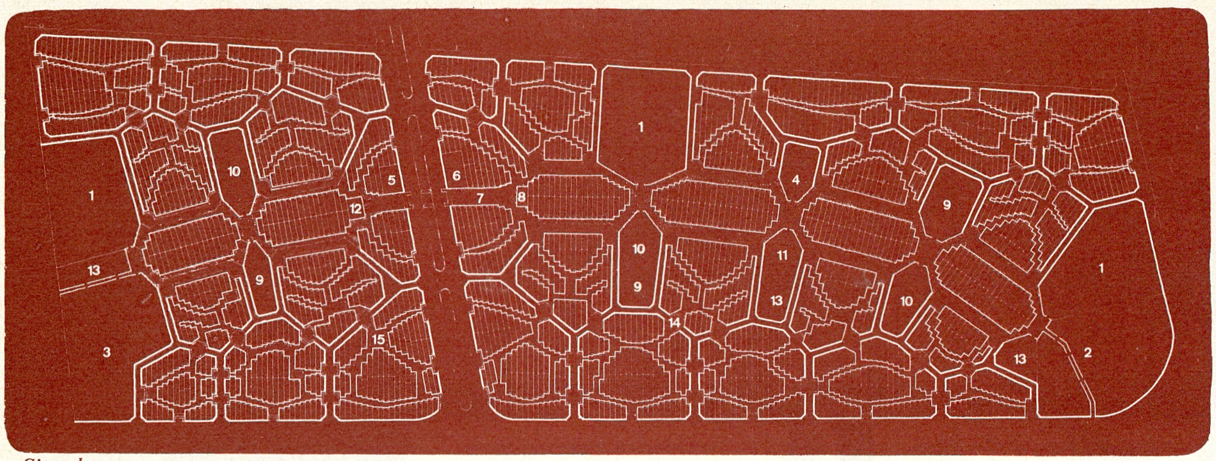
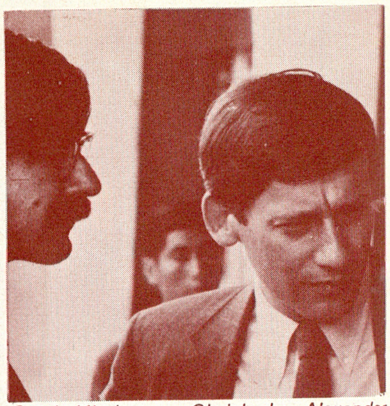
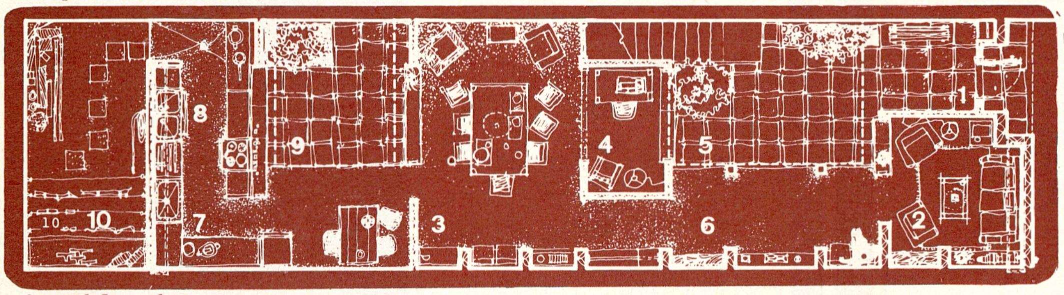
CENTRE FOR ENVIRONMENTAL STRUCTURE



Site plan

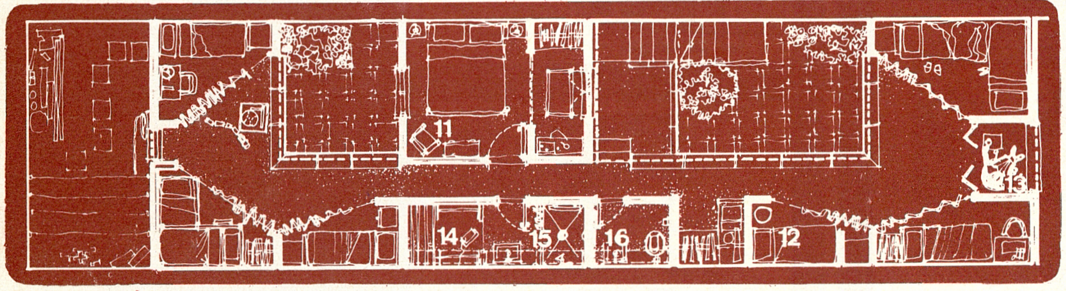


Sandy Hirshen *Christopher Alexander*



Ground floor plan

Key to site plan
1 Primary school
2 Secondary school
3 Technical 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 Centre
14 Parking
15 Outdoor room

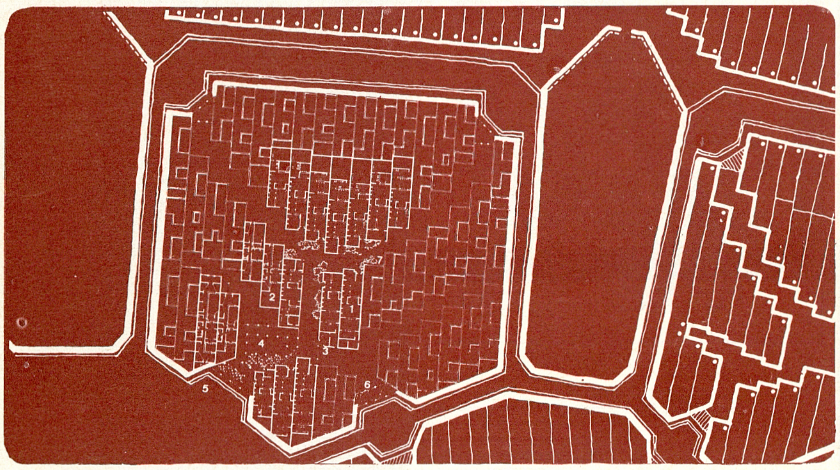


First floor plan

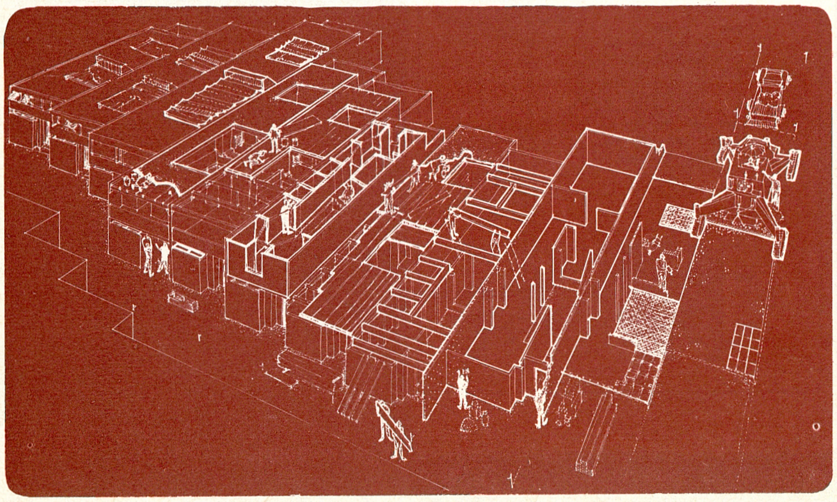
Key to house plans
1 Entrance
2 Sala (parlour)
3 Family room
4 Alcove
5 Main patio
6 Verandah
7 Kitchen
8 Laundry
9 Kitchen patio
10 Storage patio
11 Master bedroom
12 Bed alcoves
13 Mirador
14 Clothes drying
15 Shower
16 Toilet

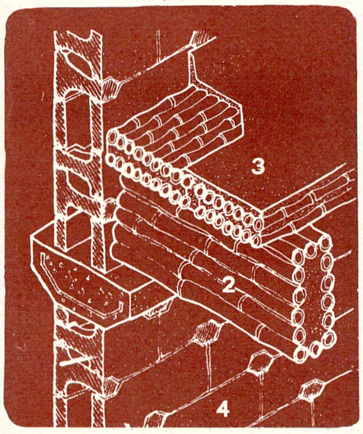
Key to housing cell
1 Ground floor plan. 2 First floor plan. 3 Shop. 4 Outdoor room. 5 Parking. 6 Cell gateway. 7 Garden.

Key to structural details
1 Floating slab. 2 Bamboo/Urethane foam beam. 3 Bamboo/Urethane foam plank. 4 Mortarless cavity wall.

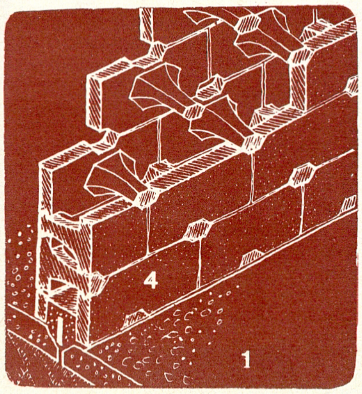


Housing cell





Structural details



The site

The site contains 1726 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.

Once each family has made its choice, 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' choice. 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 that surround the cell.

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

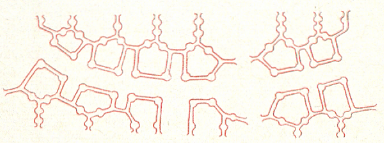
Second, during the choice process, people will be asked questions about the location they want for their house. When they are then located according to these choices, people with similar attitudes and interests will be living in the same cell.

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.

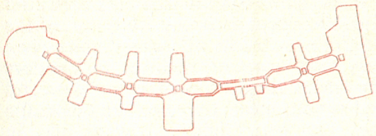
Over and above the cells, the site contains three major overlapping configurations: the road system, the pedestrian network, and the community spine.

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 per cent car ownership. This figure was given to us by the United Nations: they estimate 50 per cent car ownership in 30 years, and asked us to work to that figure.

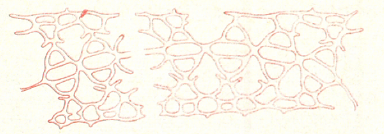


The central spine of the pedestrian system, we call the *paseo*. The *paseo* gives people a high density pedestrian spine of looped paths where a tradition of evening and Sunday walks can develop.

At frequent intervals along the paseo, there are 'activity nuclei': small open places, with the community facilities and shops grouped around them.



The 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.

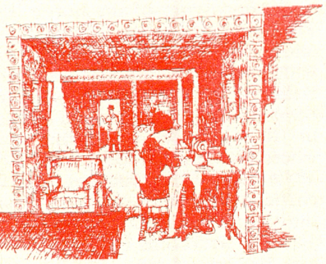
The house

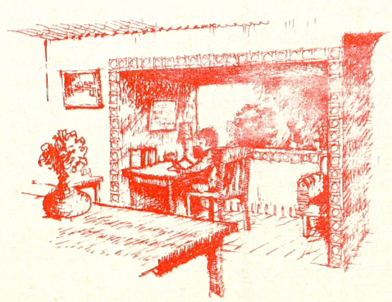
Although the choice process guarantees that no two houses will be exactly alike, all houses are based on one generic house.

This generic house is a two-storey house, 5.20 meters 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.

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, and, even in the smallest house allows visitors to be treated with proper formality.

The family part of the house centres around 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.





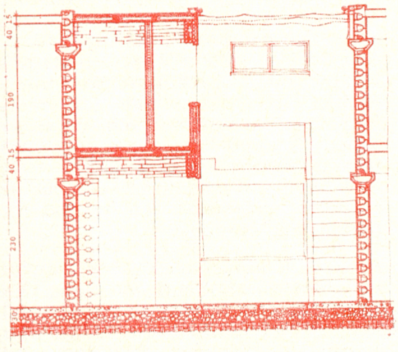
Upstairs the house contains a master bedroom, bathroom, and a number of tiny individual bed alcoves. These bed alcoves give each child a small space which is his own, for his own things; very young children may double bunk in a single alcove. Since Peruvians don't like being isolated, these alcoves are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

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 of construction 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 interlocking mortarless concrete-block walls, 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 building materials are especially suited to the local earthquake conditions.

To simplify building construction, all components are prefabricated, on site. They all conform to the 10cm 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 homeowner 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 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 five 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.

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 solved 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 neighborhood of a million. In a community of 1500 houses, it is highly unlikely that any two will be the same. 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: 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 pedestrian walkways, 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 lot and houses on a centre lot, 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 therefore depend on the size of the sala, the type of lot, and the position of the next door house on the eastern side.

It is very important to 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 lots shown on it: and 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 shows no end walls or interior walls. He now builds up the detailed design of each house, by using a set of clearly defined rules, one step at a time (*these are given in detail in the architect's report*).

Costs: The generic house will cost 119,000 soles ($2800) as of summer 1969. The smallest house will cost 79,000 soles ($1800), and the largest, with all possible extras will cost 163,000 soles ($3800). These costs are within 1000 soles of the targets set by the United Nations. They give an average of 1130 soles per square meter of interior space (not including verandas or overhangs). This is 25 per cent 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/m², compared with the usual price of 200 soles/m² for slab and footings. The mortarless concrete block walls reinforced with sulphur, costs 120 soles/m², compared with the usual price of 140 soles/m² 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/m², compared with the usual cost of 340 soles/m² for reinforced concrete slabs. The finish of the mortarless block wall and the finish of the bamboo ceilings make plastering unnecessary, and save the usual cost of 50-60 soles/m² for plaster. The dacron sailcloth cover on the patio, costs 250 soles/m² and saves the cost of windows throughout the house, at a usual cost of 500-600 soles/m². 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 1726 houses, as against the 1500 expected, saves 12 per cent of the cost of site development. ▷

The patterns*

Community patterns

Cells—subculture cells, degrees of publicness.

Road system—looped local roads, T-junctions, direct visible parking, tiny parking lots.

Pedestrian network—paseo, activity nuclei, car pedestrian symbiosis, pedestrian 50cm above car, knuckle at road crossing.

Community spine—central market, evening centres, walk-through schools, visible kindergartens, social gardens.

Cell interior—cell gateway, multi-purpose outdoor rooms, shops on corners, centripetal pedestrian paths, street football, flowers on the street.

House patterns

House shape and orientation—long thin house, perimeter wall, cross-ventilated house, light on two sides of every room, patios which live, tapestry of light and dark.

Public part of house—intimacy gradient, bathroom position, *puerto/falsa*, fiesta, staircase is a stage, thick walls.

Family part of house—family room circulation, family room alcoves, kitchen family room relationship, home workshop, two service patios, elbow room kitchen.

Sleeping areas—individual bed alcoves, bed clusters, master bedroom location, master bedroom dressing spaces, old people downstairs, servant sleeping space, two compartment bathroom, clothes drying closet.

Entrance and facade—entrance transition, front door recessed, *mirador*, front door bench, gallery surround, no ground floor windows on the street.

Patio section—translucent opening patio roof, light from two storey patios, sunshine in patios, two meter balcony.

Shop and rental—shop front possibility rental.

Construction patterns—continuous floating slab, mortarless block wall, composite bamboo/foam beam, composite bamboo/foam plank, sulphur reinforcing and topping, plumbing accumulator, continuous electric outlet.

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 *problems*.

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*.

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.

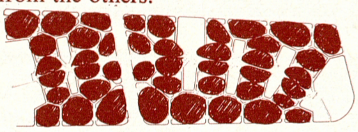
The evidence we use comes from three sources: the published literature, our observations in Lima, and our laboratory tests and experiments. We spent a month each living with low income Peruvian families in Pampa de Comas, San Martin de Porras, La Victoria and Rimac (districts of Lima) to better understand 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.

*Of the total of 67 patterns listed, the full texts of 7 are reproduced here.

Subculture cells

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 50cm 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; we hope that each cell will develop a unique 'character', different from the others.



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 sub-culture. 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 1500 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. (See Frank Hendricks, 'A situational approach to residential environmental planning: A Research Framework', unpublished report to the U.S. Public Health Service, March 1967.)

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'.

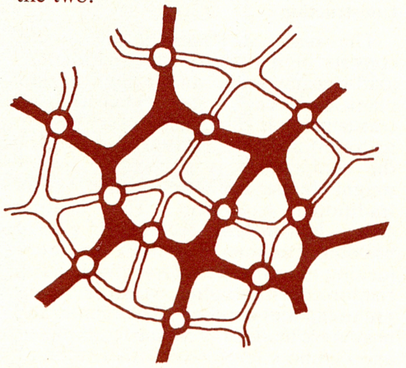
Ecological arguments help to fix the suitable cell size, and the need for radical separation between cells. To develop their own life style, the families in a cell must be able to agree on basic decisions about services, community land, etc. Anthropological evidence shows that a human group cannot maintain the face to face relations required to coordinate itself in this way, if its population is above 1500; many people set the figure as low as 500. (See for example, Anthony Wallace, *Housing and Social structure*, Philadelphia Housing Authority, 1952; currently available through University Microfilms, Inc., Ann Arbor, Michigan.)

It has been shown that the group feeling necessary to support a particular unique life style, is greatly strengthened when the group is physically separated from all adjacent groups. This suggests that cells should be inward looking, and wherever possible separated by community facilities.

(The full arguments, and empirical evidence for all these points, are presented in Christopher Alexander, *Cells of subcultures*, Center for Environmental Structure, Berkeley, California, 1968.)

Car—pedestrian symbiosis

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 space 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.



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 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. (Clare Cooper, 'Some social implications of house and site plan design at Easter Hill Village: a Case study', Institute of Urban and Regional Development, Center for Planning and Development Research, University of California, Berkeley, California, 1966, pp. 39 ff.)

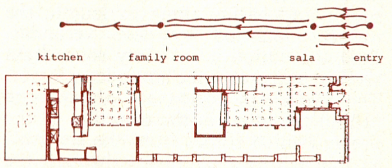
Many studies show that conversation and discussion grow naturally out of the communal car lots where men meet when they take care of their cars. Vendors always set themselves up where cars and pedestrians meet; they need all the traffic they can get. Children always play in parking lots—perhaps because 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 *auto-paseo*—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 centers of activity.

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*.



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* (parlor). 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 neighborhood friends may never enter one's house. Formal friends, such as the priest, the daughter's boyfriend 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. The photograph shows a *sala* which a family has made in a *barriada* shack. Yet 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.*

Thick walls

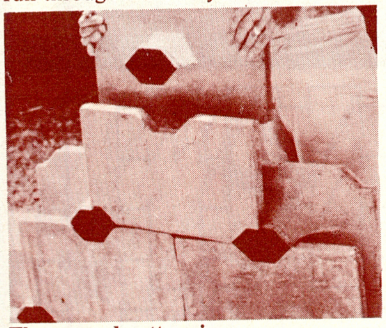
In the Proyecto Experimental house, the wall connecting the *sala*, patio, veranda and family room, has a series of small niches in it, formed by 40cm stub walls that stick out at right angles to the main wall. Each niche contains a seat, shelves, cupboard or display.

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 40cm, 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, replaced by hand, using only tools available at any hardware store. Possible examples are wood, plywood, fiberglass 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.
In order to make a room personal, then, its wall surface 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. (This argument is presented in full, with empirical evidence, in Christopher Alexander, 'Thick Walls', *Architectural Design*, February 1968.)

Mortarless block wall

In the *Proyecto Experimental*, the bearing walls, shear walls, and ground floor partitions are cavity walls made of interlocking, self-aligning concrete blocks, moulded on site. No mortar is required. The blocks simply interlock to form the wall. Blocks are made of a dry concrete mix, and may be 10 or 20cm thick: column and corner blocks are made in special moulds. Walls and columns are reinforced with sulphur. Plumbing lines and electrical conduits run through the cavity.



The general pattern is:

Context: Low cost, low rise building, in any place where concrete is one of the cheapest building materials.
Solution: Bearing walls, shear walls, columns, partition walls, and foundations may be made from EDI-Thermomod blocks. The block is self supporting up to a height of three stories. Vertical edges, corners, and horizontal upper edges are either poured concrete, with steel reinforcing, or are reinforced with sulphur-fiber. The EDI-Thermomod system is patented by Educational Design, Inc.
Problem: In areas where concrete is the principal building material, concrete block is one of the cheapest forms of wall construction. One of the biggest costs of a concrete block wall is the labor cost: each block has to be placed and mortared by a skilled mason. The EDI-Thermomod block system eliminates almost all these labor costs. The blocks are mortarless and self aligning; they weigh only 5kg apiece, and are very easy to handle. Two men can build a wall extremely fast, simply by stacking the blocks on one another. Masons are not required.

Another major cost in concrete block construction is the cost of the block itself. Here again the EDI-Thermomod block saves money. The block can be hand-manufactured on site in a simple mould, or machine manufactured. One mould produces about 400 blocks in 8 hours; a battery of five moulds will produce about 2,000 blocks a day—enough for the walls of an average 100 square meter house. Half blocks and blocks of different thicknesses can be made from the same mould. The blocks are cured after 24 hours. On site manufacture eliminates expensive storage and trucking.

The wall has several other advantages: The system is light, and earthquake resistant. The dry construction allows the blocks to move during a quake, thus preventing fracture of the wall. Since there is no mortar, blocks can be removed at any time to make new openings in the wall. The cavity can be made to serve as a conduit for plumbing and electricity—because the blocks can be removed, the conduits are easy to reach. Finally, like any cavity wall, the wall has good thermal and acoustic insulation.

The EDI block has been used to build very low cost buildings in Mexico and the south-eastern United States. Many of these buildings were built entirely by self-help; the buildings are performing well in use; those in Mexico have successfully withstood major earthquakes.

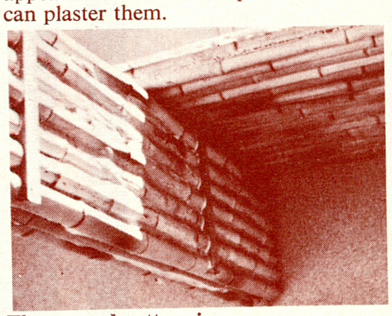
Composite bamboo beam

In the *Proyecto Experimental house*, all beams are rectangular section boxed beams, 20cm wide, 40cm deep, and 5 meters long. The beams are made of 6cm bamboos, placed over plywood templates, with a core of two lb. density polyurethane fire-retardant foam, foamed in place. The bamboos are pinned and spot glued together at 50cm intervals, with epoxy glue and wooden dowels.

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 200kg/m² (bamboo foam plank 15 kg/m², sulphur cement topping 45 kg/m², second floor partitions 50 kg/m², and live load 90 kg/m²). The roof is designed to carry 80 kg/m² (bamboo foam plank 15 kg/m², thin topping 20 kg/m² and live load 45 kg/m²). To put a third storey on the house, additional beams will need to be inserted (they can be slipped onto 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. (See table below). Families who do not like the appearance of the exposed bamboo can plaster them.



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 light weight, 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 urethene 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 spot glued bamboos together with epoxy glue and dowels. This test beam was 20cm wide, 40cm deep. We tested it over a clear span of 3.50 metres. At a uniformly distributed load of 1300 kilograms the deflection reached 0.8cm after an hour, and showed no sign of further creep 24 hours later. We may use the formula:

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

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

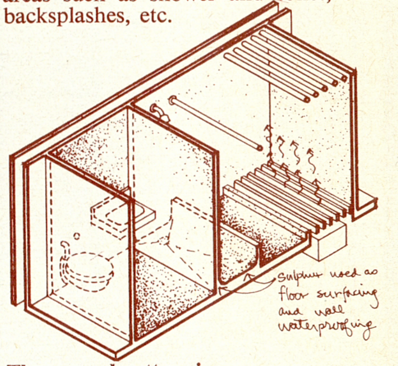
Span (metres)	Load*	(deflection less than L/360 kg).
3.00	2200	
3.50	1620	
4.00	1240	
4.50	980	
5.00	800	

*(where the design criterion is L/240, for unplastered conditions, these loads can be increased by 50 per cent)

These beams will cost 100 soles per metre (compared with about 200 soles per metre for comparable reinforced 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 be lifted and installed by two men.

Sulphur reinforcing and topping

In the *Proyecto Experimental*, the connecting surfaces of blocks which make up shear walls, bearing walls and columns are coated with molten sulphur and fibreglass for tensile reinforcement. Sulphur mixed with sand is placed 2.5cm thick on the bamboo/foam planks to create a walking surface, to create simple joints between the planks and between planks and beams, and to give continuity to the structure. Sulphur is also used as the water-proofing agent in wet areas such as shower and toilet, sink backsplashes, etc.



The general pattern is:

Context: Low cost dry block construction and/or panel construction.
Solution: Sulphur may be used as a reinforcing agent or bonding agent, wherever tensile strength is required in block walls, shear walls, planks and beams. It may be used by itself or with chopped fibres, applied hot, or as part of a sulphur-sand grout.
Problem: Jointing and reinforcing is a major part of the cost of a block wall, particularly in a high earthquake zone. In 1969 in Peru, the cost of a mortarless block wall with sulphur jointing is 20 per cent less than the cost of a block wall with mortar and reinforced concrete corners.

Test results show that the sulphur jointing has considerable tensile strength and that a sulphur jointed wall performs at least as well as the standard block wall in low rise construction. (Data are presented in John M. Dale and Allen C. Ludwig, 'Sulphur Aggregate Concrete', *Civil Engineering*, December 1967, pp. 66–68; in Allen C. Ludwig, *Utilization of Sulphur and Sulphur Ores as Construction Materials in Guatemala*, Southwest Research Institute, San Antonio, Texas, March 1969; and in John M. Dale, 'Sulphur-Fibre Coatings', *The Sulphur Institute Journal*, Fall 1965.)

Sulphur adds colour and texture in those areas where it is used. It may be tinted to produce colours other than yellow.

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