

# A design evaluation model for architectural competitions: Measuring entropy of multiple factors in the case of municipality buildings

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*Received: October 2017 • Final Acceptance: November 2017*

## Abstract

Various types of information embedded in the built environment or buildings can be measured by using methods such as entropy to give objective, precise and quantitative results. Jury evaluation is a process where buildings are evaluated subjectively without predefined selection criteria, and that criteria are weighted. The model developed in this study investigates the relationship between entropy values calculated for buildings, and the success obtained as a result of the jury evaluation. Since both design and jury evaluation are not dependent on a single factor, the relationship between single entropy values and the success of the projects cannot be questioned. Therefore, the model being developed in this study handles 5 different entropy values calculated according to 5 factors, weighted independently, and finds total entropy values. To achieve similar results to jury evaluation, a non-dominated sorting algorithm for weighting factors was utilized in relation to an inverted U graph. By finding the weighting between the entropy values, the study aims to resolve a parametric foundation for jury evaluation. Within the scope of this study, 24 municipality building projects designed for architectural project competition between 2015 and 2016 in Turkey, and which have received awards have been evaluated.

## Keywords

Entropy, Information theory, Non-dominated sorting algorithm, Municipality building, Architectural competition.



doi: 10.5505/ituja.2018.60362

## 1. Introduction

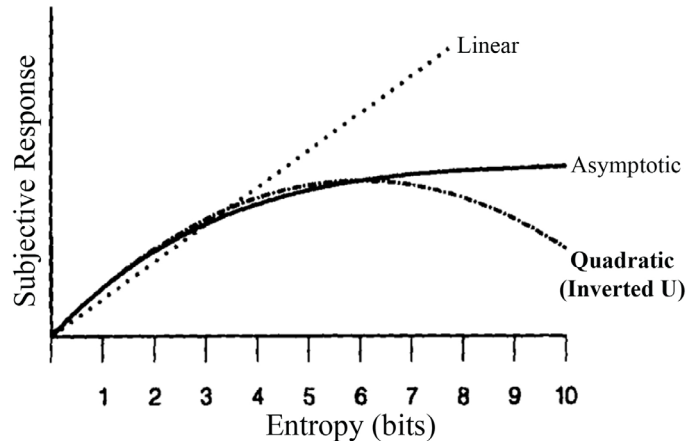
Cities, buildings, works of art, or other man-made artifacts have a high-level organized complexity and each can be handled as a source of information. People, in turn, process the transferred information and make it understandable. Glanzer (1958) defines the person (organism) as an “information processing system”.

Various subjective and objective methods are used for the assessment of built environment and buildings. While subjective methods evaluate buildings from the aesthetic perspective, based on personal likes and preferences, objective methods focus on the features of the building that can be calculated.

The level of complexity of information obtained from sources or the level of uncertainty contained in the information positively or negatively affects the assessment of objects or buildings. As Vitz (1964) stated, the organism (black box) has perceptual or cognitive response tendencies. While a high level of diversity of information coming from the information source leads to a difficulty of understanding, a low level of diversity causes monotonousness and accompanying vapidness. Instead, it is argued that an average degree of irregularity creates positive feedback from people, as well as pleasure (Vitz, 1964; Berlyne, 1974; Saklofske, 1975).

On the other hand, Maddox (1990) emphasizes that there is no satisfactory measure of complexity that distinguishes between what he defines as ordered and disordered complexity. Based on various approaches in the literature, it can be argued that it is an open-ended question as to what degree of complexity could create a more comprehensible or positive impact.

It is possible to calculate, and make visible, various types of information embedded in built environments or buildings, using methods which give objective, precise and solid results, such as entropy. Entropy may also be used as a measurement method to meaningfully compare different abstract or concrete architectural compositions. The theory of information and relevant discussions address the measurability of aspects such as complexity



**Figure 1.** 3 Possible functions between subjective response and entropy (Stamps, 2002).

and uncertainty. Entropy, which is an objective method developed to measure complexity and uncertainty, also offers significant potential in enhancing the comprehensibility of subjective tendencies that involve uncertainty.

Based on this point, a model has been proposed which aims to ensure the visibility of the relationship between the multiple entropy values obtained by the measurement of different factors of buildings, and success obtained as a result of the subjective evaluation of an architectural competition jury.

The assumption is that a jury evaluates projects according to the inverted U graph based on their entropy values, and this constitutes the basis for developing a model and the calculation of weights.

The investigation of this relationship seeks answers for the following questions:

- What is the impact of entropy on the jury assessments?
- Can the result of jury assessments be estimated/predicted according to the building's entropy value?
- Can subjective means of evaluation, like jury assessment, be associated with objective computational models?

## 2. Entropy

Although entropy has first appeared for measuring physical disorder of substance, in 1949 for measuring the disorder in information it was rediscovered by Shannon and Weaver (1949). For instance, in thermodynamics, entropy value of a substance in crystal form

**Table 1.** Entropy calculations as based on a simple letter string (Stamps, 2004).

| Message | x | # of x's | p(x) | $\log_2(p(x))$ | $p(x)\log_2(p(x))$ | $-p(x)\log_2(p(x))$ |
|---------|---|----------|------|----------------|--------------------|---------------------|
| AAAAAAA | A | 7        | 7/7  | 0.00           | .000               | 0.00                |
| ABCAABB | A | 3        | 3/7  | -1.22          | -.532              | 1.44                |
|         | B | 3        | 3/7  | -1.22          | -.523              |                     |
|         | C | 1        | 1/7  | -2.80          | -.398              |                     |
| ABCDEFG | A | 1        | 1/7  | -2.80          | -.400              | 2.80                |
|         | B | 1        | 1/7  | -2.80          | -.400              |                     |
|         | C | 1        | 1/7  | -2.80          | -.400              |                     |
|         | D | 1        | 1/7  | -2.80          | -.400              |                     |
|         | E | 1        | 1/7  | -2.80          | -.400              |                     |
|         | F | 1        | 1/7  | -2.80          | -.400              |                     |
|         | G | 1        | 1/7  | -2.80          | -.400              |                     |

$$\text{EQ1: } H_{\text{factor}} = - \sum_{i=1}^{n_{\text{levels}}} p_i \log_2 p_i$$

**Figure 2.** Basic entropy equality (Stamps, 2004).

is less than the value of substance in melted form (Crompton, 2012). In the Shannon's information theory, quantity of information that is carried with a message is dependent on the number of probabilities of outcome that can be created by that message. In the case of only one probable output, it is not possible to obtain new information from the message. Suppose if the probability of occurrence of X event is less than that of Y event, since occurrence of X event would cause bigger surprise, X event carries more information (Kan and Gero, 2005).

### 2.1. Main concepts and basic entropy equality

To make an entropy calculation, there should be present a factor and level of occurrence of that given factor. For example, the string of "AAAAAAA" is composed of 7 units. In the string, the only factor being observed is "Letter"; the only level of this factor is the letter "A". Since there are 7 of instances "A" in the string, the frequency of letter "A" is 7/7. When all units composing the string are identical, there is monotony and entropy value of string is zero. On the other hand, in cases like "ABCDEFG" where all units are different, there is a complete variety and entropy has the highest value (Table 1) (Stamps, 2004).

The basic equation that is used for calculating entropy value of information is shown in the Figure 2. In the equation, "H" defines the entropy value

that is calculated and contained in each factor and it is determined in terms of "bits"; furthermore, "p" defines the probability of occurrence of a factor (Stamps, 2004; Crompton, 2012).

To structure the entropy formula with letters, for ten pieces of elements made of letters (m=10) and for each unit to have 4 values (n=4), 10 letters are randomly created from one to four (A,B,C,D). When it is assumed that resulting product is "ABBCCCDDDD" in the letter string there are present 1 count of A, 2 counts of B, 3 counts of C, and 4 counts of D. In this case it is observed that frequency rate of letters in the string are 1/10, 2/10, 3/10 and 4/10, respectively. Once the probability of each letter is inserted into the equation and summed, entropy value of letter string is calculated as 1,84 bits (Stamps, 2003).

$$\text{Letter A; } -\frac{1}{10} \log_2 \frac{1}{10} = 0,33 \text{ bits}$$

$$\text{Letter B; } -\frac{2}{10} \log_2 \frac{2}{10} = 0,46 \text{ bits}$$

$$\text{Letter C; } -\frac{3}{10} \log_2 \frac{3}{10} = 0,52 \text{ bits}$$

$$\text{Letter D; } -\frac{4}{10} \log_2 \frac{4}{10} = 0,53 \text{ bits}$$

$$0,33+0,46+0,52+0,53=1,84 \text{ bits}$$

According to the theory of information, entropy assumes its largest value if the pieces making up the whole have equal occurrence. Therefore, irregular series carry more information than the repeating sequential series of symbols (Crompton, 2012). For example; the sequence of "baa baa baa" is a series that is easier to define, comprehend and remember than the sequence "aba aab baa" (Stamps, 2004). Miller (1956), who is a pioneer researcher, interlinked

**Table 2.** Total entropy calculation for two separate factors (Stamps, 2004).

| Fonts          | Letters  |      |                |      |               |      |
|----------------|----------|------|----------------|------|---------------|------|
|                | All same | $H$  | Some different | $H$  | All different | $H$  |
| All same       | AAAAAAA  | 0.00 | ABCAABB        | 1.44 | ABCDEFGG      | 2.80 |
| Some different | AaAaAaA  | 1.44 | ABcAABB        | 2.88 | ABcDEFG       | 4.24 |
| All different  | AaAaAaA  | 2.80 | ABcaAbB        | 4.24 | AbcdEfG       | 5.60 |

entropy and cognition, suggests that the short-term cognition of human beings is limited to 3 bits. Evidently, low entropy eases perception and cognition. Adhering to the findings of Miller (1956), Stamps (2014) has ascertained the characteristics of his designs, with respect to the 3 bits as the upper limit for each factor in his study.

A difficulty encountered in measuring entropy, is the need to calculate according to multiple factors that are completely independent from each other. In cases where factors are independent from each other, total entropy is equal to the sum of entropy values measured for factors. In Table 2, the entropy values of strings consisting of letters are calculated according to two factors that are independent from each other. In the two examples provided in Table 2, the sequences have two factors consisting of letter and font features. In the strings where all units are written in “Times New Roman” font and the letter is “A”, the entropy value is zero since there is no variance. On the other hand, in cases where each unit is featured with a different letter and font, entropy value is obtained for 2.8 bits letters and 2.8 bits fonts. Thus, total entropy value is calculated as 5.60 bits (Stamps, 2004).

## 2.2. Literature on entropy and architecture

The concept of entropy has been used for decades in various fields such as architecture and planning. For instance, it has been used in the calculation of measurable physical features of art works (Arnheim, 1971), building facades (Krampen, 1979), building silhouettes (Stamps, 1998; Stamps, 2004), site plans (Stamps, 2004), abstract compositions produced by LEGO (Stamps, 2012), important buildings reproduced by LEGO (Crompton, 2012) and urban silhouettes (Bostanci, 2008). The built environments, buildings or abstract

objects examined in the studies, were addressed as sources of information and entropy values were calculated according to different factors.

Stamps have investigated the relationship between the level of entropy and visual diversity originating from the physical characteristics of the building and the level of satisfaction and dissatisfaction. Various correlations which numerically differ were found between the values calculated according to factors such as form, color, silhouette and facade elements, and the level of pleasure (Stamps, 2002; Stamps, 2003).

Objective methods have been developed for measuring complexities and similarities of architectural drawings. Corner points of external contours of drawings are represented with different letters according to vertex characters and entropy values are measures as per the letter string being obtained (Gero and Kazakov, 2001; Jupp and Gero, 2006).

It is difficult to determine which sort of a character a stimuli or structure must have to reach a certain level of entropy. Stamps (2014) has developed techniques to produce designs of expected visual complexity and entropy values by listing the parts of the buildings to be used as well as their characteristics.

By creating the LEGO models of buildings constructed in different periods, Crompton (2012) attempts to measure the quantity of embedded information according to their shape entropies and benchmark buildings on the basis of the parts which make up the buildings. Stamps (2012), on the other hand, explores the correlation of perceived diversity depending on color and shape with the calculated complexity, using the shape and color features of LEGOs in abstract compositions.

Güzelci (2017) has calculated the entropy values of municipality buildings,

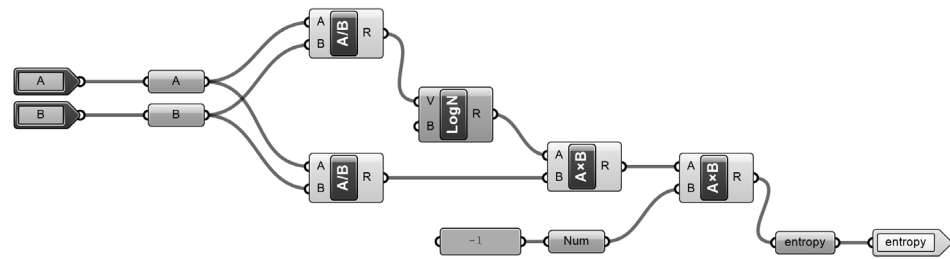


Figure 3. Entropy equation defined in Grasshopper environment.

a customized architectural typology, on the basis of physical characteristics such as solid-void, form and function, investigated whether there is a specific optimum entropy value for different municipality buildings. The study has also investigated whether there is a correlation between the success obtained as a result of a subjective evaluation by the jury of a competition for a municipality building and the project's entropy value calculated on the basis of quantifiable physical features.

### 3. Method

As observed in the literature that forms the basis of studies for calculation method developed in this study; entropy calculations of buildings and abstract compositions were conducted according to different factors (Stamps, 2004; Crompton, 2012; Stamps, 2012). Furthermore, although entropy calculations in existing literature were made considering single or multiple factors, results seem to have been evaluated independently.

The fact that complexity is obtained by summing sub-components does not reflect the internal organization among components (Klinger and Salingaros, 2000). Therefore, the "overall entropy" found by calculating and summing the entropy values dependent on factors applies in cases where there is no relationship, ranking of significance or weight among the factors.

Evidently, the municipality building projects focused under the study have complicated design problems with many different inputs. For municipality building designs, many factors aside from aesthetic values, such as functionality, circulation and size of spaces are all considered. However, no findings within the literature state that these factors impact the design equally thus contribute to the sum, when cal-

culating the overall entropy value of the building.

No valid conclusion could be reached within the study which explored the relationship between entropy values of the individual factors of the project and the success achieved in the competition (Güzelci, 2017).

Building on the results obtained from the previous studies, this study presents a model which multiplies each factors' entropy values, by given weight coefficients and then explores the correlations with the results of jury assessment.

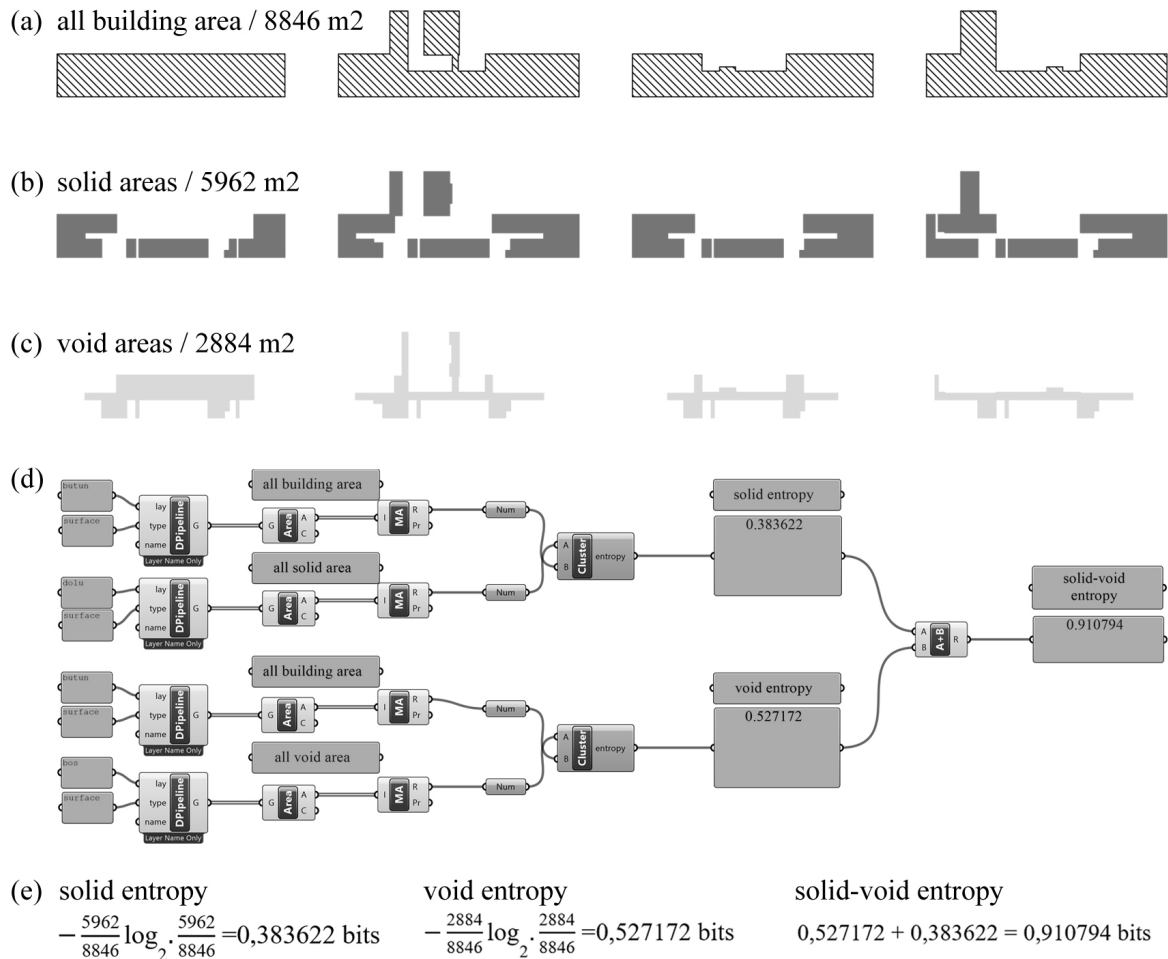
#### 3.1. Calculation of entropy values of single factors

The selected factors in this study are listed, as follows: solid-void, outline, shape, functional distribution and spatial flow (circulation). Generally, all of these factors are present as basic design features which can be examined through all buildings.

An algorithmic system was developed to calculate the results without user intervention, with aim to reduce the amount of error at a timely manner for the purpose of assessment on the entropy calculations according to 5 different factors.

The algorithm prepared in Grasshopper environment, is capable of recognizing all polygons, surfaces and letters drawn on different layers in two-dimensional drawing software programs, and using them as input in entropy calculations.

First, the main entropy equation formula was defined as a mathematical transaction in Grasshopper environment to be able to calculate entropy. Entropy calculation is conducted according to the probability of occurrence of event A, which can be defined as quantitative values in Grasshopper interface, in the space of event B (Figure 3).



**Figure 4.** Example of solid-void entropy calculation.

### 3.1.1. Solid-void entropy (Factor 1)

Crompton (2012) has formed the Empire State Building on a three-dimensional grid with size of 8x7x50 by using repeating cubes. After creating the structure entropy values are calculated as per the probability of a cell's being full or empty as being randomly selected among 3600 cells on the three-dimensional grid.

To be able to calculate the solid-void entropy, it is necessary to know the ratio of occupied and empty areas in all floor plans to the total building area. In the study, atriums, staircases, lifts and corridors were regarded as void areas, whereas all other spaces separated by door were regarded as solid areas.

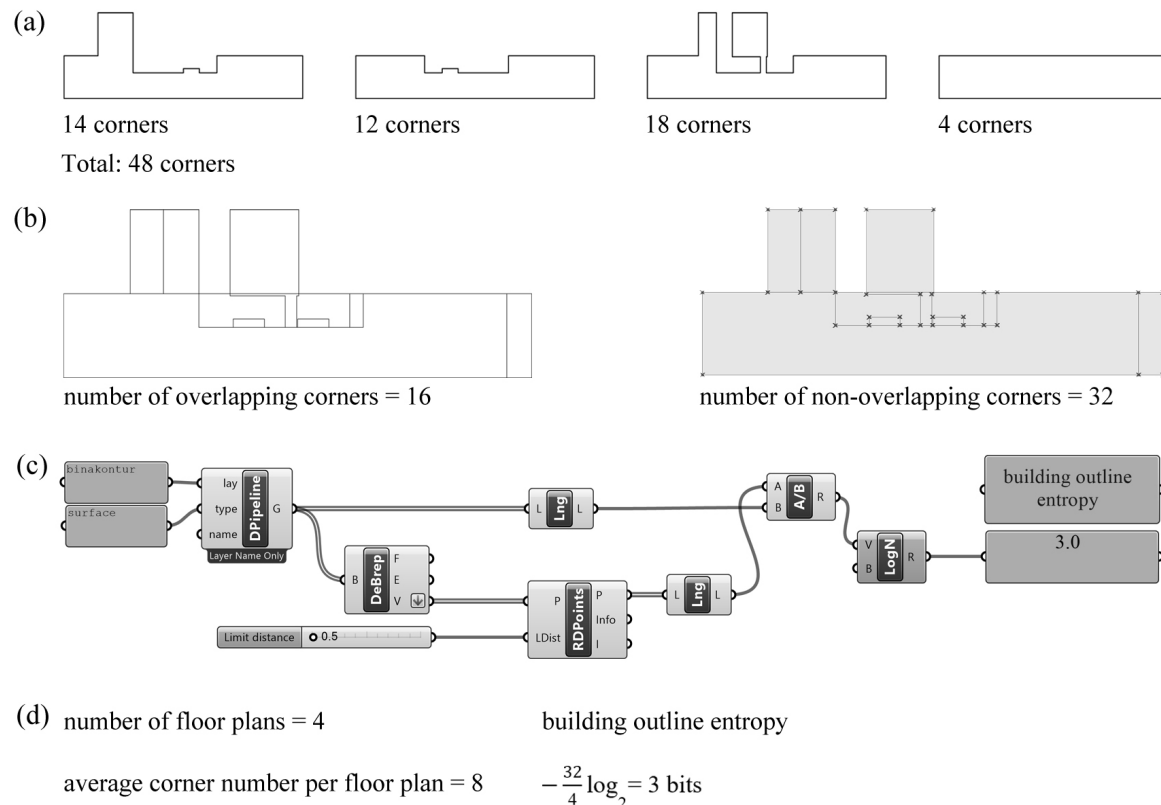
As seen in the figure; total area of all floors of the building, solid areas and void areas were found in Grasshopper environment (Figure 4a, 4b, 4c). "Solid entropy" value was calculated by inputting the entropy formula the ratio of occupied areas to total building area, and "void entropy" value was then cal-

culated by inputting the ratio of empty areas to the total building area. The "solid-void entropy" value of the building was calculated by summing these two values (Figure 4d, 4e). This sample calculation was conducted such that all floor plans were considered altogether. It is also possible to make this calculation separately for each floor plan.

### 3.1.2. Outline entropy (Factor 2)

Stamps (1999, 2004) used the number of turns in silhouette lines to calculate the complexity created by building silhouettes and the entropy value. The method used for building or urban silhouettes consisting of two-dimensional lines in that study were adapted to the floor plan contours consisting of two-dimensional lines. To be able to calculate outline entropy, it is necessary to know the number of turns / vertices of the internal and external contours of the floor plans of projects.

To calculate outline entropy, first, points are added to all vertices of the



**Figure 5.** Example calculation of building outline entropy.

outer and inner contours forming the building's floor plans, and thus vertex numbers are obtained (Figure 5a). Then, the points overlapping as a result of the superposition of the plan contours of all floors are deleted, and the number of vertex points not overlapping are summed (Figure 5b). To not complicate calculations and therefore ignore the points which do not overlap but are unnoticeably close to each other, a tolerance value in centimeters, which can be changed by the help of a "slider component" is determined (Figure 5c).

By dividing the number of all vertex points which do not overlap, by the total number of floors, the average turn/vertices number per floor is calculated. Finally, by calculating the logarithm in base two for average number of turns on the floor plan, "outline entropy" value is found. (Figure 5d).

### 3.1.3. Shape entropy (Factor 3)

Crompton (2012) calculates shape entropy of buildings remodeled with LEGOs. While making the calculation, considerations of the repetition number of LEGO parts within the total LEGO space, he identifies entropy values of parts' each individual part and

the total building by summing them.

In the municipality building projects being investigated within the scope of study, units such as manager rooms, secretary rooms, meeting rooms, service areas, toilets were found to be repeated with unchanged size and form. In a building formed by repeated parts, "shape entropy" can be calculated according to the irregularity created by the forms of spaces in the building.

To be able to calculate shape entropy, it is necessary to identify how many different units exist and the quantity of each unit. In complex buildings consisting of many spaces, such as a municipality building, it is difficult to count this manually.

Therefore, an algorithm was developed to count and distinguish different shapes from each other. First, points were assigned to the vertices of spaces drawn in the "shape" layer. According to the vertex number of each form, the edge numbers of shapes were found, and shapes were classified according to their edge numbers. Once the shapes were grouped according to their edge numbers, matching could be done more accurately by calculating edge lengths and areas as well (Figure 6).

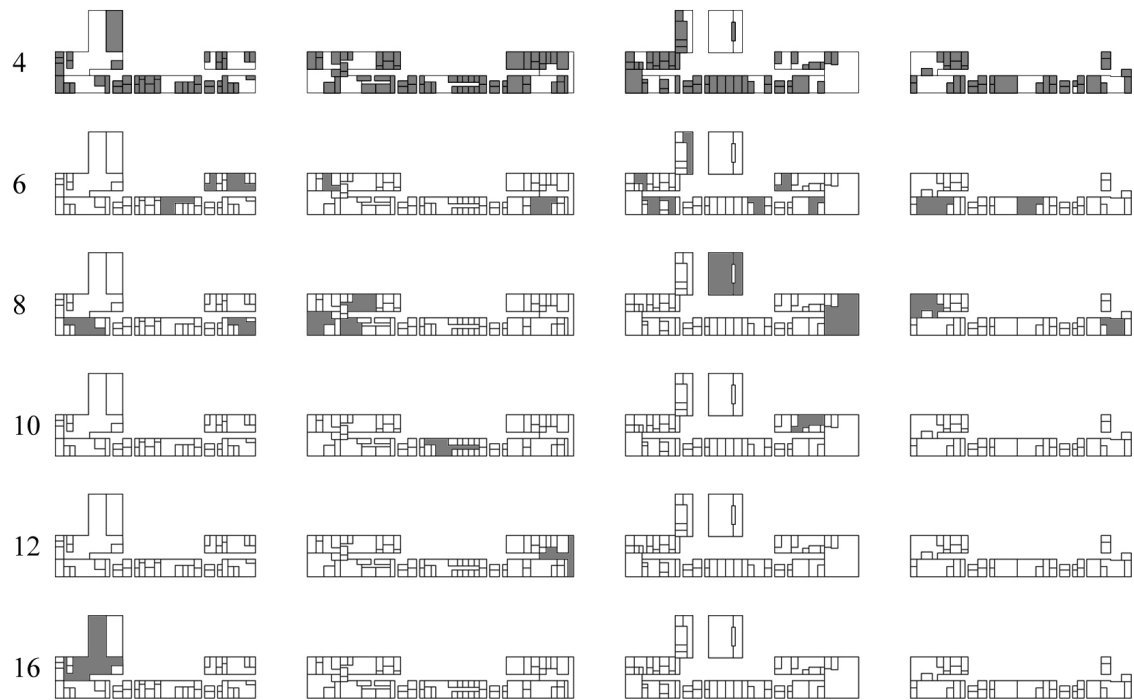


Figure 6. Grouping spaces according to their corner numbers.

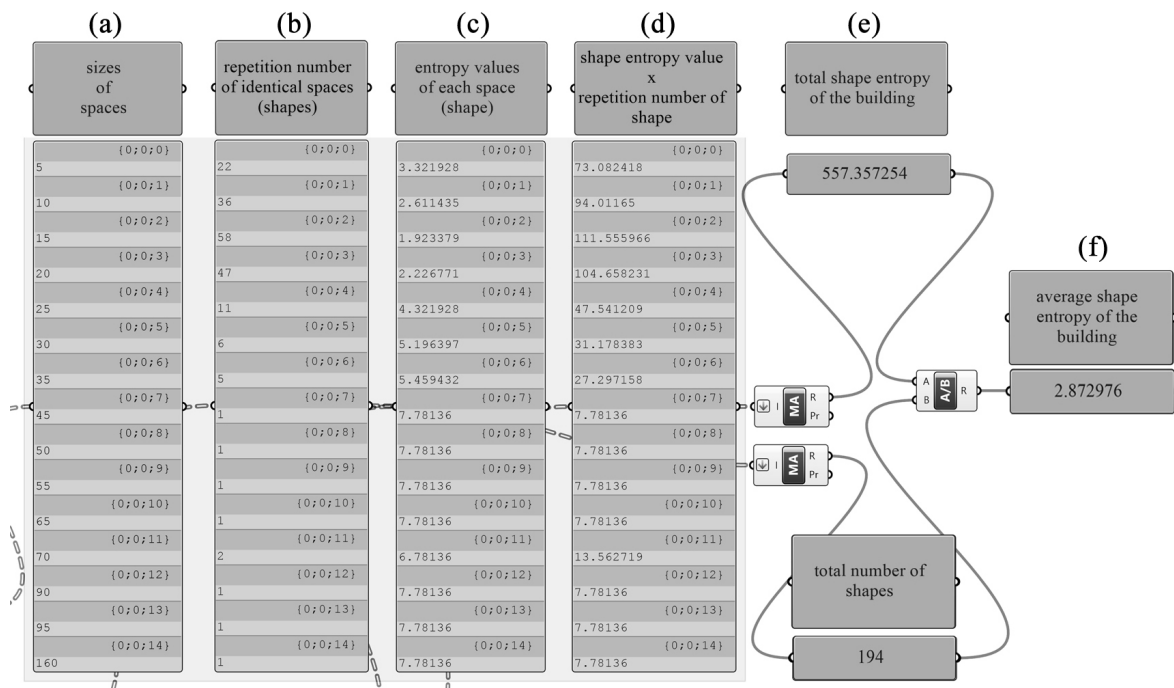
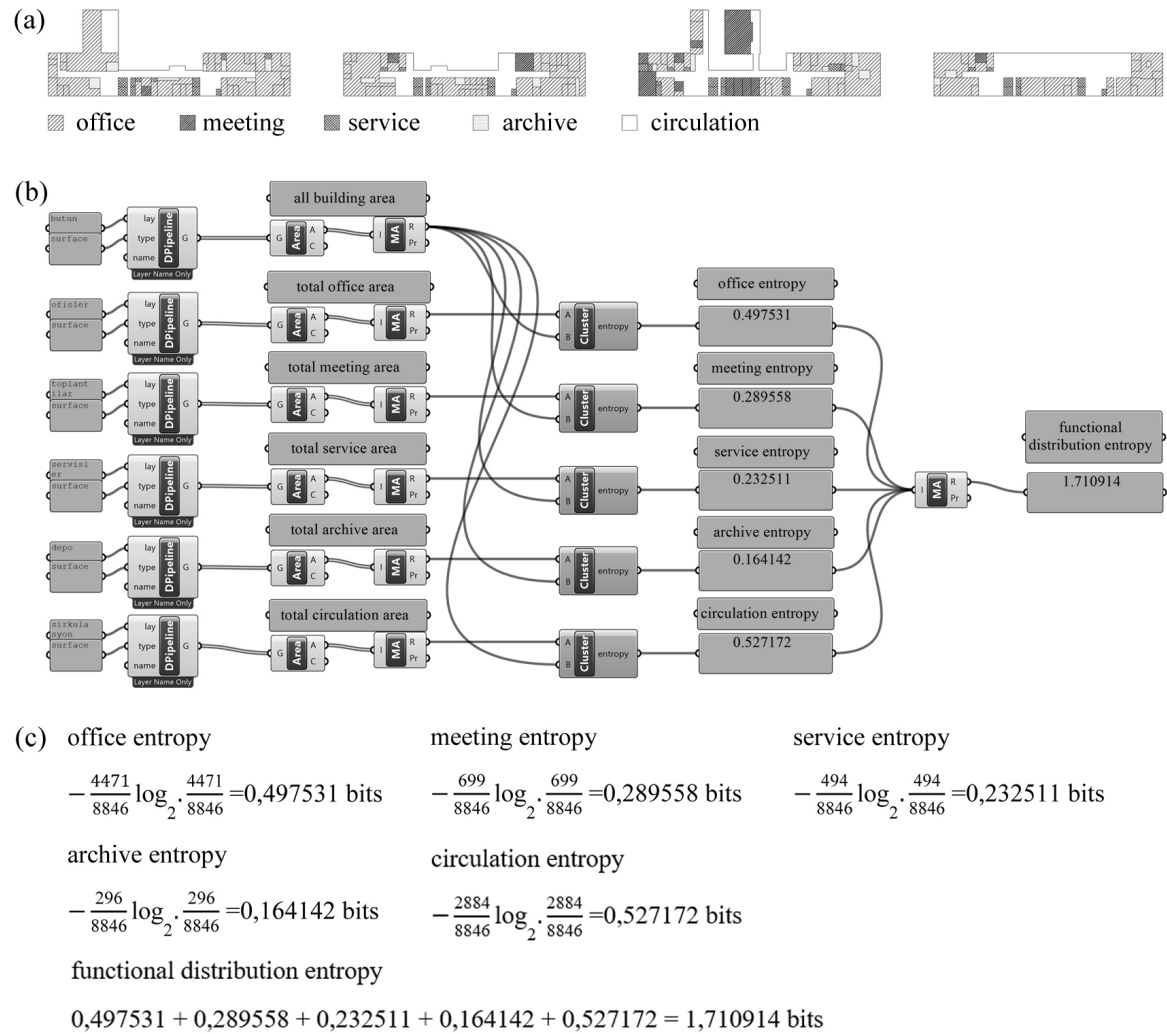


Figure 7. Example calculation of average shape entropy.

The entropy value of an individual shape is found according to the rate of incidence of a shape selected from the grouped shapes within the total space of shapes used in the project. By multiplying the entropy value found for the selected shape and the number of repetition of that shape, total amount of complexity added by that shape to the building is calculated (Figure 7a, 7b, 7c, 7d). Upon completion of this pro-

cess for all parts, total entropy is divided by the sum of all shapes making up the building to calculate the building's "average shape entropy" (Figure 7e, 7f).

In the sample calculation shown in the Figure 7; 22 units were calculated with size of 5 m<sup>2</sup> and equal number and length of edges, in the first lines of panels. Each of the 22 units with 5 m<sup>2</sup> is taken in the total space of shapes seen in the project, it has a value of



**Figure 8.** Example of functional distribution entropy calculation.

3.32 bits. Since there are 22 units with a value of 3.32 bits, the multiplication of two values bring a shape entropy of 73.08 bits to the system. In the Figure 7, the sum of entropy values in the list given on the far right-hand-side was calculated as 557.35 bits. By dividing the total entropy value of 557.35 by the total number of shapes, which is 194, the building's average shape entropy value was calculated as 2.87 bits.

The approach followed in this study differs from both the study of Stamps (2012), who made a design using the LEGO vocabulary he developed himself, and from that of Crompton (2012) who determined the entropy values of pieces by searching the whole LEGO space. Since each project investigated in this study was assessed independently, the vocabulary of shapes and distribution of shapes are subject to variance. Based on that distribution the entropy values of parts and the overall systems also vary.

### 3.1.4. Functional distribution entropy (Factor 4)

Stamps (2003) calculated color entropy according to the distribution of colors in two-dimensional abstract compositions, designed with forms of different colors. In this study, using a similar approach, “functional distribution entropy” was calculated on a color canvas created by representing functions of municipality buildings with different colors on the plan.

The minimum and maximum entropy values that can be calculated change as the number of functions increases or decreases. In this case, to be able to calculate the functional distribution entropy value and compare the functional distribution entropies of buildings using a standard method, buildings must have equal number of functions and same functions. After reviewing different municipality building projects, 5 main functions encountered in

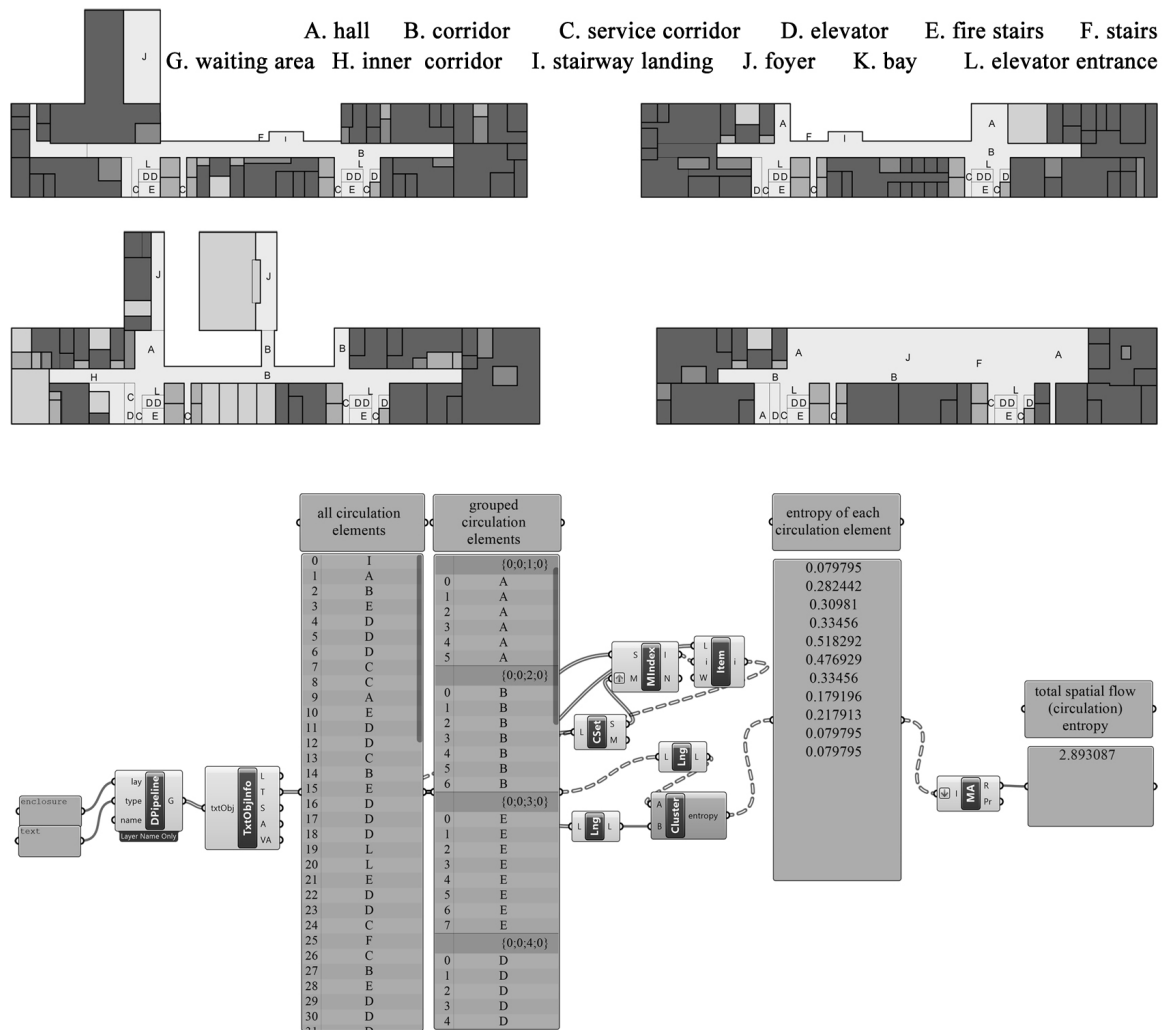


Figure 9. Example of spatial flow (circulation) entropy calculation.

all buildings were identified. As part of the study, these five functions were listed as offices, meeting rooms, archives, service areas and circulation areas.

After functions are represented by different colors on a two-dimensional drawing environment, the areas of spaces where each function has been seen were summed independently. The entropy value for each function was calculated on the basis of the ratio of the sum of the area of all units in a given function to the total area of the building. By summing the entropy values calculated separately for each of the five functions, the building's functional distribution entropy was found (Figure 8).

### 3.1.5. Spatial flow (Circulation) entropy (Factor 5)

Stamps (2004) using letters encoded as the five spatial flow elements he has developed on the site plan, Stamps

then represented the spatial flow as a sequence of letters.

Apart from the closed spaces for which shape entropy was calculated, the municipality buildings reviewed contained spatial flow elements such as halls, corridors, service corridors, elevators, fire stairs, stairs, waiting areas, inner corridors, stairway landings, foyers, bays, and elevator entrances, which related to each other physically and visually. These units could vary in shape and size.

Therefore, spatial flow elements were represented by letters instead of shapes, and the flows in floors were represented by sequences of letters. Thus, it is possible to calculate the circulation complexity embedded in a floor or in the whole building, on the basis of a sequence of letters. By summing the spatial flow entropies of floors, the building's overall spatial flow entropy value is calculated (Figure 9).

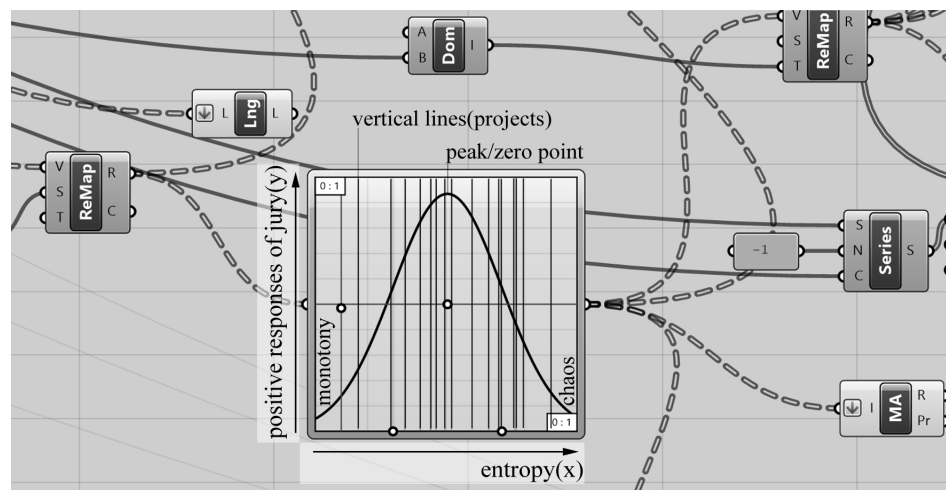


Figure 10. Placing projects on an inverted U graph.

### 3.2. Calculation of entropy values of multiple factors

Considering the multiple factors that affect entropy values, it is crucial to understand whether there might be certain relationships between those factors. By means of the developed algorithm, as per 5 different physical features of each project, 5 entropy values were found. With the idea that all factors do not influence jury evaluation equally, it is not possible to simply combine values to obtain the overall entropy of the building. Instead, in the study it is assumed that a competition jury makes subjective evaluations according to the “overall entropy” values calculated based on weights between the factors.

Berlyne (1960), Kaplan and Kaplan (1989) and Nasar (1987) emphasize that an average amount of complexity is associated positively with the preferences of people. While monotonousness implies both a low level of diversity and vapidness, chaos refers to high level of diversity and vapidness (Stamps, 2003). The design principles used to create visual diversity are used to avoid monotonousness and chaos, or avoid both of them at the same time (Stamps, 2003). It is thought that an average level of complexity in buildings, building blocks, settlements and cities creates the feeling of unity within variety (Elsheshtawy, 1997; Gunawardena et al. 2015).

An increase in positive responses as an entropy value approaches a certain value, and a decrease in pleasure as it deviates from the value in a negative or

positive direction causes a Quadratic (Inverted U) graph.

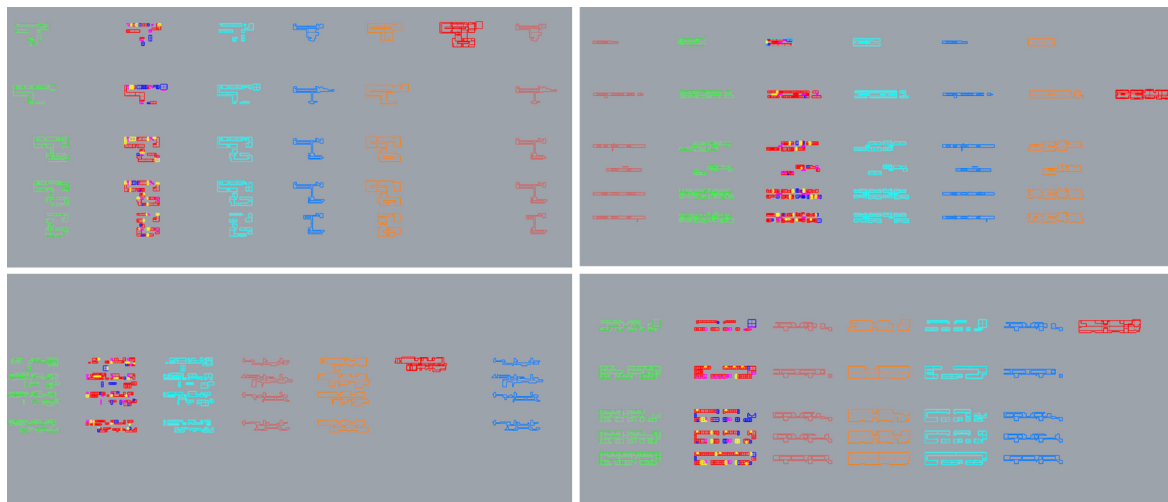
It has been emphasized previously that using irregularity at the correct rate, instead of irregularity levels that may lead to monotonousness or chaos, is critical in ensuring a design that makes a positive impact. Based on the theory that an average level of complexity is preferred, it was assumed that the total entropy value of projects selected by the jury as winner always have a level of complexity closest to the average. In this case, the entropy value of the winning project must be closest to the peak (which specified as 12.5 bits) of an inverted U graphic. The second and third place projects are intended to be on the positive or negative side of the x axis, on the condition that they are close to the peak. The honorable mention prizes would be located further from the peak, relative to the second and third projects (Figure 10).

As seen in Table 3, by multiplying each factor's entropy values of all municipality building projects consistently regardless of different competition settings by constant coefficients ( $w_1$ ,  $w_2$ ,  $w_3$ ,  $w_4$ ,  $w_5$ ), and then summing them, a building's overall entropy value is found.

A non-dominated sorting algorithm which has been developed, multiplies 5 entropy values calculated for each project by 5 constant weighting values. While the project's entropy values calculated according to these factors (a, b, c, d, e) remain constant, weight coefficients ( $w_1$ ,  $w_2$ ,  $w_3$ ,  $w_4$ ,  $w_5$ ) are constantly changed by the genetic algo-

**Table 3.** Calculation formula of overall entropy values.

| Project                                                                                              | Status                     |                  | solid-void entropy values (a) |                  | outline entropy values (b) |                  | shape entropy values(c) |                  | functional distribution entropy values (d) |                  | spatial flow(circulation) entropy values (e) |  | overall entropy values(G) |
|------------------------------------------------------------------------------------------------------|----------------------------|------------------|-------------------------------|------------------|----------------------------|------------------|-------------------------|------------------|--------------------------------------------|------------------|----------------------------------------------|--|---------------------------|
| Competition 1 to n                                                                                   | 1st Prize to Mention Prize | w1(weight value) | a1, a2,.....,an               | w2(weight value) | b1, b2,.....,bn            | w3(weight value) | c1, c2,.....,cn         | w4(weight value) | d1, d2,.....,dn                            | w5(weight value) | e1, e2,.....,en                              |  | G1, G2,.....,Gn           |
| <b>Overall Entropy Calculation Example: <math>(w1xan)+(w2xbn)+(w3xcn)+(w4xdn)+(w5xen)= Gn</math></b> |                            |                  |                               |                  |                            |                  |                         |                  |                                            |                  |                                              |  |                           |

**Figure 11.** Layers representing the factors.

rithm to conduct the multiplications. By making changes in the weighting values, the algorithm seeks to bring the overall entropy value of a project to the intended point (on the inverted U graph) of evaluation made by the jury.

#### 4. Case study

Within the scope of this study, 24 municipality building projects have been selected, which have been awarded at 4 national architectural project competitions organized in Turkey. In the scope of this research, the architectural projects of the project competitions below have been investigated:

- Konak Municipality Building Architectural Project Competition (2015)
- Efeler Municipality Building Architectural Project Competition (2016)
- İnegöl Municipality Building Architectural Project Competition (2016)
- Van İpekyolu Municipality Building Architectural Project Competition (2016)

The documents relating to the competition projects were obtained

through individual interviews with the project owners. Reasons for choosing municipality buildings were:

- Each building has similar organization schemes and functions,
- Buildings are composed of repeating parts (units) with the aim of meeting functional requirements also addressing the project brief,
- Easy comparison of architectural approaches, schemes, functional distributions and similar features (due to the fact that competition projects are designed according to the same architectural typology and similar briefs).

In the first phase of the case study, the measurement of all projects was done according to the 5 physical factors explained in previous section. With the help of the developed algorithm, the drawings which represent different building features (factors) with layers were interpreted in Grasshopper environment and 5 entropy values for each project were calculated (Figure 11).

The respective projects investigated within the scope of the research, there was no quantitative similarity observed between measured entropy values such

**Table 4.** Calculated and remapped entropy values of all projects.

| Project                               | Status(Ranking) | w1(weight value) | solid-void entropy (a) | remapped (a) values | w2(weight value) | outline entropy (b) | remapped (b) values | w3(weight value) | shape entropy values(c) | remapped (c) values | w4(weight value) | functional distribution entropy values (d) | remapped (d) values | w5(weight value) | spatial flow(circulation) entropy values (e) | remapped (e) values | overall entropy values(G) |
|---------------------------------------|-----------------|------------------|------------------------|---------------------|------------------|---------------------|---------------------|------------------|-------------------------|---------------------|------------------|--------------------------------------------|---------------------|------------------|----------------------------------------------|---------------------|---------------------------|
| Konak Municipality Competition        | 1st Prize       | 3,33             | 0,91                   | 0,89                | 3,84             | 3,00                | 0,50                | 3,19             | 4,66                    | 0,10                | 2,27             | 1,71                                       | 1,00                | 2,92             | 2,89                                         | 0,84                | 9,93                      |
|                                       | 2nd Prize       |                  | 0,94                   | 1,00                |                  | 4,28                | 0,91                |                  | 4,69                    | 0,15                |                  | 1,56                                       | 0,67                |                  | 2,62                                         | 0,35                | 9,84                      |
|                                       | 3rd Prize       |                  | 0,89                   | 0,82                |                  | 2,58                | 0,37                |                  | 5,20                    | 1,00                |                  | 1,71                                       | 1,00                |                  | 2,52                                         | 0,17                | 10,11                     |
|                                       | Mention         |                  | 0,69                   | 0,10                |                  | 4,57                | 1,00                |                  | 5,05                    | 0,75                |                  | 1,35                                       | 0,21                |                  | 2,72                                         | 0,53                | 8,59                      |
|                                       | Mention         |                  | 0,89                   | 0,82                |                  | 1,73                | 0,10                |                  | 5,11                    | 0,85                |                  | 1,54                                       | 0,63                |                  | 2,48                                         | 0,10                | 7,54                      |
| Efeler Municipality Competition       | Mention         | 3,33             | 0,92                   | 0,93                | 3,84             | 3,89                | 0,78                | 3,19             | 5,08                    | 0,80                | 2,27             | 1,30                                       | 0,10                | 2,92             | 2,98                                         | 1,00                | 11,80                     |
|                                       | 1st Prize       |                  | 0,92                   | 0,76                |                  | 4,36                | 0,77                |                  | 5,42                    | 1,00                |                  | 1,88                                       | 1,00                |                  | 2,86                                         | 0,86                | 13,43                     |
|                                       | 2nd Prize       |                  | 0,89                   | 0,65                |                  | 4,13                | 0,67                |                  | 5,07                    | 0,83                |                  | 1,76                                       | 0,74                |                  | 2,51                                         | 0,26                | 9,80                      |
|                                       | 3rd Prize       |                  | 0,73                   | 0,10                |                  | 4,91                | 1,00                |                  | 4,70                    | 0,65                |                  | 1,47                                       | 0,10                |                  | 2,94                                         | 1,00                | 9,38                      |
|                                       | Mention         |                  | 0,97                   | 0,93                |                  | 2,90                | 0,14                |                  | 4,47                    | 0,54                |                  | 1,77                                       | 0,76                |                  | 2,70                                         | 0,58                | 8,78                      |
| İnegöl Municipality Competition       | Mention         | 3,33             | 0,99                   | 1,00                | 3,84             | 3,75                | 0,51                | 3,19             | 3,58                    | 0,10                | 2,27             | 1,76                                       | 0,74                | 2,92             | 2,81                                         | 0,78                | 9,52                      |
|                                       | 1st Prize       |                  | 0,91                   | 0,72                |                  | 2,80                | 0,10                |                  | 5,01                    | 0,80                |                  | 1,64                                       | 0,47                |                  | 2,42                                         | 0,10                | 6,70                      |
|                                       | 2nd Prize       |                  | 0,97                   | 0,85                |                  | 5,00                | 1,00                |                  | 5,47                    | 0,96                |                  | 1,70                                       | 0,61                |                  | 2,80                                         | 0,10                | 11,38                     |
|                                       | 3rd Prize       |                  | 0,98                   | 0,93                |                  | 3,93                | 0,34                |                  | 5,54                    | 1,00                |                  | 1,77                                       | 1,00                |                  | 3,04                                         | 0,70                | 11,89                     |
|                                       | Mention         |                  | 0,99                   | 1,00                |                  | 4,70                | 0,82                |                  | 4,12                    | 0,10                |                  | 1,61                                       | 0,10                |                  | 3,16                                         | 1,00                | 9,92                      |
| Van İpekyolu Municipality Competition | Mention         | 3,33             | 0,95                   | 0,70                | 3,84             | 4,72                | 0,83                | 3,19             | 4,90                    | 0,59                | 2,27             | 1,75                                       | 0,89                | 2,92             | 2,97                                         | 0,53                | 10,95                     |
|                                       | 3rd Prize       |                  | 0,87                   | 0,10                |                  | 3,54                | 0,10                |                  | 4,93                    | 0,61                |                  | 1,68                                       | 0,49                |                  | 3,01                                         | 0,63                | 5,61                      |
|                                       | Mention         |                  | 0,95                   | 0,70                |                  | 4,00                | 0,38                |                  | 5,00                    | 0,66                |                  | 1,70                                       | 0,61                |                  | 3,00                                         | 0,60                | 9,03                      |
|                                       | 1st Prize       |                  | 0,98                   | 1,00                |                  | 3,72                | 0,77                |                  | 4,70                    | 0,32                |                  | 1,73                                       | 0,84                |                  | 2,63                                         | 0,28                | 9,99                      |
|                                       | 2nd Prize       |                  | 0,98                   | 1,00                |                  | 3,97                | 1,00                |                  | 4,63                    | 0,10                |                  | 1,76                                       | 0,92                |                  | 2,84                                         | 0,61                | 11,36                     |
| Van İpekyolu Municipality Competition | 3rd Prize       | 3,33             | 0,95                   | 0,55                | 3,84             | 3,28                | 0,36                | 3,19             | 4,64                    | 0,13                | 2,27             | 1,79                                       | 1,00                | 2,92             | 3,08                                         | 1,00                | 8,82                      |
|                                       | Mention         |                  | 0,92                   | 0,10                |                  | 3,00                | 0,10                |                  | 4,92                    | 1,00                |                  | 1,46                                       | 0,10                |                  | 2,77                                         | 0,50                | 5,59                      |
|                                       | Mention         |                  | 0,92                   | 0,10                |                  | 3,88                | 0,92                |                  | 4,85                    | 0,78                |                  | 1,73                                       | 0,84                |                  | 2,52                                         | 0,10                | 8,53                      |
|                                       | Mention         |                  | 0,92                   | 0,10                |                  | 3,30                | 0,38                |                  | 4,90                    | 0,94                |                  | 1,70                                       | 0,75                |                  | 2,60                                         | 0,23                | 7,15                      |
|                                       | Mention         |                  | 0,92                   | 0,10                |                  | 3,30                | 0,38                |                  | 4,90                    | 0,94                |                  | 1,70                                       | 0,75                |                  | 2,60                                         | 0,23                | 7,15                      |

as solid-void, outline, shape, functional distribution and spatial flow (circulation) entropy.

For instance, the solid-void entropy value can be between 0 and 1 bits as well as functional distribution entropy varies between 0 and 2.32 bits. On the other hand, outline, shape and spatial flow entropy values can have a wide range of values, depending on complexity in the building contour, numeric distribution of units, and distribution of spatial flow elements. Due to significant differences between numeric entropy values and weightings of factors on the subjective evaluation process, to reach an overall entropy value calculated with the consideration of all factors; therefore, the simple addition of entropy values would not produce accurate and meaningful results.

To solve this problem, the minimum and maximum entropy values calculated according to the factors were remapped between 0.1 and 1. For instance, the maximum shape entropy value 5.54 corresponds to 1, while the minimum value of 3.58 bits corresponds to 0.1. This remapping operation was repeated for all factors. Thus, it was ensured that the multiplied and summed values became comparable (Table 4).

Since optimization was done collectively for the 5 factors for each of the 24 projects, the objective of the genetic algorithm was defined as follows: Multiply the entropy values of each project by the same coefficients/weighting, and bring them to the intended position (points) on the inverted U graph, according to their overall entropy values.

For the inverted U graph, a range of entropy values between 0 to 25 bits were set. In this case, the genetic algorithm changed the weighting values to approximate the most successful projects to 12.5 bits. The weighting values fixed by the genetic algorithm after countless generations and multiplication are as follows: 3.33, 3.84, 3.19, 2.27, 2.92 (Figure 12; Table 4).

As shown in Table 4, and as stated in the aims, the genetic algorithm failed to bring all the first-prize-winning projects close to the 12.5 bits overall entropy value. The algorithm searches weighting values and overall entropy values, not only for the first projects, but also for the project's overall. This step aims to place all the projects in the desired order as close as possible. Therefore, calculated results are optimal values for all projects and factors, rather than focusing on the perfection of a given project. Weighted overall en-

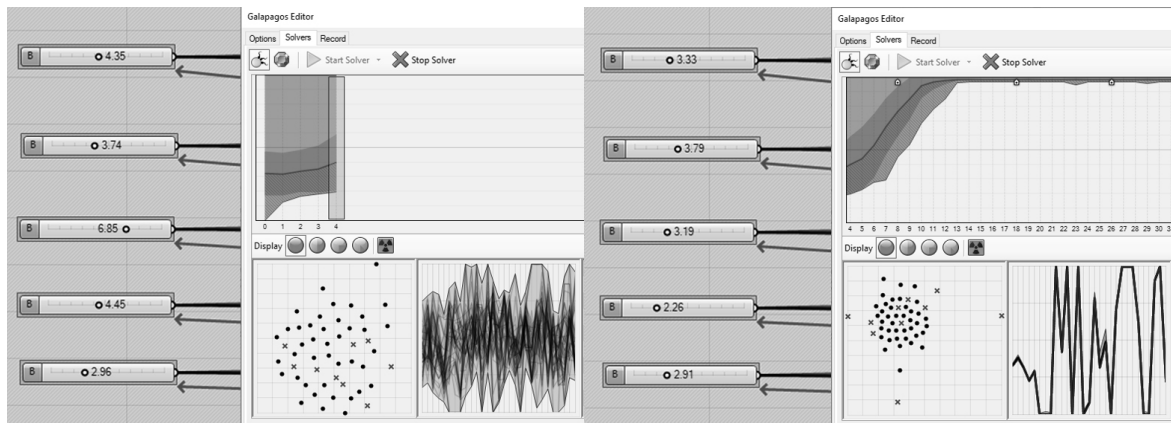


Figure 12. Searching for weights of factors with galapagos.

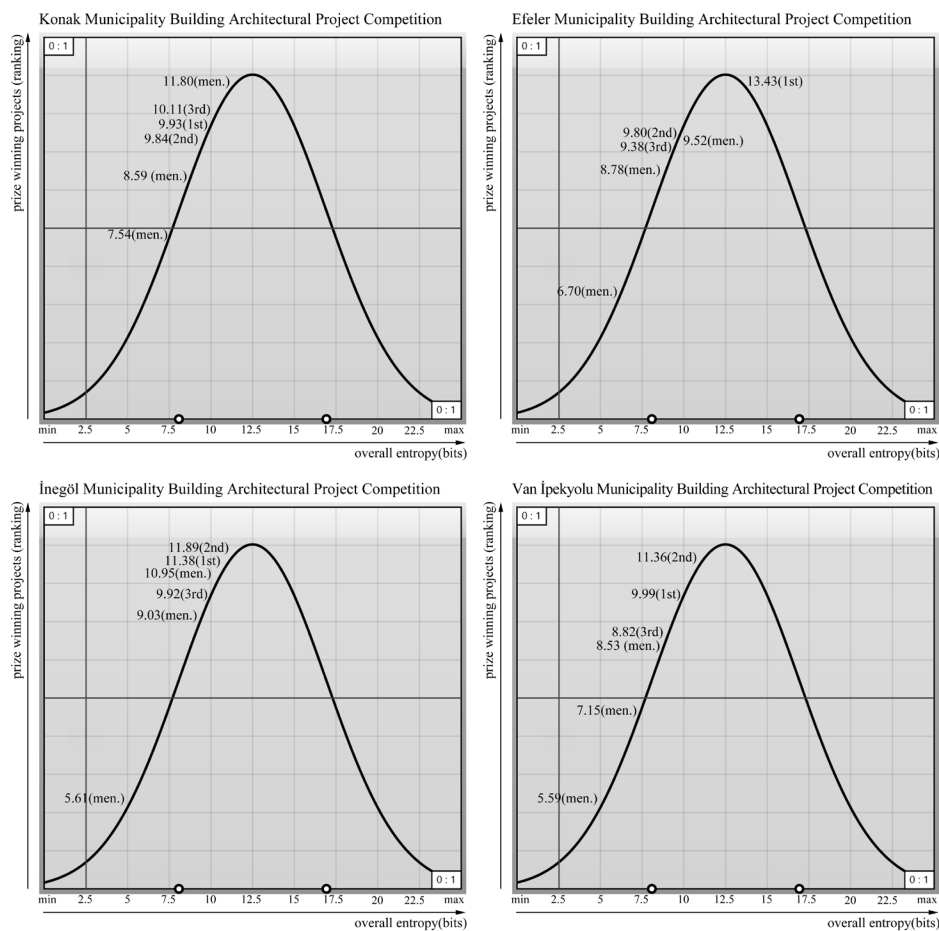


Figure 13. Outputs of optimization values represented on inverted U graphs.

entropy values of 4 different competitions are illustrated on the inverted U graphs in Figure 13.

## 5. Conclusion

We presented a methodology and the results of an analysis of a group of architectural projects that had previously been evaluated by juries in national competitions. Jury evaluations include many criteria, some of which may not be calculated. In this study, we solely focused on factors that can be digi-

tized. Our analysis was then concerned with how the selection criteria may be weighted. By calculating the weightings, it became possible to determine which factors entropy was more dominant in the evaluation process. When competitions and projects are handled independently, weighting of criteria are changed from one competition to another, relating to jury evaluations.

However, we suggest that examining a large number of award-winning projects in different competitions within

the same framework may be useful in obtaining important findings about selection criteria.

Non-awarded projects were not included in the calculation and this can be justified by the following: the tendency of the genetic algorithm reduces the weighting values significantly in order to place the non-awarded projects at the bottom in the ranking scale. In this case, the algorithm can not function properly because there are two conflicting objectives.

Developed automated algorithm proves that entropy values calculated based on various single factors differ from one project to another. In addition, the overall entropy values obtained by directly summing the calculated entropy values are not similar.

Based on the idea that the average entropy values will have a positive effect, we aimed to rank the entropy values of the projects by multiplying with coefficients with the use of a non-dominated sorting algorithm.

The projects ranked according to the 5 coefficients found by the genetic algorithm show similarities in the ranking of the jury evaluation. For this reason, instead of perfectly ranking the projects awarded in a single competition, we have tried to rank all the projects participating in the 4 competitions, concurrently.

Figure 13 illustrated that the projects which received the honorable mention were far from the peak, and the entropy values of the projects which won the first three awards were closer to 12.5 bits.

It is envisaged that the predictability of jury evaluations will increase if the number of factors in this study is increased. To solve the subjective basis of the jury evaluation, it is not possible to present absolute findings in the research according to the 5 criteria. Increasing the number of factors and number of competitions (which were limitations within this study) may increase the accuracy of the analysis and predictability of the competition results.

As a result of this study, certain weighting values have been obtained. In the study, it was found which factors are influential to which degree, in the case which a jury makes selection

as per entropy values by using coefficients.

In an application based on another sample group (competition), the weighting may differ depending on the entropy values of the projects and the evaluation criteria of the jury.

To conclude, this method is able to make a design evaluation using entropy measurements. The entropy calculation method developed in the scope of this study can be implemented for building such as hospitals, cultural centers, and schools which are composed of rational or complex forms.

This study differs from the previous studies, as it uses multiple interrelated entropy values, aiming for the evaluation of a specific architectural typology. This method can be used for the optimization and analyses of designed projects. The algorithm can also make predictions about the potential of project winning a prize in a competition.

In future work, the entropy values of the various features of the facade and the properties of the three-dimensional spaces can be calculated. Thus, an entropy value can be obtained that takes into account more features of the building.

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