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HOUSES GENERATED BY PATTERNS

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Preface: The Proyecto Experimental de Vivienda

In January 1969 the United Nations, working with the Banco de la Vivienda of Peru, asked us at the Center for Environmental Structure, Berkeley, USA, and 12 other architects from various countries to submit competition designs for a community of 1,500 houses. The houses are to be built at a gross density of 37 houses per hectare on a site of 40 hectares, 8 kilometres north of Lima. The site is bounded by two major arterial highways, and crossed by a third; these highways are fixed by the Lima transportation plan. The financial arrangements require that each house be contractor built, on its own land, at a cost ranging from 78,000 to 164,000 *soles* ($1,800–$3,800, £720–£1,520) and that the houses be sold to low-income white-collar workers (empleados) earning between 2,800 and 5,800 *soles* ($65–$135, £26–£54), per month.

We were asked to present our designs in a way which would help the evolution of Peruvian community and house design in the future. We have therefore chosen to present our work in two parts:

In part one we present our *designs*. This part includes a site plan, drawings and construction details for individual houses, and a choice-process which allows the final site and house plans to be formed, in detail, by the idiosyncratic needs of the individual families who buy the houses.

In part two we present some of the 67 general design principles which we call *patterns*. These patterns describe, in an abstract sense, the lessons which a Peruvian architect might learn from our designs, and could re-use, over and over again, in his own designs. We have combined these 67 patterns in one particular way, to form the designs presented in part one. However, in the hands of different Peruvian architects, or in the hands of different individuals designing and building their own houses, these patterns can generate an almost infinitely rich variety. In this sense, these patterns may begin to define a new indigenous architecture for Peru.

PART ONE

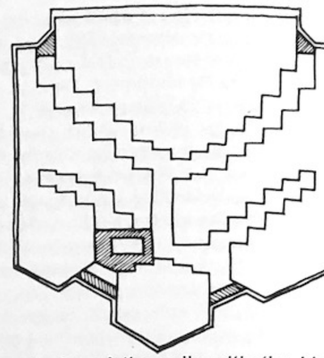
The site

The site contains 1,726 houses, at a gross density of 43 houses per hectare. House lots are 5.20 metres wide, and vary in length from 13 to 27 metres.

No two houses are alike. The exact form and length of each house is determined by a choice-process which allows families to fit their houses to their own needs and budgets.

Since the lengths of houses in the final site plan will be based on the choices which families make, and are unknown at present, the current drawing of the site plan is only approximate. Once each family has made its choices, it will be necessary to lay out a new site plan. This new plan will have the same morphology as the one shown, but the exact number of houses of different lengths, will reflect the families' choices. The morphology of the plan is fluid enough to adjust to the new lengths.

The site contains a number of cells Each cell contains 30–70 houses; it is a pedestrian island, surrounded by a sunken one lane road, which feeds small parking lots which surround the cell.



The cell

We have designed the cells with the idea that the particular group of people who live in a cell can make an impact on their cell, can give it a unique atmosphere, created by them, and can then, in a real sense 'take possession of it'.

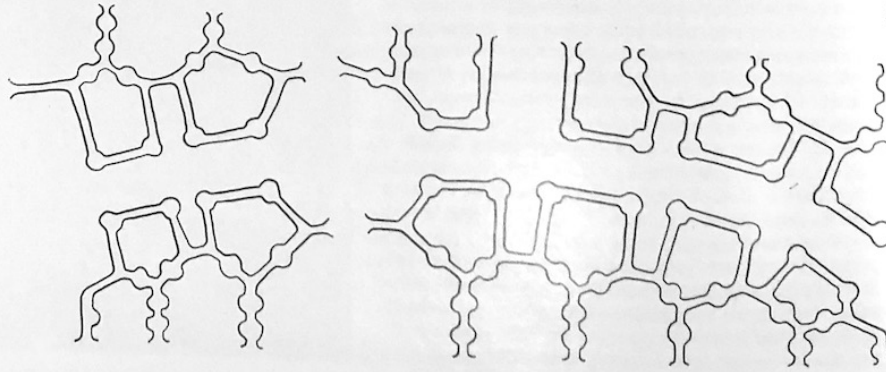
First, the basic form and circulation of each cell is unique – according to its particular location in the large plan.

Second, during the choice-process, people will be asked questions about the location they want for their house. When they are then located according to these choices, people with similar attitudes and interests will be living in the same cell.

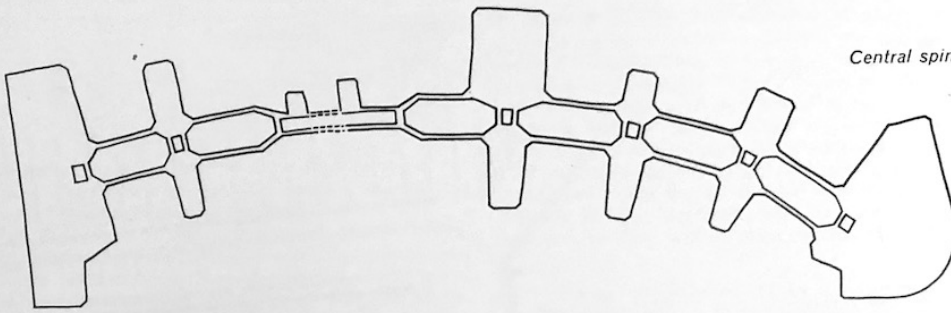
Third, the cells are physically separated, and the pedestrian passes through a physical gateway whenever he enters a cell: this will give each cell a better chance to build up its own unique flavour.

Fourth, at the heart of each cell, there is a small open place, surrounded by an unfinished, roofed arcade. It is our intention that the people who live in the cell will develop this arcade according to those community uses they think most valuable.

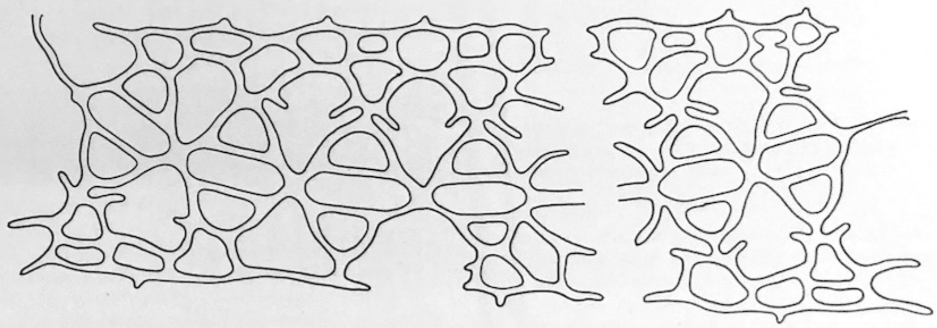
Road system



Over and above the cells, the site contains three major overlapping configurations: the road system, the pedestrian network, and the community spine. Vehicles travel on narrow one-way loop roads, around the cells, with car parking at the entrances to the cells. There are enough parking spaces to provide for 50% car ownership. This figure was given to us by the United Nations: they estimate 50% car ownership in 30 years, and asked us to work to that figure.
The central spine of the pedestrian system, we call



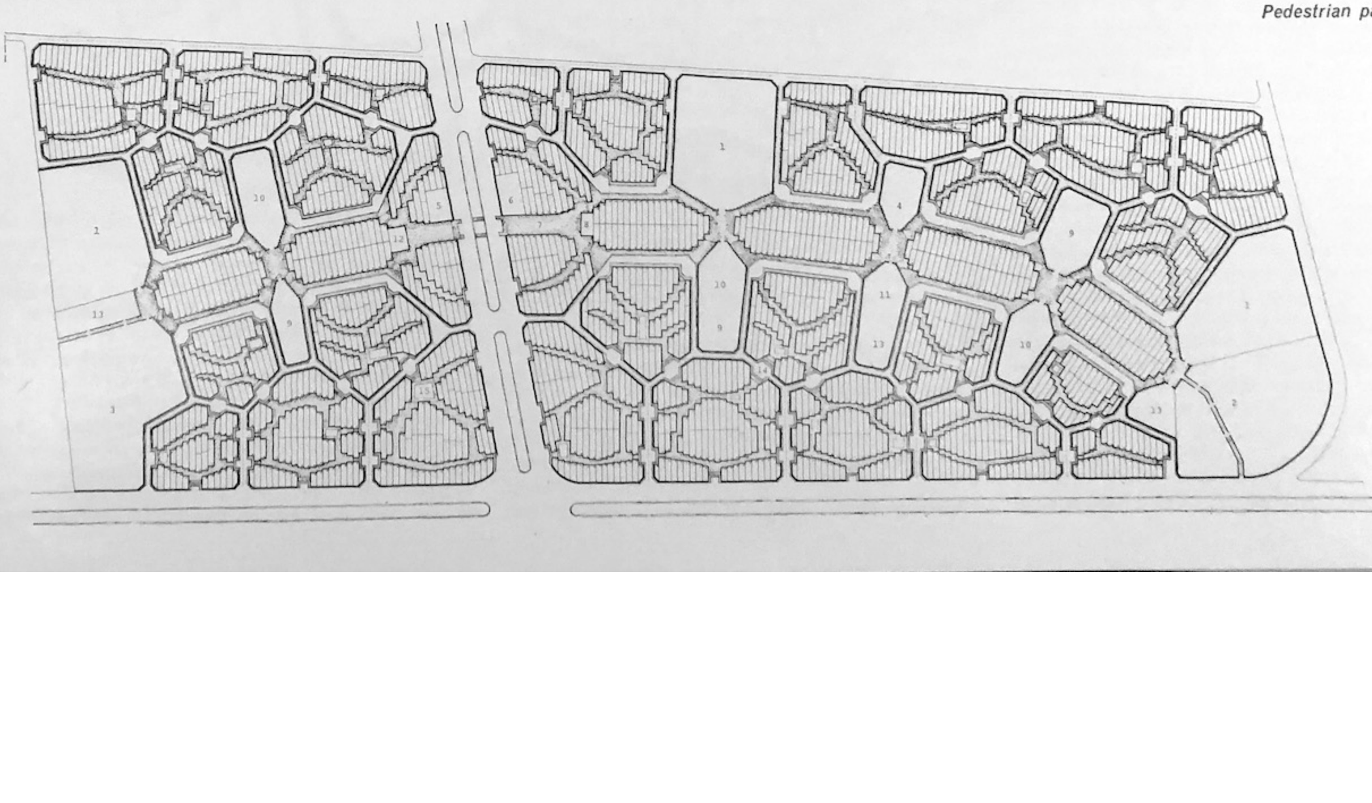
Central spine

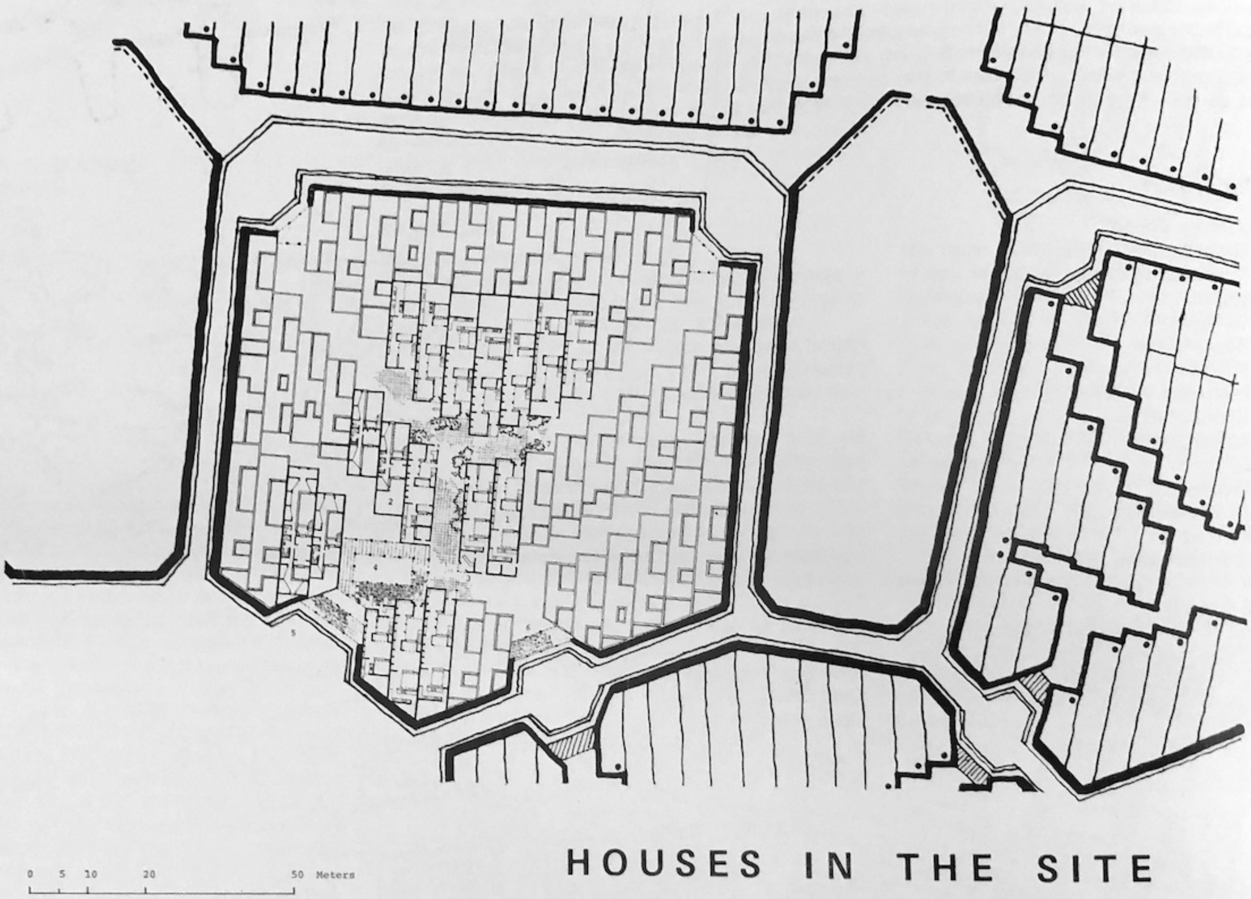


Pedestrian path system

Below The site

1 Primary school
2 Secondary school
3 Technical secondary school
4 Church
5 Cinema
6 Supermarket
7 Market
8 Municipal offices
9 Grove of trees
10 Kindergarten
11 Clinic
12 Dance hall
13 Sports center
14 Parking
15 Outdoor room





HOUSES IN THE SITE

1 First floor of house
2 Second floor of house
3 Shop
4 Outdoor room
5 Parking
6 Cell gateway
7 Garden

the 'paseo'. This name is taken from the Latin American habit of the evening and Sunday stroll (paseo in Spanish). The paseo gives people a high density pedestrian spine of looped paths where a tradition of evening and Sunday walks can develop.

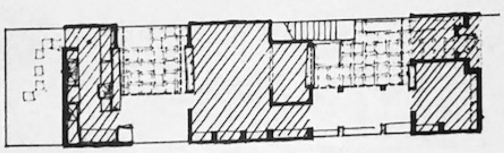
At frequent intervals along the paseo there are 'activity nuclei': small open places, with the community facilities and shops grouped around them. The community facilities are grouped in such a way as to create a special character at each of these activity nuclei.

The peripheral pedestrian paths connect cells to one another, and connect them to this main paseo. Each cell which is large enough, has a pedestrian loop in it: this will help to create the inner character of the cells, since it will become natural for people to take a walk 'around the cell'. All pedestrian paths from the outer parts of the site lead towards one of the eight activity nuclei. The nuclei will always be full of people.

The house

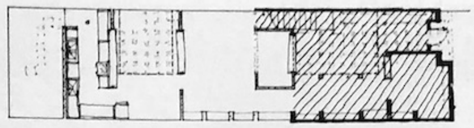
Although the choice-process guarantees that no two houses will be exactly alike, all houses are based on one generic house, see next page.

This generic house is a two-storey house, 5.20 metres wide, and about 20 metres long, which has an alternation of rooms and patios along its length, the rooms connected by deep verandas. This alternation gives every room light and air, and makes the house seem larger. The two main patios are always one behind



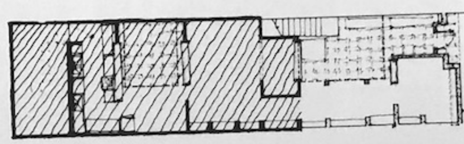
the other in the direction of the breeze (which comes from the south) – so that cool air circulates through the house in summer. In winter, the patios will be covered by dacron sailcloth covers which run horizontally on rods at roof level. They may be controlled from upstairs by cords, and make the patios usable all the year round.

The ground floor of the house contains two parts: a public part and a family part. The main features of the public part are the front patio, and the sala (formal living room or parlour). In Peruvian life there is a strong distinction between members of the family who may go anywhere in the house, and strangers who must be entertained in the sala. The sala is



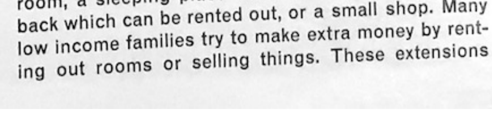
separated from the rest of the house by the front patio which even in the smallest house allows visitors to be treated with proper formality.

The family part of the house centres on the family room (comedor-estar). An alcove (two in large houses) opens off this family room to make a place where children study at night, where women can sew, where people can talk while the TV is on, etc. Behind the family room there is a kitchen, with two service patios, one on either side of it. The one between kitchen and



family room is a pleasant place, where people can eat, and work. The other provides storage for the inevitable building materials, animals, and laundry lines.

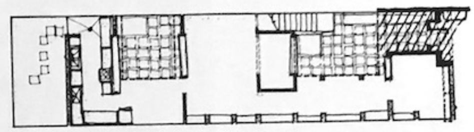
Upstairs the house contains a master bedroom, bathroom, and a number of tiny individual bed alcoves. These bed alcoves give each child a small space which is his own, for his own things; very young children may double bunk in a single alcove. Since Peruvians don't like being isolated, these alcoves are clustered around common spaces. There are two clusters; one for boys and one for girls. Every house,



even the smallest, can be extended to make room for as many as eight beds.

Every house can be extended to provide accommodation for a grandmother downstairs near the family room, a sleeping place for a servant, a room at the back which can be rented out, or a small shop. Many low income families try to make extra money by renting out rooms or selling things. These extensions are much easier if the back of the house opens on to a pedestrian way: those people who are willing to pay for it may select this option in the choice-process.

Finally, each house has a very strongly marked entrance, with deep recesses, a seat outside, and a gallery or 'mirador' at the second storey. Peruvians spend a great deal of time street watching: people hang out in doorways, sit on benches outside the doors, and watch the street from windows above. They like to be in touch with the street, but from the seclusion of their homes. Most houses in our site



plan command a direct view into the centre of the cell in which they stand, so that activity can be seen from the front window or the door.

Construction

The basic structure of the house consists of a floating slab foundation, load bearing walls, and a light weight plank and beam system. This form is conceptually very similar to traditional construction: but each of the components is a cheaper, lower-weight higher-strength version of its traditional equivalent. The floating slab is laid in large sections by a road building machine. The walls are of interlocking mortarless concrete blocks, reinforced with sulphur, with a cavity for plumbing and conduits. The planks and beams are made of urethane foam-plastic and bamboo, reinforced with a sulphur-sand topping.

All these building components can be produced in Peru today with available resources and skills. Further, the ideas embodied in these methods and products have the potential for long-range development of natural resources. These, in turn, will directly contribute to the economic growth of the people and the country, a vital factor in creating a national housing policy. Sulphur is available in huge quantities in Peru; current estimates show 50,000,000 tons of sulphur waiting to be mined in the Peruvian Andes. The use of urethane foams has been tested in various parts of Latin America; it is a seed industry of great importance, since foams are now used in many different ways, inside and outside the building industry. A urethane plant, once started, would benefit many sectors of the national economy. Bamboo is widely the 'paseo'. This name is taken from the Latin American habit of the evening and Sunday stroll (paseo in Spanish). The paseo gives people a high density pedestrian spine of looped paths where a tradition of evening and Sunday walks can develop.

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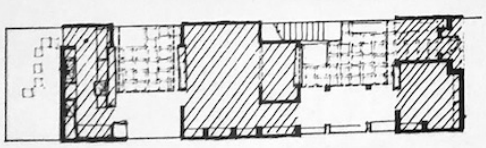

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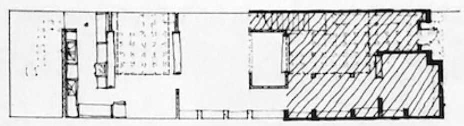

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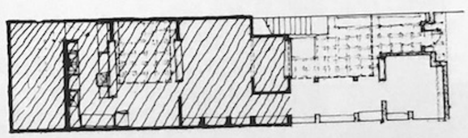

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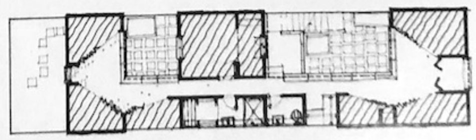

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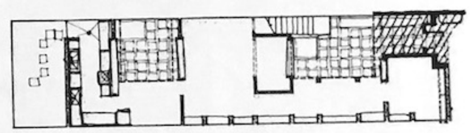

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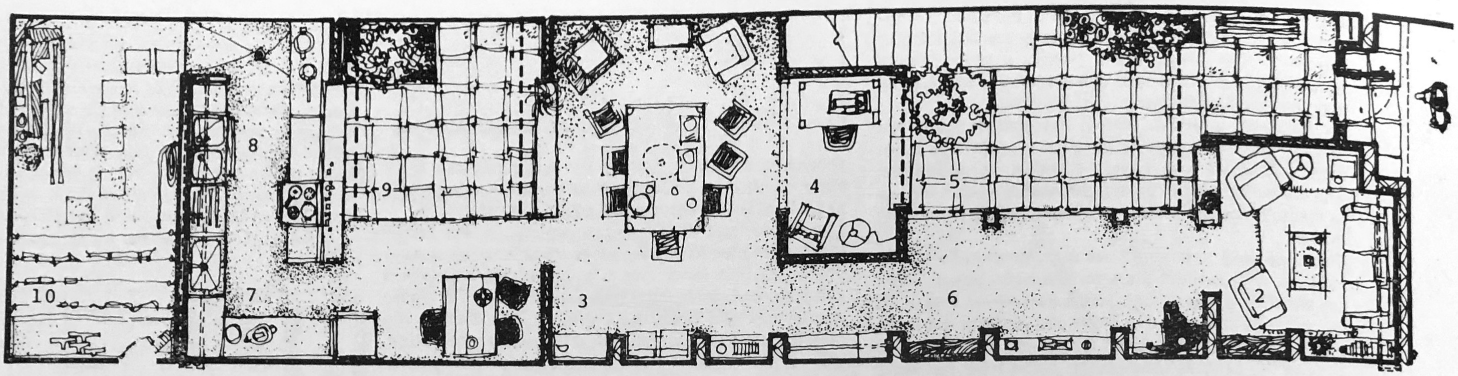
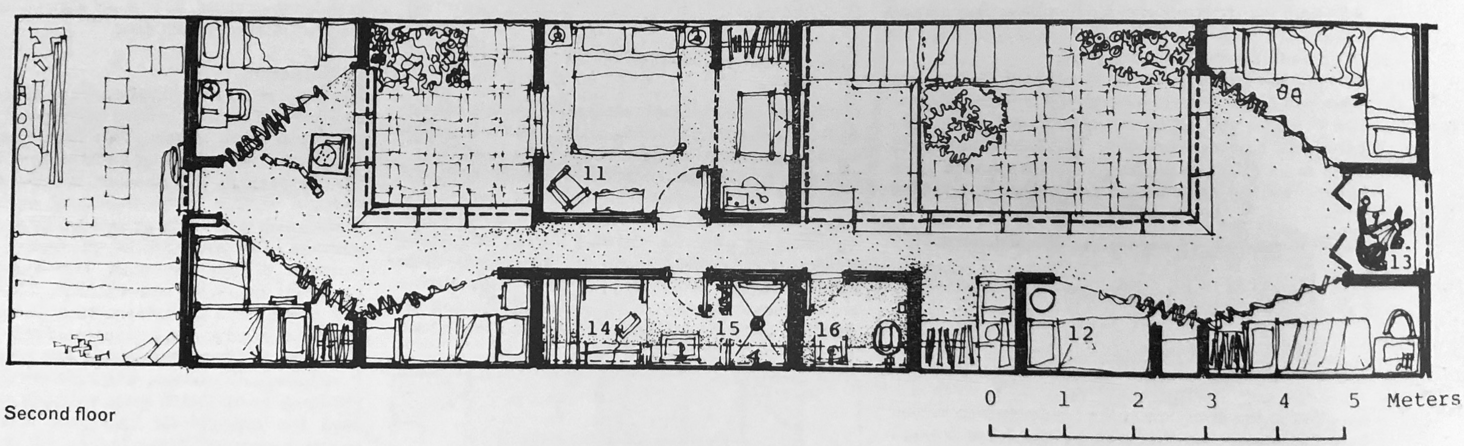
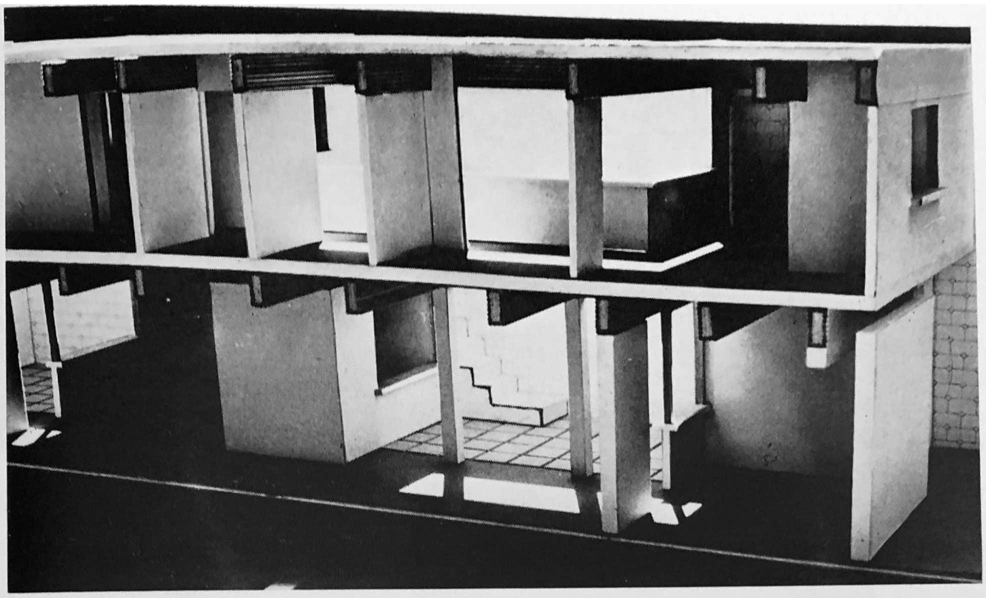


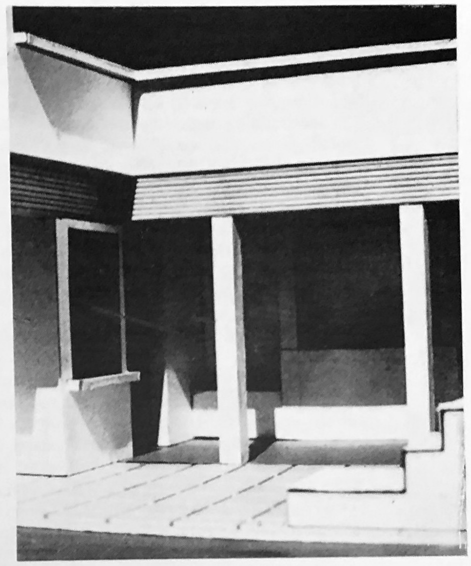
First floor

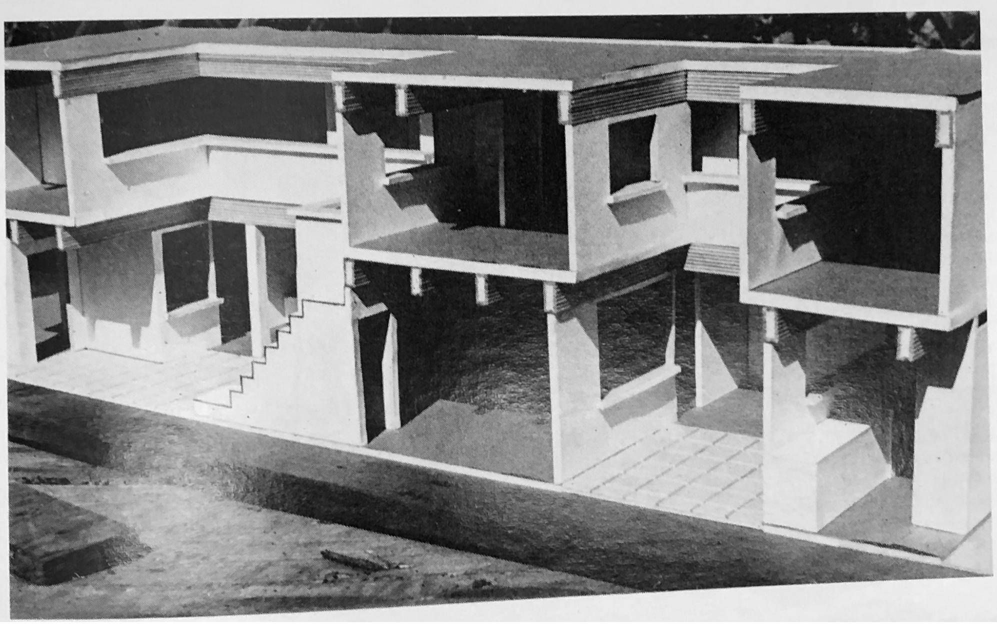


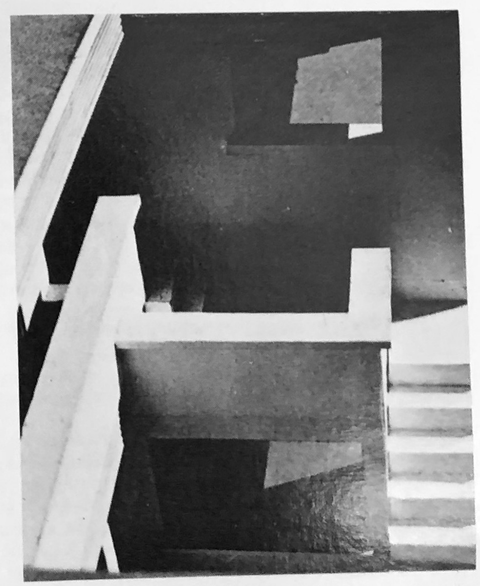
Second floor

1 Entrance
2 Sala (Parlour)
3 Family room
4 Family room alcove
5 Main patio
6 Veranda
7 Kitchen
8 Laundry
9 Kitchen patio
10 Storage patio
11 Master bedroom
12 Bed Alcoves
13 Mirador
14 Clothes drying closet
15 Shower
16 Toilet









available in the north of Peru, and may be imported cheaply from Ecuador. Though it is often thought of as a low-prestige material, it will quickly become a material of great value when used together with high performance bonding agents.

These building materials are especially suited to the local earthquake conditions. The mortarless block has been tested in Mexico under earthquake conditions, and has performed well throughout. Sulphur is now being tested in earthquake zones, and performs as well as steel reinforcing. The floating slab has a long history of success in earthquakes. The urethane-bamboo sandwich is enormously strong – and its very light weight reduces loads during earthquakes.

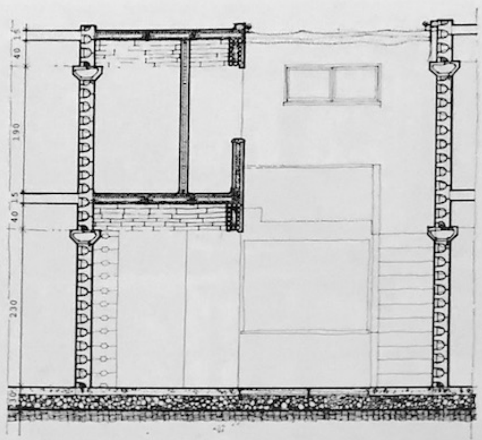
These are not merely low cost, high performance materials. The yellow diamonds of the block wall, where it is reinforced with spots of sulphur, the warm texture of the bamboo ceilings, the deep polished red of the oil stained concrete slab, and the translucent white of the dacron sailcloth patio cover, combine to create a house which is far more warm and human than the usual heavy grey of low cost construction.

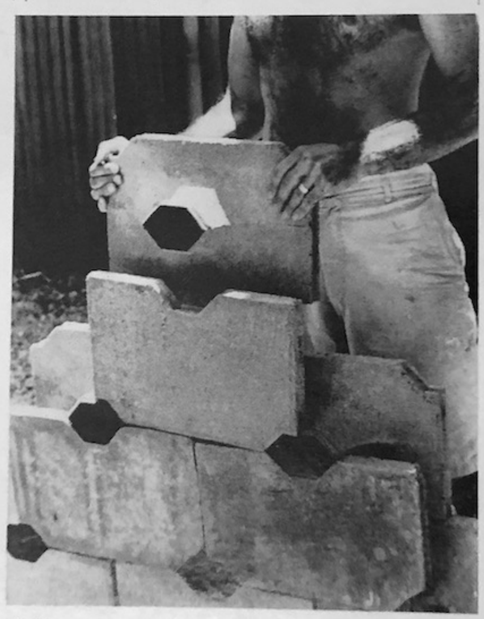
To simplify building construction, all components are prefabricated, on site. They all conform to the 10 cm module. They are assembled dry. This makes them equally suitable for use by the contractor, when the houses are first built, and by the families who live there, when they want to change their houses later.

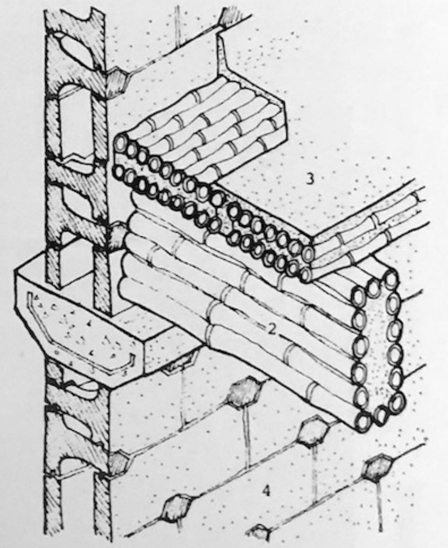
We have chosen these components with special emphasis on the idea of future do-it-yourself construction. Peruvian families add to their houses, and change them, continually. They can only do this if the components are extremely small in scale, and easy to work with home tools. We have therefore tried very hard to create a system of components that are easy to work, and can be used at the rather low tolerances that correspond to the realities of home construction. In our opinion, this is more relevant to people's needs than a system of highly machined components, which must be built to very fine tolerances. Given the assumption that home construction will always be done rather roughly, with hammer and nails, and fillers where required, our system will allow the home-owner to do almost anything he wants to do.

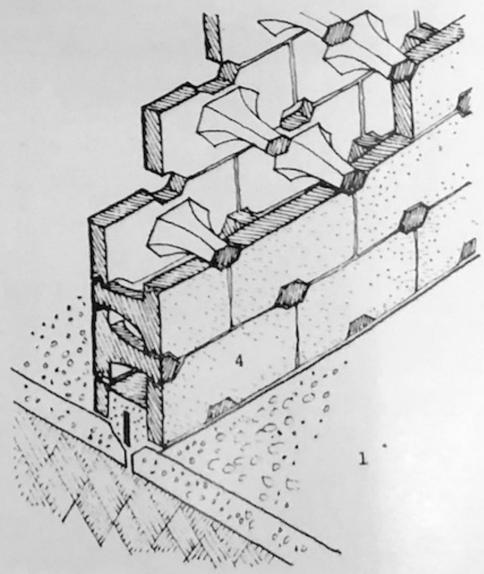
For example:

On the slab foundation, a new wall can be built anywhere, without needing extra footings. The mortarless block wall can have individual blocks removed or added, at will. The hollow wall makes it easy to add new plumbing fixtures or electrical conduit, cheaply and simply, by taking out a block. A person can make his own blocks, instead of buying them: the block

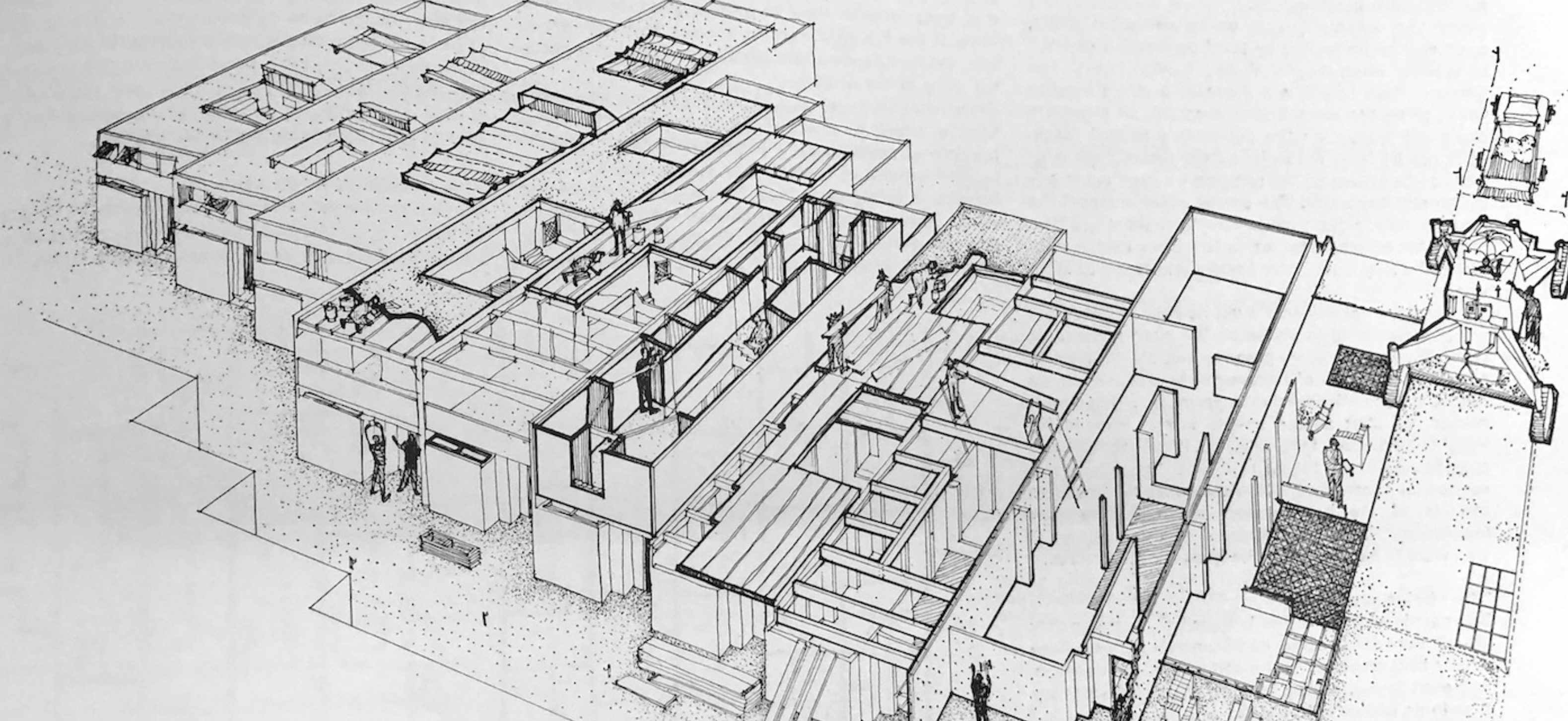








Right
1 Floating slab
2 Bamboo—urethane foam beam
3 Bamboo—urethane foam plank
4 Mortarless block cavity wall



CONSTRUCTION

moulds are designed to be operated by one unskilled person. Extra block columns can be inserted at any point. The sulphur joints, unlike cemented joints, need only to be melted by local application of heat, to loosen; when they cool they harden again. The bamboo foam beams are made in 5 metre lengths which fit across every house; they can sit anywhere along the length, on the continuous impost block. They can be hand cut to frame any desired opening. The bamboo foam planks can also be hand cut to any length and any width. The beams which support the roof are initially designed to carry a minimal live load only: if the house owner wants to make a usable third storey, he may insert extra beams next to the existing ones.

Finally, the components must be easy to get. They will be impossible to obtain on the open market. To make them available, we propose that the community contain a new kind of community service, which we call the Community Building Supermarket. This supermarket will start as the on-site factory needed for initial construction. In its later life, it will manufacture components, sell them, rent out the equipment needed for assembly, provide skilled labour for those aspects of the construction which involve new techniques, and train members of the community who want to learn these techniques for themselves.

The choice process

The people who live in our houses will, because they are all Peruvians, share certain needs and all have similar backgrounds. At the same time, each person, and each family, will be unique. The choice-process tries to do justice to this fact.

The needs which people share led us to the patterns and these patterns led us to the generic house design already presented. But even if all families share the needs which are satisfied by this generic house, they will, because they are unique, also have very different attitudes to the relative importance of these different needs. One family, which tends to be formal, will consider the need for a sala most important of all; another family in which life tends to be informal, may live most of the time in the kitchen. Although both families will want a sala and a kitchen, the first family would prefer a large sala and small kitchen, if they had to choose – and the second family a large kitchen and a small sala. The uniqueness of any family, will, in this way, be reflected by the relative amounts of money they would want to spend on satisfying their various needs.

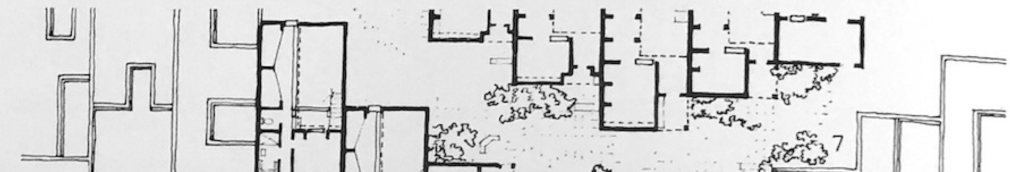
This is essentially how the choice-process works. We ask each family to decide how much they want to spend; and then we ask them to divide this money up among the various parts of the house, in the way that best reflects their individual preferences. The form of the house allows its various parts to vary in size, independently of one another; without disturbing the unity of the whole.

Even though no one part of the house can take more than a small number of different sizes, the total number of combinations is extremely large – in the neighbourhood of a million. In a community of 1,500 houses, it is highly unlikely that any two will be the same. This variety is not just visual variety: it reflects the real variety of attitudes to life which will exist among the fifteen hundred families who live in the Proyecto Experimental.

On the following pages we present the choices which a family would have to make, before buying a house in the Proyecto. These choices would, of course, have to be made before construction starts. To help people make the choices, it would be essential to build one or two model houses ahead of time, and allow people to visit them. Otherwise they would probably not be able to grasp the meaning of the choices.

The combination process

The combination process is not unlike the process by which the leaves on a tree are formed. All the leaves are defined by the same morphogenetic rules. The



PROYECTO EXPERIMENTAL DE VIVIENDA

LIMA, PERU

FAMILY CHOICE SHEET

By answering the questions on this sheet, you may decide how big to make the various rooms inside your house. Start by deciding how much money you want to spend on the house, altogether. You may choose any amount between 79,000 soles and 163,000 soles.

When you have decided how much you want to spend altogether, you may start making choices about individual rooms and finishes, and about the location of the house in the community. Each of these choices costs money. To make your choices, you will have to decide which things matter most to you.

The available choices are shown below. The numbers which follow each item, show, in thousands of soles, how much each of the various choices costs. Write the number you have chosen for each item, in the column on the right. When you have finished, add up the numbers on the right. You must be sure that the total is the same as the total price you are willing to pay for your house. Thus, for instance, if you want to spend 95,000 soles on your house, the numbers in the right hand column must add up to 95.

On the pages which follow this one, we give you the detailed explanation of these choices one by one, so that you can understand clearly what you are choosing. You should read these detailed explanations before you try to make your choices.

			Your Choice
SALA	Choose one of these	3 8 14 20	
FAMILY ROOM	Choose one of these	22 24 26 28 32 35	
MAIN PATIO	Choose one of these	18 21 23 27	
KITCHEN-LAUNDRY	Choose one of these	13 22	
BED ALCOVES	Choose one of these	6 9 13 16 19 22	
MASTER BEDROOM	You must choose this	11	
GRANDMOTHERS BED ALCOVE	Choose one of these	0 1	
LAUNDRY-STORAGE PATIO	Choose one of these	6 7 8 10	
CAR HOUSE DISTANCE	Choose one of these	0 3	
RENTAL/BACK DOOR	Choose one of these	0 2 4 8 10	
SHOP	Choose one of these	0 8 10 20	
EXTRAS	You may choose more than one of these, or none. Write the total on the right	1 1 1 1 2 3 5	
FINISHES	You may choose more than one of these, or none. Write the total on the right	1 1 2	
		TOTAL:	

PROYECTO EXPERIMENTAL DE VIVIENDA

LIMA, PERU

1. SIZE OF SALA

In all houses, the sala is a receiving room, separate from the comedor-estar. The very smallest sala you can have is a tiny alcove just large enough to hold two chairs and a sofa, inside the front door. Or you can have a sala more like an ordinary room.

Choose one:

Tiny sala	COST: 3,000 soles
Tiny sala with option for medium sala later	COST: 8,000
Medium sala	COST: 14,000
Large sala	COST: 20,000

2. SIZE OF FAMILY ROOM

Your family room can have a number of different sizes. All of these rooms have one small alcove off them, where children might do their homework, or a woman might sit and sew. In the smallest one, this alcove is very small. In the larger ones, there is a second alcove.

Choose one:

Small room + one (small) alcove	COST: 22,000 soles
Small room + one alcove	COST: 24,000
Medium room + one alcove	COST: 26,000
Large room + one alcove	COST: 28,000
Medium room + two alcoves	COST: 32,000
Large room + two alcoves	COST: 35,000

As you will see on the next page, the master bedroom size is determined by the family room size which you choose. For this reason the costs of the family room shown here include the extra costs created by larger master bedrooms.

3. MAIN PATIO

Every house has a main patio, which contains the stair, is flanked by the sala, the family room, the entrance, and by a veranda which connects the sala and family room. This patio is covered in winter by a dacron sailcloth. The patio is always 3 meters wide, but its length may vary. Especially if you intend to plant things there, you should choose one of the larger ones.

Choose one:

Tiny patio	COST: 18,000 soles
Small patio	COST: 21,000
Medium patio	COST: 23,000
Large patio	COST: 27,000

4. KITCHEN-LAUNDRY

There are two kitchens to choose from. The small one has no sitting space in it, and has the laundry counter out of doors, in the storage patio. The large one is twice as large, has room for a table in it, and has the laundry counter under cover. Both kitchens contain, as an integral part, a small kitchen patio, which will be covered in winter, and gives you extra room to work, room for children to play, etc.

Choose one:

Small kitchen	COST: 13,000 soles
Large kitchen	COST: 22,000

5. NUMBER OF BED ALCOVES

Every house will have a master bedroom; but this is the only conventional bedroom. All the other beds will be in individual bed alcoves, containing a bed, a dressing space, and storage, and nothing more. These bed alcoves will be arranged in two small clusters, one for boys and one for girls.

At least one of the alcoves will be an extra large one, large enough to hold two bunk beds. If you would like to have two of your children sleeping in bunk beds like this, you may choose a number of alcoves which is one less than the number of children in your family.

You may choose how many individual bed alcoves you want (each alcove costs 3,000 soles), and you may also say how you want the alcoves clustered. Choose one of the following. (The first number is the number in the front cluster, the second in the back.)

Two beds:	2,0	COST: 6,000 soles
Three beds:	3,0 or 2,1	COST: 9,000
Four beds:	4,0 or 3,1 or 2,2	COST: 13,000
Five beds:	4,1 or 3,2 or 2,3	COST: 16,000
Six beds:	4,2 or 3,3 or 2,4	COST: 19,000
Seven beds:	4,3	COST: 22,000

6. MASTER BEDROOM, BATH AND STORAGE

The master bedroom and storage are always above the family room. These rooms can vary in size, but their size must always correspond to the size of the family room you have chosen. In this sense, you have no real choice of sizes here, though it may influence your choice of family room size: the bathrooms are always the same size.

The fixed cost of this room is 11,000. All additional costs are included in the costs of family rooms. For all family rooms the master bed costs are:

Master bedroom	COST: 11,000 soles

PROYECTO EXPERIMENTAL DE VIVIENDA

LIMA, PERU

7. GRANDMOTHER'S BED ALCOVE

Every house has the possibility of placing a bed alcove, on the ground floor, just next to the family room, for an old person. You may choose to have this bed alcove built today, or you may build it yourself, later.

Choose one:

Grandmother's bed alcove built now	COST: 1,000 soles
Not built now	COST: zero

8. LAUNDRY-STORAGE PATIO

Every house has, at the very back, an extra patio which gives you room for expansion on the ground floor, a place where servant quarters may be constructed, a place to hang laundry, and to store building materials and large objects. If you want to use this patio to build rental space, or a little shop, do not choose the very small patio.

Choose one:

Very small	COST: 6,000 soles
Small	COST: 7,000
Medium	COST: 8,000
Large	COST: 10,000

9. CAR HOUSE DISTANCE

Some houses have parking lots right next to them, others do not. In no case is a house more than 50 meters from the nearest parking lot. If you have a car or if you expect to have a car in the near future, you may want to choose a house near a parking lot. Otherwise you may prefer the quietness and safety of a pedestrian street, especially if you have children who play outside the house.

Choose one:

There is a parking place within 15 meters of your house	COST: 3,000 soles
There is a parking place between 15 meters and 50 meters from your house	COST: zero

10. RENTAL AND/OR BACK DOOR

If you hope to rent out a small room in the future, or if you are particularly anxious to let your servant have a back door which is separate from the front door, you may have a lot which has a back or a side opening onto a walkway. If you choose a lot that has a second entrance, you may have a small room for rental, built there today, or you may leave it unbuilt, and build it yourself later. If you choose a shop you may not choose a rental unit.

Choose one:

Corner lot with second entrance on side and rental space built today	COST: 10,000 soles
Corner lot with second entrance on side	COST: 8,000
Lot with second entrance on back and rental space built today	COST: 4,000
Lot with second entrance on back	COST: 2,000
Lot with front only	COST: zero

11. SHOP

You may want, now or in the future, to open a small shop. In this case you will want to have a location where a shop can prosper - either next to the main market, or at some corner which many people are going past. If you choose a shop location by the market, you will have the shop built now, automatically. If you choose one of the other shop locations, you may have the shop built now, or you may choose to leave it unbuilt now, and then build it yourself later. If you have chosen a rental space, you may not choose a shop.

Choose one:

Market location, with shop built now	COST: 20,000 soles
Corner location, with shop built now	COST: 10,000
Corner location, shop not built now	COST: 8,000
No possibility of building a shop	COST: zero

12. EXTRAS

If you find that you can purchase adequate space for your family without using all the money that you plan to spend on housing, or if some of these extra features mean more to you than extra space, you may want to choose some of the optional features listed below.

Fiberglass patio covers instead of sailcloth on front patio and middle patio	COST: 5,000 soles
Electric hot water heater, connected to bathroom, kitchen and laundry	COST: 3,000
Second wash basin for family	COST: 1,000
Wash basin and WC for servant, enclosed	COST: 2,000
Colored tiles around the main door	COST: 1,000
Bench near the main door	COST: 1,000
5 meter Eucalyptus saplings near front door	COST: 1,000

13. FINISHES

In Proyecto Experimental the basic finishes are the finishes of the building materials, block and bamboo. If you want to, you can have plaster or white wash in the sala or comedor.

Plastered ceiling in the sala	COST: 1,000 soles
Plastered ceiling in the comedor-estar	COST: 2,000
White washed block walls	COST: 1,000

Finally, you may choose where you want your house to be in the larger community. There are two choices: neither has any cost.

14. QUIET AREA OR BUSY AREA

There are two kinds of housing area to live in. In one kind of area there are many people walking up and down the pedestrian way outside the houses. During the day and in the evening, there will almost always be some people on the street. In the other kind of area there are far less people walking through.

Choose one:

Many people going past your house.
Few people going past your house.

15. NEARBY COMMUNITY FACILITIES

The church, market, clinic, parks, kindergartens, schools, secondary school, technical school, evening entertainment, are all fixed positions on the site, and each has a housing area that is particularly closely tied to it. Choose the one which you would most like to be near:

Church
Market
Clinic
Park
Kindergarten
Schools
High school
Technic?l school
Evening entertainment

* * *

individual leaves are formed by the interaction between these rules and the local conditions to which the leaves are subject. As a result, each leaf becomes unique, according to its position in the whole tree; yet in a generic sense the leaves on the tree are all the same. The combination process works in the same way.

All houses are formed by the same sequence of rules, based on the form of the generic house. But each house has to meet certain particular conditions: those imposed on it by the family's choices, and those imposed on it by its position in the site – orientation, the lengths of next door houses, location of nearby footpaths, and so on. Each individual house is formed by the interaction of the local conditions which it has to meet, and the generic rules of the combination process.

For example, in order to make the house-form coherent, the shape of the house entrance must be different for houses with a small sala and houses with a medium sala; it must be different for houses on a corner site and houses on a centre site; it must be different according to the length of the next door house on the eastern side (since the entrance is always on the east). The rules which form the house entrance (Steps 6, 7, 8 below), therefore depend on the size of the sala, the type of site, and the position of the next door house on the eastern side.

It is only this high degree of interaction between the rules of the combination process and the local conditions which guarantees that all houses are internally coherent, and that each house fits coherenty into the larger site plan. Like the leaves on a tree, all the houses will be different, yet all of them coherent and all of them the same.

We must stress the fact that the rules of the combination process are almost mechanical, and can be carried out by any trained draughtsman. *The low cost of the houses cannot support any individual design time.* We estimate that a trained draughtsman will need about one hour per house, to translate the family choice sheet into a set of working drawings and specifications for the contractor.

The draughtsman has one master site plan with the house sites shown on it; one file for each family, containing the family choice sheet, and a blank house plan, which shows the side walls only, 5.20 metres apart, for both floors, and no end walls or interior walls. He now builds up the detailed design of each house, by using the following rules, one step at a time:

Step 1

Assignment of houses to cells
Assign each family to a cell in the site plan, on the basis of their answers to questions 14 or 15 on the choice sheet. Location across the site is determined by choice 14. If they want to be in a busy area, place them along the paseo. If they want to be in a quiet area, place them far from the paseo. Location along the length of the site is determined by the community facility they want to be near (choice 15).

Step 2

Determination of house length
Fix the house length as the sum of the lengths of the chosen sala, patio, family room, kitchen and back patio (choices 1, 2, 3, 4, 8).

Step 3

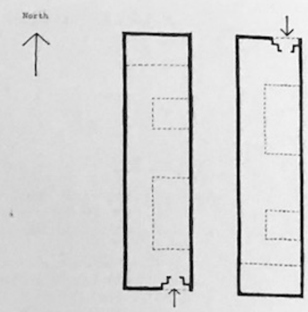
Assignment of houses to sites, within the cell
Within the cell fixed by step 1, assign each house to a lot whose length is as near as possible to the length determined by step 2, and which also satisfies the family's choices concerning shop location, rental/back door, and distance from parking lots (choices 9, 10, 11). (At this point the new site plan will be slightly different from the current site plan – since each house will have a slightly different length. It will now be necessary to make minor changes in layout and arrangement of houses, so that pedestrian paths, loop roads and parking lots still have a coherent form.)

Step 4

Detailed site conditions for each house
Since the house is now fixed within the site plan, the positions of next door houses, positions of adjacent paths and roads, the front end of the house and orientation of the house are now fixed. Transfer these to the drawing of the individual house.

Step 5

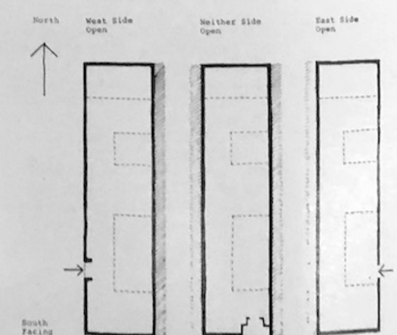
Position of patio openings
The patio openings are always on the east side of the house. Sketch in patios for different orientations as shown.



Step 6

General position of front door
The position of the front door is given as a function of patio position (step 5), and the presence or absence of adjacent houses. Sketch entry arrows according to this table.

The arrangements for houses facing north are mirror images of the arrangements for houses facing south. To avoid duplication, all future diagrams will be shown for south facing houses only. Arrangements for north facing houses are obtained by taking the mirror images of these arrangements.



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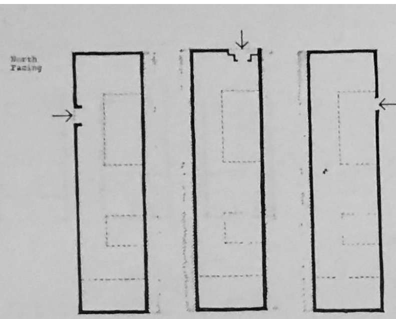
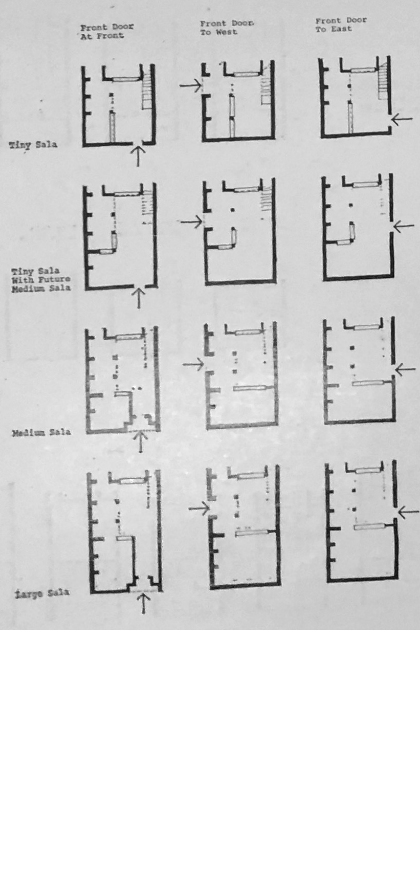


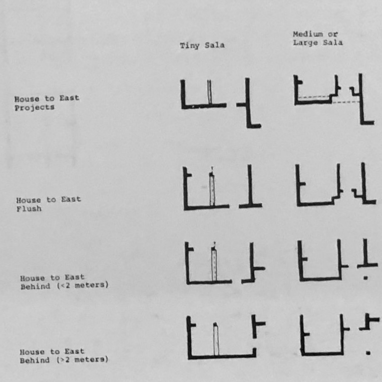
Step 7

Sala size and position and exact position of front door
The design of sala and front door, in relation to one another, are given as a function of door position (step 6) and the size of sala shown on family's choice sheet (choice 1). Draw sala and entrance according to this table.



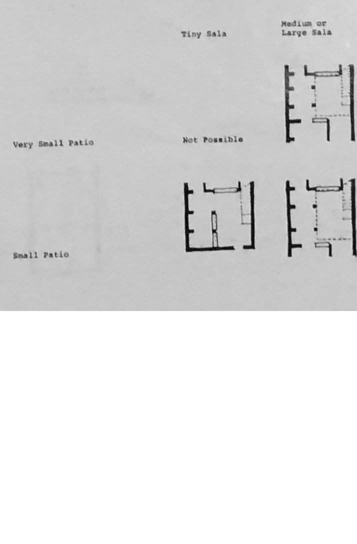
Step 8

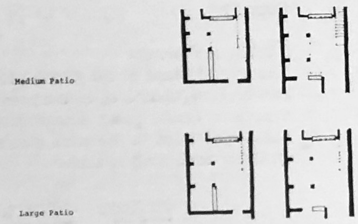
Detail of front door if at front end
The front door is on the east side of the front end of the house (step 6). Its detailed treatment depends on the position of the house next door and to the east, and on the sala size (step 7). Draw according to this table.



Step 9

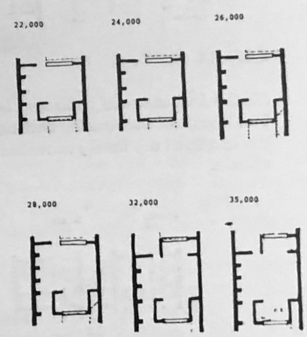
Size of front patio
The position of the front wall of the family room alcove and veranda column positions are fixed according to the family's choice of patio size (choice 3), and the size of the sala (step 7). Draw according to table.





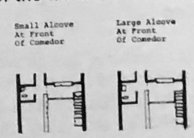
Step 10

Family room
The family room is fixed directly by the amount the family wants to spend on it (choice 2). Draw as shown.



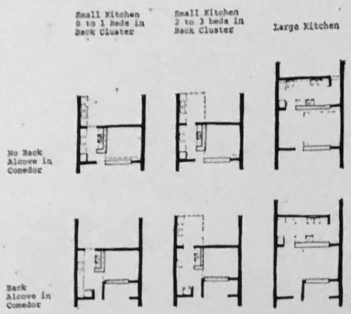
Step 11

Stairs
The position and size of the stair landing vary according to the size of the front alcove. Draw as shown.



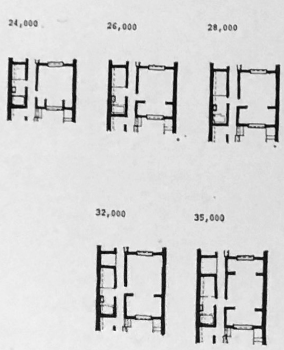
Step 12

Kitchen and laundry
The arrangement of the kitchen is determined by the kitchen size (choice 4), by the presence or absence of a second family room alcove (step 10), and by the number of beds in the back cluster upstairs (choice 5). Draw according to table.



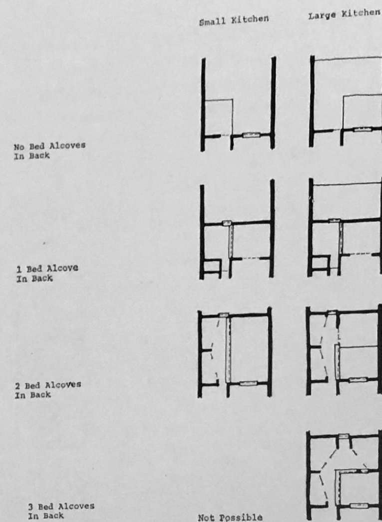
Step 13

Master bedroom and bathroom layout
The layout of the master bedroom is given directly by the length of the family room below (step 10). Draw as shown.



Step 14

Back cluster of bed alcoves
The layout of bed alcoves in the back cluster depends on the number chosen by the family (choice 5), and the kitchen size (step 12). Draw according to table.



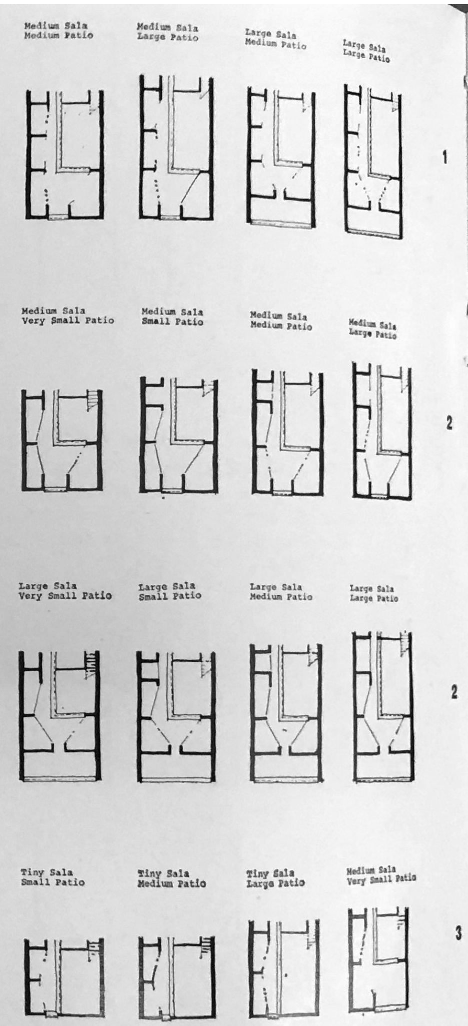
Step 15

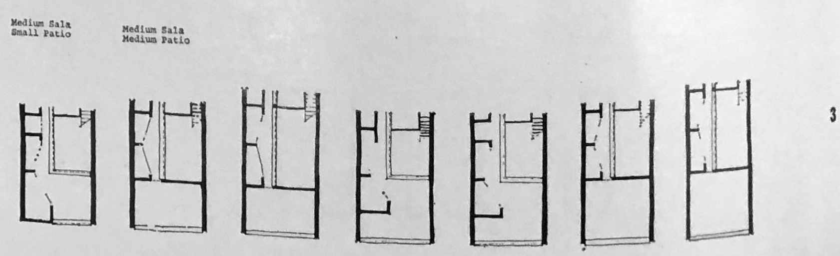
Front cluster of bed alcoves
The layout of bed alcoves in the front cluster depends on the number chosen by the family (choice 5). Draw according to table.

Four front bed alcoves (1)

Three front bed alcoves (2)

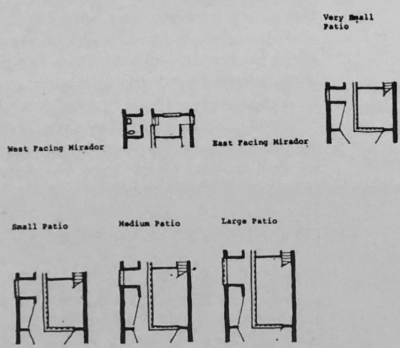
Two front bed alcoves (3)





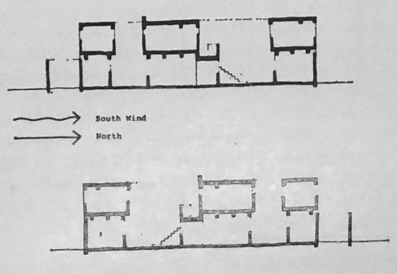
Step 16

Mirador
Front mirador is given by step 15. Side mirador occurs in corner houses only. Draw according to table.



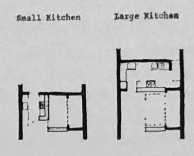
Step 17

Position of windscoop
The windscoop always faces the south wind. It is on the main patio in a south-facing house, and on the kitchen patio in a north-facing house. Draw in positions shown.



Step 18

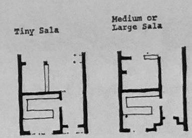
Bed alcove for grandmother
If the family has asked for a bed alcove (choice 7) downstairs, it is placed in the kitchen patio, next to the family room. Draw according to table.



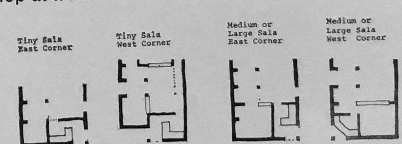
Step 19

Position of shop
If the family has asked for a shop (choice 11) the house either fronts on the market, or has a corner lot. The exact arrangement depends on the relative positions of the corner, the sala, the kitchen. Draw according to table.

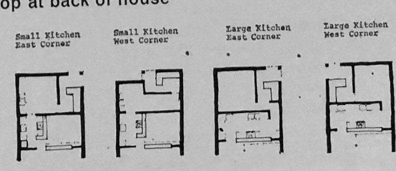
Shop facing market



Shop at front of house

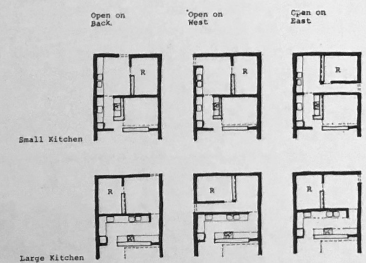


Shop at back of house



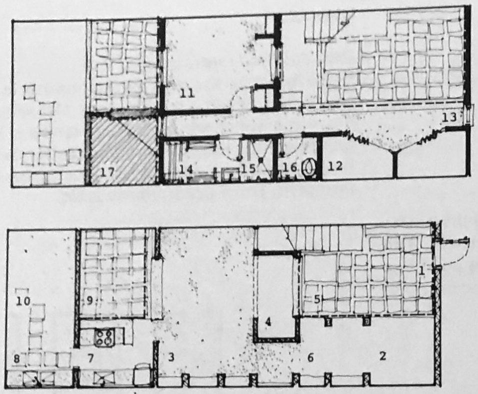
Step 20

Back door and rental space
If the back or the side of the house is open to a pedestrian way, the back door is placed according to the site and the position of the kitchen. If the family has asked for rental space (choice 10) this is built in the position marked R; otherwise this position is left unroofed. Draw according to table.

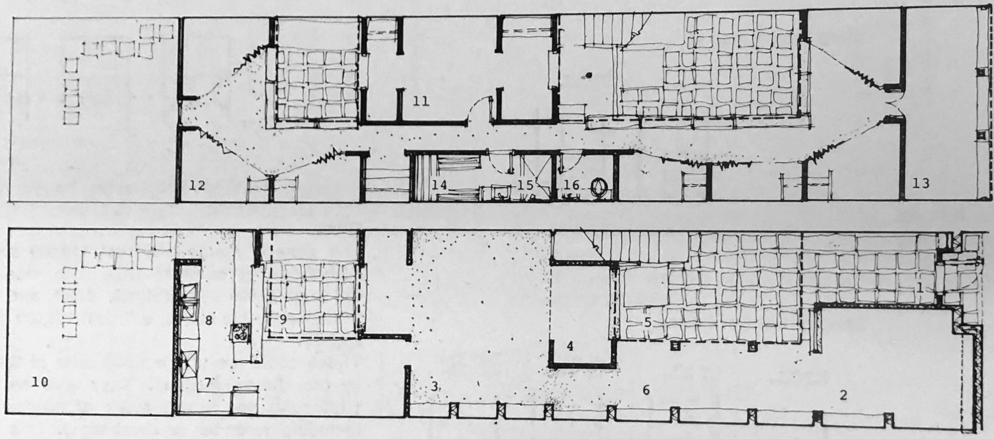


Costs
The generic house will cost 119,000 *soles* ($2,800, £1,120) as of summer 1969. The smallest house will cost 79,000 *soles* ($1,800, £720), and the largest, with all possible extras, will cost 163,000 *soles* ($3,800, £1,520).
These costs are within 1,000 *soles* of the target set by the United Nations. They give an average of 1,130 *soles* per square metre of interior space (not including verandas or overhangs). This is 25% less than current low-cost construction in Lima.
Our major cost savings have come from the following sources. The foundation slab, without footings, costs 100 *soles* per square metre, compared with the usual price of 200 *soles* per square metre for slab and footings. The mortarless concrete block wall reinforced with sulphur, costs 120 *soles* per square metre, compared with the usual price of 140 *soles* per square metre for a mortared block or brick wall. The long side walls are two-leaf party walls, thus halving the usual cost of individually owned walls. The bamboo-urethane floors and roofs cost 200 *soles* per square metre, compared with the usual cost of 340 *soles* per square metre for reinforced concrete slabs. The finish of the mortarless block wall and the finish of the

Left Small house, second floor **1**, first floor **2**
Below Large house, second floor **3**, first floor **4**

1

2

1 Entrance
2 Sala (Parlour)
3 Family room
4 Family room alcove
5 Main patio
6 Veranda
7 Kitchen
8 Laundry
9 Kitchen patio
10 Storage patio
11 Master bedroom
12 Bed alcoves
13 Mirador
14 Clothes drying closet
15 Shower
16 Toilet
17 Future bed alcove

3

4

bamboo ceilings make plastering unnecessary, and save the usual cost of 50–60 *soles* per square metre for plaster. The dacron sailcloth cover on the patio, costs 250 *soles* per square metre and saves the cost of windows throughout the house, at a usual cost of 500–600 *soles* per square metre. We have eliminated several doors at a cost of 550 *soles* per door. The ABS accumulator and use of the cavity wall as a vent, saves the cost of several metres of waste pipe, vent pipe, and connections. The fact that our site plan has 1,726 houses, as against the 1,500 expected, saves 12% of the cost of site development.

All costs are for summer 1969. The savings are based on innovations in the building and site development only, since land and financing costs were fixed.

PART TWO

Introduction

We now present some examples of the 67 patterns from which we have built our designs. We do not present these patterns merely to explain our designs, but because we believe that each of them expresses a generally valid principle, which can be used over and over again. *This is the essential point of the patterns: they are re-usable.* Since many of them deal specifically with Peru, we hope that they may be particularly useful to Peruvian architects and builders.

A pattern defines an arrangement of parts in the environment, which is needed to solve a recurrent social, psychological, or technical problem. Each pattern has three very clearly defined sections: *context, solution* and *problem.*

The *context* defines a set of conditions. The *problem* defines a complex of needs which always occurs in the given *context.* The *solution* defines the spatial arrangement of parts which must be present in the given *context* in order to solve the *problem.*

If the needs in the *problem* are correct, and do occur as stated in the given *context,* then this arrangement of parts, or an equivalent one, must always be included in any design for the given *context.* Any design for this context which does *not* include the pattern, is failing to solve a known problem.

This does not mean, of course, that the patterns are absolute. The rightness or wrongness of a pattern is an empirical matter, and as such is always open to further observation and experiment. For this reason, we have tried to state the observations and evidence behind the patterns as clearly as possible, so that they can be checked by others, and rejected when incorrect.

The evidence we use comes from three sources: the published literature, our observations in Lima, and our laboratory tests and experiments. We spent a month each living with low income Peruvian families in Pampa de Comas, San Martin de Porras, La Victoria and Rimac (districts of Lima) to better understand their way of life. We built and tested each of the major building components, with supportive testing from professional laboratories. Where our observations are hard to support, we have stated them as conjectures.

Each of these patterns is part of a larger system of patterns, called the pattern language, which we are developing at the Centre for Environmental Structure. When the pattern language is working, as it will be within a few months, it will allow any designer who uses it to draw out all the patterns appropriate to a particular design for any design problem in the city. Even more important, each designer can contribute to the language: he will be able to communicate his design ideas to other designers, by expressing them as patterns.

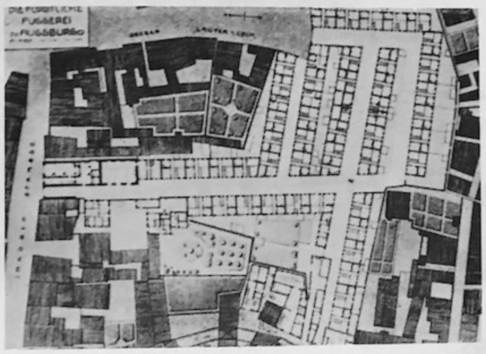
One final note. The patterns which are presented here were originally prepared for the Proyecto Experimental competition. Each pattern therefore ends with a short statement which explains how the pattern has been realized in the geometry of THE PROYECTO EXPERIMENTAL. This statement is just an example of the way the pattern was used by *us,* in *our* design. It is *not* part of the pattern itself. The pattern itself always starts with the words THE GENERAL PATTERN IS.

Subculture cells

THE GENERAL PATTERN IS:

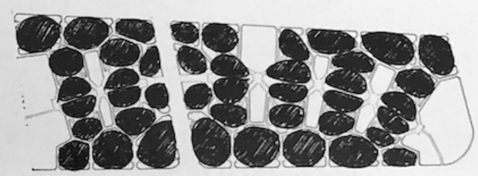
Context:
Any urban area which contains more than a few hundred dwellings.

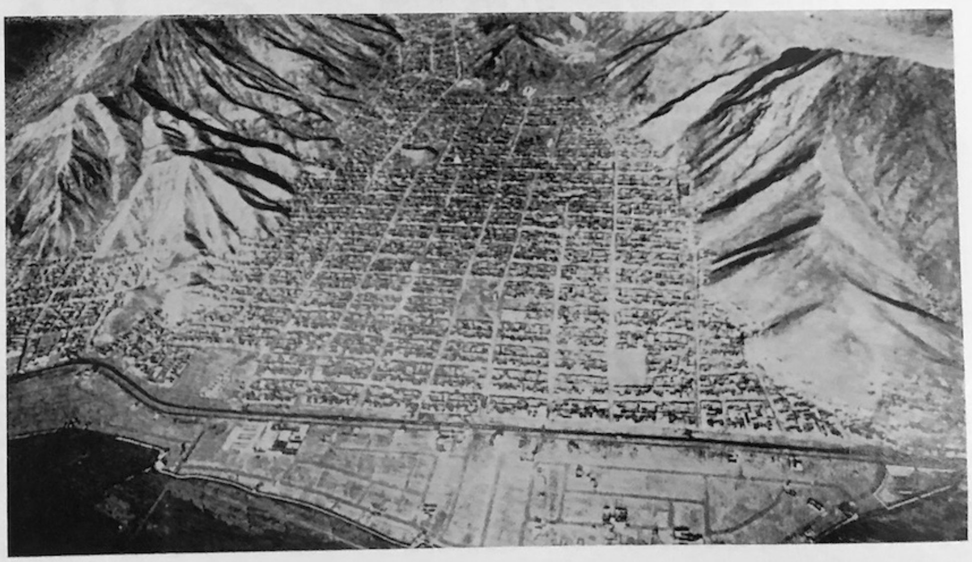
Solution:
The area is made up of a large number of small inward focused residential 'cells'. The cells are separated as sharply as possible from one another; if possible by open land, community facilities, or public



land.
Each cell is intended, in the long run, to sustain a different way of life: a different subculture. A subculture is defined as a group of people (not necessarily friends) who share certain attitudes, beliefs, habits and needs not shared by others; and who may require special environments, local organizations, or services to support these special needs. The community facilities which surround any given cell should reflect the particular interests characteristic of that subculture. All community facilities (including roads, schools, hospitals, churches, parks, industry, commerce, entertainment) are placed in the boundaries between cells.
The arguments which define cell size, are not yet fully clear. At present it seems that no cell should contain more than 1,500 people, or less than 50, with a mean cell population of about 500.

Problem:
People need an identifiable unit to belong to. They want to be able to identify the part of the city where *they* live, as distinct from all others. Available evidence suggests that the areas which people identify with are *extremely* small – of the order between 100 and 200 metres in diameter. They cannot identify these areas, unless the areas are well differentiated from one another: and studies show that areas will not be strongly differentiated from one another unless they support identifiably different ways of life. This suggests that any urban area should be broken into a number of small 'subculture cells', each supporting an identifiably different way of life.[1]
Psychological arguments lead to the same conclusion. There is strong evidence to suggest that a person cannot develop his own life style fully, unless he does so in an ambience where others share his life style.
In a homogeneous urban area, differences of life style tend to vanish, and ego-strength, self-confidence and character formation deteriorate. This again suggests that the urban area should, as far as possible, support a large variety of strongly differentiated life styles, each supported by a 'subculture cell'.
Ecological arguments help to fix the suitable cell size, and show the need for radical separation between cells. To develop their own life style, the families in a cell must be able to agree on basic decisions about services, community land, etc. Anthropological evidence shows that a human group cannot maintain the face to face relations required to co-ordinate itself in this way, if its population is above 1,500; many people set the figure as low as 500.[2]
It has also been shown that the group feeling necessary to support a particular unique life style, is greatly strengthened when that group is physically separated from all adjacent groups. This suggests that cells should be inward looking, and wherever possible separated by community facilities.[3]
IN THE PROYECTO EXPERIMENTAL, the community is divided into 43 small residential cells, each containing between 25 and 75 houses. The cells are clearly separated from one another. All houses in a cell face inwards, and the outer cells are surrounded by a narrow road sunken 50 cm below grade, so that these cells are elevated pedestrian islands.
Families choose the cell they want to be in, according to its relative 'quietness', and according to the community facilities nearby. As a result, the families in any one cell will probably share attitudes and interests;





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we hope that each cell will develop a unique 'character', different from the others.

Looped local roads

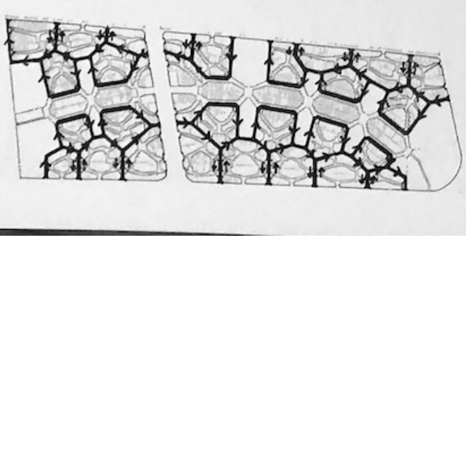
THE GENERAL PATTERN IS:

Context:
Any residential area served by local roads.

Solution:
These local roads are narrow one-way 'loop' roads serving a maximum of 50 parking spaces. They need be no more than one lane wide, the surface should be rough. A loop road is defined as any road in a road network placed so that no path along other roads in the network can be shortened by travel along the 'loop'.

Problem:
Through traffic is fast, noisy, and dangerous. At the same time cars are important, and cannot be excluded altogether from the areas where people live. To safeguard these areas, the roads must be laid out to discourage all through traffic – hence the loops. The loops themselves must be designed to discourage high volumes or high speeds: this depends on the total number of houses served by a loop, the road surface, the road width, and the number of curves and corners. Our informal observations suggest that a loop is, and feels, safe as long as it serves less than 50 cars. At this level, there may be a car every two minutes at rush hour, and far fewer during the rest of the day. The number of houses served will vary, according to the average number of cars per house. At $1\frac{1}{2}$ cars per house, such a loop serves 30 houses; at 1 car per house 50 houses; at $\frac{1}{2}$ car per house, 100 houses.

IN THE PROYECTO EXPERIMENTAL, all access to houses is provided by one lane, one-way, loop roads. No one of these loops serves more than 100 houses or 50 parking spaces (at 50% car ownership).

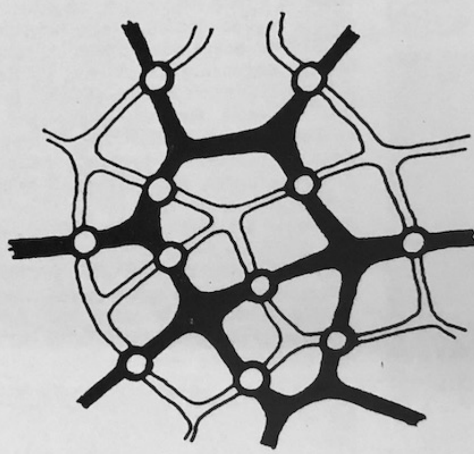


Car – pedestrian symbiosis

THE GENERAL PATTERN IS:

Context:
Any area which contains pedestrian paths and local car roads.

Solution:
The system of pedestrian paths and the system of roads are two entirely distinct orthogonal systems.



They cross frequently; so that no point on either system is more than about 50 metres from a crossing. Every time they cross, both paths and roads swell out, making room for pedestrian activity and for parking and standing.

Problem:
It is common planning practice to separate pedestrians and cars. This makes pedestrian areas more human, and safer. However, this practice fails to take account of the fact that cars and pedestrians also need each other: *and that, in fact, a great deal of urban life occurs at precisely the point where these two systems meet.* Many of the greatest places in cities, Piccadilly Circus, Times Square, the Champs Elysées, are alive *because* they are at places where pedestrians and vehicles *meet*. New towns like Cumbernauld, where there is total separation between the two, seldom have the same sort of liveliness.

The same thing is true at the local residential scale. A great deal of everyday social life happens where cars

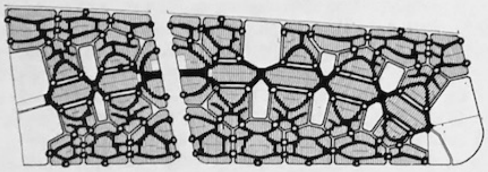
and pedestrians meet. In many low income areas, for example, the car is used as an extension of the house. Men, especially, often sit in parked cars, near their houses, drinking beer and talking.[4]

Many studies show that conversation and discussion grow naturally out of the communal car lots where men meet when they take care of their cars. Vendors always set themselves up where cars and pedestrians meet; they need all the traffic they can get. Children always play in parking lots – perhaps because they sense that this is the main point of arrival and departure; perhaps because they enjoy the cars.

In Peru, there is a new version of the paseo: the 'autopaseo' – several friends hop into a car, and drive around, visiting their friends, often not even getting out of their cars, but talking from house to car and back.

None of these things can happen in a plan where car roads and pedestrian paths are separated, unless the two meet frequently, and the places where they meet are treated as minor centres of activity.

IN THE PROYECTO EXPERIMENTAL, the car roads



form loops, and the pedestrian paths form a diagonal network which crosses these loops at right angles. Where they cross, there are parking lots, cell gateways, and spaces for pedestrian activity. The two systems form a double gradient: car densities dominate towards the outside of the site, pedestrian densities dominate towards the inside of the site, with a smooth gradient between the two.

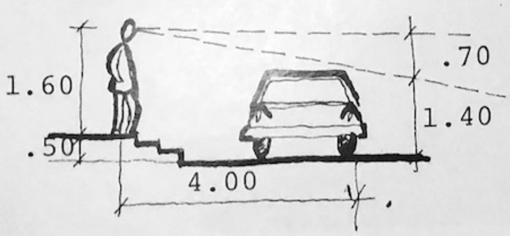
Pedestrian 50 cm above car

THE GENERAL PATTERN IS:

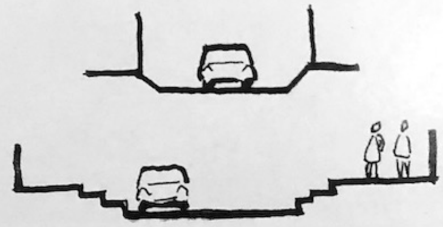
Context:
Any area which contains roads with traffic densities of more than a few vehicles per day.

103 *Solution:*
These roads are sunk 50 centimetres below all pedestrian paths.

Problem:
In the modern city, the car is king; the pedestrian is made to feel small. This cannot be solved by keeping pedestrians separate from cars; it is in their nature, that they have to meet. But where they meet, the car must be 'put down', symbolically, and the pedestrian world given more importance. This is most easily achieved if the car is physically below the pedestrian. Our experiments suggest that the effect first makes itself felt, when the car is about 50 centimetres below the pedestrian paths. There are two possible reasons for this figure.
Most people's eye level is between 1.30 and 1.60 metres. A typical car has an overall height of 1.40 metres. Although tall people can see over the cars, even for them the cars fill the landscape, since a standing person's normal line of sight is 10 degrees below the horizontal.[5] To get the top of a car that is four metres away, completely below the line of sight, it would have to be standing between 50 and 80 centimetres below the pedestrian.



It may also be that the car overwhelms the pedestrian because of a constant, unspoken possibility that a runaway car might at any moment mount the kerb and run him down. A car can climb an ordinary 15 centimetre kerb, easily. For the pedestrian to feel certain that a car could not climb the kerb, the kerb height would have to be greater than the radius of a car tyre (30–38 cm): thus at least 40 cm, preferably 50 cm.
IN THE PROYECTO EXPERIMENTAL, all local roads are 50 cm below grade. The pedestrian precinct defined by each cell, is an island, floating 50 cm above the road which surrounds it. Where a pedestrian path crosses a local road, there are three steps down.



Activity nuclei

THE GENERAL PATTERN IS:

Context:
Any community large enough to support community facilities.

Solution:
The community facilities are clustered round a small number of very small open spaces which we call activity nuclei. The facilities in any one nucleus are clustered in such a way that they co-operate functionally. (See problem statement.) All paths in the community pass through these activity nuclei.

Problem:
One of the greatest problems with new communities, is the fact that the available public life in them is spread so thin, that it has no impact on the community, and is not in any real sense 'available' to the members of the community. Yet studies of pedestrian behaviour make it clear that people seek out concentrations of other people, whenever they are available.[6]

To create these concentrations of people in a community, facilities must be grouped densely round very small public open spaces which can function as nuclei – and all pedestrian movement in the community channelled to pass through these nuclei. These nuclei need two properties.

First, the facilities grouped around any one activity nucleus must be carefully chosen for their symbiotic relationships. It is definitely not enough merely to group communal functions in so called community centres. For example, church, cinema, kindergarten, and police station are all community facilities – but they do not support one another mutually. Different people go to them, at different times, with different things in mind. There is no point in grouping them together. To create intensity of action, the facilities which are placed together round any one nucleus must function in a co-operative manner, and must attract the same kinds of people, at the same times of day.

For example: When evening entertainments are grouped together, the people who are having a night out can use any one of them, and the total concentration of action increases. When kindergartens and small parks and gardens are grouped together, mother and young children may use either, so their total attraction is increased. When schools and swimming pools and football space are grouped together, they form natural centres for school children.

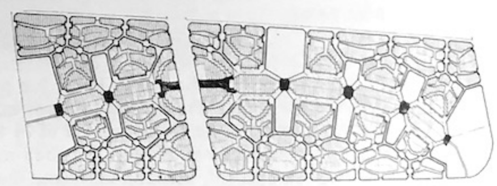
Second, the open places which form the nuclei should be very small indeed. Our observations suggest that 15 × 20 metres is the ideal size; if the space has to be larger, it should be long and narrow, with its short dimension no more than 20 metres.

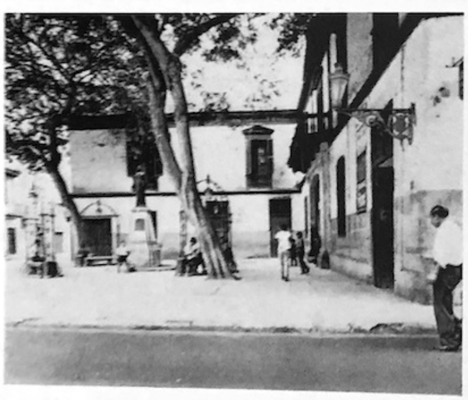
Our observations in Lima showed, again and again, that places which are larger look and feel deserted, and discourage activity. The reasons for this recurrent observation are obscure, but the following facts may have something to do with it. A person's face is just recognizable at about 20 metres, and, under typical urban outdoor noise conditions, a loud voice can just be heard at 20 metres.

This may mean that people feel tied together in spaces whose diameter is less than 20 metres, and lose this feeling in larger spaces: perhaps a major factor in the development of activity.

IN THE PROYECTO EXPERIMENTAL, all community facilities open on to one of eight small squares, *and all pedestrian paths in the community* lead towards these eight small squares.

Each of the activity generators is unique, according to the facilities which surround it. The market square is surrounded by small shops, has a supermarket at one end, the artery crossing at the other, and contains market stalls. The evening centre is surrounded by bars, cinema and dance hall, and contains clustered lights for night time activity, and sheltered tables round the edge. The open spaces between kindergartens and walled eucalyptus groves, contain shallow tiled pools, where toddlers can splash and play, with seats around them for mothers. The open space between church and clinic contains flowers,





grass and bushes, cared for by the church. The open spaces in front of primary schools, and sports centres, contain a stepped depression, large enough for football in the middle, the steps deep enough to form seats for people who want to watch the games.

Walled gardens

THE GENERAL PATTERN IS:

Context:
Any small park or public garden in an urban area.

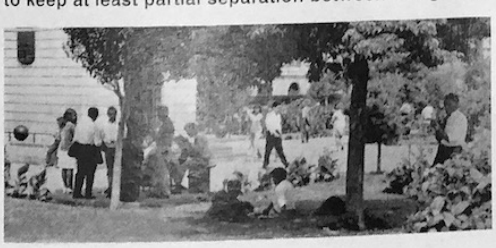
Solution:
It is walled, or partly enclosed, yet close to major centres of pedestrian activity.

Problem:
People need contact with trees and plants and water. Their symbolic character is not replaceable. In some way, which is hard to express, people are able to be more whole in the presence of nature, are able to go deeper into themselves, and are somehow able to draw sustaining energy from the life of plants and trees and water.

The small parks and gardens in a city try to solve this problem; but they are usually so close to traffic, noise, and buildings, that the impact of nature is entirely lost. To be truly useful, in the deepest psychological sense, they must allow the people in them to be in touch with nature – and must be shielded from the sight and sound of passing traffic.

In those few cases where there are small walled gardens in a city, open to the public – Alhambra, Morocco, Copenhagen Royal Library Garden – these gardens almost always become famous. People understand, and value the peace which they create.

This is a particularly crucial problem in desert areas like Lima. In the desert, trees and plants are infinitely precious. Gardens are almost like oases – people flock to sit and talk and lie in them, wherever they exist. In such desert areas it is doubly important to keep at least partial separation between the garden



and its surroundings, so that the garden can be fully felt, and the oasis character isn't lost.

At the same time, just because they are so precious, such gardens need to be close to major centres of pedestrian activity, so that people can use them and enjoy them often.

IN THE PROYECTO EXPERIMENTAL, there are three small walled gardens containing grass, seats, paved areas and eucalyptus trees. Each one opens on to one of the activity nuclei along the paseo. The eucalyptus will be a fast growing variety, suitable for Peru, and should reach a height of 25 metres in five years. The gardens will be irrigated by the irrigation water that comes in from the north-east corner of the site.

Multi-purpose Outdoor Room

THE GENERAL PATTERN IS:

Context:
Any local part of a residential community.

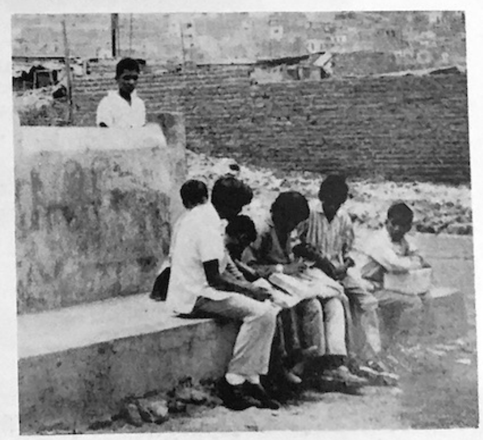
Solution:
There is, within view of every house, at least one 'multipurpose outdoor room' with the following characteristics. It is open to the sky, surrounded or at least partly surrounded by a continuous roofed arcade always at least two metres deep, and, where possible, built up against the walls of existing buildings.

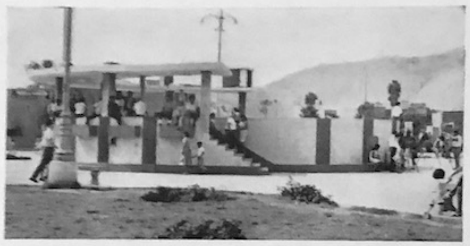
The outdoor rooms are left unfinished, with the understanding that they will be finished by people who live near them, to fill whatever needs seem to be most pressing. They may contain sand, or water faucets, or play equipment, for small children. They may contain steps, and seats, where teenagers can meet. Someone may build a small bar in a house that opens into the arcade, making the arcade a place to eat and drink. There may be games for old people, like chess and checkers.

Problem:
In existing modern housing projects, people rarely feel comfortable lingering outside their houses. There are few places where it is 'all right to be'. Yet at the same time, it is clear that almost everyone wants, at some time or another, to linger in some public space. Our observations in Peru show that the men seek corner beer shops, where they spend hours talking and drinking; teenagers, especially boys, choose special corners too, where they hang around, waiting for their friends. And of course these things are not peculiar to Peru – something like it happens everywhere. Old people like a special spot to go to, where they can expect to find others; small children need sand lots, mud, plants, and water to play with in the open; young mothers who go to watch their children, often use the children's play as an opportunity to meet and talk with other mothers.

Few modern housing projects provide for these needs; it is very hard to provide for them. On the one hand, indoor community rooms are too enclosed. When provided, they are rarely used. People don't want to plunge in to a situation which they don't know; and the degree of involvement created in such an enclosed space, is too intimate to allow a casual passing interest to build up gradually to full involvement. On the other hand, vacant land is not enclosed enough. It takes years for anything to happen on vacant land; it provides too little shelter, and too little 'reason to be there'.

What is needed is a framework which is just enough defined so that people naturally stop there, and tend to stop there; and so that curiosity naturally takes





people there, and allows them to stay there. Then, once community groups begin to gravitate towards this framework, there is a good chance that they will themselves create an environment which is appropriate to their activities. Some possible examples of such future developments are given in the solution statement.

We conjecture that a small open space, between 10 and 20 metres in diameter, and surrounded on all sides by an open roofed arcade, may just about provide the necessary balance of 'openness' and 'closedness'. The arcade should be at least 2 metres deep, for the reasons given in 'Two Metre Balcony'.

Even if this conjecture turns out to be correct in theory, it will undoubtedly be very hard to implement. Only detailed experiments, in communities, will show up the finer points that are needed to make this pattern work in practice.

IN THE PROYECTO EXPERIMENTAL, each cell contains one open space about 6 × 10 metres, surrounded by a two metre deep, roofed arcade, and several smaller, non-continuous sections of the same arcade in other places. Each one of these arcades is placed at a node in the system of pedestrian paths. They are left unfinished, with the understanding that community residents may build in games like table tennis, *bochas* or *sapo*, sand-pits, seats, water faucets, walls, and small shops or bars, according to their needs.

Flowers on the Street

THE GENERAL PATTERN IS:

Context:
Any pedestrian path outside houses.

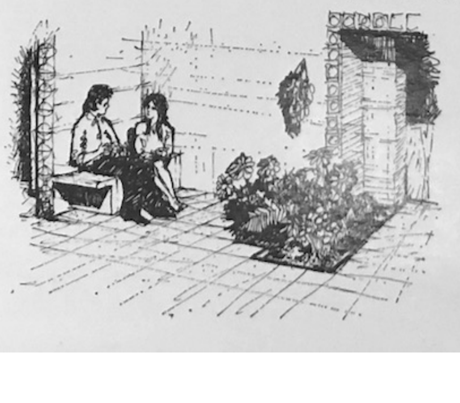
Solution:
The paths are paved with removable paving stones and it is understood that the people who live in any given house may take up the stones outside their house, to plant flowers, trees and grass.

Problem:
The overall effect of a community, especially in a desert area like Lima, is largely determined by the planting. An area with well kept plants is beautiful; the areas without them seem arid by comparison.

However, the only plants in a community which get looked after, are those which individual people plant, and care for – public planting usually flops – no one takes the responsibility of looking after it, and there is no money for gardeners.

We may thus establish a principle: the planting in a community should be in the form of small gardens, clearly associated with the front of specific individual houses, and planted by the individuals in these houses.

However, only a few of the people in any given community really enjoy gardening. If all the houses are provided with front gardens, three quarters of them will be left unkept – and will very likely end up as dust and weeds. There must be a way of giving gardens to all those people who will look after them, and to no one else. This is easily done. If the footpaths are all paved with the understanding that anyone who wants to can take up the paving stones and plant things, the only people who will bother to do so will be those who really want a garden.



IN THE PROYECTO EXPERIMENTAL, the pedestrian paths outside houses are paved with large, removable earth-cement paving blocks laid over unfinished earth. It is understood that any homeowner who wants to plant flowers or trees or grass outside his house, may remove these paving stones to do so.

Patios Which Live

THE GENERAL PATTERN IS:

Context:
Any patio intended for active use.

Solution:
1 It has sources of traffic and activity on at least two sides (opposite each other), and functions, at least in part, as a circulation space.
2 It is placed so that you can see out of it, into some other larger space beyond.
3 At least one side of it is roofed, this roofed part being at least two metres deep, and connected to the rest of the building.

Problem:
Many of the patios built currently in modern houses are dead. They are intended to be private open spaces – but often remain unused.

Informal observation suggests that patios are unused for the following reasons:

1 No one ever goes to them when they do not have any natural relation to the activities in the house – this is especially true for those that are dead-ends, off to one side of rooms. To overcome this, the patio should have activities opening off at least two opposite

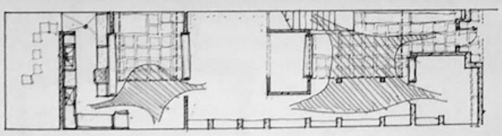
sides, so that it becomes the meeting point for these activities, provides access to them, provides overflow from them, and provides the cross-circulation between them.

2 They are so enclosed that they become claustrophobic. Patios which are pleasant to be in always seem to have 'loopholes' which allow you to see beyond them, into some further space. The patio should never be perfectly enclosed by the rooms which surround it, but should give at least a glimpse of some other space beyond.

3 They are oppressive. No one wants to sit surrounded by blank walls, disconnected from the house, with a little square of sky overhead. To solve this problem, the patio needs to be partly roofed. This provides a sitting space that is less nakedly exposed to the sky, and, if the roofed position is continuous with the interior of the house, makes the patio seem more like a part of the house, and people will drift more naturally into it.

The veranda formed by this overhanging roof will not work unless it has room for a small table and a couple of chairs, so that people can sit there and talk and drink. This requires at least two metres.

IN THE PROYECTO EXPERIMENTAL HOUSE, both the kitchen patio and the main living patio are



surrounded on three sides by activities, contain a two metre veranda which connects the patio to the house, and are placed so that natural circulation moves through the patio.

Tapestry of Light and Dark

THE GENERAL PATTERN IS:

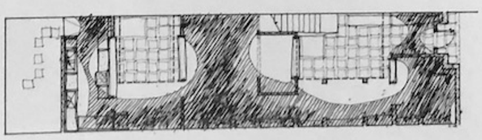
Context:
Any building where people live during the daytime.

Solution:
Openings and covered areas alternate in such a way that the interior of the building is a tapestry of alternating light and dark spaces, with special emphasis on the boundary areas where dark changes to light.

Problem:
In a building with uniform light level, there are few

'places' which function as effective settings for human events. This happens because, to a large extent, the 'places' which make effective settings are defined by light. People are by nature phototropic – they move towards light, and, when stationary, they orient themselves towards the light. As a result the much loved and much used places in buildings, where most things happen, are places like window seats, verandas fireside corners, trellised arbours; all of them defined by non-uniformities in light, and all of them allowing the people who are in them to orient themselves towards the light.

There is good reason to believe that people need a rich variety of settings in their lives.[7] Since settings are defined by 'places', which in turn seem often to be defined by light, and since light places can only be defined by contrast with darker ones, this suggests that the interior parts of buildings where people spend much time should contain a great deal of



alternating light and dark.

IN THE PROYECTO EXPERIMENTAL, each house has a sequence of alternating patios and rooms along its length.

Intimacy Gradient

THE GENERAL PATTERN IS:

Context:
A house in Peru, or any other Latin country.

Solution:
There is a gradient from front to back, from the most formal at the front to most intimate and private at the back. This gradient requires the following strict sequence: entry-sala-family room-kitchen-bedrooms.

The most important element in this sequence is the sala (parlour). It is essential that the house contain a sala. If the house is so small that cost rules this out, the house should at least contain a tiny receiving alcove immediately inside the front door.

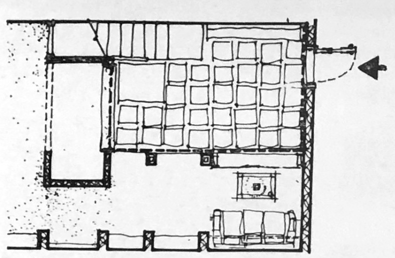
Problem:
In Latin American countries, such as Peru, friendship is taken very seriously and exists at a number of levels. Casual neighbourhood friends may never enter one's house. Formal friends, such as the priest, the daughter's boy-friend and friends from work may be invited in but tend to be limited to a well furnished and maintained part of the house, the sala. This room is sheltered from the clutter and more obvious poverty of the family which are visible in the rest of the house. Relatives and intimate friends, such

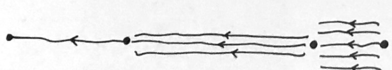
as *compadres,* may be made to feel at home in the *comedor-estar* (family room) where the family is likely to spend much of its time. A few relatives and friends, particularly women, will be allowed into the kitchen, other workspaces, and, perhaps, bedrooms of the house. In this way the family maintains both privacy and pride.

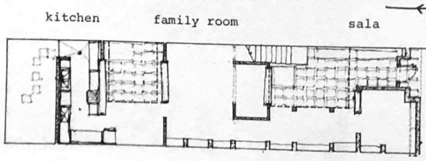
This is particularly evident at the time of a fiesta. Even though the house is full of people, some people never get beyond the sala; some don't even get beyond the threshold of the front door. Others go all the way into the kitchen, where the cooking is going on, and stay there throughout the evening. Each person has a very accurate sense of his degree of intimacy with the family, and knows exactly how far into the house he may penetrate, according to this established level of intimacy.

Even extremely poor people try to have a sala if they can. Many modern houses and apartments in Peru combine sala and family room in order to save space. *Almost everyone we talked to complained about this situation. As far as we can tell, a house must not, under any circumstances, violate the principle of the intimacy gradient.*

IN THE PROYECTO EXPERIMENTAL, there is a strict gradient from formal to informal, front to back.







Each house contains entry-sala-family room-kitchen in that order. Those houses too small to have a proper sala, have a small receiving alcove, just inside the front door, which functions as a sala.

Family Room Circulation

THE GENERAL PATTERN IS:

Context:
The family room (*comedor-estar*) of any low income Peruvian house.

Solution:
The room is relatively long and narrow. The dining table is in the middle; traffic in and out of the house goes through one end, and there are seats or leaning spaces at this end; the TV set is at the other end, in a darkened corner.

Problem:
For a low income Peruvian family, the family room (*comedor-estar*) is the heart of family life. The family eat here, they gossip here, they watch TV here, and everyone who comes into the house comes into this room to say hello to the others, kiss them, shake hands with them, exchange news, gossip. The same happens

when people leave the house.

The family room cannot function as the heart of the family life, unless it helps to support these processes. The room must be so placed in the house, that people naturally pass through it on their way in and out of the house. The end where they pass through it, must allow them to linger for a few moments, without having to pull out a chair to sit down; this requires 'leaning space'. The TV set should be at the opposite end of the room from this throughway; since a glance at the screen is often the excuse for a moment's further lingering. If possible the part of the room for the TV set should be darkened; the family room and the TV function just as much during midday as they do at night.

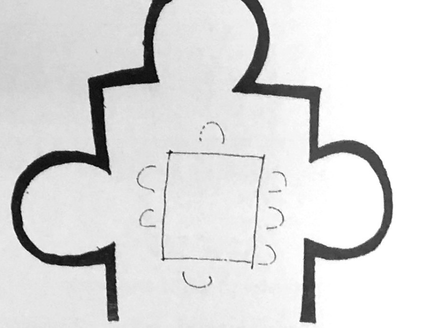
IN THE PROYECTO EXPERIMENTAL HOUSES, the main part of the family room (not including alcoves), is 3–3.80 metres wide, running across the plot. There is room for a large dining table in the middle, close to the kitchen. Circulation from the front of the house to the kitchen, goes past one end of the table, perpendicular to the room's main axis, and there are seats and leaning niches at this end of the room. The far end of the room is windowless, and contains an electric outlet for TV.

Family Room Alcoves

THE GENERAL PATTERN IS:

Context:
The family room of any house.

Solution:
There are a number of alcoves off the family room (preferably at least two). Each alcove is between one and two metres deep; the alcoves are all narrower than the walls they open from; and their ceilings are



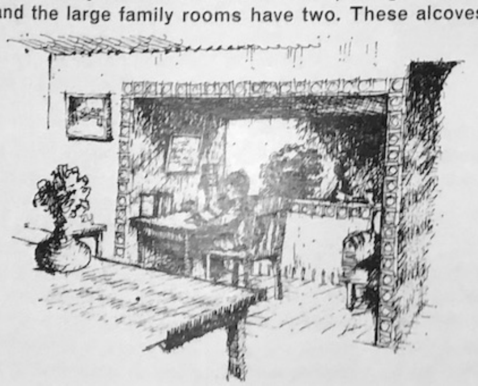
lower than the ceiling of the main room. Each alcove looks at the other alcoves.

Problem:
In modern life, the main function of the family is emotional; it is a source of security and love. But thees qualities will only come into existence, if the members of the house are physically able to *be* together, as a family.

In modern life, this is often difficult. The various members of the family come and go at different times of the day; even when they are in the house, each has his own private interests: sewing, reading, homework, carpentry, model-building, games. In many houses, these interests force people to go off to their own rooms, away from the family. This happens for two reasons. First, in a normal family room, one person can easily be disturbed by what the others are doing: the person who wants to read, is disturbed by the fact that the others are watching TV. Second, the family room doesn't usually have any space where people can leave things and not have them disturbed. Books left on the dining table get cleared away at meal times; a half finished game can't be left standing; naturally people get into the habit of keeping some activities away from the family.

To solve the problem, there must be some way in which the members of the family can be together, even when they are doing different things. This means that the family room needs a number of small spaces where people can do different things. The spaces need to be separate from the main room, so that any clutter that develops in them does not encroach on the communal uses of the main room. The spaces need to be connected, so that people are still 'together', when they are in them: this means they need to be open to each other. At the same time they must be secluded, so that a person in one of them is not disturbed by the others. In short, the family room must be surrounded by small alcoves. The alcoves should be large enough for one or two people at a time: about two metres wide, and between one and two metres deep. To make it clear that they are separate from the main room, so they do not clutter it up, and so that people in them are secluded, they should be narrower than the family room walls, and have lower ceilings than the main room.

IN THE PROYECTO EXPERIMENTAL HOUSES, small family rooms have one alcove opening off them, and the large family rooms have two. These alcoves are 250 cm wide and between 120 and 160 cm deep. Ceiling height in the alcoves is 2.20 metres (compared with 2.70 in the main part of the family room).



Thick Walls

THE GENERAL PATTERN IS:

Context:
Interior wall, in any part of a building which is intended to be personal.

Solution:
The wall has 'depth', at least 40 cm, which is created by a hand-carvable rigid space frame, in which a continuous variety of niches, shelves, seats, cupboards, leaning posts, and window seats occur at frequent intervals. This hand-carvable space frame is made of materials which are readily available on the retail market, and easily cut, modified, painted, nailed, glued, or replaced by hand, using only tools available at any hardware store. Possible examples are wood, plywood, fibreglass, styrofoam, polystyrene. The space frame is highly redundant structurally: large sections of it may be removed, without weakening it, and pieces or sections may be added in such a way that these sections become continuous with, and indistinguishable from, the original surface.

Problem:
Rooms with large, flat, unbroken wall surfaces almost never have any personal character, and it is very hard for people who live in such rooms to make them personal. A room becomes personal only when the imprint of its inhabitants is clearly visible, the walls crowded with treasures and belongings: presents, pictures of sweethearts and grandparents, flowers, vases, knick-knacks, books, collections; these treasures built integrally into the fabric of the room, and the surface of the room moulded to the character of its inhabitants. If a room has large unbroken wall surfaces, made of unmouldable materials, none of this is possible. It is hard to store things in the open, without cluttering up the room, and it is not possible to build these things in a personal way into the fabric of the room.

Wall surfaces must be deep enough to contain a variety of niches and recesses, where special things can be placed, without being in the way; and the wall must be made of materials which allow these niches and recesses to be adapted to the idiosyncracies of the things which are to be placed there, and to the habits which go with them.[8]

IN THE PROYECTO EXPERIMENTAL HOUSE, the wall connecting the sala, patio, veranda and family room, has a series of small niches in it, formed by 40 cm stub walls that project at right angles to the main wall. Each niche contains a seat, shelves, cupboard or display.

Entrance Transition

THE GENERAL PATTERN IS:

Context:
Any house entrance.

Solution:
The path from the street into the house passes through a zone where levels, materials, view, light and other qualities change.

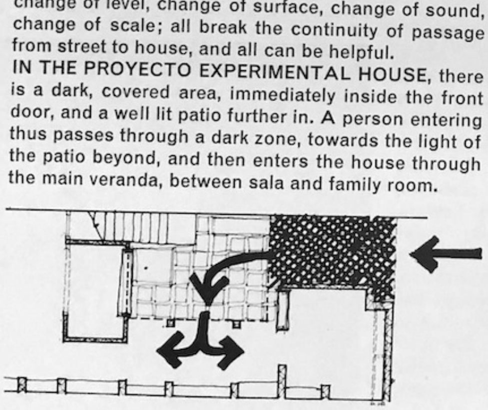
Problem:
There is no doubt that houses which provide a graceful transition space between street and house, are nicer than those which open abruptly off the street. If the transition is too abrupt there is no feeling of arrival, and the house fails to be an inner sanctum. The following argument may help to explain it. While people are on the street, they adopt a mask of 'street behaviour'. When they come into a house they

naturally want to get rid of this street behaviour and settle down completely, into the more intimate spirit appropriate to a house. But it seems likely that they cannot do this, unless there is a transition from one to the other, which helps them to lose the street behaviour. The transition must, in effect, destroy the momentum of the closedness, tension and 'distance' which are appropriate to street behaviour, before they can relax completely.

Evidence comes from the report by Serge Bouterline and Robert Weiss, *The Seattle World's Fair.*[9] The authors noticed that many exhibits failed to 'hold' people; they drifted in, and then drifted out again within a very short time. However, in one exhibit people had to cross a huge, deep-pile, bright orange carpet on the way in. Though the exhibit was no better than other exhibits, people stayed. The authors concluded that people were, in general, under the influence of their own 'street and crowd behaviour', and while under this influence could not relax enough to make contact with the exhibits. The bright carpet presented them with such a strong contrast as they walked in that it broke the effect of their outside behaviour, in effect 'wiped them clean', with the result that they could then get absorbed in the exhibit.

There are many ways of marking the transition from street to house: change of view, change of light, change of level, change of surface, change of sound, change of scale; all break the continuity of passage from street to house, and all can be helpful.

IN THE PROYECTO EXPERIMENTAL HOUSE, there is a dark, covered area, immediately inside the front door, and a well lit patio further in. A person entering thus passes through a dark zone, towards the light of the patio beyond, and then enters the house through the main veranda, between sala and family room.



Front Door Recesses

THE GENERAL PATTERN IS:

Context:
Any Peruvian house which has a front door opening directly off a public path.

Solution:
The front door is surrounded, on both sides, by deep recesses, each at least 50 cm deep – if possible by double recesses. The effect of the recesses is helped by an opening in the door, or a dutch door.

Problem:
'Hanging out' is a standard part of Latin culture. People like to watch the street. But people do not always want the same degree of involvement with the street. The process of hanging out requires a continuum of degrees of involvement with the street, ranging all the way from the most private kind, to the most public kind. A young girl watching the street may want to be able to withdraw the moment anyone looks at her too intently. At other times, girls, young men, and the women of the house, may want to be watching the street, near enough to it to talk to someone who comes past, yet still protected enough so that they can withdraw into their own domain at a moment's notice. At still other times, old men, less afraid of real involvement on the street, will actually sit out, in front of their doorways, and feel secure provided that the seat is still clearly identified with their house.

In the most common kind of hanging out, people lean in doorways, half in, half out. They can see what is happening outside, they can talk to anyone they want to – yet they can withdraw in a moment. To invite this activity, front doors need deep recesses, large enough to hold a person (thus at least 50 cm deep), and, if possible, a way of hanging over the door, like that which a dutch door provides.

IN THE PROYECTO EXPERIMENTAL HOUSE, each front door is surrounded on the outside by one or more deep recesses, according to the exact position of the entrance with respect to other houses. The front doors are of the dutch door type.

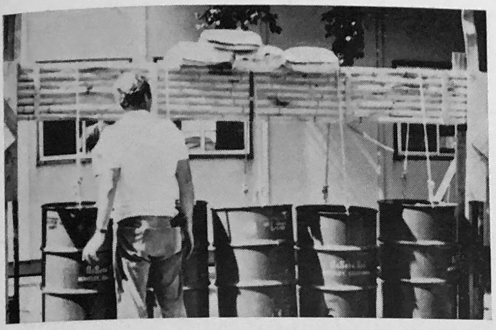
Composite Bamboo Foam Beam

THE GENERAL PATTERN IS:

Context:
Short spans and light loads in countries where bamboo is abundant and cheap.

Solution:
Beams may be made of bamboos (pinned and glued with epoxy) to form a box which is filled with plastic foam. Spans may range from 3 to 5 metres with corresponding variation in beam spanning. Allowable loads are shown in the problem statement.

Problem:
Concrete beams are expensive, very heavy, hard to move around, and hard to work. In many buildings, especially those where people will be building for themselves (as in self-help housing) beams need to be lightweight, and easy to work. In earthquake zones, it is also necessary to reduce dead loads as far as possible. If bamboo is locally available and petroleum resources allow local manufacture of urethane foams, then it is possible to make lightweight bamboo/foam beams, with excellent structural characteristics.



We have built three different beams of this type, and tested them. It is clear from our tests that bamboo/foam beams of this type are about as strong as softwood beams of the same size. The most serious problem is deflection. Bamboo is extremely strong in tension, and the urethane foam makes the beam section rigid; but the bamboos tend to slip past each other in horizontal shears.

In the third of the three test beams, we pinned and spotglued bamboos together with epoxy glue and dowels. This test beam was 20 cm wide, 40 cm deep. We tested it over a clear span of 3.50 metres. At a uniformly distributed load of 1,300 kilograms the deflection reached 0.8 cm after an hour, and showed no sign of further creep 24 hours later.

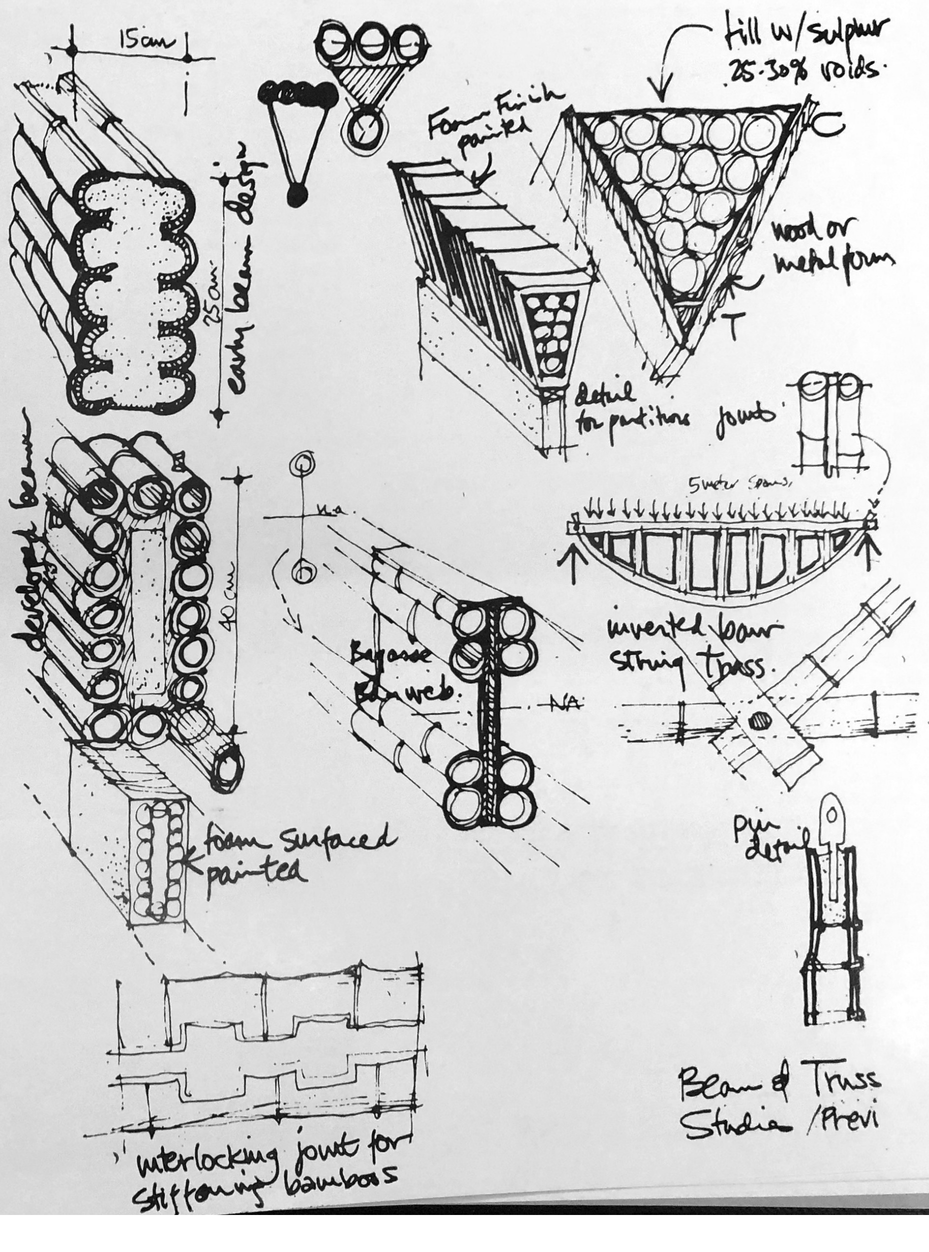
We may use the formula:

$$\text{Deflection}_{Max} = (5/384)WL^3/EI$$

to obtain a value for EI, and extrapolate the following figures for maximum allowable uniform loads, at various spans:

Clear span between supports (metres)	Maximum allowable uniformly distributed load, for beam deflection less than L/360 (kg).
3.00	2200
3.50	1620
4.00	1240
4.50	980
5.00	800
	(where the design criterion is L/240, for unplastered conditions, these loads can be increased by 50%)

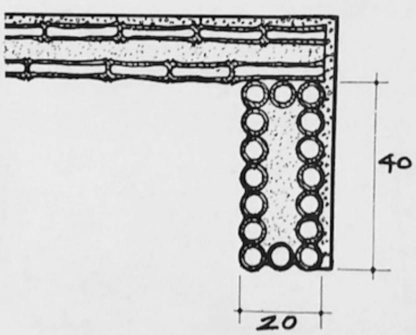
These beams will cost 100 *soles* per metre (compared with about 200 *soles* per metre for comparable rein-



forced concrete beams), and weigh about 20 kilograms per metre (compared with 50 kg per metre for a reinforced concrete beam of similar strength). Furthermore, these beams can be cut with simple tools: they can easily be lifted and installed by two men.

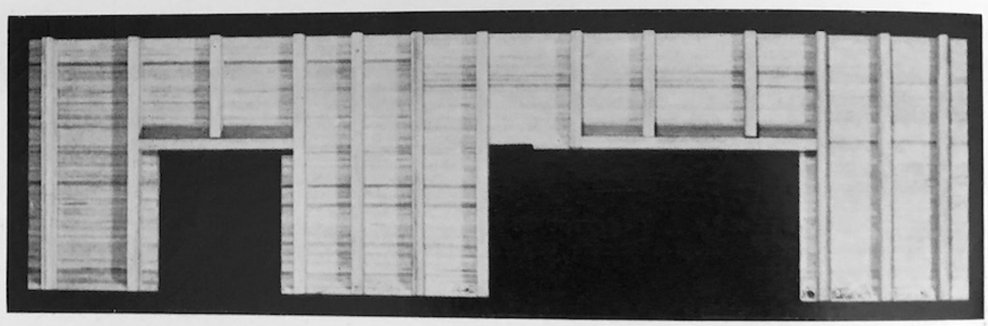
It is important to note that the beam type described here is by no means the last word in composite bamboo/foam beams. Much development is needed to try others which use different indigenous materials in place of bamboo, other foams like high-density sulphur foams, and new glues and bonding agents. The sketches illustrate some of these possibilities.

IN THE PROYECTO EXPERIMENTAL HOUSE, all beams are rectangular section boxed beams, 20 cm wide, 40 cm deep, and 5 metres long. The beams are made of 6 cm bamboos, placed over plywood templates, with a core of 2 lb density polyurethane fire-retardent foam, foamed in place. The bamboos are pinned and spot glued together at 50 cm intervals, with epoxy glue and wooden dowels.



The framing model is shown below. The second storey floor beams are all supported by interior partitions or columns, and have clear spans of 3 metres or less – except in the family room, where they span 4.50 metres between shear walls and impost blocks, and are spaced close together to make up for the long span. The roof beams span the full 4.80 metres between impost blocks, and are spaced at intervals ranging from 1.50 to 2.40 metres.
The second storey floor is designed to carry 200 kg per square metre (bamboo foam plank 15 kg per square metre, sulphur cement topping 45 kg per square metre, second floor partitions 50 kg per square metre and live load 90 kg per square metre). The roof is designed to carry 80 kg per square metre (bamboo foam plank 15 kg per square metre), thin topping 20 kg per square metre and live load 45 kg per square metre). To put a third storey on the house, additional beams will need to be inserted (they can be slipped on to the impost block easily), and the topping on the roof increased.
At these loads, the beams have a deflection of less than 1/360 of the span, and can safely be plastered. Families who do not like the appearance of the exposed bamboo can plaster them.

Below top first floor ceiling
Below bottom second floor ceiling



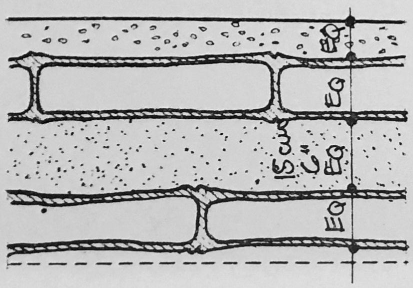
Composite bamboo foam plank

THE GENERAL PATTERN IS:

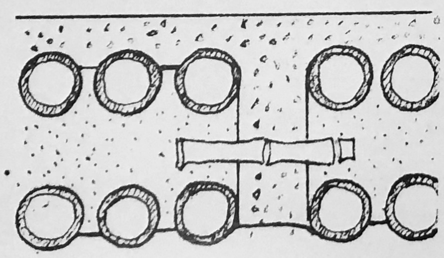
Context:
Short beam spacings and light loads in countries where bamboo is abundant and cheap, compared with other materials.

Solution:
Floor and roof planks may be made from bamboo/polyurethane foam sandwich. Maximum span for this system is approximately 2.50 metres unless panels have additional thickness and reinforcing. Allowable loads are shown in the problem statement.

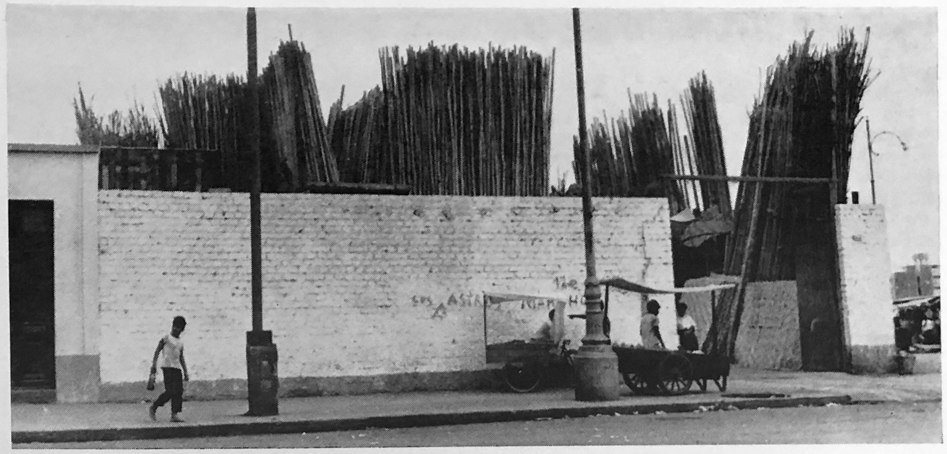
Problem:
Conventional reinforced concrete beam and plank is expensive and heavy. A number of recent experiments have shown that sandwich planks with plywood, gypsum or cement asbestos skins and polyurethane foam cores have enough strength to span 2-3 metres with normal live loads; they have been widely built and tested in many parts of the United States. In a country where bamboo is readily available, and wood expensive, it seems natural to use bamboo as the outer skin of the sandwich instead of plywood.
We built a test plank, with bamboos for the lower skin, and 3 mm fibre board for the upper skin. This plank performed very well in tests. At final failure the upper skin failed, in shear; the bamboo held. The following table shows the deflection test data.
These figures are for a centre load, on a plank 70 cm wide, over a span of 170 cm.

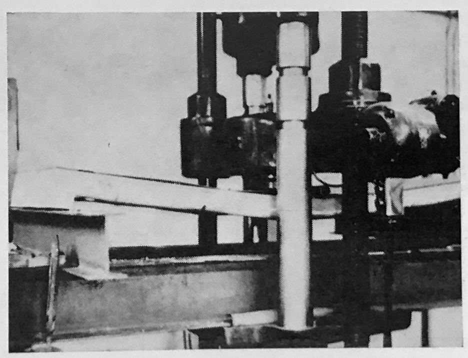


Plank section



Plank joint





Load (kg)	Deflection (cm)
45	.25
91	.50
136	.75
182	.95
227	1.15
272	1.30
318	1.50
364	1.70
409	1.90
454	2.10
546	2.55
636	3.00
729	3.50

This rudimentary plank, which has half bamboos in the lower skin, and very little in the upper, is too weak. We recommend a stronger plank, which has whole bamboos top and bottom.
By means of the formula

$$\text{Deflection}_{\text{Max}} = (1/48)WL^3/EI$$

we may obtain a value of EI for the weaker plank. Reckoning that the moment of inertia will be tripled in a plank with whole bamboos top and bottom, we estimate that the stronger plank will support the following loads, at the stated spans:

Clear span between supports (metres)	Maximum allowable uniformly distributed load, for plank deflection less than L/360 (kg per square metre)
1.00	200
1.50	590
2.00	250
2.50	128
3.00	74

These planks are extremely light: they weigh about 1.3 kilograms per square metre, they can be hand carried, and laid by two men. Since they can easily be made in long lengths, it is advisable to lay them over several supports, thus getting the benefit of the negative moments. The urethane core gives them excellent thermal and acoustic performance. The foam can also be used as base for applying plaster or

can be painted when desired.
Since the plank relies heavily on the use of polyurethane foam, it is important to add a note on the manufacture of these foams: particularly since the countries which are most likely to benefit from the use of bamboo, like Peru, will have to create urethane manufacturing capacity from scratch.
Capital equipment will cost £20,000 to £40,000. The organization of the factory and one year's operation will cost £80,000 to £100,000; with £40,000 of this amount going for the initial inventory of raw materials. At these costs it will be important to use polyurethane foams for other purposes too. They can be used for beams (see Composite Bamboo Foam Beam) e.g. for interior partitions, and in a slightly different chemical formulation, for the manufacture of furniture, bedding and soft seating.[10]

IN THE PROYECTO EXPERIMENTAL HOUSE, the second floor and roof structure are bamboo/polyurethane foam sandwich planks laid over beams. The outer skins of the plank sandwich are made of 6 cm bamboos, and the core is 2 lb density polyurethane. A sand-sulphur topping is poured after planks are in position to form the upper walking surface, and the jointing between planks.
The planks are 15 cm thick (including the topping), 50 cm wide and 5 metres long. They are supported by similarly constructed beams (see Composite Bamboo Foam Beam) spaced at intervals between 1 metre and 2.40 metres, according to position in the structure. Since planks are 5 metres long, they act as continuous members over at least two supports after the topping is poured over them. If families do not like the exposed bamboo, the plank will readily take plaster.

Notes

1 See Frank Hendricks, 'A Situational Approach to Residential Environmental Planning: A Research Framework', unpublished report to the US Public Health Service, March 1967.
2 See for example, Anthony Wallace, *Housing and Social Structure,* Philadelphia Housing Authority, 1952; currently available through University Microfilms, Inc., Ann Arbor, Michigan.
3 The full arguments, and empirical evidence for all these points, are presented in Christopher Alexander, *Cells of Sub-cultures,* Centre for Environmental Structure, Berkeley, California, 1968.
4 Clare Cooper, 'Some Social Implications of House and Site Plan Design at Easter Hill Village: A Case Study', Institute of Urban and Regional Development, Centre for Planning and Development Research, University of California, Berkeley, California, 1966, pp. 39 ff.
5 Henry Dreyfus, *The Measure of Man,* New York, 1959, sheet F.
6 e.g. Jan Gehl, 'Mennesker til Fods (Pedestrians)', *Arkitekten,* No 20, 1968.
7 see Roger Barker, *The Structure of Behaviour: Explorations of its Structure and Content,* Appleton-Century-Croft, New York, 1963.
8 This argument is presented in full, with empirical evidence, in Christopher Alexander, 'Thick Walls', *Architectural Design,* February 1968.
9 Cambridge, Mass., 1963.
10 For a general discussion of urethane foams in building, see *Structural Potential of Foam Plastics for Housing in Underdeveloped Areas,* Architectural Research Laboratory, University of Michigan, Ann Arbor, Michigan, November 1965.