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THE PATTERN OF STREETS

Christopher Alexander

This paper describes a new pattern for the streets in a metropolis. Average speeds in an area laid out according to this pattern would be 45 mph, as against the 15 mph typical for urban areas today: yet mean trip length is increased by only 5 percent. The principal features of the pattern are: all streets are parallel; there are no cross streets; streets are connected by freeways 3 miles apart.

This paper is about the geometry of the street pattern in a metropolis.

The present net-like pattern of streets (whether it is a formal grid like Manhattan, or an informal net like London) is so well fixed in our minds, that it hardly occurs to us that city streets might have an entirely different pattern. Even the coming of the freeways has not changed our thinking. So far the freeway has been superimposed on the existing street pattern; the pattern of ordinary streets below the freeways has not changed at all.

Yet the net-like pattern of street which we are used to is obsolete. Congestion is choking cities; the demands which now exist require a totally new geometry for the relations between streets.

First, I shall describe this new geometry. Second, I shall try to show that this geometry is a natural consequence of the demands which the street system is subject to today.

THE GEOMETRY

The geometry is shown in diagram form in Figure 1. Its essential features are:

1. All streets are parallel. There are no cross streets, and no two streets intersect.
2. The streets are about 500 feet apart.
3. Streets are one way, alternate streets running in opposite directions.
4. At 3 mile intervals multilane freeways run under the streets at right angles to them.[1]
5. Pairs of streets are connected to the freeways by clockwise loops.
6. Neither pedestrians nor parked cars are allowed on the streets.
7. The strips of land between the streets, where the buildings are, are continuous pedestrian areas. Access driveways in these areas go all the way from one street to the other, but are interrupted by frequent ridges, so that vehicles cannot move on them at more than walking pace.

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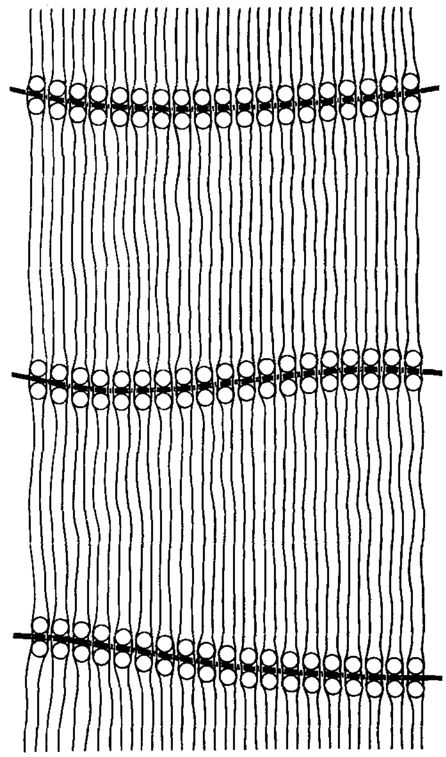


FIGURE 1
The streets and freeways are deliberately drawn crooked. It is not essential that they be straight, only that they be roughly parallel. Their exact alignments will be determined by local variations in land-use and topography.

The diagram is deliberately concise. It is meant to convey the essential relations just described, without containing any additional (and arbitrary) information. In particular, it is not essential that the streets be perfectly parallel, nor that their pattern be repeated exactly. Indeed, *the essential relations 1-7 could be obtained in many existing cities by closing cross streets.*

GENERATING DEMANDS

I shall now state the nine demands which generate this pattern. All nine hinge on the problem of congestion. Each of them is an inexorable force in modern urban life.

REQUIREMENT 1: *Movement in the city must allow the maximum free use of personal vehicles.*

People like their cars. The desire for cars is a force so potent, that we cannot possibly ignore it. Even when cars and trucks as we now know them have become obsolete, the desire for some equivalent form of individual vehicles will remain.

REQUIREMENT 2: *Average speeds must be as high as possible. Average trip times must be as low as possible.*

Once we recognize requirement 1, then we are also forced to recognize one of the great mechanical failures of the modern city. Congestion chokes it. We cannot move around it fast enough. Though cars and trucks can average 60 miles per hour on freeways, most trips across town have an average speed of 15 miles per hour.[2]

At present commuters spend as much as two hours driving every day: this failure of our cities is exhausting. But it is more: it is a major economic failure. Low speeds waste salaried time, and constant starting and stopping double driving costs; both add considerably to the cost of living.[3] The biggest problem, however, is that parts of the metropolis are virtually inaccessible to one another. People only 10 or 15 miles apart cannot reach each other when they want to because they are an hour apart by road.

The present loss of speed on city streets is largely caused by traffic intersections, left hand turns, parked cars, and the possibility of pedestrians suddenly stepping out.[4] Requirement 2 therefore demands that the street pattern have neither left hand turns across traffic nor intersections in it, that all parking be off streets, and that pedestrians cannot step into the streets.

REQUIREMENT 3: *The street pattern must connect any two points with roughly* *equal efficiency.*

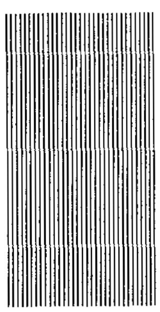
The freeway and the system of linked lights have both been invented to solve requirements 1 and 2. But they improve flow only along certain lines of movement. Both fail to recognize a third essential fact of modern urban society: namely that it is a pluralist society. In a modern metropolis, anybody may want to reach anybody else.[5] The spatial points which different individuals seek access to are so varied that they are unpredictable. We therefore must make access to all points equally possible.

REQUIREMENT 4: *The system of streets must be essentially at ground level.*

In science fiction, or in theory, it might be possible to solve requirements 1, 2, and 3 by building north-south streets at one level and east-west streets at another level with ramps between them. In practice the cost would be prohibitive and the ramps would require too much space. In the low density areas, which occupy nine-tenths of a metropolis, solutions of this kind will simply not get built.

THE SOLUTION

FIGURE 2



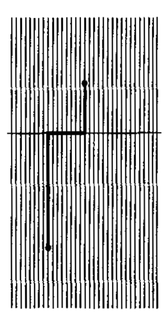
The only space-filling pattern of lines which is free from intersections, and yet entirely at one level, is a packing of parallel lines. Requirement 1, 2, and 4 therefore demand a pattern of parallel streets without cross streets. To solve requirement 3, streets are connected by infrequent freeways which run at right angles to the streets. How far apart can these freeways be before they start creating serious detours?

Suppose that the freeways are m miles apart. Let us call each area between two freeways, a "band." Each band is m miles wide. There are now two essentially different kinds of trip:

a) Those which start and finish in different bands, shown in Figure 3. These are exactly the same length they would be if cross-streets existed.

b) Those which start and finish in the same band, shown in Figure 4. These are longer than they would be if cross-streets existed. The amount of the detour is twice the shorter distance to the nearest freeway. Given independent random distributions of starting points and destinations, integration shows that the mean detour, on such a trip, will be $m/3$ miles.[6]

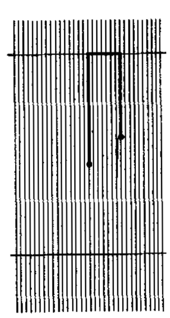
FIGURE 3



Let us now ask what proportion of all trips do in fact start and finish in the same band. We begin by tabulating the frequencies of different trip lengths in a modern metropolis. The figures below are from San Diego.[7]

We observe now, that for any given trip length ℓ, some trips will fall entirely within a band, while others will start in one band and finish in another. We may think of the trips as lines of length ℓ falling at random onto the city, and assume that trips are equally likely to fall at all angles to the freeways. The probability then that a trip of length ℓ will fall entirely within a band is the same as the probability that a matchstick of length ℓ, thrown at random onto a pattern of parallel lines m apart, will fall entirely between two lines. This is given by the standard formula:[8]

FIGURE 4



$$p(m,\ell) = 1 - \frac{2\ell}{\pi m} \text{ if } \ell \lesssim m$$

$$= \frac{2}{\pi}\left[\text{arc sin}\frac{m}{\ell} - \frac{\ell}{m} + \frac{\sqrt{\ell^2 - m^2}}{m}\right] \text{ if } \ell > m$$

For m equal to 1 mile, 2 miles, and 3 miles respectively, this function yields the following probabilities of a one-band trip, for the trip lengths shown:

	ℓ	1	2	3	4	5	7	10
	1	.36	.16	.11	.08	.06	.03	.03
m	2	.68	.36	.22	.16	.13	.10	.06
	3	.79	.58	.36	.25	.20	.15	.11

Trip lengths	1 mile $\frac{1}{2} \lesssim \ell < 1\frac{1}{2}$	2 miles $1\frac{1}{2} \lesssim \ell < 2\frac{1}{2}$	3 miles $2\frac{1}{2} \lesssim \ell < 3\frac{1}{2}$	4 miles $3\frac{1}{2} \lesssim \ell < 4\frac{1}{2}$	5 miles $4\frac{1}{2} \lesssim \ell < 5\frac{1}{2}$	7 miles $5\frac{1}{2} \lesssim \ell < 8\frac{1}{2}$	10 miles $8\frac{1}{2} \lesssim \ell < 11\frac{1}{2}$
Percent of all trips	28%	11%	11%	9%	9%	24%	8%

Since each one-band trip is lengthened by a detour whose average length is $m/3$ miles, we may compute a mean detour for each combination of m and trip length, as below. If we then multiply the mean detours for each value of m by the relative probabilities given in the first table and add them, we obtain the overall mean detours given in the last column.

		Mean detours (miles)							Overall mean detour
	ℓ	*1*	*2*	*3*	*4*	*5*	*7*	*10 miles*	
	1	.12	.05	.04	.03	.02	.01	.01	.05 miles
m	2	.45	.24	.15	.11	.09	.07	.04	.21
	3	.79	.58	.36	.25	.20	.15	.11	.41

Under present conditions, with cross-streets, the overall mean trip length in the San Diego case is 4.12 miles. This is typical for metropolitan areas all over the Western world. On a system of parallel streets with freeways 1 mile apart (if the origin-destination pattern remains the same), the overall mean trip length would be 4.17 miles. With freeways 2 miles apart, it would be 4.33 miles. With freeways 3 miles apart, it would be 4.53 miles.

We see therefore, that even with freeways 3 miles apart, the lack of cross streets only increases the average trip length by 10 percent. What is more, this estimate is high. It is based on the assumption that origins and destinations will be the same as they are now. Yet the new pattern of streets will undoubtedly generate a new pattern of land use and a new distribution of trip lengths. For example, 70 percent of all trips either start or finish in a commercial area.[9] Commercial areas will therefore locate near freeways, most of these trips will have no detour, and the number of detours will be halved, thus reducing the average detour from 10 percent to 5 percent.

If the freeways are 3 miles apart, the average trip length in a system of parallel streets will therefore be only 5 percent greater than in the present system with its cross streets. At the same time, the average speed of trips will increase from 15 miles per hour to about 45 miles per hour, a threefold increase. The huge savings in time and fuel costs will more than offset the slight increase in distance.

SUBSIDIARY DEMANDS

The pattern proposed is therefore an adequate solution to requirements 1, 2, 3, and 4. However, from a human point of view, it creates a very unusual environment, different from the pattern we are used to in two important ways.

First of all, the detours, even though they may be quicker and cheaper, will be hard to get used to. In extreme cases, houses which are only a few hundred feet apart as the crow flies may be two miles apart by road. Will this distortion of geometric distance be psychologically acceptable?

Secondly, the pedestrian is no longer free to wander at will from street to street. Since the streets are high-velocity arteries, the pedestrian must stay within the strip of land between the streets. Will he be able to tolerate this imprisonment?

Let us consider the question of distance, first. Much evidence suggests that the geometric conception of distance has already disappeared in the modern automobile city and has been replaced by a conception of "time-distance." Consider the following examples:

a. On trips within the city distances are rarely expressed in miles, since the fluctuation of traffic gives physical distance no useful significance. Instead we express distance in minutes of driving time, and say that we live 35 minutes from the airport, 3 minutes from downtown, and so on.

b. Even when we do speak of physical distance in the city, we do not mean Euclidean distance but street distance. If two places are ten blocks apart (five along and five across), we call them ten blocks apart, even though the Euclidean distance is seven.[10]

c. Finally, in many hilly areas too steep for streets directly up the slope, streets follow contour lines. In many such places there may be two houses no more than a few hundred feet apart that are more than a mile apart by road because they lie on parallel streets, one above the other. Does anybody even notice?[11]

These examples strongly suggest that the Euclidean distance between two points is immaterial; it is the time taken which really counts. From this point of view, the pattern proposed is perfectly acceptable.

Now let us consider the problem of pedestrian "imprisonment": The present net-like street pattern is based on the idea that you can walk from any point to any other point. This seems natural and essential.

Let us ask ourselves, however, under what conditions it came about. It came about at a time when most people walked wherever they went. A person's friends, his place of work, and the stores and institutions which he visited were close to his house. Under these conditions it was natural, and essential, to be able to walk in all directions.

But these conditions no longer exist.[12] In a modern metropolis friends, job, and stores are usually beyond walking distance. To reach them we must drive or use public transit: The spatial neighborhood community no longer has the social meaning which it used to have. People walk for pleasure and in cases of emergency, but it is no longer necessary to be able to walk in all directions. It is true that the spatial neighborhood still plays a minor part; it provides useful "neighborly" conveniences, help in times of sickness, the opportunity to borrow tools, mutual support in times of trouble. However, it has been shown that these kinds of neighbor contacts are generated most often between houses on the same side of the street, and that they hardly ever develop *across* streets.[13] It is therefore clear that pedestrian access to houses across the street adds nothing to what remains of neighborhood community, and there is no reason to preserve it. The creation of streets which are impassable to pedestrians is perfectly all right, provided that the following requirement is met:

REQUIREMENT 5: *It must be possible to take long walks from any house; and it must be possible to walk to neighbors' houses, to borrow things and to get help.*

The requirement will be met if the area between the streets is a continuous, publicly accessible, pedestrian area.

The remaining details of the pattern are then dictated by the following requirements:

REQUIREMENT 6: *There must be a smooth transition between streets and freeways.*

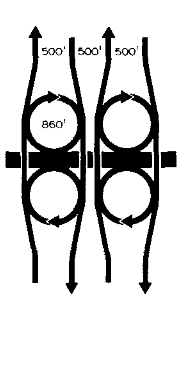
REQUIREMENT 7: *Vehicles turning on and off a street must not endanger other high speed traffic on the street.*

REQUIREMENT 8: *Vehicles must be able to get to within a few feet of any building.*

REQUIREMENT 9: *Wherever the pedestrians go, they must be safe from traffic.* (This does not require absolute separation between pedestrians and vehicles. It does require, however, that wherever pedestrians and vehicles meet, the vehicles must be moving at walking pace.)

What are the details of the street pattern needed to meet these requirements? First of all, since U-turns and left-hand turns are not allowed either on or off the streets (requirement 2), the streets need only be one way. There is nothing to be gained from making them two way, since there would then have to be a continuous divider strip down the middle of each street. Each strip of land, however, must have access from both directions. The one way streets must therefore alternate. Each strip of land is then between a pair of streets which run in opposite directions.

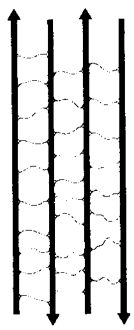
FIGURE 5



Let us now consider the solution to requirement 6. Under normal circumstances, the transition between streets and freeways would be by means of cloverleaf interchanges. However, these interchanges take up too much land. It would be impossible to put one on every street.[14] Instead we place a clockwise loop, tangent to the freeway, between alternate pairs of streets and on each side of the freeway. The right-hand lane of the freeway will be reserved for loop traffic only.[15] The loop itself will be sloping so that access to the freeway is downhill, thus helping the required acceleration. Exit from the freeway is uphill, helping the required deceleration. If we assume an exit speed of 40 miles per hour, the loops will need a diameter of about 860 feet.[16] Since the loops are placed only between alternate streets, the streets themselves can have a minimum spacing of about 500 feet.

Let us now consider movement on the strips of land between the streets. In a

FIGURE 6



strip 500 feet wide, most buildings will not front on the street directly. Requirement 8 therefore demands that all these buildings have driveways leading to the street; indeed, since the streets are one way, cars must be able to get to every building from both streets. This means that every driveway must cut right across the strip of land from one street to the other. To ensure that every movement on or off the street is a smooth right-hand curve (requirement 7), the driveways meet the street in fishtails.

Finally, the driveways between streets must not cause danger to pedestrians (requirement 9). On the other hand, requirement 5 demands that the entire strip between the streets be a continuous pedestrian area. The driveways must therefore be unsurfaced, and must be interrupted at frequent intervals by concrete ridges, perhaps 4 inches high, so that vehicles cannot move at more than walking pace between the streets, and do not endanger the pedestrians they meet.

The pattern of parallel streets solves the problem of congestion. As far as I can see, the pattern is causally self-contained and raises no new problems of its own; it is compatible with the other elements of the existing city. But it is not in itself a plan; it is merely a basic scheme. Like the grid pattern, it will have to be modified, transformed, and interrupted, as the need arises.

Finally, let me repeat: It is not necessary to build this pattern from scratch. The essential features of the pattern can be obtained in most existing cities *gradually,* by closing cross streets, one at a time.

NOTES

[1] The freeways could also pass over the streets. However, this is likely to be more expensive.

[2] Ministry of Transportation, *Research on Road Traffic* (London: Her Majesty's Stationary Office, 1965), pp. 108-109.

[3] J. W. Gibbons and A. Proctor, "Economic Costs of Traffic Congestion," *Highway Research Board Bulletin* 86, (Washington, D.C., 1954), pp. 1-25. Malcolm F. Kent, "Fuel and Time Consumption Rates for Trucks in Freight Service," *Highway Research Board Bulletin* 276, (Washington, D.C., 1960), pp. 1-19. Running Cost of Motor Vehicles as Affected by Highway Design," *National Cooperative Highway Research Program Report* 13 (Interim Report), (Washington, D.C., 1965) pp. 2, 14.

[4] G. F. Newell, "The Effect of Left Turns on the Capacity of Traffic Intersections," *Quarterly of Applied Mathematics,* XVII (April, 1959), 67, 76. J. G. Waldrop and J. T. Duff, *Factors Affecting Road Capacity* (London: Road Research Laboratory, 1956).

[5] Melvin Webber, "The Urban Place and the Nonplace Urban Realm," in Melvin Webber and others, *Explorations into Urban Structure* (Philadelphia: Univ. of Pennsylvania Press, 1964).

[6] Let us say that the start and finish are at distance x and y respectively from one (arbitrarily chosen) freeway. Then the nearest freeway is either x or m-x from the start, or else y or m-y from the finish, whichever of the four is least: and the detour, which is twice this shortest distance, is therefore

$$d = \text{Min}\,[2x, 2(m-x), 2y, 2(m-y)]$$

If we plot x against y, we see that this function gives $d = 2x, 2(m-x), 2y, 2(m-y)$ respectively, in the labelled triangular regions of the graph:

FIGURE 7

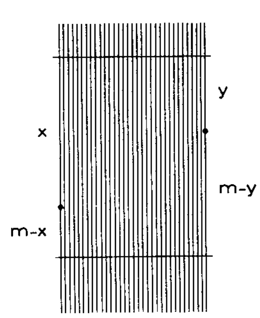
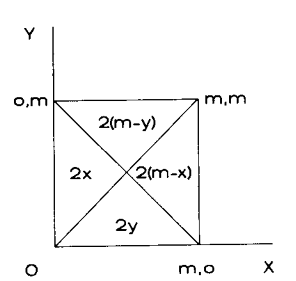


FIGURE 8



If x and y are random variables, taking values between o and m with equal likelihood, then we may find the mean value of d, by integrating d over the whole square $o \lesssim x \lesssim m$, $o \lesssim y \lesssim m$, and dividing by m^2. Since the integral is the same for each of the four triangular quarters, we get:

$$\bar{d} = \frac{4}{m^2}\int_0^{m/2} 2y(m-2y)dy = m/3$$

[7] Edward M. Hall, "Travel Characteristics of Two San Diego Suburban Developments," *Highway Research Board Bulletin* 2039, (Washington, D.C., 1958), pp. 1-19, fig. 11.

[8] M. G. Kendall and P.A.P. Moran, *Geometrical Probability* (London, 1963), p. 70.

[9] Frank B. Curran and Joseph T. Stegmaier, "Travel Patterns in 50 Cities," *Highway Research Board Bulletin* 203, *op. cit.,* pp. 99-103, table 8.

[10] See also Kevin Lynch, *The Image of the City* (Cambridge: MIT Press, 1960).

[11] There are many excellent examples in the Berkeley hills.

[12] Webber, *op. cit.* and "Order in Diversity: Community without Propinquity," in Lowdon Wingo, Jr. (ed.), *Cities and Space.* Published for Resources for the Future, Inc. (Baltimore: The Johns Hopkins Press, 1963), pp. 23-54.

[13] Paul Ritter, "Social Patterns and Housing Layout," Thesis prepared for the University of Nottingham, England, 1957. Also described in Paul Ritter, *Planning for Man and Motor* (New York: Macmillan, 1964) pp. 27-32.

[14] J. E. Leisch, "Spacing of Interchanges on Freeways in Urban Areas," *Journal of Highway Division,* American Society of Civil Engineers, LXXXV (December 1959).

[15] Joseph McDermott and Charles McLean, "Improving Traffic Flow at Transfer Roadways on Collector-distributor Type Expressways," *Highway Research Board Record* 59, (Washington, D.C., 1964), pp. 83-103.

[16] "A Policy on Geometric Design of Rural Highways," *American Association of State Highway Officials* (Washington, D.C., 1954), p. 263. Where the traffic circles are tangent to the freeway, there will be a weaving section; the traffic leaving the freeway conflicts with the traffic entering. However, provided the part of the circle tangent to the freeway is tangent to it for at least 300 feet, the conflict will then be no worse than that normally found at the weaving section of a clover leaf interchange, and weaving can take place safely without any stops.