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COMPUTATIONAL ANALYSIS FOR DESIGN DEVELOPMENT EVALUATION IN SPATIAL PLANNING

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ABSTRACT

The influence of new technological software on architectural design is increasing with every passing day. This led to new horizons discovery in spatial analysis and design interpretation and extended by engaging different techniques based on computational design and human-computer interaction. Throughout the architectural design process, decision-making on spatial performance parameters such as visibility, density, and building typology is frequently taken by examining a limited number of materials. They are conventionally optimized by employing repetitive experimentations without systematically evaluating the complete range of potential designs and their efficient outcomes. A computational design analysis approach of spatial morphological structure based on several indicators is presented in response to this challenge. This research compares contextual spatial analysis with computational methods and determines the consistency of Eskisehir technical university master plan expansion mechanisms through the relationship between layout and spatial arrangement, connectivity and accessibility, and built area and open space of the university map in two different periods (2005/2020). For density measurements, Ground Space Index (GSI), Floor Area Ratio (FAR), and Open Space Ratio (OSR) calculations in urban spatial planning are analyzed. Furthermore, the Isovist analysis (Attractiveness, Extent of observation, line of orientation, and arrangement) and their visual quality was examined using the logical interpretation approach. The collected visual and numerical data show that the visual quality of the observer's full view, as seen from the center of the university campus master plan, is directly related to the open space and built environment. The visibility and density characteristics of the university campus master plan showed that these analytical techniques are very responsive to the design limitation and context requirements. The presented application has evaluated the visual aspects of each of the university campus maps to deliver a technique to the designers so that they may implement their requested visual characteristics in future design expansion.

Keywords: Computational analysis, Spatial planning, Architectural design, Development mechanisms, Campus master plan

1. BACKGROUND

The expansion of urban space, which ultimately determines a city's sustainability, is a critical issue for space planning and urban management. Growing areas have become denser, yet they have been planned inefficiently, resulting in abandonment and land transformation. Enormous data may be synthesized into significant information via spatial analysis. These data incorporate properties such as a big frequency, a variety of operators, and a temporal sequence [1, 2].

The master plan of the university campus presents a leading outline of expected campus growth and defines a set of architectural guidelines that are meant to direct design decisions in a way that adapts to the university's changing needs. The initial space layout concept is an important first step in any architectural design process. According to many existing examinations, the major master plan characteristics that usually impact decision-making are dependent on the layout and spatial arrangement, connectivity and accessibility, and built area and open space. These are generally studied by engaging conventional spatial analysis. Recently, multiple studies on university campuses aim to increase spatial

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growth capacity, optimize the successful outcomes of space creation, and maintain the validity and availability of an appropriate density of open space and built area on campus.

The design of urban spatial forms is an interplay of qualitative and quantitative planning based on urban transformation objectives [3, 4]. It is critical to disclose effective and sustainable planning that permits the assessment of the effects of spatial change [5, 6, 7]. The advantages of this operation include higher quality of living, social connections, and neighborhood relationships, improved pedestrian and biking activity, an enhancement in major sectors, and the multifunctionality of the urban area [8]. However, there is no quantitative analysis of the integrity between urban spatial form and planners' spatial design planning purpose depending on the planned system [9, 10]. Contemporary computational design competencies permit cutting-edge data analysis, interpretation, and the emergence of complicated forms and spontaneous evolving novel processes as well.

Accordingly, this research examines Eskisehir Technical University campus master plan aiming to decode university expansion requirements and cooperate with design specifications to direct the development plan decisions. It investigates a process by comparing multiple maps from different periods (2005/2020) to evaluate the expansion of the campus master plan. Furthermore, the analysis aimed to better understand how this university campus master plan could evolve and expand and the main spatial elements and environmental components that control its evolution mechanism. The in-depth analysis of the campus master plan engages two different techniques, “Contextual Analysis” and “Computational Analysis”. The analysis fundamentally tends to answer these questions: What main master plan elements have a key role in directing the expansion? How do the built area and open space interact during spatial development?

In order to efficiently respond to those questions, contextual and computational analysis techniques were involved by exploring design problems and environment requirements. The gathered data were classified into several categorical dimensions based on the research intents. The assessment process of layout and spatial arrangement, connectivity, accessibility, built area, and open space was the emphasis of contextual analysis. Whereas computational analysis allowed for the inquiry of density and visibility measurements through several indicators and techniques such as GSI, OSR, FAR variables [11], and Isovist visibility analysis [12], using the computational design plugin Grasshopper inside Rhino software.

2. CASE STUDY AREA OVERVIEW

Eskişehir Technical University (ESTU) is situated in the Anatolian region of Turkey, exactly in the city of Eskişehir. The foundation of ESTU was back in 2018 after its detachment from Anadolu University. The main university campus “Iki Eylül”, has a total area of 4710 decares, including the land assigned as the area of future expansion. It has a land area size of 4.3 million square meters and a campus area of 114,034.47 square meters. The functions, approximate sizes, and interconnections between the open-closed spaces of the spatial elements that will be built in addition to the existing buildings and amenities have been identified. Simultaneously, the active campus plan is 574 000 m2, and the campus extension area is planned to be 454000 m2 (Figure 1.). Based on the proposed development plan, the campus is arranged to be expanded toward the north, away from Hasan Polatkan Airport on the southern side, along with the Muttalip highway on the eastern wall, and the transportation axis that runs parallel to the western wall.

Currently, the university is trying to put in place again its spatial identity with a contextual and environmental approach. The relationship between different spatial parameters is required to be well arranged. The density of land-use and build/ non-built areas should be redefined according to the plan development proposed within the parcels organization.

This analysis describes the characteristics of the environmental and spatial functions, which are intended to be sustainably carried out in the "İki Eylül" Campus between 2020 and 2035, and the resource requirement needed for the study. It is aimed to prepare and implement the spatial limitations and context requirements within the early formulation of the generative design system. The development plan is prepared according to future spatial planning and existing design parameters of sustainable campus concept including a requisite target.

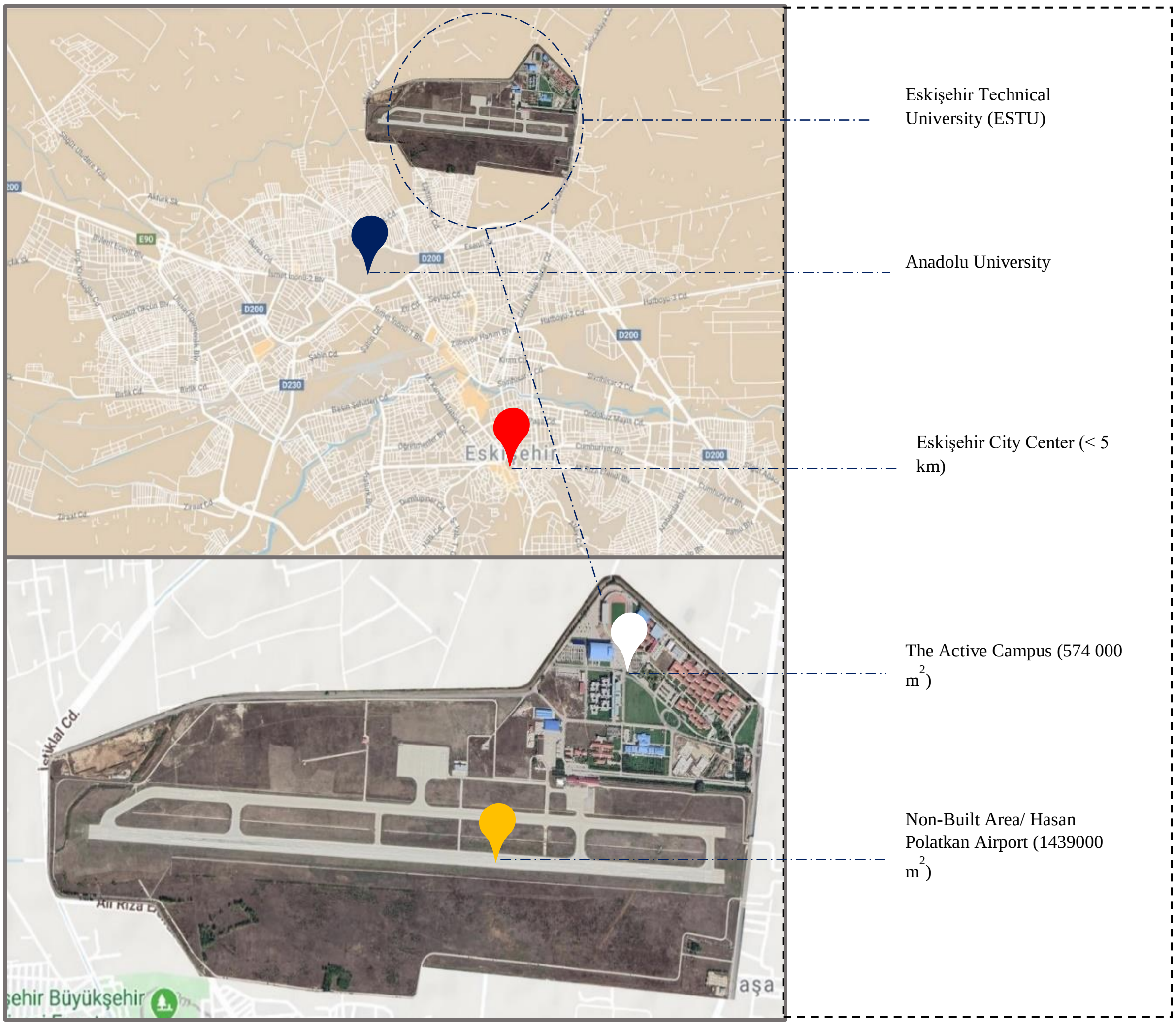

Figure 1. ESTU location in the city of Eskişehir map. (Source: by the author).

Getting a clear overview of the design elements of the university campus development plan makes the following analysis phases more oriented. Information about the expansion intent and the future crucial mechanisms of development comes in the first generative design system parameters. Generally, layout and spatial arrangement, connectivity and accessibility, and built area and open space are the most effective elements assigned by the plan. Those elements are more explored engaging different analyses discussed in the next sections of the research [13]. Recently, the university aims to increase the land's growth capacity and optimize the successful outcomes of space creation and also maintain the validity and availability of an appropriate density of open space and built area on campus.

3. METHODS AND APPLICATIONS

Throughout the architectural design, decision-making on spatial performance parameters such as visibility, density, and building typology, is frequently taken by examining a limited number of materials, optimized by repetitive experimentations, without carefully evaluating the complete range of potential designs and their efficiency outcomes [14]. To systematically investigate the influence of spatial planning and the associated variable values, the study engaged different analysis methods. The analysis would not claim to give specific proposals to campus decision-makers or designers; instead, it helps to assess, classify and comprehend the existing data in reality as well as provide a conceptualization forward for research on the related subject. It employs the comparative research method [15] to focus on architecture features and concerns responding to the improvement of campus infrastructures and mechanisms of integration. Special focus is given at particular points in time to the transformations of the master plans of the university, the map in 2005 compared to the map in 2020 (Figure 2.). The in-depth analysis of the campus master plan engages two different techniques, "Contextual Analysis" and "Computational Analysis". It is through examining these master plans in an integrated and comparative way that we would be able to consider such discussions as the key that determines the main parameters required in future generations. The contextual analysis is based on a qualitative assessment of the plans and observation-based interpretation of the needed data and information. Whereas, the computational analysis uses a quantitative assessment by engaging several parametric techniques to seek to explain various elements of the research subject. For this experiment two different techniques of analysis have been performed, density analysis and visibility analysis.

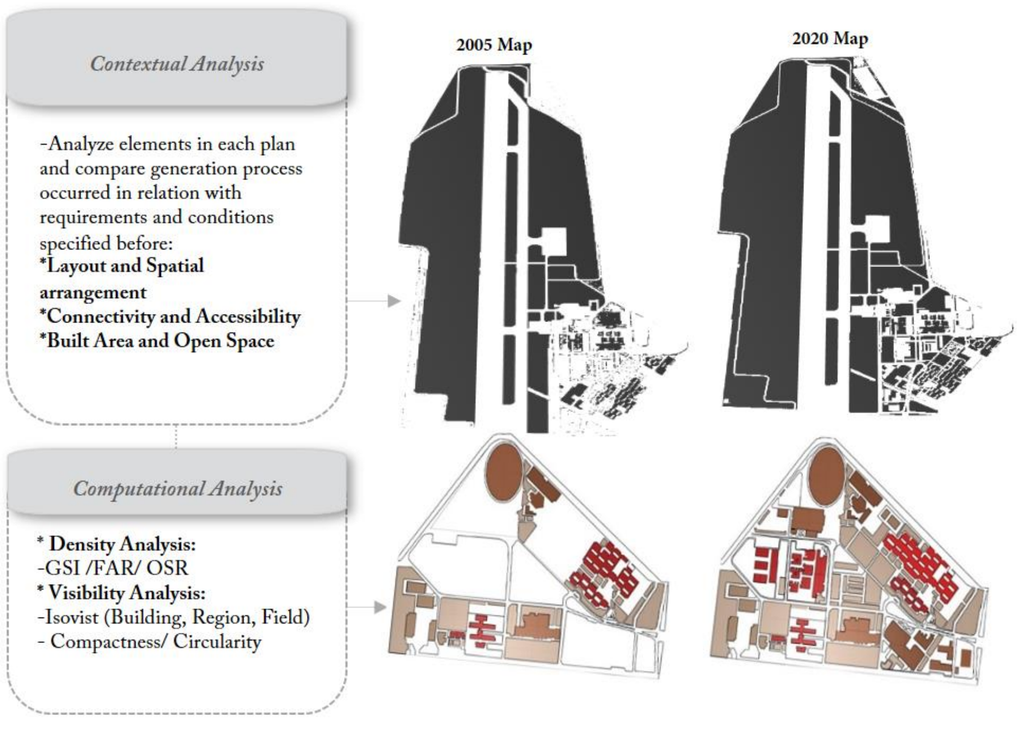

Figure 2. Contextual analysis and computational analysis aspects for the data collection part (2005/2020 Maps). (Source: by the author).

It is believed that density analysis is one of the most used techniques to recognize spatial development [16]. It allows measuring different indicators considering open space partition and building volume. This technique engages different parts of the urban fabric such as parcels, footprints, blocks and streets to measure density in a specific area. For that reason, many other analytical applications could be anticipated in further advanced measures. Frequently a ratio between different techniques can be also engaged to comprehend relatively the performance between several elements. Some research examined how each street is connected to the network in terms of integration and direction variance [17]. While they proposed another approach to analyzing density by using different variables such as GSI, FAR, and OSR [11]. The Ground Space Index (GSI), measures buildings' footprints in a specific area by dividing the total built footprint area by the base land area. The outcomes are usually visualized through ground-based drawings. The Floor Area Ratio (FAR), essentially focuses on calculating the built area density in combination with the building's floor area existing in the same environment divided by the general base land area. It is known also as the indicator of land-use intensity that aims to understand the effect of volume features on a specific site. The higher level of ratio signifies a high number of floors per area. The Open Space Ration (OSR) is focused on measuring the existing open space through a specific area. The ratio of open space is calculated by dividing the non-built area by the floor area. It is also engaged in measuring the indicator of an area's spaciousness, daylight measurements and ground levels.

Visibility analysis is one of such measurement tools which refers to a set of points visible from a given vantage point. In Hillier and Hanson's experiment, the space is viewed as a series of axial lines that form the longest view lines in a convex space. Their study indicates that the context of space has employed Isovist analysis to interpret visual perception. The communication of space comprises a set of tools for analyzing spatial systems using simple path and node diagrams [18]. In the campus mater design, Isovist indexes such as area, degree of displacement angle, maximum radius boundary, and enclosure are very practical. This allowed them to assess some of the environment's basic dimensions, characteristics that their implicit or explicit preconceptions adopted to establish a more basic perception and a more comprehensive representation of the environment. As a result, the space is defined as a collection of accessible points extending from a single point in the same area [19].

Within this section of the analysis, attempts have been made to measure the qualitative aspects of the environment and different findings have been obtained. This type of analysis requires a careful calculation of different parameters such as compactness and circularity [20]. The complex relationship between the built area and open space in the campus master plan is reflected by this analysis. To have desirable results a large amount of computing time should have been carried out in both formulation and application of the parametric model. The visualization of spatial visibility is performed by colors referring to different results. The visibility analysis focused as well on different Isovist applications, it was instructive to see the closeness of the plans as well as the openness of the areas and how they behaved. These applications are mainly used to calculate the visibility of the buildings and their relations with the open spaces [21].

4. COMPUTATION AND ANALYSIS IMPLEMENTATION

The main intention of this part of the research is to clarify the university campus structure with the potential for sustained expansion, carrying the basic framework for the campus's favorable development. The dependence between layout and spatial arrangement, connectivity, and accessibility, built area and open space of the university map in two different periods are used to compare contextual spatial analysis with computational methods and determine the consistency of Eskisehir technical university master plan expansion mechanisms.

4.1. Contextual Analysis

Studying the development of a master plan over time will allow exploring the various mechanisms that affect its formulation [22]. For this aim, an in-depth qualitative analysis of the two different master plans was carried out enabling us to concentrate on the specifics and suggestive complexities of how the campus reacted to various circumstances and environmental limitations. The contextual analysis explores the connection between the different spatial elements through ESTU University's master plans. In doing so, it has sought to investigate how the plan has evolved in relationship to density, street networks and building patterns.

4.1.1. Layout and Spatial Arrangement

The main campus layout was developed spontaneously as long as there was no clear development plan for its expansion. Its spatial arrangement is defined by a range of repetitive structures. The campus master plan is strongly representing the existing circumstances of the area. It is essential to explain, identify and encourage campus identity to build a clear sense of location [23]. Establishing a relevant layout for the campus area as well as the environment surrounding is a task that should be effectively accomplished. ESTU campus master plan is created with regions geographically restricted or self-identified with the same initial progress and expansion. It is not impressive that the 2020 plan layout does not differ extensively from the 2005 plan, except that a few more buildings have been constructed inside the boundaries of the empty predefined regions (Figure 3.). In the north, the plan expanded in the same formularization with slight changes in building patterns. The layout allows for alignment along the main axis, starting from the lower region of "Muttalip Bulvarı" to the northern area where there are a variety of important university functions (basically social functions). The pattern of expansion is maintaining the initial pattern that creates a focal point and a central dense environment with an appropriate distribution. Buildings placed in the north and northeast areas show the same patterns and look similar in several characteristics, thus highlighting an ideal continuity and a simplified identity of the master plan. Placing the main entrances of each building in all the regions away from the main street was also an investigation. This has created a boundary between the inside and exterior of separated regions with interconnection and thereby enables the campus inward centralization. The spatial arrangement of the campus master plan does not anticipate sustainable growth guidance proposing for future spatial expansion and generation.

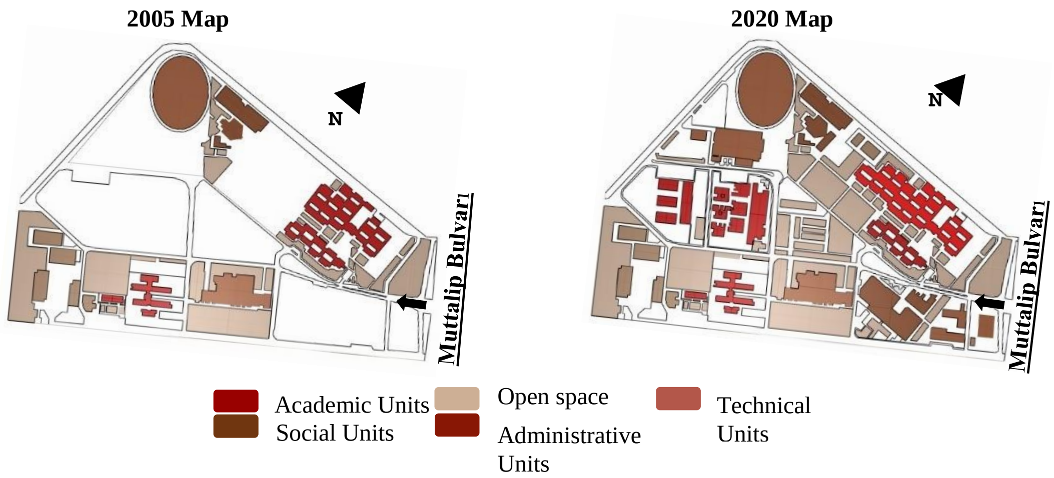

Figure 3. Layout and spatial arrangement of the university campus master plan (2005/2020 Maps). (Source: by the author).

4.1.2. Connectivity and Accessibility

The campus master plan is segmented with intersections between a series of the main axis and sub axis which permit street networks to be one of the essential elements of spatial connectivity. The main street as a core of the plan is dividing the area into two main parts north/south. It remains the same in both maps while other street networks disappeared and some others emerged. The main street has major importance and centrality which could be seen from its connectivity with other street networks and that makes it a geometrical force to areas division. The creation of a significant linear sub axis connecting the main street and the north part along with its boundary features progressively declining lines to the South allows the master plan to be more accessible. Also, every part of the plan is properly identified by the circulation of streets and bypasses that describe the connection between the buildings and their surroundings in two different patterns (Figure 4). The plan establishes vertically high division paths leaning significantly to the right. They allow for external circulation of the area while setting the key buildings inside the circulation zone in a symmetrical plan and generate spatially different street network patterns. The street on the west-east side of the university serves as a basis for the campus, with small service streets connected to it. The most significant pedestrian spine existing at the campus is that of the northeast. In addition, the external pedestrian street specifically marks the boundary between the inside and outside of each section of the plan. The comprehensive public transport network also covers easy transport and bus lines within the same main street direction. Some parts adjacent to the main street were kept unplanned, visibly emphasizing different paths that entered the main street. Pedestrians and vehicles move in parallel in the same direction. This is what makes the quality of pedestrian routes across the campus don't respond to the general accessibility. Although the main entrance orients the street network and the distribution of the parcels and functions within the master plan, the accessibility is not effectively integrated as a key element in the expansion of the university campus master plan. Furthermore, the relationships between various parcels and functions are neither geometrically represented nor integrated to maintain campus continuity.

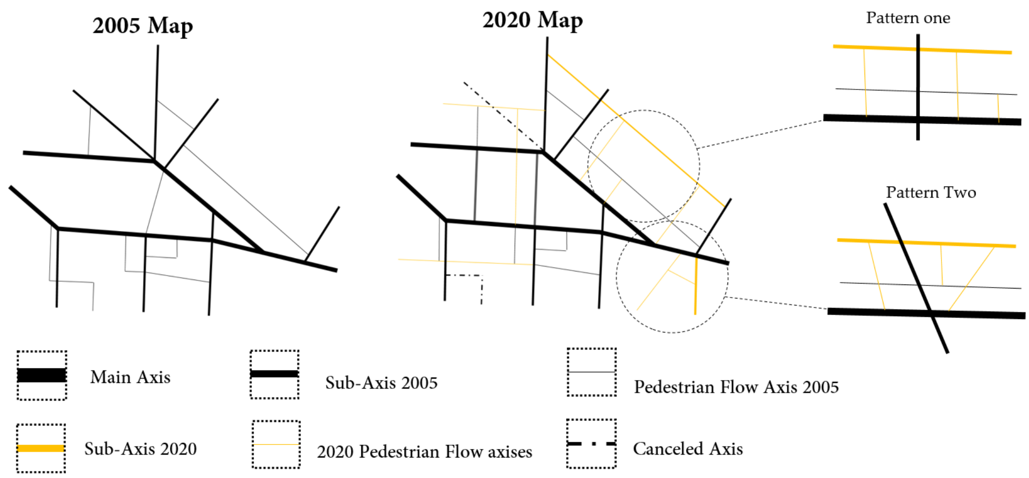

Figure 4. Connectivity and accessibility of the university campus master plan (2005/2020 Maps). (Source: by the author)

4.1.3. Built Area and Open Space

The university campus master plan was not fully built but somehow defined as an expression of randomization, which can be demonstrated by the grid system arranged in different locations without any expressive logic. The open space implementation and character are significantly presented as identification of the campus layout. The spatial arrangement was not a challenge towards uniformity but on the contrary in the creation of proportional distribution that connects the campus. The university master plan includes many open spaces, primarily in the campus core. It is providing a strong distinction between the north and the south, which highlights the central region. This refers to the spatial alignment of buildings around the main street, the layout of the plan in the north and the development of the eastern area where the main entrance is situated (Figure 5.).

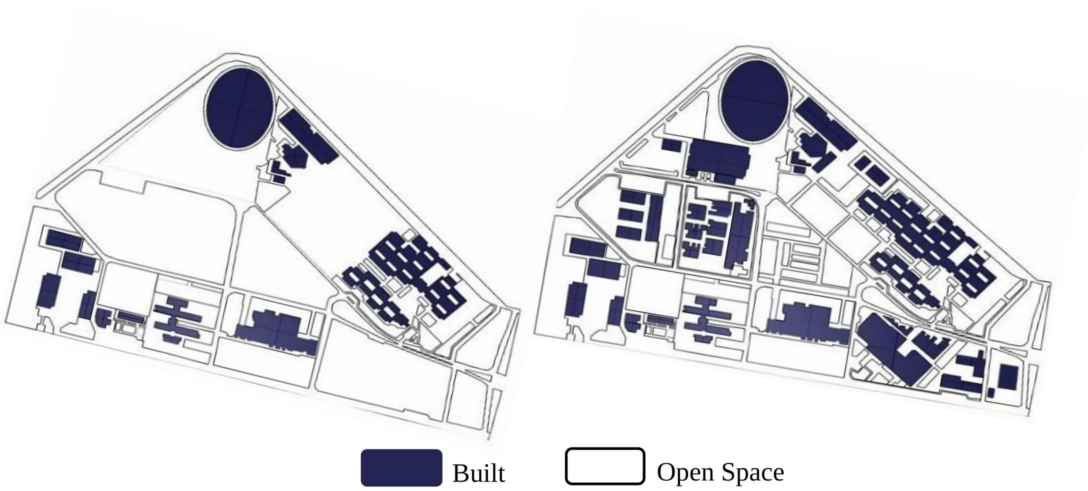

Figure 5. Built and Open Space of the University Campus Master Plan (2005/2020 Maps). (Source: by the author)

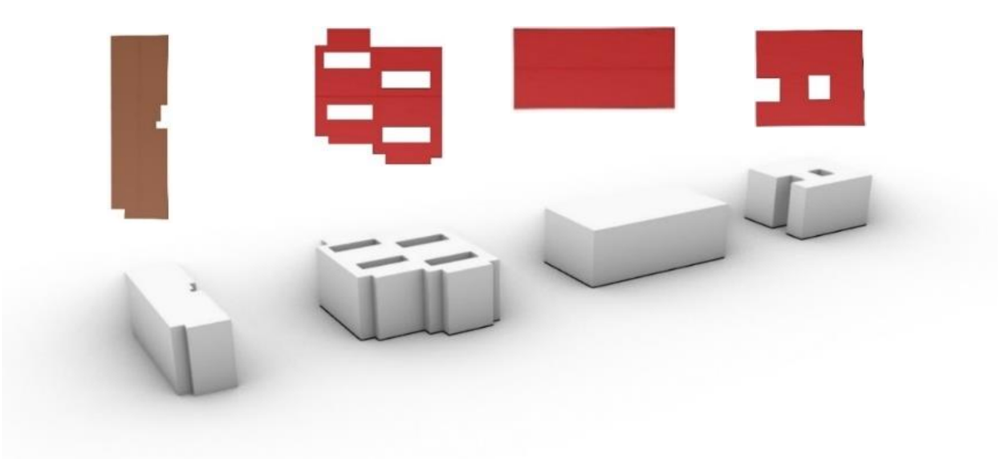

Figure 6. Buildings Design Patterns at the University Campus Master Plan (2005/2020 Maps). (Source: by the author)

The relationship between buildings, parcels and the street networks was a result of unplanned generation which called for a focus on the spatial typology. A significant built and open space proportion is presented in each of the northern and south-western regions of the campus. This combination reflects simultaneous campus components, interaction centers and a prosperous university campus social environment. The master plan for the campus proposes increasing growth rates to generate open space. This approach is retaining the same design pattern in almost all parts of the master plan. The buildings' designs are based on four main different patterns (Figure 6.).

4.2. Computational Analysis

Within this section of the research, an analysis of the two university campus 2005/2020 plans relied on computational techniques by measuring different features such as density, visibility compactness and circularity. It tries to explore the potential of the computational analysis methods to understand the university campus master plan development mechanisms and approaches. The computational analysis method is used effectively on the master plan scale to test various designs and their performance, but many challenges are presented while applying it on the real scale due to data calculation and parameters manipulation (24). Several difficulties in limiting inputs and more important specifying the time involved in the process.

The computational analysis demands qualified practical designers to determine success purposes based on the understanding available at each phase of the creation of a master plan and interpreting the implications of the land use, density and design choices on those aims into numerical and geometrical data. For this experiment two different techniques of analysis have been performed, density analysis and visibility analysis.

4.2.1. Density Analysis

Density as discussed previously plays a crucial role in the formation of university master plan development phenomena. The relationship between the built environment and open space is very important to understand the growth behavior and predict future alternatives for space generation. This analysis is based on considering those two spatial elements with each one's characteristics. The set of indicators is modeled considering the morphological properties of the elements. Spacematrix, as an analytical approach [11], parametrically represents urban topologies and comprises a three-dimensional reference system that allows for the assessment of variable values for structures of various geometries. Through this study, density analysis employs many components and functions using Grasshopper in Rhino to measure the necessary spatial parameters and presents the measurement findings in a graphical and comprehensible format, evaluates the spatial morphological structure, and highlights the limitations of urban organization structure. The integration of spatial syntax with computational interaction will support the examination of urban process changes.

Urban compositions cover different regions of the Spacematrix, allowing for the investigation of, on the one hand, well-known architectural features such as perimeter pattern buildings and area structures, and, on the other hand, the involvement that the completely separate factors play in the performance, density, and open space arrangement in this research case. The system is preconfigured by defining different parameters. On the X-axis is the ground space index, or GSI, and on the Z-axis is network density. The computational model's additional components are the open space ratio, OSR, and the number of floors. The building coverage of the master plan area is represented by GSI (GSI = F/A), where F represents the building footprint and A signifies the land surface which equals 574 000 m2. FAR identifies the relationship between total gross floor area and land area. Additionally, OSR could be computed using the variables FAR and GSI as OSR = (1-GSI)/FAR. After defining the scope and limitation of the research, an algorithmic model was prepared to simulate all the parts of the generative design system. The model is based on visual scripting that may be represented in long definitions and several components. This made the manipulation and control of all the processes difficult and time-consuming (Figure 7).

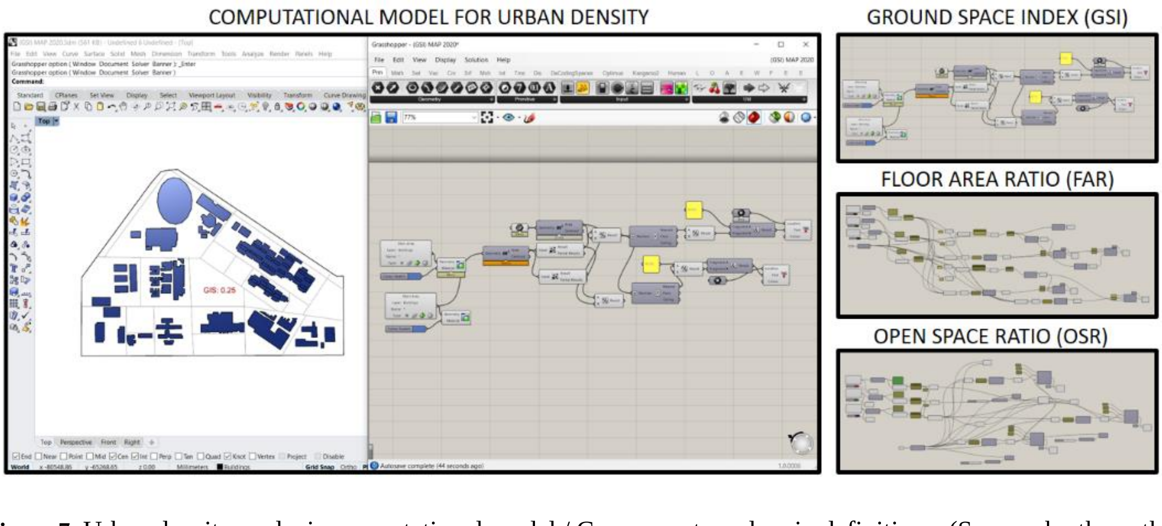

Figure 7. Urban density analysis computational model / Components and main definitions. (Source: by the author)

Therefore, many of those components are grouped under clusters with names to facilitate intervention (size, heights, and depth). The algorithmic model is a significant structure that went through many iterations to define the interconnection between the three system parts (functional connectivity, responsive density, and design pattern) by engaging several components and combining transmission between them. A large number of input parameters have to be redefined and engaged within the process to conduct more flexible actions. This makes the definition of the system inside Grasshopper canvas more complex and lets the designer intuitively face difficulties in managing components interaction.

The main indicators measured with this computational analysis showed a significant level of effectiveness in spatial analysis and simulation requiring just buildings' footprints as input data. It is a visual examination of the space density based on the buildings' footprint data applied with parametric design tools (GH codes). Engage both open space and building blocks, as well as computational techniques, to decode the university campus master plan's characteristics into indicators. First by formulating a computational data set for each building plan footprint recognizing both the volume and the environment open space. It is also shown that the density analysis gives more accurate outcomes than the spatial analysis methods concerning open space proportion and spatial layout structure classifications (Figure 8.).

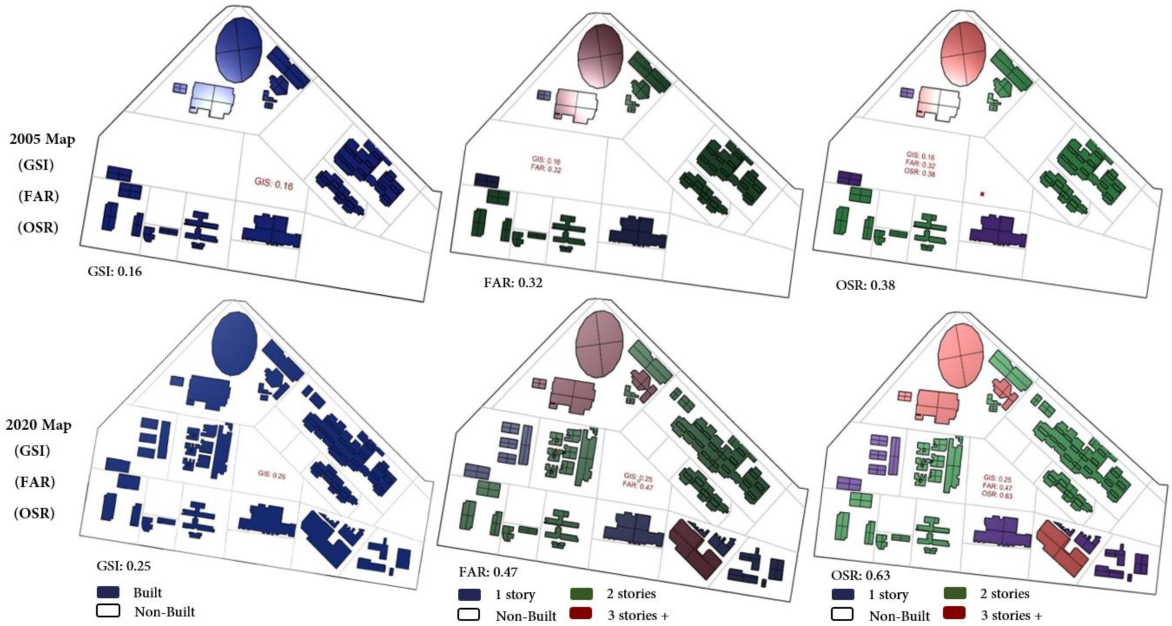

Figure 8. Indicators of the morphological properties at the campus master plan (2005/2020 maps). (Source: by the author)

A research stated that attractiveness could be discovered in different forms such as closeness, relationship, usage, and importance according to the design aim [25]. The analysis in this study only focused on the interaction between open space and built areas. Other social and cultural aspects are not involved in the research because they depend on the users' personal feelings and desires that do not enhance the objectivity of the computational parameters. The attractiveness potential for the ESTU campus is calculated to embrace the street networking, open space, build environment, and the buildings' interconnections. The calculation considered the distance between the various campus facilities, the distance to the main entrance, and the user experiences resultant attractiveness of a grid point.

4.2.2. Visibility Analysis

Isovist describes the part of space that can be seen from a certain viewpoint and calculates the visibility of objects [12]. The properties of Isovist are the correlation with subjective spatial experience. The Isovist region works with mapping the changes of visual properties along a specific path where the Isovist field is mapping properties on a scalar field. By displaying the number of arrays in contact with each face of the extruded volume, it is also conceivable to compute the building visibility and gather numerical data. Many components and functions used represent distinct types of Isovist calculations such as, Isovist field, Isovist region, properties and object visibility (Figure 9.). The engaged parameters are defined as follows:

- Attractiveness: index evaluates the amount of view expansion from the viewer's initial position and is related to the spatial experience of "expansion and context."
- Extent of observation: This index indicates the length between the viewer's point and the axis of the Isovist range composition, which demonstrates the degree of visual attraction and visual direction in the area where the viewer is considered to be.
- Line of orientation: This index evaluates the longest potential visibility and is related to environmental experience.
- Arrangement: The dimension of all covered boundaries is equal to this index. The restricted or bypassed edges are those whose values in the spatial perception are undefined or indeterminate. This index is related to the impressive spatial experience.

According to the stated design pattern and environmental parameters, the outcomes present a variety of possibilities from various locations. Numerous parametric Grasshopper analysis components just use assessment experience. An efficient interconnection of the algorithmic model enabled fast generation and instant results interpretation in any stage of the generation so that the impact of each specific data input could be tested and compared for a 2D scale. The Grasshopper definition is applicable for all experiment trials according to their input parameters and data manipulation. The algorithmic model is initially developed by extracting data from the main gird and involving them in the subsequent components such as lines and polygons that represent visibility values (Figure 9.).

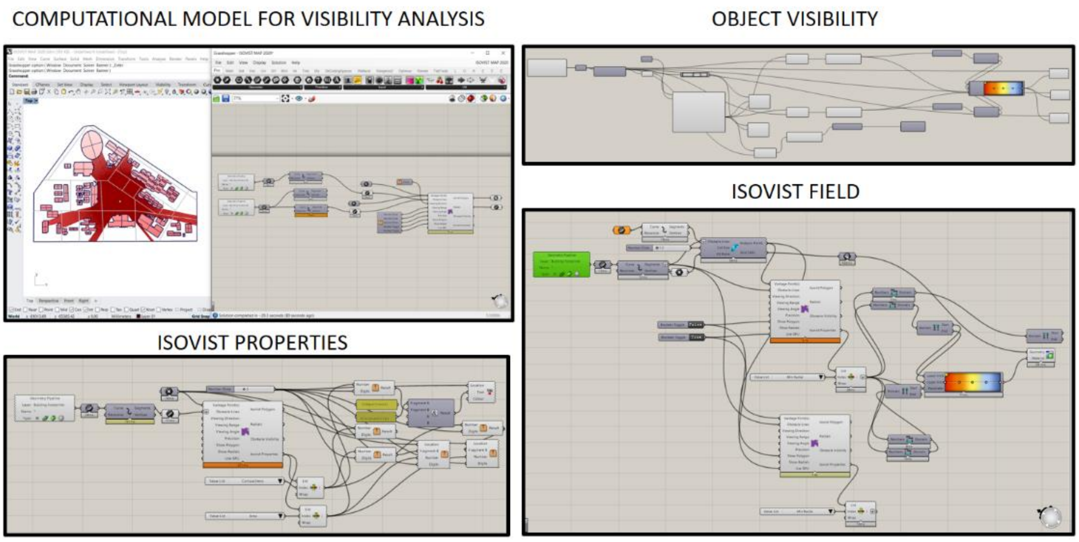

Figure 9. Visibility analysis of computational model / Components and main definitions. (Source: by the author)

According to the Isovist analysis, the high visibility is shown more at the intersection of the streets which could be taken as a context requirement for generative design system application. There are also significant trends of open space existence from the southwest to the northeast, which are illustrated in orange and blue colors. The coherence presented in the distribution of volumes within the area, some of them are better integrated and have high visual representation values, while others show the opposite features. Both plan analysis results lead to an assumption that integration and openness central environment of open spaces are unclear concerning design.

Some areas on the university campus give the chance to visually connect all the parts of the plan while moving through the center. The main street in the center of the campus coming from the northeast main entrance is more dynamic than the others, and this provides both diagonal and horizontal connections between all the regions inside the campus. The open space between buildings is visibly presented in the design of most buildings. The Isovist shows that these types of design patterns are strongly clear enclosed. Also in terms of measure, the buildings with interior open space present a contrasting character to the rest of the environment (Figure 10.).

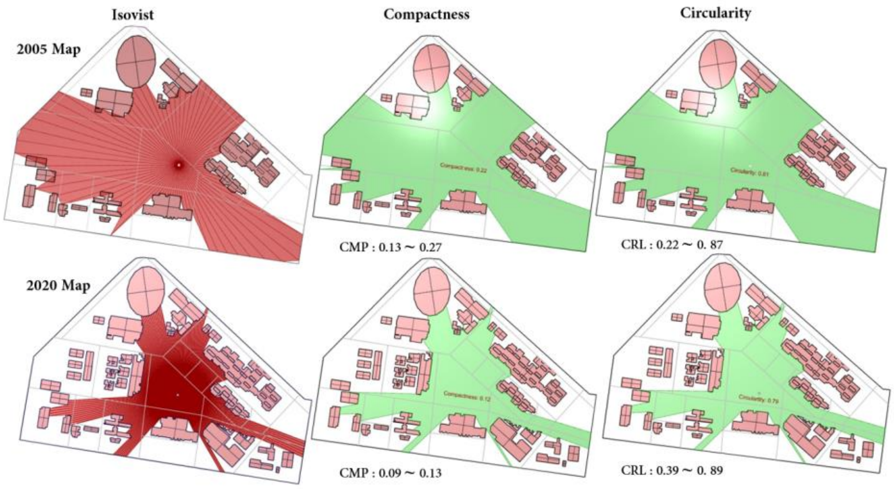

Figure 10. Visibility analysis results - CMP/CRL (2005/2020 Maps). (Source: by the author)

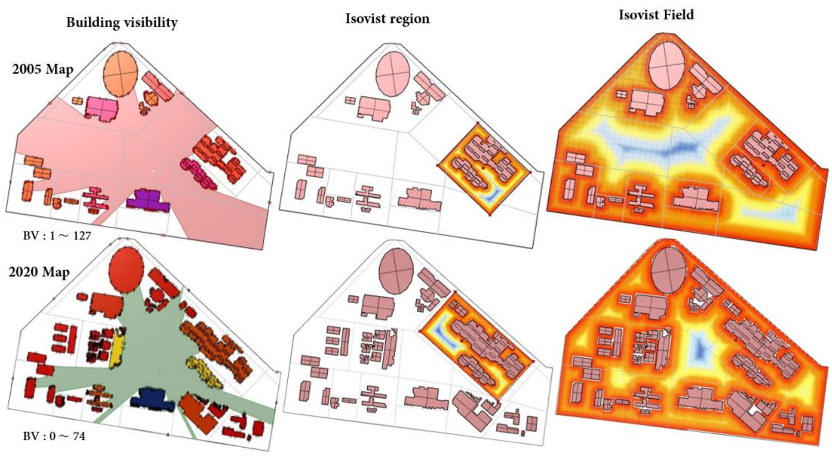

Figure 11. Visibility Analysis Results Isovist (2005/2020 Maps). (Source: by the author)

The colored space in between the buildings represents a relatively compactness and circularity even if the results of the Isovist area seem to be nominal. This is the case in different open spaces which connect the area and play the role of a central environment. The blue color symbolizes exceptionally high space openness as seen from a given location, whereas the orange color represents relatively low space openness as experienced from a specific point. The point of reference is chosen to be on the center of the maps where all street networks intersect. The visibility analysis shows the value of centrality within a specific area. Some point of the environment has a small Isovist area but has relatively a high visual integration value because of density variance. These types of spaces are more considerable when it comes to inside integration, however, they feel very disconnected from the whole environment. Some other parts remain discrete to be detected by the analysis tool.

5. RESULTS DISCUSSION

Studying the development of Eskisehir technical university's master plan over time allowed us to explore the various mechanisms that affected its formulation. Many authors believe that the campus should be diverse, compact, strongly integrated, well-structured, sustainable and urbanized [26]. The 2005 map demonstrates a significantly decreased degree of compactness compared to the subsequent map, significant areas are still being preserved given the major development of the campus, which has undergone a noticeable reconstruction in recent years. While on the 2020 plan, a compromise between conception and realization is becoming considerably more influential, and campus improvement and expansion are at the center stage. It was a challenge to maintain the layout characteristics of the previous maps, while simultaneously developing new approaches to connect with multiple growing conditions throughout the university campus. To underline the aspects for evaluating the composition of the campus in this qualitative research, the results show that the main problems identified for university campuses are; layout and spatial arrangement, connectivity and accessibility, built area and open space (Table 1.).

The use of different design patterns without clear respect to the proportion of open space in a combination of built and non-built areas in the university campus highlighted difficulties in analyzing the environment by observation and visual analysis. As a result, utilizing computational techniques to evaluate the same master plan maps might be more effective. University campus buildings with their simple design pattern are distinguished from early buildings' characteristics. Also, it can be noticed that some of the buildings that were designed later have different architecture. The outcomes from this analysis highlight the development behavior of the university campus master plan give much more about the urban fabric morphology. This allows seeing that spatial development is differing from structured axial morphologies of the street network to a non-structured street network where the buildings and blocks are not regularly located alongside parcels division. The decision of the most attractive point for the design system differs from one area to another and it is linked to the user experience. In this study, the weight adjustment was permitted to be modified based on the unique requirements and characteristics. A more accurate analysis could be done to specify the exact attractive locations of each user of the university campus. Many other attributes such as social and cultural characteristics may be involved in future research.

Table 1. Numerical data of the university campus master plan from spatial analysis (2005/2020 Maps)

	Old Map 2005 (m²) / (R%)	**Existing map 2020 (m²) / (R%)**
Campus Total Area	11403447 m2	11403447 m2
Administrative Units	0.91%	≈ 2.1%
Social Units + Outdoor	80.32%	≈ 62%
Technical Units	0.87%	≈ 1.9%
Academic Units	17.9%	≈ 34%
Total distance/circumference	/	9.46 km = 9.460 m
Total parking area	/	49,044.00 m2

Engaging new computational methods within the design process can provide support for some of its steps, by generating several possibilities that search beyond predetermined design concepts or by changing some phases in unpredicted procedures. It seems that computationally generated design possibilities will be further responding to the user needs and integrated by the designer into a coherent whole under relation software-designer. Computational analysis technique, in which algorithmic model is employed, provides availability of highly specific and dynamic results open to precision and interpretation. This presents an important dominance for spatial and architectural design development. It is used effectively on the master plan scale to test various designs and their performance, but many challenges are presented while applying it on the real scale due to data calculation and parameters manipulation. Several difficulties in limiting inputs and more important specifying the time involved in the process. The computational analysis demands qualified practical designers to determine success purposes based on the understanding available at each phase of the creation of a master plan and interpreting the implications of the land use, density, and design choices on those aims into numerical and geometrical data.

The analysis values show that the proportion of open space within the environment is decisive to highlight the integration and openness of the space. The main benefit of this computational analysis is to facilitate the interpretation of the design environments where the marginal visibility is colored with orange and central visibility in red. The following table summarizes the features and related indicator values of the investigated university campus master plan, such as GSI, FAR, and OSR, among others, that are required for the development of a future design system (Table 2.).

Table 2. Computational design analysis outcomes (Numerical Data) (2005/2020 Maps).

	Old Map 2005 (m^2) / (R%)	**Existing map 2020 (m^2) / (R%)**
Campus Built Area	≈ 67230 m2	454034 m2
Campus Un-built area	≈ 52736 m2	119966 m2
Active campus area	≈ 187196 m2	574000 m2
General open space	≈ 67%	20.90 %
Open space per parcel	40.30%	20.90 %
Open space per building	17% - 20%	17% - 40%
GSI	0.16	0.25
FAR	0.32	0.47
OSR	0.38	0.63
Building Visibility	1□127	0□74
Compactness	0.13□0.27	0.09□0.13
Circularity	0.22□0.87	0.39□0.89

The results show that density and visibility analysis may lead to predicting open space proposals for future design processes. A better analysis still can be engaged by many other computational tools among several practices. However, for this study scope, the visibility and density analysis can allow a generative design system to engage the collected data in the generation process. Besides, the university campus plan that was analyzed is mainly focused on features such as open space, street networks and building block interconnection. It also provides a comprehensive visual representation of the results that could be improved and clarified. It was interesting to comprehend how space functions and how future growth should behave. The visual analysis methods could be used as well to evaluate different other studies and assess the strengths and weaknesses of many design proposals to reach some effective design decisions.

The relationship between a digitalization degree and a regional incorporation degree can be used to assess the method's sophistication. The numerical specifications may be transferred into other computational analysis capabilities via an interactive platform to investigate the relationship between the digitalization degree and the appropriate framework extent of the spatial dimension.

6. CONCLUSION

It is always crucial to make effective decisions on design development when data availability is limited. Nowadays computational studies, which are primarily subjects in the field of architecture and urban planning, have become the focus of the intersection of computer capacities and spatial planning. The search in this kind of situation is based on exploring new techniques and tools that could provide numerical data to help designers and architects to achieve better designs. Consequently, the significance of sophisticated computer programs is getting increasingly crucial in today's architectural fields of study, since several advanced software applications such as Grasshopper are widely acknowledged as generative tools. The measures involved in the research at a basic level compared to capacities that visual programing techniques could perform. All the data collected, including the use of an algorithmic tool to assist the programming methodology of the computational analysis, are regarded as empirical representations that demonstrate the outcomes of integrating design features in the master plan expansion studies. The engaged techniques need to be diverse to search for more performative possibilities with variance in characteristics and design patterns results.

This research is based on contextual and computational analysis of the university campus master plan in two different periods (2005/2020). On one hand, contextual analysis enabled one to pay attention to the specifics and suggestive complexities of how the campus reacted to various circumstances and environmental limitations. On the other hand, visibility and density characteristics of a university campus master plan development showed that these analytical techniques are very responsive to the design limitation and context requirements. Some spatial characteristics are formulated and converted into indicators so may be computed using Grasshopper as a computational tool. This initiates a particularly appropriate data collection for both campus buildings and open spaces. Perhaps in a more complex spatial fabric environment, these techniques have to be improved to process a huge number of numerical data and spatial structures. The analysis techniques used in this section of the research can be enriched and introducing some other data processing methods and morphological assessment approaches that consider open space and built area characteristics. The main intention is to recognize the university campus structure allowing the potential for sustained expansion, carrying the basic framework for the campus' functional development. The campus should be diverse, compact, strongly integrated, well-structured, sustainable, and urbanized. The presentation of the campus area to be as beneficial as possible for our research is provided in the form of maps. Much information is included such as density, zoning, build non-build, and pattern characteristics to describe the university campus typology. Some details such as scale, area limits, and locations are easy to describe, whereas many other attributes like design quality, walkability, and accessibility need different types of data to be calculated.

Correspondingly, this research is a comparative study that explores two spatial design analysis methods which are contextual analysis and computational analysis. It tends to prospect how can computational analysis can assist architects and urban planners in better understanding the development mechanism of specific university campus master plans. In addition to that, this research aims to facilitate the definition of the campus master plan crucial spatial problems that need to be decoded by involving more sophisticated approaches and systems such as computational and generative measurements. To sustainably design or generate an expansion of any university campus master plan, there would be a complete understanding of the development mechanisms and the interconnection logic of its spatial elements. For a public space and as a part of the urban tissue of the university campus, functional connectivity, responsive density and design pattern are the major elements that influence the generation process of the master plan.

Designers remain in control of making the main decisions, and they may determine the appropriate layout from the produced possibilities and post-process the findings to display comprehensive conceptual illustrations. Involving equivalent variables, might be extended to other spatial studies in research consideration. The outcomes of this comparative analysis within this work can be further improved and adapted to other university campus master plan specific situations in terms of design and building arrangement details, mainly of interest for open spaces and different form-shaped buildings. It was claimed that by evaluating Isovist indexes, a novel computational procedure to assess the visual quality of spatial structures could be presented. The findings demonstrated an interaction between the proportion of open space and built area and the Isovist indexes, which might be useful for urban designers and architects during design expansion decision-making. It is almost unexpected to provide any examples of absolute or subjective dominance in terms of visual quality based on the findings achieved, but the presented application has evaluated the visual aspects of each of the university campus maps to deliver a technique to the designers so that they may implement their requested visual characteristics to the future design expansion. Even though the Isovist parameters and the steps that help implementations have effective internal consistency, various outcomes have been reached despite the high potential analyses in the planning process. This procedure might be employed by other researchers as an adequate framework for other comparable investigations if further studies that will be conducted.

CONFLICT OF INTEREST

The authors stated that there are no conflicts of interest regarding the publication of this article.

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