EVALUATION OF STREETSCAPE COMPLEXITY CREATED BY STREETSCAPE SIGNAGE USING DIFFERENT OBJECTIVE ANALYSIS TECHNIQUES

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Abstract: This research was conducted to measure the streetscape complexity created by streetscape signage. Four objective analysis techniques; Shannon entropy, Simpson Index, Gini Coefficient, Fractal Dimension analysis and human visual perception (subjective measurement) were used as the measurement tools of visual complexity created by streetscape signage. The perspective views of hundred urban streetscapes with commercial and public signage from the Colombo Municipal Council area were displayed to a group of subjects and their perception of the complexity due to signage was identified. Meanwhile, the objective measurements were undertaken. The variety and the number of streetscape signage available along either side of the streetscapes were used for the Shannon entropy and the Simpson index calculations. The number of visual elements available in each signage along the streetscapes was used for Gini Coefficient calculations while the monochrome perspective views were applied for the Fractal Dimension analysis using the Fractalyse software. Finally, the results of the subjects' perception and the objective analysis methods were compared. According to the comparisons, the result of the Gini coefficient was more equivalent with the human perception. While the Shannon entropy and the Simpson Index calculations showed minor deviations, and the result of the fractal dimension analysis was not compatible with the human perception.

Keywords: visual complexity, streetscape signage, subjective analysis, objective methods, urban landscape

Introduction

Visual complexity is an important concept of our urban life. Travelers and the residents of a city often feel the visual complexity in streetscapes as well as everywhere in the city. Visual complexity is a direct consequence of the spatial distribution of the streetscape elements and is concerned with perception and cognition of the information. In environmental psychology, complexity is related to the involvement component, which means: "how much there is to see in a visual array?", and to the concept of affordance that refers to what a perceived scene has to offer as far as the perceiver is concerned (Kaplan, 1988). There are lots of ways to explain visual complexity; however, there is no fixed definition for the visual complexity since it is a subjective phenomenon. The most frequent question is the level of visual complexity which is tolerable to viewers while creating a pleasant environment to the city. This has been the subject of series of researches dealing from the physical aspects of the urban environment to its social dimension. This research is another attempt of measuring visual complexity using different objective and subjective analysis methods and a comparison among them to find out the best complexity measurement method for the urban residential streetscapes in Colombo district Sri Lanka.

Streetscape is a key element of townscape because of its substance that creates the city's attractiveness and affects the pedestrians' comfort (Ashihara, 1983). Streetscape is a combination of several profiles such as the sky, ground, buildings, vegetation, and pedestrian behaviors on the street. Therefore all these profiles are

contributing to the streetscape visual complexity. Physical complexity of streetscapes could be defined and measured by analyzing physical attributes of the streetscape. However, streetscape visual complexity is a complex phenomenon and defining visual complexity is somewhat difficult task since it is basically a subjective experience. Perceiving visual complexity is different person to person based on their personal views and expectations. Thus defining and measuring visual complexity becomes difficult. Most of the time visual complexity measurements were undertaken subjectively using surveying techniques. In this paper, an attempt was carried out to compare the subjective judgments on visual complexity of streetscapes created by streetscape signage with four objective measurement techniques such as Shannon's entropy, Simpson index, Gini coefficient and fractal dimension analysis.

There are lots of methods to measure visual complexity. In this study, the human perception is considered as the most accurate judgment on the visual complexity, since the human is the focal point. In literature there are different kinds of objective analysis methods. In this study, the main objective is to find out the most suitable objective analysis method, which is compatible with human perception to measure the visual complexity created by streetscape signage. With this objective, four most popular visual objective analysis techniques were selected to compare with the human perception. A brief introduction for each objective analysis method is given below.

Shannon's Entropy

The visual complexity can be measured using different types of indices. One of such indices is the Shannon's diversity index where it is also known as the Shannon Weaver index and the Shannon entropy. The measure was originally proposed by *Claude Shannon* to quantify the *entropy* (uncertainty or information content) in strings of text. The idea is that the more different letters there are, and the more equal their proportional abundances in the string of interest, the more difficult it is to correctly predict which letter will be the next one in the string (Regen, 1990). The Shannon entropy quantifies the uncertainty (entropy or degree of surprise) associated with this prediction. It is most often calculated as follows:

$$H' = -\sum P_i \ln P_i$$

P_i is often the proportion of individuals belonging to the i th landscape type in the landscape of interest. Subsequently the Shannon entropy quantifies the uncertainty in predicting the identity of an individual landscape that is taken at random from the whole landscape.

In this research, P_i is considered as the number of individuals belonging to the i th visual element of the streetscape signage.

e.g. P_i - The number of signage

i - The visual element, the shape of signage

Assumptions of the Shannon's entropy

If the entropy value of a signage is high, the contribution of that visual element to the streetscape visual complexity becomes high.

If a streetscape has a high overall entropy value, the visual complexity of that streetscape is high.

Simpson Index

The second method applied in the study is Simpson index. The Simpson index was introduced in 1949 by *Edward H. Simpson* to measure the degree of concentration when individuals are classified into types (Simpson, 1949). The measure equals the probability that two entities taken at random from the dataset of interest represent the same type. It equals:

$$\lambda = \sum_{i=1}^R p_i^2$$

Where, p_i is the type of interest.

If the dataset is small, and sampling without replacement is assumed, the probability of obtaining the same type with both random draws is:

$$l = \frac{\sum_{i=1}^R n_i(n_i - 1)}{N(N - 1)}$$

Where n_i is the number of entities belonging to the i th type and N is the total number of entities in the dataset.

For this research, the second version of the equation was applied. Since the idea is to measure the visual complexity, n_i is considered as the number of elements under a particular signage and N is the total number of signage considered in the study. The inputs are same as the Shannon's entropy.

Assumptions of the Simpson index

If a streetscape has a low overall Simpson index value, the visual complexity of that streetscape is high.

Gini Coefficient

The third method applied in the study is Gini coefficient analysis. The Gini coefficient measures the inequality among values of a *frequency distribution*. A Gini coefficient of zero expresses perfect equality, where all values are the same. A Gini coefficient of one (or 100%) expresses maximal inequality among values (for example, where only one person has all the income or consumption, and all others have none). (UNDP, 2012).

The Gini coefficient is the ratio of the area that lies between the line of equality and the Lorenz curve (marked A in the diagram) over the total area under the line of equality (marked A and B in the diagram). The Lorenz curve is given in figure 01.

Figure 01: Lorenz Curve for Gini Coefficient Calculation

Assumptions of the Gini coefficient

Gini Coefficient 0 – all signage of the streetscape with similar complexity

Gini Coefficient 1 – maximum inequality of complexity among different signage of the streetscape

Fractal Dimensions

The forth objective analysis method is the fractal dimensions. The term fractal dimension itself was brought to the fore by *Benoit Mandelbrot* based on his 1967 paper on *self-similarity* in which he discussed fractional dimensions. A fractal dimension is a ratio providing a statistical index of *complexity* comparing how detail in a *pattern* (strictly speaking, a *fractal* pattern) changes with the *scale* at which it is measured. Fractal dimensions are used to characterize a broad spectrum of objects ranging from the abstract to practical phenomena, including turbulence, river networks, urban growth, human physiology, medicine, and market trends (Falconer, 2003).

In this study fractal dimension was applied to measure the complexity based on the availability of edges of signage

Assumptions of fractal dimension analysis

If the streetscape has a high fractal dimension value, the streetscape has a higher number of signage with sharp edges or higher number of physical elements with sharp edges. Thus the complexity of the streetscape is high.

If the streetscape has a lower fractal dimension value, the availability of edges is low and the complexity of the streetscape is low.

Objective

The objective of this research is to measure visual complexity using variety of objective analysis techniques to assess the applicability of these methods with high confidence in measuring visual complexity.

Method

Study area

The research was conducted in Colombo Municipal Council area. Hundred commercial streetscapes were selected representing large number of signage (more than 20 signage -40 streets) streetscapes with medium number of signage (5-19 signage – 30 streets) and streetscapes with low/no signage (less than 5 signage – 30 streets).

Method includes two sections; subjective analysis of the perspective views of the streetscapes and the objective analysis of the same views.

Subjective analysis of the streetscapes

Along the selected residential streetscapes, perspective photographs were taken from different viewpoints to cover commercial and public signage of the streetscapes. Perspective views were analyzed to symbolize the view of pedestrians travel along the street. Figure 02 displays perspective views taken at the selected viewpoints along a selected streetscapes.

Figure 02: Perspective Views along one Streetscape

The obtained perspective views along 100 streetscapes were displayed to 50 subjects representing different age sex and ethnic groups. The subjects were asked to mark the visual complexity level of each streetscape in a five point scale after carefully observing perspective views obtained from each streetscape. The five point scale had 5 levels of visual complexity.

Highly uniform: the signage and their surroundings are similar to each other. The variability along the streetscape is at a minimum level

Uniform: The signages are by and large show similar characteristics.

Neither complex nor uniform: The signages at the streetscape do not show a significant variability in both ends to create complexity.

Complex: The signages show some differences in their visual characteristics causing complexity in streetscapes.

Highly complex: the signages are different to each other significantly causing high complexity in the streetscape.

Based on the subjects' view and their individual preferences, the 100 streetscapes were categorized into one of the levels of the five point scale.

Objective analysis of the streetscapes

Shannon's entropy and Simpson index calculation

For this task, eight visual elements were analyzed in the streetscape views. Analyzed elements and their levels are given in the table no.01.

Table 01: Visual Elements and Their Levels

Visual element	Level of the visual element	Visual element	Level of the visual element
Type of the signage	Advertisement, signage for vehicles, signage for pedestrians, etc	Color of signage	White, black, blue, green, other
Shape of signage	Square, rectangle, rectangle with small protrusions, L shape, circle, irregular, other	Language	Sinhala, English, Tamil, All
Size of elements inside the signage	Large, Medium, Small	Size of signage	Large, Medium, Small
Availability of pictures	Yes, No	Availability of External things	Bulbs, decorative openings, ornaments

The visual elements of the signages at the considered 100 streetscape views were categorized into above selected elements groups and the levels with the help of perspective views. The counted numbers under each element and the levels were utilized for the Shannon's entropy and Simpson index calculation in Excel. The values were obtained separately for each signage for Shannon's entropy and Simpson index calculations. The sum of each value for a streetscape was obtained by adding the individual values of 8 visual elements together. It was considered as the Shannon's entropy and Simpson index for the streetscape.

Gini coefficient calculation

For this task, the numbers of prominent elements visible in the streetscape signage were counted. From the signage, first, main visual elements were selected. From these main visual elements, the sub visual elements were counted, they are called the figures. Those figures were taken for the Gini coefficient calculation.

Fractal dimension calculation

The gray scale photographs were analyzed using freely downloadable "Fractalyse" software and the fractal dimension value for each photograph was obtained. Following this procedure 100 fractal dimension values were obtained for the selected 100 streetscapes.

Results and discussion

Subjective analysis

Perspective views of the hundred streetscapes were displayed to fifty subjects and they were asked to rank the streetscapes based on the given five point scale. Afterward the ranks were counted for each streetscape and the percentage of marking each streetscape under each rank in the five point scale was calculated. If the percentage was over 50% under a specific rank, subsequently that streetscape was grouped under the specified category. Table 02 shows the number of streetscapes under each category in the five point scale.

Table 02: Ranking of Streetscapes

Five point scale category	No. of streetscapes under each category	Percentage %
Highly complex	12	10
complex	17	16.25
Neither complex nor uniform	36	40
Uniform	28	30
Highly uniform	7	3.75

Survey results illustrated that there were 12 streetscapes with a high visual complexity. These streetscapes comprised of different advertisements and public signage causing high complexity to the streetscape. As a result the visual complexity of these streetscapes increased. Supplementary, more than 50% of subjects ranked seven streetscapes as highly uniform. Most of the streetscapes were categorized under "neither complex nor uniform" category.

The next step is the comparison between subjective the results of subjective analysis with the results of objective analysis. Through below paragraphs, the comparisons are explained one by one.

Comparison between Shannon's entropy and subjective analysis

The entropy of the streetscapes ranged between 1 and 12. Figure 03 displays the graph showing the number of streetscapes under different entropy values. For displaying purpose, the entropy values were grouped into 6 categories.

Figure 03: Number of Streetscapes under Different Entropy

There were 34 streetscapes with the entropy in between 6 and 8 while 19 streetscapes had entropy in between 4 and 6. Entropy of 14 streetscapes ranged between 2 and 4 whereas 13 streetscapes acquired entropy in between 10 and 12. Eight streetscapes obtained entropy below 2 whilst 12 streetscapes showed entropy in between 8 and 10. In consequence the entropy of the majority of streetscapes ranged between 4 and 8.

The next objective of the research was to find out the correlation between the entropy and the survey results. Figure 04 displays the above correlation.

Figure 04: The Correlation Between the Entropy and the Rated Visual Complexity

Figure 05 displays the correlation between the entropy and the streetscape survey results. The correlation between the subjects' impression on the visual complexity and the entropy was 0.73.

Comparison between Simpson index and subjective analysis

The Simpson index value ranged between 0.3 and 1.0. Figure 05 displays the graph showing the number of streetscapes under different index values. For displaying purpose, the index values were grouped into 8 categories.

There were 26 streetscapes with Simpson index values in between 0.5 and 0.6 while 20 streetscapes displayed values in between 0.3 and 0.4. Nineteen streetscapes had Simpson index values in between 0.4 and 0.5 while 27 streetscapes had higher index values in between 0.6 to 1.0.

Figure 05: No. of Streetscapes under Different Simpson Index Values

The next step was the comparison between Simpson index values and the subjective analysis. The result of the comparison is given in figure 06.

Figure 06: Correlation between Simpson Index and the Subjective Analysis

The correlation between subjects' impression and the Simpson index on the visual complexity was 0.60. It displayed relatively less correlation compared with the Shannon's entropy.

Comparison between Gini coefficient and the subjective analysis

Figure 07 displays the correlation between Gini coefficient and the subjective analysis of the visual complexity.

Figure 07: The Correlation between Gini Coefficient and the Subjective Analysis

According to the comparison, there is a good correlation between subjective analysis and the Gini coefficient calculations. The correlation is 0.78. This is the highest correlation between subjective and objective analysis methods. Therefore the Gini calculation is more comparable with the human perception of the visual complexity.

Comparison between fractal dimension analysis and the subjective analysis

The gray scale photographs were analyzed using “Fractalyze” software to find out the fractal dimension values for the streetscapes. Figure 08 display two photographs with higher fractal dimension value and a lower fractal dimension value.

A view with high fractal dimension

A view with low fractal dimension

Figure 08: photographs used for Fractal Dimension Analysis

The calculated fractal dimension values ranged in between 1.32 and 1.99. There are three streetscapes with lowest fractal dimension values around 1.3. Highest number of streetscapes (17) obtained fractal dimension value in between 1.9 and 2.0. It seems that most of the streetscapes have sharp edges. It indicates that the visual complexity is higher in most of the streetscapes. However, the result of fractal dimension analysis is different from the results of other three analysis methods. The conclusion obtained from the other three method is most of the streetscapes in the study area displayed very low visual complexity while fractal dimension calculation showed most of the streetscapes are having higher visual complexity. Thus the result of the fractal dimension analysis is not trustworthy.

The next step is to find out the correlation between fractal dimension analysis and subjective analysis of the streetscapes. Figure 09 displays this correlation.

Figure 09: Correlation between Fractal Dimension Analysis and the Subjective Analysis

The correlation between fractal dimension analysis and the subjective analysis was 0.53. Thus this method showed the least correlation between subjective and objective analysis methods. Thus the applicability of this method to measure visual complexity on urban residential streetscapes is questionable.

Conclusions

The study was conducted to find out the best objective analysis method to measure the visual complexity on streetscapes created due to signage in Colombo city. For this task, two methods were applied; subjective analysis method and four objective analysis methods. In this study, the subjective analysis was considered as the most accurate method since human perception is more important than other evaluation methods. The other four methods, Shannon's entropy, Simpson index, Gini coefficient and fractal dimension analysis methods were compared with the human perception to find out the best objective analysis method. This finding is very important since the subjective analysis is not practicable always with intensive field visits. If there is an objective analysis method compatible with subjective judgments it can be applied in different complexity involved developments such as streetscape designing urban planning etc.

According to the calculations, Shannon's entropy showed 0.73 correlations with the results of subjective analysis while Simpson index displayed 0.60 correlations. The fractal dimension analysis displayed the least correlation; 0.53. The highest correlation was obtained by the Gini coefficient analysis; 0.78.

Thus the results of the Gini coefficient are more compatible with the human perception. Secondly, the Shannon's entropy displayed the good correlation with human perception. The other two methods have poor correlation with the human perception.

Therefore finally it can be concluded that the Gini coefficient analysis is a best objective analysis method to measure the visual complexity of streetscapes in the study area and this method can be used as a substitute for subjective analysis.

This finding is useful for the urban planning regulations. The values obtained through the Gini coefficient are trustworthy as the human perception. Therefore in urban planning, to make better land use plan to match with the human perception these values can be utilized.

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