Relational Complexes In Architecture

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This article by Christopher Alexander and his four associates represents a continuation of the investigations that were first published in the RECORD in April, 1965 under the title "The Theory and Invention of Form." This work seeks to make use in architectural design of the new mathematics of relationship and the capabilities of the computer, while at the same time remaining fully cognizant of the complexities and subtleties that are an essential part of all architecture. The six examples of "relational complexes" illustrated were originally part of a study done for the Bay Area Rapid Transit District in San Francisco. Those responsible for making decisions at BART did not, in the end, make use of this material, which is certainly beyond the scope of most programing studies. In Professor Alexander's view, however, this unconventionality is precisely the point; he feels that it is investigations such as these that will permit the architect to cope most effectively with the increasingly complex problems that confront him. Text begins overleaf.

Relations of vehicular circulation in a suburban station

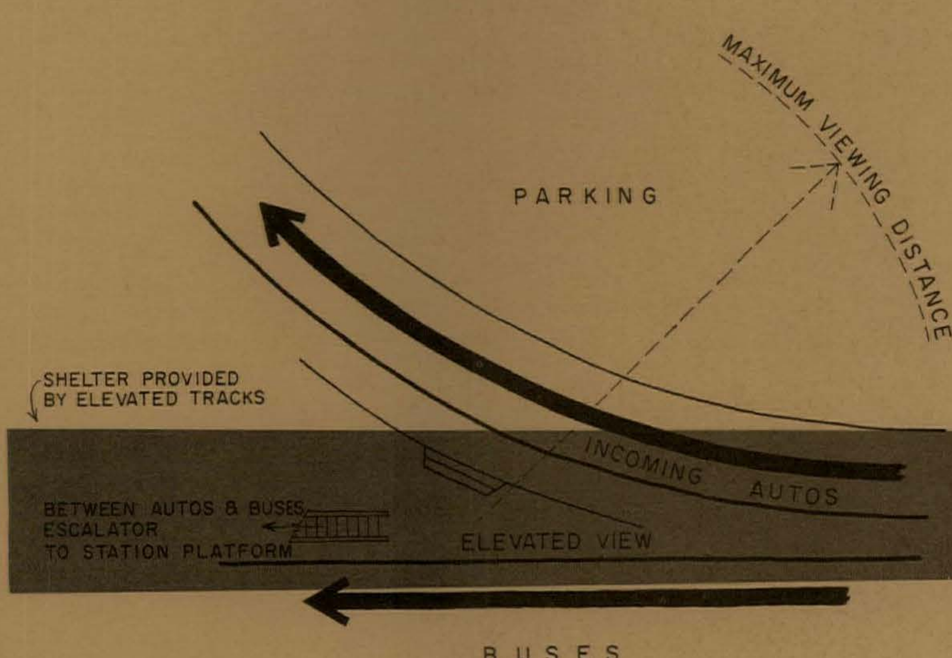
This complex deals with the problem of creating a smooth connection between the train and various feeder services at a suburban station.

A typical suburban station is on an elevated track structure and escalators and special entering facilities will be concentrated at one point along the station's 700-foot length. Complete separation is necessary between bus and auto traffic.

Additional functional requirements

- The bus stop should be as close as possible to the train.
- Commuters should be driven as close to the train as possible.
- People should be able to load and unload from their cars without crossing streams of moving vehicles.
- Buses should be able to load and unload on their right-hand side.
- Incoming vehicles must not spray rainwater on waiting passengers.
- People want to walk in straight lines directly toward their objective.
- Homecoming commuters must be able to find the car waiting for them without difficulty.
- Passage to and from autos and buses must be protected from rain, and waiting must be under shelter.

To satisfy the above requirements, both bus and drop-off lanes must be immediately adjacent to the main entrance escalator. The bus must pass to the left of the pedestrian zone in order to unload on the right. The drop-off lane must be concave so that arriving cars can spot vacant spaces. To ensure that pedestrians do not have to cross traffic streams, the only use that can be made of the area inside the concavity, across the drop-off lane from the escalator, is one that never happens in the morning—pick-up parking. To allow homecoming commuters to spot their wives as fast as possible, they must approach the parking from above; the escalator therefore points towards the parking. Since pedestrians walk in parking stall lanes, these lanes should point towards the escalator to make direct connection. The pedestrian area between the two lanes must be under the elevated track in order to be dry. In wet weather the pedestrian waits and the car drives to pick him up from its parking place under the structure. The bus and drop-off lanes must themselves be under cover so that the road next to the waiting pedestrians is dry. To avoid doubts about where pick-up cars are waiting, parking must be all in one area.



Resulting relations

- The escalator descends onto pedestrian viewing platform.
- The escalator is between the bus lane and the drop-off lane.
- Pedestrian viewing platform, bus- and drop-off lanes are under the elevated track structure.
- All parking is in one area.
- The drop-off lane is concave towards the parking area.
- The pedestrian viewing platform is raised above the parking area.
- The lanes in the parking area are oriented towards the escalator.

Architects are frequently so preoccupied with the details and the appearance of buildings that they take the underlying relationships—the most basic physical relationships—for granted. Worse still, many present-day efforts to make design more systematic tend to obscure these relationships instead of drawing attention to them. Since it is these underlying relationships which have the most profound effect on the way a building functions, it is our intention to try and make them more explicit.

An architectural problem is defined by systems of interacting requirements, which are statements of human need that can only rarely be expressed in terms of numbers or quantities. A typical example of such a requirement would be the phrase:

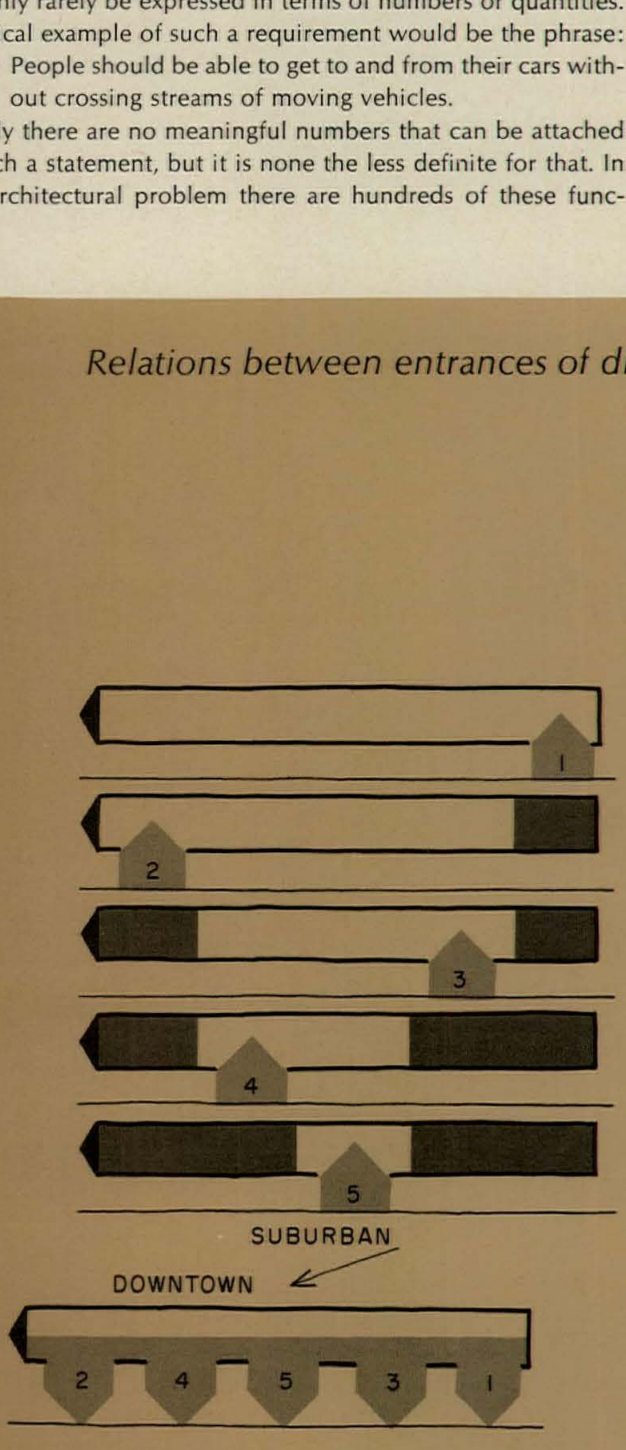
- People should be able to get to and from their cars without crossing streams of moving vehicles.

Clearly there are no meaningful numbers that can be attached to such a statement, but it is none the less definite for that. In any architectural problem there are hundreds of these functional requirements. Some of them may be independent o each other, but most interact closely with several others. W shall try to show that, in order to make serious functional im provements in the design of buildings, it is necessary to inven a new way of describing these functional relations, which w shall call *relational complexes*. We shall use as illustration some examples from our recent work for the Bay Area Rapi Transit District, but we think that the principles apply to an architectural situation.

A relational complex is a physical solution to a functional problem

It describes the interlock of the various simple physical rela tions which control the way the building works. Let us defin in detail what we mean by the interlock of simple physical re lations. A simple relation describes a particular way in whicl two or more elements are arranged with respect to one an

Relations between entrances of different transit stations



The problem dealt with in this complex is that of even distribution of passengers along the train to prevent overcrowding. In suburban stations there is a major entrance which concentrates at one point along the station's 700-foot length all station control, escalators and ticketing equipment. There are also minor entrances, a security gate and an auxiliary stair for rush-hour use only. At rush hours the typical pattern is for 70 per cent of passengers to use the major entrance, while 30 per cent use minor entrances. At all other times only the major entrance is used. The typical rush-hour train is 10 cars long.

Additional functional requirements

- Every passenger should be able to find a seat immediately.
- Boarding passengers must await the train at those points along the platform where incoming cars are emptiest.
- Passengers want to use whichever car will minimize their walking distance at the destination station.
- People do not walk more than about 100 feet along the platform, and therefore tend to congregate around the entrance.

Since existing suburban stations always have their entrances at the center of the train's length, the middle part of the train is crowded while the ends remain empty. To avoid this, each station at which the train stops on its way downtown must have its entrance at a different point along the train's length. If the volumes expected at each station are known, the pattern of entrances can be calculated so that, as the train fills up, passengers are evenly distributed along it. The downtown stations must have a sufficient number of entrances to equalize throughout the incoming train the effect of the passengers' desire for the shortest possible walk at their destination station. The same consideration has an important effect on outbound trains. As long as there are plenty of entrances to downtown stations, people will place themselves at the point on the platform which corresponds to their home station exit, thus creating the same even distribution as on inbound trains. To enhance the effect of this, each zone of the downtown station can be marked with the names of those suburban stations whose exits have the same position as that zone.

Resulting relations

- Different suburban stations have their major entrances at different points along the station length, the position of each entrance corresponding to the emptiest section of an arriving city-bound train.
- Each downtown station must have exits at various points along its length.
- Different positions along downtown station platforms are marked to correspond to positions of different suburban station exits.

other: it is a specification of arrangement. One such relation in a transit station would be that of *adjacency;* for example, the ticket machines must be adjacent to the change machines. Another relation might be *concavity,* the car arrival lane must be concave in the direction of the parking lot. If the platform must be between the tracks, this is a relation of *betweenness.* A building can contain the elements named in a relation without possessing the relation itself. Take the last relation named, that the platform must be between the tracks. A two-track, center platform station does contain it, a station with side platforms does not.

When two relations have an element in common, we say they interlock. Thus, consider the following two relations:

- The escalator must *face towards* the parking lot.
- The escalator must be *between* the car and bus lanes.

These two relations both have the escalator as an element, therefore we say that the relations interlock.

A relational complex is a collection of interlocking relations

Consider the two relations just named, together with a third:

- The car lane must be *concave towards* the parking lot.

These three relations interlock in three ways: in the escalator, in the parking lot, and in the car lane. They form an elementary relational complex.

In this example each relation interlocks with each of the others. In general, however, in a collection of many relations, it is very unlikely that such a high degree of interaction will take place. How many of the relations must interlock before they form a complex? It is naturally very difficult to answer this question precisely, but we shall not call a collection of relations a relational complex unless the interlock between them is considerable. A collection of many relations, with only a few interlocks between them, has no good claim to be considered as a whole. We must therefore enlarge our first definition.

Relations between circulation flow and the station platform

This complex deals with the over-all flow pattern in a downtown station. Rush-hour volume of people coming to and leaving downtown stations is concentrated at the ends of the station. Rush-hour traffic is highly directional—the typical morning pattern of 85 per cent in and 15 per cent out being reversed at night.

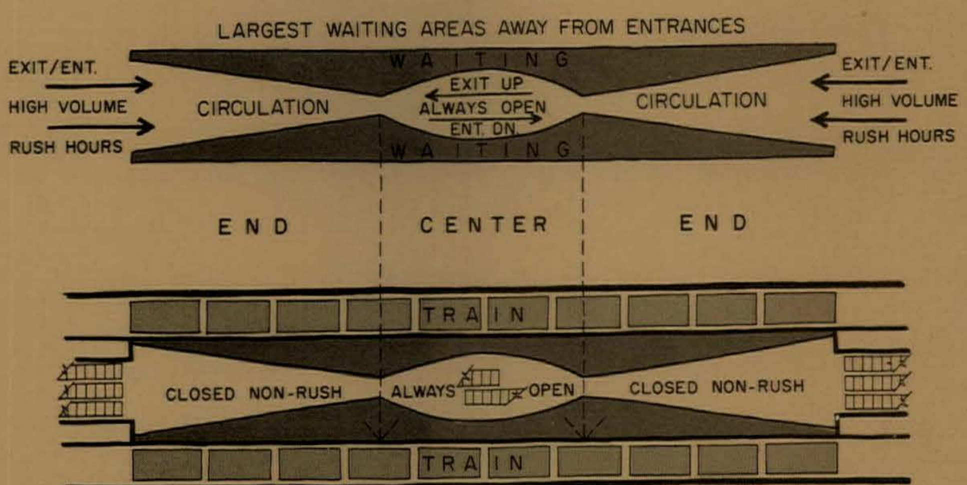
Additional functional requirements

- The sizes of various exits and entrances must be proportional to the volume of passengers going and coming in different directions.
- The system must be able to accommodate rush-hour traffic without wasting money on space and machines not used 23 hours of the day.
- No one train door should delay the train because more passengers use it than the others.
- The total effective cross-section of 'flow channels' must be large enough to take the maximum required flow.
- To avoid bottlenecks, the persons-per-minute capacity of flow channels must be the same at all points.
- The complex must be capable of accepting extra escalators and machinery to handle a possible future increase in volume.

There are three reasons why major exits must be at the ends of the station. First, people walk to and from downtown stations; assuming a roughly circular tributary area whose diameter is large in relation to the station's 700-foot length, the vast majority of passengers will find entering and leaving the station more direct via the ends. Second, when a full train unloads, end exits, with only half the capacity of a center exit, can function twice as efficiently because they are not converged on from both sides. Finally, the end of the platform is the only place where extra escalators can be added. The last 280 feet of platform are thus one-directional and carry 85 per cent of the rush-hour flow. These parts are closed at night, but the two-directional center section is open for the whole operating day. The circulation zone is wider near the escalator to accommodate the morning surge; but, to encourage people to move along the platform in the evening, the most comfortable waiting zones will be farthest from the escalator.

Resulting relations

- The main entrances/exits are at the ends of the station.
- The subsidiary entrance/exit is at the center of the station.
- The station is divided into three sections, a 140-foot center and two 280-foot end sections.
- Each end section and escalator is one-directional and reversible.
- The center section, open at all hours, is two-directional.
- Openings between center and end sections are constricted and equipped with a lockable night gate.
- The circulation channel is tapered: widest at escalators and narrowest at dividing points.
- Waiting areas are tapered to complement circulation channel.
- Vending machines are adjacent to constrictions between sections.



A relational complex must have high density of interlock, detailed functional significance

The density of interlock must be very high; there must be many elements in common between the different relations. This is the same as saying that each *element* in the complex must be related simultaneously to many other different elements. Even when the interlock of the relations in the complex is clear, it will usually be necessary to add some further detailed information about the way the individual relations interact with one another, so as to assure their proper integration. In addition, the complex *as a whole* must have inescapable functional significance. The individual relations must be so interdependent functionally that it is impossible to consider them as separate entities.

Each of the six relational complexes described in this article was derived by studying the interaction of functional requirements according to the theory first set down in Christopher Alexander's "Notes on the Synthesis of Form," a condensed version of which appeared in April, 1965 (pages 177, 186). The use of this theory yields systems of requirements whose internal interactions are very dense. Each system, because it is a system, guarantees in advance that the solution of its requirements will be a relational complex, not just a collection of relations. Each system therefore gives a complex.

None of these relational complexes is a complete description of a whole building; it is an abstracted relational property which the building must have in order to work successfully. Unlike a building, which contains both inessential and essential features, a relational complex contains only those elements that are absolutely necessary to solve the problem stated by the requirements.

The six examples give a fairly clear picture of what a relational complex is; and they make it clear that it is relational complexes that really control the way a building works.

Relations affecting the agent's booth in underground stations

This complex deals with the problem of surveillance. Most existing transit stations fail to solve this problem, and crime and lack of control over crime is perhaps the biggest factor in the decline of big-city subways. In the Bay Area system, underground stations would typically be multi-leveled and the length of trains would vary from ten to two cars. There would only be one station agent. It is feasible to build an underground station with no intermediate column supports. Non-moving escalators are usable as emergency exits from the station.

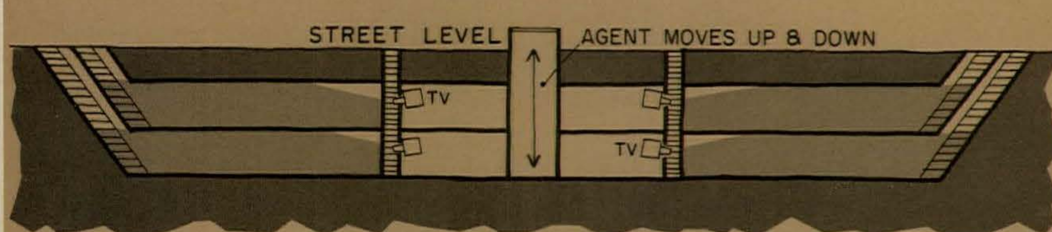
Additional functional requirements

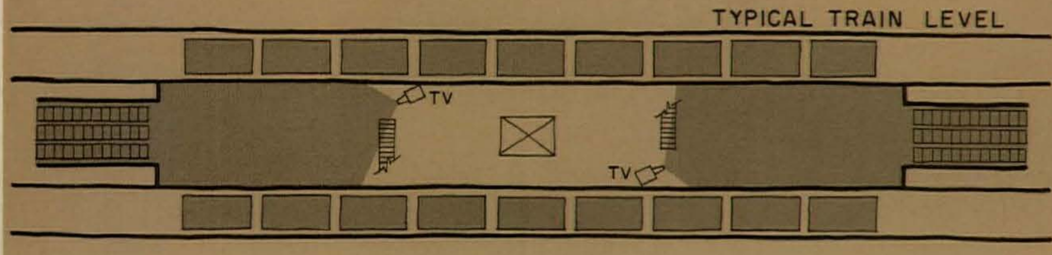
- Every part of the station that is in use must be very obviously under surveillance, as much to discourage crime as to detect it.
- To reduce crime, no operating part of the station should be deserted.
- To reduce the payroll, the minimum number of police, maintenance and supervisory personnel should be employed on train and station.
- The station agent must be able to oversee the whole station and investigate individual incidents without losing his general overview.
- The station agent must be able to see, and, in case of difficulty, reach the ticket gates.
- Passengers in distress should know that, if they scream for help, the ticket agent will hear them.
- Waiting facilities should be arranged so that women waiting alone at night will not become uneasy.
- In any emergency it must be possible to empty the station in a few minutes with the help of fire escapes.

The solution to this problem makes the agent's booth a two- or three-story tower, extending up to the surface ticketing area and down to the platform level, and placed in the middle of a station with center platforms at each level. Within the tower, the agent must be able to move up and down freely, and he must be able to leave the tower at any level. Waiting areas are concentrated around the tower where women are safe at all times, while minimum use of TV cameras can supplement direct visual control of the remote zone. Stairs and escalators must be at the outer ends of zones providing an unobstructed view.

Resulting relations

- The agent's booth is an elevator enclosed in a vertical tower in the center of the station.
- There is access from the tower to public areas at every level.
- The tower enclosure is one-way transparent, allowing vision out but not in.
- At each level, there is a waiting area adjacent to the tower.
- The station is divided into a center section and two end sections.
- Fire stairs are within the barriers, separating end from center sections.
- Escalators are at the extreme ends of the station with no public access from the sides or back.
- At each level the platform must be between the tracks.
- Each of the three sections must have a clear span, with all the vertical supports beyond the platform.
- Television cameras are mounted on the barriers between the sections, cover rest of platform.





Why have we chosen to define the idea of a relational complex in such a formal way?

Isn't it true that designers already do very much the kind of thing which we have done, but without being so pretentious? Why have we chosen to use the name 'relational complex,' and to keep repeating it? The answer is simple.

Architects are not used to thinking in relational terms. Yet relational complexes control the way that buildings work. Although it is true that relationships of this kind are present in every building, nevertheless the designers of buildings do not, at present, discuss such relational structures openly. As a result, although the details of buildings may be successful, and the buildings may seem good to look at, the fundamental relationships which underlie their form are often wrong.

It is impossible to get the form of buildings right until these structures of abstract relationships, which underlie forms and control the way they work, are explicitly recognized as the most important aspect of the building. That is why we have isolated the abstract structures of relationship and given them the name, relational complexes. Indeed, we believe it will soon be clear that the main task of design is the invention and development of relational complexes *as such;* and that the remaining details of a building are quite unimportant by comparison.

That is the first, and most important, reason for emphasizing and repeating the idea of the relational complex.

There is a second reason.

Many architects are getting interested in systematic methods of design. On the face of it, this is encouraging. In order to be systematic in design, one must define the features of a building with which the design is trying to deal. We might hope, therefore, that, as soon as designers start trying to be systematic, they will automatically discover that relational complexes are the most essential features of a building. So far, however, this has not happened.

Relations between street and platforms in underground stations

This complex deals with the problem of making access to the train in a deep underground station as direct as possible and eliminating the mezzanine, which is an undesirable feature of most traditional subway stations. This mezzanine between surface and platform level is hard to police, difficult to clean, breaks the flow from surface to train, adds about 10 feet to excavation costs; and, because of its deserted, dangerous appearance, contributes greatly to the menacing character for which subway stations are notorious.

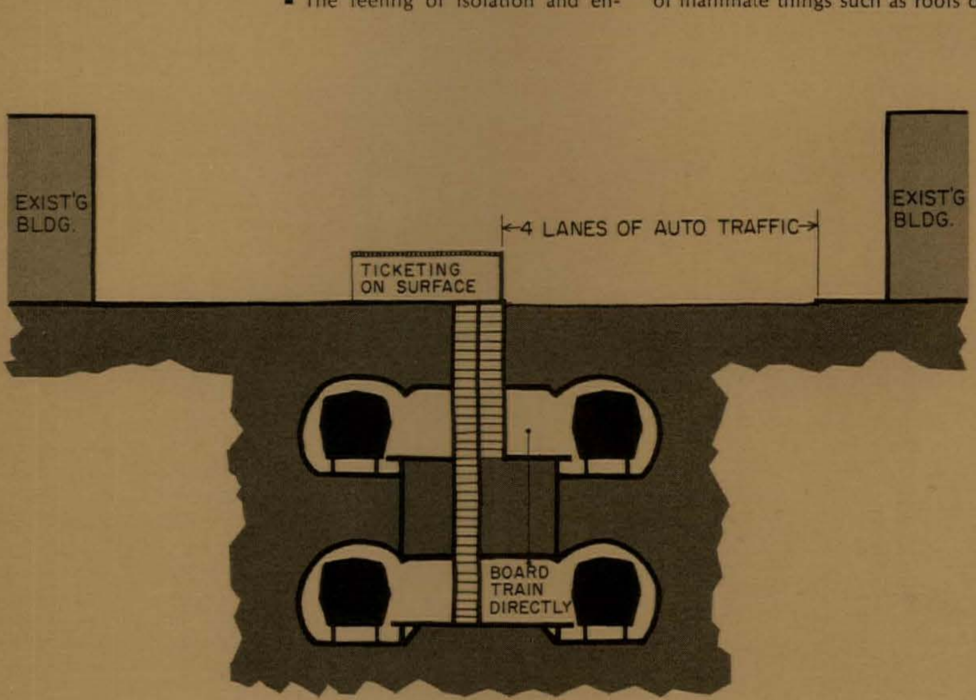
Additional functional requirements

- The feeling of isolation and enclosure which tempts assaults, particularly at exits, toilets, stair landings and blind corners must be eliminated.
- Transition from the outside of the station to the train must be immediate. Trains should be close to the surface so that no one will think it too much trouble to use the system.
- Waiting facilities must be arranged so women waiting alone at night will not become uneasy.
- The total surface area needing maintenance and cleaning must be reduced to a minimum.
- People prefer a view of other people, movement, or cars to a view of inanimate things such as roofs or parking lots, or empty platforms.
- Waiting areas must accommodate the crowd caused by train delay.
- The closed-in feeling must be eliminated and a connection maintained with the outside world.
- The cost of overcoming soil loads and hydrostatic pressure in deep underground structures must be kept to the minimum.
- There must be a hesitation point for umbrella raising etc., just before people emerge in the open.

The problem can be solved if all ticketing takes place in kiosks on the surface, with warning signals to mark the arrival of trains, and if single-flight, unbroken escalators lead from these kiosks to the platform. A single escalator with a break at the intermediate level would not work, as the upper half would have insufficient capacity, and the access flow at the intermediate level would cause impossible congestion. Waiting areas are immediately next to the agent. Trains are as near the surface as possible to allow access by a single escalator trip and to reduce excavation costs. The smaller underground volume and surface area concentrates people together making the station less deserted, and easier to patrol, as well as cutting cleaning and maintenance costs. Surface ticketing areas are safe at night, and, during the day, give increased exposure to daylight. The kiosk provides a hesitation point.

Resulting relations

- Ticketing is in kiosks on the surface.
- Unbroken escalators lead direct from the surface to each track level.
- Track levels are as close to the surface as possible.
- Waiting areas are immediately next to the station agent.



An understanding of relationship should replace the false sophistication of numbers and measurement

Many of the first approaches to systematic methods in architecture have been based on the belief that a problem becomes clear when it is stated in numerical terms. As a result, designers put great emphasis on rates of flow, decibel levels, room sizes expressed in square feet, lighting levels and minimum dimensions. The added precision of these statements is certainly systematic. However, instead of drawing attention to relational complexes and helping architects to think in these terms, such numerical precision actually has a tendency to obscure basic relationships. Worse still, the elaboration of numerical statements, because it falsely conveys an impression of great thoroughness and sophistication, makes it seem unnecessary to probe any further into the underlying nature of the building.

This potentially damaging preoccupation with numbers is a hold-over from the late 19th-century thought that something was not precise unless you could measure it, a belief current i the days when mathematics and physics dealt largely with num bers and quantities. Today mathematics and the older science are more sophisticated. People in these fields have begun t realize that the fundamental nature of things depends far mor on relationship and structure than on number and quantity Unfortunately the younger sciences (like economics, engineer ing, ergonomics, operations research, and systematic design have not yet made this transition from number to structure Within these fields, and in architecture, there is still no way c talking about relational structure, *as such*.

For a science in its infancy this is only natural: things whic can be expressed in terms of numbers are very easy to mak explicit; pure relations are very hard to talk about explicitly But we must leave this 19th-century immaturity behind as fas as possible. Design is the invention of relational complexes. W must learn to define them, and to design them.

Relations between seats and aisles in a transit car

This complex deals with the problem of maximizing the seating capacity of the transit car while at the same time increasing passenger comfort. A minimum of 75 seats is allowable per transit car, in which approximately 80 per cent of all passengers travel alone. Dimensions of the transit car are as follows: outside width 10 feet 6 inches; length to coupler faces, 70 feet. Included in each car will be a "cab" in which the train operator can sit.

Additional functional requirements

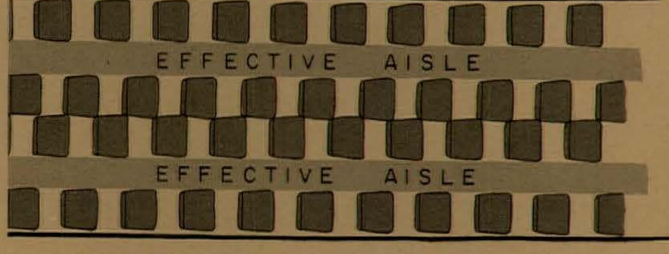
- Nobody wants to sit touching a stranger; each person wants a clearly demarcated seat of his own.
- No person should have to struggle past another person's legs to get in and out of his seat.
- There should be as many seats per transit car as possible.
- There should be no waste space under and between seats.
- Family groups, couples, or card-playing commuters need a seating arrangement which allows them to maintain an inward privacy in appropriate contact with one another.

Existing transit cars, when designed to seat as many passengers as possible, are laid out with a center aisle and double seats on both sides of the aisle. If we accept this pattern, the car cannot hold more than 76 seats, and the only way to provide sufficient individual space and leg room would be to widen the seats and increase the space between them, which would reduce the number of seats in the car.

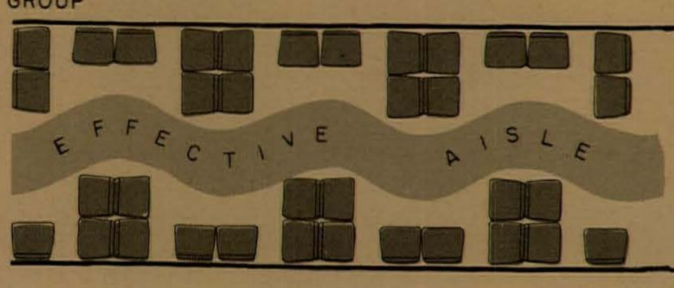
These requirements can, however, be solved simultaneously by using two aisles, each giving direct access to seats on either side of it. Because seats are single, no one need touch any stranger and no one has to pass anyone else to leave his seat. Further, no extra passing space is needed between a person's knees and the seat in front, and because of this, seats can be closer together than usual, yielding 96 seats per car. The staggering of seats, which places each arm rest next to an aisle, comfortably allows the seat width to be two inches less than usual, and keeps the over-all car width to 10 feet.

These provisions are adequate for the 80 per cent of passengers who travel alone, but a different pattern is needed for those who travel in groups. By relaxing the requirement for single, non-touching seats and replacing it with U-shaped groups of seats staggered on either side of a single aisle, we arrive at an arrangement which allows group travel, but in which no one has to pass anyone else to leave his seat. The density is lower than in the pattern for individual travel, but is still higher than conventional cars.

INDIVIDUAL



GROUP

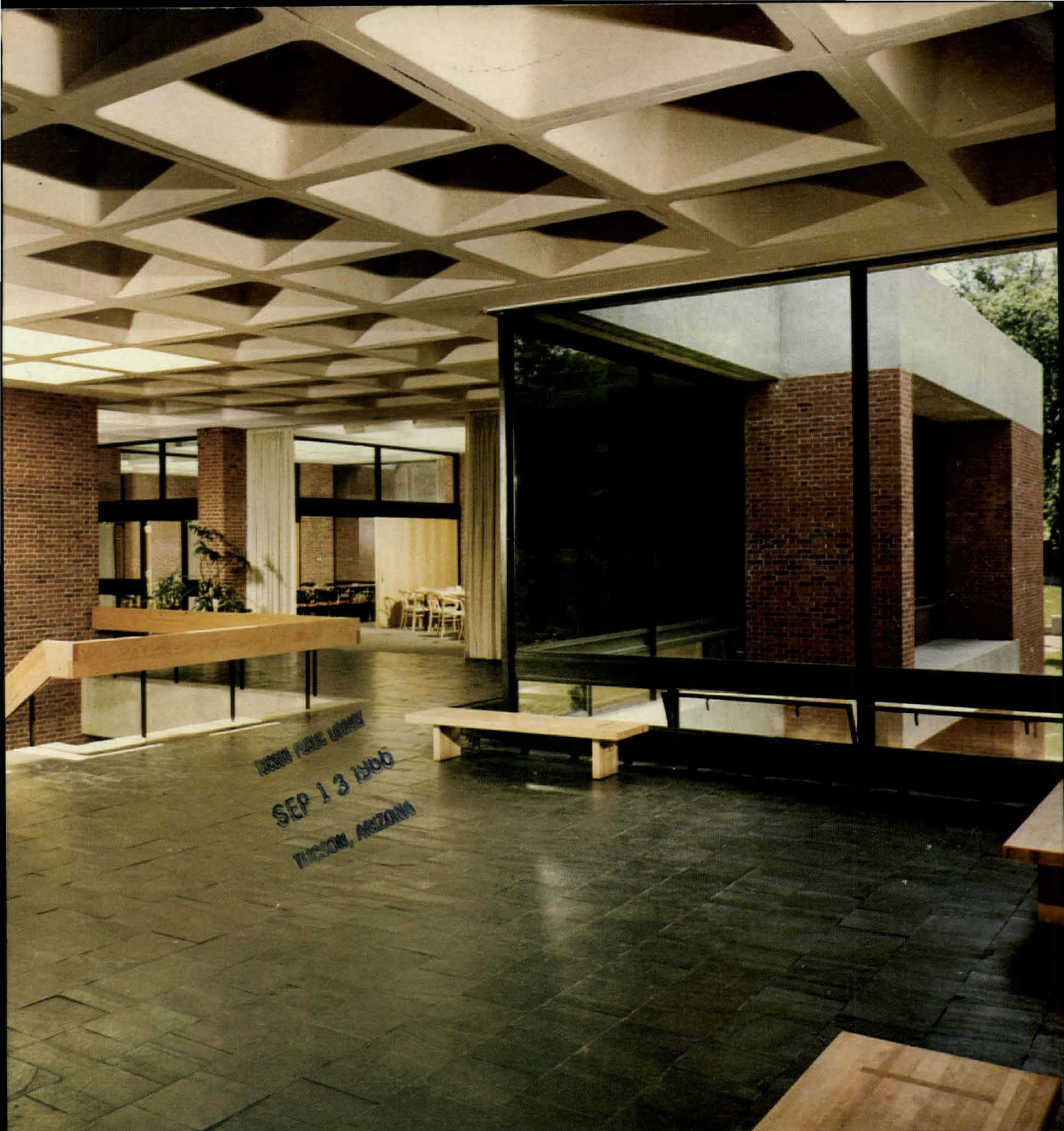


Resulting relations (individual)

- All seats are single seats.
- There are two aisles, each serving a row of single seats on either side.
- Each seat is staggered with respect to seats next to it, or opposite it across an aisle.

Group relations

- There is one aisle.
- Seats are arranged in U-shaped groups of six.
- Groups of seats are staggered, on either side of the aisle.



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