

## Article

# Evaluation of the Interventions to Built Heritage: Analysis of Selected Façades of Kaunas by Space Syntax and Sociological Methods

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**Abstract:** This paper is an attempt to analyse the correlation between the perception of people and their evaluation regarding contemporary interventions and changes on the façades of cultural heritage buildings, which might affect cultural sustainability. The paper uses two different experimental methods for the analysis of the building façades from various eras in the city centre of Kaunas, which experienced interventions that affected the appearance of the structures. The first experiment performed is a sociological survey, and the second one is a façade analysis conducted by the space syntax method. The paper follows the theory of Nikos Salingaros for measuring the properties of the size distribution on the façades and implements Bill Hillier's methodology for symmetry index analysis. The research demonstrates some significant correlations between the results of Space Syntax modelling and the sociological survey answers, thus demonstrating the possibility of modelling and predicting changes in the perception of architectural transformations of the façades with potential usability in the monitoring of the transformation of cultural heritage objects, preservation of the cultural identity of a cityscape, etc.

**Keywords:** space syntax; façade configuration; visual perception; built heritage; Kaunas; cultural sustainability



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## 1. Introduction

The expression of genius loci in architecture implies the reflection of memory and symbols, which serve to root the society that can be traced on the cultural heritage and the language of architecture. This property of architecture is essential for human beings to associate themselves with the place since it contributes to culture and cultural sustainability. As stated by Abusafieh, there is a significant link between culture and sustainability, and the rules, values, beliefs, and norms of the culture transfer the sustainability of vitality of the communities [1]. If people see the reflection of themselves in the environment they inhabit, they feel more comfortable in these environments. However, the interventions implemented with respect to cultural heritage due to the need for new spaces in developed cities can establish unavoidable transformations of heritage buildings in the city centres. Furthermore, they can negatively affect the requirement of the cultural heritage buildings to remain recognisable as historical marks, which might affect the cultural sustainability of these artefacts. Moreover, they can impact the language of architecture, which might give rise to inadmissible results and disrupt the existing architectural language permanently. Such a significant alteration or even demolition of cultural heritage is not a sustainable way of urban development in opposition to a way for cultural heritage to continue to resonate in future developments [2]. Therefore, it is essential to identify the impact of these changes on the perceptions of people.

In this regard, this research tries to analyse the correlation between the changes in the façades of cultural heritage artefacts with the perception of the people before and after the adaptive reuse applications, which involve contemporary interventions, and the impact of adaptive reuse on the volume of the façades. The analysis for identifying all these different aspects can be achieved by various methods which are used in architectural research. One of the most common methods which has been used in recent years is analysis by eye-tracking technology [3,4]. With this technology, it is possible to identify the parts of the façades which catch the attention of observers the most. However, identifying the reasoning behind this selection cannot be achieved by eye-tracking glasses. Therefore, more detailed research is required to determine and understand the perception process. In the course of perception, especially if the observer does not have enough knowledge or has uncertain evidence, it is likely that the observer will use prior knowledge to achieve an optimal solution [5]. Therefore, it would be beneficial to use the other possible approaches such as fractal analysis of the façades or pattern approach and apply them as the sources of prior knowledge for analysing, classifying, and predicting responses [6,7].

This paper follows the theory of Salinargos to measure the properties of the size distribution on the façades to analyse the changes, and the aesthetic synergy of the adjacent buildings is determined by implementing Hillier's methodology for symmetry index analysis [8,9]. The paper begins by examining the definition of a façade in architecture. This is followed by an explanation of the adaptive reuse of cultural heritage and how adaptive reuse strategies can affect the façades of buildings and sustainable development. The paper then gives information about the methodology and the method of the two experiments (the first one with a sociological survey and the second one is a façade analysis) and how they were implemented. Furthermore, it discusses the results of both experiments regarding the analysis of the building façades in Kaunas and determines the changes established by the interventions.

## 2. Literature Review

### 2.1. *The Function of Façades in Architecture*

According to the Cambridge Dictionary, a façade is the front of a building [10]. However, structures can contain different façades, which are not necessarily the front but also the side or the back of the building. Most of the time, people have their first connection with the design by the front façade, and as Pallasmaa describes, the door handle is the first handshake that people share with a building [11]. Especially when the front façade of the building is analysed, it is possible to state that it is the display of a design that provides information to observers or users in a similar way as one visual representation of an object with a visually complex design gives valuable information about the more visually complex object, as Dotson states [12]. Furthermore, according to various studies, the changes that appear on the façades can affect the preference, complexity, and impressiveness of the buildings for observers. They can change the familiarity and the liking of the structures [13,14]. As Mao et al. state, the façades of heritage buildings can also establish an impact on the behaviour of people and human activities in public spaces [15]. Therefore, even though the façades might seem as if they are one of the physical elements of the structures, they do have an important role both in the environment and in the perception of the structures for people.

It could be argued that the same façade might look differently from different observation points while changing proportions, making some parts invisible, etc. In this case, two aspects of façades as building faces should be mentioned:

- If the description of the façade is focused on the architectural pattern concept (Salinargos) instead of a detailed description of architectural form, then it opens a way to look for some general, fundamental features of architectural composition which are not sensitive to small changes in form because of changing observation points.
- Based on the logical analogy with the human face recognition process, it could be assumed that at least known façades, e.g., cultural heritage objects that are perceived

in situ and potentially through various media channels, could be recognised from various positions of observation.

In this regard, the message or the information that the front façade provides with the language it uses is essential because it establishes the initial impression that people need to understand or perceive the whole structure.

According to Gehl, there are two types of façades. The first type is the active façade which gives an adequate impression to observers or users since it contains the material whereby people can communicate with the language of the architecture [16]. The other one is the passive façade which does not cause any feelings or emotions. As Ellard states, the buildings which have passive façades are structures where people feel as if they are on the wrong side of the façade [17]. However, it might not just be a matter of being active or passive, but it might also be about the reflection it creates on people's perceptions. In that regard, it is essential to understand the languages that architecture uses for communicating with people on buildings' façades.

The urbanist and controversial theorist Salingeros states that architecture is established by two distinct, complementary languages: a pattern language and a form language [18]. The pattern language involves the interaction of human beings with their environment, and it is appropriate for local customs, society, and the climate where the building is. It is a set of repeatedly tried and true solutions inherited from the previous generations, which developed optimisations that create a sense of well-being for the people. However, Alexander was the first to propose the definition of a pattern language for architecture [19]. As he points out, while many, if not most, of the patterns in pattern language, are universal, there are an infinite number of existing individual patterns that can be included. According to him, each pattern language tends to reflect a different mode of life or customs or behaviours. Additionally, it is appropriate to specific climates, geographies, cultures, and traditions. Therefore, the pattern language of a building establishes the interpretation of the architecture and how architecture was formed in different regions by the effects of the local architecture and experience. Furthermore, it reflects the culture.

On the other hand, form language is defined by the elements of a building that establish the whole. The elements which determine the form are the floors, the walls, the windows, the doors, the ceilings, the partitions, and all the architectural components which together represent the style. In the accumulation of all the different elements in the form language, the building expresses its architectural style. Furthermore, every traditional architecture has its own form language as well. It has been established from various influences of daily life, traditions, and practical concerns, which act together to define the structures that take the most natural visual expressions of a specific culture. Architecture becomes an accumulation of the circumstances of culture and a signifier of the collective when establishing a system of relations between the differentiating elements. Therefore, the form language which was used in architecture is also affected and influenced by the culture, like the pattern language. Pattern language makes buildings more readable and understandable since it is possible to have a universal form language, but it is not that easy to have a pattern language valid in every culture since they have their own characteristics related to the region. When architecture utilises both of these languages in its design, it establishes a valid architecture, and furthermore, primarily with the effect of the pattern language, it establishes an environment for the people where they feel familiar with their surroundings. According to Alexander, it is possible to improve the patterns by testing them against experience by recognising how the patterns make people feel regarding the existence of the patterns in their surroundings [19]. However, in his research, Alexander did not describe patterns and how to test them quantitatively.

The quantitative approach regarding the description of the patterns has been designed by Salingeros. In this book called *A Theory of Architecture*, he explains the scientific basis of creating architectural forms, hierarchical cooperation, modularity, and the number of design choices in the formation of architecture [18]. As he states, architecture is an expression and, at the same time, the application of geometrical order; therefore, if the order can be

understood, it will give the knowledge to understand the language of architecture and what it is trying to explain to users/observers as well. When the information quality which passes to the user/observer is rich, it is more likely that there will be an emotional bond established. However, the method Salingaros established has a high degree of interpretation regarding the selection of symmetries and asymmetries or which elements of the façade should be analysed.

Furthermore, the selection of the elements of the patterns for the identification of the symmetries is indefinite as well. When the elements of the patterns are identified by different people, their interpretations might be dissimilar. Therefore, it is possible to state that the same façade might give different results depending on the perception or the evaluation of the person who identifies the elements. As a result, his model establishes a level of subjectivity to some extent. In his approach, he mainly focuses on the structural order and the scaling rules, which are independent of architectural styles or architectural shapes as well.

According to Salingaros, there is an ideal scaling factor, which is approximately equal to the logarithmic constant 2.7, and it leads to the scaling coherence of the objects [18]. His proposal of the scaling rule derives from Alexander's scaling rule; however, he adds another dimension to it, which is the designation of the ideal number for the scale. On the one hand, his approach helps the architects or the people who want to understand what architecture is communicating by establishing a set of rules and order in the process. On the other hand, it does not consider other aspects of the perception of architecture, such as the colour, material, and texture. All these aspects have an impact on perception as well. Therefore, the method that should be followed is still ambiguous. However, according to Hillier, the meaning reflected in the façades of the buildings by the language that architecture is adopting can be identified [20]. Furthermore, limits can be set towards meaning by distinguishing the idea of meaning from aesthetics in architecture. Therefore, it might be possible to achieve quantitative data and measure the meaning or how the meaning is changing by analysing the architecture, specifically the façades affected by the interventions of adaptive reuse.

In the last decades, specifically in recent years, interventions regarding cultural heritage buildings in the city centre started to be seen more in Kaunas, Lithuania. One of the reasons for this can be explained by the nomination for Inscription on the UNESCO World Heritage List. In the course of the preparation of the protection and management plans for the city centre, the demolition of existing buildings or construction of new structures in this area started to be controlled and regulated by different institutions [21]. Furthermore, additions and interventions to the heritage buildings are administered and authorised as long as they are coordinated with the relevant governmental organisations responsible for cultural heritage protection. Therefore, with the requirement for more space in this valuable area of the city, heritage revitalisation and all the new additions to these buildings started to be seen more often [22]. Moreover, adaptive reuse projects in the city accelerated and monitoring façade changes became more essential [23,24]. As a result, the structures which were used in this research were selected from the cultural heritage buildings from various eras in the city centre of Kaunas, which had different interventions regarding their façades.

## 2.2. Adaptive Reuse and Built Heritage

Over the centuries, the concept and treatment of heritage and approaches to the conservation of it have changed as values have changed as well. As Vecco states, the monument is no longer considered alone but is now taken in its context in heritage studies [25]. Therefore, the adoption of an integrated approach towards heritage, its evaluation and its preservation does not merely affect the structure itself but also has an impact on the environment. Adaptive reuse is a commonly used method that provides a new function to an existing structure; therefore, the structure adjusts to the current needs. Even though most of the time, the reason for this action is due to the requirements of the market and financial gain, in contemporary conditions, adaptive reuse is implemented with respect to the cultural

heritage buildings for their protection. According to Haldrup and Bærenholdt, heritage has traditionally been bound with the conservation of the imagined past [26]. However, heritage is not only about the past, but it also has a reflection in the present. By the method of adaptive reuse, it is possible to keep the progression of the artefacts and, at the same time, the environment, which can help people to associate with them better and more easily.

In the book called *Uses of Heritage*, Smith states that there is no such thing as ‘heritage’, and heritage has to be experienced for it to be heritage [27]. Therefore, heritage must be a part of daily life, and it should contribute to the genius loci of the environment. According to Vecco, genius loci is the intangible quality of a material place, which can be perceived both physically and spiritually through visible tangible and perceivable non-material features [28]. Therefore, while adaptive reuse can provide the continuity of the material characteristics of the heritage, its outcome, which is cultural sustainability, can contribute to its non-material aspects. It is crucial to indicate that one of the leading characteristics of heritage is that it is a carrier rather than a solid concept. It only endures when used on a daily basis and perceived by society itself. In that regard, adaptive reuse provides both aspects for the cultural heritage buildings to be experienced.

However, adaptive reuse has another constraint which is its collaboration with the sustainable development of the environment. Most of the time, the meaning of sustainability is merely associated with the sustainability of nature, recycling, and self-sufficiency; however, sustainability has many different aspects which have a direct impact on the built environment as well. As stated by various authors, the main assets of sustainable development are society, the environment, and the economy. However, according to Hawkes, sustainable development contains a fourth pillar, which is culture [29]. The main concern of sustainability and sustainable development is the protection and continuity of resources that are irreplaceable. In that regard, it is possible to state that cultural heritage is irreplaceable when it vanishes as well. It is crucial to maintain the continuity of cultural heritage to maintain the culture and, at the same time, maintain the built environment. According to Hristova, a city remembers through its buildings; thus, the preservation of the old urban fabric is analogous to the preservation of memories in the human mind [30]. Therefore, a city is a collective memory of its people, and it is a way of remembering which is associated with objects and places. Associations that people obtain through the built environment help establish potential stimuli for people to remember, which is one of the crucial impacts of architecture on people. Therefore, when the built environment carries its own characteristics, it stays recognisable to the people, which supports sustainability. Sustainability derives from the ability of continuum. Therefore, adaptive reuse of buildings also has the same impact on the environment since it helps the structures to continue their lives and helps to keep the environment the way it is. However, some of the interventions with respect to the structures can change the perception of the building as well as the proportion and the symmetry, which has an impact on the intelligibility of the structure. As Rabun and Kelso state, a building to which the adaptive reuse will be applied with a change of use must be evaluated from both the exterior and the interior, and the assessment of it must be done in a comprehensive manner [31]. Furthermore, it is essential to pursue the acceptance of the artefact in its environment. Therefore, modern additions, which might affect the recognition of the original elements, need to be omitted. As a result, there are various factors that have a direct and indirect effect on the process of adaptive reuse and the built environment and its perception.

To understand these effects, a pilot study was conducted in Kaunas, Lithuania, by two experiments. The first experiment is based on a sociological survey, which checks how well people perceive changes of the building façades. In contrast, the second experiment attempts to model those changes of the façades in a mathematical way. Statistical analysis of relations between the results of both experiments is employed to identify if and how human perception could be reflected and potentially predicted before any modifications of the façades based on mathematical analysis. Changes of the exterior of buildings are chosen

as the most subjectively perceived and the least function-based aspect. The methodology of both experiments is described in more detail in the third section.

### 3. Methodology and Experiments

As Hillier states, building façades are physical shapes that are capable of being understood as communicators of information. However, to understand the shapes, the shapes need to be identified and recognised by the observer [9]. According to him, the recognition of the shape of an object occurs in two stages. The first stage of recognition is the syntactic stage, and the second stage of recognition is the semantic stage. In the first stage, people tend to determine the object by the identification of the elements that they perceive in its configuration; however, in the second stage, people attach meaning to the object or they interpret what they see. In that regard, it might not be possible to measure the attached meanings or interpretations; however, the syntactic stage of recognition can be measured by analysing the configuration as the symmetry index.

Symmetry is a concept acquired from mathematics, specifically from the group theory by Miller and Carter [32,33]. However, it is widely used in other disciplines, such as physics, chemistry, biology, psychology, art, and architecture. According to the APA Dictionary of Psychology, symmetry is “the mirrorlike correspondence of parts on opposite sides of a centre, providing balance and harmony in the proportions of objects, and it is considered an aesthetically pleasing quality” [34]. Furthermore, as Hodgson states, symmetry can be a persisting feature for the perception of the visual world since it provides valuable means which can be encoded for the purpose of efficient recognition of the objects [35]. Therefore, symmetry is a distinctive peculiarity for the perception of objects, and furthermore, it is essential for analysing and understanding nature, art, and architecture.

According to Mitra and Pauly, symmetry and structural regularity in architectural design are not coincidental [36]. Most of the time, it is the consequence of economical, manufactural, functional, or aesthetic considerations that make the structure universally appealing. Therefore, symmetry can affect the visual perception of the architecture in our environment by its peculiarity of reflecting the nature and natural orders that can influence the recognition of the objects and the sense of beauty.

The symmetry of architectural objects can be measured by the symmetry index, which Hillier has suggested. According to him, the symmetry index is a considerable ratio in which low and high values can demonstrate similarities and differences in how the parts relate to the whole [20]. Therefore, by measuring the symmetry indexes of the buildings before and after the cultural heritage intervention and comparing them to the results of surveys on human perception of the selected façades, it might be possible to identify how the perception of the building has changed and if it could be reflected by the offered space syntax indexes. In that regard, two experiments are conducted in this research.

The first experiment involved a sociological survey performed by online communication tools, and the second experiment involved checking the façades by Space Syntax based modelling. The experiments contained the analysis of the façades of eight buildings in Kaunas, Lithuania, which underwent an adaptive reuse process. All eight buildings are located in the new town section of Kaunas city centre, and they have undergone small- or large-scale interventions such as additions to the roof or additions to the building itself, which have affected their appearance. The experiments aim to understand the effects of the interventions, which are later added to the buildings. Therefore, all eight buildings are analysed by the depthmap program before and after the adaptive reuse to detect the changes in the symmetry indexes of the structures. At the same time, a sociological survey is performed to understand how people’s perception is affected by the interventions. At the end of both analyses, the results are compared. At the same time, correlations between the survey answers (attractiveness and perceived symmetry) and space syntax indexes (symmetry index plus some other offered indicators) were calculated. There was no separate analysis of correlations before and after changes of the façades. At the moment, the

research aims to check if space syntax indexes can reflect certain objective features of the façades that correspond to the subjective perception.

### 3.1. Experiment I: Sociological Survey

#### 3.1.1. Design

The social survey prepared for this research is a questionnaire which contains 16 photographs of 8 different buildings which underwent a change from their original appearances due to different forms and scales of interventions. The buildings selected for this research are cultural heritage buildings from various eras in the city centre of Kaunas. While it was possible to find the prior status photographs of some of the buildings, with other ones, it was not possible to find any documentation regarding the earlier situation due to there either being no photographs, or the width of the street not allowing us to see the whole building. Therefore, in 6 of the buildings, the additions were deleted with the help of various software. The survey aims to examine people's perception of the buildings before and after the adaptive reuse.

In the design of the survey, a qualitative approach and non-probability sampling were adopted. The goal of adopting a non-probability sampling was not to achieve objectivity in selecting samples or attempting to make generalizations (i.e., statistical inferences) from the sample studied by the broader population of interest. Therefore, generalizations from the sample to the population under study are secondary considerations. With a purposive and convenience sampling technique, 66 participants in total took part through an online survey platform. The selection of the participants adopted snowball sampling, which is a non-probability sampling method commonly used in the process of collecting data from participants. It is one of the most common methods of sampling in qualitative research, central to which are the characteristics of networking and referral. The researchers usually start with a small number of initial contacts (seeds) who fit the research criteria and are invited to become participants in the research. The agreeable participants are then asked to recommend other contacts who fit the research criteria and who might also be willing participants, who then, in turn, recommend other potential participants, and so on. Researchers, therefore, use their social networks to establish initial links, with sampling momentum developing from these, capturing an increasing chain of participants. Sampling usually finishes once either a target sample size or saturation point has been reached" [37]. The potential participants who were willing to participate in the research with an average knowledge of cultural heritage were asked a set of questions. The participants were asked to transfer the experiment to their circles that fulfilled the same criteria. Therefore, the focus group involved people who are already interested in architecture and the changes happening in their cities. Participants were heterogeneous regarding age, ranging between 12–75 years old, and heterogeneous regarding place of origin. In the process of data collection, the data regarding gender, age, and education level were collected. However, we decided to use these criteria in broader research which would focus on the analysis of these specific variables. Therefore, it was found to be irrelevant to the experiment as the network of people created by the snow sampling method did not demonstrate enough differences between age groups. Furthermore, the main aim was not to measure different people's reactions but the reactions to the buildings.

The survey was structured in three main sections and four subsections for the second and third sections. The main difference between the second and third sections was that while the second section reflected the status of the buildings before the interventions, the third section reflected the current status of the buildings.

In the implementation of the survey, 16 photographs were presented to the participants (Figure 1).



**Figure 1.** Presented photographs with the sample numbers below. Each column demonstrates before and after version of a building with its sample number.

The buildings for the experiment were selected according to the following criteria:

- cultural heritage objects;
- the recent renovation of the buildings, including façades with the old part still visible in architectural composition;
- possibility of describing the façades mathematically as a set of polygons with clear boundaries created by architectural elements.

As it was not possible to obtain the photographs of the same buildings in frontal view before reconstruction, in order to avoid additional influence on the survey results because of the technique differences, it was decided to make visualizations for both situations before and after the reconstructions. Fifteen of the photographs were modified with the objective to model in 3D software the previous appearance before the modifications were completed; the 3D modelling was combined with rendering and postproduction in photo editing software to recreate the previous stage of the building as close as possible in appearance to the photographs, literature information, and online sources (Table 1).

In order to analyze the perception of the changes in the buildings and not make it difficult to see them or perceive them from a different angle, the digital recreation was kept in the same position and angle from the actual renovation state of the buildings (Figure 1). The modification of the façades contains the following steps:

Evaluation of the buildings, which requires 3D modelling or just image modification.

1. For 3D modelling: a. Measure in Google Earth distance, b. Import photograph in Google Sketchup, c. Usage of Google Sketchup tool [Match new photo] to set position, angle and draw distances to compare to the measured distances from Google Earth, d. Model the roof as a surface, e. Export the model to Blender, f. In Blender, set tool for textures and sun position, g. Rendering by cycles, h. Save image file as PNG, i. Import to GIMP, j. Masking tool in the original photograph, k. Modify the tool for the PNG photographs to position in the original photograph and l. Save picture.



2. For the photographs which do not require modelling in 3D, the GIMP program is used as follows: a. The masking tool, b. Layer tool, c. Match colour, d. Position, e. Copy, f. Modify layer and g. Save file.

After the modification of the photographs, the first section of the survey was organised with general questions about gender, age, and education level to obtain demographic characteristics of the survey participants. However, the data of this section were not used in the analysis of this article.

The second and third sections were organised based on each photograph (named sample), followed by four sub-sections. These sections aimed to measure the capacity to recognise the building's level of attractiveness and the composition features of the façade, such as symmetry, rhythm (known as repetition in our survey), and the elements that provide a level of hierarchy in the façade.

In both sections, the first subsections were based on a scale from 1 to 10 regarding the building's attractiveness level. This was set using the Likert scale, where the lowest value corresponded to 1 and was equal to not attractive, and the highest value, equal to 10, corresponded to very attractive (Figure 2).

**Table 1.** Description of the 3D modelling process of the photographs.

Photograph	Style	Construction Date	Addition/Renovation Date	Addition/Renovation Description	3D Model Object + Rendering	Photo Edition Modification
Sample 1	Modernism	1938	2020	Roof shape modification, windows addition	-	-
Sample 2	Historicism	1870	2002	Roof shape modification, building height, fourth floor, curtain panel, terrace, balcony, handrail	Roof	Sky, nearest building
Sample 3	Historicism	1901	2006	Roof shape modification, building height, curtain panel	Roof	Sky, nearest building, walls, surroundings
Sample 4	Historicism	1902	1999	Roof height, third floor, windows, doors, balcony, drains	Roof	Sky, nearest building, walls, surroundings
Sample 5	Modernism	1937	2013	Roof height, fourth floor, windows, doors, balcony, drains, handrails	Roof	Sky, nearest building, walls, surroundings
Sample 6	Modernism	1938	1982	Roof height, third floor, windows, doors, balcony, drains, handrails	-	Sky, nearest building, walls, surroundings
Sample 7	Historicism	1896	2021	Roof, windows, doors, balcony, curtain panel	-	Sky, nearest building, walls, windows, doors, surroundings
Sample 8	Historicism	1897	2011	Roof height, third floor, fourth floor, windows, doors, balcony, handrails	-	Sky, nearest building, walls, windows, doors, surroundings

On a scale of 1 to 10, how attractive is this building?



1   2   3   4   5   6   7   8   9   10

Not attractive                                 Very attractive

**Figure 2.** Sample sheet of the social survey regarding attractiveness.

The second subsection contained the same scale from 1 to 10, and it aimed to understand the perception of symmetry of the façade. Again, the Likert scale was applied where the lower value corresponded to 1, which is equal to completely asymmetrical, and the value of 10 corresponded to highly symmetrical. In this subsection, a red segmented line in the center of the building was added using photo editing software to guide the participants over the main façade of the buildings (Figure 3).

On a scale of 1 to 10, how symmetrical is this façade?



1   2   3   4   5   6   7   8   9   10

Completely asymmetrical                              Highly symmetrical

**Figure 3.** Sample sheet of the social survey regarding symmetry.

The third subsections were open questions regarding the repetitive elements in the buildings, and the fourth subsections were open questions related to the most striking

















features. All the elements mentioned above belong to the second section, summarised in two-scale questions and two open questions.

### 3.1.2. Analysis of the Data

According to the sociological survey, the additions or the changes on the façades impacted the attractiveness levels of the buildings. While attractiveness decreased in the 1st, 3rd, 4th, 5th, 7th, and 8th buildings, it increased for the 6th building. However, attractiveness levels stayed the same for the 2nd building. The common characteristics of the buildings where the attractiveness levels decreased can be identified as the height of these structures. The additions can be easily detected from the street level in all of these structures. Furthermore, the additions are significant when they are analyzed in the sense of proportion. Therefore, it might be possible to state that the human eye level and proportion have a particular impact on the perception of these additions.

On the other hand, decreased symmetry of the 3rd and the 4th buildings affected the attractiveness levels of these structures in a negative way. However, even though the symmetry perception increased for the 1st and 8th buildings, their attractiveness levels still decreased. The increased symmetry affected the perception and the attractiveness of the 6th building in a positive way. However, it did not have a specific outcome for the 2nd building since both symmetry and attractiveness stayed the same for this structure. The perception of symmetry levels decreased for the 4th and the 5th buildings, which also diminished the attractiveness levels (Table 2).

**Table 2.** Results of the sociological survey: Decrease  Increase  Stable .

Building	Attractiveness Level before the Addition	Attractiveness Level after the Addition	Result	Perceived Symmetry Level Before the Addition	Perceived Symmetry Level after the Addition	Result
Sample 1	7	3		4	5	
Sample 2	9	9		10	10	
Sample 3	5	3		9	3	
Sample 4	8	5		6	4	
Sample 5	7	5		4	3	
Sample 6	7	8		1	10	
Sample 7	8	7		7	7	
Sample 8	8	1		4	8	

For the 1st, 2nd, and 3rd buildings, the roof's addition was found to be one of the most striking elements of the buildings after the additions. However, the participants also stated that the contrast between the old and new established a striking effect. On the other hand, the diverse nature of the 4th building was found to be striking, and according to one participant, the building was found to be irregular and asymmetrical. According to the participants at the 7th building, the tower was described as significant and striking; however, after the interventions, the tower was found to lose its significance. Furthermore, the glass windows which were added to the ground floor caught participants' attention. For the 8th building, participants described the roof windows as striking because they do not follow any axis, and they look random. However, after the intervention, the roof is mainly described as aggressive, although still striking due to its establishing a contrast.

### 3.2. Experiment II: Façade Analysis

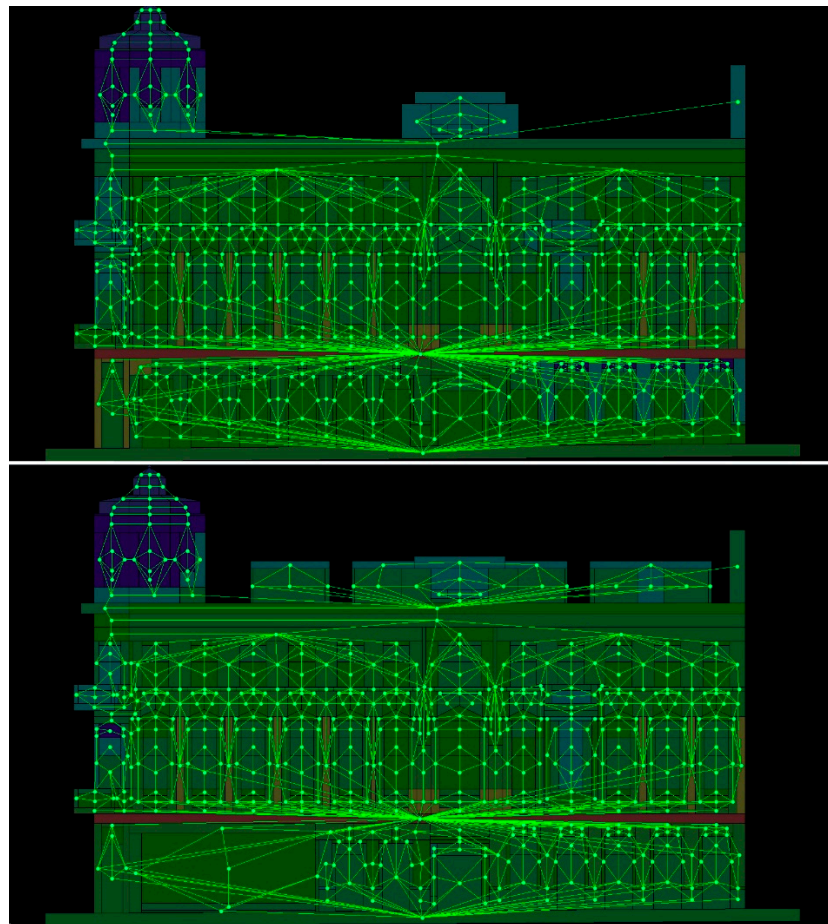
#### 3.2.1. Design

The aim of the façade analysis was to check if Space Syntax based modelling could reflect subjectively perceived features of the buildings, such as perceived symmetry and attractiveness.

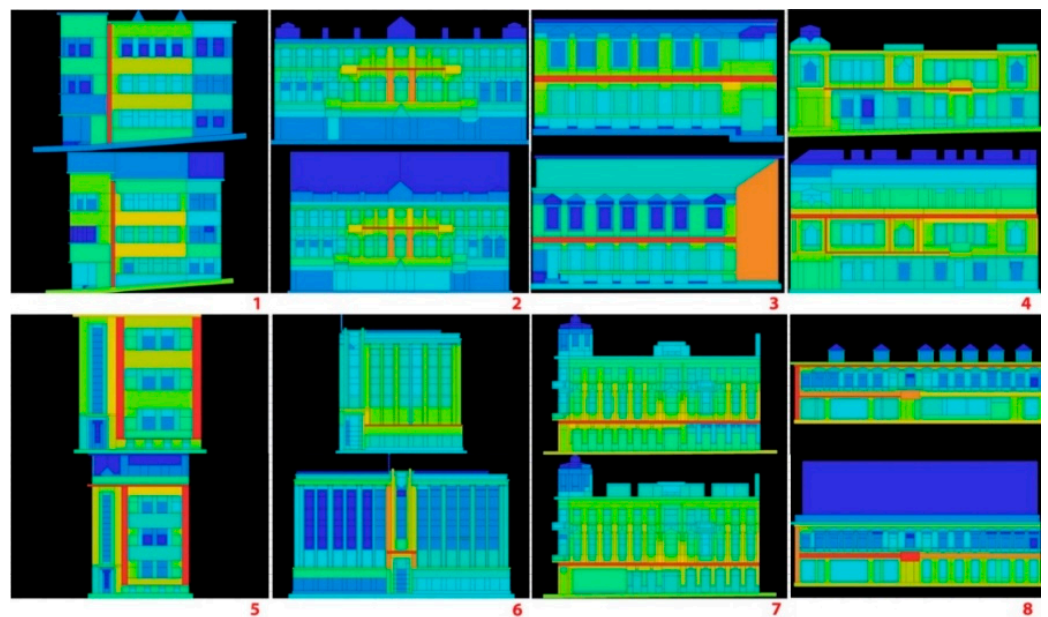
In the process of the preparation of the data, the façades of the buildings are measured by a laser meter, and the data are transferred to the computer as a drawing by the Autodesk AutoCAD program. After the required drawings are assembled, every façade is divided into plains by drawing polygons to create convex spaces formed by the elements of the façades, such as windows, doors, decorations, etc. Based on the mathematical graph model, each polygon of the façade is treated as a node. Links between the adjacent nodes are formed if they have common boundaries. Distance from one node to its neighbor while crossing the common boundary is considered one topological step in further calculation. The various graph centralities are calculated within the above described network of nodes and links—for example, the mead depth of a precise node is calculated as a sum of its distances to all the other nodes within the network measured in topological steps; betweenness of a node is calculated as a sum of the shortest routes in terms of a number of topological steps between all the pairs of the nodes within the network which cross the calculated node; connectivity of a precise node is calculated as a sum of the neighboring nodes with common links, etc.

The methodology was grounded in the façade modelling approach based on the convex graph. According to Hillier, a convex graph could be constructed based either on the tessellation of the façade into uniramous parts or on its divisions according to architectural details [9,20]. The tessellation approach is the most developed in Hillier's research, but it is oriented towards the analysis of general form instead of its details. The second approach was chosen as more appropriate in a selected urban setting where all buildings have relatively similar volumes and numerous different architectural details. In this case, a little generalized, each part of the architectural façade defined either by architectural details (e.g., decorative elements, lines) or formed by the borders of the other elements (e.g., openings of the windows or doors) was marked as a convex space defined by a polygon. Each convex space was converted into a mathematical graph node. Edges of the graph or links between the nodes were formed according to the following rule: convex spaces/nodes should have a common boundary in the form of a line in order to be connected by a common edge (Figure 4). The procedure of modelling was conducted while using depthmap software [38].

Eight recently renovated historical buildings (Figure 5) in the Kaunas New Town heritage area were selected as representatives of two architectural styles: historicism and interwar modernism. The choice was grounded by the wish to increase the sensitivity of modelling by focusing on changes to the same façades before and after renovations. Therefore, space syntax modelling was conducted for both situations before and after the renovations.



**Figure 4.** The mathematical graph is shown on the façade of the analysed building.



**Figure 5.** Analysed building façades with Integration values marked by colours—red colour means higher numerical values, blue—the lowest, yellow—the interim (for integration meaning look below). The façade after renovation is shown beneath the ones before renovation. Each column demonstrates before and after version of a building with its sample number below.

Based on the mathematical graph, various analysis types of centralities of the nodes that are traditional for Space Syntax were calculated, including the following:

- Node count (NC)—total number of the nodes in the graph within radius  $n$ ;
- Connectivity—number of neighbouring nodes which have a common edge with the calculated node; the mean values in order to represent general properties of a whole façade were used (Con mean);
- Choice or betweenness centrality as a sum of shortest hypothetical journeys between all pairs of nodes that cross the calculated node; the shortest distance was found on the basis of the smallest number of topological steps—one change of node is equal to one step; the normalised mean Ch values (Ch mean norm) were chosen in order to have better possibilities for comparison between different façades;
- Mean Depth or sum of the topological distances from the calculated node to the rest of the nodes on the network. The mean value of this index is used in order to represent an analysed façade in general (MD);
- Integration (Mean Integration as a generalising index for a whole façade was used, marked as MI) as the normalised version of closeness centrality is inversely proportional to the sum of distances from the calculated node to all the other nodes in the network. The distance was calculated using topological but not metrical steps, where movement of the visual focus from one node-architectural element to its neighbouring node is considered one step. Accordingly, the distance between two nodes equals the number of nodes on the possibly straightest line between them.

A number of secondary, additionally calculated indexes were used, starting with symmetry index (SI). “The ratio of the total number of elements to the number of elements that . . . (have identical integration or mean depth (MD) values and) . . . index the degree of balanced asymmetry in shape” (Hillier, 2007:89). In other words, the calculation is conducted while dividing the number of different MD values by a number of elements of a façade that are represented by mathematical graph nodes—for example, if we have 10 nodes with such values as 1,1,1,2,3,3,5,5,6,6, then  $SI = 4/10$ .

One additional index was proposed in order to address the architectural composition of the investigated façades more precisely:

Symmetry index 2 (SI2) is equal to the ratio of elements with at least one node with the same MD value. SI2, more precisely, can represent part of the elements, which could be seen as symmetric, and its max value is equal to 1. If the above-mentioned example with 10 elements is used, then  $SI2 = 9/10$ .

Finally, in order to have a more complex view, some more results of calculations were used in the analysis as follows:

- Standard Deviation of Integration (Dev Int)—more minor deviation means that in topological terms or distances measured in nodes or elements of the façades, they differ less and could be seen as more compact compositions;
- There are various synergies between the other indicators, such as  $SI^*$  (multiplied)  $SI2$ ;  $SI^*MI$  (Mean Integration);  $SI2^*MI$ ;  $SI^*SI2^*MI$ ;  $SI/Dev$ ;  $SI2/Dev$ ;  $SI^*Dev$ ;  $SI2^*Dev$ ;  $NC^*SI$ ;  $NC/Con$ ;  $Con^*MI$ ;  $NC^*SI2$ , etc.

Statistical analysis of relations between space syntax variables and the survey results was conducted while calculating Pearson correlations.

### 3.2.2. Analysis of the Data

Many statistical methods, including Pearson correlation, require that dependent and independent variables are approximately normally distributed. In statistical analysis, “. . . independent variables are variables that are manipulated or are changed by researchers and whose effects are measured and compared . . . The other variable(s) are also considered the dependent variable(s). The dependent variables refer to that type of variable that measures the effect of the independent variable(s) on the test units” [39]. The space syntax indexes were seen as independent and survey results as dependent variables.

Both the Kolmogorov–Smirnov Test of Normality and the Shapiro–Wilk test on all collected data were performed. According to the results of the Kolmogorov–Smirnov Test,  $p$ -values of all variables exceed 0.05 while varying from 0.21327 (attractiveness) to 0.97384 (Mean Connectivity) and do not differ significantly from that which is normally distributed. The mean  $p$ -value of all variables is 0.696392. According to the Shapiro–Wilk normality test, the majority of variables do not differ significantly from that which is normally distributed, with  $p$ -values exceeding 0.05 and varying from 0.0529034 (NC\*SI2) to 0.491186 (Connectivity mean). The mean  $p$ -value for those variables is equal to 0.327459. Five variables have  $p$ -values lower than 0.05: SD—0.0334651; SI2/Dev Int—0.00050362; NC—0.0296501; NC/SI—0.040611; NC\*SI—0.0345589. The bigger part of the data of these five variables still demonstrated the feature of normal distribution, so they were used in calculation with some extra concern towards the results.

The calculated Pearson correlation between the syntactic indexes and both perceived symmetry and attractiveness of the façades is presented in Table 1. Despite a pretty significant number of both positive and negative correlations, only four of 42 results are significant at the level of 0.05 (marked in red in Table 3). On the other hand, another four results could be seen as being near significant (marked in yellow in Table 3), and even if, speaking statistically, there is not enough evidence to say that these correlations appeared not by accident, they could be used for some insights for future research.

**Table 3.** Pearson correlations between syntactic indicators and both—perceived symmetry and attractiveness in all façades (before and after intervention). Correlation marked by red colour is significant at the 0.05 level. Nearly significant correlations are marked in yellow.

	Perceived Symmetry		Attractiveness	
	Pearson Correlation	Sig. (2-Tailed)	Pearson Correlation	Sig. (2-Tailed)
SI	−0.159	0.556	−0.371	0.157
MI	−0.380	0.146	−0.364	0.166
SI2	−0.046	0.866	−0.242	0.367
MD	−0.280	0.294	−0.203	0.451
Dev Int	−0.502	0.048	−0.343	0.194
SI*SI2	−0.141	0.602	−0.347	0.188
SI*MI	−0.286	0.284	−0.428	0.098
SI2*MI	−0.199	0.460	−0.325	0.220
SI*SI2*MI	−0.231	0.388	−0.386	0.140
SI/Dev Int	0.379	0.148	0.033	0.903
SI2/Dev Int	0.385	0.141	0.116	0.668
SI*Dev Int	−0.417	0.108	−0.420	0.105
SI2*Dev Int	−0.392	0.134	−0.395	0.130
NC	0.474	0.064	0.377	0.150
Con mean	−0.318	0.230	−0.232	0.388
Ch norm mean	−0.484	0.058	−0.311	0.241
NC/SI	0.401	0.124	0.405	0.119
NC*SI	0.543	0.030	0.319	0.229
NC/Con	0.495	0.051	0.411	0.114
Con mean*MI	−0.516	0.041	−0.452	0.079
NC*SI2	0.614	0.011	0.371	0.157

The significant strong or moderate, depending on scale, correlations are following:

- −0.502 between perceived symmetry and Dev Int of MI. This means façades that are more “compact” in terms of connectivity and topological distances could be perceived as symmetrical by people and this is not necessarily related to strict architectural symmetries.
- 0.543 between perceived symmetry and NC\*SI. This means that architectural composition consisting of a more significant number of elements and having a more extensive index of “flexible” symmetry expressed by SI could be perceived as more symmetrical.

However, additional consideration should be given to this index in the future as NC\*SI values demonstrate normal distribution only partially.

- $-0.516$  between perceived symmetry and Con\*MI. This means more topological connections together with more prominent syntactic integration (more compact composition in topological terms and contacts between the forms) in façades are perceived as less symmetrical. For example, this might be explained by the statement that too big a number of compositional connections and contacts between various forms makes a façade less perceivable as symmetrical.
- $0.614$  between perceived symmetry and NC\*SI2. This means that a more significant percentage of elements in the composition, which corresponds to Hillier's idea of "flexible" symmetry, together with a more significant number of elements, is related to the perceived symmetry in a façade.
- Nearly significant correlations with the perceived symmetry do not add anything essentially new to the ones described above except correlation with normalised choice ( $-0.484$ ;  $p$ -value  $0.058$ ). The possible explanation for this depends on the answer to the question, "what syntactic choice means in architectural composition?" and requires further investigation.
- In the case of attractiveness, no significant correlations were found, thus possibly reflecting the more subjective nature of this feature of architectural compositions. On the other hand, nearly significant negative correlations of  $0.452$  ( $p$ -value  $0.079$ ) with Con\*MI might speculatively identify a potential relation between attractiveness and more topologically scattered composition.

#### 4. Discussion and Conclusions

Adaptive reuse of built heritage is a challenging topic since it does not only contain the implementation of the physical changes to the structures, but it also affects social and cultural sustainability. When an adaptive reuse project of a heritage building is prepared, the architects need to consider the resulting changes to the urban fabric and the perception of both the experts and the non-experts. While the opinion of the experts can be more related to the design itself, it might be possible to state that the non-experts' opinions are more subjective due to their perception of the environment at a personal level. Every intervention and alteration can add a different layer to the structure and can influence the proportion of the design. In that regard, it is essential to understand the potential impact of these changes.

According to the sociological survey performed in this study, symmetry and attractiveness of a structured look is related even if, according to the collected data, no significant correlations between them were found. Therefore, when the structure becomes more asymmetrical, it is perceived as less attractive by the participants. However, if the intervention followed the same axis and the same symmetry of the main design, as long as the addition was not dominant, it did not affect the attractiveness of the building. Therefore, it is possible to state that, in most cases, the symmetry was perceived in a more classical way by the survey participants regarding architectural compositions based on central vertical axial symmetry. However, the space syntax models used in the second experiment can be more beneficial for understanding more complex situations—not only the axial symmetry but also different types of symmetries.

In most cases, windows had an impact on the whole of the participants while they were making their decisions regarding repetitiveness. Furthermore, the decorative elements tended to give the impression of repetitiveness to the participants.

According to the façade analysis of the second experiment, the perceived features of architectural composition could differ depending on architectural style. However, the presented research results demonstrate a few essential things:

- Hillier's proposed façade analysis method, at least in the tested sample and two presented architectural styles, could be related to human perception of architecture, thus proving the possibility to model and predict human reactions to architectural changes.



- The original methodology based on the symmetry index alone could be productively expanded by adding more indexes.
- In all cases, the syntactic indexes were sensitive even to formally small changes of architectural composition introduced by the renovations, so they could be potentially used for monitoring or evaluation of modification of the objects of cultural heritage, for example, while identifying acceptable limits of changes of indexes, predicting acceptability of changes by observers, etc.
- Potential connections between attractiveness and visually presented patterns of integration values of the façades could be noted in some cases. However, they were not caught by statistical analysis while using integration values but are worth investigating in the future.

The results support the idea of the continuation of the presented research and open new perspectives for predictive modelling, control, and monitoring of evolutionary changes of immovable cultural heritage. Therefore, this research is preliminary, and it does not provide final answers. Rather, it is merely confirming the new directions for research and raising more targeted discussion.

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