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Spatial Configuration and Passenger Behavior at Complex Buildings

Istanbul Sabiha Gökçen Airport

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ABSTRACT

The behavior of the passengers in complex buildings may be affected by the spatial configuration of the building, also the functional demands of each individual. This research investigates complex buildings'spatial configuration and visibility characteristics' impact on the choice of the service facilities that are related to the behavior of the passengers at an airport. The functional demands of an airport do not only rely on passenger activity and finding the gate. Passengers use the travel-related functions but also the retail facilities, and food/drink services at an airport according to their needs. The location of these facilities has the potential to attract people during their time until their flight. The optimized locations of these facilities may generate well-operated management by answering the functional demands and a time saver for the passengers.

The general aim of the research is to point out the dependents of the choice of these facilities related to the syntax parameters such as some of the food services can locate in the highest visibility areas and some of them locate in very deep spaces and some of them lose customers because of the configuration of the airport. The method of the research involves the behavioral pattern of the passengers through the food/drink services and their relationship with the spatial structure of the airport. However, the whole wayfinding dynamics of the airport generally, is led by the arrows and signs through the destination, the random movement through the food/drink facilities will show the actual influence of the spatial structure on the behavioral patterns.

The spatial characteristics will be discussed with visual connectivity, isovist measurements (e.g., circularity, occlusivity, isovist perimeter), and how they are related to the actual passenger populationat these facility zones at an airport. The common area of departures and domestic flights of the airport will be used for the research to investigate how people are using these spaces

according to their locationand visibility potential. In the case study, the selected nodes will be counted in the gates, and the numeric data of the passengerswill be compared with the syntax measurements to achieve a correlation also detecting the ignored facilities because of the spatial structure that is meant to develop more optimized facility service to the passengers. The research includes a syntactic analysis at İstanbul Sabiha Gökçen Airport's Domestic flights facility area to investigate the usage of these areas. The human movement through the airport leads the users to create a path regarding their activities, therefore the spatial configuration of the airport has a significant impact on the routes of the passengers and the choice of the facility within their functional needs.

KEYWORDS

Spatial Configuration, Space Syntax, Human Movement, Isovist, Airport Design, Passenger Activity

1 INTRODUCTION

The architecture of the transportation-related complex buildings requires achieving multiple servicesin a single environment. The distinction between transportation operations and service/facility operations establishes a multi-level influence on both spatial arrangement and passenger behavior. This research seeks to depict the main influences on passenger activity and facility choice within the airport building starting from the second security (passport control zone) to the flight gates.

Regarding with the research task, the study is structured in three stages. First, the functional demands of facility area of an airport and the distribution of these facilities according to wayfinding activity are investigated to understand the spatial structure. Second, the impact of spatial configuration on passengers in relation to facility choice and human flow between these facilities is characterized within space syntax approaches. Third, the interpretation by observational and syntactic analysis, thus, a statistical test is applied to realize the relationshipbetween spatial configuration, visibility characteristics and passenger choice.

The layout of the research area is distinguished inside Sabiha Gökçen International Airport's domestic flights lounge, where the retail, food, and drink facilities exist near the gate area. The research involves visibility measurements generated by VGA on Depthmap, the isovist measurements of the analyzed nodes on Syntax 2D. The measurements also cover the metric distances to the gates and flight information billboards from each node that cover the entire facility area. The results of the research are tested in SPSS, which consists of the correlation between distance to the *external stimulus of signage*s *and gates* and *passenger frequency* through the nodes.

2 THEORY

The airports are giving the service of transportation, also promise a wide range of secondary activities to the passengers during their waiting time. The activities may be related to the travel; it needs to be at a satisfactory level for the activities that are not related directly to the travel. These activities and facilities show a big variety depending on the airport's type. Wayfinding in airports is often discussed regarding spatial configuration. Arthur and Passini (1992), state that signage usage is more preferred than simplifying the wayfinding activity within the plan layout of the building. In addition, Weisman (1981) implies that the complexity of the environment creates wayfinding problems which become quite critical whenthe user of the building has time management in mind during the spatial navigation. However, the signage and info billboards are planned by architects and airport management, it is implied that many passengers lose time during their wayfinding yet lose a lot of time until their flight inthe terminal. For these cases, the airport managements have the decision of zoning extra employees for the help of wayfinding for the passengers (Dada, 1997).

The impacts of the difficulties in wayfinding are implied in Space Syntax Studies, as the signage problems (Dewar and Mitchell, 1984), the complexity of the plan (Weisman, 1981), (O'Neill, 1991), the dimensional factors of the environment (Best, 1970). These factors are also guide the passenger through the choice making points during their navigation in the terminal. Sarma (2006) also states that the shopping spaces and the choice of the facilities are influenced by the spatial configuration within Space Syntax approaches. Spatial configuration and movement density relationship is also shaping the wayfinding activity (Hillier, 1993). Haq and Zimring (2001) also stated that connectivity and topological depth have a significant impact on wayfinding performance.

The plan complexity which is mentioned as the average number of topological connections per choice point (Inter Connection Density) by Michael O'Neil (1991), again can be considered as another factor in limiting the visual accessibility. Especially in a complex building like an airport with many variables on the user's mind, visual accessibility can be a problem when the accessibility is limited by the plan configuration. Gibson (1950) mentions that if the destination is visually accessible the movement is positively becoming safer in the environment. In this framework, Braaksma and Cook (1980) proposed a relationship between terminal buildings that stated as a node-link network and visibility characteristics between the specified nodes, and they implied that the low visibility measures create wayfinding problems in terminal buildings within a sightline analysis inside a node-link network as a visibility index.

On the other hand, Benedikt's (1979) research on isovist and isovist fields provides the knowledge of the spatial configuration distinguished by the facts of the visual capability of thesight from a vantage point. Regarding the contributions to isovist studies, this research seeks to acknowledge the isovist measurements and spatial configuration relationship within a specific complex building, an airport as a case study area.

The external stimulus (Fewings, 2014) is defined as the external factors that trigger the human senses of hearing, smell, etc., also the non-spatial information that is determined as info signs, arrows, flight info billboards is also considered as impacts of the wayfinding activity. In this regard, the facility services of food and drink, the retail shop smells, or colors, and flight info billboards are takenas non-spatial information in the research to investigate the general influence of attractors on passenger behavior in the selected area. Yet, when the passenger is a novice user, some airportscan be a real struggle for the passenger (Hölscher, 2006) when trying to find the way for the firsttime within the spatial environment and aggregated attractors. Regarding the syntactic research on spatial configuration and passenger activity, this study is structured to investigate this activity, within the capabilities of sight and spatial layout perspective. For this exploration, isovist measurements in an airport environment are established to achieve a relationship with the passenger flow and facility choices.

3 DATASETS AND METHODS

This research is structured in two main analyses of the space. First, the spatial configuration and visibility characteristics are tried to be identified within the syntactic analysis. The spatial layout and syntactic information are converged with behavioral data which is obtained by on- site observations and actual human counts. The research also seeks a correlation between syntactic measures and behavioral patterns of the human flow; therefore, the collected data is tested in SPSS for statistical accuracy. The data collected from observations and spatial layout relationships are interpreted in terms of human aggregations and secondary attractors of the airport's spatial environment.

The domestic flights area as a case study zone is structured into two main corridors that lead to gates and food/drink facilities. The area starts just after x-ray and security check; therefore, thefacilities cannot be used by common area users or international flights passengers. The domestic flights area includes food and drink facilities, takeaway kiosks, retail shops e.g., gifts and clothing. The research's aim here is to find out the main attractors of human movement through the space in relation to individuals' decisions on facility choices and other attractors such as smoking terraces, distance to gates, or the flight information signs as billboards. According to these specific attractors, the passenger behaviors are observed and interpreted with spatial layout's syntactic characteristics.

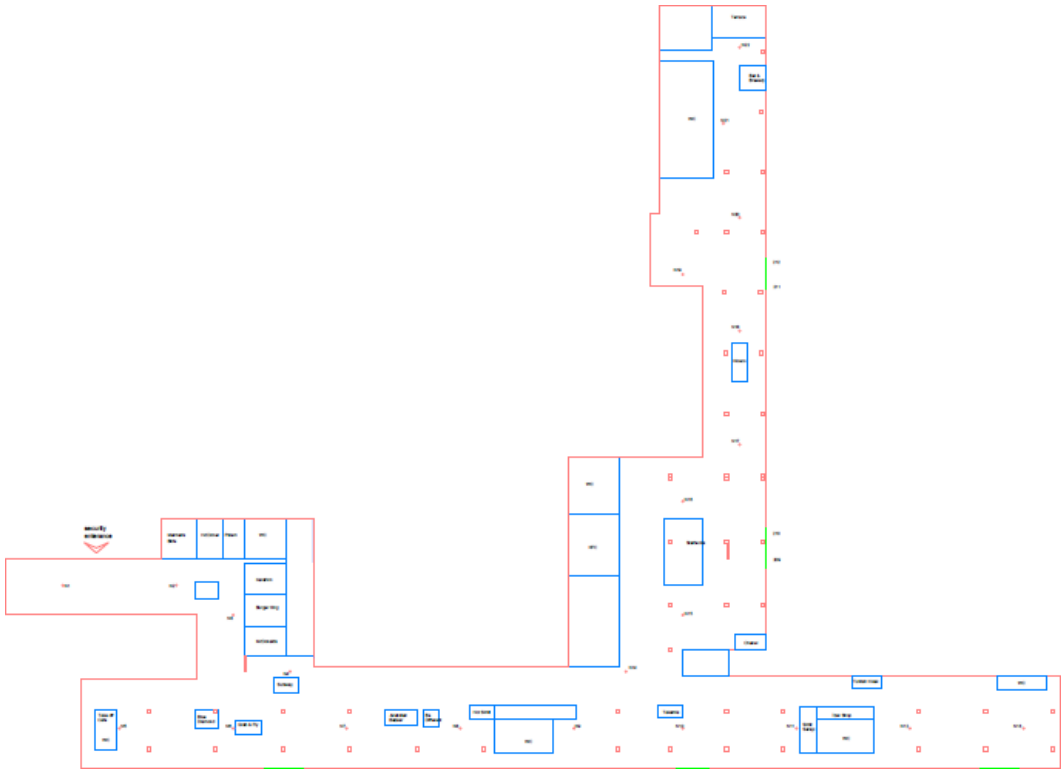

Figure 1. General layout of the domestic flights area

Figure 2. Visible areas and occlusions in the spatial structure

The main area's CAD drawing is reduced to only visible areas and boundaries for syntactic analysis. The facility walls with glass and mid-height walls are added into the visible area for accurate isovist analysis.

The syntactic analysis of the space is distinguished within a grid layout to fully cover the space for the observations and each intersection point with thirty meters is selected as twenty-two nodes are analysed researched within syntactic, metric, and behavioral aspects.

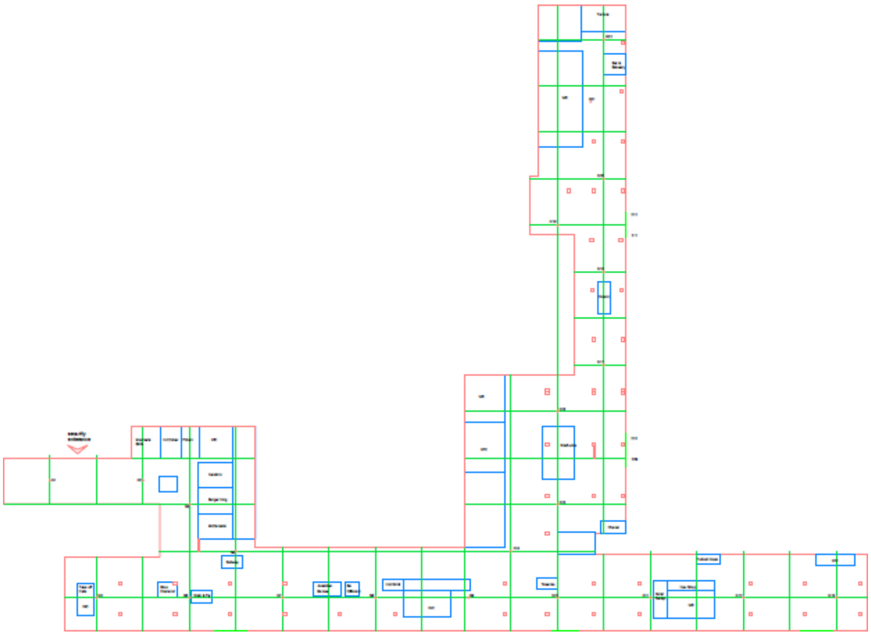

Figure 3. Grid layout and nodes used for analysis

The syntactic measures that are used in the analysis of the nodes:

-Area

-Perimeter

-Circularity

-Connectivity

-Occlusivity

-Variance

-Openness (specific calculation for each node's point isovist as a reference to Wiener; Franz, 2005)

The metric data is calculated from each node.

-Distance to gates

-Distance to flight information boards

The spatial measurements and human frequency at nodes (whole passenger frequency that coversthe four (4) grid squares around the node for 360° interpretations of the isovist from node's vantage point. The table below shows each measurement and passenger frequency within the environment. The isovist measurements are used as mean values of each node. The method for each grid area is based on the entire grid area's mean value of syntactic measurements also the passenger frequencyfor each node.

The main and secondary flight information boards and gate numbers are distinguished with metric distances because they require direct navigation through the spatial structure as independent variables. Table 1 shows the syntactic and metric data for each node, and the human frequency.

NODE	DISTANCE TO BILLBOARD	DISTANCE TO GATE	MEAN PERIMETER	MEAN AREA	MEAN CIRCULARITY	MEAN CONNECTIVITY	MEAN VARIANCE	MEAN OCCLUSIVITY	FREQUENCY OF PEOPLE
node 1	4.2	50.1	243.74	1121.27	52.98	124	20.29	0.582	15
node 2	3.8	37.5	374.52	1447.89	96.87	163	14.96	0.52	27
node 3	1.4	12.7	418.18	3645.72	176.4	203	26.76	0.41	57
node 4	2.3	5.2	1026.62	2578.46	408.75	278	92.93	0.17	42
node 5	10.8	11.6	1080.35	1384.14	843.26	145	38.65	0.163	44
node 6	8.2	4	875.35	2056.67	372.57	218	53.3	0.24	29
node 7	8	5.8	888.45	2108	374.45	217	27.8	0.285	14
node 8	15	13.3	626.79	2328.37	540.12	129	7.29	0.49	51
node 9	6.6	6.6	775.25	1763.22	340.86	172	34.6	0.22	16
node 10	4.9	5.2	618.61	1542.5	248.09	205	27.4	0.33	28
node 11	3.8	3.8	708.11	1510.35	331.99	164	40.9	0.24	18
node 12	4.6	1.8	392.19	1426.43	107.83	156	11.4	0.445	9
node 13	11.2	1.8	670.59	1502.96	178.2	156	27.6	0.29	7
node 14	8.4	12.2	1482.1	3752.09	585.43	420	76.8	0.19	34
node 15	9.3	3.5	1298.56	2772.64	608.18	311	52.7	0.13	45
node 16	7.6	4.9	534.61	1683.22	169.79	180	18.9	0.29	32
node 17	4	3.4	910.06	2125.04	389.74	255	44.8	0.1719	22
node 18	1.6	3.5	770.25	1755.75	122.8	128	42.7	0.2	19
node 19	7.8	4.1	258.28	1300.62	51.29	101	17.8	0.66	13
node 20	1.8	3.1	763.75	1360.81	428.66	155	34.3	0.19	23
node 21	6.1	10.6	681.15	1603.13	571.3	175	54.8	0.209	25
node 22	13	18.2	693.77	1552.51	310.03	131	35.8	0.21	31

Table 1. Measurements and passenger count for each node

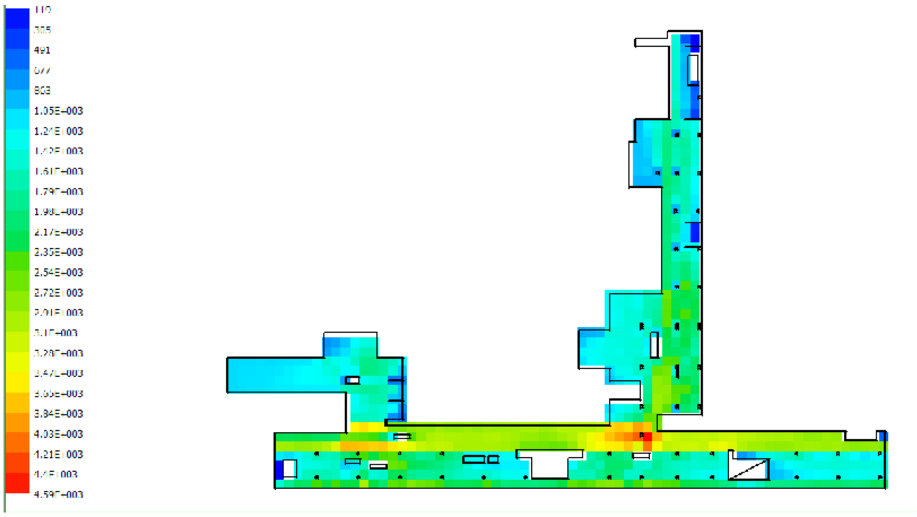

Figure 4. Isovist area graph (Syntax 2D)

The field graph of isovist *area* describes that the connection point of two main corridors of gates has the maximum level of the visible area (node 14). However, the lowest values of isovist area located at the one edge of the space, this area leads the passengers to two distinct attractors: wc zone and smoking terrace. This area of the space has the lowest values of visibility measures, yetit is crowded regarding these secondary attractors.

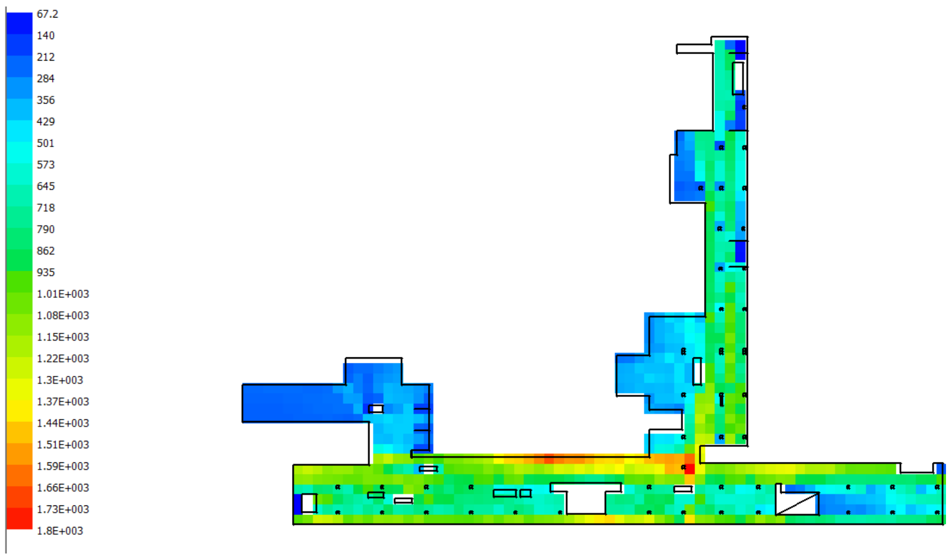

Figure 5. Isovist perimeter graph (Syntax 2D)

Isovist *perimeter* values, imply that the entrance area of the domestic flights has the lowest valueof isovist perimeter, because of the closed security area and the escalator blocking center of thespace. In this respect, people tend to pass the escalators to have higher control o f their sight,therefore, the food facilities around this area have the lowest number of people according to the observations.

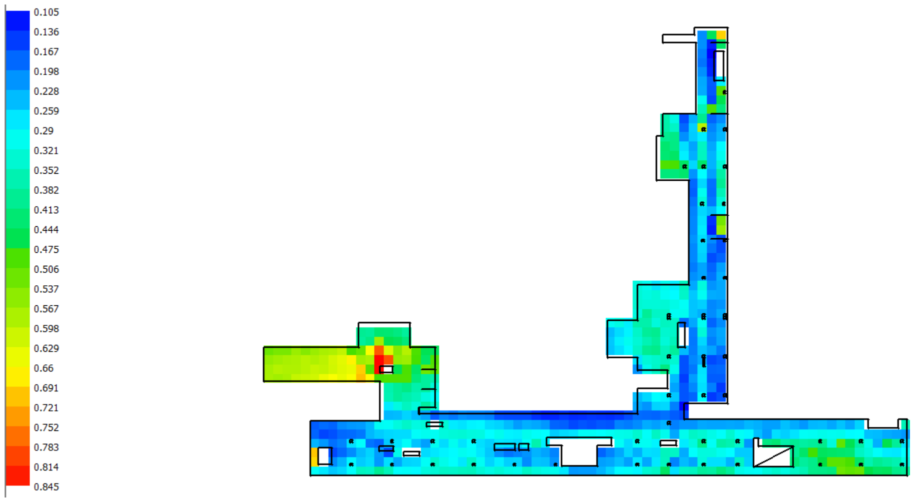

Figure 6. Isovist occlusivity (Syntax 2D)

Occlusivity values show that the main occlusion created by the spatial structure is the main escalator in front of the food facilities. According to the graph, the red value indicates the highest level of occluded radial boundary, therefore, the main corridors of the flight area have lower values of occlusivity which gives the passenger more visual control of the area. The flight information billboards are also placed in the areas which have lower values of occlusivity to catch the passenger's attraction on a linear route.

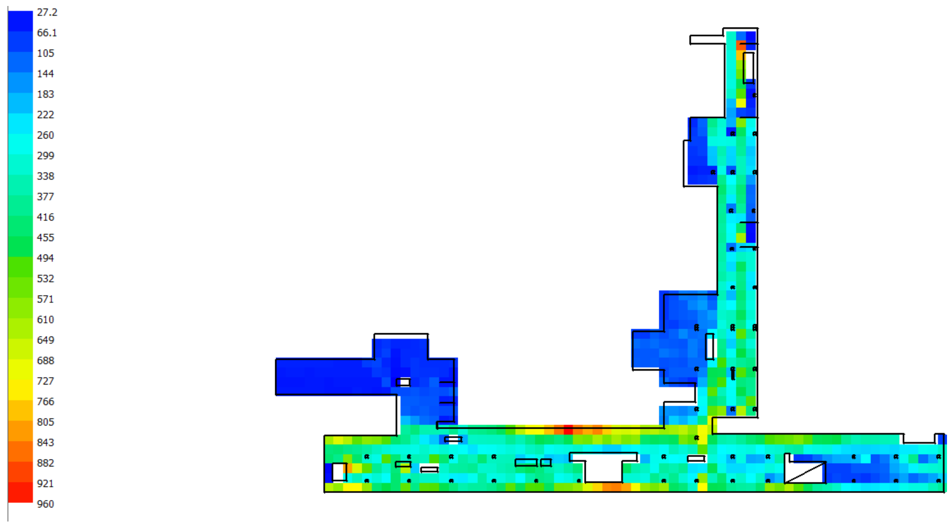

Figure 7. Isovist circularity (Syntax 2D)

Circularity values of the space, is depending on the mean radial length and the isovist area todetermine how much the area is approaching into a circle which is directly related with compactness and complexity (Benedikt, 1979) The highest value of circularity is expected to have higher number of human flow because of the shape of the environment, it is observed that thelargest visible counter for food/drink facilities are placed at areas with highest values of circularity to attract more people during their movement.

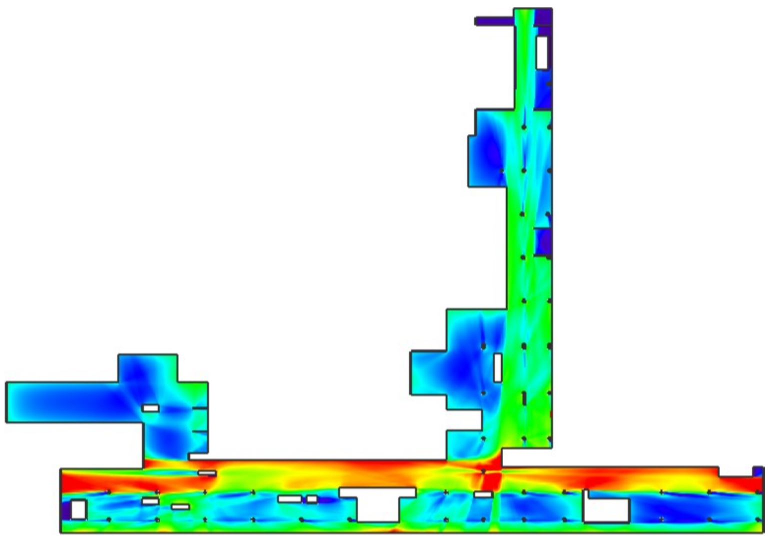

Figure 8. Variance measurement of the field isovist (Isovist.2.4)

Variance is defined as the mean of the square of deviation between all radial lengths and averageradial length of an isovist (Benedikt, 1979). The highest value of variance measures may indicate the complexity or the skewness of the isovist. According to the passenger frequency at highervalues of variance, people are aggregating through the nodes with higher mean variance levels, but not overall isovist area from that vantage point.

Openness is referred as the ratio of open and closed edges of the isovist. In this study, closed edges as counted as the visible walls or boundaries, open edges are defined as the isovist's own occlusions (Turner, et al. 2001), (Wiener; Franz, 2005). The openness values of each node are calculated and the total number of people inside the whole isovist from the vantage point, rather than the frequency of people only in each node. The value of the openness is generated with the actual isovist vertices lengths; therefore, no mean value is existing in the calculation; the whole human frequency is calculated the total number of people inside of the single isovist area.

Two defined behavioral data are analyzed for this research.

-Number of people inside the node means *all visible areas inside of the node boundaries.*

-Number of people inside the point isovist, that it means *all visible areas inside the isovist boundaries.*

NODE	DISTANCE TO BILLBOARD	DISTANCE TO GATE	PERIMETER	AREA	CIRCULARITY	CONNECTIVITY	VARIANCE	OCCLUSIVITY	OPENNESS	FREQUENCY (node)	FREQUENCY (isovist total)
node 1	4.2	50.1	243.74	1121.27	52.98	124	20.29	0.582	0.42	15	42
node 2	3.8	37.5	374.52	1447.89	96.87	163	14.96	0.52	0.69	27	54
node 3	1.4	12.7	418.18	3645.72	176.4	203	26.76	0.41	1.36	57	138
node 4	2.3	5.2	1026.62	2578.46	408.75	278	92.93	0.17	1.71	42	147
node 5	10.8	11.6	1080.35	1384.14	843.26	145	38.65	0.163	4.89	44	224
node 6	8.2	4	875.35	2056.67	372.57	218	53.3	0.24	2.08	29	160
node 7	8	5.8	888.45	2108	374.45	217	27.8	0.285	2.3	14	166
node 8	15	13.3	626.79	2328.37	540.12	129	7.29	0.49	2.2	51	151
node 9	6.6	6.6	775.25	1763.22	340.86	172	34.6	0.22	3.32	16	174
node 10	4.9	5.2	618.61	1542.5	248.09	205	27.4	0.33	1.4	28	125
node 11	3.8	3.8	708.11	1510.35	331.99	164	40.9	0.24	3.06	18	162
node 12	4.6	1.8	392.19	1426.43	107.83	156	11.4	0.445	0.9	9	76
node 13	11.2	1.8	670.59	1502.96	178.2	156	27.6	0.29	1.58	7	140
node 14	8.4	12.2	1482.1	3752.09	585.43	420	76.8	0.19	2.84	34	169
node 15	9.3	3.5	1298.56	2772.64	608.18	311	52.7	0.13	4.4	45	210
node 16	7.6	4.9	534.61	1683.22	169.79	180	18.9	0.29	2	32	150
node 17	4	3.4	910.06	2125.04	389.74	255	44.8	0.1719	3.27	22	170
node 18	1.6	3.5	770.25	1755.75	122.8	128	42.7	0.2	2.17	19	164
node 19	7.8	4.1	258.28	1300.62	51.29	101	17.8	0.66	1.26	13	113
node 20	1.8	3.1	763.75	1360.81	428.66	155	34.3	0.19	2.62	23	168
node 21	6.1	10.6	681.15	1603.13	571.3	175	54.8	0.209	3.5	25	188
node 22	13	18.2	693.77	1552.51	310.03	131	35.8	0.21	0.14	31	-

Table 2. All metric data, isovist data and behavioural data

4 RESULTS

The research aims to find a relationship between passenger flow in airport domestic flight areas and the human eye's perceptual characteristics within specific attractors in the airport environment. These attractors have been defined as primary attractors e.g., gate entrances, flight information billboards, food/drink/retail facilities, as secondary attractors e.g., lavatory entrances and smoking terraces.

The investigated spatial configuration data and behavioral data are evaluated in SPSS for the accuracy of the comparison. Two distinct data sheets were evaluated on SPSS, and Pearson Correlation test is implemented. According to the first test, the mean of isovist measurements and passenger frequency at selected nodes implies that there is a statistical correlation between passenger activity at nodes and isovist area (r=0,608, p=0,003), isovist circularity (r=0.469, p=0,028) and mean radial variance (r=0.443, p=0,039). The test shows that there is an accurate correlation between isovist area and passenger flow at each node which states that people tend to choose the facilities whichare located at the highest isovist area rather than the highest isovist perimeter. This argument signifies those passengers in the flight area seek not to lose visual control by staying or passing through these zones that have a high level of visual boundaries.

The circularity level correlations also imply that the spatial configuration allows the passenger to flow at distinguished areas which tend to complete a full circle which increases the circulation through the environment. In addition, isovist area and circularity measurements are naturally affected by the shape of the geometry, the food/drink and retail facilities are intentionally located at higher levels of isovist area and isovist circularity to catch the attention of the passengers.

The variance correlation signifies that, again the spatial configuration thus the complexity of the space has an impact on the human flow with the human aggregation at higher levels of mean variance at selected nodes. The variance of the radials is defined by Benedikt (1979) as the second moment of the mean of radial length on and dispersion of the perimeter relative to x, the third moment about the radial length is defined as skewness which implies the asymmetry of the dispersion relative to x, therefore the mean variance correlation with passenger frequency states an accuracy with skewness and complexity of the environment.

Correlations

		PERIMETER	AREA	CIRCULARITY	CONNECTIVITY	VARIANCE	MEAN OCCLUSIVITY	FREQUENCY OF PEOPLE
Frequency of people	Pearson Correlation	0.244	.608**	.469*	0.323	.443*	-0.229	1
	Sig. (2-tailed)	0.273	0.003	0.028	0.143	0.039	0.305	
	N	22	22	22	22	22	22	22

*Correlation is significant at the 0.05 level (2-tailed).

**Correlation is significant at the 0.01 level (2-tailed).

Table 3. First test on SPSS

Second test on SPSS calculates the correlation between metric distance to flight info boards, metric distance to gates, mean perimeter, mean area, mean circularity, measured isovist openness and total number of people inside the isovist area. According to the results, the *distance to gate* has a *negative correlation* with number of the passengers inside the isovist area (r=- 0,620, p=0.003), which implies people are hesitating to leave the gate nearby therefore, they are keeping the visual connection with the gate entrance when they are moving or selecting a facility to rest.

Correlations

		DISTANCE TO BILLBOARD	DISTANCE TO GATE	MEAN PERIMETER	MEAN AREA	MEAN CIRCULARITY	OPENNESS	TOTAL NUMBER OF PEOPLE
Frequency of people	Pearson Correlation	0.231	-.620**	.702**	0.237	.632**	.501*	1
	Sig. (2-tailed)	0.314	0.003	0.000	0.300	0.002	0.021	
	N	22	22	22	22	22	22	22

*Correlation is significant at the 0.05 level (2-tailed).

**Correlation is significant at the 0.01 level (2-tailed).

Table 4. Second test on SPSS

Another result shows that passengers also tend to keep the visual perimeter when the whole isovist area is analyzed. When the nodes were specified *on the grid* and frequency is calculatedonly inside the grid, the results were accurate with the isovist area. But when the point *isovist* is analyzed, isovist perimeter has an impact on the general layout.

Isovist openness values show a significant correlation with the total number of people in the isovist area (r=0,501, p=0.021). The physical enclosure of the environment on each isovist decreases the openness value also might be correlated with jaggedness measurements. Therefore, according tothe results, passengers seem to locate at visually open areas rather than physically enclosed areas.This signification might be influenced by the locations of the flight info boards, inherently people want to see the flight information to get in the queue for the plane, thus, the locations with lower openness value are not suitable for the visual comfort related with the eye contact with the information board from a distance.

5 CONCLUSIONS

This study comprises an interpretation of passenger activity inside an airport environment. The passenger activities are observed within the spatial configuration of the space and the visibilityaspects of the human-environment relationship. Airports provide many functions besides the main function of the transportation building, such as the food/drink facilities for the free time until the flight, take away kiosks for passengers with more limited time, smoking areas, and lavatories. The navigation through the flight area and the whole airport, in general, is mainly dictated by the infosigns, flight information billboards, and airport employees that guide the passengers. This research focuses on the passenger flow characteristics inside a flight area with food/drink and other facilities within the syntactic and behavioral aspects.

According to the findings, people at transportation buildings seem to get influenced by the attractors of the environment like flight info boards or gate doors and by the facility distribution around the whole spatial structure. The syntactic values imply that isovist measurements like; area, circularity, variance, and openness have a significant impact on passenger behavior inside the airport environment. Also, the distance from gates distinguishes a correlation with the human frequency from specific nodes within their isovist area. Another result shows that spaces like smoking terraces are demanded a lot by many passengers but locate only in a small and distinct space, that location behaves like a significant attractor in that area. As a result, many variables have an impact on the passenger behavior in the airport environment, in this research, this relationship is investigated through space syntax context with isovist measurements and behavioral aspects.

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