Proceedings of the Ninth International Space Syntax Symposium
Edited by Y O Kim, H T Park and K W Seo, Seoul: Sejong University, 2013

VISIBILITY AND EXPOSURE IN WORKSPACES

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Abstract

This paper addresses the analysis and redesign of workplaces in justice facilities regarding user comfort and organizational hierarchy. A method based on isovists and axial maps is proposed for the evaluation of environmental aspects of individual workstations concerning visibility, exposure, privacy, comfort and social interaction.

The workplaces of two Justice Courts are analyzed before and after layout reformulation and refurbishment. For each layout the workstations are evaluated in terms of visibility and exposure to the built enclosure, to coworkers, to external landscape and to internal movement flows. These results are compared to a survey made with workers addressing personal, organizational and behavioral factors.

The study demonstrates the use of the proposed method in the evaluation of workplaces, showing some evidence on the relation between the occupation of better evaluated workstations and higher organizational hierarchy. The results suggest some degree of correspondence between the calculated features of visibility and exposure and user evaluation of their workstations, contributing to the design of better workplaces.

Keywords: *building configuration, office layout, visibility, exposure, isovists*

Theme: *Building Morphology and Performativity*

Introduction

Space syntax methods have been currently used in the analysis and design of workplaces, where configurational properties of office layouts have been successfully correlated with patterns of space use and user movement (Penn, Desyllas and Vaughan 1999). In addition, spatial attributes and psychosocial factors such as autonomy, privacy, communication and sense of community affect job satisfaction and work performance (Wineman and Adhya2007).

Departing from the twofold probabilistic and deterministic models associated respectively to generative and conservative building types (Hillier and Hanson 1984), the analysis of office layouts using visibility graphs demonstrates the importance of high levels of local visibility, global integration and movement to generative organizations (Sailer 2012). In more conservative organizations such as Justice Courts, on the other hand, spatial segregation associated to organizational hierarchy and visual control are key aspects of office layouts. Inside smaller scale workplaces, especially open offices, visibility involves psychosocial aspects such as to user comfort and behaviour (Beck 2012).

Environmental properties of workplaces related to user comfort and interaction comprise physical and social factors that might be perceived through vision. Visibility of the built enclosure, for instance, the surrounding surfaces, openings and landscape, affect user perception and sense of security and control. The visual information available from a certain vantage point might be analyzed using isovists, which describe attributes such as area – the amount of visible space, perimeter – the enclosing surfaces, and occlusivity – the openings between surfaces (Benedikt 1979). In addition, visibility relations among coworkers afford supervision and control and affect user perception of privacy and user sense of belonging to his workgroup. Therefore visibility relations comprise not only the ability to see the surrounding space and people, but the complementary exposure to colleagues and public.

In this paper a method based on isovists and axial maps is proposed for the evaluation of environmental aspects of workplaces concerning visibility, exposure, privacy, comfort and social interaction. A sample of four office layouts is analyzed, comprising two Federal Justice Courts, A and B, before and after layout reformulation and refurbishment. For each layout the workstations are evaluated in terms of visibility and exposure to the built enclosure, to coworkers, to external landscape and to internal movement flows. The results from that analysis are compared to a survey made with corresponding workers of groups A and B. The survey concerns personal, organizational and behavioral factors, such as hierarchy, workers habits, computational work, social interaction with public and colleagues, and workers evaluation of their workplace, workstation and office furniture. In the next section materials and methods are presented, followed by results and discussion, and in the final part some conclusions are driven.

Materials and Method

The Federal Justice Courts analyzed in this paper are located in the same building and floor. Court A is located in the east wing with two facades facing South and East, as shown in Image 1. Court B is in the north Wing with three facades facing East, North and West, as shown in Image 2. Both Courts have a reception area, a court room, an open office for the secretary, partitioned rooms for consultancy and Director, and two private offices for the Judges. Organizational hierarchy of the coworkers according to their functions is depicted using a 1 to 6 scale ranging from trainees, employees, supervisors, the Director and the Judges, as represented with a color scale in Images 1 and 2. In addition, a second hierarchy scale based on job time is calculated for each coworker, as the mean time working for Federal Justice and the time working in each Court A or B.

Figure 1: Layouts of **Court A** before (left) and after reformulation (right) – workstations of Judges in red, Directors in yellow, employees in green and blue, trainees in purple.

Before layout reformulation, both Courts presented a room without windows located between the Judge's offices. That room was originally designed for Judge's consultancy, but it was in fact occupied only by trainees. In both reformulated layouts of Court A and B, employees and trainees share the same consultancy room, located close to Judge's offices. In addition, Court B has a partitioned room for two employees of the secretary, both before and after renovation. In addition before reformulation Court B had only one Judge, and the employees of his consultancy occupied the other private office.

Figure 2: Layouts of **Court B** before (left) and after reformulation (right) – workstations of Judges in red, Directors in yellow, employees in green and blue, trainees in purple.

Both workgroups A and B answered the same survey, before and after layout reformulation. The survey comprises personal factors such as sex, age, height and weigh, organizational factors about functional hierarchy, job time and behavioral factors such as computational work, direct work with public, work within and outside ones workstation, interaction with colleagues and work breaks. In addition, respondents are asked to evaluate their workplace and workstation choosing a value in a five step evaluation scale ranging from -2, -1 for bad, 0 for regular, 1 and 2 for good. Workplace evaluation comprises environmental attributes such as temperature, lighting and acoustics. Workstation evaluation concerns respective location in the room, user field of vision while seated, user perception of privacy and comfort and evaluation of furniture and equipment. Workers evaluation is computed using the mean value (En) for each workstation (n), and this

result is compared to visibility and exposure values calculated using isovists and axial maps as follows.

Visibility and exposure from each workstation are computed using a bad to good scale varying from 0 to 4, where the best workstations combine high visibility and low exposure, and the worse ones present low visibility and high exposure, computed as follows.

$$Vn = Ve + Vc + Vl + Vm$$

Vn – degree of visibility and exposure for workstation (n), varying in a bad to good scale from 0 to 4;
Ve – visibility of the office's built enclosure from each workstation regarding surfaces and openings;
Vc – visibility and exposure to coworkers and supervisors;
Vl – visibility of the outside landscape;
Vm – visibility and exposure to movement flows in internal circulation lines;

These features are calculated based on isovists attributes, while the vantage point of the isovist corresponds to the position of the user seated in his workstation. Whereas the full isovist measures the whole visual information available turning the head around, the front half-isovist corresponds to the field of vision of the user facing the computer as follows.

$$Ve = \left(\frac{Fa}{Ia} + \frac{Fp}{Ip} + \frac{Fo}{Io}\right) * \frac{1}{3}$$

Fa – front half-isovist area;
Ia – full isovist area;
Fp – front half-isovist perimeter;
Ip – full isovist perimeter;
Fo – front half-isovist occlusivity;
Io – full isovist occlusivity;

Visibility and exposure to coworkers and supervisors are also calculated using half-isovists, where the user is able to see the colleagues within his front half-isovist and at the same time he is exposed to the surveillance of all colleagues within his back half-isovist, as exemplified in Image 3.

$$Vc = \frac{Fc}{Ic}$$

Fc – number of co-workers within the front half-isovist;
Ic - number of co-workers within the full isovist;

Visibility of the landscape is computed using half-isovists as well, based on the angular dimension of isovist sections corresponding to the windows to the front and to the back of each user as exemplified in Image 3 and calculated as follows.

$$Vl = \frac{(\Sigma Fw - \Sigma Bw)}{180}$$

Fw – angle of isovist sections corresponding to windows within the front half-isovist;
Bw – angle of isovist sections corresponding to windows within the back half-isovist;

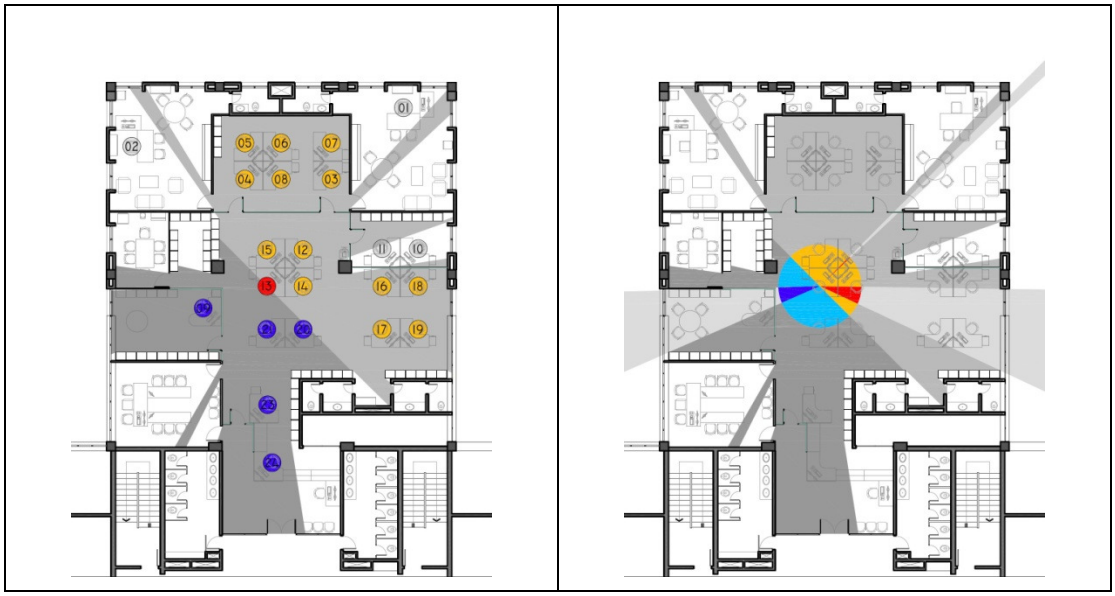

Figure 3: Left: example of isovist based measurement of visualization and exposure to coworkers – vantage point in red, front -isovist in light grey, back half-isovist in dark grey, visible coworkers in yellow, colleagues to the back in purple and non-visible colleagues in grey. Right: example of isovist based angular measurement of visualization of windows for the same vantage point – sections corresponding to visible windows to the front in red, wall sections to the front in yellow, sections corresponding to windows to the back in purple, wall sections to the back in blue.

Visibility and exposure to movement along internal circulation lines is estimated using axial maps depicting the spatial configuration of circulation lines in each layout. The potential movement is computed based on the syntactical depth measured from the root axis of the system, corresponding to the hallway, balanced by the value for global integration of each axis, as shown in the examples in Image 4. The amount of visibility and exposure to potential movement is considered as the mean value for the axes that give access and directly surround each workstation, calculated as follows.

$$Vm = \frac{(\Sigma Dx)}{X} \qquad Dx = \left(\frac{Dr}{Dm}\right) * \frac{1}{Gx}$$

Dx – balanced syntactical depth for axis (x);
X – number of axes surrounding the workstation;
Dr – syntactical depth on axis (x) measured from the root axis, corresponding to the hallway;
Dm – maximum depth in the system measured from the root axis;
Gx – global integration of axis (x);

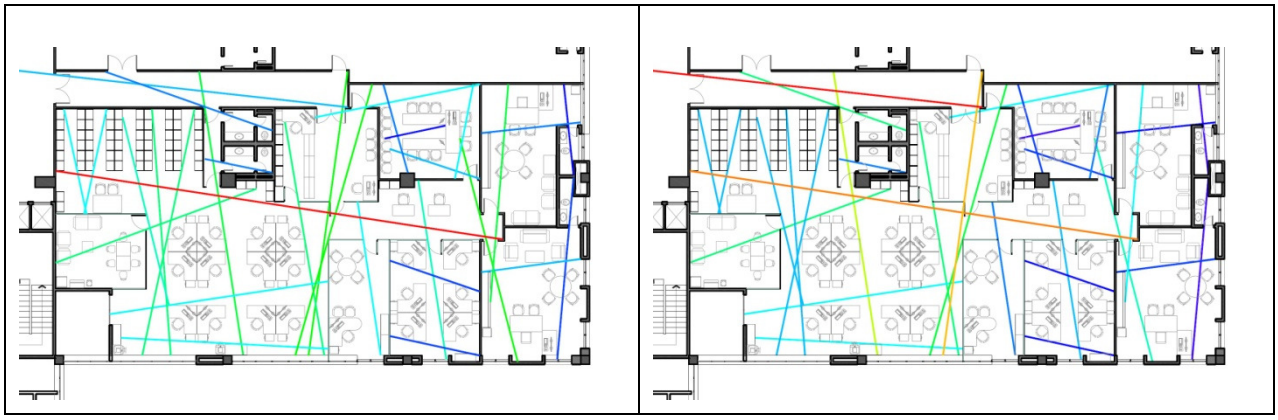

Image 4: Left: Example of axial map showing global integration – more integrated lines in red, intermediate in green to blue and more segregated lines in purple. Right: Example of axial map showing syntactical depth from the Court entrance balanced with global integration – red for shallower axes, intermediate ranging from yellow to green and blue, purple for deeper axes

Results

The former layout of Court A presents the following results, as shown in Image 5. Visibility and exposure (Vn) present mean value (M =2,14) and standard deviation (SD =0,46). Best workstations are occupied by employees in the secretary ($V11$ =2,73) and in the consultancy room (V 6=2,51 $V5$ =2,50), together with the Director ($V9$ =2,59). Worst workstations are both in the reception ($V21$ =0,93 $V22$ =1,27), one of them occupied by an employee and the other one unoccupied.

In Court A the survey was answered by only 11 people before renovation, with a regular to good evaluation (mean En =0,6) and low variance among respondents (SD =0,3). Best evaluated workstations are occupied by an employee in the secretary ($E10$ =1,1) and by the Director ($E9$ =1,0). Worst evaluated ones are occupied by an employee in the consultancy room ($E7$ =-0,1) and a trainee in the secretary ($E20$ =0).

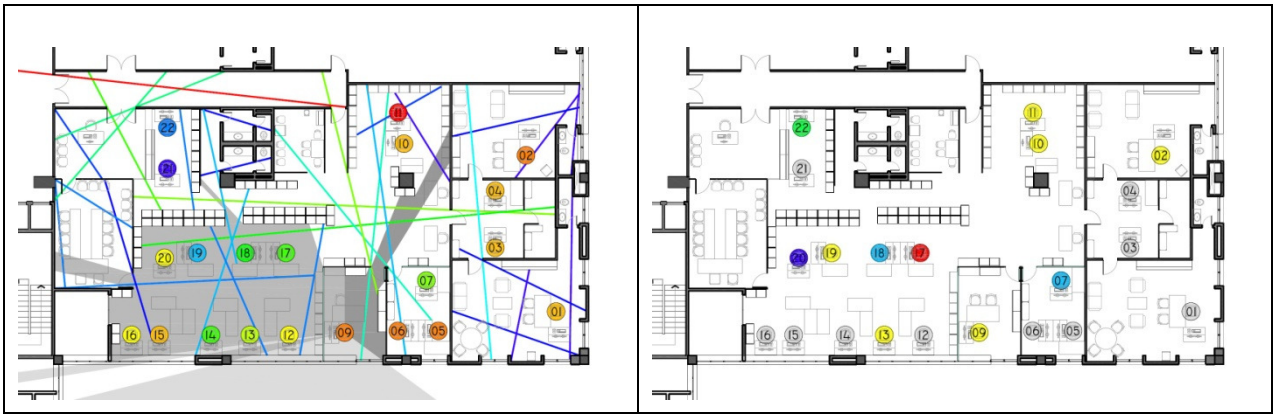

Figure 5: Results for the **former** layout of **Court A.**Left:axial map showing balanced depth; isovist sections for Director's workstation; Isovist-based visibility and exposure analysis of workstations – red and orange for best, yellow and green for intermediate, blue and purple for worst; Right: survey evaluation of workplaces – same color scale.

After layout reformulation Court A presents the following results, as depicted in Image 6. Visibility and exposure (Vn) present mean value (M =1,83) and standard deviation (SD =0,67). Best

workstations are in the secretary, occupied respectively by an employee and a trainee ($V10$ =2,82 $V16$ =2,65), and in one of the Judge's offices ($V2$ =2,78). Worst workstations are occupied by a trainee in the secretary ($V17$ =0,69) and an employee in the reception ($V22$ =0,92).

Again the survey was answered by only 11 people, not necessarily the same ones as before. Results presented a better evaluation (mean En =1,2) with low variance among respondents (SD = 0,5). Best evaluated workstations are occupied by a trainee in the consultancy room (E8=2,0) and by an employee in the secretary ($E13$ =1,75). The worst evaluated workstation is considered regular by a trainee in the secretary ($E17$ =0,25).

Figure 6: Results for the **reformulated** layout of **Court A.**Left: axial map showing balanced depth; isovist sections for Director's workstation; Isovist-based visibility and exposure analysis of workstations – red and orange for best, yellow and green for intermediate, blue and purple for worst; Right: survey evaluation of workplaces – same color scale.

The former layout of Court B presents the following results, as shown in Image 7. Visibility and exposure (Vn) present mean value (M =1,97) and standard deviation (SD =0,53). Best workstations are occupied by employees in the office used as consultancy room ($V5$ =2,85) and in the secretary ($V6$ =2,79), together with the Director ($V9$ =2,64). The worst workstation is occupied by an employee in the reception ($V24$ =0,76).

Before layout reformulation In Court B the survey was answered by 12 people, with a regular evaluation (mean En =0,2) and high variance among respondents (SD = 0,7). Best evaluated workstations are occupied by employees in the consultancy room and in the secretary ($E5$ =1,0 $E12$ =1,0), together with the Director ($E9$ =0,75). Worst evaluated ones are occupied by an employee in the same private office used as consultancy room ($E7$ =-0,75) and a trainee in the secretary ($E16$ =-0,75).

Figure 7: Results for the **former** layout of **CourtB.** Left: axial map showing balanced depth; isovist sections for Director's workstation; Isovist-based visibility and exposure analysis of workstations – red and orange for best, yellow and green for intermediate, blue and purple for worst; Right: survey evaluation of workplaces – same color scale.

After layout reformulation Court B presents the following results, as depicted in Image 8. Visibility and exposure (Vn) present mean value (M =1,80) and standard deviation (SD =0,62). Best workstations are occupied by one of the Judges (V1=2,70) and by two employees respectively in the consultancy room and in a partitioned part of the secretary ($V7$ =2,68 $V10$ =2,57). Worst workstations are in the reception, both occupied by employees ($V24$ =0,71 $V23$ =0,86).

Again the survey was answered by only 12 people, not necessarily the same ones as before. Results presented a god evaluation (mean En =0,9) with considerable variance among respondents (SD = 0,7). Best evaluated workstations are occupied by one of the Judges, the Director and two employees in the secretary respectively ($E2$, $E9$, $E10$, $E11$ =0,75). The worst evaluated workstation is considered bad to regular by a trainee in the secretary ($E17$ =-0,25).

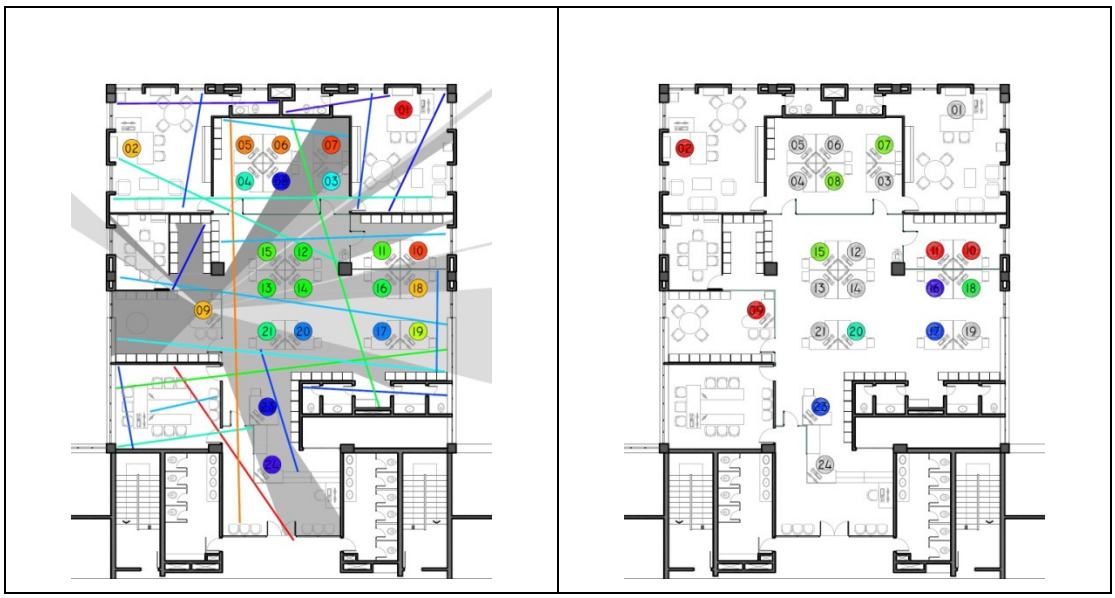

Figure 8: Results for the **reformulated** layout of **CourtB.** Left: axial map showing balanced depth; isovist sections for Director's workstation; Isovist-based visibility and exposure analysis of workstations – red and orange for best, yellow and green for intermediate, blue and purple for worst; Right: survey evaluation of workplaces – same color scale.

Discussion

Computation of visibility and exposure values presented slightly higher results before for the former layouts for both Courts. On the other hand, the survey showed better evaluations after layout reformulation for both Courts as well. Comparing the results obtained with the two methods, no correspondence was found for Court A in neither layouts. In Court B little correlation was found in the former layout (R^2 =0,25) and better correlation in the reformulated one (R^2 =0,41).

This might be due to the influence of personal factors while answering the survey, for instance, interpretation of the questions, overweighting of some factors against others, in addition to the small number of respondents. Besides, the evaluation of the workstations might as well have been influenced by other factors such as temperature, lighting and furniture. In the reformulated layouts, the better evaluations might be influenced by the new furniture considered to be ergonomically better.

However the factors that affect visibility and exposure might be intuitively recognized in the layout plans, especially together with the depiction of the front and back half –isovists and the balanced depth from the surrounding axis. This might be easily visualized in image 7, where the isovist corresponding to the Director presents a large front half, with many window sections, and a little back half-isovist. In addition, the Director is able to surveil most of the workers, which are placed to his front, and his workstation is surrounded by only one axis with high balanced depth.

If we analyze the results more closely, workstation to workstation, two groups might be recognized considering the correspondence between results from the survey and the calculation of visibility and exposure. While some user's evaluation of workplace found no correspondence with visibility values, others showed a consistent correlation. Disregarding five of the most inconsistent results for each case, better correlations are found as follows. In Court A with 6 remaining respondents, correlations are better before (R^2 =0,76) than after layout reformulation (R^2 =0,13). Considering the 7 remaining respondents in Court B, the correlations are quite significant both before (R^2 =0,89) and after layout reformulation (R^2 =0,83), as summarized in the table below.

Attribute		**Court A - Former**	**Court A - Reformulated**	**Court B - Former**	**Court B - Reformulated**
Visibility and Exposure *(Vn)*	Mean Value	2,14	1,83	1,97	1,8
	Standard Deviation	0,46	0,67	0,53	0,62
Survey Evaluation *(En)*	Mean Value	0,6	1,2	0,2	0,9
	Standard Deviation	0,3	0,5	0,7	0,7
Correlation *(Vn - En)*	Whole sample	$R^2 = 0$	$R^2 = 0$	$R^2 = 0,25$	$R^2 = 0,41$
	Consistent results	$R^2 = 0,76$	$R^2 = 0,13$	$R^2 = 0,89$	$R^2 = 0,83$

Conclusions

In spite of the small number of respondents, the latter analysis demonstrates a significant correspondence between the calculated features of visibility and exposure and user evaluation of their workstations. The results suggest a relation between the occupation of workstations and hierarchy, since the best evaluated places are used by superiors and employees with the most job time in each Court. Further studies might investigate the analyzed features separately, assessing the individual contribution of enclosure, coworkers, landscape and movement to user visibility, exposure and hierarchy. The results show some evidence that the proposed method might be of use in the evaluation and redesign of office layouts. In this way Space Syntax, Human Factors and Ergonomics might contribute to the design of better workplaces.

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