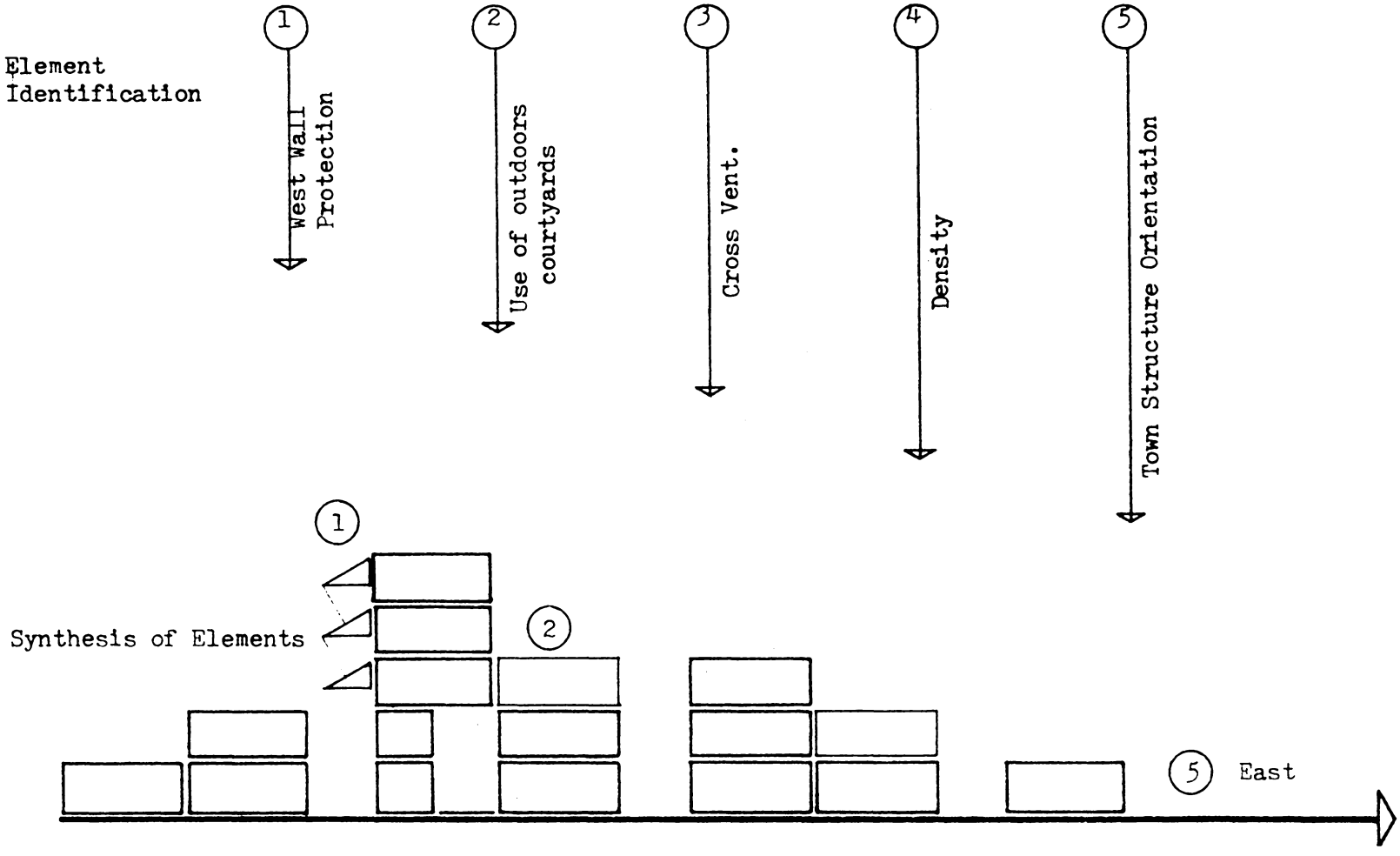



Fig. 7. Synthesis of Elements

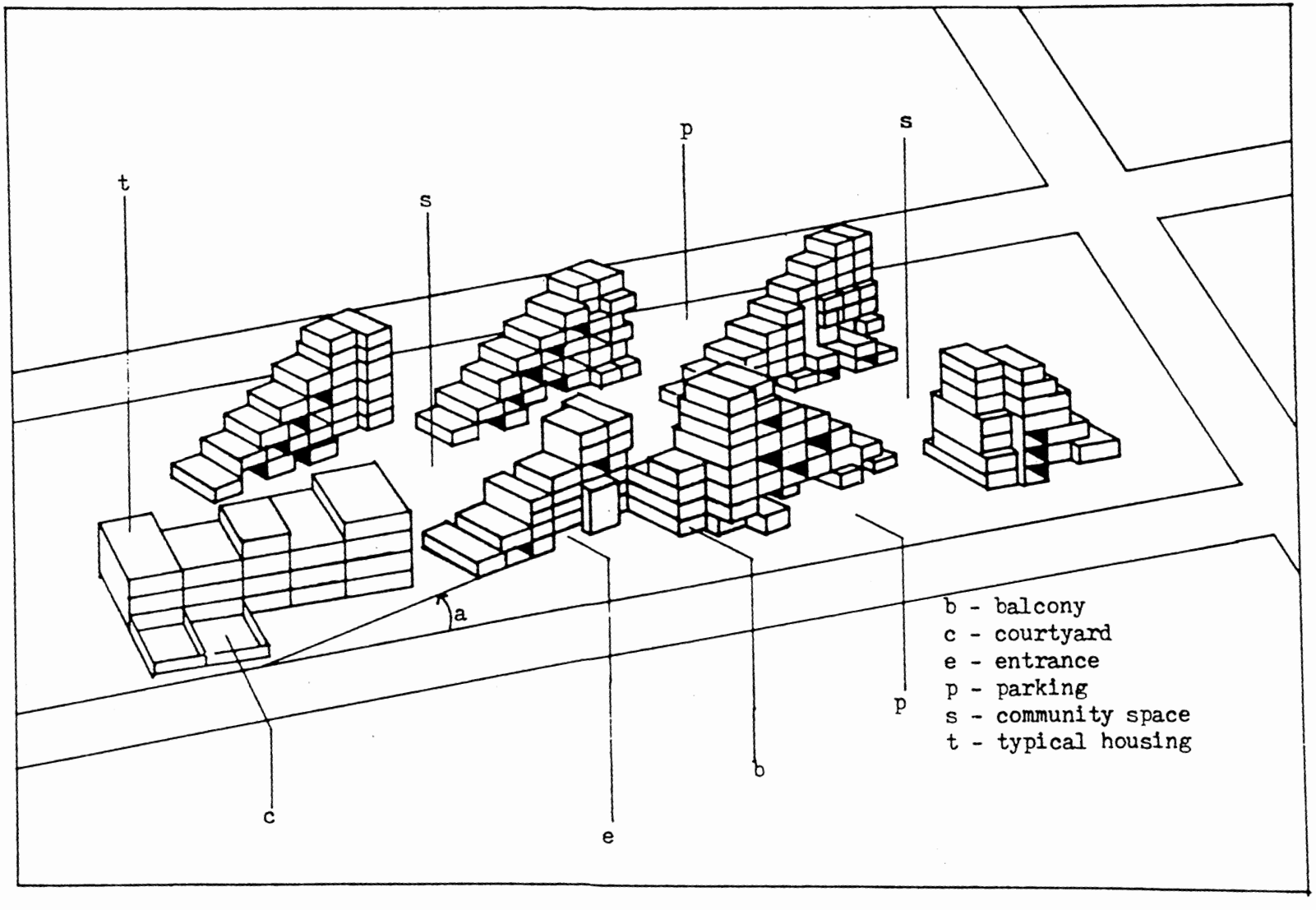



Fig. 8. Massing

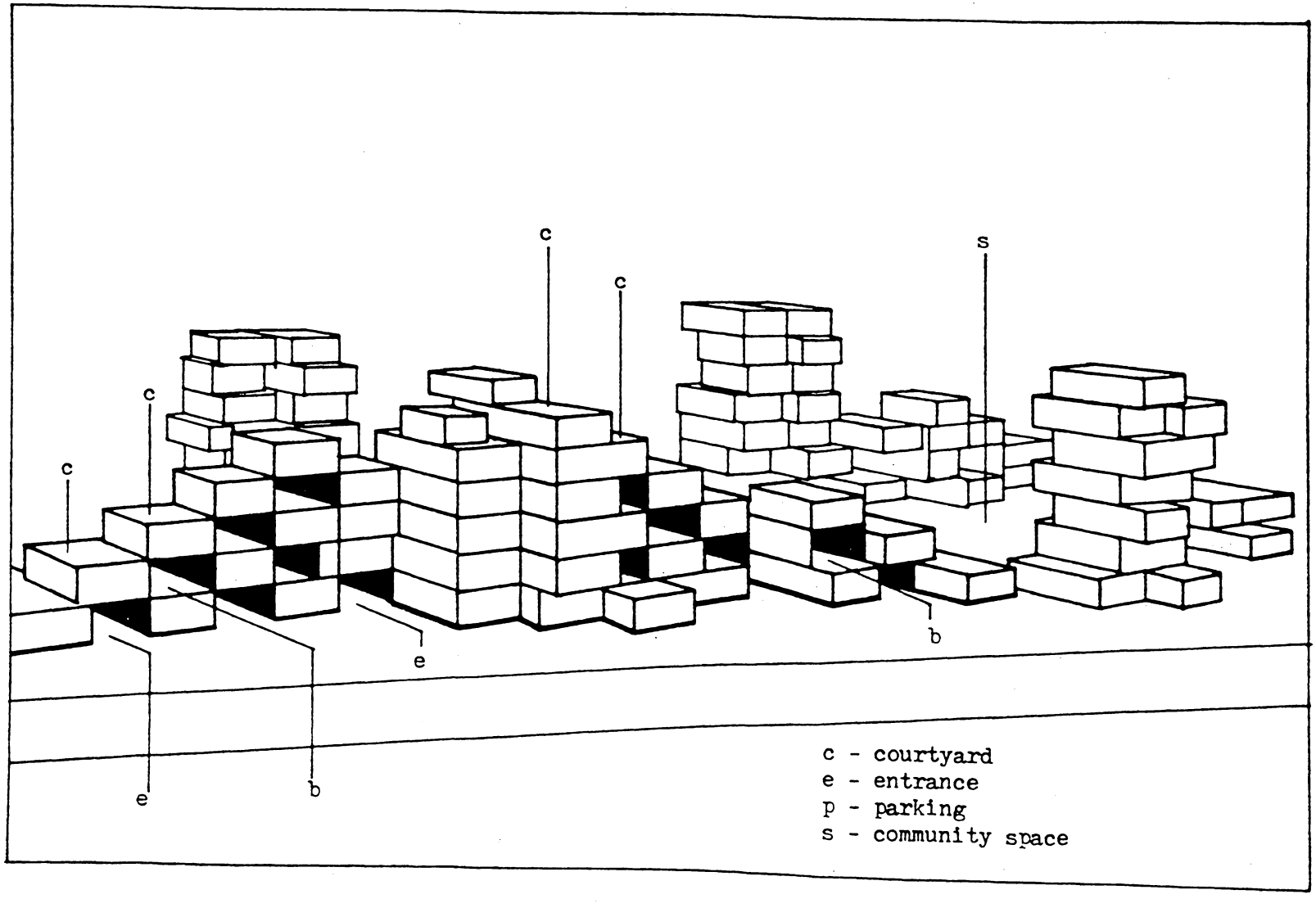



Fig. 9. Alternative

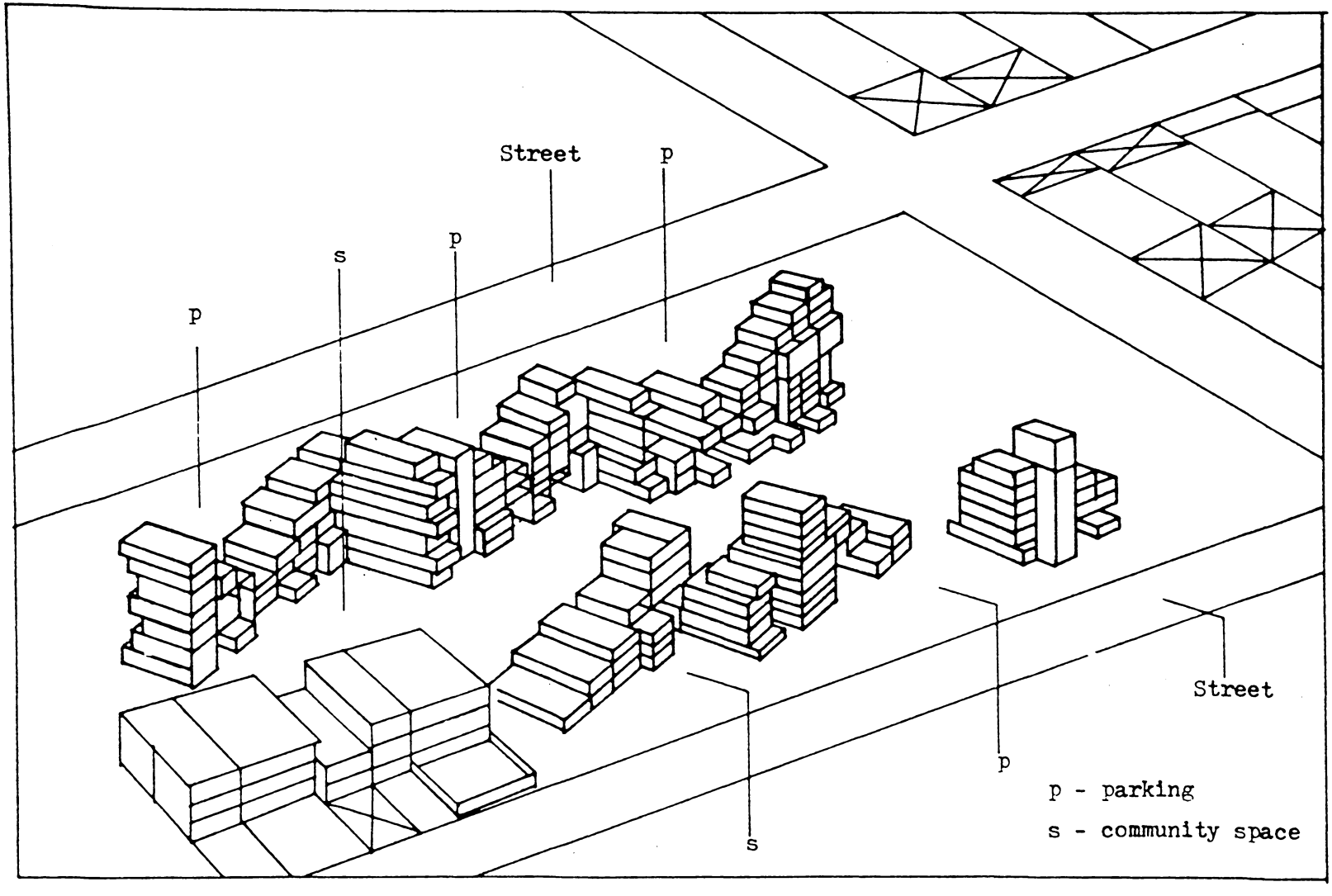



Fig. 10. Alternative

or capacity insulation that uses materials of low thermal diffusity rather than low thermal conductivity delays the transmission of radiant heat applied periodically to the exterior.[12]

4.2.5 Evaporative Cooling

When air is passed over water, evaporation takes place. The air will be cooled, but its vapor content increases. Under hot, dry conditions, this phenomenon is effective. However, for warm, dry conditions, refrigerant instead of evaporative cooling should be used.[13]

5. Building Systems Criteria

The criteria discussed in this section emphasizes certain aspects of systems buildings components that should be enhanced to maximize flexibility in buildings. Although numerous design criteria may be stated, the purpose here is to specifically outline the arrangement and the relationship between the spaces in order to achieve greater flexibility in apartment housing.[14]

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[12]"Housing as Climatic Protection in Hot-Dry Environments", Physiological Objectives in Hot Weather Housing, p. 58.

[13]Ibid, p. 43.

[14]Andrew Rabenech, David Sheppard, Peter Town, "The Structuring of Space in Family Housing: An Alternative to Present Design Practice, Progressive Architecture, November, 1974, pp. 100-103, (Building Systems Development, London).

The system should be able to provide many different designs and plans with as few components as possible. The variations in design will be able to house different family sizes with different kinds of needs and living patterns. Plan forms should allow a variety of possible interconnections between rooms. By providing more than one means of access to a given space, its potential use is enhanced. In all cases, there should be adequate usable outdoor, as well as indoor spaces. For example, balcony areas should have access from a number of spaces.

One objective is to find practical ways of adding and/or subtracting spaces as family needs change. Rooms and spaces within the unit should avoid extremes in size. This is a criterion that responds to user needs by providing the right amount of space for the actual functional use. Since at present there is no code or minimum standards, a table of minimum requirements as specified by the Department of Housing and Urban Development has been listed in Table 3. It is to serve as a starting point with the understanding that new designs may well extend beyond the conservative minimum requirements.

Rooms should also be neutral in terms of form, i.e., simple volumes. This concept implies that spaces such as living, dining and bedrooms should provide more flixibility in terms of furniture arrangement according to user needs. Often certain designs limit the ways in which a space may be used.

Table 3. Minimum Requirements

Minimum sizes for separate rooms

| Names of Space (1) | Minimum Area (Sq. Ft.) | | | | | |
|---|---|---|---|---|---|---|
| | LU with 0-BR | LU with 1-BR | LU with 2-BR | LU with 3-BR | LU with 4-BR | Least Dimension |
| LR | NA | 160 | 160 | 170 | 180 | 11' - 0" |
| DR | NA | 100 | 100 | 110 | 120 | 8' - 4" |
| BR (Primary) (2) | NA | 120 | 120 | 120 | 120 | 9' - 4" |
| BR (Secondary) | NA | NA | 80 | 80 | 80 | 8' - 0" |
| Total Area, BR's | NA | 120 | 200 | 280 | 380 | |
| OHR | NA | 80 | 80 | 80 | 80 | 8' - 0" |

Minimum sizes for combined spaces

| Combined Space | LU with 0-BR | LU with 1-BR | LU with 2-BR | LU with 3-BR | LU with 4-BR | Least Dimension(3) |
|---|---|---|---|---|---|---|
| LR-DA | NA | 210 | 210 | 230 | 250 | |
| LR-DA-SL | 250 | NA | NA | NA | NA | |
| LR-DA-K (5) | NA | 270 | 270 | 300 | 330 | |
| LR-SL | 210 | NA | NA | NA | NA | |
| K DA (6) | 100 | 120 | 120 | 140 | 160 | |

Abbreviations: BR - Bedroom; LR - Living Room; SL - Sleeping Area; DA - Dining Area; LU - Living Unit; 0-BR - LU with no separate bedroom; DR - Dining Room; NA - Not applicable; K - Kitchen; OHR - Other Habitable Rooms

(2) Primary bedrooms shall have at least one uninterrupted wall space of at least 10 ft.

Source: HUD Min. Property Standards, Multi Family Housing, US. Dept. of Housing and Urban Development, Vol. 2, 1973 Ed.

Doors and windows should be located so that the rooms can be used in a variety of ways. Openings may appear anywhere along the wall panels without any fixed pattern. This would then permit the placement of windows at any point along the width or height of the panels to meet user needs in the space. Moreover, space limiting physical constraints such as fixed ceiling lights should be avoided.

The plan form should allow many different allocations of functions to rooms, and variety of zoning possibilities. For example, a storage space can be adaptable for use as a utility room in a housing unit. A wide range of alternative uses of space are then possible at a minimum cost. Either a utility room should be provided, or kitchens or bathrooms should be large enough to house domestic equipment and appliances. An extra room should be provided for use as a secondary living room, guest room, study, play room or office space.

Building subsystems equipment or furniture should not be incorporated in the building components (wall panels, slabs, etc.), although they may be supplied as part of the building contract. Certain components of the building system should be adaptable so that they can be produced on site if the cost of transportation is an important factor. The building configuration should allow for minimum alteration costs should there be a need for additional expansion of the building.

# 6. Proposed System

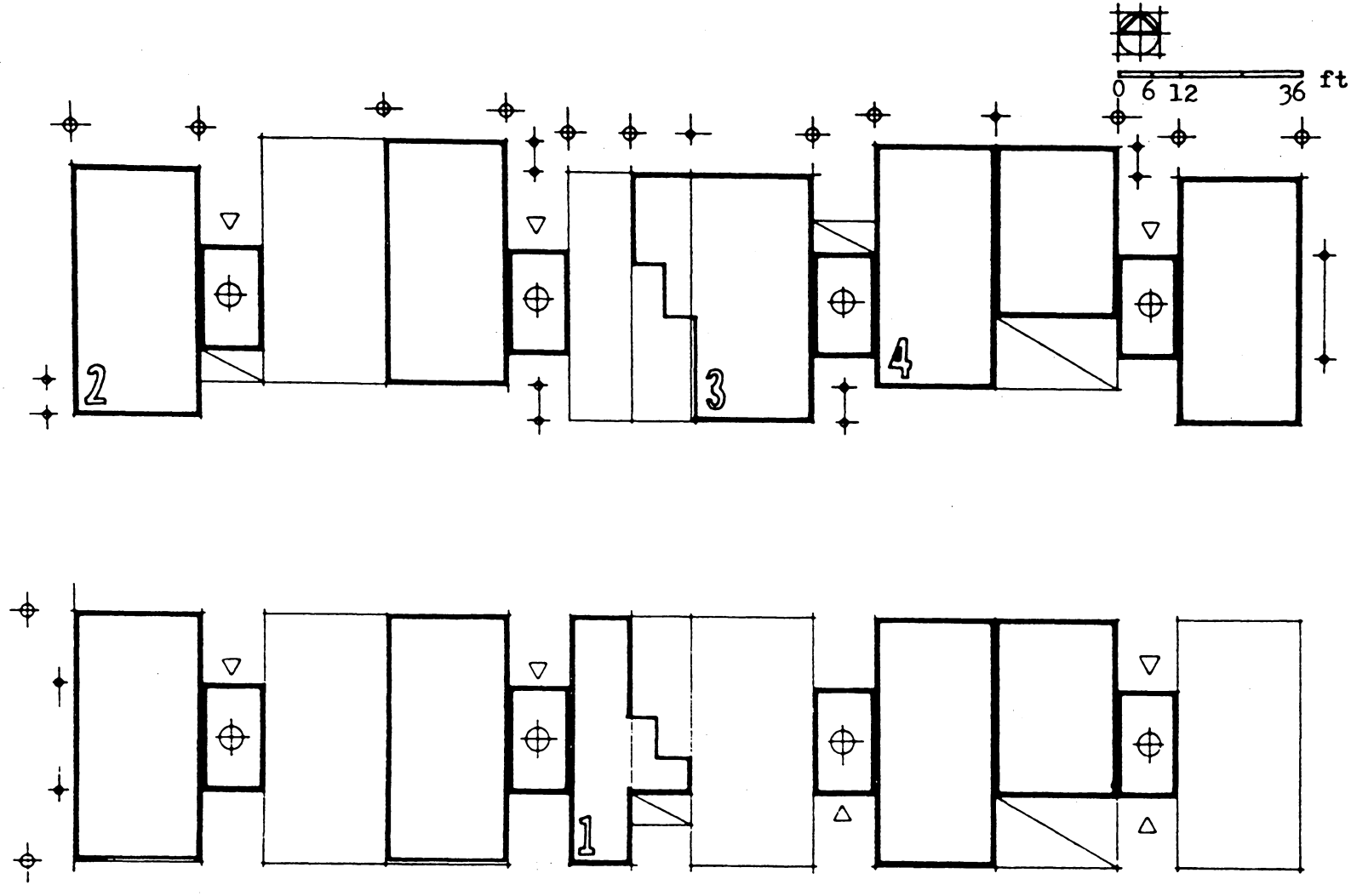



Fig. 11. Plan Variation

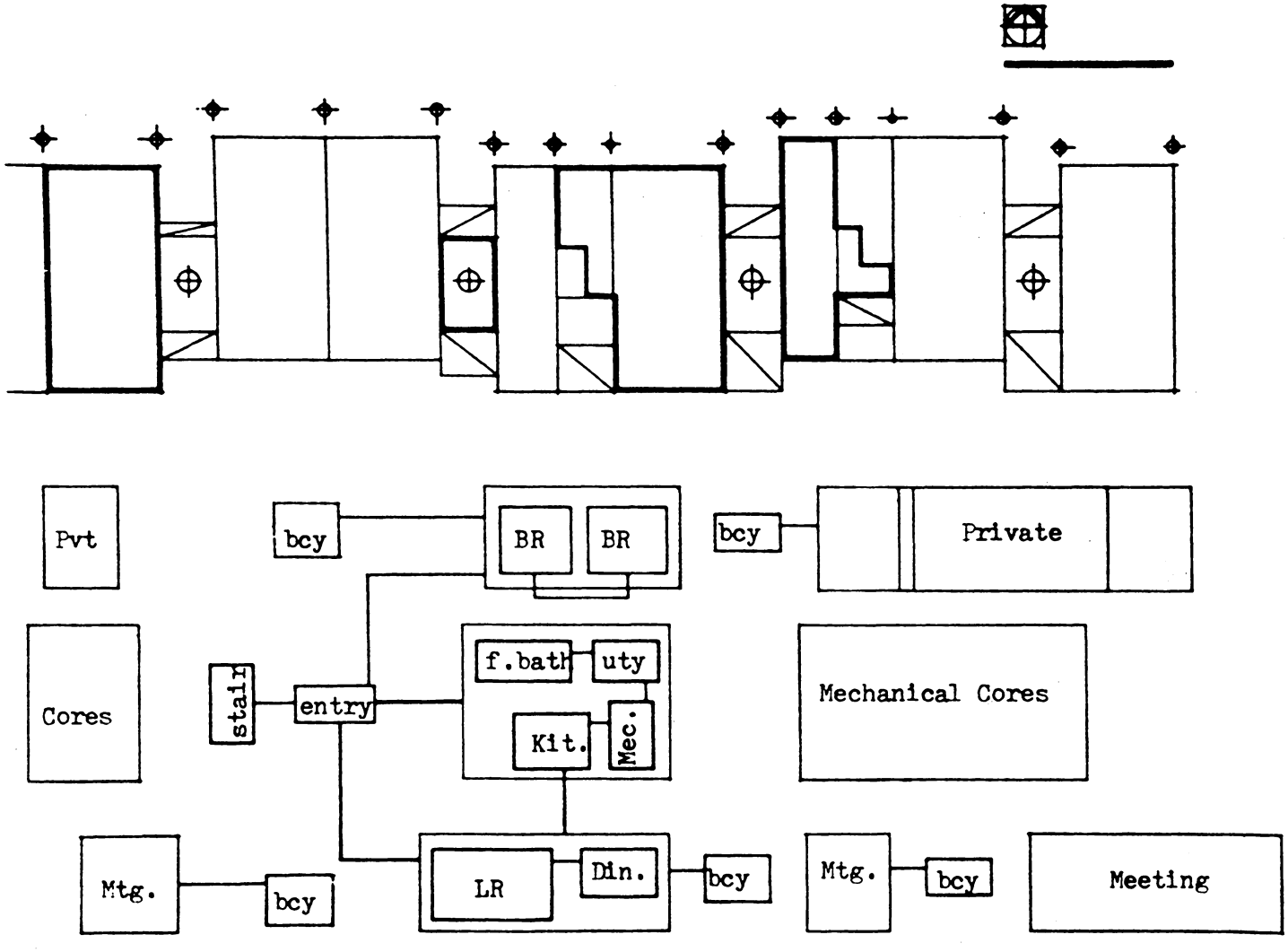



Fig. 12. Organization Relationship

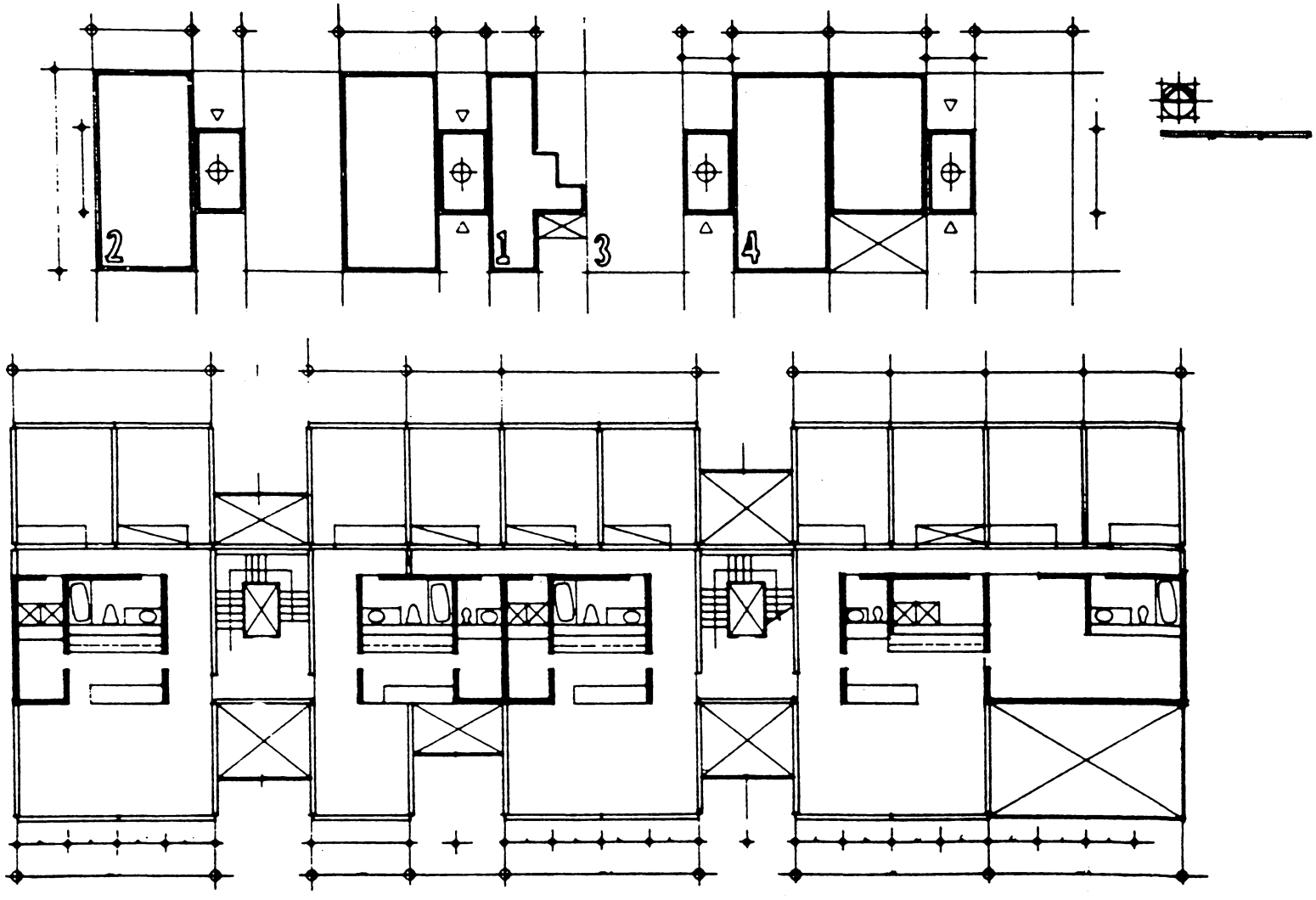
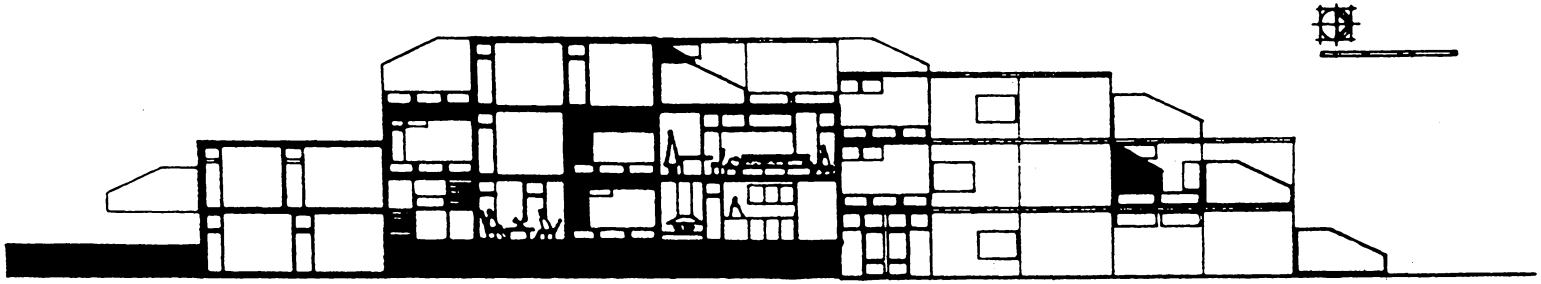
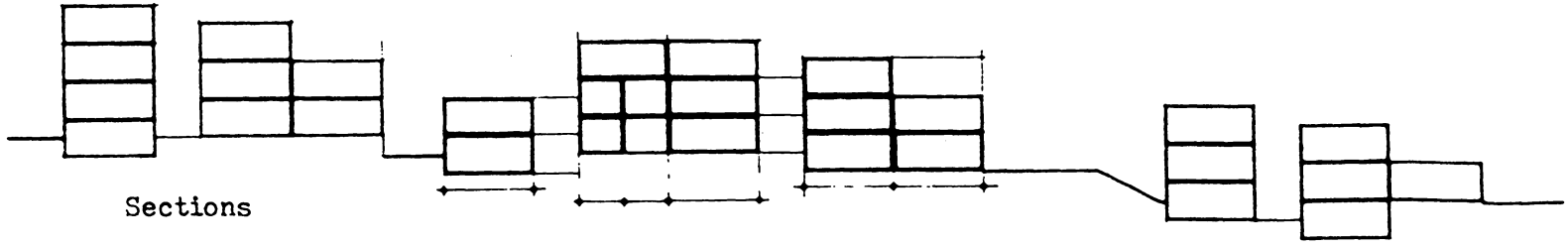



Fig. 13. Plan Arrangement



Elevation/Section





Sections

Fig. 14. Elevation Section

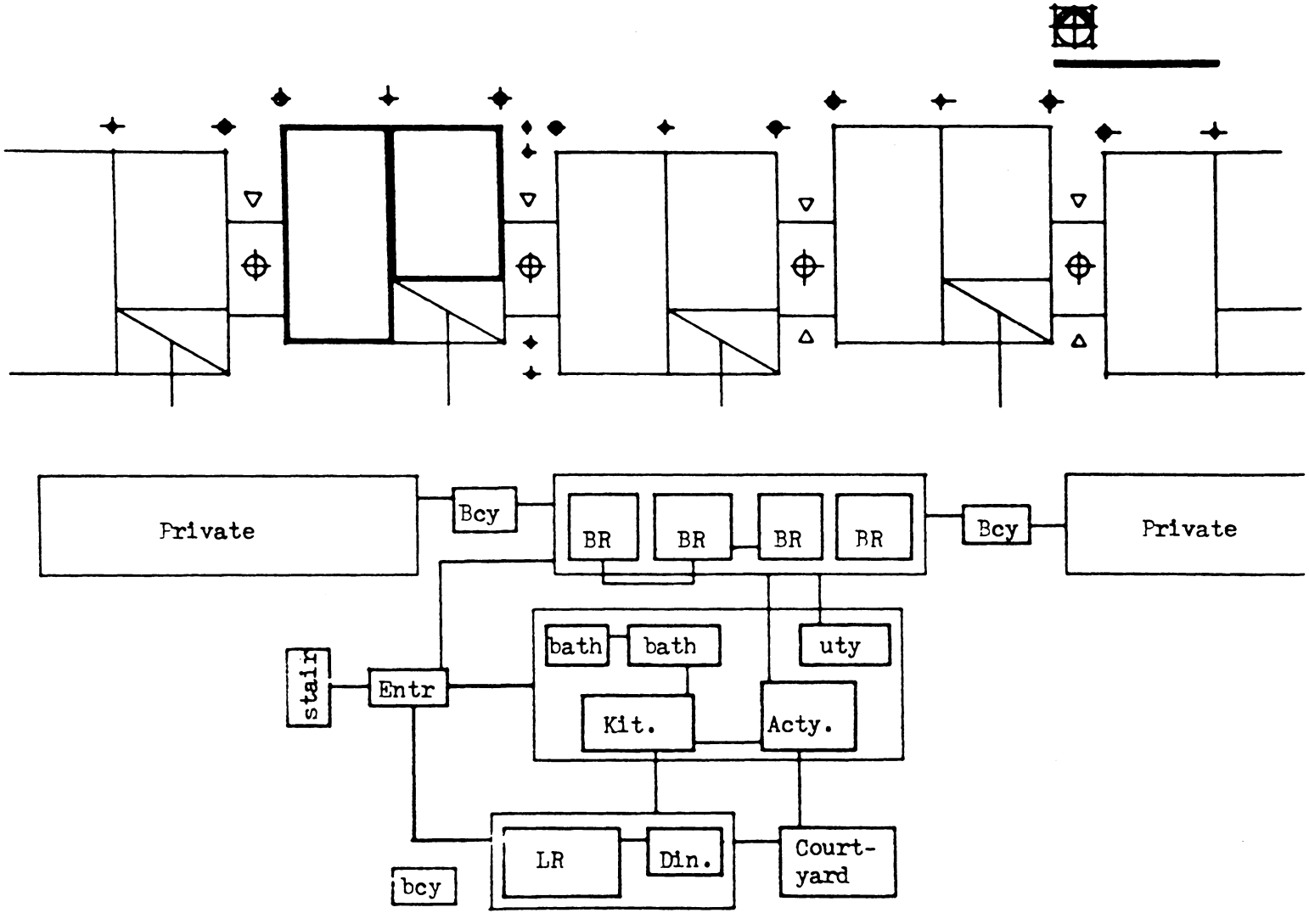



Fig. 15. Organization Relationship (Largest Unit)

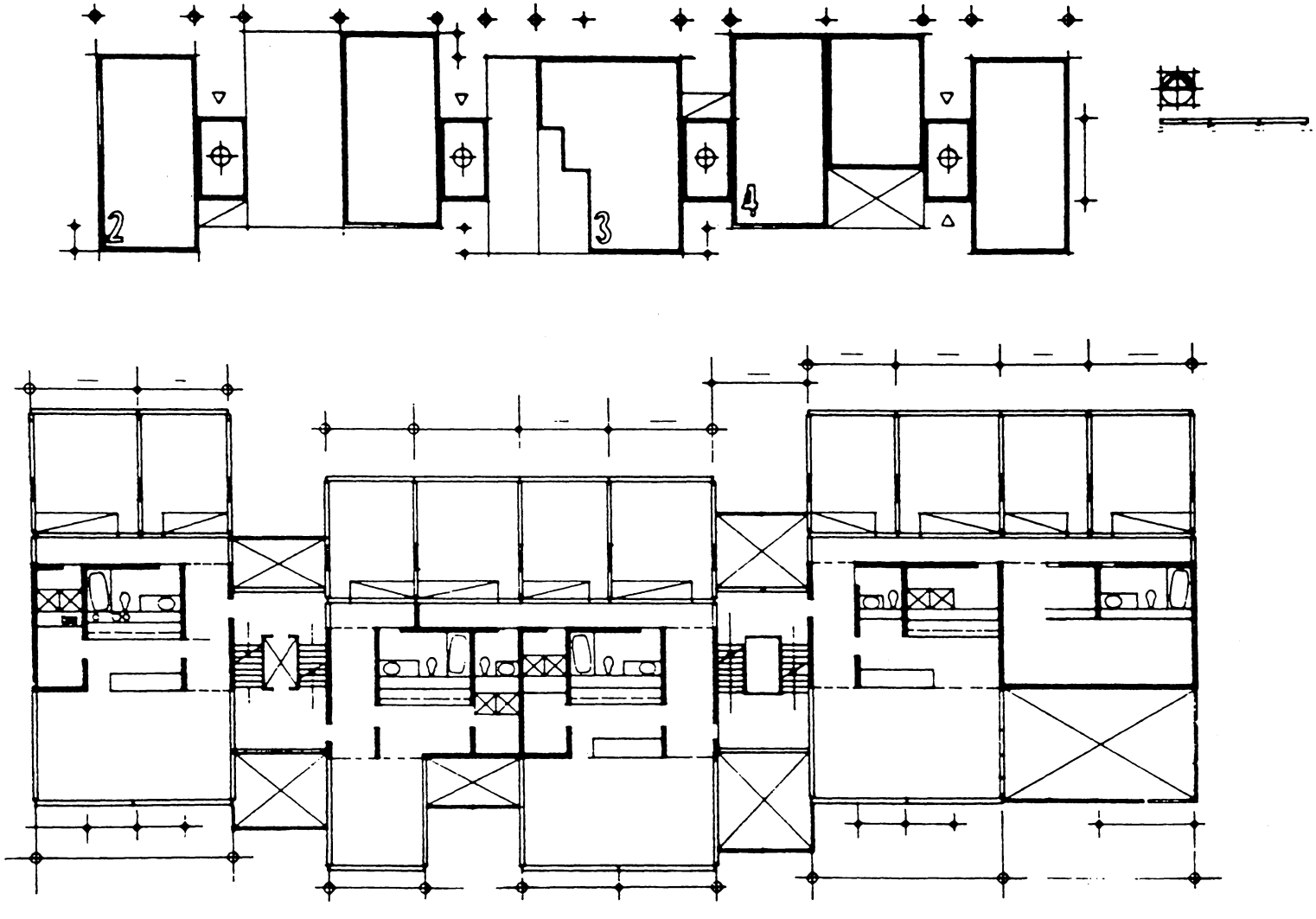
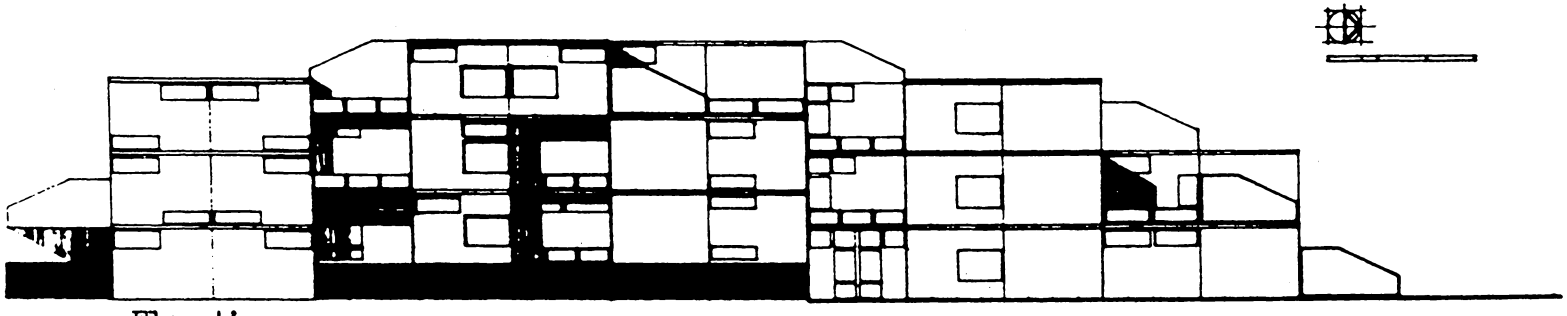
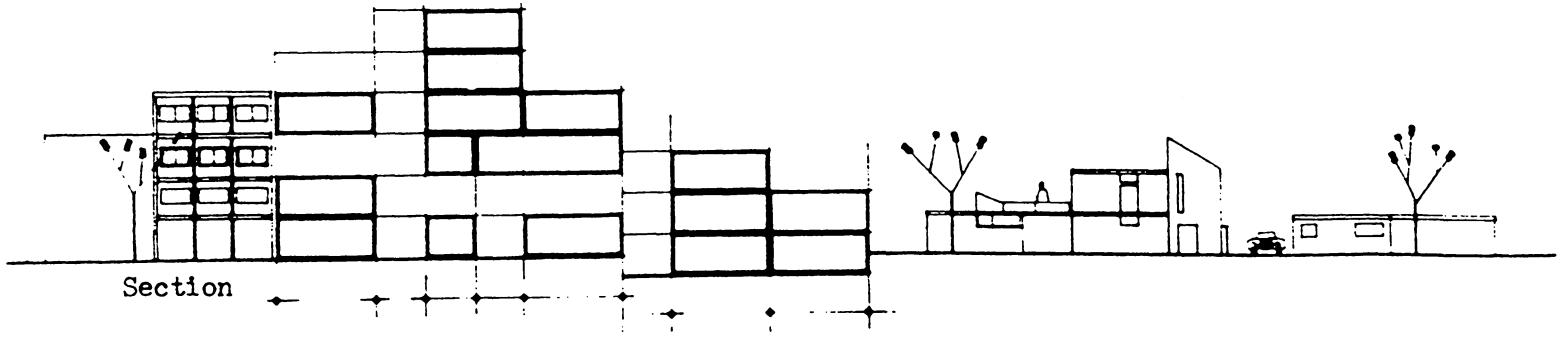



Fig. 16. Alternative



Elevation



Section

Fig. 17. Elevation Section

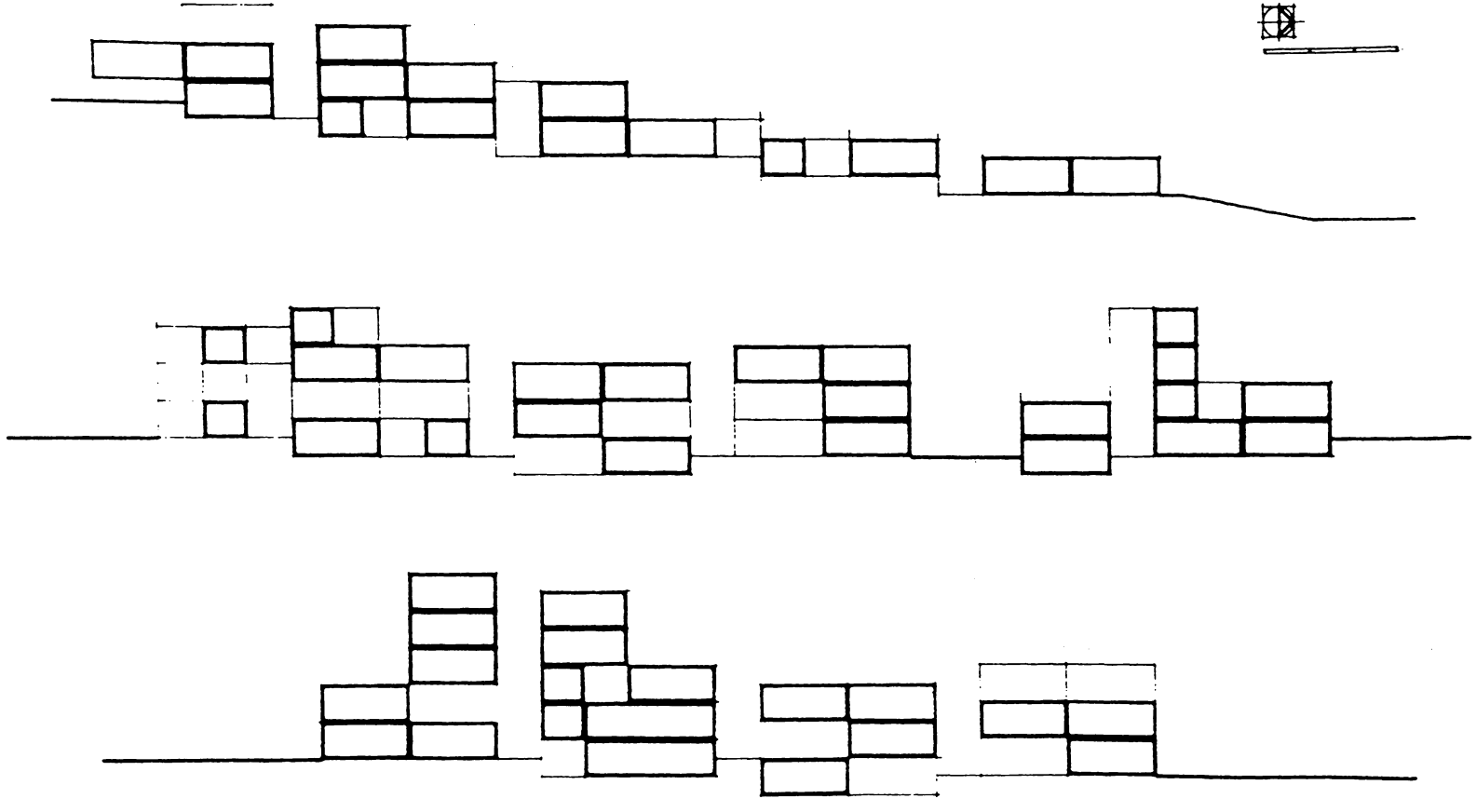


Fig. 18. Combinational Flexibility

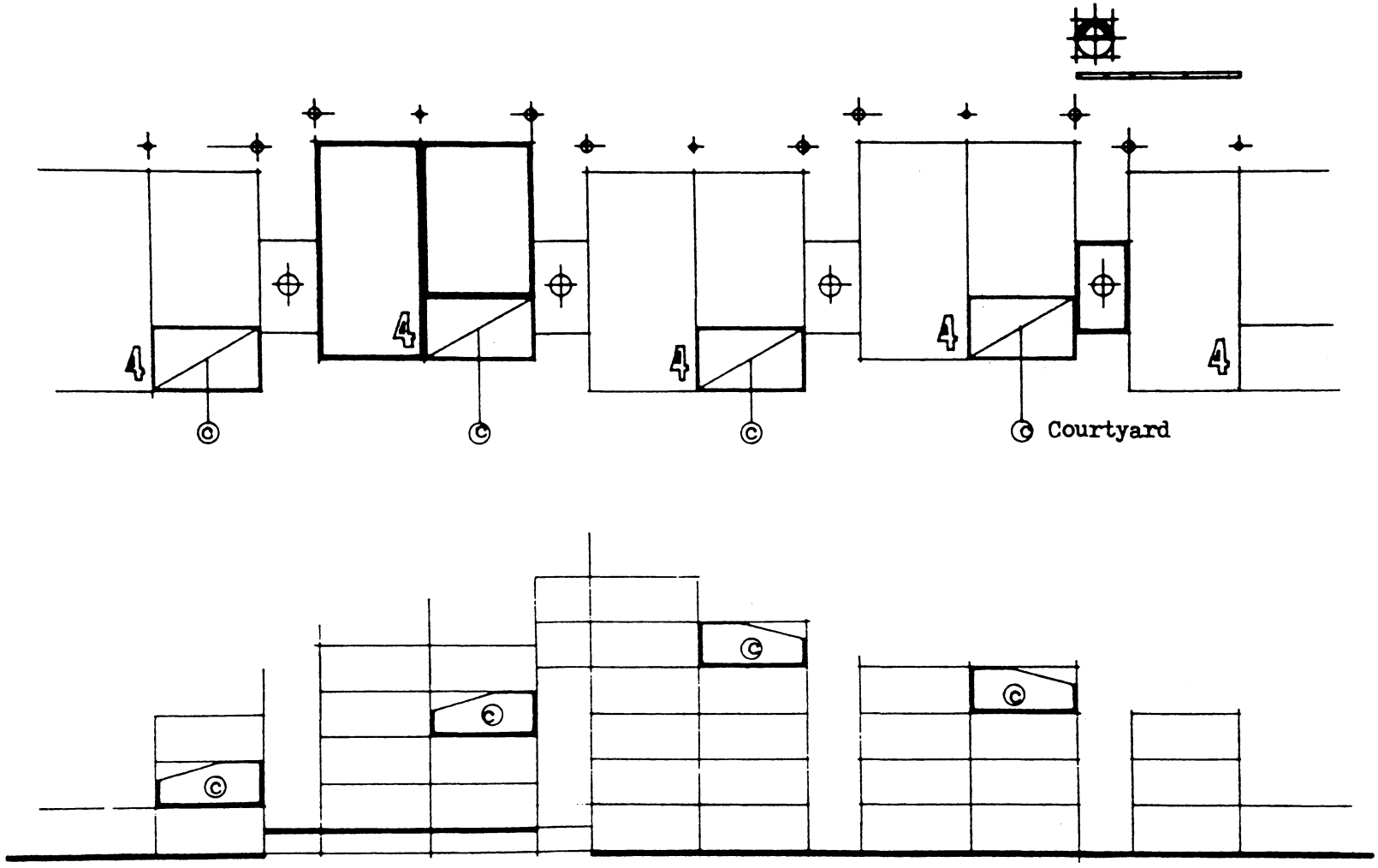



Fig. 19. Courtyards

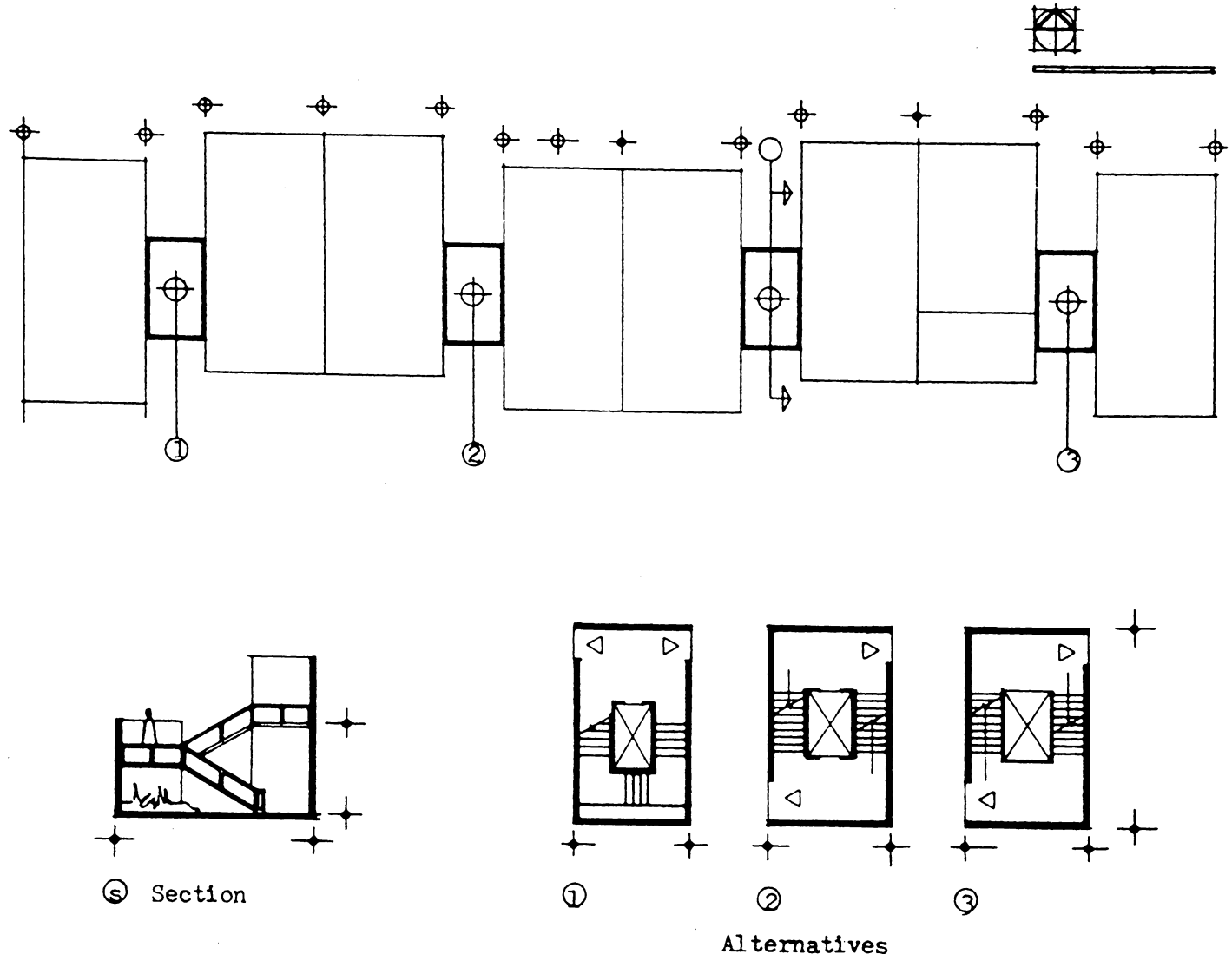



Fig. 20. Vertical Circulation

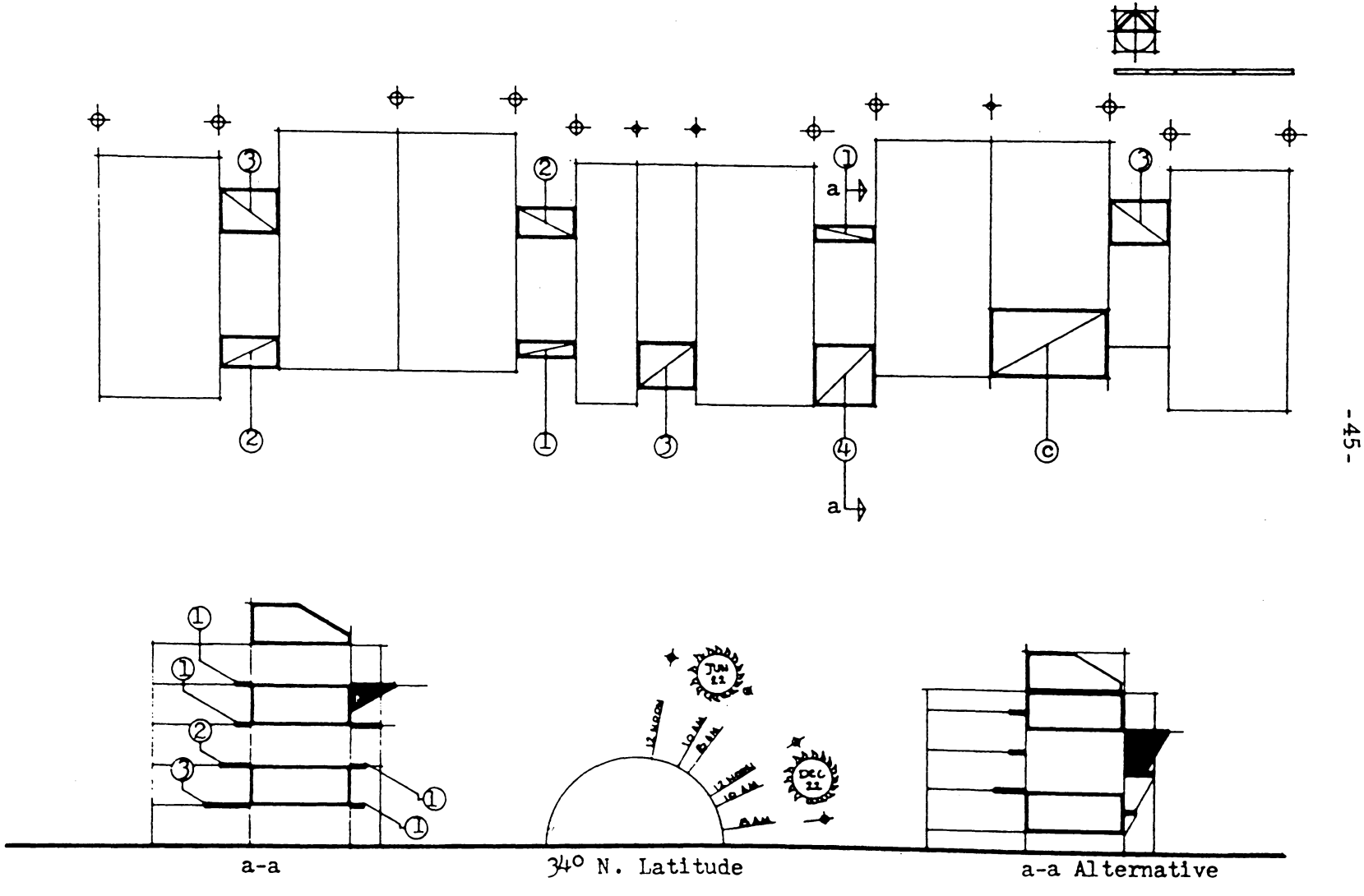



Fig. 21. Sun Control

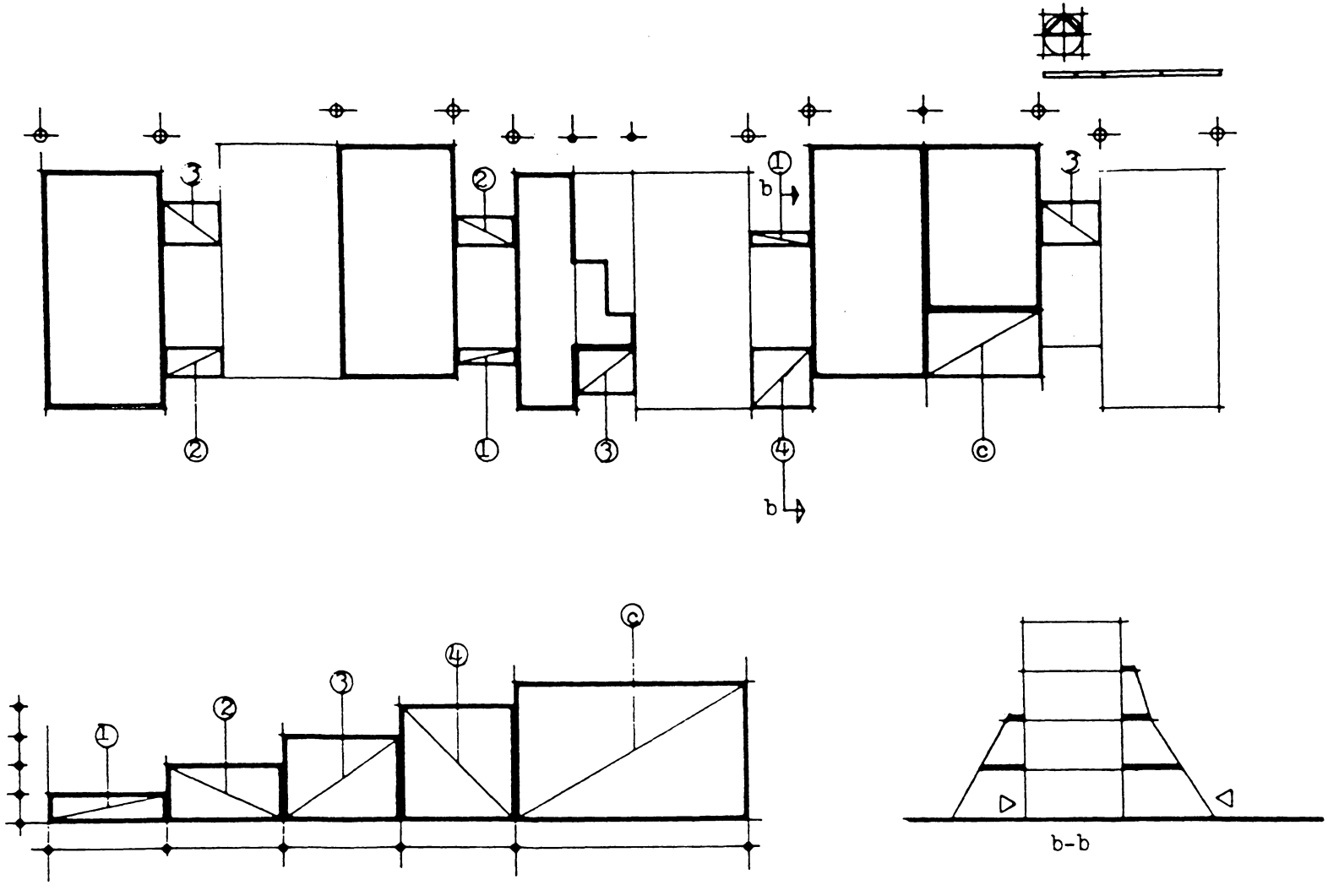



Fig. 22. Balcony Flexibility

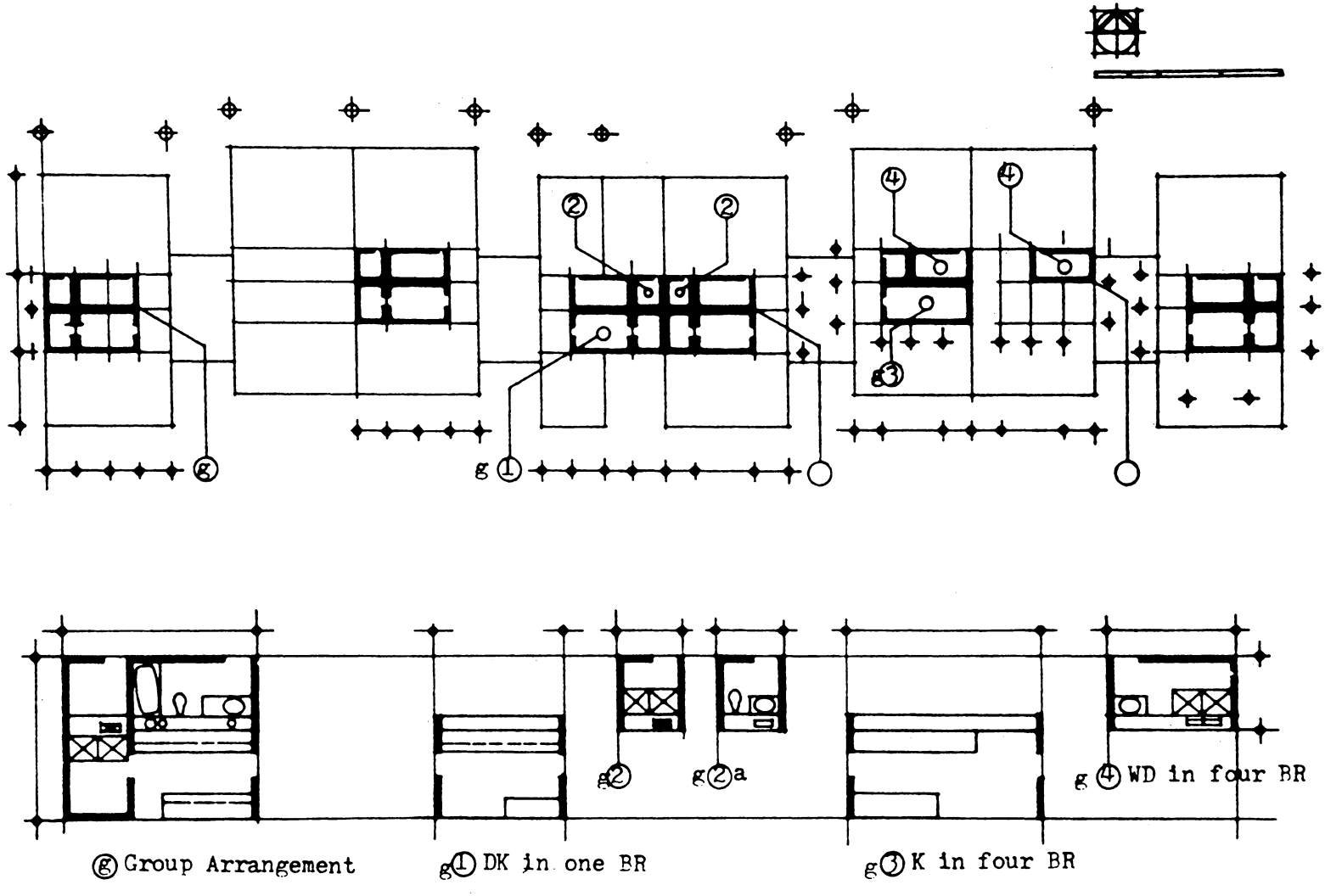



Fig. 23. Core Flexibility

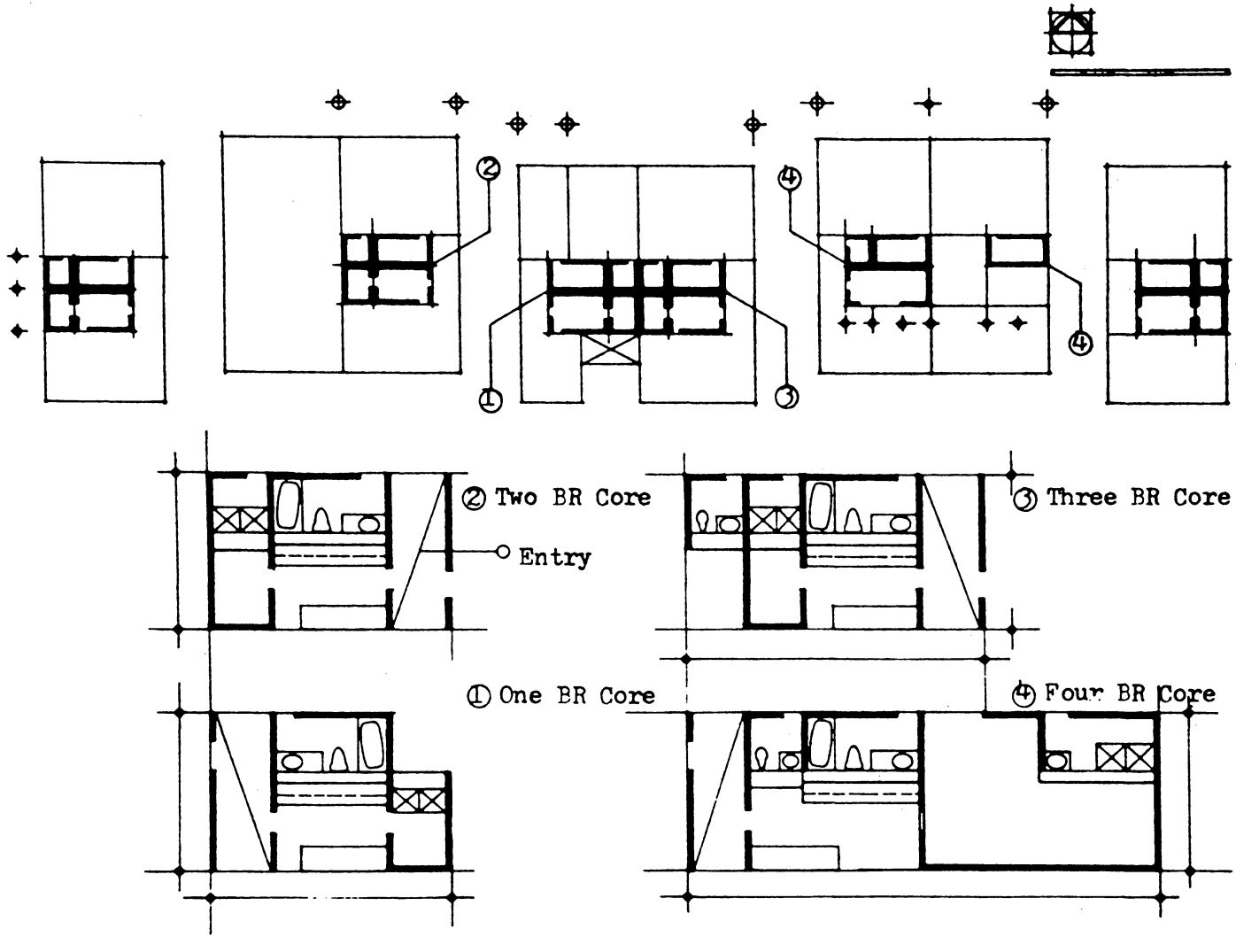
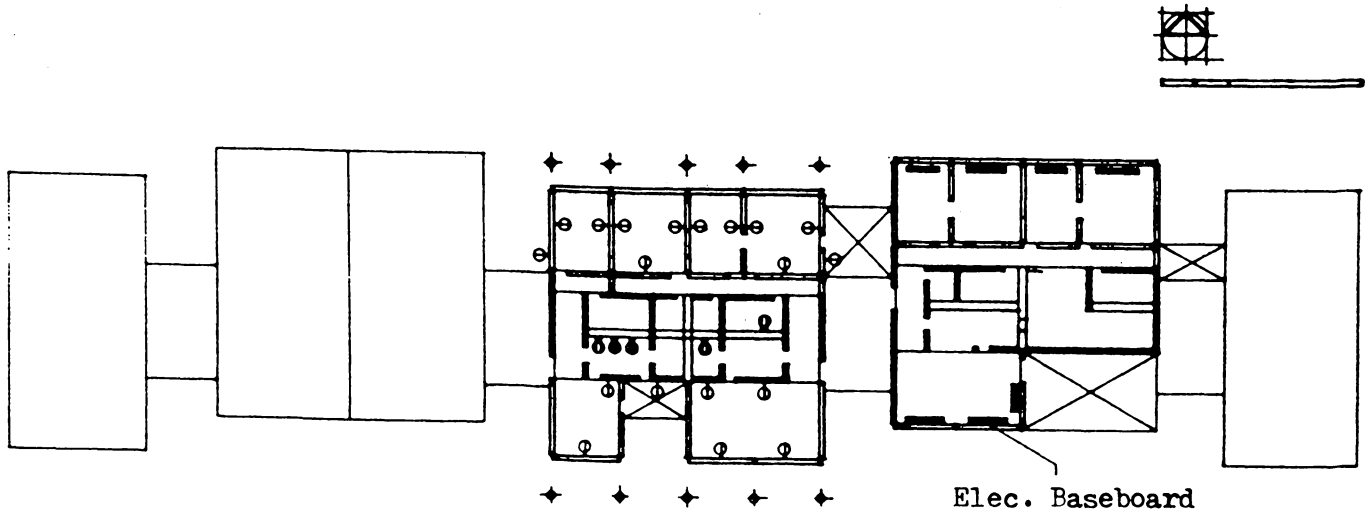
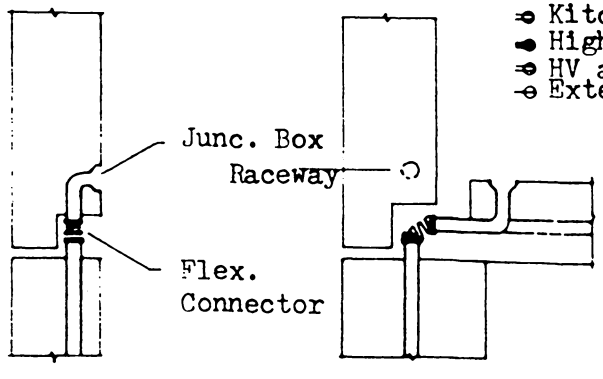


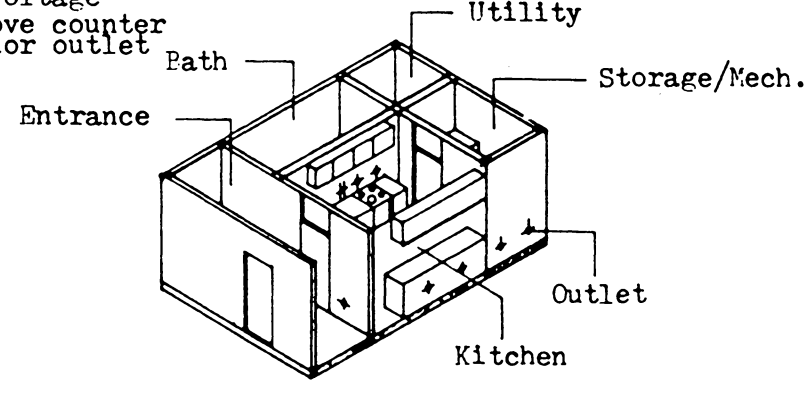

Fig. 24. Variation in Core




Key

- Interior outlet
- Kitchen counter
- High voltage
- HV above counter
- Exterior outlet




Core Module

Fig. 25. Core;Elec. & Htg. Sys.

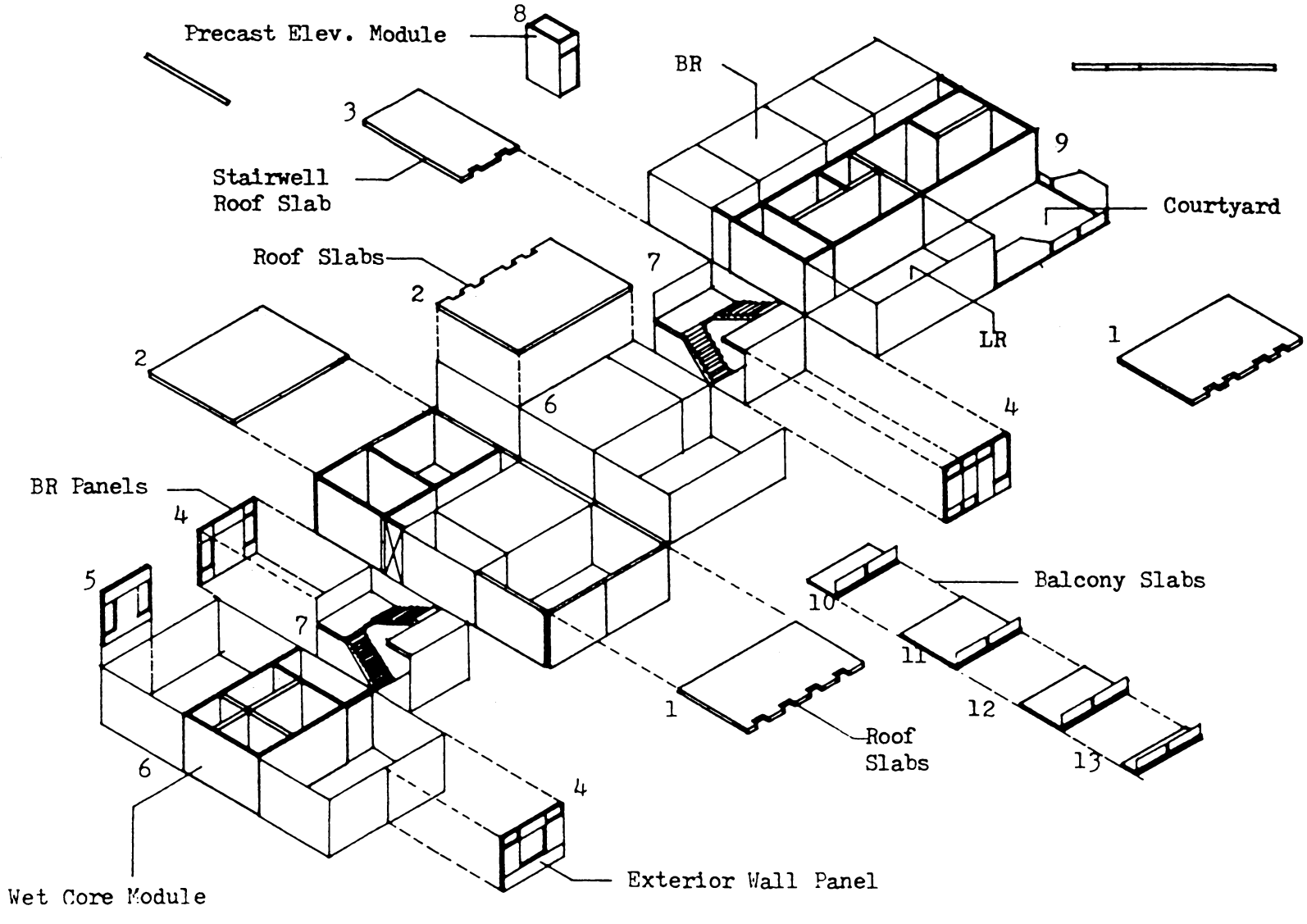



Fig. 26. Components

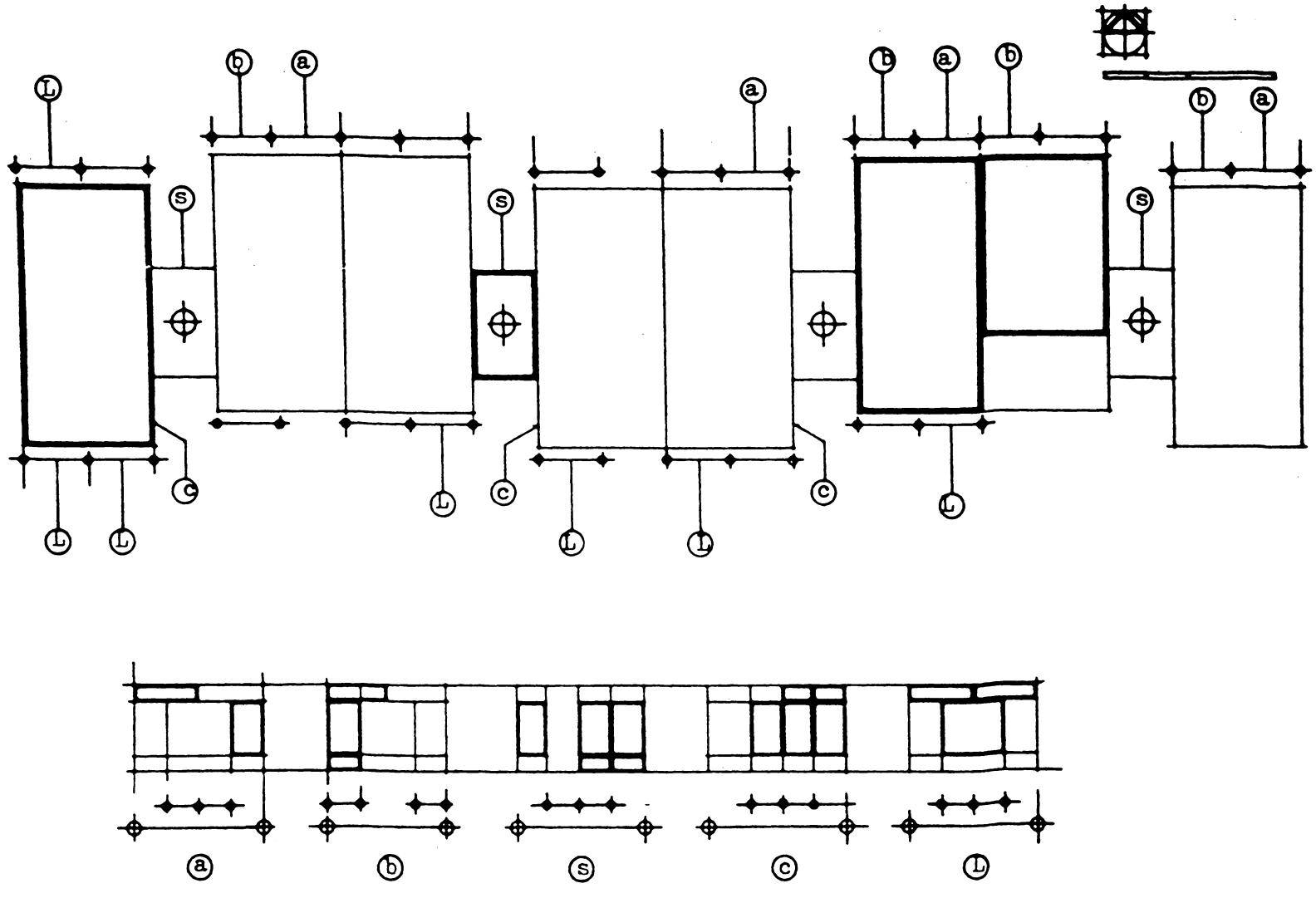






Fig. 27. Panel Flexibility

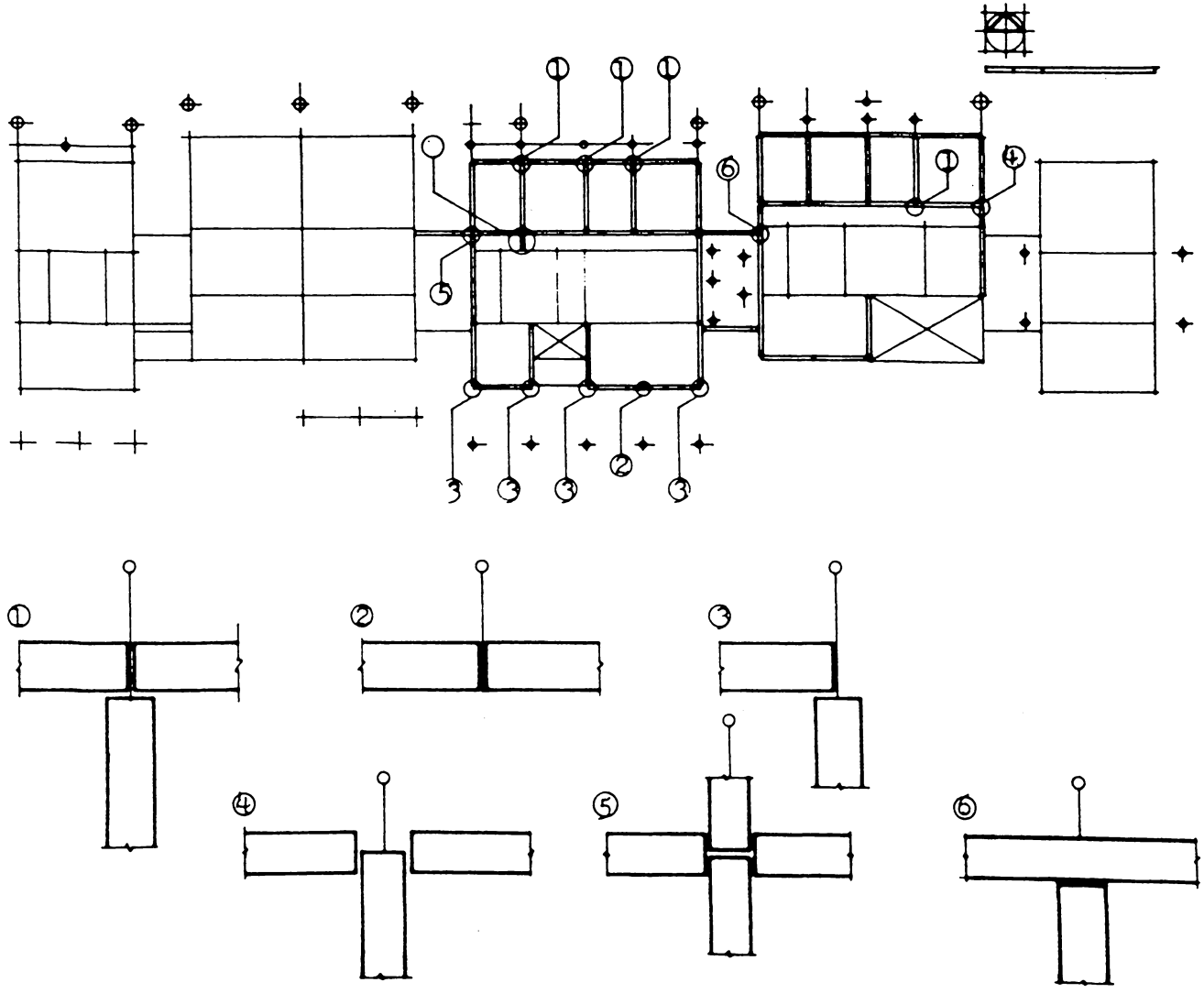



Fig. 28. Joint Plans

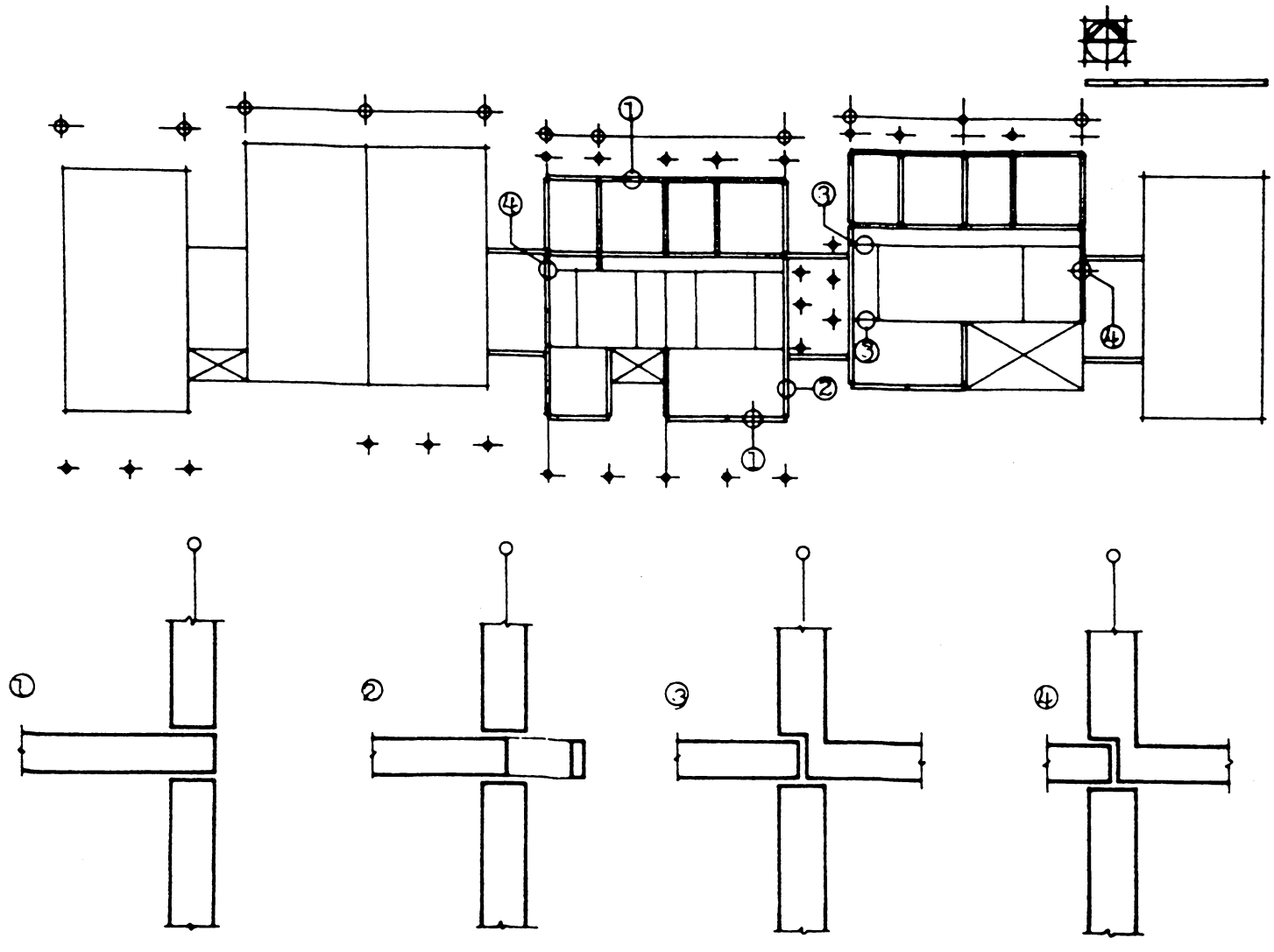
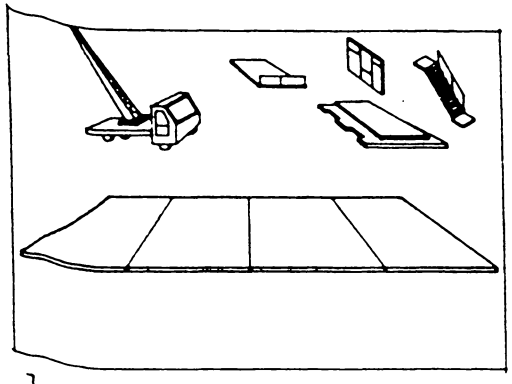
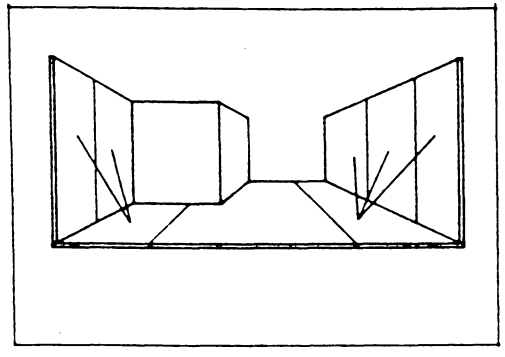


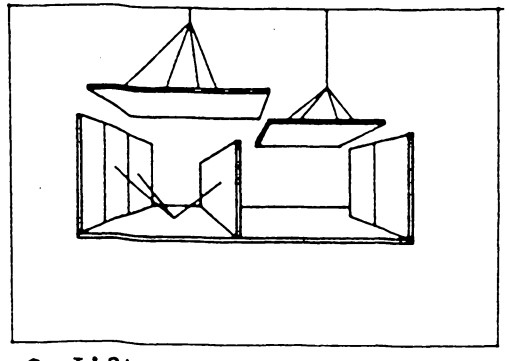

Fig. 29. Joint Sections



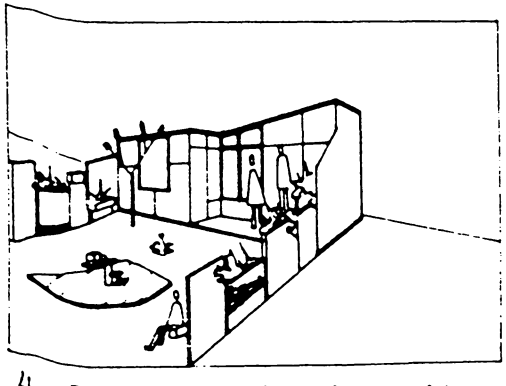
1. Site preparation; pour foundation slab.



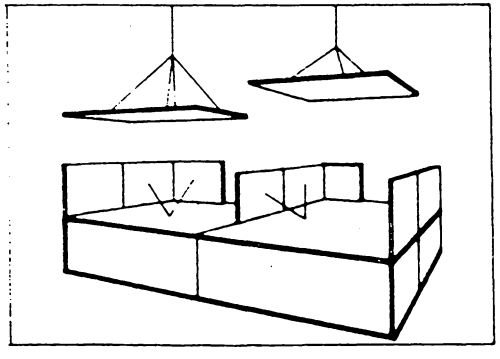
2. Position wet core module in place; erect wall panels.



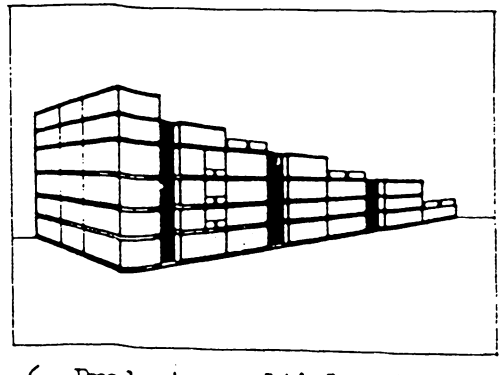
3. Lift and position roof slabs; compile connections.



4. Product - a housing unit; 1-4 rooms.



5. Repeat 2-3 till all floor panels are in place.



6. Product - multiple story housing.

Fig. 30. Construction Sequence

7. Connections

It is important to consider any aspect of a given system (joint) in light of all other constraints and factors (see the matrices in Sec. 8). The scheme for joints illustrated in Fig. 28 is the result of a study among factors such as scale, labor, equipment, structure, time, etc. Most of the connections in the proposed scheme occur at corners, thereby minimizing interior joint finishing. In contrast, the horizontal joints occurring at the facade are, by design, intended to delineate floor to floor separation. Fig. 29.

The efficiency of on-site labor and material dictates that wet cores be treated as completely separate units. This would resolve the problem of alignment and joint conditions created by many panels within a small area. In addition, wet cores with many separate wall panels would be uneconomical and would require on-site skilled labor. The dry panels that are fewer in number are then connected to the wet core to form complete box structures.

Although the scope of this thesis in regard to joints has been at the schematic level of design, a further detailed development of the concept should respond to the local (climatic and seismic) conditions of Iran. Since housing units may be located in areas that are subject to frequent earthquakes, a design goal should be to develop much stronger

joint reinforcing, in contrast to the joint design of many European building systems. There are numerous references that illustrate detailed technical information for joints, such as reinforcing, insulation and grouting.[15] (For further references, see the bibliography.) A design process for the details of joints should be made similar to that of the schematic, and the optimization of constraints (local code requirements, skilled labor and technical knowledge) should be developed.

7.1 Building Material

Historically, ever since 6200 B. C., handmade, sun-dried brick have been used. Masonry materials with a composite component (e. g., brick and steel) still dominate the present building industry. Table 4. In the hot, dry climate of Iran, timber is scarce and highly costly. Masonry materials are preferred, because they respond to a lower thermal diffusity and have a much higher capacity insulation that delays heat (see definition in 4. 2. 4).

The proposed solution, then, is a precast reinforced concrete system as an alternative to the slow brick-by-brick method of construction. The very nature of concrete enhances the feeling of permanence of the traditional bearing wall masonry construction; yet, ensuring fire safety, as compared to its wood counterpart. When the principles of

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[15]Schmidt, Thesta, International Survey of Methods. Frederick A. Praeger, N. Y., Washington, 1969.

Table 4
% Building Materials of Tehran Compared to All Other Urban Centers

| TYPE | Reinforced Concrete | Stone & Steel | Stone & Wood | Brick & Steel | Brick & Wood | Wood | Wood & Clay | Clay & Mud | Bamboo |
|---|---|---|---|---|---|---|---|---|---|
| % | 34.5 | 27.9 | 3.8 | 64.0 | 23.9 | 3.4 | 4.6 | .9 | .9 |

NOTE: 34% of buildings of reinforced concrete are in the city of Tehran. The brick and steel combination is the most predominant building material in Tehran.

Source: Art & Architecture, #21, March-April, 1974, p. 48 (Printed in Tehran, Iran).

capacity insulation are applied to the design of precast concrete, the system would respond appropriately to the extreme characteristics of a hot, dry climate.

7.2 Selecting Environmental Comfort System

The criteria for human comfort are well documented, and there are numerous HVA/C systems available that can adequately maintain a comfortable environment.

In the matrix of Fig. 31 there are three HVA/C systems listed, along with some twelve constraints that are essential for the selection of a comfort system. (For the sake of simplicity, only three systems types have been listed in this presentation. There may be many more systems types, as well as numerous other constraints added to this typical matrix format.) The advantages and disadvantages of these typical HVA/C systems types are analyzed in the matrix.

This matrix is also a mechanism to weigh factors (scoring) and evaluate each HVA/C type in terms of a given problem situation. One approach for evaluation is to score each systems type in terms of its interfacibility with a given set of conditions in a particular situation, i.e., how each HVA/C system type interfaces with the climatic, socio-economic, cultural and building systems components. In addition,

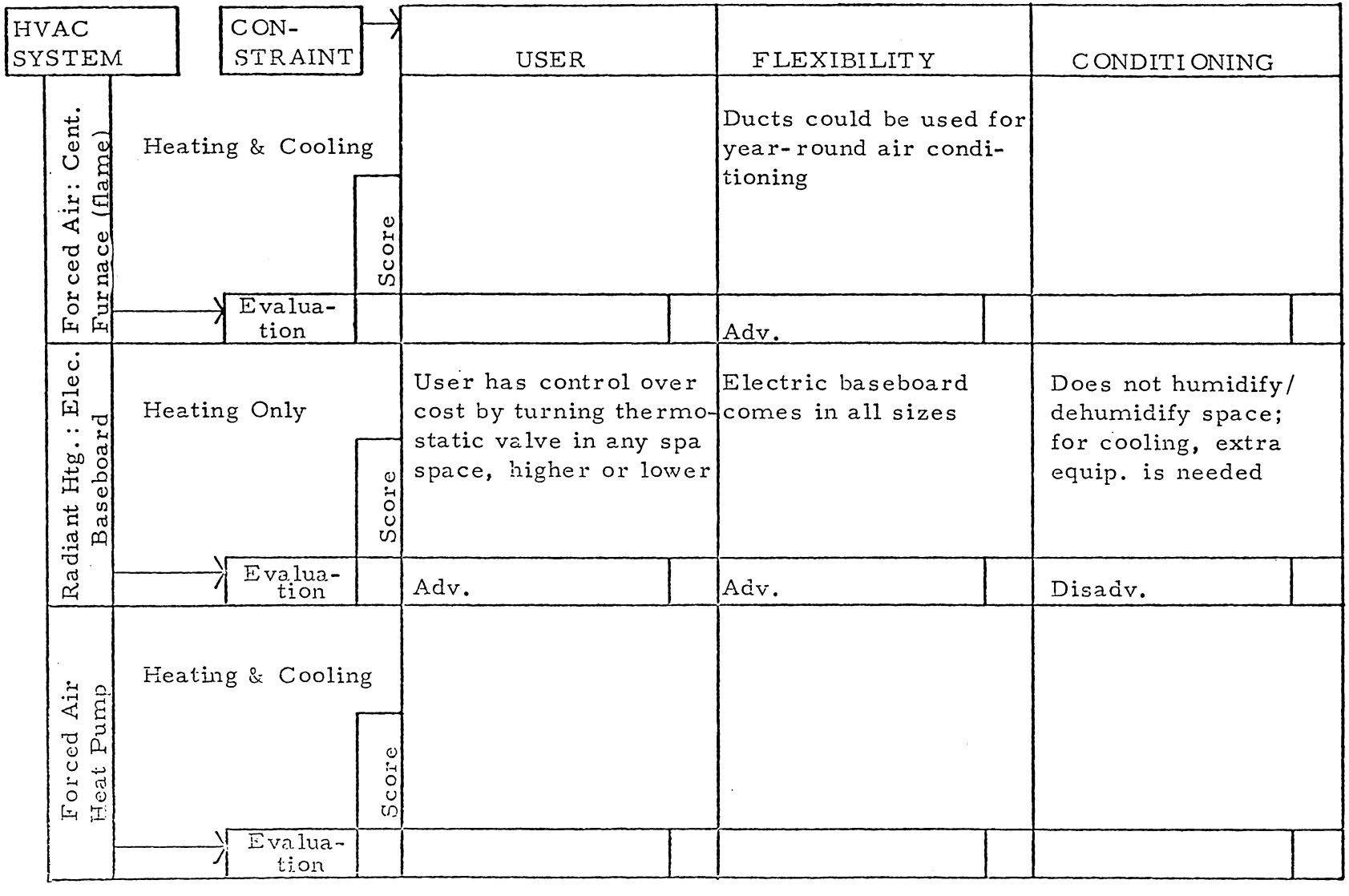


Fig. 31. Interface Matrix

| HVAC SYSTEM | CONSTRAINTS | SAFETY | MECH. SPACE REQUIRED | MAINTENANCE/ PORTS |
|---|---|---|---|---|
| Forced Air: Cent. Furnace (flame) | Heating & Cooling | Involves combustion air; flame is required | Mechanical space required for chimneys and furnace equipment | Requires more part replacing; higher maintenance cost |
| | Score | | | |
| | Evolution | Disadv. | Disadv. | Disadv. |
| Radiant Htg.: Elec. Baseboard | Heating Only | Flame & combustion air are eliminated; heating is safer | Does not require mechanical space | Has a lower maintenance rate |
| | Score | | | |
| | Evaluation | Adv. | Adv. | Adv. |
| Forced Air Heat Pump | Heating & Cooling | No flame or chimney combustion air | Small units are less efficient resistance heating | Has easy accessibility |
| | Score | | | |
| | Evaluation | Adv. | Adv. | Adv. |

(cont.)

| HVAC SYSTEM | CON-STRAINT | ENERGY | ROOM CONTROL | RESPONSE TIME |
|---|---|---|---|---|
| Forced Air: Cent. Furnace (flame) | Heating & Cooling | | Air motion unifies thermal conditions, carries humidity from body; gives freshness and cleans air | Relatively short response time |
| | Score | | | |
| | Evaluation | Disadv. | Adv. | Adv. |
| Radiant Htg.: Elec. Baseboard | Heating Only | Efficiency increases with increasing output/in. ft. | Each room can have an individual thermostatic control | Has a relatively longer response time |
| | Score | | | |
| | Evaluation | Adv. | Disadv. | Adv. |
| Forced Air Heat Pump | Heating & Cooling | Operates with efficiency of energy use | | |
| | Score | | | |
| | Evaluation | | | |

(cont.)

| HVAC SYSTEM | CON-STRAINT | ACCOUSTICS | COST | CLIMATE |
|---|---|---|---|---|
| Forced Air: Cent. Furnace (flame) | Heating & Cooling | Air moving in ducts is a noisy operation | Cost of chimney equipment & space (mechanical) is involved | |
| | Score | | | |
| | Evaluation | Disadv. | Disadv. | |
| Radiant Htg.: Elec. Baseboard | Heating Only | Is silent | Compared with forced air, the cost of chimney/equip/mechanical space is eliminated; lifetime cost of replacing deteriorated parts is less | |
| | Score | | | |
| | Evaluation | Adv. | Adv. | |
| Forced Air Heat Pump | Heating & Cooling | | No cost of chimneys, extra equip.; life cycle operation cost is less than electric baseboard | Efficiency reduces when outdoor temp. drops (for very cold climates) |
| | Score | | | |
| | Evaluation | | | Disadv. |

(cont.)

there are detailed engineering data such as occupancy characteristics and relative cost of energy that must be considered in light of such interfaces. Trade-offs must then be made to select a method(s) for thermal and power services.

7.2.1 Iran's Condition

Evaporative cooling should be employed in the areas of Iran that have a dry climate. However, along the shores of the Caspian Sea or the immediate southwest coast of the Persian Gulf, where the air is moist, evaporative cooling is less effective than it is in typical hot, dry conditions. Thus, design features advocated for hot, dry conditions need modification in these humid areas. Air movement,(free or forced) when desired, should be secured. Any interference with air movement due to evaporative cooling devices must be minimized. Greater attention should be given to insulation and other heat protective devices. Refrigerant devices should be designed to dehumidify as well as cool the air.

With seasonal variations occurring in most parts of the country, it is essential that options for efficient heating systems be provided. Climatic data for the specific location, availability and cost of resource fuel, among other factors, (see Table 5) should be analyzed simultaneously to determine whether cooling, as well as heating, is needed.

Table 5

% Fuel Consumption of Building in Tehran as Compared To All Other Urban Centers

| Type | % |
|---|---|
| Oil | 35.9 |
| Gas | 21.7 |
| Wood | .4 |
| Coal | 48.5 |
| Oil & Gas | 48.1 |
| Oil & Wood | 2.1 |
| Oil & Coal | 36.6 |
| Wood & Coal | 4.3 |
| Other | 3.2 |

NOTE: For example, .4% of city (family) dwellers that use wood for fuel consumption live in Tehran: predominant source is oil and gas.

Source: Art & Architecture, #21, March-April, 1974, p. 48, (Printed in Tehran, Iran)

7.2.2 Options

A criterion for the selection of a comfort system is to provide options that are flexible and compatible with the components of the proposed building system. Flexibility implies the degree of adaptability by which mandatory (or optional) requirements for a comfort system are incorporated in the design of the building system.

7.2.3 Option One:

Forced Air System

The service core is centrally located and a forced air HVA/C system with diffusers around the periphery of the heart module can feed the spaces in the housing unit. A forced air system that throws air to the exterior wall ('Coanda Effect')[16] eliminates extra on-site duct work, since service modules are also produced in the factory (see discussion on 9.8 ). It is also economical for duct work to be incorporated in the service module, and then shipped to the site as complete mechanical cores. The advantages of such a HVA/C comfort system is that there is provision for both cooling and heating with a minimum of duct work.

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[16] A Compendium of Building Concepts Used in Operation Breakthrough, U.S. Department of Housing and Urban Development, p. 82.

7.2.4 Option Two:

Electric Baseboard with Unit Air Conditioners

Here, the user has more freedom in terms of selecting the comfort system for cooling. For heating, electric baseboards may be essentially provided, whereas cooling may be optional. If cooling is needed, unit air conditioners may be mounted on the exterior wall panel of each dwelling unit at a later time. The wall panels of the proposed scheme are flexible and have designated portions that can be knocked out for the mounting of the air conditioning unit.

7.2.5 Option Three:

Wall Units for Heating and Cooling

The heating and cooling unit (as one package) may be mounted on the exterior wall of each dwelling unit. In a similar fashion discussed in Option Two, the designated knockout portions of the exterior precast panel allows room for the mounting of the heating and cooling package. This is an economical solution for year-round air conditioning.

8. Systems Type

This section describes a general process that has resulted in the selection of the particular systems type. In order to select a system in a given design situation, several available systems concepts may be studied.

The first part of the matrix (Fig. 32 ) examines three systems types - precast concrete, cast-in-place, and lift slab concrete systems - along with some fourteen chosen factors (there may be many more factors included in such a study, as well as several other system types). This matrix lists the important characteristics for each factor of a given systems type. This would establish a mechanism in order for the designer to become familiar with important qualities (advantages or disadvantages) of each systems type.

The second matrix (Fig. 36 ) emphasizes the importance of the information obtained from the previous matrix, and enables one to objectively evaluate the critical constraints in terms of a given project situation. This matrix identifies the constraints in a given project and evaluates them in terms of the given criteria. A number scale of one to ten has been chosen to evaluate the constraints and their importance in terms of the set criteria. As an example, factors such as Labor, Time and Scale are among the most critical constraints for selecting a systems type in Iran, and hence have scored the highest points for a precast concrete system. A system with the highest average score is the most advantageous in terms of the criteria for selection.

Finally, the matrices of Fig. 33, 34, 35 ) listing some thirteen factors discussed previously illustrate the importance of the inter-relationships among the factors themselves. In order to select the most feasible systems type, each factor should be weighed against the others

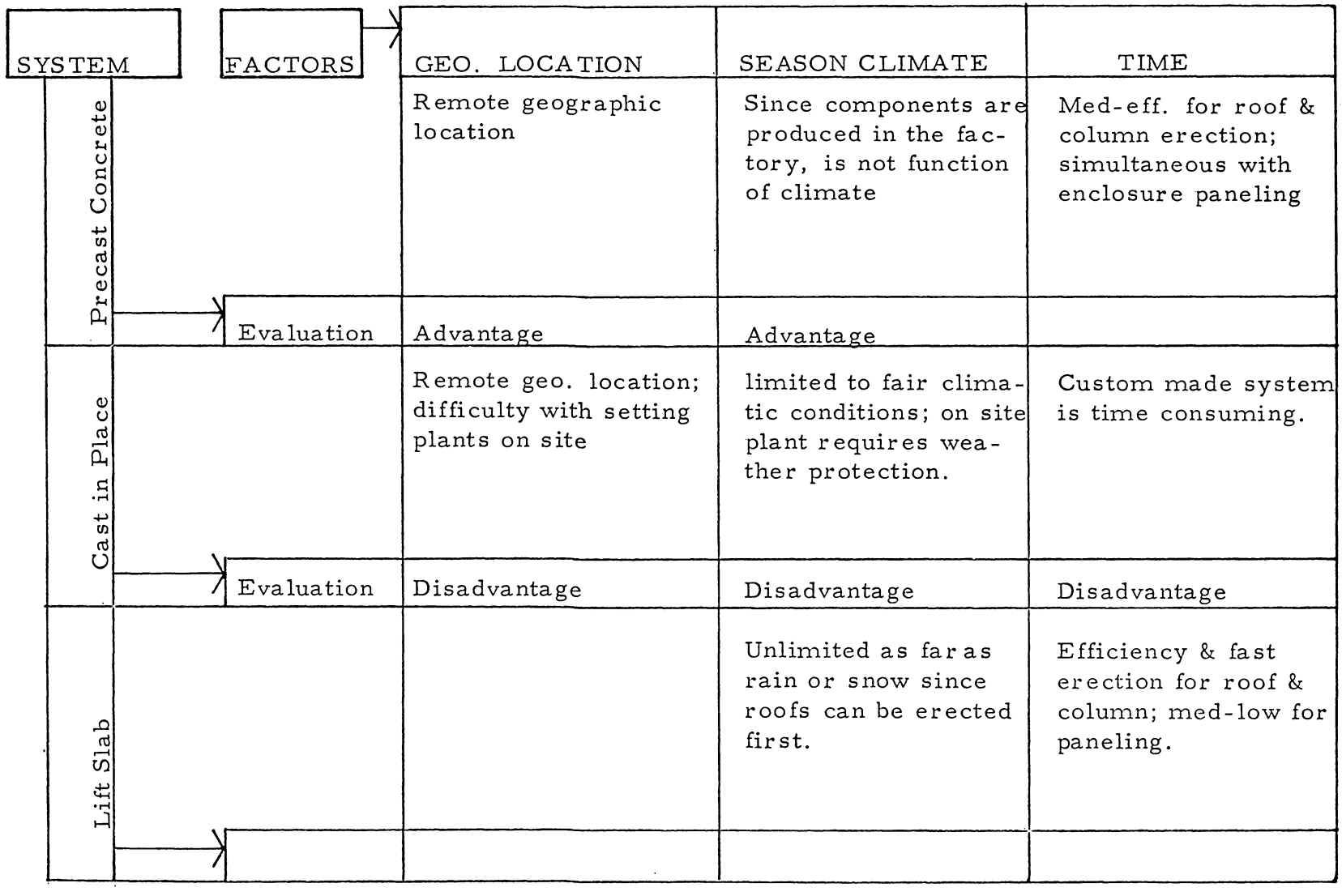



Fig. 32. Information Matrix

| SYSTEM | FACTORS | EQUIPMENT/ QUALITY | COST | REPETITION |
|---|---|---|---|---|
| Precast Concrete | | With better equipment in factory, more superior sys. component produced. | Cost of transport should be compared with quality of factory made pre-cast. | Economical/feasible good with repetition; saves time & labor |
| | Evaluation | Advantage | Disadvantage | |
| Cast in Place | | With less superior equipment than in factory quality of components is a concern. | On site production cuts transport cost with a semi-complicated mobile auto plant. | Not feasible with repetition; takes time/ labor compared with precast. |
| | Evaluation | Disadvantage | Advantage | |
| Lift Slab | | Lift slab equip. produces good quality, continuous slab/flat | Less cost for roof & columns; more cost of partitioning; flat slab uses min. struc. depth; savings in reduced ht of buildings | |
| | Evaluation | | | |

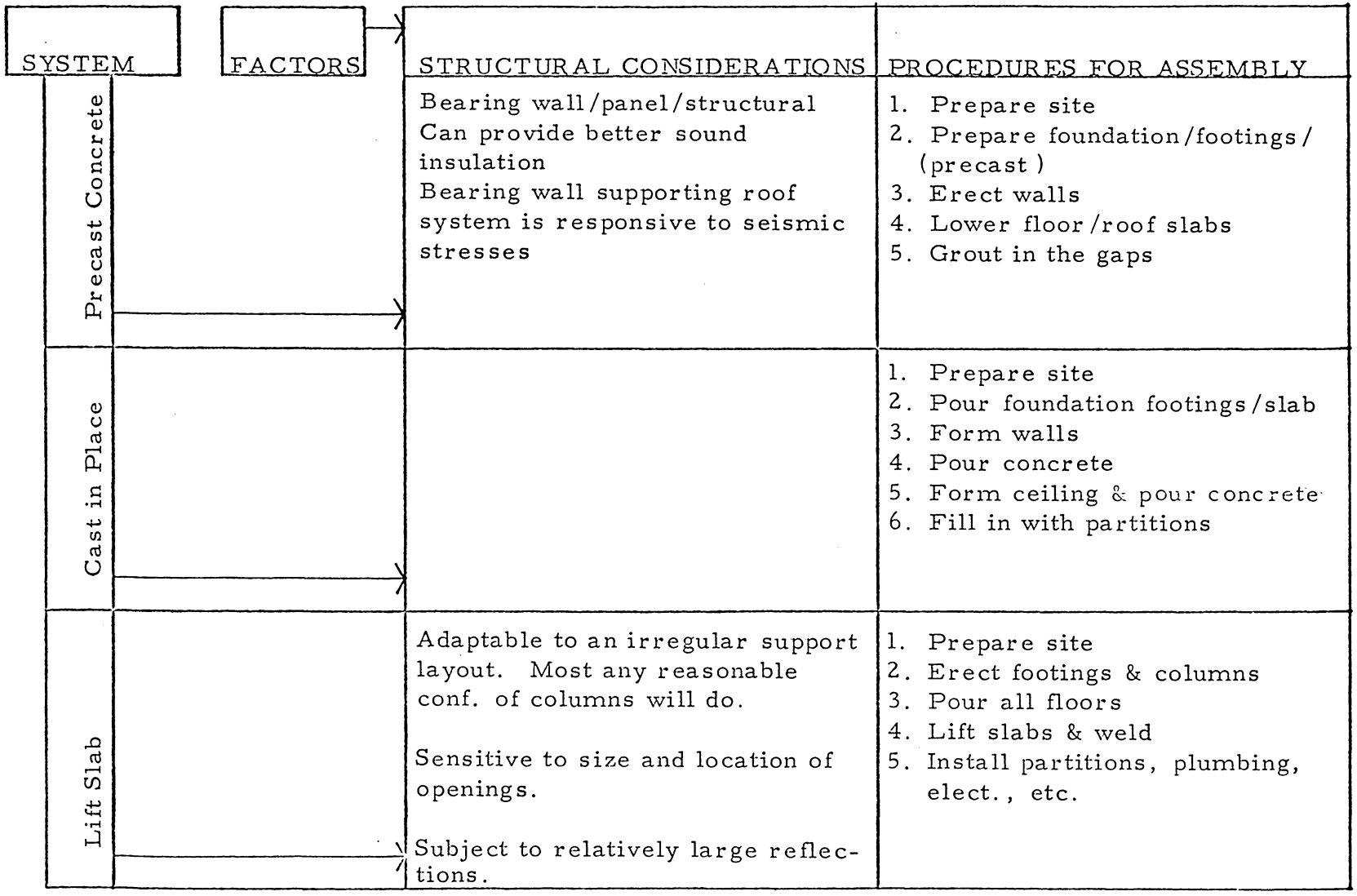
(cont.)

| SYSTEM | FACTORS | JOINTS | SEISMIC | HANDLING |
|---|---|---|---|---|
| Precast Concrete | | Importance must be given to jointing the pre-cast | Much stronger joint reinforcing needed in contrast to open joints of the Britain | Should be considered in early design stage; handling loopes could be precast in panels. |
| | Evaluation | | | |
| Cast in Place | | Relatively little problem with joints. | Easier to respond to seismic constraints. | Not generally a problem since components are cast on site. |
| | Evaluation | | | |
| Lift Slab | | Connection of panels (precast) to slabs may raise problems, especially interior panels | Heavy wt. struc. sys. is a disadvantage with foundation conditions. | No special care for floor & column handling; they are mechanically handled. |
| | Evaluation | | | |

(cont.)

| SYSTEM | FACTORS | FORMING | EQUIPMENT/MACH. | SKILL/ON OFF SITE |
|---|---|---|---|---|
| Precast Concrete | | Simple on site; little forming reqd. for grouting joints | Light Med. Heavy<br>Heavy | Low Skill on site<br>Medium off site |
| | Evaluation | Advantage | | Advantage |
| Cast in Place | | A lot of form work; "Building out of wood & then tearing it down." | Light | |
| | Evaluation | Disadvantage | | Disadvantage |
| Lift Slab | | Simple on site | Med. (Lift jacks) | Med. skill on site<br>None off site |
| | Evaluation | | | Advantage |

(cont.)



| SYSTEM | FACTORS | STRUCTURAL CONSIDERATIONS | PROCEDURES FOR ASSEMBLY |
|---|---|---|---|
| Precast Concrete | | Bearing wall/panel/structural<br>Can provide better sound insulation<br>Bearing wall supporting roof system is responsive to seismic stresses | 1. Prepare site<br>2. Prepare foundation/footings/ (precast)<br>3. Erect walls<br>4. Lower floor/roof slabs<br>5. Grout in the gaps |
| Cast in Place | | | 1. Prepare site<br>2. Pour foundation footings/slab<br>3. Form walls<br>4. Pour concrete<br>5. Form ceiling & pour concrete<br>6. Fill in with partitions |
| Lift Slab | | Adaptable to an irregular support layout. Most any reasonable conf. of columns will do.<br><br>Sensitive to size and location of openings.<br><br>Subject to relatively large reflections. | 1. Prepare site<br>2. Erect footings & columns<br>3. Pour all floors<br>4. Lift slabs & weld<br>5. Install partitions, plumbing, elect., etc. |

(cont.)

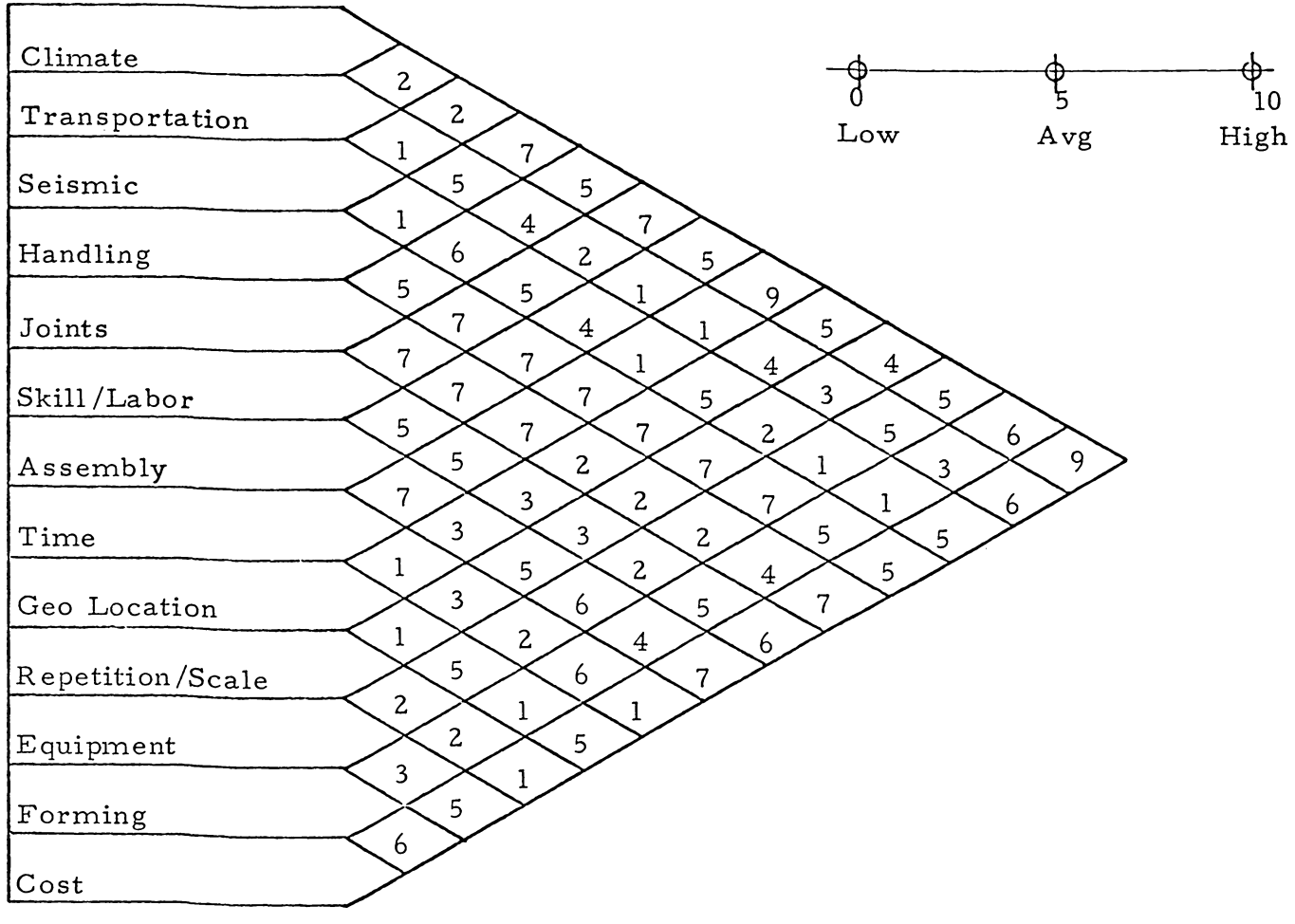



Fig. 33. Lift Slab Concrete System

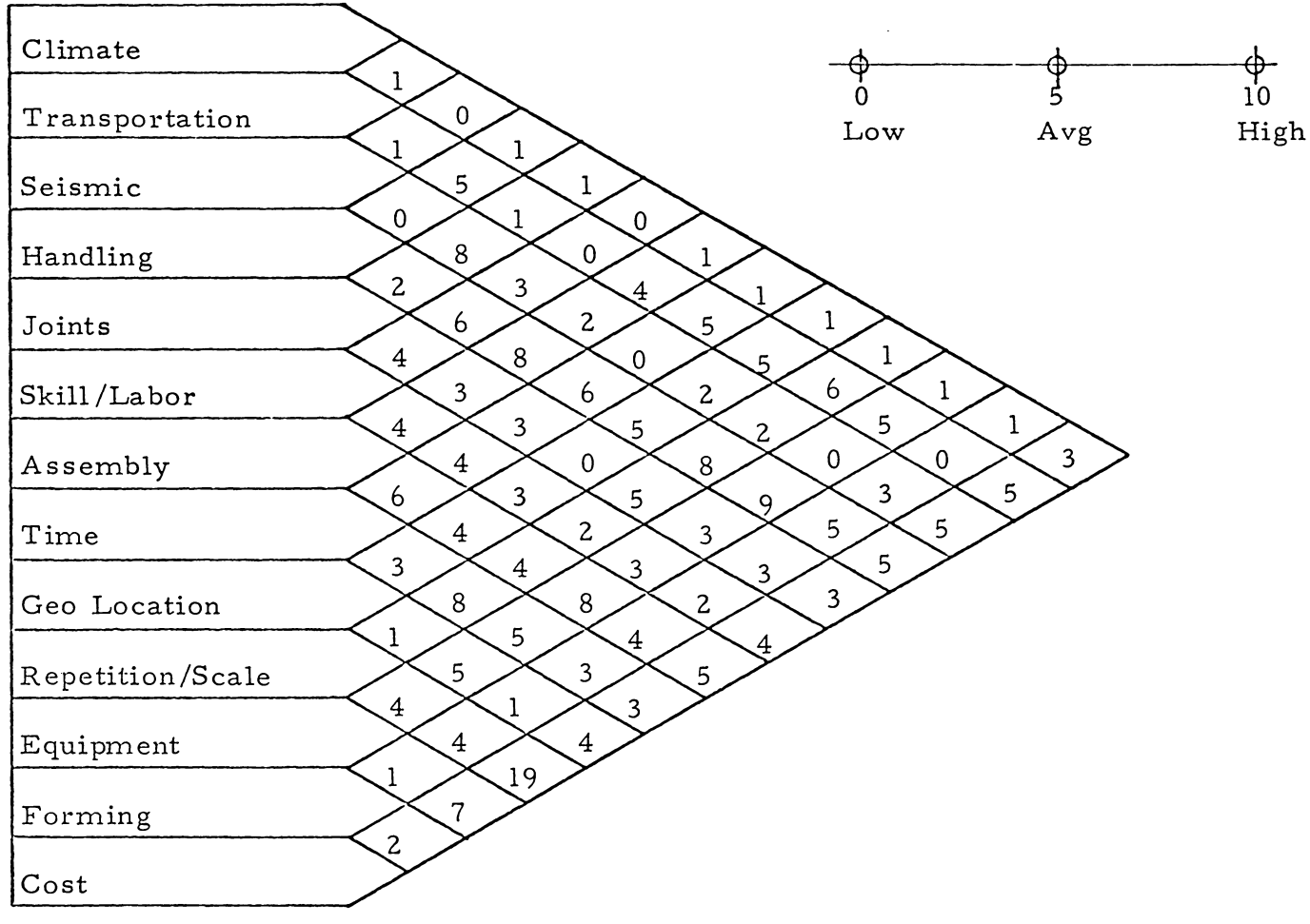



Fig. 34. Precast Concrete System

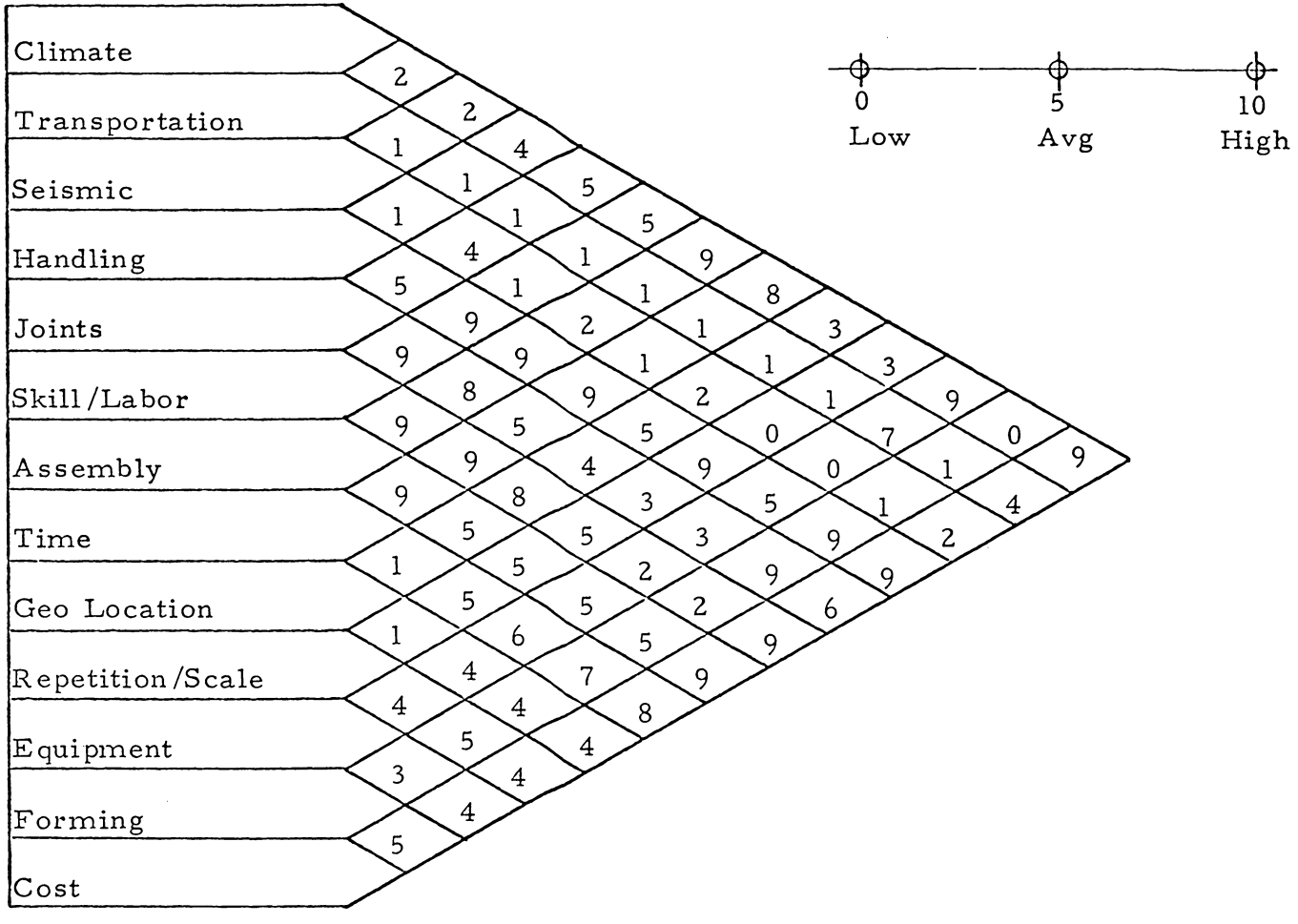



Fig. 35. Cast in Place Concrete System

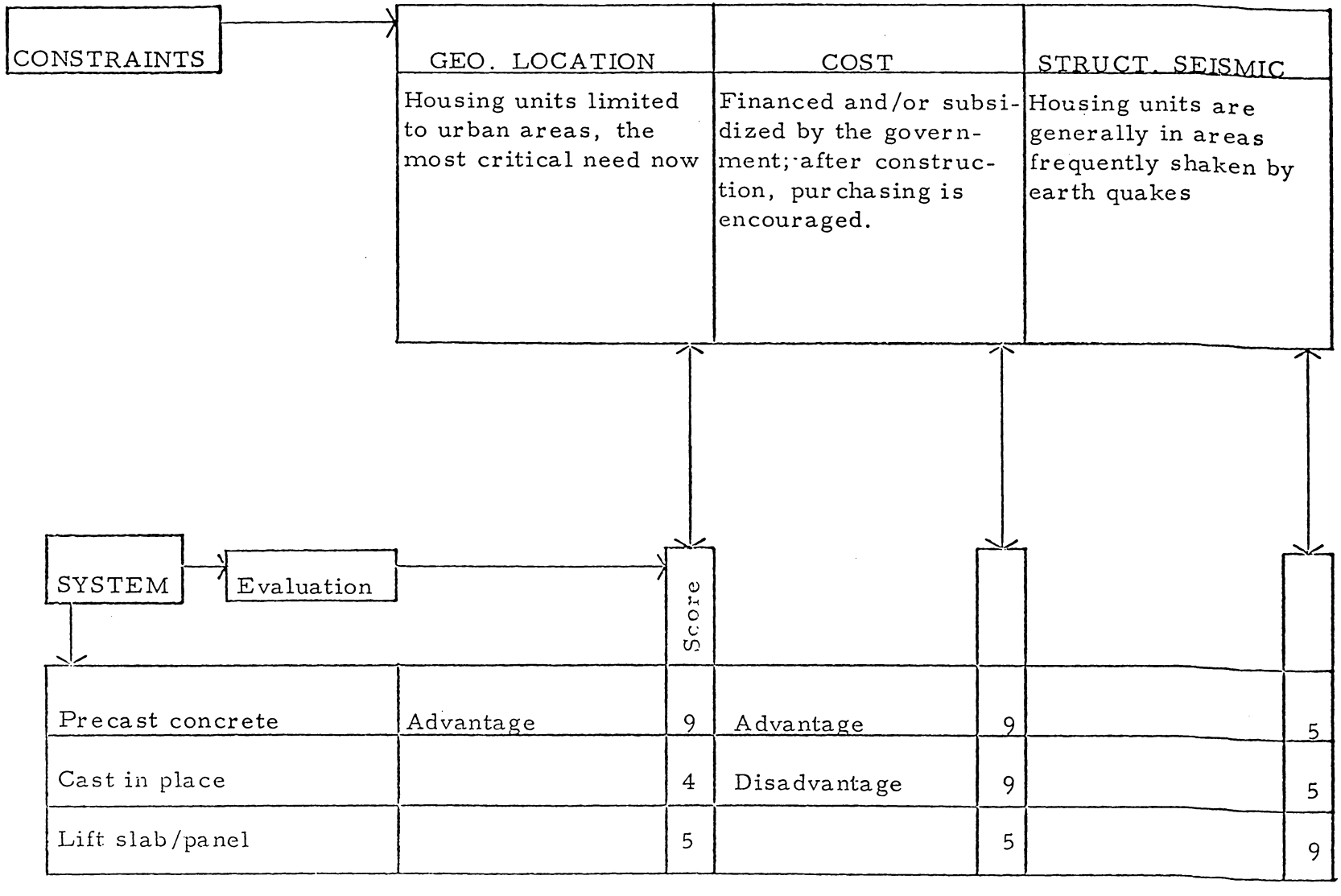
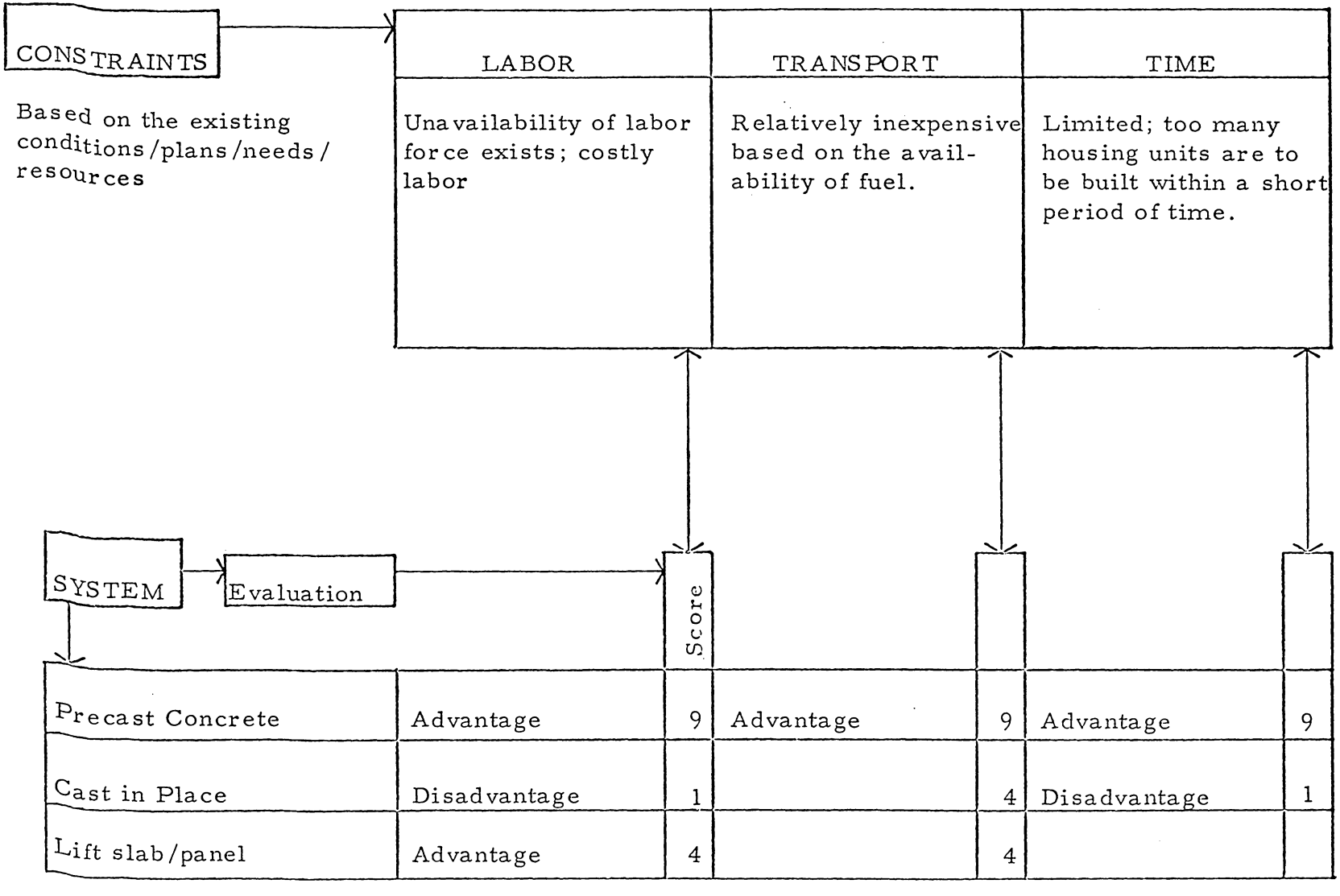
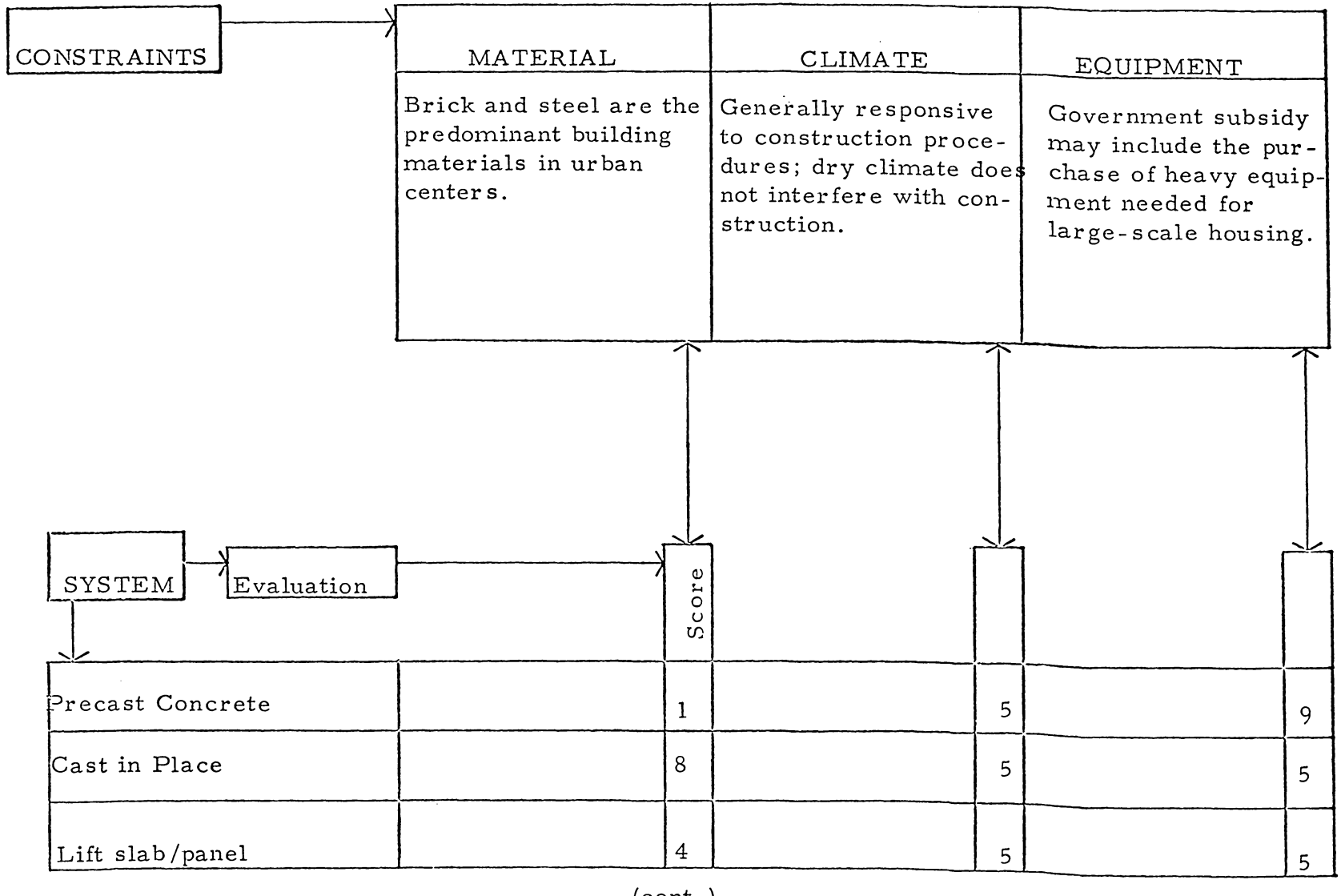


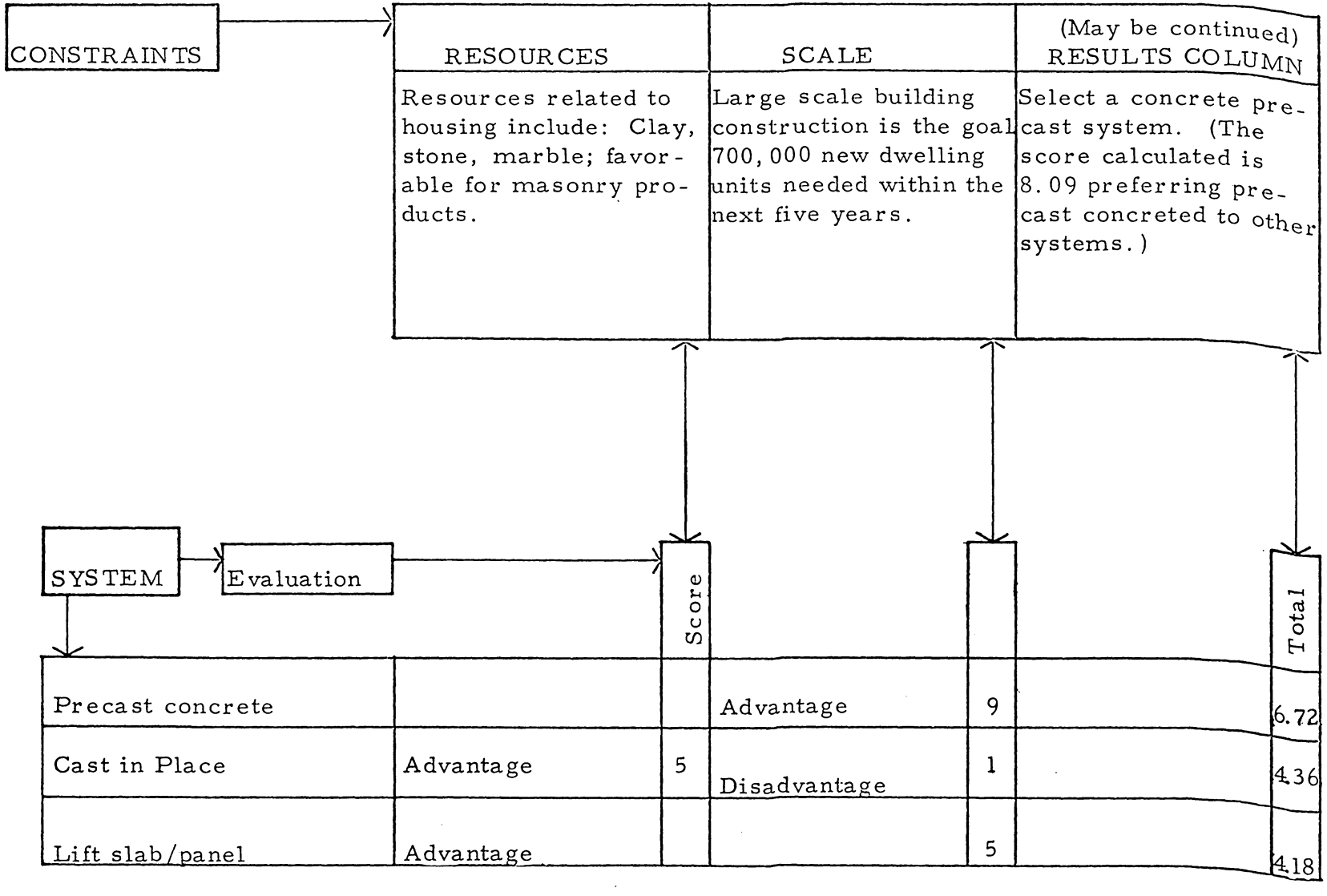

Fig. 36. Optimization Matrix


CONSTRAINTS
Based on the existing conditions/plans/needs/ resources
LABOR
TRANSPORT
TIME
Unavailability of labor force exists; costly labor
Relatively inexpensive based on the availability of fuel.
Limited; too many housing units are to be built within a short period of time.
SYSTEM
Evaluation
Score
Precast Concrete
Advantage
9
Advantage
9
Advantage
9
Cast in Place
Disadvantage
1
4
Disadvantage
1
Lift slab/panel
Advantage
4
4

(continued)


CONSTRAINTS
MATERIAL
CLIMATE
EQUIPMENT
Brick and steel are the predominant building materials in urban centers.
Generally responsive to construction procedures; dry climate does not interfere with construction.
Government subsidy may include the purchase of heavy equipment needed for large-scale housing.
SYSTEM
Evaluation
Score
Precast Concrete
1
5
9
Cast in Place
8
5
5
Lift slab/panel
4
5
5

(cont.)


CONSTRAINTS
RESOURCES
SCALE
(May be continued)
RESULTS COLUMN
Resources related to housing include: Clay, stone, marble; favorable for masonry products.
Large scale building construction is the goal 700,000 new dwelling units needed within the next five years.
Select a concrete precast system. (The score calculated is 8.09 preferring precast concreted to other systems.)
SYSTEM
Evaluation
Score
Total
Precast concrete
Advantage
9
6.72
Cast in Place
Advantage
5
Disadvantage
1
4.36
Lift slab/panel
Advantage
5
4.18

(cont.)

in the same matrix. For instance, "cost" relates to "repetition/scale" in a precast concrete system matrix of Fig. 34 , and scores a (9). The high score in this case reveals the significance of the two above mentioned factors in terms of the precast concrete system. Given the stated criteria where the goal is the production of large scale building components, the "cost" factor seems feasible (9) for the precase concrete system.

On the low side of the scale, the two factors "joints" and "handling" relate to each other with a score of 2. Although it indicates a low score, it suggests the possibility of conceptually incorporating handling loops in the design of the joints of the precase concrete panel system.

Having rated the system in the entire set of matrices, the systems type is then selected in light of the factors that have more value than other factors in the same matrix and have also scored highly in the matrix of Fig. 36.

In this study, a precast concrete system has been chosen as the most appropriate for the stated criteria.

## 9. Discussion of Parameters

### 9.1 Socio-Cultural

The precast concrete system was proposed in response to the housing needs of a growing middle class population that will be living in apartment type dwelling units in urban Iran. The criterion for the

social parameter is the development of a new trend in family structure: the emergence of a nuclear family organization that is within the context and lifestyle of the urban centers. This development is comparable to that in western cultures, with the concomitant in work and leisure patterns.

9.2 Economic

The government has already encouraged and initiated apartment living[17] at a time when the demand for urban housing has been increasing rapidly. There is also a program of large scale, high-rise apartment buildings being implemented in the capital.[18] The demand for housing has been accompanied by a rise in urban land value. The scarcity of urban land has also resulted in the sky-rocketing of prices.

9.3 Climate

*The system has been developed with concern for the natural climate* of Iran.

Traditionally, the buildings have been immediately adjacent to each other, creating a compact urban form. High density cluster housing has functional advantages in a hot, dry climate. The proposed scheme is

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[17]Art & Architecture, #18 and 19, June - November, 1973, p. 99, (Printed in Tehran, Iran).

[18]Ibid, p. 99.

a compact solution with staggering dwelling units, each protecting the adjacent ones against intense heat. It also creates a variation in the facade, thereby breaking the monotony of the typical facades of buildings in urban Iran.

The climatic parameter has also defined the framework for certain massing expressions in the proposed scheme. In the proposed massing, roof spaces have been designated as outdoor living areas. These outdoor spaces correspond to the courtyards of traditional houses.

9.4 Architectural

The proposed system of dwelling units ought to reflect the cultural characteristics of a highly developed society in Iran. The scheme should also meet the needs of a highly sophisticated segment of the urban population.

The design approach has been to investigate the organizational relationship of spaces in the existing housing. These characteristics have been transformed into the new design.

The system developed in this thesis is capable of accommodating families of various sizes and spacial needs. It also takes into consideration the future needs of families, as well as their present socio-economic status.

The spaces are organized in such a way that knock out panels enable spaces to be added or taken out without violating the overall organization of the whole scheme. (Fig. 28 ). In addition, the system is capable of creating combinations of housing units with different sizes, yet within close proximity of each other in a community. This closeness has useful social advantages. For instance, when the needs of a family change, spaces may be added or dwellings may be exchanged. This encourages residents to gain attachment to their community and enhances the concept of settlement.

The relationship of the indoor to outdoor areas has been developed to its fullest potential in the design of the proposed scheme. In the scheme the access to the outdoor courtyard or balcony areas is from a number of spaces that include the living, dining and bedroom areas. (Fig. 12) The balconies are of different sizes and offer greater flexibility for using outdoor areas.

The need for family privacy, regardless of family size, is enhanced in the proposed scheme by differentiating the meeting, transition and private areas. Fig. 15 . Children's bedrooms in the large units are located away from noisy meeting areas for privacy.

The kitchen spaces are located so that the distance from the outside parking areas is minimized. The primary bedroom (master) can have

access to the secondary one. This arrangement offers flexibility in terms of the use of the secondary bedroom. An opening between the two spaces increases the potential use by the provision of access from one space to another.

9.5 Finance

The government policy encourages the purchase or rental of apartments within large complexes of high-rise structures. Through subsidies individual ownership is encouraged.

The design of the proposed scheme is adaptable to the rental or purchase of individual housing units on single family traditional sites (discussion in 3.2).

9.6 Maintenance Cost

Trade-offs must be made during the early stages of design to incorporate building components that minimize operation costs and lifetime maintenance; i.e., a more expensive flooring might be economical to select compared with a less expensive one that requires more maintenance, and therefore higher operational costs. This aspect of maintenance cost is of particular importance, since over 90% of the building costs are associated with the use of the building.

The compact configuration of the proposed building system is energy-saving in terms of heating and air conditioning. This implies

a reduction in long-range operational costs. Balconies function as buffer spaces, separating spaces of the adjacent housing units. This arrangement reduces the cost of materials for accoustical insulation by decreasing the amount of insulation materials in wall panels.

Kitchen, bath and utility spaces are integrated into a wet core package. The integration of wet areas minimizes the initial cost of plumbing, compared to a scattered arrangement. Such integration also can be produced in the factory, resulting in a lower initial investment.

Although the wet areas are integrated, the sub-systems should not be built into the fabric of the core; e.g., plumbing should not be built into the wall panels. This concept offers greater accessibility to parts and ease of maintenance, in addition to saving operational costs.

9.7 Systems Catalog

The characteristics of systems components (scale, shape, number) should be considered in the early stages of the design process. An optimum system can be developed when components of a given system are minimized and their use is maximized.

Certain components of a building system such as slabs (1) and (2) of Fig. 26 that perform various functions at different locations have been sized differently by design. This results in a visual differentiation of parts that would simplify the putting of the right component on the right

location during assembly. Slab ( 1 ), which spans the living areas, has more reinforcement and is smaller than ( 2 ), which has less reinforcement and spans the sleeping areas.

Trade-offs must also be made during the early stages of design with the consideration of a whole range of other factors (structural, functional and handling of building components) that simplify assembly procedures; e.g., this wholistic approach results in greater efficiency during the assembly period and is similar to the process discussed in 8., p. . Such an approach has also set the criteria for determining shape, number and scale of the building components.

9.8 Transport-Assembly

The building system has responded to the requirement that the prefabricated components be shipped to the site in accordance with user needs. The proposed system expedites the transporting and assembling of units for individual families on traditional urban sites, as well as in large scale developments.

The wet cores (kitchen, utility, storage and bathroom areas) that require extra technical labor can be completed at the factory and shipped to the site with the necessary dry panels. This approach would reduce the need for on-site skilled labor and thus constitutes another strong factor in the set criteria. The precast dry panels cast in the factory with interior /exterior finishes can minimize field work.

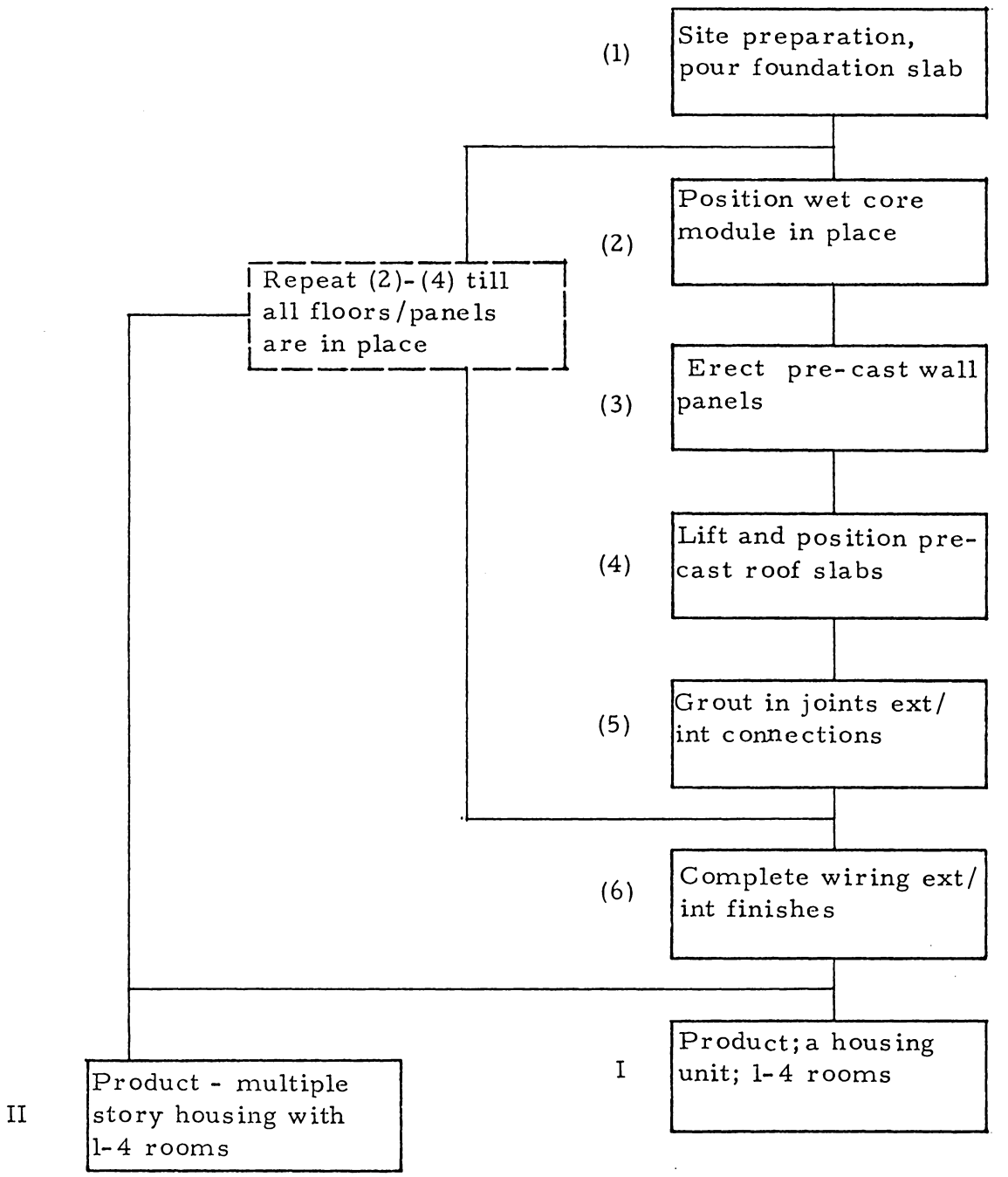


Fig. 37. Construction Sequence

During site preparation (Fig.37), foundation slabs (cast-in-situ) are poured. The heart module for a typical housing unit is one single box that is lifted and correctly positioned. The dry panels are set vertically and temporarily tied to the floor slab by rods. Floor and/or ceiling slabs are then lifted into position. The necessary connections between the walls and floor slabs and the core modules are made afterwards.

The final stage for a typical housing unit is completing the wiring and the interior/exterior finishing. In the case of multi-storied compact housing, the process is the same from (1) through (5), until all of the floor slabs are in place.

## 9.9 Systems Approach

This thesis has been a mechanism for experimentation in dealing with various chosen factors as they would relate to "designed" criteria. Trade-offs have been made uniquely during the early design stages of the analytical process. The socio-economic, cultural and environmental parameters have defined the scope and limitations of the design process. The most critical aspects have been identified and analyzed in the design process.

Within the framework of the parameters, there has been an optimization of certain factors in the design process. The optimization process

depends upon a set of conditions within the system and the established criteria (problem identification). One factor within a given system may require maximization, while the same factor elsewhere with a different set of conditions may not even carry any significant weight (rationalization). The minimization or maximization of factors for a given condition in Iran has been used as a methodology and trade-offs have been made to define the order of priorities.

Optimization is similar in process to that applied in linear programing in which the solution to a system of simultaneous sets of factors (equations) is analyzed. Then, the optimization process is performed by maximizing or minimizing a variable.

This approach is an ideal that offers potential application in architectural systems programing to develop a more objective methodology for design. Variables given in a detailed list of parameters can be designated by a set of leters (a, b, c . . .). Such variables may carry different weight, *represented by (2a), (4c), etc. A sum of the variables with their coeffi*cient factor can be defined within a certain context. An equation is then formed as a parameter which is made up of a set of variables. A series of such equations (parameters) are then obtained with each parameter corresponding to that of the given project situation. The optimization of the variables is then performed methematically. The result is a variable

or a factor (x) which would be the most critical in the list of priorities. A design task is to see how this variable is met in the proposed solution.

## 10. Appendix

The following table summarizes the principles for hot,dry environments and important applications.

Table 6
Summary of Principles for Hot Dry Environments and Important Applications

| PRINCIPLES | IMPORTANT APPLICATIONS |
|---|---|
| Reducing human heat | Flexible plan & conservation of floor space |
| Ease of cleaning | Easily cleaned surfaces |
| Reducing gain and promoting losses from body by radiation | Shade trees where possible, especially roof areas |
| External shade | Shade bushes where possible, especially to E and W exposures |
| Reduced ground reflection | Continuous building in E-W rows |
| Attached shade | Vegetation where possible |
| Water cooling of exterior | Dark/White color for while solar response |
| Minimum solar projection | Eaves and other horizontal projections on equatorial exposures |
| High reflectivity and reemission of exterior | Awnings, external shades, shutters, etc. especially on equatorial exposures |
| Convection over surfaces exposed to radiation | Vertical projections near window openings on equatorial exposures |
| Insulation (capacity type) | Water spraying of roof and walls exposed to radiation |
| Convection over inner surfaces | Water layer on flat roof |
| Low emissivity of inner surfaces | |
| Moderate ceiling height | |

Source: Physiological Objectives in Hot Weather Housing, U.S. Aid Missions, HUD Office of International Affairs, p. 46.

(cont.)

| | |
|---|---|
| Reducing gain and promoting losses from body by conduction<br>Insulation<br>Controlled ventilation<br>Ventilation of roof spaces<br>Evaporative cooling<br>Refrigerant cooling<br>Reducing heat liberation in building<br>Minimize heat liberation<br>Remove liberated heat | Avoid parapets and mutual interference of roof structure to wind<br>Wood, earth, stone, or other material of low diffusity for roof<br>Ceiling height generally not over 8 ft.<br>Continuous walls with capacity insulation where exposed to radiant load<br>Doors, windows for both tight closing and easy opening<br>Ventilation of roof space and spaces between successive roofing laters<br>Water blinds or box coolers with fans<br>Air/intake through earth tunnels<br>Basement construction<br>Air conditioning by refrigeration<br>Capacity insulation around oven & fire box<br>Narrow air space lined with aluminum foil in oven wall<br>Liquid or gas fuel or power where economically feasible<br>Vent to outside over stove |

Source: Physiological Objectives in Hot Weather Housing, U.S. Aid Missions, HUD Office of International Affairs, p. 46.

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# A BUILDING SYSTEM OF URBAN HOUSING, WITH SPECIAL REFERENCE TO IRAN

by

Alireza Banai-Kashani

(ABSTRACT)

This thesis takes a holistic approach to the development of a building system that responds to the socio-economic, cultural and climatic parameters of urban Iran. The scheme developed is a system of precast (prefabricated) concrete panels that are connected to prefabricated wet core modules, abbreviated "pancore." Specifically, pancore meets the needs of a rapidly emerging nuclear middle-class family structure, which is concentrated in the urban centers of Iran. Up to the present, the limitations of time and lack of skilled labor in Iran have hindered attempts to provide adequate housing on a mass scale. Now that the pattern of family living has been undergoing change, there is an ever-increasing demand for a different style of urban housing; that is, individual apartment-type dwelling units on a large scale. The proposed scheme not only responds to the above-mentioned criteria, but also surmounts the dependency on skilled labor, since major building components can be produced in the factory.

The design process has emphasized the application of the systems approach, both at the micro and macro levels of analysis. Matrices have been developed to evaluate and optimize the design concepts. The optimization and trading off of the design ideas have been uniquely made during the early design development, hence incorporating systems ideas in the building design. The proposed scheme is a result of the application of a holistic approach to architectural systems design. Criteria such as user needs, environmental parameters, and traditional design procedures have been utilized to formulate the design goals.