The Spatial Culture of Factories

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The Spatial Culture of Factories

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This paper argues that factory layouts have social functions over and above the purely technical ones and that such functions can be described with accuracy. It relates the fundamental design choices that are identified by the analysis to the spatial requirements of organizations. Thus, it suggests that the design of factory space has strategic effects on the culture of workplaces. Spatial variables are based on the theory of space syntax developed at the Unit for Architectural Studies, University College London. Measures of interaction are based on network theory. The analysis rests on evidence from six case studies of factories located in England and in Greece.

Introduction

Authors on industrial organizations have sometimes recorded social functions of factory layouts over and above the purely technical ones. But the architect who is interested in such functions cannot always claim to understand factory space as a well-defined problem of socially aimed design. More precisely, there are no quantitative techniques that could be applied to the planning, organization, evaluation, and comparison of the social effects of different layouts, to match those which are available for dealing with more technical considerations, and which are documented in the engineering (Apple, 1951; Mallick and Gaudreau, 1951; Ireson, 1952; Reed, 1961; Muther, 1961; Moore, 1962) and the architectural literature (Mills, 1959; Munce, 1960; Manning, 1966; Mills, 1967; Drury and Sugden, 1974; Groak, 1974; Drury, 1980).

The aims of this paper are largely exploratory. It proposes to use the theory and method of space syntax (Hillier and Hanson, 1984) in order to describe and measure some basic spatial variables, and to relate them to variables of social interaction drawn from network theory (Mitchell, 1963; Boissevain and Mitchell, 1973). Taken together, these variables seem to describe the spatial logic of organizations. The intention is to arrive not only at an understanding in principle of the social properties of layouts but also at a statement of the fundamental strategic differences between one design and another. The appreciation of such differences is crucial at the early design stages when influential decisions are sometimes made without explicit justification, and at later stages when the suitability of buildings for the organizations that they house is reconsidered.

The exercise is not only of interest to architects but also to management and organization theorists. Because the social properties of layouts seem to correspond to underlying spatial requirements of organizations and to characterize in subtle but pervasive ways the culture of workplaces.

1 This paper is based on a PhD thesis submitted to the University of London (Peponis, 1983) and contains a more detailed report of the research, including the analysis of additional minor case studies and the discussion of other theoretical questions, in that thesis.

2 It is impossible to acknowledge here all the people who have assisted in the course of the research. The author would like, however, to mention the pervasive theoretical influence of Bill Hillier, the patient help of Mavra Kanaris, Kostas Livieratos, and Dr. Dimitris Kyrktetas, and the contribution of Evita Pericakas who helped to formulate and sometimes prove some of the mathematical formulae presented in the Appendix. Thanks to A. Kourkoulas, E. Constantopoulos and R. Burdett for comments to this paper.

3 At the time when the paper was originally published the correspondence address was: John Peponis, Unit for Architectural Studies, Bartlett School of Architecture and Planning, 22 Gordon Street, London WC1H OQB, UK. The current correspondence address for the author is: John Peponis, School of Architecture, Georgia Institute of Technology, 247 Fourth Street NW, Atlanta, GA 30332, USA.
Spatial effects of category, control, and generation in factories

This paper does not attempt to review industrial organization theory with respect to space, let alone deal with the many approaches to the social functions of space in general. In this section, the intention is to draw out the major relationships of layout to organization as recorded in certain key studies. References will be made to the architectural literature only when this will clarify the problems under consideration.

Industrial buildings play some role in constituting spatially the major organizational divisions. Early management theorists proposed that people who belong to the same organizational section or are under the same supervisor should share the same space (Gulick, 1937, p. 7). Later, the spatial coherence of organizational groups was set against the background of coherence with respect to technology and time schedules (Miller, 1959). The very distinction between product and process layouts is of course about the way in which technology and space come together to define organizational units (Ireson, 1952). But while the role of space in defining organizational boundaries is widely acknowledged, the relationship between space and the differentiation of organizational statuses is less well understood. Architectural research on offices has, for example, suggested that status is related more to symbols, such as the extent and quality of furnishing, than to overall configurational properties (Duffy, 1974, p. 234). This echoes a wider belief in organization theory (Burns and Stalker, 1961, p. 149-150; Etzioni, 1961, p. 36). The present paper will nevertheless suggest that space acts in a very pervasive and consistent way to discriminate between statuses in terms of their location in the overall building configuration.

Industrial buildings also seem to act as theaters for strategies of control. In certain rapidly developing firms, management isolated the research and development group in either a separate building or behind major partitions in order to resolve the conflict between laboratory and shop floor work styles and retain control over the flow of communication (Burns and Stalker, 1961, p. 142). In a mining firm, a bureaucratic style of management was instituted which reduced the number of face-to-face encounters between management and workers and imposed a greater separation between the offices and the workforce (Gouldner, 1954). Until recently, the architectural implications of these rather broad sorts of correlation between management style and space were not drawn out. Design guidance concentrated on particular details, such as the distribution of amenities and its impact on workers interaction which, it was suggested, was to be kept to a minimum (Mallick and Gaudreau, 1951, p. 319; Manning, 1966, p. 1100). The search for more relaxed forms of control in the 1970’s has, however, led to the introduction of broader principles in layout design. Volvo’s car factories, for example, have been designed in the belief that the program of workers’ participation would work better in buildings which offer identifiable territories for each workgroup (Gyllenhammar, 1977). But the relation of space to styles of control remains a puzzle to the extent that most references are normative rather than based on empirical study and analysis. This paper will argue that different models of control are embedded not only in the overall configuration but also in the fine tuning of building layout.

The third major social function of space seems to be related to the generation of social relationships over and above those which are implied, required, programmed or otherwise derived in a direct way from formal organization and factory rules. Early studies of social relationships between workers have argued that relations of neighborhoods influence the formation of cliques (Roethlisberger and Dickson, 1939, p. 513), sometimes subject to the layout of the plant (Walker and Guest, 1952, pp. 71-73, 156). Spa-
tially-based informal interaction was found to be of crucial importance to styles of management which allow workers a degree of “responsible autonomy” (Trist et al., 1963). But as with control, there is very little precise understanding of the physical parameters involved with the generation of social interaction. One study, for example, has demonstrated that for a small sample of work organizations, there is no relationship between the amount of interaction and distance (Farbstein, 1975, p. 334-336). Similarly, contrary to generally held opinion, another study has found no significant relationship between the amount of interaction and the degree of subdivision of offices (Duffy, 1974, p. 217). It is therefore of some interest that the present study has identified significant correlations between physical variables, describing the relational properties of space, and interaction variables.

The subsequent sections will attempt to unravel the functions of category differentiation, styles of control, and generation of interaction, so as to make at least some of their spatial correlates explicit and quantifiable.

**Spatial variables**

Building plans are analyzed as systems of relationships of boundaries and permeabilities following the method of space syntax (Hillier and Hanson, 1984). The plan is first considered as a set of constituent spaces. In order to allow comparisons, the same repeatable and unambiguous procedure is adopted. First, the plan is subdivided into the largest and fewest convex spaces that are needed to cover the whole premises. The resulting set of spaces may or may not correspond to the way in which the building is conceptualized by its occupants or the observer. Then, the convex spaces are represented by points and the connections of permeability between them by lines. The resulting graph is called a convex map, and constitutes the basis for spatial analysis. Figures 1 and 2 show the plan and corresponding convex map of one of the factories.

**Fragmentation Index**. This is the smallest proportion of spaces which are needed to cover half the total area of the premises. The measure indicates how fragmented the overall plan is, either by means of partitions or by deformations of shape.

*Figure 1* 
Diagrammatic plan, ground floor, S.S.: (1) Foreman’s office, (2) superintendent’s office, (3) closing room, (4) pre-assembly, (5) cutting, (6) making, (7) leather store, (8) development office, (9) manager’s office (during visits), (10) training room, (11) canteen, and (12) quality control.

[Figure slightly revised to contain more details.]
Depth and Real Relative Asymmetry (RRA). The key syntactic property measured on the basis of the convex map is that of depth. The depth of one space A from another space B is the minimum number of spaces that must be crossed to reach A from B or B from A. Thus, depth is about the proper ties of separation or integration in a pattern. Two measures of depth are used for most of the analysis. The real relative asymmetry (RRA) of a space represents the average integration of that space into the pattern to which it belongs considered as a whole. The RRA of a pattern as a whole represents the extent to which the pattern in question tends to separate or to integrate its parts. RRA values are adjusted between theoretical and empirical limits so as to allow direct comparisons across patterns irrespective of their size (see Appendix). Lower RRA values index integration, higher values index segregation.

Connectivity and Control Value (CV). The second major syntactic property concerns the relationship of spaces, not to the pattern as a whole, but to their immediate neighbors. But connectivity, or the number of connections to neighbors, is replaced by a measure which captures in a subtler way the relative strength of connection of a space into a pattern. The control value (CV) of a space increases in proportion not only to the number of connections but also in proportion to the extent that each of the neighbor spaces is itself poorly connected. Spaces with stronger CV exert more control over access to their neighbors (see Appendix).

Ringyness. A third syntactic property which is considered is whether there are different ways for moving from one space to another. This is a function of the number of loops or rings in the system. The relative number of rings (RR) is a measure which expresses the number of circulation loops as a proportion of the maximum number of loops possible (see Appendix).

The set of syntactic properties introduced above differs from the properties normally used to describe buildings, in at least two important respects. (1) It focuses not on the qualities of individual spaces that can be perceived directly, from one position, but on the relational properties of the whole pattern which can be comprehended abstractly. (2) It focuses not on metric or geometric properties but on more abstract properties of a topological nature. It is suggested that these less than obvious properties must be considered if the underlying social logic of space is to be understood. But also, from a more technical point of view, the method permits comparisons between buildings which would otherwise be as unmanageable, because of their irregular shapes and seemingly chaotic interiors, as factories often are.

Figure 2
Convex map of F5 superimposed on layout plan. Dotted lines indicate the subdivision of the plan into convex spaces. [Figure slightly revised.]
Interaction variables

The pattern of social interaction raises questions concerning its information content and its social regulation. For the purposes of this study, however, it will be considered as a purely physical morphology. Any system of regulation and any exchange of information must work themselves out in terms of the distribution of people in space and time, their movement in the premises and the modulation of their co-presence.

Interaction will be described in terms of measures borrowed from the theory of networks as applied in social studies (Mitchell, 1963; Boissevain and Mitchell, 1973).

Frequency. Frequency will discriminate between encounters according to whether they occur at least once an hour, a day, a week, or less frequently.

Density. Density will express the relationships of encounter established between a set of individuals as a proportion of the total number of relationships that could theoretically be established (Barnes, 1963; Niemeijer, 1973).

Boundaries and Definition Ratios for Interaction Groups. The notion of density permits the quantification of the strength of encounter boundaries. An encounter boundary is said to exist when the density of interaction among a group of people, however selected, is significantly greater than interaction between members of the group and individuals outside it. The significance is measured using chi-square tests according to a suggestion by Niemeijer (Niemeijer, 1973, p. 59). It is also proposed here that the greater the difference between internal and external group density the more the group may be said to be well defined. The ratio between internal and external density for various selected groups will accordingly be called a definition ratio.

Qualitative and quantitative data

Though the intention of this study is to build precise models of the social functions of factory space, and of the spatial requirements of organizations, the limits of quantification are, at this early exploratory stage, open to negotiation against the evidence. In trying to study space as being an important social structure in its own right, this study had to deal, first and foremost, with the problem of description. Nevertheless, it was decided to complement numerical data by building a general background against which they could be interpreted even if this background was not to be established with equal rigor, as compared to numerical data. The emerging duality between quantitative and more qualitative data is to be accepted as a necessary concomitant of an exploratory study and as a basis for further development of the theory of quantitative description.

A sample of case studies

This paper reports the analysis of a small sample of six case studies. These were selected with two considerations in mind. Since the aim is to identify general principles, the sample should be as varied as possible. On the other hand, the evaluation of the precise influence of spatial variables on factory cultures seemed to require more controlled comparisons. To these two methodological considerations, a practical limitation was also added. Few companies were prepared to allow access to detailed plans and to permit questionnaire distribution and interviews. In the end, the six major case studies reported here were deemed to satisfy the requirements of the study.

The technological systems span across the types of batch, mass, and process production (Woodward, 1965; Harvey, 1968; Hickson, Pugh and Pheysey, 1969; Blau et al., 1976). Production involved different degrees of variety of tasks and the organization provided different degrees of routine procedures for dealing with such tasks (Perrow, 1970; Hage and Aiken, 1969). The size of factories, both in terms of the number of employees and in terms of the area of the premises
also varied. Given this range of types and sizes, any invariant relationships that may be identified can perhaps be treated as indicative of more pervasive trends, despite the small size of the sample.

The requirements of more controlled comparisons were also satisfied in that at least some pairs of cases were similar in crucial respects. One pair in particular allowed the variables of technology, products, size, organization, and location to be held as constant as possible while both the culture of the factories and their spatial organization seemed to vary in interesting ways. The detailed comparisons will be presented in subsequent sections of this paper.

### Three tasks of field work
The researcher spent a working week in each of the premises and completed the following tasks. 1. Any building plans which were available were completed and modified according to observations. In all but one case, that of a vast cement plant, the drawings thus obtained represented adequately and fully the buildings at the time of the visit. For the cement plant, full details extended to only parts of the premises. The overall layout of the site and the installations was, however, completed. 2. A questionnaire was distributed to a random sample of employees. The questionnaire listed the names of the members of the sample and asked each individual to state whether he met other members of the sample “hourly,” “daily,” “weekly,” or “less frequently.” Any meeting in the premises during the working day was to be included. In every case but one (that of the car plant), replies to the questionnaire represented 10% or more of the number of people employed in the premises. No other question was asked in the questionnaire, which was only used as a source for interaction data. 3. Field notes were taken according to observations and interviews with small samples of employees, foremen, and managers. These constituted a background of “qualitative data” against which other data could be interpreted.

### The basic profile of six factories

#### F1
**Location.** Greece.
**Area.** 26,145 m².
**Number of Employees.** 725.
**Type of Production and Product:** F1 is a batch production, mechanical engineering factory. Typical products include industrial installations, road and rail bridges, silos, and excavators. F1 also includes a workshop for the serial production of conveyor rollers.

**Buildings.** The main production processes are located in a large building which has practically no internal subdivisions. A typical sequence of operations moves across an area for cutting metal in profile or sections, a pre-assembly area, a welding area, and a machine shop, all arranged in that order along the length of the building. Boundaries between these areas are unclear. Production, and especially pre-assembly, extends outside the building into the courtyard. Large sections of the courtyard are used for storing materials and products.

The pylon and galvanizing shops open directly onto the main shop floor. The roller shop and the press shop are located in separate buildings near the edge of the site. There is a separate two-story administration block. But production management, quality control, programming, and the drawing office are dispersed in offices along one of the long walls of the main production building. Foremen offices are scattered across the premises and are sometimes shared by several people.

**Features of Interaction.** The main process of production entails dramatic reorganizations of space, as large products are pre-assembled before welding and assembled and disassem-
bled to test for fit before shipment. Foremen and superintendents engage in negotiations over the use of space. These negotiations are complicated by the interventions of production management and coordination officers who try to change the order of priority of different products. Interaction is made all the more visible because management offices are dispersed and people can be seen to walk through production areas to meet each other.

The intensive interaction was enmeshed with processes of informal dissemination of information and with an ongoing negotiation of the personal authority and reputation of members of management. Thus, interaction was a mechanism of social control over and above the control of productive operations. This extended with respect to the local union. While recognized by management, the union was suspected by some as being unrepresentative of the workforce. Union officers, formally engaged in production like everyone else, seemed to enjoy an exceptional freedom of movement extending into offices. They were apparently suspected to act like informers.

**F2**

**Location.** Greece.

**Area.** 45,650 m².

**Number of Employees.** 726.

**Type of Production and Products.** F2 is a mass production factory producing domestic washing machines, cookers, and refrigerators.

**Buildings.** F2 is a single building grown in three stages. The shop floor has few partitions but is broken up by virtue of its shape as well as by large pieces of equipment and fences. In principle, plant layout is by process, but there is some ambiguity because the continuity of lines by product is preserved as far as possible. There is one metal cutting and press shop, one surface coating and one paint shop, and three assembly shops corresponding to the main products. Besides these shops, there are auxiliary areas including a machine shop, an insulation injection shop, an electrical circuits assembly shop, and various other pre-assembly areas. All these shops are mostly separated out without built partitions and major boundaries. Foremen offices are dispersed so as to be near the corresponding production areas, and are raised so as to allow unobstructed visual inspection. All other office accommodation is in a double-story structure along part of the front of the building.

**Features of Interaction.** The administration of production, unlike F1, involved frequent formally scheduled meetings for all levels of management. But supervisory practices were underlain by a dilemma. Older superintendents preferred to walk around the shop floor and gain a direct view of problems. Younger superintendents attempted to rationalize the control over production by insisting that there should be written reports and by avoiding casual contact. However, the cooperation of the managerial team, down to superintendent level was assisted by the opportunities for frequent encounter which resulted from the grouping of offices.

On the shop floor, workers had developed a form of informal spatial organization. Individuals working in neighboring positions formed cliques of friendship. These cliques established themselves territorially. Territorial boundaries assumed irregular shapes. The point of reference for each territory was usually some tool crib appropriated for storing coffee and other shared facilities. The edges of territories consisted of the working positions of the more distant members and were impossible to guess without prior knowledge of territorial group membership.
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Features of Interaction. As a consequence of automation, people had no fixed positions. Most workers engaged in mechanical, electrological, and building repairs and were instructed to move toward the various sections as necessary. Only a small number of individuals were assigned to patrol or inspect particular sections. Another small group was permanently employed in the packing plant. With the exception of this last group, it was practically impossible to encounter anybody in the production area by chance. But though people were hard to encounter, it was occasionally possible to find large groups engaged in conversation. There appeared to be no fixed habits with respect to the frequency of location of such meetings. The presence of people was more often indicated by the discovery of small cupboards or benches with personal belongings and by graffiti. Generally, the observer was able to locate the traces of people but not people themselves, as if engaged in a loser’s hide-and-seek game.

Spatial dispersion and mobility made conventional forms of supervision impracticable. Thus, management relied on a rigorous set of rules which specified the individual responsibilities of employees. Within those specifications, there was a necessary delegation of control.

F3
Location. Greece.
Area. Not known. Length of major straight line across the production site: 670 m.
Number of Employees. 400.
Type of Production and Product. Fully automated, computer-controlled cement factory.
Buildings. The factory site includes the main production installations, a laboratory and control block, a commercial deliveries block, and an administration block which is linked to a mechanical workshop and components store. Foremen offices were in the main administration block but control rooms for various processes were dispersed in key points around the site. The installations themselves are a maze of machinery, access platforms, cat-walks, stairs, and conveyors. This is the main reason why no complete set of plans could be completed and no estimation of the area of the installations could be arrived at.

Production begins with the crushing and prehomogenizing of limestone and of clay which are the principal raw materials. The materials are then fed into feed bins located at one end of an essentially linearly arranged main production process. From the bins, the materials are fed into a raw grinding mill, they are blended and then stored. In the next stage, materials are fed into a pair of rotating kilns from which they emerge as clinker. Clinker is stored in a pair of silos from which it is fed into grinding mills. The final product, cement, is then stored in two more silos to be eventually delivered either directly into bulk carrier vehicles or to the packing plant.

Spatial analysis covered the overall site plan, the interiors of all buildings, and the section of plant between the prehomogenized materials bins and the kilns. This section of the installations, amounting to about half of the total length of plant, excluding the kilns, was mapped in detail by the researcher.

F4
Location. Britain, same town as F5 (belongs to the same company as F5 and is managed by the same manager).
Area. 3687 m2.
Number of Employees. 264.
Type of Production and Product. Serial production of children’s shoes.
Buildings. F4 is an open plan rectangular portal frame “box.” A double-story front section accommodates the offices on the ground floor and the canteen and other amenities on the first floor. The office of the manager of F4 and F5 is in that section of F4. The production superintendent’s as well as the foremen’s offices open directly on the totally undivided shop floor. Each of the main processes of production occupies a distinct area. Leather cutting occupies a stretch of the shop floor by the edge for better lighting. After cutting, pieces are stitched up in the closing area which takes up the best part of the front half of the shop floor. Then, the shoe parts for small batches of pairs are assorted in a pre-assembly area which is arranged along the middle of the shop floor. The shoes are finished in the making area where soles are stitched or injected. From the making area, which takes up the back half of the building, shoes are taken to the loading bay for shipment.

Features of Interaction. The open plan subjected people to an overwhelming co-presence and public exposure. This became evident in three key respects. (1) Foremen offices are treated not only as places for handling paperwork but also as places where foremen can adjust, modulate, and differentiate their stance toward individual workers. The lack of an “office” for the cutting foreman was thus resented as a deprivation of privacy and of the means which are necessary for carrying out his job. (2) Quality control entailed a thorough check of samples of finished products. Often foremen and group leaders disputed the cause and origins of problems. But the open plan seemed conducive to some friction because people were unwilling to lose face publicly and because each supervisor was able to observe and comment upon events in the area of other supervisors. (3) The open plan and glazed office partitions allowed the shop stewards to be aware of the whereabouts of management thus limiting the latter’s degree of discretion. Shop stewards in F4 would inform their counterparts in F5 about the arrival of F5’s superintendent or the departure of the manager from F4, as a sign that problems were being discussed and decisions were forthcoming.

F5
Location. Britain, same town as F4.
Area. 2943 m2.
Number of Employees. 252.
Type of Production and Products. Serial production of children’s shoes.
Buildings. F5 is a subdivided factory grown by the addition of shops around an original engineering plant. Each of the processes of cutting, closing, pre-assembly, and making occupies a room of its own. The main offices, including clerical accommodation for both F5 and F4 are in a separate block connected to the shop floor through a chicane corridor. Foremen’s offices are by their corresponding areas. The superintendent’s office also opens on the shop floor.

Features of Interaction. Subdivision did more than give to each group a separate room. First, it allowed the superintendent to differentiate his behavior sheltered from excessive public view, as he himself acknowledged. Thus, he developed more personalized relationships. Second, it allowed foremen to modulate their presence in their area so as to retain control while not appearing to be “on people’s backs.” Finally, the arrangement of circulation made the presence of foremen in each other’s area appear casual and not give rise to resentment, because every room was on the way to another room beyond it.
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The Contrast Between F4 and F5

In terms of management style, the contrast between F4 and F5 is obvious. In F4, management is formal, public, and strict, relying on the enforcement of rules. In F5, personalization and the modulation of behavior are the very means of managerial control, which relies on the ability to handle informality and to judge character.

At the time of the visit, F5 seemed more successful in meeting production schedules. Furthermore, employees and supervisors alike agreed that F5 was a more pleasant place to work in. The differences were sometimes attributed to the qualities of personalities. However, upon questioning, it became obvious that due to company policy, personnel was normally exchanged between factories. This periodic come and go cast some doubt on the explanation of social climate in terms of personality qualities and made the search for a spatial dimension to the differences in factory culture more interesting.

F6

Location. Britain.

Area. 50,357 m² (includes the two shops studied only).

Number of Employees in the Sections Studied. 375

(At the time of the study there were extensive lay-offs).

Type of Production and Product. Mass production of cars.

Buildings. For the purposes of this study, F6 comprises the trim and final assembly shops of a large car plant. Final assembly is housed in a long and narrow strip on the ground floor. The line moves from the front toward the back of the building as the engine is fixed onto the chassis, the body is dropped, and the other assembly operations are completed. Cars are then driven back through various test areas and through the final spraying booths before emerging in the final inspection area. Senior foremen’s offices and foremen’s common rooms are mostly concentrated along a raised corridor and are not visible from the shop floor. Every foreman has, additionally, a work desk by his area.

The trim shop covers the greater part of the first floor of the building. It has a less regular shape and the line bends around several times. On either side of the main assembly line there are sub-assembly and pre-assembly areas. As with the trim shop, most foremen’s accommodation is separated off onto a mezzanine level platform which also houses a section preparing car seats for F6 and other plants of the company. Management offices are located along the front of the first floor, with separate access from the outside. There are changing rooms connected to each of the many staircases that run through the building, at half level between the ground and the first floors. In general, the spatial and technical organization of F6 is not different from that which is usually described for similar factories in the literature (Walker and Guest, 1952; Beynon, 1975).

Features of interaction. Social life in the plant seemed characterized by at least three features. First, the changing rooms seemed occupied at most times of the day by workers who took informal breaks to rest, socialize, or play cards. Second, workers seemed to organize themselves in informal cliques comprising those in neighboring positions along the line. This form of organization allowed them to work “up the line”. In this respect, F6 is no different from other plants (Walker and Guest, 1952, p. 147). Third, during break times, a large number of workers seemed to prefer solitary rest to social encounter. They could be found sitting along the line, or even in cars, against a company prohibition. The workplace during working hours, the solitary rest during official
were described in two ways, by their average depth from the outside and by their average RRA which indexes their integration into their perspective complexes taken as wholes. Two stable relationships emerged (see Table I).

1. Management offices are deeper into the building than foremen’s offices which are in turn deeper than the shop floor-depth being measured from the nearest entrance. This is not an obvious relationship since management offices appear easily accessible located as they often are along the front of the building.

2. The degree of segregation of the same sets of spaces from the rest of the complexes is in the same order. Thus, status seems associated with spatial segregation and indirect accessibility.

<p>| Table I. The Depth, RRA, and RH(RA) of Management (M), Foremen’s (F) and Shop floor (S) Spaces |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|</p>
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<th>Factory</th>
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<th>Mean 'F' depth</th>
<th>Mean 'M' depth</th>
<th>Mean 'S' RRA</th>
<th>Mean 'F' RRA</th>
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<tr>
<td>F6</td>
<td>3.97</td>
<td>5.69</td>
<td>5.54</td>
<td>1.105</td>
<td>1.289</td>
<td>1.368</td>
<td>0.990</td>
</tr>
</tbody>
</table>

* RRA measures the integration of a space or a set of spaces into the complexes to which they belong. Low RRA values indicate greater integration. RH(RA) measures the degree of difference between the three RRA values of the "S," "F," and "M" sets of spaces for each factory. Lower RH(RA) values indicate greater differentiation of the three sets with respect to their RRA. The depth of a set of spaces indicates how easily they are accessible from the nearest available entrance. Lower values indicate more direct accessibility. The table suggests that there is a tendency for: RRA(S) ≤ RRA(F) ≤ RRA(M) and D(S) ≤ D(F) ≤ D(M).
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F6 is an exception to the first relationship insofar as foremen’s offices are deeper than management’s. F3 is an exception to both relationships. Thus, the more abstract relationship, revealed by RRA values, is more pervasive. Social category seems realized spatially at least as powerfully as it may be realized by means of status symbols.

The order of inequality between the M, F, and S RRA values seems to transcend differences not only to technology and size but also of layout. Thus, the inequality is genotypical to the small sample of factories. The strength of the inequality was, however, variable and could be measured by means of “Relative Entropy of RRA,” RH(RA), which expresses the difference between values as a proportion of their sum (see Appendix). When the strength of the inequality was thus measured, it was found that the degree of status differentiation was independent of the overall degree of segregation or integration as well as from the other properties of layouts. Thus, factories could be compared with respect to the realization of the genotypical relation of status, taken as a variable in its own right (Table I).

The Spatial Dimensions of Control
While the previous section established an abstract relationship between statuses, this section discusses the particular way in which statuses are accommodated in the fine fabric of the building. One obvious difference between management and foremen’s offices concerns their spatial cohesion. Management offices can be at least some steps remote from the shop floor and are generally connected by independent links both to one another and to the outside. Foremen’s offices, on the other hand, are dispersed on the shop floor and have no independent connections. There can be exceptions to the rule. F1 disperses management offices without providing them with links that do not traverse production areas; F6 clusters some of the accommodation for foremen away from production areas. But the general rule seems to be that foremen cannot control their relation as a group without controlling the shop floor, which is organizationally their main function. The detailed implications of this intimate relation of the foremen’s office to the shop floor are less obvious.

To identify what seemed to be interesting differences, the location of foremen’s offices was described in terms of the properties of the shop floor spaces to which the offices were directly connected. Three questions were asked. (1) What proportion of such spaces are so integrated as to belong to the lower quartile of RRA values of the complex? (2) What proportion of such spaces are so large as to belong to the set of largest spaces which add up to 50% of total area? (3) What is

<table>
<thead>
<tr>
<th>Factory</th>
<th>Proportion of offices linked to lower RRA quartile</th>
<th>Proportion of offices linked to largest spaces adding up to 50% of total area</th>
<th>CV_{(Sh)}</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>0.818</td>
<td>0.545</td>
<td>1.455</td>
</tr>
<tr>
<td>F2</td>
<td>0.813</td>
<td>0.438</td>
<td>1.910</td>
</tr>
<tr>
<td>F3</td>
<td>1.000</td>
<td>0.000</td>
<td>0.389</td>
</tr>
<tr>
<td>F4</td>
<td>1.000</td>
<td>1.000</td>
<td>1.336</td>
</tr>
<tr>
<td>F5</td>
<td>1.000</td>
<td>0.500</td>
<td>0.772</td>
</tr>
<tr>
<td>F6</td>
<td>0.452</td>
<td>0.032</td>
<td>0.858</td>
</tr>
</tbody>
</table>

CV_{(Sh)} is calculated by taking into account only the connections of the shop floor space which controls access to the foremen’s office to other shop floor spaces. Thus, the value is not distorted by virtue of control over the foremen’s office itself, or by control over other single rooms. CV values above 1.000 indicate spaces connected more strongly than the average. The lower RRA quartile comprises the 25% of the total number of spaces in the factory which have the lowest RRA values.
the strength of connection of these spaces to other shop floor spaces, as measured by CV? (Table II).

The analysis demonstrated that in all cases but F6, foremen’s offices are adjacent to well-integrated spaces. But the sample was otherwise split in two respects. In some factories, foremen’s offices were connected to rather small spaces while in others they were connected to large ones. Furthermore, in some cases, foremen’s offices were linked to spaces which were well and strategically connected into the shop floor network while in other cases they were linked to rather more secluded spaces.

On the basis of these splits, it became possible to identify two modes of control. In the direct control mode, foremen’s offices are located by integrated, large, and strategically connected spaces. In the indirect control mode, foremen’s offices are connected to more segregated, small, and secluded spaces. While in the first mode, control can be continuously exerted from the office, in the second mode, control can be modulated and requires the decision of foremen to circulate. In the first mode, foremen are always publicly seen while on duty; in the second mode, some privacy is provided.

The Structure of the Pattern of Encounter

The first analysis of questionnaire replies revealed at least two significant and unexpected facts concerning factory interaction. (1) Factories engender a pattern of interaction which, by its very density, seems to transcend organizational divisions and local groups of neighbors. The total encounter density for the factory population is about 0.50 or more in all cases but F6. (2) The temporal accumulation of density exhibits three regular relationships. The hourly increment, \(D(H)\) is the smallest in all cases but one. The daily increment \(D(D)\) is the largest in every case. The daily and hourly increments taken together account for just under half the total density for each factory. Thus, the pattern of interaction seems to have some temporal structure quite independently from the effects of technology, size, organization, and building plan (Table III).

Further analysis of the questionnaire replies explored whether organizational groups are associated with statistically significant encounter boundaries. Levels of interaction within organizational groups were compared to levels of interaction across them. For the purposes of this exercise, organizational groups were defined as the main productive divisions accountable to the production manager, with the addition of an “office” group comprising all office employees.

It was found that, in each factory, organizational boundaries are realized as encounter boundaries. Furthermore, the strength of the boundaries consistently falls as one moves from the hourly to the “less frequent” time increments, but remains statistically significant in all instances. The weakening of the

<table>
<thead>
<tr>
<th>Factory</th>
<th>Population size</th>
<th>Number of replies</th>
<th>(D(H))</th>
<th>(D(D))</th>
<th>(D(W))</th>
<th>(D(LF))</th>
<th>(D(T))</th>
<th>Proportion of (D(T)) realized daily</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>725</td>
<td>67</td>
<td>0.071</td>
<td>0.155</td>
<td>0.121</td>
<td>0.146</td>
<td>0.493</td>
<td>0.458</td>
</tr>
<tr>
<td>F2</td>
<td>726</td>
<td>73</td>
<td>0.060</td>
<td>0.213</td>
<td>0.137</td>
<td>0.096</td>
<td>0.507</td>
<td>0.538</td>
</tr>
<tr>
<td>F3</td>
<td>400</td>
<td>38</td>
<td>0.050</td>
<td>0.299</td>
<td>0.171</td>
<td>0.217</td>
<td>0.738</td>
<td>0.473</td>
</tr>
<tr>
<td>F4</td>
<td>264</td>
<td>46</td>
<td>0.058</td>
<td>0.258</td>
<td>0.192</td>
<td>0.181</td>
<td>0.690</td>
<td>0.458</td>
</tr>
<tr>
<td>F5</td>
<td>252</td>
<td>45</td>
<td>0.039</td>
<td>0.185</td>
<td>0.151</td>
<td>0.159</td>
<td>0.535</td>
<td>0.417</td>
</tr>
<tr>
<td>F6</td>
<td>375</td>
<td>38</td>
<td>0.046</td>
<td>0.063</td>
<td>0.045</td>
<td>0.059</td>
<td>0.213</td>
<td>0.498</td>
</tr>
<tr>
<td>Average</td>
<td>457</td>
<td>51</td>
<td>0.054</td>
<td>0.196</td>
<td>0.136</td>
<td>0.143</td>
<td>0.529</td>
<td>0.474</td>
</tr>
</tbody>
</table>

\(D = \text{density, } (H) = \text{hourly increment, } (D) = \text{daily increment, } (W) = \text{weekly increment, } (LF) = \text{less frequent increment, and } (T) = \text{total.}\)
interaction boundary with time seems to indicate that the effects of spatial co-presence progressively take over from the effects of organizational divisions (Table IV).

The effects of status differences were explored by comparing the encounter densities of foremen and managers to the average density of each factory, and by analyzing the relationship among foremen and managers. In every case, every possible relationship among foremen and managers was actually realized. Small numbers preclude the attribution to statistical significance to this result. The total density of encounter of both foremen and managers was higher when compared to the average for each factory. Thus, higher statuses seem to have greater internal cohesion as well as higher levels of overall interaction.

The above findings suggest that the density of encounter is unevenly distributed through factory populations. The formal properties of the distribution and temporal accumulation of density seem to confirm that organizations can be characterized by the systematic morphology of encounter that they engender.

**The Spatial Arrangement of Encounter**

The preceding section acknowledges fully that the pattern of interaction, characterized as it seems by interaction boundary with time seems to indicate that the effects of spatial co-presence progressively take over from the effects of organizational divisions (Table IV).

The effects of status differences were explored by comparing the encounter densities of foremen and managers to the average density of each factory, and by analyzing the relationship among foremen and managers. In every case, every possible relationship among foremen and managers was actually realized. Small numbers preclude the attribution to statistical significance to this result. The total density of encounter of both foremen and managers was higher when compared to the average for each factory. Thus, higher statuses seem to have greater internal cohesion as well as higher levels of overall interaction.

The above findings suggest that the density of encounter is unevenly distributed through factory populations. The formal properties of the distribution and temporal accumulation of density seem to confirm that organizations can be characterized by the systematic morphology of encounter that they engender.

### Table IV

**Organizational Group Definition Ratios at Cumulative Time Intervals**

* OGNI = organizational groups internal density, and OGE = organizational groups external density.

<table>
<thead>
<tr>
<th>Factory</th>
<th>(H)</th>
<th>(H) + (D)</th>
<th>(H) + (D) + (W)</th>
<th>Total</th>
<th>Chi-square for total</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1: OGI/OGE</td>
<td>0.519/0.019 = 27.3</td>
<td>0.832/0.110 = 7.6</td>
<td>0.874/0.229 = 3.8</td>
<td>0.922/0.395 = 2.51</td>
<td>201.030</td>
</tr>
<tr>
<td>F2: OGI/OGE</td>
<td>0.138/0.032 = 4.31</td>
<td>0.375/0.210 = 1.79</td>
<td>0.470/0.370 = 1.3</td>
<td>0.542/0.465 = 1.17</td>
<td>11.030</td>
</tr>
<tr>
<td>F3: OGI/OGE</td>
<td>0.211/0.012 = 17.6</td>
<td>0.755/0.252 = 3</td>
<td>0.844/0.453 = 1.86</td>
<td>0.898/0.701 = 1.28</td>
<td>23.230</td>
</tr>
<tr>
<td>F4: OGI/OGE</td>
<td>0.133/0.008 = 16.63</td>
<td>0.535/0.142 = 3.77</td>
<td>0.744/0.31 = 2.4</td>
<td>0.905/0.486 = 1.86</td>
<td>151.600</td>
</tr>
<tr>
<td>F5: OGI/OGE</td>
<td>0.124/0.003 = 41.3</td>
<td>0.467/0.049 = 9.53</td>
<td>0.622/0.119 = 5.23</td>
<td>0.741/0.256 = 2.89</td>
<td>144.800</td>
</tr>
<tr>
<td>F6: OGI/OGE</td>
<td>0.096/0.000</td>
<td>0.223/0.000</td>
<td>0.315/0.006 = 52.5</td>
<td>0.423/0.011 = 38.45</td>
<td>179.400</td>
</tr>
<tr>
<td>All groups: OGI/OGE</td>
<td>0.175/0.019 = 9.21</td>
<td>0.467/0.152 = 3.07</td>
<td>0.614/0.289 = 2.12</td>
<td>0.680/0.423 = 1.61</td>
<td>355.98</td>
</tr>
</tbody>
</table>

### Table V

**Spatial Group Definition Ratios at Cumulative Time Intervals**

* SGII = organizational groups internal density, and SGE = organizational groups external density.

<table>
<thead>
<tr>
<th>Factory</th>
<th>(H)</th>
<th>(H) + (D)</th>
<th>Total</th>
<th>Chi-square for total</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1: SGII/SGE</td>
<td>0.241/0.018 = 13.4</td>
<td>0.569/0.138 = 4.12</td>
<td>0.560/0.390 = 1.436</td>
<td>42.96</td>
</tr>
<tr>
<td>F2: SGII/SGE</td>
<td>0.433/0.042 = 10.3</td>
<td>0.557/0.245 = 2.27</td>
<td>0.644/0.465 = 1.385</td>
<td>11.99</td>
</tr>
<tr>
<td>F3: SGII/SGE</td>
<td>No data available because people have no fixed positions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F4: SGII/SGE</td>
<td>No data available because people have no fixed positions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F5: SGII/SGE</td>
<td>0.169/0.004 = 42.3</td>
<td>0.621/0.095 = 6.54</td>
<td>0.775/0.359 = 2.16</td>
<td>116.49</td>
</tr>
<tr>
<td>F6: SGII/SGE</td>
<td>0.440/0.017 = 25.9</td>
<td>0.600/0.069 = 8.70</td>
<td>0.640/0.158 = 4.05</td>
<td>39.13</td>
</tr>
<tr>
<td>All groups: SGII/SGE</td>
<td>0.255/0.024 = 10.6</td>
<td>0.488/0.159 = 3.07</td>
<td>0.627/0.386 = 1.62</td>
<td>158.54</td>
</tr>
</tbody>
</table>

---

The Spatial Culture of Factories

Peponis, J.
hourly density is negatively associated with spatial integration. This may be explained by supposing that remote spatial groups have less opportunities for encounter with the rest of the factory population while also being more sheltered from external and unpredictable supervision. This may encourage more internal interaction. (2) Individual factories exhibit at least one significant correlation between each spatial variable and interaction variables. The correlations are much stronger that those computed for compounded data. However, the time interval at which they occur, as well as their direction suggest that there are crucial differences in the spatial culture of factories. This possibility is taken up in more detail in the next section.

The general conclusion which emerges with respect to the effect of space on interaction is, therefore: (1) membership of the same space is associated with interaction boundaries, and (2) position in an integrated space is associated with higher density of interaction.

From this conclusion, an important implication can be derived. Factory cultures may provide a dual basis for interaction and solidarity, formal organization and spatial arrangement. On the basis of this duality there may well be divergent paths toward the development of social relations, especially when organizational and spatial boundaries do not coincide. Space may create a “surplus” of opportunities for encounter and of structure. The way in which organizations may assimilate or respond to this will be discussed in the next section.

A discussion of strategic differences

This section shifts the attention to the features which are particular to each factory, as they emerge from the analysis. Thus, it attempts to identify the fundamental issues and the strategic choices that may constitute factory design as a problem field.
Table VI. Kendall Rank Correlations Between Density and Syntactic Variables (with Significance Levels)

<table>
<thead>
<tr>
<th>Variable</th>
<th>H</th>
<th>D</th>
<th>T</th>
<th>BSGH</th>
<th>BSGD</th>
<th>BSGT</th>
<th>WSGH</th>
<th>WSGD</th>
<th>WSGT</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RRA</td>
<td>-0.690</td>
<td>0.071</td>
<td>0.276</td>
<td>-0.386</td>
<td>0.296</td>
<td>0.276</td>
<td>-0.357</td>
<td>-0.071</td>
<td>0.077</td>
</tr>
<tr>
<td>SRRA</td>
<td>0.028</td>
<td>0.423</td>
<td>0.222</td>
<td>0.153</td>
<td>0.218</td>
<td>0.222</td>
<td>0.165</td>
<td>0.423</td>
<td>0.419</td>
</tr>
<tr>
<td>CV</td>
<td>-0.600</td>
<td>0.000</td>
<td>0.333</td>
<td>-0.296</td>
<td>0.276</td>
<td>0.333</td>
<td>-0.414</td>
<td>-0.138</td>
<td>0.005</td>
</tr>
<tr>
<td>DCV</td>
<td>0.045</td>
<td>0.500</td>
<td>0.174</td>
<td>0.210</td>
<td>0.222</td>
<td>0.174</td>
<td>0.126</td>
<td>0.351</td>
<td>0.500</td>
</tr>
<tr>
<td></td>
<td>0.200</td>
<td>0.414</td>
<td>0.333</td>
<td>0.447</td>
<td>0.138</td>
<td>0.333</td>
<td>-0.138</td>
<td>0.138</td>
<td>-0.447</td>
</tr>
<tr>
<td></td>
<td>0.287</td>
<td>0.126</td>
<td>0.174</td>
<td>0.114</td>
<td>0.351</td>
<td>0.174</td>
<td>0.351</td>
<td>0.351</td>
<td>0.114</td>
</tr>
<tr>
<td>F2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RRA</td>
<td>0.828</td>
<td>0.200</td>
<td>0.466</td>
<td>0.287</td>
<td>0.200</td>
<td>0.287</td>
<td>0.215</td>
<td>0.467</td>
<td>0.414</td>
</tr>
<tr>
<td>SRRA</td>
<td>0.011</td>
<td>0.287</td>
<td>0.094</td>
<td>0.002</td>
<td>0.287</td>
<td>0.094</td>
<td>0.066</td>
<td>0.279</td>
<td>0.126</td>
</tr>
<tr>
<td>CV</td>
<td>0.028</td>
<td>0.435</td>
<td>0.174</td>
<td>0.174</td>
<td>0.425</td>
<td>0.174</td>
<td>0.165</td>
<td>0.423</td>
<td>0.222</td>
</tr>
<tr>
<td>DCV</td>
<td>-0.414</td>
<td>-0.600</td>
<td>-0.333</td>
<td>-0.600</td>
<td>-0.600</td>
<td>-0.333</td>
<td>-0.788</td>
<td>0.501</td>
<td>-0.690</td>
</tr>
<tr>
<td></td>
<td>0.126</td>
<td>0.045</td>
<td>0.174</td>
<td>0.045</td>
<td>0.174</td>
<td>0.016</td>
<td>0.098</td>
<td>0.028</td>
<td></td>
</tr>
<tr>
<td>F5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RRA</td>
<td>-0.105</td>
<td>-0.400</td>
<td>-0.400</td>
<td>-0.359</td>
<td>-0.316</td>
<td>-0.316</td>
<td>0.105</td>
<td>0.105</td>
<td>0.105</td>
</tr>
<tr>
<td>SRRA</td>
<td>0.400</td>
<td>0.164</td>
<td>0.164</td>
<td>0.203</td>
<td>0.224</td>
<td>0.224</td>
<td>0.400</td>
<td>0.400</td>
<td>0.400</td>
</tr>
<tr>
<td>CV</td>
<td>0.316</td>
<td>-0.800</td>
<td>-0.800</td>
<td>-0.120</td>
<td>-0.527</td>
<td>-0.527</td>
<td>-0.316</td>
<td>-0.316</td>
<td></td>
</tr>
<tr>
<td>DCV</td>
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<td>0.025</td>
<td>0.025</td>
<td>0.391</td>
<td>0.103</td>
<td>0.103</td>
<td>0.224</td>
<td>0.224</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.105</td>
<td>0.800</td>
<td>0.800</td>
<td>0.598</td>
<td>0.105</td>
<td>0.105</td>
<td>0.105</td>
<td>0.105</td>
<td>0.316</td>
</tr>
<tr>
<td></td>
<td>0.400</td>
<td>0.025</td>
<td>0.025</td>
<td>0.083</td>
<td>0.400</td>
<td>0.400</td>
<td>0.400</td>
<td>0.400</td>
<td>0.222</td>
</tr>
<tr>
<td>F6</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RRA</td>
<td>-0.105</td>
<td>-0.400</td>
<td>-0.400</td>
<td>-0.359</td>
<td>-0.316</td>
<td>-0.316</td>
<td>0.105</td>
<td>0.105</td>
<td>0.105</td>
</tr>
<tr>
<td>SRRA</td>
<td>0.400</td>
<td>0.164</td>
<td>0.164</td>
<td>0.203</td>
<td>0.224</td>
<td>0.224</td>
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<td>CV</td>
<td>0.316</td>
<td>-0.800</td>
<td>-0.800</td>
<td>-0.120</td>
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<td>-0.527</td>
<td>-0.316</td>
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<tr>
<td>DCV</td>
<td>0.224</td>
<td>0.025</td>
<td>0.025</td>
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* Coefficients significant at least at 0.050 level are italicized.
* BSG = between spatial groups density.
* WSG = within spatial groups density.
* DCV = distributed control value. Takes into account only spaces that lead to other spaces, thus excluding offices, support spaces and other spaces with only one connection.
* Figures for F4 are in parentheses for two reasons: (1) F4 has too few discrete groups to allow the computation of significant correlations, and (2) spatial groups are not distinguishable from organizational groups.
F1
This factory is distinguished by the second strongest definition of organizational groups in the sample. On the other hand, the spatial differentiation of statuses (RRA inequality) is the weakest. Furthermore, the shop floor intervenes not only in the relations of foremen, but also in those of management offices. The highest ring ratio and the lowest fragmentation index in the sample suggest that the building emphasizes integration. Thus, in several respects, the building does not seem to support formal organizational structure and may even work against it. This seems to contradict the maintenance of strong interaction boundaries between organizational groups.

Another problem arises with respect to the interpretation of the data on encounter density. F1 has the second weakest total and daily encounter density, as compared to the rest of the sample. This is perhaps surprising, since batch production is known to entail uncertainties and complexities (Woodward, 1965, Chapter 9; Reeves and Turner, 1972) which can normally be resolved through a considerable amount of face-to-face interaction. Only at the hourly level does F1 emerge as the factory with the strongest encounter density, and, interestingly, this is the level at which there is a significant positive association between spatial integration (weak RRA values) and encounter density. Thus, some restriction seems to limit the rate of encounter and to even-out the effects of space as one moves from the hourly to the longer durations.

The origins of this restriction may be located not only in formal organizational boundaries but also in the dangers inherent in the process of interaction itself. It will be remembered that interaction entails considerable friction as it is entangled with the negotiation of personal position and with suspicions of ‘informing.’

To make sense of these paradoxes the following argument is proposed with respect to the strategic effects of design in the case of F1. If production itself gives rise to a dense and shifting pattern of interaction, formal organization can be preserved in an unenforced way if the building tacitly works to differentiate statuses and to provide opportunities for independent interaction not too exposed to general interference. Where the building fails to do so, the imposition of formality will entail friction and will have to work not only as a means for controlling production but also as a means for reversing the effects of space.

F2
In at least two fundamental respects, F2 illustrates the opposite strategic possibilities as compared to F1. In F2, the definition of organizational groups at hourly, daily, and total levels is the weakest in the sample. This is hardly surprising given the unresolved coexistence of process and product principles of layout and organization. Yet, F2 preserves an about average spatial differentiation of statuses and provides most management offices with connections independent of the shop floor. When one bears in mind that the layout emphasizes integration (low RRA, high number of rings), it can be seen that integration does not have to work against the preservation of status differences. The combination of status differentiation and integration is indeed borne out by the combination of formal and informal practices of supervision and control and also by the personalized but rule-governed system of industrial relations.

F2 also offers the opportunity to appreciate another tension entailed in the spatial culture of factories. The density of interaction at F2 is unexceptional. But there is a negative and strong association between spatial integration and density at the overall and the external hourly levels. Against the general tendency in the sample as a whole, spatial integration works against the density of interaction. This can perhaps be explained by the following argument. Informal interaction requires the back-
up of strong local groups which allow individuals to transgress formal restrictions. Groups in remote positions have, in their very isolation, a natural basis for preserving their identity. Those in central positions may, however, need to preserve their identity by imposing artificial boundaries to interaction.

This might throw a different light on the aspects of territorial behavior recorded above. All the irregularly shaped territories were in central areas of the plant. Since F2 exhibits no less than average density of interaction across the whole population, it can be suggested that, at least in this case, territoriality does not seem to fragment the network of encounter in discrete cliques but to provide a basis for the extension of the network across the shop floor. This is borne out by the fact that the definition of spatial groups is, despite of the manifest territorial behavior, the weakest in the sample. Territoriality may perhaps be understood more as a spatial strategy for establishing and regulating interaction than as an inherent and invariant human need. The spatial culture of F2, which is at first glance given in the acknowledgment of territorial behavior, is at a more fundamental level associated with the inverse relation of spatial integration to encounter. If the argument proposed above is correct, this inverse relation indicates another way of resolving the conflict between the spatial generation of unprogrammed encounter and the restrictions imposed on interaction by the organization and the system of production.

**F4 and F5**
The subtle but pervasive effects of space are perhaps to be seen more clearly in the comparison of F4 to F5, where other variables are held under as much control as it is practically possible in real case studies. It will be remembered that in F4 and F5 the same formal organization and production technology seem to be associated with different styles of management, factory cultures, and building layouts. The syntactic analysis seems to suggest that the layout corresponds to factory culture in ways which are too systematic to be coincidental.

The differences between these two factories extend beyond the contrast between an open plan (F4) and the most subdivided plan in the sample (F5). Despite subdivision, F5 has an integrated layout (low RRA). But at the same time, there is a clear spatial differentiation of spatial statuses (strong RRA inequality). Thus, subdivision does not work against integration nor does integration work against differentiation. By an equally subtle spatial adjustment, every major production space lies on at least one circulation loop. Thus, one can move across the space without necessarily appearing to intrude.

This rich organization of space is coupled to an intensive spatial culture, indicated by the association between spatial integration and encounter densities, and by the preservation of strong definition ratios for spatial groups.

Each of the characteristic properties of F5 is absent in F4. Thus, the contrast between F4 and F5 is of some strategic relevance. It suggests that space is not a neutral background to technology and organization. On the contrary, it always seems to generate something like a “surplus” of social effects, of unprogrammed relationships. These can either appear as mere disturbances to the formal regime, as in F4, or they can be incorporated into the style of management. The second option is greatly assisted by the syntactic properties of layout designs. Buildings do not generate organizational scenarios but they act as conditions of possibility for their enactment.

**F6**
F6 offers another illustration of the double pressures that seem to be exerted on encounter by space. As suggested by the analysis of F2 and F5, syntactic integration sometimes hinders interaction by exposing it to supervision and sometimes enhances it by...
offering more opportunities for encounter. At F6, the overall total density is positively associated with integration while the overall hourly density reverses the relation of the association. This may be in the logical order since the hourly level is that at which the work pressures and the effects of formal organization would be expected to be more strongly felt.

But the most interesting problem posed by F6 is perhaps related to size. It may be noticed that the observed intense social activity in backstage areas, such as changing rooms, is in contrast to the lowest recorded density in the sample. But this may be explained if one takes into account that, in a factory with a large population, people’s names will not be known beyond the limits of local groups. Questionnaire replies may not be an adequate means for measuring the density of interaction in situations where space creates a diffuse and extended community which transcends acknowledged acquaintances.

At least one more key feature of the factory may be related to size. Foremen are given not only a workbase by their areas, but also shared common rooms near the offices of senior foremen. This ensures that they can overcome dispersion and size and retain their cohesion as an organizational status. In other factories, no such reinforcement of ordinary encounter seemed necessary.

F3
The last factory to be considered poses the problem of size in a different way. F3 spreads a relatively small number of people over a vast and spatially more complex area. Yet, the overall encounter density is the highest in the sample to the point where the definition of organizational groups is weakened. But the system of encounter in F3, based as it was on informal habits and instructions transmitted through systems of telecommunication, was impossible to observe.

F3 is a peculiar factory, in comparison to the rest of the sample, in other ways. It is the only case not subject to the RRA inequality. Furthermore, it is the only factory where control and supervision operate in a context in which workers too are mobile over wide areas. In other words, F3 suggests that modern automated process production factories alter the sociospatial rules which seem to underpin other types of production.

Are there strategic dilemmas in factory design?
The discussion so far has revealed some underlying relations between the organization of space and the constitution of factory cultures. These relations are not always simple nor do they always point in the same direction. It is perhaps possible to summarize systematically the questions arising from the discussion by focusing on what appear to be the strategic dilemmas in factory design. This should help not only to conclude the findings of this research but also to frame the possible foci for further research as well.

1. The means by which statuses are constituted as spatial categories is separation. Separation is achieved by the introduction of boundaries or by distortions of the shape of the interior which do not allow direct lines of visibility and permeability to link the various parts of a building. But categoric differentiation is not produced in proportion to the mere addition of boundaries. On the contrary, the example of F5 amply illustrates how differentiation can be achieved within an otherwise integrated layout. Given some explicit decision to differentiate, the task of design is to distribute boundaries so as to achieve differentiation without compromising the presence of other qualities in the layout. Overall integration, which sometimes makes communication easier, may, for example, be preserved. The rather subtle distinction between overall segregation and the differen-
The pervasive distinction between formal and informal organizational dimensions seems related to the generative and modulating effects of space on encounter. From the preceding discussion, it appears that space is never a neutral background to interaction. Co-presence generates relationships over and above those established by the organization. Organizations are characterized by the way in which they accommodate the “surplus” of relationships. From this point of view, the fundamental distinction occurs between organizational cultures which work against the effects of space on encounter and organizational cultures which seem to integrate such effects. In the first category belong F4, where effort is directed toward overcoming the effects of co-presence, and F2, where “territoriality” works to even out the differences in the opportunities for encounter which are associated with people’s positions in the layout. In the second category belongs F5, where the organization rests on the unenforced rate of interaction sustained by the building.

The above distinction suggests that the general term “informal” may be inadequate to describe the relevant range of spatial cultures. The type of “informality” which works in parallel if not against the spatial requirements of formal organization, is to be contrasted to the “informality” which forms part of certain management styles as such. The key to the way in which the generative effects of space are assimilated may reside in the way in which the problems of category and control are resolved. Pathological cases such as F1 may perhaps be explained in terms of the incongruence between the generative dimensions of space on the one hand and the categoric and control dimensions on the other.

The critical question in the assessment of layouts seems to reside in the way in which the proper-
ties which affect the opportunities for encounter are enmeshed with the properties which affect the exercise of control and the differentiation of category. Future architectural research may be directed toward a clearer understanding of the design parameters which are entailed in this enmeshment. This may help to prevent the design of layouts which are pathological either because they are incompatible with the spatial requirements of organizations or because they pull the different genotypical dimensions in opposite directions. From the point of view of the theory of organizations, the main conclusion which emerges is that organizations have both probabilistic and structural spatial dimensions which can be described precisely and quantitatively. Given a set of fundamental dilemmas inherent in the spatial requirements of organizations, different organizational cultures are characterized by the way in which they resolve these requirements. Buildings do not in themselves determine organizational culture, but they limit the range of options for the day-to-day behavior of management and employees. Thus, buildings may be considered as data which are relevant to the theory of organizations.

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Authors bio at the time of the original publication:
John Peponis has been teaching at the MSc course in Advanced Architectural Studies, and has been involved in research at the Unit for Architectural Studies, both at the Bartlett School and University College London. Other than factories, he has researched and written on the spatial organization of museums, health centers and other complex buildings. He has also been involved in the development of a model for the experimental study of patterns of movement in urban areas, under the direction of Bill Hillier. He is currently practicing as an architect in Greece. Current research interests include the further development of the themes introduced in this report and the parallel study of the relationship between spatial design and policy in buildings and in urban areas.

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References

Hillier, B. and Hanson, J. (1984), The social logic of space, Cambridge: Cambridge University Press.


Muther, R. (1961), Systematic layout planning, Massachusetts: USA.


Reed, R. J. (1961), Plant layout, factors, principles and techniques, Homewood, Ill.: Richard Irwin.


Appendix. The definition of spatial variables

A building complex C is represented as a graph of points and connecting lines.

1. Definition. The depth between two points a, b of a complex C noted as D(ab) and is equal to the minimum number of connections that must be used to reach b from a or a from b.

The mean depth of a point a in a complex C is defined by the expression:

$$ MD(a,C) = \frac{\sum_{b \in C} D(a,b)}{(k-1)} $$

where k = number of points in C.

The relative asymmetry of a point a in a complex C is defined by the expression:

$$ RA(a,C) = \frac{2(MD(a,C) - 1)}{(k - 2)} $$

for all a, C : 0 ≤ RA(a,C) ≤ 1

The real relative asymmetry of a point a in a complex C is defined by the expression:

$$ RRA(a,C) = \frac{RA(a,C)}{RA_0(k)} $$

where k = number of points in C and:

$$ RA_0(k) = \frac{6.644k \cdot \log_{10}(k+2) - 5.17k + 2}{k^2 - 3k + 2} $$

The expression RA_0(k) gives an approximation to the empirically found average RA(a,C) for complexes of size k. Values of RRA vary about 1 so that values above 1 indicate deeper than average complexes and values below 1 indicate shallower than average complexes.

The mean depth, relative asymmetry, and real relative asymmetry of a complex C taken as a whole, is given by the averages:

$$ MD(c) = \frac{\sum_{a \in C} MD(a,C)}{k} $$

$$ RA(c) = \frac{\sum_{a \in C} RA(a,C)}{k} $$

$$ RRA(c) = \frac{\sum_{a \in C} RRA(a,C)}{k} $$

2. Given a set of RA values, their entropy can be measured using the expression:

$$ H(RA) = \sum_{a \in C} \frac{RA(a,C)}{\sum_{a \in C} RA(a,C)} \cdot \log_{10} \frac{RA(a,C)}{\sum_{a \in C} RA(a,C)} $$

For sets of three RA values (such as the three averages of M, F and S spaces), the H(RA) can be relativized to take values between 0 and 1 using the expression:

$$ RH_3(RA) = \frac{H(RA) - \log_{10}2}{\log_{10}3 - \log_{10}2} $$

where log_{10}2 and log_{10}3 represent minimum and maximum values, respectively, for hypothetical systems of three cells taken as a measuring yardstick.

3. Definition. The control value of a point a is given by the expression:

$$ CV(a) = \sum_{b(a,b) + 1} \frac{1}{Val(b)} $$

where Val(b) is the number of connections of a point b connected to a.

4. The relative number of rings of a system is given by the expression:

$$ RR = \frac{L - k + 1}{2k - 5} $$

where L = number of connections in the system, k = number of points in the system, and (2k - 5) represents the maximum number of independent planar rings in a graph of k points.
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