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THE SOCIAL POTENTIAL OF BUILDINGS:
Spatial structure and the innovative millieu in scientific research laboratories

Introduction

The effects of buildings on people at a social level are controversial. On the one hand there is a lot of circumstantial evidence that the built environment matters a great deal: some buildings have 'good' working atmospheres others seem worse; some housing estates are held to be social disasters, others seem to function perfectly well from a social point of view. There are many who believe that building design is at the root of these functional issues. On the other hand researchers have had a great deal of trouble proposing how in principle the built environment *could* affect people, let alone demonstrating clear evidence that it does so. There is not a lack of theory, it is just that the main theories in the field seem flawed, and seem not to be backed up by solid empirical evidence.

A common school of thought holds that if the built environment has effects at all it must be on the psyche, since this must be the level at which an individual and the environment interact. What other levels are there? Another school holds that it is possible for the environment to be involved at a more social level: that the buildings we build may be collective expressions of society and social values. Both of these schools cast the built environment in a passive role either as a 'setting' for individual action or as an 'expression' of common social values. Its social impact is thus regarded as almost tangential.

Recently however, there have been advances in both theory and research that cast the built environment in a far more active relationship to society, and suggest that building design, and specifically the patterns of space created by buildings, may play a central role in many social phenomena.

Generative buildings

An important example of the centrality of space in the social function of organisations is given in buildings which are about the generation of innovation or a rapid response to changing circumstances. In these organisations the 'generative' potential of the building plan may be a prerequisite of success. Significant support for this thesis is given by the pioneering work of Tom Allen on R&D organisations in engineering. In paired studies of defence research projects in the USA where routinely two independent teams are commissioned with the same brief and the performance of their design solutions tested, Allen studied the information and communication networks used by the successful teams in arriving at innovative solutions. The most important contacts from the point of view of innovative problem solving are not those within the project team, but those between people working on entirely different projects. To quote his own summary:

"Despite the hopes of brainstorming enthusiasts and other proponents of group approaches to problem solving , the level of interaction within the project groups shows no relation to problem solving performance. The data to this point lend overwhelming support to the contention that improved communication among groups within the laboratory will increase R&D effectiveness. Increased communication between R&D groups was in every case strongly related to project performance. Moreover it appears that interaction outside the project is most important. On complex projects, the inner team cannot sustain itself and work effectively without constantly importing new information from the outside world ... such information is best obtained from colleagues within the organisation... In addition, high performers consulted with anywhere between two and nine organisational colleagues whereas low performers contacted one or two colleagues at most." (Allen,1977, p122-3)

There is little doubt that if management could predict which contacts would be instrumental in problem solving it would take steps to organise those people into project teams, however the implication from Allen's studies is that this may be an impossible task. For any given project we just don't know in advance what information will be needed and what will prove important. The more we move towards the frontiers of knowledge the less we are able to predict who needs to talk to whom, and the more we must rely on random contacts occurring at the right time. Our own research into scientific research laboratories (Hillier, O'Sullivan & Penn, 1990; Hillier & Penn, 1991) suggests that it is at this point that building configuration is instrumental in the process.

Figure 1a shows the plans of two scientific research laboratories studied as a part of a major update of design guidance carried out for the UK Government. Lab X belongs to a well known public charity involved in medical research aimed at a well defined set of diseases. Its research strategy by all accounts is directed at a programme of well funded research with specific and defined goals. Lab Y, in which there is an 'old' building (horizontal in plan) and below it a 'new' building, houses a number of publicly funded research groups whose research goals are more entrepreneurial and self directed. Research success over the years for both labs is very high, but there is little doubt that if measured in terms of say Nobel prizes lab Y would have to be considered the 'high flier'. Figure 1b shows a useful representation of the building plans for each lab in which all the open space is coloured in black. This allows one to see the effective circulation space structure of the two buildings. Figures 1c and 1d show the break up of the space structure in the two buildings into convex bays and the linear links that join these together. It is striking that the two labs break up and differentiate their open space structure in such similar ways. The heavy lines are the internal links between bays within labs. The main difference between lab X and the old part of lab Y is that these circulation links between bench bays within laboratory rooms in Lab X are deep from the

corridor and near the windows, and in lab Y the links are shallow to the corridor, just inside the entrance door.

There are also fundamental similarities in the space use patterns in the two buildings. Observation studies have found that in both buildings reading and writing take place underneath the external windows deep in the lab from the corridor, in both general laboratory bench work is fairly evenly distributed through out the depth of the lab, and in both largescale movement - in and out of the building or from the individual laboratory to other facilities in the building - use the main corridor and stairs. Within the labs more localised patterns of movement, from bay to bay, use the internal links within each laboratory in preference to the main corridor. It is precisely the similarities in space use patterns which give rise to the most striking differences between the two buildings. If we measure the mean distances of people observed in each of the four categories of space use from the internal linking spaces (Table 1), we find that for lab X interaction and contemplative activities are shallow to the link but largescale movement is distant, while in lab Y both interaction and movement are close together. The relative distances of the different space use categories from the link spaces in these cases comprise what we call 'probabilistic inequality genotypes' describing the different functional relations we observe in the two buildings.

In effect, what we see happening is that people within both labs move and talk in the local link spaces. In lab X these are deep within the lab and so as you move through the corridor system you are virtually unaware of the presence of people and the focus of interaction within the research groups. In lab Y however the focus of interaction is just an open door away from the corridor and is reflected in a significant degree of interaction taking place on the threshold between the corridor and lab itself. As you move around the largescale circulation system you are constantly aware of the activity taking place within each laboratory, and it is not uncommon to see people walking along the corridor stop and join in a conversation.

Finding ways of describing and quantifying the properties of building plans as systems of space through which people move have been a central concern of our research efforts at UCL. In particular two measures of spatial layout based on the line and convex maps shown in Figures 1c&d have turned out to be important in our understanding of movement in buildings. We call these the measures 'global' and 'local integration'. Global integration measures the mean number of changes of direction you need to make to go from any line to any other in the system under consideration. It thus measures the average complexity of routes that pass through any segment of a line. A line is integrated if the routes through it are less complex and involve few changes of direction, it is segregated if they involve many changes of direction. It turns out that the amount of largescale movement along any line is related to how integrated it is. The second measure we call local integration is carried out in exactly the same way except that it looks at a system of space within just three changes of direction from each line in turn. It turns out that locally integrated lines form the focus of local movement and interaction in many building types.

Of course, we have no direct evidence for a link between these phenomena and the research output of the two labs since research output is notoriously difficult to quantify. However, Allen's findings linking the quality of output to communication between research groups (in a study where direct comparisons of product were possible thanks to the paired nature of American defence research procurement) suggested a possible further step. If we could find relationships between the amount of between-group communication (Allen's critical factor) and building configuration it would move us a step closer to understanding whether building design was indeed involved in productive and innovative research environments.

The main phase of research which followed therefore took a sample of 24 building floors in seven sites in different parts of the UK. The sample spanned public, private and university sectors, and covered a range of scientific disciplines. All the laboratories selected were considered 'good' within their field. The study itself addressed a wide range of spatial and environmental issues, and included detailed surveys of spatial and equipment provision (Figure 2a shows the ground floor of a large world class physics laboratory), observations of space use patterns (Figure 2b for instance shows a 'dotmap' describing the location and activity of everyone observed on 30 rounds of observations). In addition a questionnaire survey was carried out of all building users to determine the strength of communication networks. The questionnaire listed by name all, or a large sample, of the people who worked in the survey area. Respondents were asked to score on a five point scale the frequency with which they had contact with each individual name in the list. They were also asked whether or not they found that person useful in their work. Although the questionnaires were confidential they were not anonymous, since we needed to know for each respondent which contacts were within their research group and which were between groups.

The first findings were predictable: everyone knows everyone in their own research group, sees them daily and finds them useful in their work. Next we had to look at how often each name on the list was cited by every respondent in order to eliminate the possible effects of different interpretations of the question by different respondents - in this way each name on the list had an equal chance of being cited by each respondent. The findings here were strong. People who are found useful by many people outside their own research group are neither the most frequently nor least frequently seen. There was also a strong relationship between the number of inter-group contacts expressed as a percentage of possible contacts and the number of these that were felt to be useful in people's work.

The most striking findings were made, however, when we took the whole sample of building floors, and looked at the mean number of inter-group contacts in each. Here the mean degree of spatial integration of the floor predicted the strength of the networks strongly and significantly. More importantly, the rates of contacts 'useful' in people's work was strongly related to building integration for the seven whole buildings (Figure 3). More spatially integrated buildings, it seemed, increased the level of useful work related inter-group communication that Allen had found to be so important for innovation.

A still more significant factor was the measure of the ratio of global integration to local 3 step integration in the plan. This measures the degree to which local and global integration patterns are brought together or separated in a building plan. Figure 4 shows the correlation for the seven whole buildings.

The strength of these findings is such that it leaves little doubt that the spatial configuration of laboratory buildings can affect patterns of communication amongst researchers, however it does raise a question regarding the precise mechanism that could give rise to these effects. Light has recently been cast on this through the work of Paul Drew and Alan Backhouse at the University of York (Backhouse and Drew 1990). In a study of a large open plan professional design office they used careful observations and video recordings to look at the behaviour of workers engaged in work related interaction. They found that when an individual is at his workstation he is usually regarded by others as engaged in work and should not be disturbed. However, should that individual leave his workstation to move to some other area, whether or not that movement is dictated by the needs of work, he is regarded as 'free' and so available for 'recruitment' into interaction. They write:

"In plotting the movements of individuals when away from their workstations, we found a markedly high incidence of 're-routings' - cases where a person notably deviated from his route of prior intention at the behest of another, or in order to recruit another person into interaction. As an individual moved into the vicinity of a 'significant' other, he would be a) engaged or 'recruited' , b) his task orientation would be altered from the planned to the contingent, and c) his prior task would become relegated to become a task 'pending' attention. The evidence for this was found in the high incidence of individuals responding to verbal and non-verbal recruitments, and altering their intended course of action to accommodate such recruitment. Interestingly, not only does the recruited undergo a task-reorientation, but the recruiter must also change his task as he cannot have planned or expected the appearance of the recruited. In this sense a clear division is apparent between the organisation of planned immediate work and the unplanned, contingent achievement. As such the accomplishment of 'work' is often a contingent and unplanned process." (Backhouse & Drew, p16-17)

This micro-scale mechanism suggests that movement in buildings may be more intimately involved in the work process than has hitherto been recognised or allowed for. If, as Backhouse and Drew suggest, a significant proportion of work related interaction arises in this 'contingent' and unplanned manner, then providing the opportunity for movement and the recruitment which results may be the key to maximising work related communication. The model has other attractive properties. To the degree that movement takes people from one part of the organisation past workstations of people from other parts of the organisation, the opportunity for recruitment will serve to create contacts between organisational segments. If as Allen has suggested, these are the important contacts from the point of view of innovative problem solving, we can begin to imagine the way that this might work.

We can also imagine what will happen if we set out to design our buildings and organisations with efficiency in mind. Let us assume that the state of knowledge in the task area covered by an organisation is broadly understood by management and that pains have been taken to structure the organisation in a relatively rational way. It follows that groups within the organisation will reflect the current understanding and existing state of knowledge of the task area. People who this understanding gives us to believe need to interact often will be located within a group, those between whom there seems to be no rational need for communication may be separated. Steps may even be taken in the interests of organisational 'efficiency' to minimise the intrusion of unrelated groups on each other and to minimise the need for movement on the part of staff by making sure that all facilities required for work are conveniently located near to each group. These would seem to be reasonable steps to take in order to produce a rational and efficient building plan.

What would be the effect of such a plan on the progress of the state of knowledge in the organisation? We believe that the effects would be chronic rather than acute. By and large the existing state of knowledge in a field is a pretty good starting point for problem solving, but slowly it would become apparent that other organisations were making the innovative breakthroughs. These breakthroughs are so rare in any case that their lack may never be noticed. The solutions to problems in the 'efficient' organisation would largely be produced as a result of the people put together for that purpose by the organisation on the basis of current knowledge, and because the opportunity to interact with people outside that definition of knowledge would be reduced in the interests of efficiency the boundaries of knowledge would seldom be challenged or broken.

In this sense we believe that organisational efficiency and true innovation run counter to each other. Innovation requires probabilistic interaction and the opportunity to recruit provided by bringing the largescale movement structure close to the workstation. Moreover it requires that the largescale movement structure takes people with knowledge in one field past people with problems to solve in another. In this way it seems possible that spatial configuration of buildings and the disposition of the organisations that inhabit them are actively involved in the evolution of the boundaries of scientific knowledge itself.

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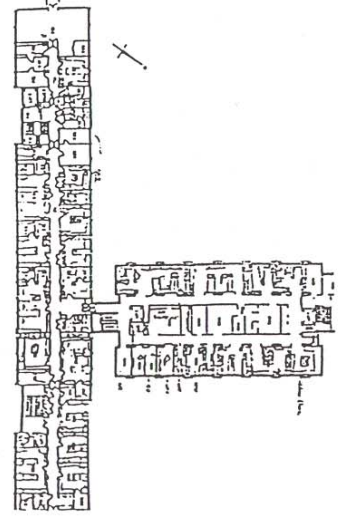Visible colleges: structure and randomness in the place of discovery, (Hillier & Penn) Science in Context, 4,1(1991)pp23-49.
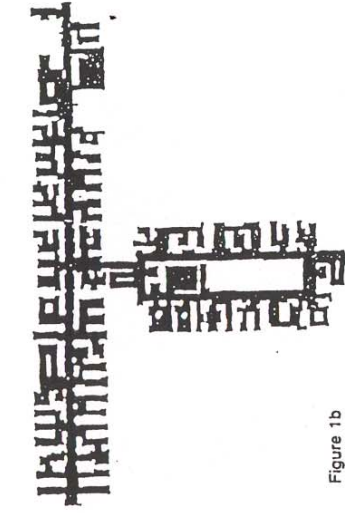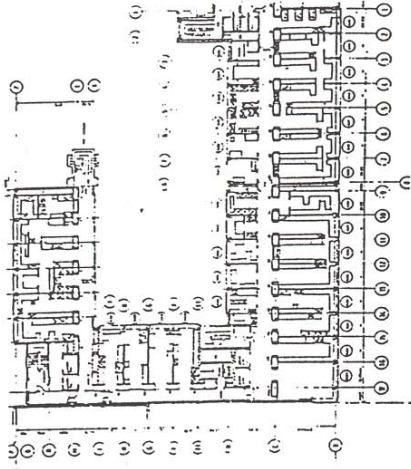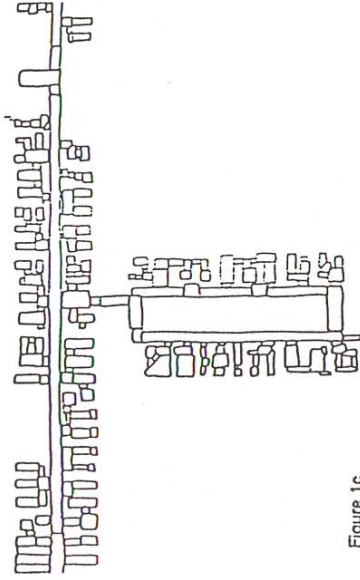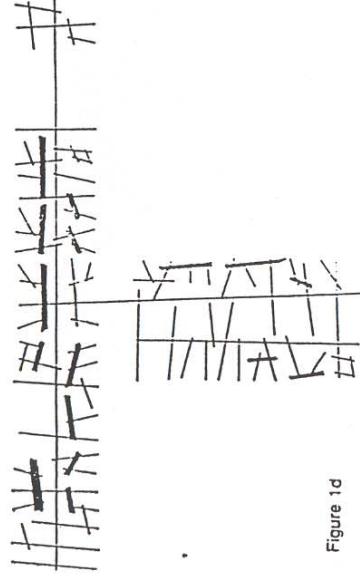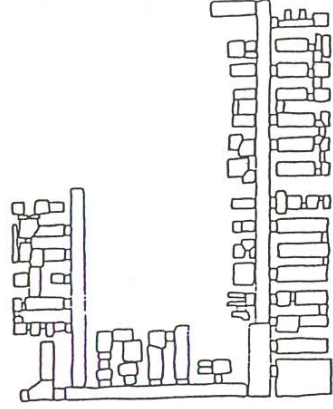
Figure 1a

Figure 1b

Figure 1c
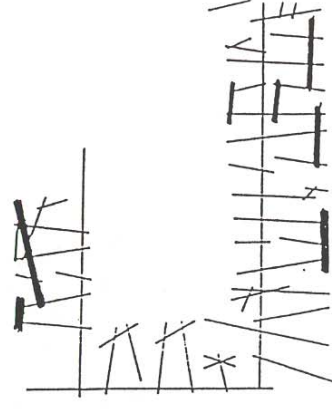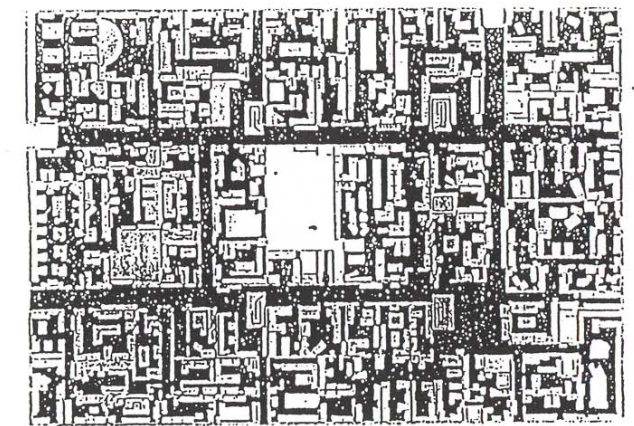
Lab X

Figure 1d
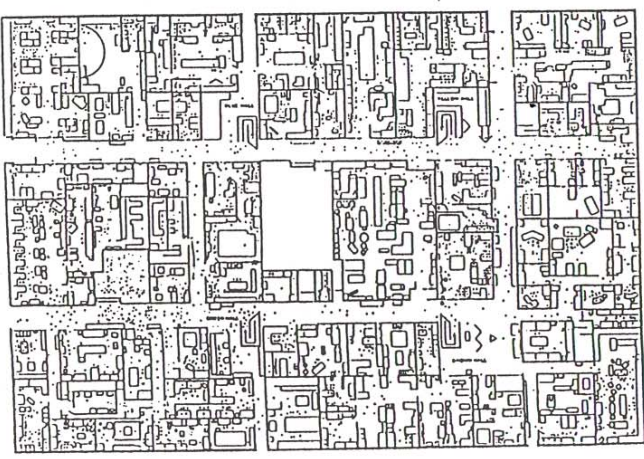
Lab Y

Figure 2b

Figure 2a

Table 1.

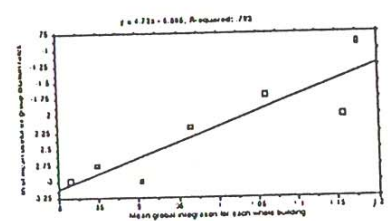|	Movement	Interactive	Practical	Contemplative
Lab X	4.9	.93	2.85	1.09
Lab Y	1.3	1.17	1.41	2.03

Figure 3. *The correlation of the mean integration value for each whole building with the mean useful contact rates for all the buildings in the sample.* r=.891. p<.0005
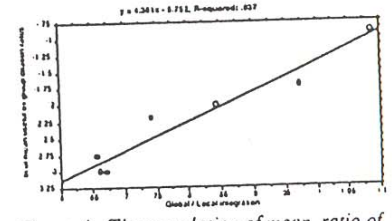

Figure 4. *The correlation of mean ratio of global to local integration with mean useful contact rates for each building in the smaple.* r=.968, p<.0001