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AN EXAMINATION OF THE IMPACT OF THE SPATIAL LAYOUT OF MARKET STALLS ON THE QUALITY OF THEIR VISIBILITY USING ISOVIST FIELD: A COMPARATIVE ANALYSIS

Abstract

City markets attract people with their content. Whether this content will be visually perceived depends on its exposure to users. It is generally known that users naturally gravitate towards spaces that are clear and easy to navigate. Visual-spatial quality is therefore one of the main characteristics of such city spaces, which are often overlooked in the design process, and it is necessary to work on their improvement. The purpose of this research is to make a contribution in terms of the possibility of incorporating visibility analysis into the decision-making process in city markets design by using isovist fields to evaluate their visual-spatial configurations.

Keywords: isovist, visibility, comparative analysis, spatial layout

ИСПИТИВАЊЕ УТИЦАЈА ПРОСТОРНОГ РАСПОРЕДА ПИЈАЧНИХ ТЕЗГИ НА КВАЛИТЕТ ЊИХОВЕ ВИДЉИВОСТИ КОРИШЋЕЊЕМ *ISOVIST* ПОЉА: КОМПАРАТИВНА АНАЛИЗА

Сажетак

Градске пијаце привлаче људе својим садржајем. Да ли ће тај садржај бити адекватно визуелно перципиран зависи од његове изложености корисницима. Опште је познато да корисници природно гравитирају ка просторима који су прочишћени и једноставни за сналажење. Визуелно-просторни квалитет је једна од главних карактеристика оваквих градских простора, који се у процесу пројектовања често занемарују, те је неопходно радити на њиховом унапређењу. Сврха овог истраживања је давање доприноса у смислу могућности инкорпорирања анализе видљивости у процес доношења одлука у пројектовању градских пијаца коришћењем *isovist* поља за евалуацију њихових визуелно-просторних конфигурација.

Кључне ријечи: "isovist", видљивост, компаративна анализа, просторни распоред

1. INTRODUCTION

The shape of the market building floor plan, which implies the dimensions of the building, but also the dimensions and arrangement of the market stalls, affects visibility. In other words, the design of the shape of the circulation space can improve the visibility of the stalls to customers, and thus the conditions of their purchase. However, the "shape" is not explicitly defined in the visibility literature. The shape is a general term and can be referred to different layout properties. The visibility literature does not offer any quantified measures to evaluate how a floor plan determines visibility, especially not for facilities such as cities markets.

The computerized 2D abstraction of possible visual perceptions at the observer's position, or isovist, was developed by Benedikt and Davis [1]. Michael Benedikt defined an isovist as "the set of all points visible from a single vantage point in space with respect to an environment" [2]. He introduced a set of analytical measurements of isovist properties for the purpose of quantitative descriptions of spatial environments. Benedikt begins by considering the volume visible from an observer's location and then simplifies this representation by taking a horizontal slice through the "isovist polyhedron". The shape and size of an isovist are liable to change with the observer's position. Benedikt further notes that, in order to quantify a whole configuration, more than a single isovist is required, which led him to formulate the "isovist field" of his measurements [2]. Isovist fields record a single isovist property for all locations in a configuration using contours to show how these features vary through space [3].

The aim of this paper is to examine the impact of the spatial layout of market stalls within market buildings on their perceptibility by the users, which in this paper is called visibility. Two specific city markets were selected for the study - Limanska Market and Futoška Market, which are the most commonly visited markets in Novi Sad. They are best supplied with agricultural products and various goods and accordingly, they are considered one of the busiest places in Novi Sad. A comparative visibility analysis for the existing and experimental spatial distribution of stalls in these markets was performed. Visibility analyses were performed using Grasshopper within the Rhinoceros.

2. METHOD

In this paper, the inner spaces of the two city markets are converted into "isovist fields" in the computational analysis to examine the visual qualities of these spaces. Grasshopper provides an isovist component that computes the 2-dimensional single isovist. Although a 3-dimensional representation of visible space can be calculated, due to the speed of calculation in architectural analyzes, the calculation of isovist is most often used as a 2-dimensional one. The single isovist is computed by projecting a series of vectors from the point and observing where the vectors intersect with geometry in the space. These points of intersection are being connected to each other to form the total area of visible space. Among the many possible attributes of a ground plan [2], this article focuses on three measures: area of visual fields, convexity and circularity.

- Area of visual fields (isovist area) expresses the surface of all space visible from all vantage points in the plan. In the isovist literature, distance from an observer's location to a point in the isovist boundary is called a radial. To obtain isovist area size, measured as the square meter area of the isovist polygon, the isovist component breaks the isovist into a number of simpler shapes, such as polygon triangulation. The sum of the area of these simple shapes gives the area of the isovist. The control of the number of simple shapes, that is the accuracy of the calculation, is possible by determining the number of radials. Isovist area evaluates the spacious or narrow qualities of a place. In a narrow area, shorter radials are available to the observer's position producing a sense of insecurity, and vice versa [4]. Each isovist will have its own area value, and the merging of the areas of these surface shapes generated from each point gives the total area of the visual fields.
- Convexity assesses whether the isovist has a convex shape at the generating place [3]. An isovist with convexity equal to or approximate to 1 is more integrated and usually refers to places with regular shape. On the contrary, an isovist with convexity close to 0 has more occluding edges, and such places tend to be fragmented.
- Circularity estimates the roundness of space. An isovist with higher circularity indicates it is more compact and closer to a round shape [5]. The circularity also ranges from 0 to 1. An isovist with circularity close to 0 reflects elongated space, while an isovist with circularity close to 1 represents spaces that have similar radial lengths.

These measures are shown to be among the indicative ones in relation to the visibility of architectural or urban spaces by several studies [6-8]. In addition, they correlate well with a number of other geometric values [9] such as perimeter and connectivity (correlate with the area), dispersion (correlates with circularity), etc.

The isovist fields are applied and analyzed firstly on the existing layouts of market stalls of two city markets – Limanska Market and Futoška Market in Novi Sad. These markets have approximately similar surface sizes, but different shapes, as well as a different number of market stalls and ways of setting them up. The percentage of area occupied by market stalls at the Limanska Market is 23,54% and at the Futoška Market 18,41%. After analyzing the current situation, an experimental scenario was performed where the approximate shape of the layout of the Futoška Market was applied to the floor plan of the Limanska Market, and vice versa. In both cases, the existing number of stalls was retained, and thus the existing percentage of occupied space. The aim of using the experimental scenario is to show that a change in the visual-spatial quality of the market space, which is caused by a change of the layout of the stalls, is measurable. In that sense, additional work could be done on its optimization.

3. RESULTS AND DISCUSSION

Visibility analysis using isovist fields involves generating a regular network where isovist is calculated for each point in this network. The properties of these multiple isovists can then be represented by giving different colors to the grid points. For this work, a grid cell size of 0.1m was adopted and it has been used in all analyzes. In each field of the grid, one central point is defined as a vantage point from which the isovist area is measured. Based on the obtained values, each field of the grid is assigned with a certain color. Points that are closer to blue in visualization results in this paper refer to low values of the isovist area measured by square meter, and points that gravitate to red refer to high values. Other input parameters, such as viewing range, viewing angle and precision, are required to run isovist analysis. The adopted value for viewing range is 50 m, for the viewing angle 360 degrees and for the precision 360 radial rays. Figures 1 and 2 show the results of the analysis for the isovist area property of the existing condition of the Limanska and Futoška markets, respectively. Figure 3 shows the results of the analysis for the isovist area property for the new layout of stalls of the Limanska Market modeled on the existing layout of the Futoška Market.

Figure 1. *The results of the analysis for the isovist area for the existing layout of the Limanska Market measured in square meters*

Figure 2. *The results of the analysis for the isovist area for the experimental layout of the Futoška Market measured in square meters*

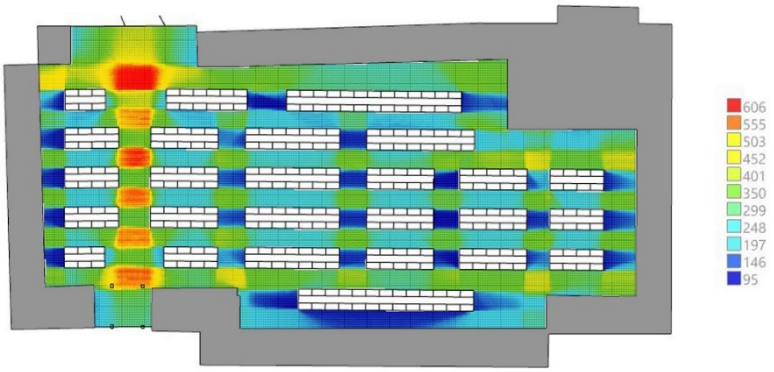


Figure 3. *The results of the analysis for the isovist area for the existing layout of the Limanska Market measured in square meters*

By the same logic, Figure 4 shows the results of the analysis of the isovist area property for the new layout of the stalls of the Futoška Market modeled on the existing layout of the Limanska Market.

Figure 4. *The results of the analysis for the isovist area for the experimental layout of the Futoška Market measured in square meters*

To evaluate a spatial configuration based on isovist fields we used average values (μ), the standard deviation (σ), as well as the coefficient of variation (CV) of the three selected isovist properties: isovist area, convexity, and circularity. Table 1 shows the existing and new results for the Limanska Market, and Table 2 provides the same data for the Futoška Market.

Table 1.Results of analysis for the existing and the experimental layout of market stalls at the Limanska Market

Limanska Market	**Existing layout**			**Experimental layout**		
	μ	*σ*	*CV*	*μ*	*σ*	*CV*
Isovist area (m^2)	179,8672	75,5044	0,4198	296,4935	100,1461	0,3378
Convexity	0,3610	0,1747	0,4839	0,4493	0,1754	0,3905
Circularity	0,4159	0,1131	0,2720	0,4403	0,2165	0,4918

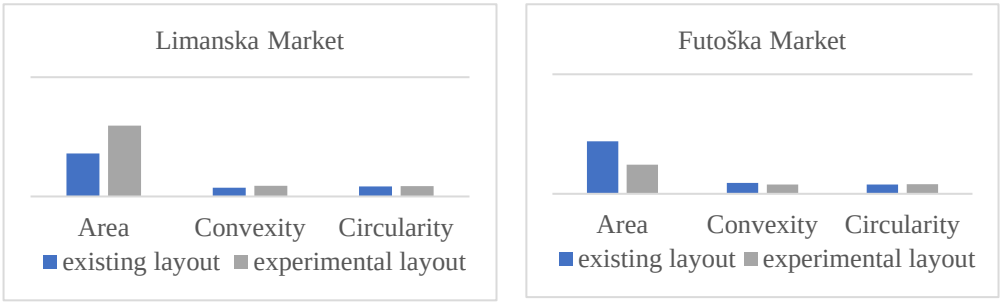
Table 2.Results of analysis for the existing and the experimental layout of market stalls at the Futoška Market

Futoška Market	**Existing layout**			**Experimental layout**		
	μ	*σ*	*CV*	*μ*	*σ*	*CV*
Isovist area (m^2)	220,2232	79,0899	0,3591	121,3204	57,3507	0,4727
Convexity	0,4565	0,1849	0,4050	0,3893	0,1799	0,4621
Circularity	0,3894	0,1278	0,3283	0,3973	0,1143	0,2877

According to the data from the tables, it is noticeable that there are differences in the results for the existing and experimental layout of the market stalls. The results of the analysis for the Limanska Market show a significantly higher value of the isovist area in the experimental layout compared to

the existing one. The data that additionally speaks in favor of this improvement is the coefficient of variation of the values of the isovist area of the experimental layout which is 0.8 times less than the variability of the values of the isovist area of the existing layout. A lower coefficient of variability indicates smaller deviations of all analyzed values from the mean value. Convexity for the experimental layout was increased 1.2 times compared to the existing one, also with reduced variability. For circularity at the experimental layout, it can be stated that it has retained approximately the same value, with a slight decrease of 0.94 times.

The results of the analysis for the Futoška Market show a decrease in the values of isovist area and convexity in the experimental layout of 0.6 and 0.9 times, respectively. This was followed by a simultaneous increase in variability of 1.3 and 1.1 times for mentioned visual properties, respectively. When it comes to circularity, it can be stated that there was a slight increase of 1.02 times in the experimental layout. Figure 5 shows a comparison of the results between the Limanska and Futoška markets for all three analyzed attributes



a) *b)*

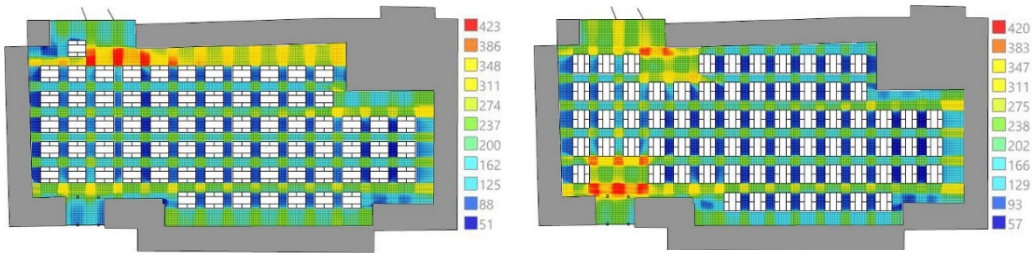
Figure 5. *The comparison of the results of the mean values of the area, convexity, and circularity between the existing and experimental layout for a) the Limanska Market b)the Futoška Market*

Based on the results of the comparison it can be concluded that the existing layout in the Futoška Market has better characteristics in terms of isovist area and convexity. On the other hand, the visual characteristics of the Limanska Market were improved by the experimental layout of the stalls regarding isovist area and convexity. Differences in circularity values were found to be negligible in both analyzes. To summarize, the existing layout of market stalls at the Futoška Market is better compared to the layout at the Limanska Market in relation to the analyzed visual characteristics. A visual simulation of each of the three attributes calculated for each layout takes approximately 120 seconds.

In addition, an analysis of different layouts with a different grouping of market stalls was conducted on the example of the Limanska Market. We considered three situations in which the stalls were first grouped in pairs next to each other in a row, then four in a row, and finally eight in a row. Since the stalls require functional space for the vendors, it was decided to overlap the functional spaces of the formed groups, so that the rows of stalls were placed in parallel. Thus, clusters of four, eight, and sixteen stalls were obtained, which define the shape of the circulating space. By overlapping the functional spaces of the stalls the circulating space is increased.

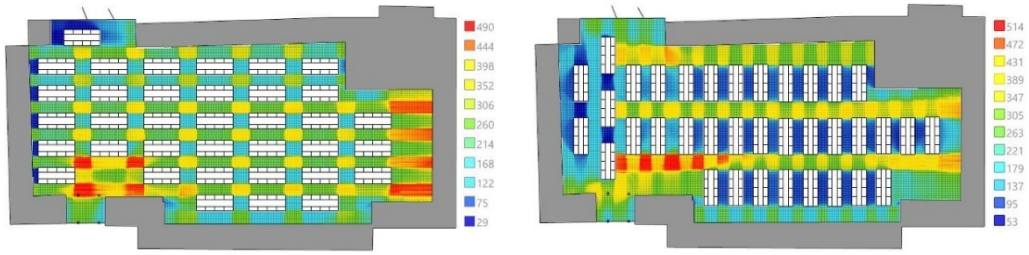
Apart from grouping the stalls, their orientation was also taken into account. They were placed first in the east-west direction, and then in the north-south direction. Thus, six layouts for three groups of stalls were obtained and analyzed. A total of 288 stalls were used for all six examples. This number of stalls could not be organized individually (without grouping) with a functional space between them. Visibility analyzes were performed with the same input parameters as previously performed and described analyzes.

Figures 6, 7, and 8 show the results of the analysis of the isovist area property for the layouts composed of the market stalls grouped by two in a row, four in a row, and eight in a row, respectively with two types of orientation.



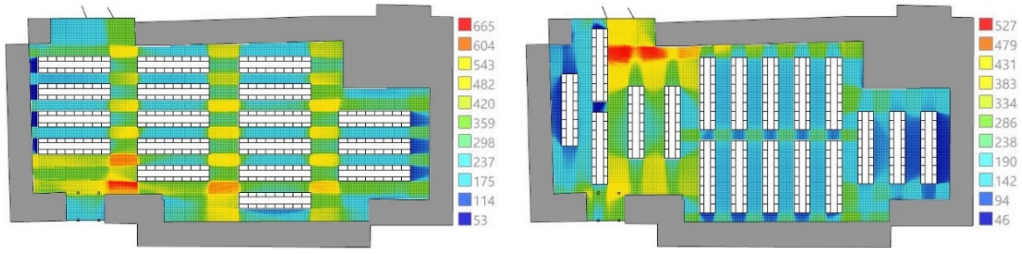
a) *b)*

Figure 6. *The results of the analysis for the isovist area measured in square meters for the layout composed of rows of 2 stalls at the Limanska Market with a) an east-west orientation b) a north-south orientation.*



a) *b)*

Figure 7. *The results of the analysis for the isovist area measured in square meters for the layout composed of rows of 4 stalls at the Limanska Market with a) an east-west orientation b) a north-south orientation.*



a) *b)*

Figure 8. *The results of the analysis for the isovist area measured in square meters for the layout composed of rows of 4 stalls at the Limanska Market with a) an east-west orientation b) a north-south orientation.*

Table 3 shows the results obtained for all six layouts. Since the differences in values of convexity and circularity are insignificant compared to the differences in values of the isovist area, only the values for isovist areas are shown in the table for easier comparison.

Table 3.Results of isovist area analysis for the six layouts of differently grouped and oriented market stalls at the Limanska Market

Isovist area (m^2)	**East-west orientation**			**North-south orientation**		
	μ	σ	*CV*	μ	σ	*CV*
Groups of 2 stalls in a row	196,6031	78,6031	0,3998	194,9475	77,4199	0,3971
Group of 4 stalls in a row	259,2570	92,0482	0,3550	250,2087	111,1209	0,4441
Group of 8 stalls in a row	324,0892	110,5334	0,3411	218,7052	97,0380	0,4437

According to the data from the table, it is noticeable that there are differences in the results for all six layouts. The difference between east-west and north-south-oriented layouts is insignificant in the first case, for a group of 2 stalls in a row, but it is noticeable that it increases with the number of grouped stalls. In all three cases, the east-west orientation showed better isovist area results which

can be related to the larger dimension of the market building which is in the same direction. On the other hand, the increase in the number of grouped stalls has also led to an increase in the value of the isovist area. This can be explained by the larger interspace that occurs when the stalls are joined in a row. This analysis confirms the assumption that different grouping of stalls, their orientation, as well as the shape and width of the interspace, have an impact on visibility results. These results can be further improved because there are numerous possibilities for grouping stalls as well as their mutual combinations.

4. CONCLUSION

The results presented in this paper show that the applied approach is highly applicable for improving visual qualities of the inner space of the city market. It has been shown that the ability of the isovist analysis as a tool to examine how to set up market stalls and to help make decisions when choosing layout is justified.

The visibility analysis presented in this paper refers only to the 2D environment, but since market stalls generally have the same uniform heights, in this paper, this should not be understood as an essential limitation. There are other limitations in the research that should be mentioned. The paper does not take into account social and dynamic aspects such as the presence and movement of people, which can also be an obstacle to perceiving space depending on the extent to which it is occupied.

This research primarily studied impacts of the overall shape and layout of market stalls on visibility at every point of space for customers. Additional design parameters which could have an effect on the quality of visibility should be identified and studied, such as: the shape and width of circulation space between market stalls; dimensions of the exhibition parts of the market stalls; possible positions of observers during movement through space; the position and the distance between stalls with the types of products that are likely to be purchased during the same visit to the market, and similar.

Future studies are encouraged to examine the use of isovist analysis as a tool that can contribute to improving the quality of visual characteristics in architectural and urban environments.

ACKNOWLEDGEMENT

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