Configurational Affinities Between Building Floorplates and Office Layouts

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A configurational model of analyzing floorplates and office layouts

This study is aimed at understanding the effect of shapes of floorplates of buildings on office layouts accommodated in them. It constructs a configurational model and proposes that floorplate shapes influence the spatial integration of layouts according to the design principles used for generating the layouts. Gauging the potential of building shells for accommodating various office layouts is directly linked to the adaptive reuse and the sustainability of buildings in general and workplaces in particular.

The research by Duffy (Duffy, 1974; Duffy, Cave & Worthington, 1976) addresses the complex relationship between static building shells and dynamic office layouts based on the principal distinction between different longevities of shell, scenery and settings. Office layouts are initially described according to "subdivision" and "differentiation" (1974, 1992) and later in terms of "autonomy" and "interaction" (1997, 1998); these are related to degrees of partitioning or clustering and the allocation of individual or collective workspaces. Shells are described in terms of local characteristics of their regions including proportions, size and depth of spaces and the potential for merging and subdividing spaces. Similarly, ORBIT and Broadgate studies (Duffy et al. 1998), BOSTI and ICFM have elaborated the typological analysis of floorplates in the light of best matches for kinds of office layouts.

In the studies mentioned above, the descriptions of layouts are based on local properties, such as the average degree of enclosure of a workplace, or the average number of other workplaces visible from a workplace. Also, the analysis of building floorplates is based on local features of their regions. In contrast, the conclusions about fitting layouts into floorplates are argued to be global for the entire organization and are drawn from adding up local accommodating of departments or teams into sub-regions of floorplates without capturing adequately the global structure of space. The bridging between the two sides of these models is also problematic due to the highly quantitative nature of descriptors of shells that are matched against the qualitative characterizations of layouts.

In response, this paper proposes global affinities between features of office layouts and characteristics of floorplates based on global descriptions of layouts and floorplates according to the concept of "spatial configuration" and methods of "space syntax" (Hillier and Hanson, 1984; Hillier, 1996; Peponis, et al. 1997). Over and above the questions of *what* kinds of shells fit specific layouts and *whether* parts of layouts can physically be accommodated in shells, here it is inquired *how* the overall structure of layouts is affected by characteristics of shells. The issue is confronted by emphasizing the importance of the relational correspondences among parts and the whole and understanding *how* parts of layouts relate to each other once realized in shells.

Office layouts are on the one hand spatial materializations of the organizational criteria and on the other are inseparable from their container shells. The analysis of office layouts in their actual state as contained inside shells is marred by the issue of understanding the degree to which these layouts reflect design principles which respond to organizational requirements, and the degree to which they reflect the characteristics of shells. The understanding of these two separate effects in their own right is not possible by analyzing real conditions of layouts contained in actual shells. Regardless of the number of cases that may be observed, no meaningful generalization can be drawn by aggregating conditions of pairs of shells and layouts, since each pair is affected by particular requirements and individual design approaches.

The description and analysis of floorplate shapes can proceed on its own right without regard to the present or potential layouts to be accommodated in them. This is in contrast to the fluid and ever-changing layouts which cannot be considered outside their containers. The issue of dealing with the two interdependent factors of pairs of floorplates and layouts is approached by keeping one side constant. Accordingly, it is possible to understand the effect of various floorplates on a specific hypothetical layout by analyzing the conditions of this layout after it has been accommodated in these floorplates. Therefore, a few ideal layouts will be formulated based on key composition principles encountered in actual office layouts. For this, a large sample of office layouts will be analyzed with the assumption that the effect of container shells on them is evened out due to the size of sample in consideration. Second, the proposed hypothetical layouts will be introduced into the floorplates of the same sample and will be analyzed in order to investigate the effect of floorplates on them. Differences found among layouts after they are inserted into floorplates will be attributed to characteristics of floorplates and this will constitute the basis for understanding how floorplate shapes affect layouts. Two additional intermediate steps are necessary for this: First, justifying the choice for spatial descriptions of office layouts which are related to important behavioral aspects in offices linked to organizational productivity. Second, searching for or proposing descriptions of shape which take into account spatial characteristics of continuous environments of office shells and which anticipate spatial features of future layouts.

Links between layout integration and aspects of organizational performance

Space syntax has been used to study how the spatial structure of office interiors relates to patterns of space use, including movement, co-awareness, encounter, interaction and the creation of interfaces between different organizational groups, roles and statuses (Grajewski, 1993; Hillier and Penn 1991; Penn et al, 1999; Peponis and Stansall 1987; Rashid and Zimring, 2003; Serrato and Wineman, 1999). Most of these studies entail one particular representation of the office layout known as the axial map. In the axial map, the layout is represented according to the fewest and longest lines needed to cover all circulation. The studies cited also demonstrate the functional role of one particular property of the lines map, namely integration. Integration, in this case, is a measure of directional distance. More integrated layouts involve fewer direction changes as one moves from one part to another; more integrated individual circulation lines can be reached from everywhere else making fewer turns. Here, the significance of the lines-map and integration are taken as given and it is asked what properties of floorplate shape affect the integration of internal circulation. For the purposes of this argument, internal circulation includes not only shared corridors, but also circulation areas inside leased space; only lines giving access to single private rooms or well defined private areas are excluded.

Configurational descriptions of floorplate shapes

The shape of a floorplate is defined as the area of the usable space bound by the building perimeter, where atria and cores have been removed as holes. Most of the shape descriptions used in geography and geomorphology consist of relations between discrete elements of areas, perimeters, axes, and radial axes (Haggett and Chorley 1969). Critiquing these methods, Blair and Biss (1967) emphasize that measures which are based on the area and the length of boundary enclosing the shape are too crude and not sensitive enough to capture features resulting from the shape indentations. Another class of shape descriptions is based on infinitesimal representations of shape where each and every modular unit contributes in the aggregate shape measure, hence pertaining to a configurational logic. Examples of these descriptions are the compactness (Blair and Biss, 1967) and polyomino indices (Matela and O'Hare, 1976). These descriptions have been of little use for the architectural research since they regard abstract representations with no direct links to the human perception of environments.

In contrast, architectural research utilizes representations of a perceptible scale, where there exist a close relationship between elements of shapes under consideration and human perception of the environment. For example, the depth from core to perimeter used by Duffy (1976) while being based on discrete elements relates directly to human perception in building floors and has direct implications for kinds of accommodated layouts. The compactness of shape measured by the ratio between area and perimeter length has been employed by architects as a simple empirical measure of describing plans and, as March and Steadman (1971) argue, it relates "somehow to convenience in circulation, lengths of service runs, amount of external walling and a number of other factors affecting cost." However, the measure can be easily proven false by showing that a perimeter jagged in the small scale of local indentations, hence a greater value of this ratio, may coincide with a compact shape.

Only a few measures proposed by the space syntax research are aimed towards properties of shape per se, since most of them address on the contrary the analysis of space, often with a clear bias of neglecting metrics. Psarra and Grajewski (2001) describe building plans by analyzing the visibility between units of the tessellated perimeter in terms of the synchronous visual information of the open plan provided to a moving observer. The three proposed indices remain unchanged after affinity transformations of shapes and therefore cannot be used for describing unequivocally building floorplates. In contrast, the "visibility graph analysis" uses grid points that fill the entire space rather than just the perimeter, consequently grasping the metrics of shape (Turner, Doxa et al. 2001). The method describes differences of buildings parts from the viewpoint of the co-visibility between locations and the number of turns needed to travel between locations. However, the study does not compile any overall shape description. For instance, the main central space in a museum gallery is shown to have a good visibility reach in comparison to other peripheral spaces, but apart from this, no comparison is possible between the museum in consideration and other buildings.

With regard to the quest for finding descriptions of floorplate shapes, the infinitesimal and modular methods have a threefold advantage: First, these methods lend themselves to associations with continuous qualities of space given the nature of open building floors. Second, modular representations allow gauging floorplate characteristics in a configurational way therefore being compatible to the configurational measure of integration in office layouts. Third, modular methods take into account dimensional aspects of shape by weighing the configurational analysis with the metrics of size and distance.

Relative Grid Distance

To a moving observer, unoccupied and not partitioned open floors present continuous experiences of perceiving almost the same internal edges and faces. By covering distances in open-plan floors, a moving observer experiences size, length, and the walking effort. Given a uniform distribution of workstations, there exists a direct connection between metric distances drawn inside open-plan floors and the number of workstations and the tributary circulation connected to a main circulation segment. The differentiation between distances drawn inside a floor justifies the differentiation of axial depths and the integration of layouts that are accommodated in it. Hillier (1999) recognizes the length of line as one of the two major features that negotiate the internalizing of geometrical order into the structure of graphs. Accordingly, the metric length of the line is translated into the graph structure with direct consequences to the integration of the line.

Area and shape are two characteristics of floorplate that support many descriptive concepts about building floors. We tend to associate the first with quantitative aspects of the number of workstations, construction and maintenance costs and value. The area determines at a great deal what functions can be accommodated in buildings. In the other hand, the notion of shape is linked to qualitative aspects of buildings. Between two buildings with the same floor area, the one with elongated floorplate provides an added value to activities that rely on the proximity to perimeter, whereas, the one with a compact floor suits functions that require energy conservation, enclosure and proximity between locations. In contrast to the measurement of area, there are no exact and implicit ways of describing shape, specifically with regard to distances contained in the shape.

The obvious implication of combining the two notions of "area" and "shape" is the ability to define the kinds of "internal metric distances" afforded by the floorplate, which despite a primarily qualitative nature, are yet quantifiable (Taylor 1971). While keeping constant areas, the differentiation among distances is a direct and obvious effect of shape and just shape. Distances are not just consequences of shapes; they are what define a particular feature of shapes. Hence, a new description of shape which is based on metric distances is proposed in order to gauge how distances are affected by shape and how distances can be used to characterize shape.

"Relative grid distance" (rgd) is a measure of universal metric distance. It is computed based on a representation of a shape as a grid of square tiles of unit side; distances are measured from the center of each tile to the centers of all other tiles along orthogonal axes. Rgd is based on simple "grid distance" values and represents a shape in comparison to a square of the same area. For example, the floorplate shape of Nickelodeon, One Astor Plaza, New York, has rgd = 1.160 (figure 4a). Rgd is a measure of compactness of the shape; greater values show more concavity and elongation.

Convex Fragmentation

The circulation system in a building facilitates the connection between its locations by means of extending convexity. To a moving observer, changes of direction of travel are associated with the kinetic directional inertia. While convex floorplates inflict no constraint on a system of circulation introduced into them, floorplate shapes with wings and holes are likely to add a degree of concavity onto the layout circulation. Hence, the convex fragmentation of shape may allow gauging how far a shape has affected the nature of the overlaid layout with regard to increasing the number of directional changes.

While in a convex shape all connections between points occur without changes of direction, in a fragmented shape, some connections need 1 or 2 directional changes. Attributing the difference in directional changes to the disparity between the two shapes, a new index of shape is measured by summing up all directional changes that the shape can afford. In actual buildings, most corridor systems are organized along two major axes. Hence, from the infinite possible directions that pass through locations in a shape, two orthogonal axes are chosen as guide rulers.

The second proposed measure is "convex fragmentation", or cf. This gauges the extent to which the floorplate is broken into different overlapping maximal convex areas (i.e. no convex areas are considered which are sub-shapes of other convex areas). Convex fragmentation is calculated as the sum of overlapping convex depths between any two unit tiles on the floorplate shape. All unit tiles within a convex area are set to have zero distance between them. Tiles in other convex areas are set to have a depth value equal to the number of maximal overlapping convex spaces that must be traversed in order to reach the convex space that contains them. For example, the floorplate shape of One Astor Plaza has a cf = 0.849 (figure 4b). The measure of cf is always bigger or equal to 0. The value 0 indicates a convex shape, whereas larger values show the fragmentation in the shape due to indents and existence of wings or holes.

A Configurational Typology of Office Floorplates

The two measures proposed here are conceived according to a configurational model. In addition, the two measures have the advantage that they correspond to empirical intuitions about space use. Thus, relative grid distance captures metric distance which is associated with walking effort, while convex fragmentation captures directional distance which is associated with orientation.

No.	Name	Architect (layout)
1	3com Corporation	Studios Architecture
2	Andersen (after)	DEGW & SOM
3	Andersen (before)	Unknown
4	Allen & Overy	The Switzer Group
5	Arthur Andersen	BDG McColl
6	Apicorp	Ove Arup & DEGW
7	Apple Computer	Gensler
8	Andersen Consulting	Eva Jirična Architcs.
9	Buch und Ton	Quickborner Team
10	Chase Manhattan B.	The Switzer Group
11	Chiat/Day Advertis.	Frank Gehry & Assc.
12	TBWA Chiat/Day	Gaetano Pesce
13	Citicorp	SOM
14	Commerzbank AG	Norman Foster Prtn.
15	Data-Firmengruppe	Kauffmann Theilig
16	Davis Polk Wardwell	Gensler
17	DEGW London Offic.	DEGW
18	Discovery Channel	Studios Architecture
19	DuPont	Quickborner Team
20	The Equitable	The Switzer Group
21	Ford Foundation	Roche/Dinkerloo
22	Ford Motor Co.	Quickborner Team
23	f/X Networks	Fernau & Hartman
24	Greenberg Traurig	The Switzer Group
25	Hoffmann La Roche	Gensler
26	IBM Regional HQ.	The Switzer Group
27	IBM (UK) Limited	M. Hopkins & Part.
28	IBM Australia	Daryl Jackson Int
29	Interpolis	Abe Bonema Kho Ie
30	Direct. of Tel. MPBW	Whitehall Dev. Grp.
31	Eastman Kodak	Quickborner Team
32	Lend Lease Interiors	Bligh Voller, DEGW
33	Leo A Daly	TVS
34	Lowe & Partners	Sedley Place
35	McDonald's Finland	Heikkinen-Komonen
36	McDonald's Italia	Atelier Mendini
37	MGIC	SOM Warren Platner
38	Nickelodeon	Fernau Hartman
39	Olivetti A	DEGW, De Luchi
40	Olivetti B	DEGW, De Luchi
41	Olivetti C	DEGW, De Luchi
42	Orenstein-Koppel	Quickborner Team
43	Sears 40th floor	SLS/Environetics
44	Sears 70th floor	Environments Grp
45	Steelcase Inc.	Steelcase
46	BT, 5 Longwalk	Norman Foster Prtn.
47	BT, The Square	Arup Assoc., DEGW
48	Vitra International	Frank Gehry & Assc.
49	Weyerhaeuser Cmp.	Sidney Rodgers
50	WMA Consulting	Valerio Dewalt Train

Table 1. The sample of floorplate and office layouts.

The analysis of shapes according to the two measures is implemented using the computer application Qelizë which has been developed as part of this research and is accessible at (http://www.morphostudio.net/qelize/.)

A sample of 50 actual floorplates is analyzed using the two measures. The real floorplates, listed in table 1, have been selected so as to ensure the availability of published plans of some of the layouts actually accommodated in them. Figure 1 shows how the sample is distributed according to the measures introduced above. Compact shapes are situated in the bottom left region. As we move upwards we find shapes with more fragmentation. For the most part, fragmentation arises as a result of relatively small indentations along the perimeter or the placement of internal cores within a relatively compact convex shape-hull. The actual correlation is descriptive of an empirical characteristic of the office building type and not a result of mathematical necessity. Shapes of office floorplates, as being affected by issues of lighting, structures, code compliance and building cost, occupy a specific zone in the family of possible shapes.

The statistical clustering of the sample according to the two measures of rgd and cf reveals six groups (figure 1). Accordingly, a new classification into six types of floorplate is proposed based on combined degrees of rgd and cf of their shape:
1) "Compact blocks external core" includes floorplates with compact shapes and those with external cores and a few small internal cores;
2) "Bars" includes floorplates with elongated rectangular shapes and external cores;
3) "Deep space small central core" includes floorplates with internal cores which are relatively small in comparison to the depth between core and perimeter;
4) "Shallow space large central core" includes floorplates with ring-like configurations of shapes with large cores in high-rise buildings, central atria and internal courtyards;
5) "Pavilions" includes floorplates with distinct pavilions and floorplates with many large internal cores or atria;
6) "Wings" includes elongated foorplates broken into distinct wings.

A Configurational Typology of Office Layouts

The variability of office layouts is studied based on the 50 layouts from the buildings described earlier. These layouts represent best practice in office design from the 1960s to the present. Layouts are represented with axial maps which were described earlier. Axial maps are quantitatively analyzed according to their "mean connectivity" (number of intersections of each line), "mean integration", "connectivity skewness", "integration skewness" and the statistical co-variation of these measures. In addition, a heuristic examination suggests two fundamental dimensions of variability. First, while some layouts are characterized by dense patterns of intersection, others are characterized by

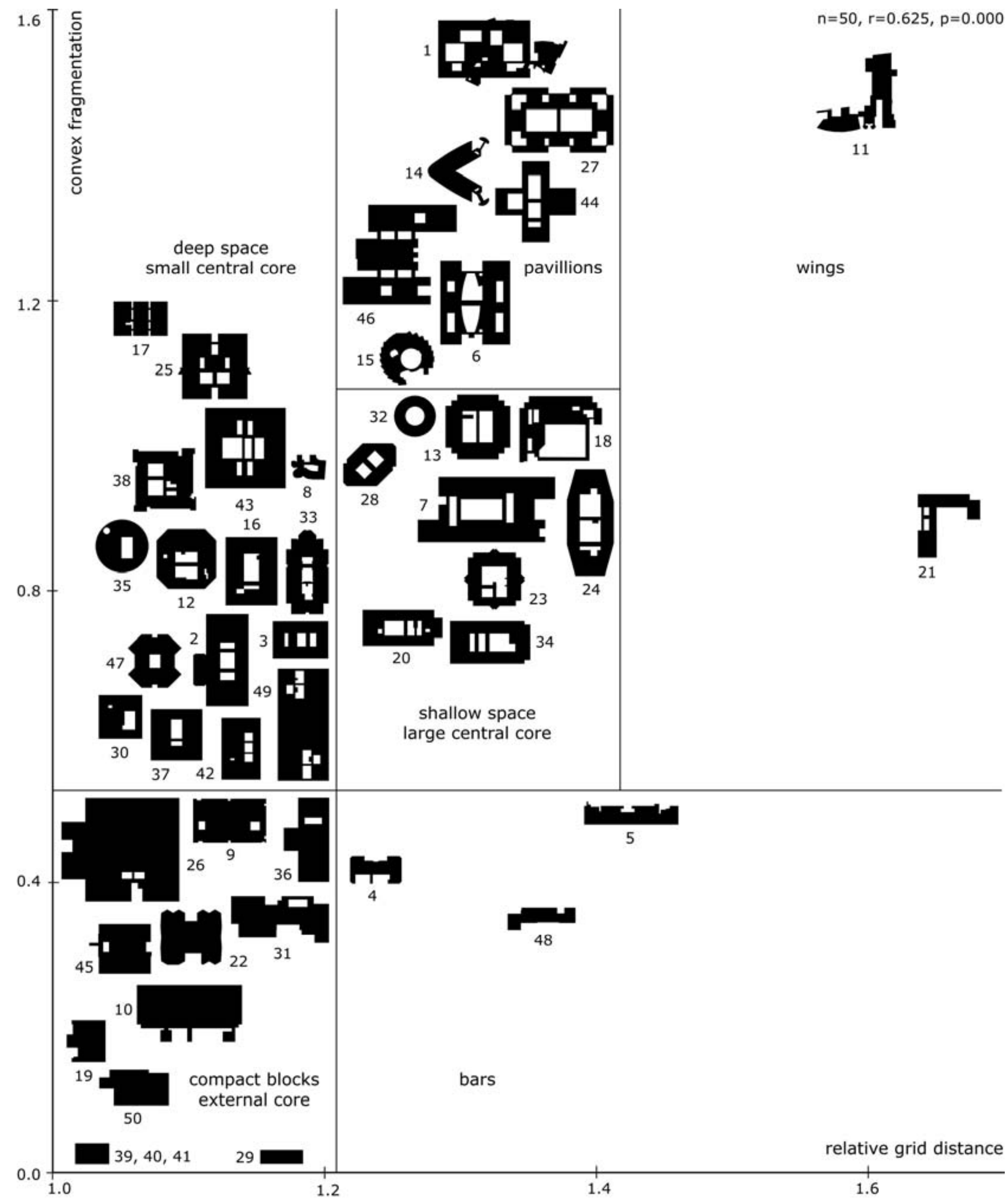

Figure 1. Fifty floorplate shapes compared according to compactness and fragmentation

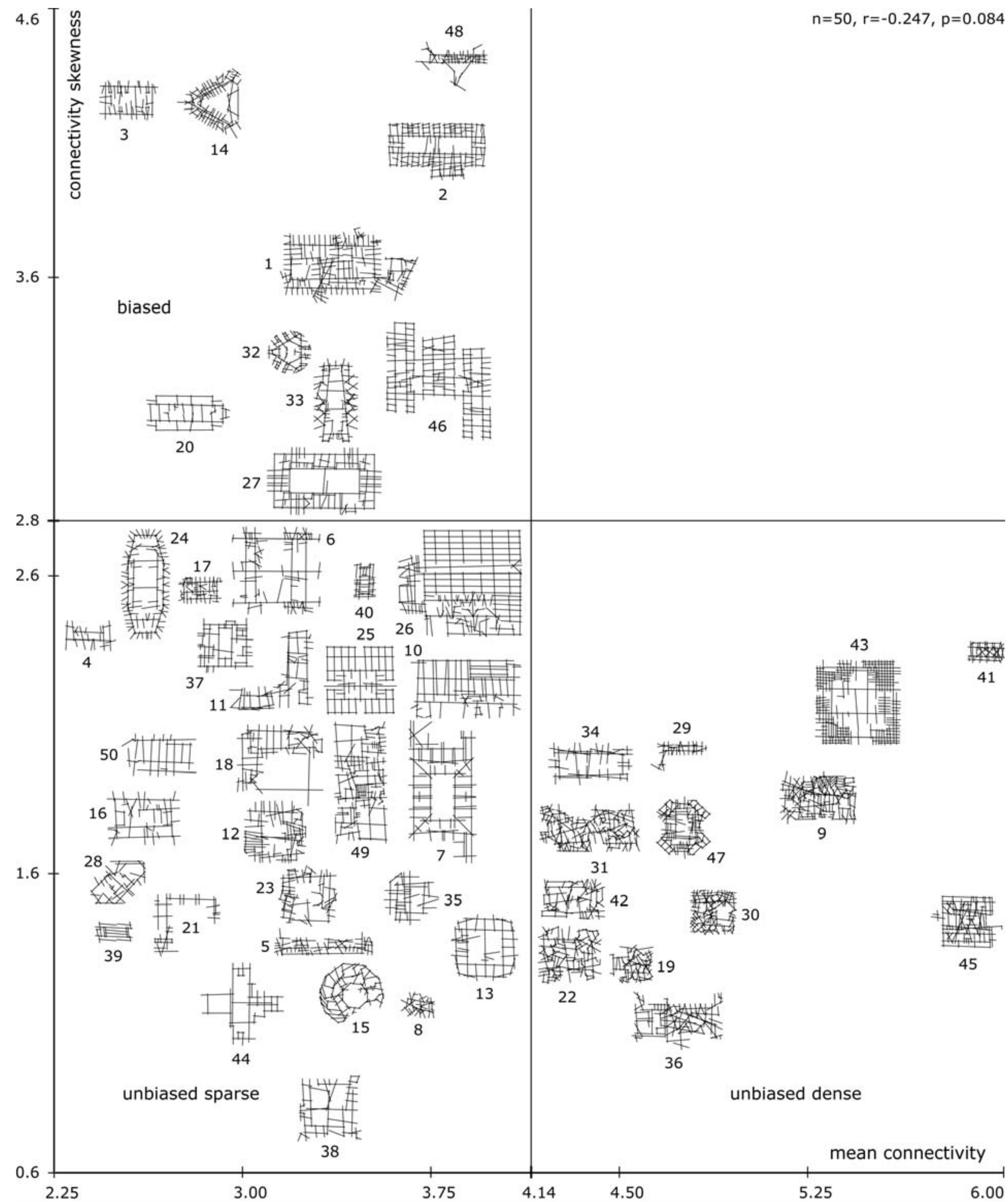

Figure 2. Fifty office layouts compared according to connectivity and connectivity bias

relatively sparse patterns. Second, while some layouts are directionally unbiased, in the sense that we can clearly identify main circulation lines with very high connectivity running in one direction, others are unbiased in the sense that lines with high connectivity run in different directions.

The heuristic intuition corresponds most clearly to a very strong statistical pattern regarding the relationship of connectivity and connectivity skewness. There are no left-skewed connectivity distributions in the sample. High skewness always indicates a small number of lines with a very high number of connections. When mean connectivity is plotted against connectivity skewness, as shown in figure 3, all layouts fall within a clear L-shape, with no example in the top right quadrant.

Considering the two measures of connectivity and connectivity skewness, the sample lends itself to a perfect two-step statistical splitting into three groups (figure 2). Accordingly, three types of real office layout are distinguished. The first type, termed "biased", represents layouts with low connectivity and high connectivity skewness falling in the top left quadrant. The fishbone pattern, whether linear or looped, is held to be an ideal type representing the underlying structure of these layouts (figure 3). The second type, termed "unbiased-sparse", includes layouts with low connectivity and low connectivity skewness composed of elementary and simple systems where a few lines connect to each other without noticeable differentiation; these fall in the bottom left quadrant. The third type, named "unbiased-dense", includes layouts with high connectivity and low connectivity skewness; these fall in the bottom right quadrant and can be dense orthogonal grids or seemingly irregular bürolandschaft layouts. The grid evenly extending in both dimensions is conceived as the ideal type representing the underlying structure of these layouts (figure 3).

Among the three types, unbiased-sparse layouts are the least integrated, biased layouts are more integrated while unbiased-dense layouts are even more integrated, indicating that there are two ways of increasing integration in actual office layouts: increasing the density of intersections and increasing skewness or bias so that a few lines act as powerful integration spines.

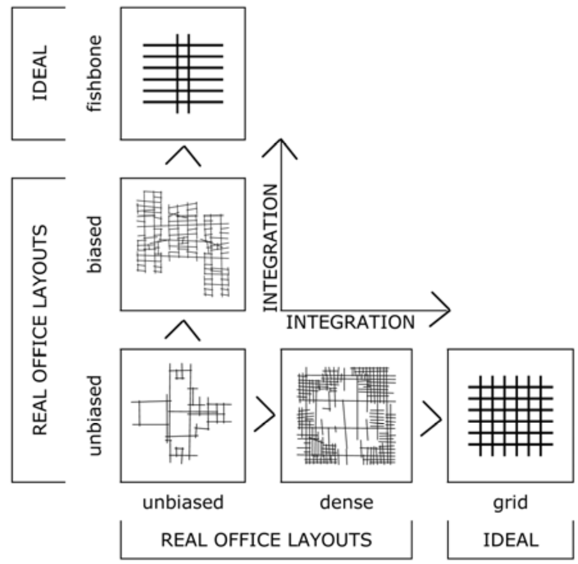

Figure 3. Two ideal layouts representing two selected types of real layouts and two alternative ways of increasing integration

Affinities and Design Principles

The hypothetical layouts of grids and fishbones are generated in the 25 actual floorplates corresponding to US buildings included in the sample. The grain for both hypothetical layouts is based on clusters of 4 workstations of about 8x8 ft and circulation width of 4 ft. Dimensions are allowed to vary slightly to fit the mullion grid or the depth from core to perimeter. In each case a circulation ring is created around the central core. Where possible, the main fishbone axis is taken through the core, across the entire available longest length of the floorplate; secondary axes branch in parallel rows either from the main axis, or from the circulation ring around the core. The layouts are represented with linear maps and their integration is calculated. The hypothetical grid plan is shown in figure 4e and its axial map is shown in figure 4f. The hypothetical fishbone layout is shown in figure 4g and its linear map in figure 4h.

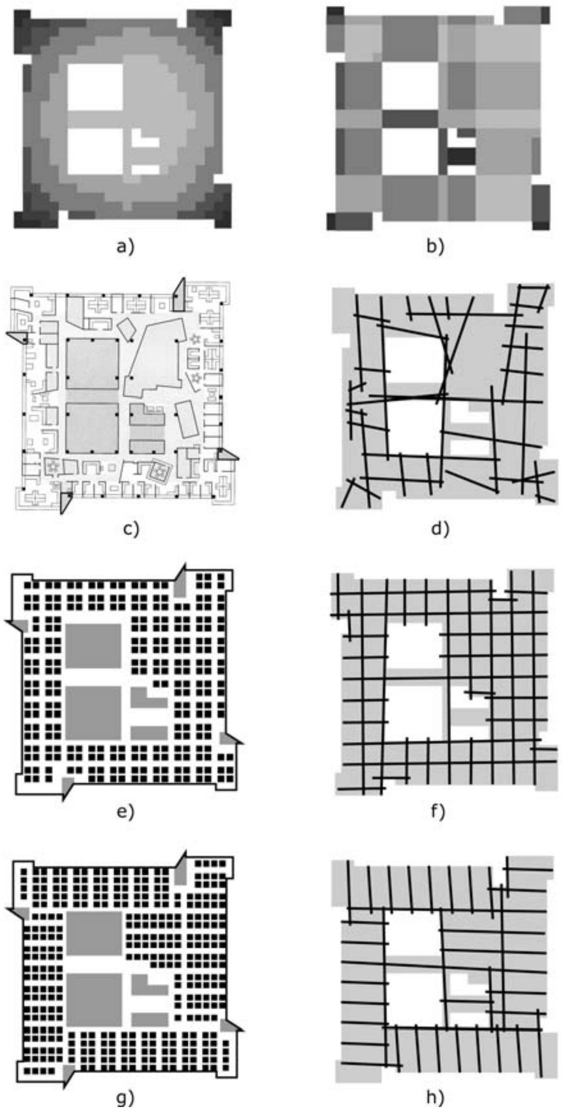

Figure 4. A floorplate analyzed according to rgd and cf and loaded with a real layout and two hypothetical layouts

For grid layouts, integration correlates best with cf at (r=-0.860, p=0.000). More convex floorplates are associated with more integrated grid layouts. For fishbone layouts, integration correlates best with rgd at (r=0.817, p=0.000). These correlations demonstrate that the effect of floorplate shape on interior layout integration is mediated by the generative principles of the layout. Fishbone and grid layouts, for example, are affected by floorplate shape not merely in different but actually in opposite ways.

Floorplate shapes influence global properties of internal layouts which are important from the points of view of function and cognition - integration affects not only the flow of movement, communication and awareness as a by-product of movement, but also spatial orientation and wayfinding. In this way it is possible to complement models of office space that emphasize more local properties, or properties associated with metric distance.

The effect of floorplates is evident in two levels: First, the effect of floorplate shapes upon layouts is more evident for layouts with high density and low differentiation and for layouts which are highly structured and differentiated due to a few strong primary circulation corridors. Accordingly, more compact floorplates are associated with greater integration of dense and unbiased layouts and with lesser integration of biased layouts. Second, the effect of floorplates upon integration of layout circulation is more predictable for floorplates which are compact, have external cores or have smaller and fewer internal cores.

There exist an underlying correspondence between a morphological typology of layouts (which distinguishes between the fishbone and the grid as alternative principles for increasing integration) and a morphological typology of shapes (which distinguishes between more compact and convexly unified shapes and shapes with a clear differentiation of wings). Thus, office layouts with high density and low differentiation among circulation paths are likely to be highly integrated when accommodated in floorplates with low fragmentation, such as "compact block external core" and "bars", figure 5. In contrast, these layouts are likely to be poorly integrated when accommodated in "pavilions" and "wings" floorplates. Highly differentiated layouts with long primary corridors are likely to be poorly integrated in "deep space small central core" and "compact blocks external core" floorplates and highly integrated when accommodated in "bars" and "wings" floorplates. These findings suggest the possibility of proposing new configurational affinities between building shells and office layouts based upon the compactness and fragmentation of floorplate shapes and the degrees of bias and density of office layouts.

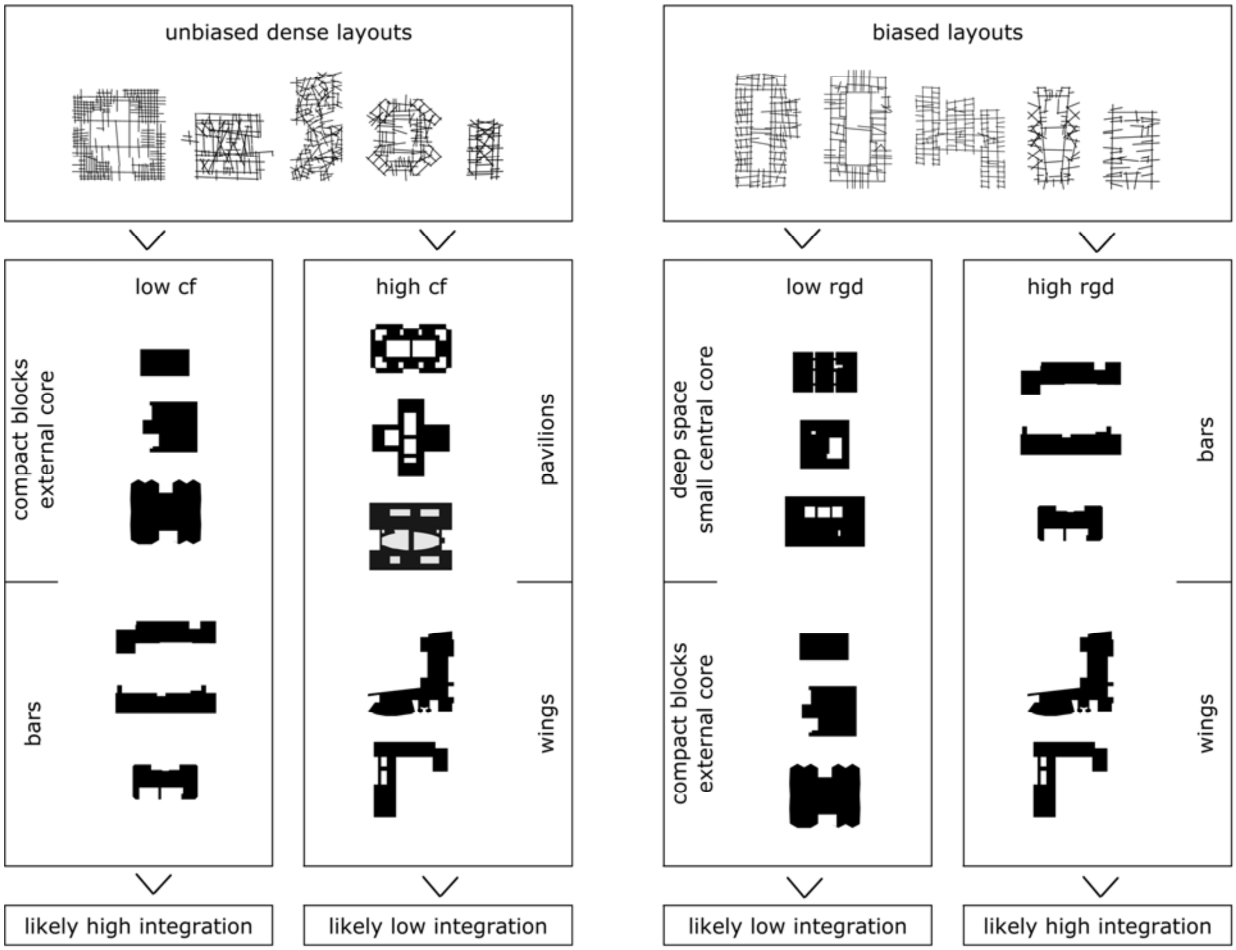

Figure 5. Affinities between types of floorplate and types of layouts

Architects act as advocates who reconcile between constraints and potentials of shells and programmatic requirements underlying office layouts. The shape of floorplates, as a particular aspect of office shells, is one among the multitude of factors intervening in the design of an office layout. The paper does not attempt to offer by any means normative guidelines about specific choices for office layouts resulting from characteristics of floorplates. In contrast, it suggests affinities between floorplates and kinds of office layouts which reveal tendencies and constraints within which designers work and sometimes have to overcome.

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