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The journal aims to link interdisciplinary human habitat studies in the EURO-MED region, from architecture and urbanism to regional planning, including the relationship between human-dominated and natural systems. It seeks to pursue the goals of multi-stakeholder operations such as SUDs, UfM Action Plans and more, towards resilient cities and sustainable social structures.

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EDITORIAL

"Journal of Mediterranean Cities" is dedicated to focusing on habitat studies and challenges facing our cities. The journal provides science-led strategic insight and guidance for sustainable and resilient cities, with a general perspective on coastal cities, with a particular focus on the Mediterranean region. Topics draw on scientific knowledge and research to make regional policies and practices as future-proof as possible. The Schools of Architecture and Urbanism are considered as potential driving forces and hubs for the profound science-led transformation and integration in the region, and thus, the Journal aims to bring together schools of Architecture and Urban Studies from different regions, in one platform. All articles are published in English and undergo a peer-review process.

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The text is single-spaced; uses a 12-point font; employs italics, rather than underlining (except with URL addresses); and all illustrations, figures, and tables are placed within the text at the appropriate points, rather than at the end. The text adheres to the stylistic and bibliographic requirements outlined in the Author Guidelines. If submitting to a peer-reviewed section of the journal, the instructions in ***Ensuring a Blind Review*** have been followed.

A manuscript goes through the peer-review process. Authors submit manuscripts to **Editorial office** via the online system. The acknowledgement letter should be sent to the author to confirm the receipt of the manuscript. The Chief Editor first

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This issue contains 2 articles. The editors seek to publish articles considering urban actions in the area of Littoral Territories, Urban Studies, Housing Strategies, Heritage & Vernacular Studies, Environmental Sciences, and educational systems in coastal regions.

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With kind regards,
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Use of Photogrammetry and Terrestrial Laser Scanning to Measure Superficial Weathering Damage on the Façade of Hanfelden Castle, Austria

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ABSTRACT

Hanfelden Castle is one of the few Renaissance castles in Austria, which were subsequently hardly redesigned and changed since the tower building from the 14th century, and the extension in the 16th century to the today's appearance. This includes the façade with plaster layers from the 16th to the 18th century on the south and west side. Under these conditions, the concept for future scientific research of the object should essentially cover two needs: On the one hand, a collection of 3D basic data as complete as possible should be created for further work with the help of geospatial-technological methods, and on the other hand, methodological-technical expertise should also be built up (no substantial investigations have been undertaken in this direction). Additionally, and with regard to the determination of mostly conservation measures- the façade should be preserved - it has been important to check the façade made of plaster, natural stone or brick for the extent of superficial damage - such as weathering, flaking, bulging or bending. Therefore, non-contact 3D measuring systems are compared and applied as an alternative to visual inspection using standard cherry pickers or scaffolding. These so-called geospatial technologies applied in this study include methodological aspects of terrestrial photogrammetry, UAV assisted photogrammetry, and terrestrial laser scanning (TLS). This study used historical data/recordings and photogrammetric results from 1986 as well as newer techniques from the structure from motion (SfM) method (2019, 2022) and terrestrial laser scanning (2019, 2022). The different data recording methods and different result data in a multi-temporal and multi-sensoral approach, comparable for the changes to the facade, were a challenge for the study. Despite the different methodological approaches of the technologies used, the overarching goals of the study were, on the one hand, to detect and map the damage to the facade that has become increasingly apparent over the years. On the other hand, it has been shown that the applied 3D methods used (individually or in combination) represent a time-saving and cost-effective alternative to visual examinations using lifting platforms. The data sets obtained in the campaigns described should be homogenized and summarized in the sense of a historical BIM and serve as a basis for further work on the object. The focus was on multi- and interdisciplinarity as well as on taking into account the needs of science to science and science to public dissemination.

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1. Introduction

In the last years, Geospatial Technologies became a usual tool for heritage managers, conservators, restorers, architects, archaeologists, painters, and all other categories of experts involved in cultural heritage activities, which can be found in numerous national and international case studies (e.g. El-Hakim et al. 2004, Kersten 2006, Kersten et al., 2012; Fassi et al., 2013; Micoli et al. 2013, Dostal 2014, Erenoglu et al. 2017, Maietti, F. et al., 2018, Doumit 2019, Galantucci & Fatiguso 2019, Sulzer et al. 2021).

The aim of this paper is to present a specific application of Photogrammetry, Structure from Motion (SfM), Terrestrial Laser Scanning, and Object-Based Classification tools to obtain detailed information about the historical and current status of façade from a last middle-aged castle. Would it be possible to obtain new information about the structure and development of façade with the applied methodologies of Geospatial Technologies? This paper goes beyond the pure geovisualization of the investigated cultural heritage, but additionally attempts the automatic classification of different façade structures and layers as well as the changes from 1986 until 2022, which are caused mainly by weathering. Additional information about the construction history, by visualizing building structures (construction joint) by means of different high resolution digital surface models will be achieved with this methodology. The final achieved information will help to assist conservation and reconstruction activities.

Photogrammetry enables the creation of accurate 3D models from two-dimensional images. It's a 3D scanning technique that uses multiple images taken from different angles to create a 3D model of an object or scene. It is a versatile tool that can be used in many fields, such as surveying, engineering, architecture, 3D printing, and video game development. Photogrammetry is also a method used in the preservation of cultural heritage sites, museum objects, or architectural monuments. Photogrammetry offers many advantages over traditional 3D modeling methods, including accuracy, precision, cost savings, and speed. If you are looking for an efficient and cost-effective way to create accurate 3D models, then photogrammetry is the perfect solution (Aicardia et al., 2018).

"Structure from Motion" (SfM) is a technique combining photogrammetry and computer vision that reconstructs orthophotos and 3D surface models based on overlapping images from drones or conventional cameras (Sulzer et al., 2021). Orthophotos are true-to-scale and distortion-free parallel projections onto a reference plane (Donath, 2008). The creation of such orthophotos of historical façades enables the documentation and analysis of façades for numerous applications such as restoration, historical preservation, visualization, analysis of the structural condition and damage (Kersten et al., 2012). These therefore represent a significant contribution to the preservation of cultural heritage or culturally valuable objects (Sulzer et al., 2021).

The question of the significance of (terrestrial) laser scanning in the cultural heritage context and how it should be evaluated in comparison with other modern technologies can be seen as the subject of many fundamental discussions. Representative of this is the work of Eppich and Hadzic (2013), in which the authors, based on a review of the relevant cultural heritage literature between 1975 and 2009, attempt to show the interactions between technology and cultural heritage application. This paper clearly demonstrates how and to what extent certain technologies have found their way into the field of cultural heritage. On the one hand, the relatively long tradition of conventional surveying tools such as the theodolite or - with some delay - digital cameras and GNSS is remarkable. On the other hand, this also documents the rapidly increasing penetration of the research field by thermal photography and laser scanning.

2. Hanfelden

Hanfelden Castle is located in the Murtal district (Styria, Austria) at an altitude of around 900m (fig.1). It is located at a key topographical position in the Pölstal south of the Triebener Tauern, an important Alpine

crossing (1270m) between the Mur Valley and the Enns Valley, which was already the shortest connection between the Adriatic and the Danube region in Roman times. The location of the castle is characterized by a particularly favorable climatic terrain, as it is located in the lower area of a mighty alluvial fan of a western side valley that pushes the Pöls River to the eastern side of the Pöls valley. A few kilometers away is the Oberzeiring silver mine, which was important in the High and Late Middle Ages. Hanfelden Castle is based on a late medieval, three-storey, tower-like stone building, built around 1350, and was expanded from 1494 by Hans Han (ca. 1450 – 1516; Hollegger, 2018) and his son Peter Han in several construction phases into an early Renaissance castle (Theune and Winkelbauer, 2019; Theune et al., 2020). It can be assumed that the building as early as 1520/30 largely corresponded to its current appearance and after that only conversions and redesigns of the façades were made, which can be associated with several changes of ownership. After the male line of the Han family died out, the castle was owned by the mostly aristocratic families Rauchenberger, Stübich, Pichl, Herberstein, Prandau, Pfefferhofen and Schwarzenberg. In 1856 the tradesman Franz Xaver Neuper acquired the building for storage purposes or to accommodate workers or servants and it is still owned by the family today (Fuerhacker & Theune, 2016).

What particularly distinguishes Hanfelden castle is its unadulterated, authentic appearance (fig. 2). This is due to the fact that no major changes have been made to the building for around 250 years and that it largely corresponds optically to the oldest known depiction by G. M. Vischer from 1681 (fig. 3). Fig. 4 represents the castle from the year 1830, where baroque ornaments are visible, which are partially still now on the façade. The castle was placed under monument protection in 1965 and is conscientiously looked after by the Federal Monuments Office (Bundesdenkmalamt).

Figure 1. Location of Hanfelden Castle.

Figure 2. Perspective view from West (Photo Sulzer 2019)

The aim of the conservation and restoration measures that have been taking place since 2015 is primarily to preserve the original substance. A modern use of the castle, for example for residential or other purposes, which would require massive interventions in the original substance, is not planned. Damaged or missing parts of the wall are stabilized or supplemented, and missing roofs are reconstructed in order to prevent further deterioration. Particular attention is paid to the integrity of the roof of the main building.

Figure 3. Hanfelden Castle (1681), G. M. Vischer: Topographia Ducatus Stiriae, 1681

Figure 4. Hanfelden Castle (1830), J. F. Kaiser - lithographirte Ansichten der Steyermärkischen Städte, Märkte und Schlösser, Graz 1824-1833

The façade of the south and west side of the castle has several layers of plaster, which can be assigned to several chronological phases:

(1) The oldest phase (before 1510), which as far as can be seen is limited to the ground floor, shows a quarry stone masonry made of medium to large, worked stones (0), the spandrels of which were subsequently filled with small stones or pieces of slag pressed into the mortar and were not further plastered.

(2) The second phase (around 1510/30), which extends over the entire south and west façade, consists of a simple, white-colored plaster. At the south-east corner, ocher-colored cuboids with a border of red iron oxide were painted on. The gate frame in the middle is included in this phase.

(3) The third phase, which can also be seen in the Vischer engraving (1681, fig. 4), also shows a white coloring. Although no corner ashlars were painted on, there are remains of flat painting, especially in the southern area of the west façade. Since the plaster has partially fallen off in these areas or there is a newer layer of plaster, it is unclear which depiction it is.

(4) The youngest and last layer of plaster consists of a baroque brownish-grey structured plaster (around 1730) on which white structures have been applied. On the ground floor there was a large plinth zone depicting cuboids, horizontal cornice bands ran between the floors and on the first and second floor rectangular and profiled decorative fields were applied between the windows framed in white. The southeast corner was again painted with ashlars.

Since large areas of the façade have fallen victim to the weather in recent decades, the primary goal of the conservation measures is to secure the areas that are still preserved. Not just one of the cleaning phases should be preserved, but all of them. This represents a kind of artificial condition of the façade, since areas from different periods can be viewed at the same time, which is a great benefit, especially for building research. The broken edges are stabilized by applying a plaster of similar composition and lifted areas are secured by backfilling with a preservative mortar.

3. Methodology of the multitemporal and multisensorial analyses of the western façade

In Hanfelden Castle, the Graz Universities (Institute for Geography at University Graz and Institute for Geodesy at Graz Technical University) were able to use different methods of remote sensing, such as photogrammetry and laser scanning, as well as geovisualization, as part of the NAWI Graz cooperation (fig. 5). Aim was to document their potential in the recording and presentation of a unique cultural

heritage. Classical recordings of the castle were done by Aigner (2002). Basic photogrammetric measurements were done by Graz University of Technology in 1986. Repeating photogrammetric measurements and recordings of the façade of the castle were done in 2019. Additionally, UAV flight campaigns have been used to generate highly accurate orthophotos (aerial maps), surface models and three-dimensional visualizations of the roof, façades etc. in 2019 and 2022. These initiatives were supported by terrestrial laser scanning of the circle wall, façades, and inner courtyard.

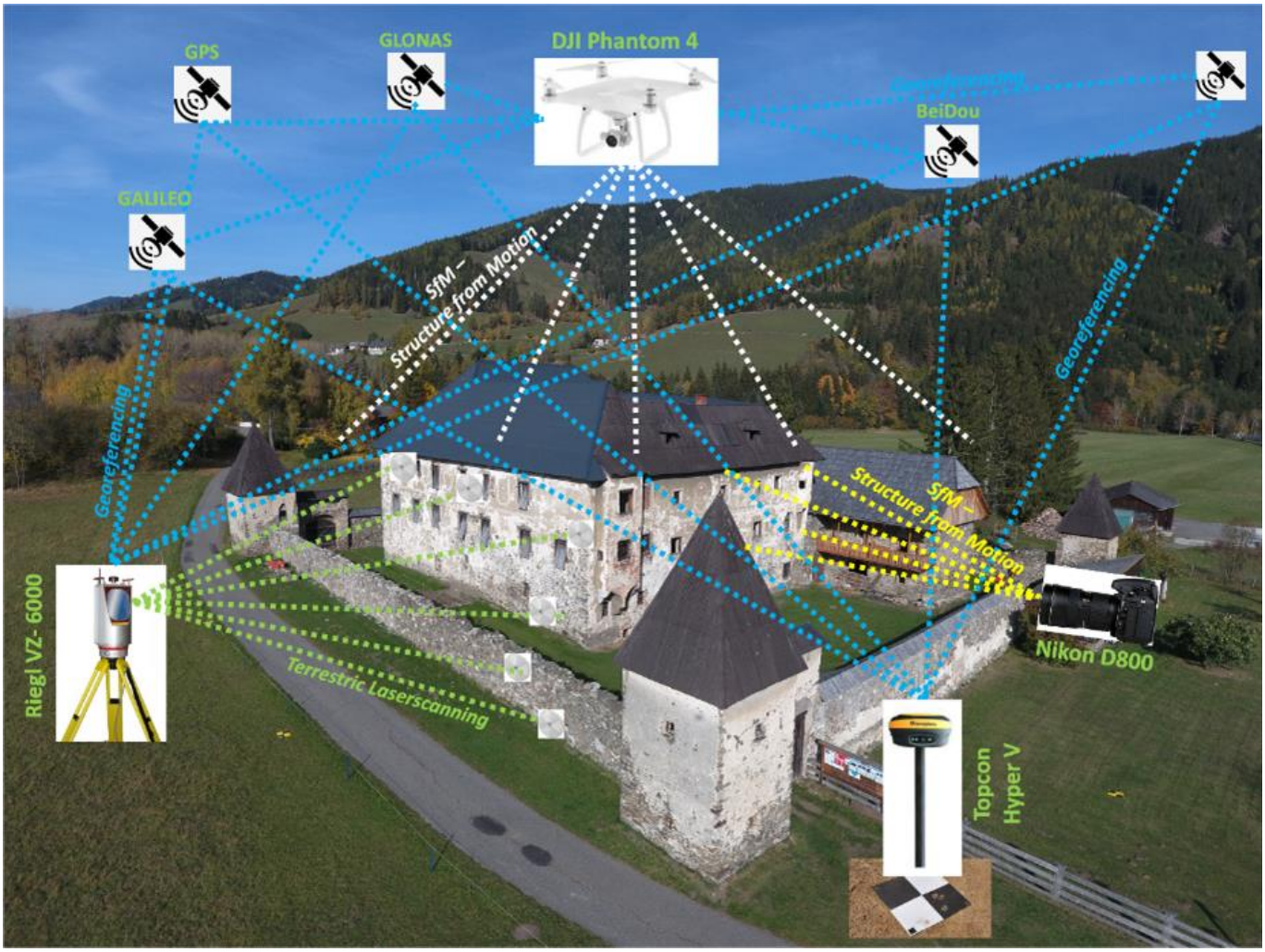

Figure 5. Methodology of data acquisition

The terrestrial photogrammetric recordings of the façades were carried out in 1986 and 2019. The aim was to create site and elevation plans on a scale of 1:100. Three large-scale plans were prepared as part of the project. The color negatives and positives, which were taken with the Hasselblad medium format camera, are also located at the Institute for Geodesy at Graz University of Technology.

After 33 years, the views of Hanfelden Castle were recorded again in 2019, with the primary aim of producing high-resolution orthophotos of the building façades for damage assessment and façade restoration purposes. Fig. 6 and fig. 7 document the weathering of the façade over a period of 33 years.

To register and control the terrestrial photogrammetric recording, control point signals were attached to the façade s of the two buildings at the level of the ground floor, the 1st and 2nd floor. A closed traverse (4 main station points and 3 intermediate points) was measured using the Total Station TPS1201R from Leica Geosystem GmbH. The signaled control points, but also supplementary natural control points and other points were measured polarly from the viewpoints. The terrestrial photogrammetric recording of the façades of Hanfelden Castle was taken with the digital single-lens reflex camera Nikon D800 (lens: Nikon AF Nikkor 20 mm 1:2.8 D). A total of 244 photographs in RAW format were acquired. The terrestrial photogrammetric evaluation with the primary goal of creating orthophotos for the individual façades was largely carried out in the Agisoft Metashape software and then post-processed with the Global Mapper software.

Figure 6. View from southwest 1986 (Photo Kaufmann)

Figure 7. View from southwest 2019 (Photo Sulzer)

In order to visually capture the castle and its surrounding wall in its entirety, an aerial survey was carried out using a small, unmanned aerial vehicle, commonly referred to as a UAV, as part of the surveying campaign in 2019. The aircraft (DJI Phantom 4) was operated at two different altitudes, about 33 m and 63 m above ground. This made it possible to generate a spatially very high-resolution (ground resolution 2 cm) database, namely an image mosaic of aerial photographs that can be directly compared with maps). In addition to these orthogonal overview flights, the individual sides (façades), the neighboring building and the ring wall were recorded with high precision (resolution in the cm range). These UAV flights were repeated in 2022.

Structure from Motion (SfM) is a topographic survey technique which can produce three-dimensional (3D) point clouds and therewith orthophotographs and digital elevation models (DEM) based on two-dimensional (2D) imagery. Algorithms are used to register matching points from a selection of overlapping images – e.g., different positions and angles - of an examined object. This allows the camera positions and orientations to be calculated, with the point clouds or models being output in an arbitrary reference system. Thereby the need of reference data and Ground Control Points (GCP) is inevitable for georeferencing and scaling (Carravick et al., 2016). Basically, SfM is a flexible and inexpensive alternative to TLS and allows to generate high-resolution orthophotographs and DEMs based on UAV images. Using recordings from 2019 and 2022, changes in the condition of the façade can be determined, which helps to improve the information required for restoration.

The application possibilities of laser scanners in the scenario discussed here are - apart from the purpose of the investigation - essentially determined by two further influencing factors, the technical specifications of the Riegl VZ 6000 with a maximum range of 6000 m used in the campaign and the associated recording parameters. The former include:

• Accuracy (the degree of conformity of a measured quantity to its actual (true) value (one sigma @ 150 m range under RIEGL test conditions): 15 mm,
• Precision, also called reproducibility or repeatability, is the degree to which further measurements show the same result 10 mm,
• Minimum Range: 5 m
• Laser Beam Divergence 0.12 mrad per 100 m distance (measured at the 1/e 2 points. 0.12 mrad corresponds to an increase of 12 mm of beam diameter),
• Laser Beam Footprint (Gaussian Beam Definition) 15 mm @ exit
• Field of View maximum 60° (from +30° to -30°) vertically and 360° horizontally,
• Minimum angular step width 0.002 rad in both directions (Riegl, 2015).

As already indicated, these parameters influence the configuration of the second group of factors. In the case of the given problem, the scanning density at the object (i.e., the façade) naturally had to be kept as high as possible (or the step size as small as possible); in order to achieve this, a balanced relationship between the scan step size to be set and the distance to the object had to be selected. Unlike in the case of long-range scans where the resulting amount of data also plays a certain role, in the present case the so-called minimum range distance is more important, the minimum distance that has to be kept in order not to destroy the receiving unit of the device. With these specifications (as little as possible more than 5 m from the façade and (for geometric reasons) as central a position as possible in front of the object), the problem arose that the surrounding wall of Hanfelden threatened to prevent the optimal positioning of the scanner or would have covered the lower parts of the building. For this reason, a telescopic tripod was used instead of the usual tripod, with the help of which the scanning platform could be raised to a height of 2.6 m, thus ensuring an unobstructed view of the entire west façade (fig. 8 and fig. 15).

Figure 8. Scanning position "west façade"; the (remote-controlled) scanner is located about 10 m in front of the object at a height of 2.6 m; this does not obstruct the view

The 2D drawings were produced using the rectified images from 2019 and 2022 of the building's façade resulting out of the SfM procedure. Additional to current digital images referential archive documents from 1986 allow to characterize and quantify the state of façade deterioration over the course of time. Further on, different layers/categories were used for the mapping and digitization of the façade's features. For the differentiation of the features, the façade materials and condition were considered (Patias et al., 2011).

The elements of the façade were categorized for the investigation according to the phases of development (see section 2 and legend in fig. 16). In addition, line signatures were used for the year 2022 to highlight cracks and exfoliation processes on the façade.

4. Results

The Surfer software was used to create 10 orthophotos and 7 plans on a scale of 1:100 in PDF format (paper format: A3 and A4, fig. 10) for 2019. Furthermore, a virtual tour of the façade of Hanfelden Castle was created in the form of a video using the CloudCompare software from the photo-textured 3D model. The 10 resulting orthophotos of the façades of Hanfelden Castle, which were created using terrestrial photogrammetry and geodetic measurements, are in JPG format (incl. World File) and in 7 plans in PDF format (paper format: A3 and A4; scale 1: 100, fig.10) provided. The geometric resolution of the Orthophoto is 2 mm/pixel (fig. 9).

Figure 9. Orthophoto with an original resolution of 2mm

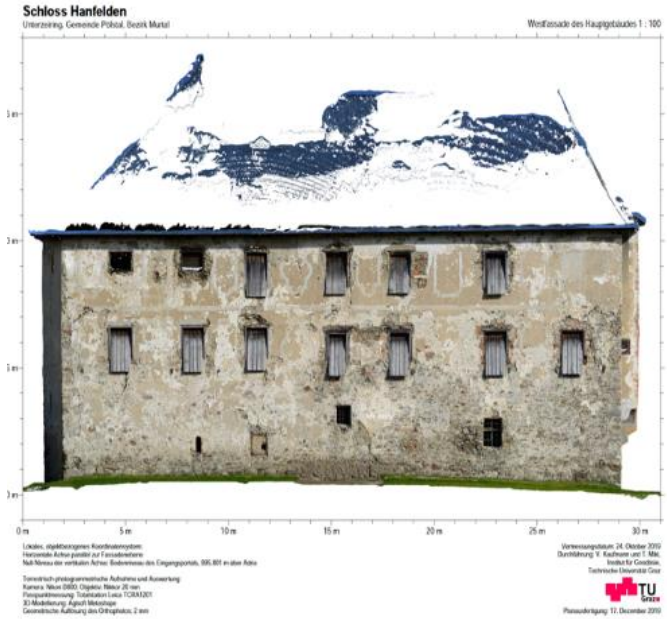

Figure 10. Orthophotomap 1:100

The SfM method for the UAV data was used to generate DEMs and orthophotos of the western façade of the castle for 2019 and 2022. The resolution of 2022 compared to 2019 and 1986 allows for a high level of detail (tab. 1). See the table for resolution details. These differences in resolution – which corresponded to the technology of the time and the purpose of the photos at the time – and thus in the details that can be derived from the recording, must be taken into account in the interpretation.

Table 1. Information about UAV images and SfM statistics.

Year	Resolution	Cameras	Points Dense Cloud
2019	4.23mm/pix ortho & 1.69mm/pix DEM	539	3,886,370
2022	0.838mm/pix ortho & 3.35mm/pix DEM	1191	35,953,993

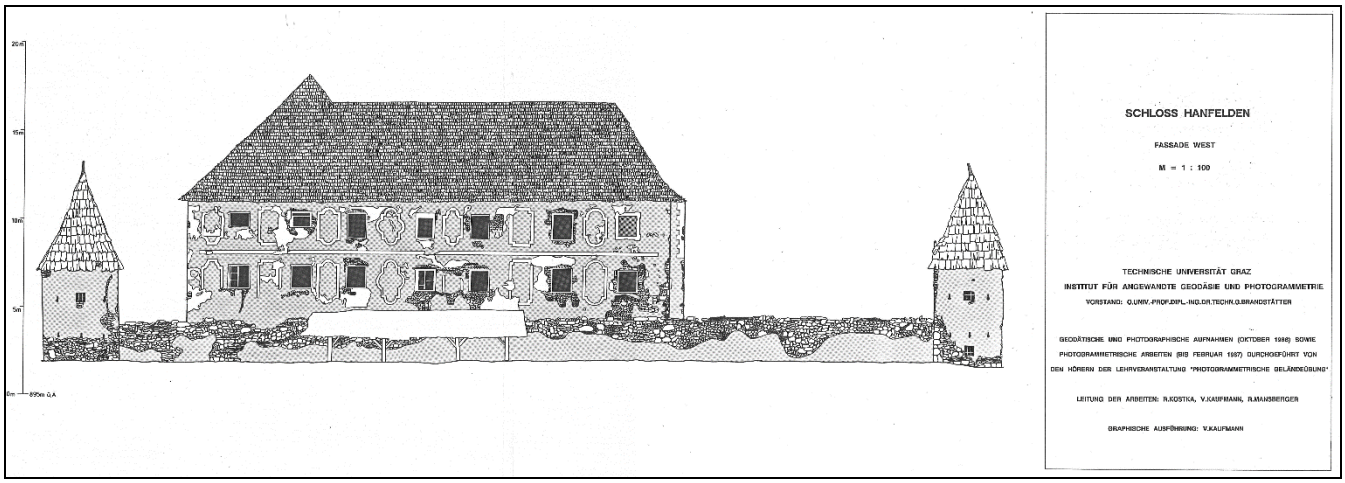

Figure 11. Sketch Map of the western façade and ring wall in 1986.

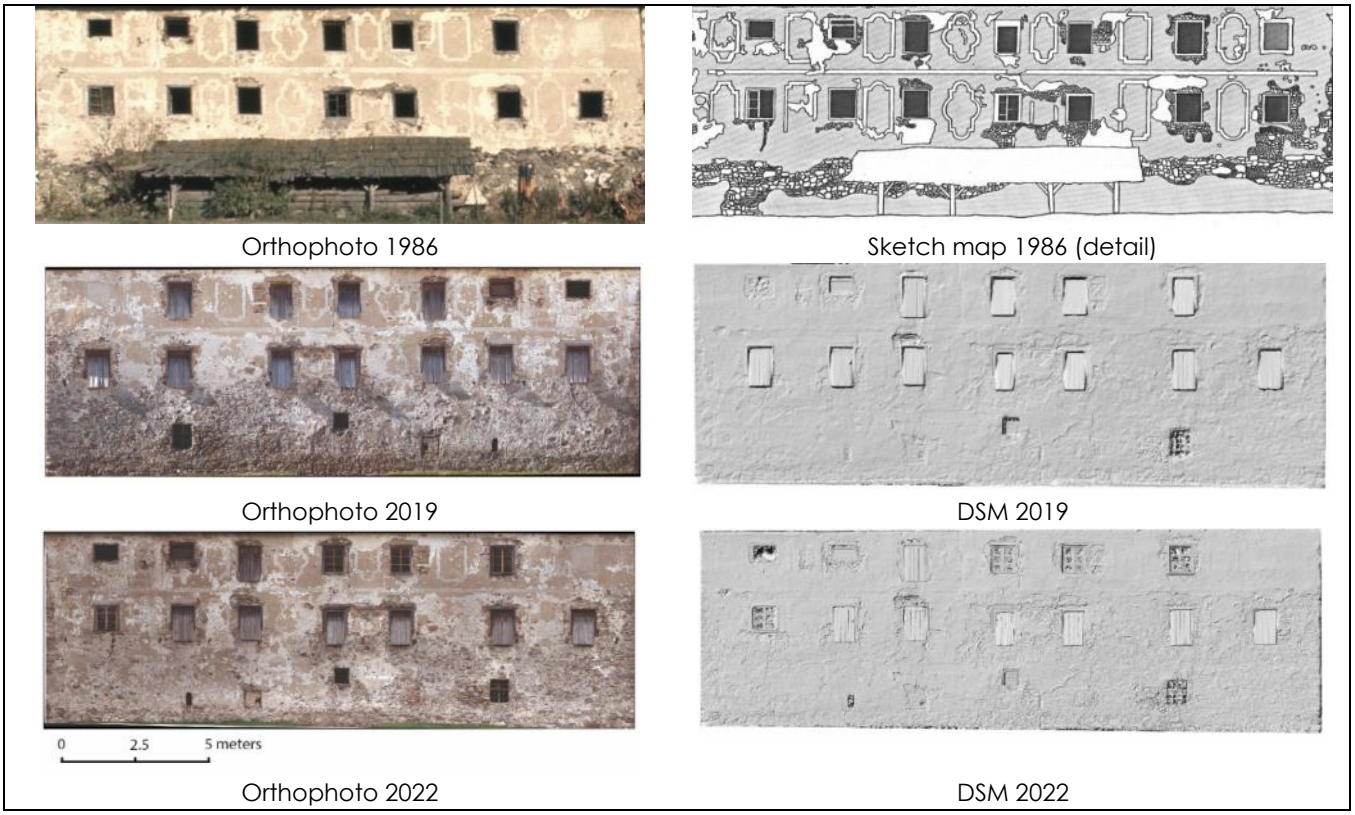

Figure 12. Orthophotographs (1986, 2019, 2022), Sketch map from 1986, and Digital Surface Models (DSM) from 2019 and 2022

Figure 13. Terrestrial Laser Scanning: Digital Surface Model (DSM) from 2022 (detail)

Figure 15 documents the potential of high-resolution Digital Surface Models (DSM). Structural elements of construction history (vertical crack in the middle) which represents the additional, newer part of the castle on the right side. Left side was part of the older one. Different plaster layer can be distinguished and identified (see fig. 15), and areas where the layers are upwelling. Especially this damage has to be fixed, to protect the plaster layers again further and ongoing destruction.

The capture (fig. 14) shows the initial scan result, the point cloud consisting of approx. 25 million points was not processed; but merely coloured to improve the display.

Figure 14. Raw scan of the west façade; the red circles mark the reflectors attached to the wall for georeferencing and comparison with the other partial scans

As a result of the scan of the west side of the main building of Hanfelden, which was carried out at 300 kHz with a (horizontal) frame resolution of 0.020 rad and a (vertical) line resolution of 0.019 rad, a point cloud with a size of approx. 1 GB was created with a relatively short runtime of about 20 minutes. After removing the scattered or background pixels that were not relevant for the investigation, a total of about 23 million measurement points remained for further processing. At this point it must be noted that due to the relatively wide horizontal scan angle, different distances to the detected object naturally occur, which in the present case range between 7.8 m in the nadir and 18.8 m in the lateral areas. Using the information provided by the device manufacturer, an approximate point distance of 2.7 mm is calculated for the first (optimal) case, which corresponds to approx. 137,175 points converted to an area of 1 m². In the worst (lateral) case, 1 m² contains only about 23,700 dots (average point to point distance: 6.5 mm). Although the printing conditions can only imperfectly reproduce the level of detail of the original data set (Gspurning et. al., 2021). Figure 15 shows very well the high dot density and which details can be identified.

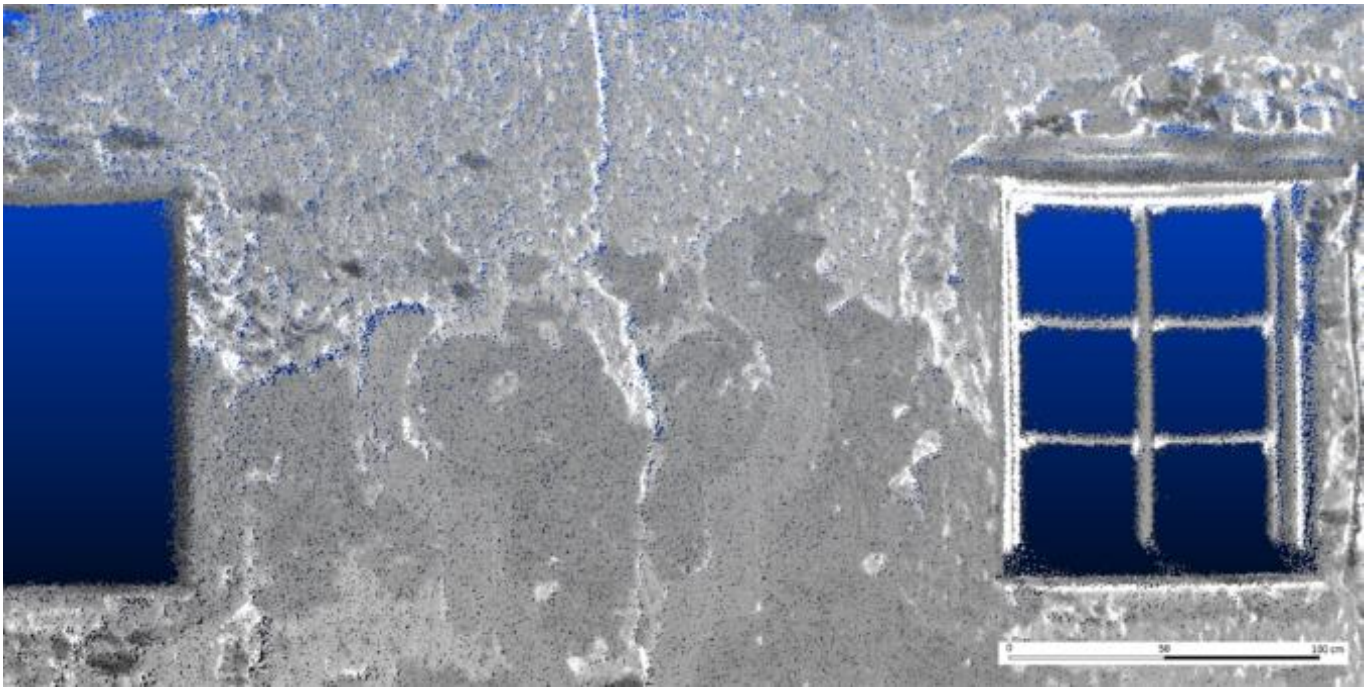

Figure 15. Section of the façade; due to the different reflectance of the wall surfaces, structural details such as ornaments on the wall or even structural damage can be seen very well

Figure 15 show typical structural damage and represents the limit of what is possible; while the approximately view cm deep edge as well as larger structural damage are still reflected in the generated point cloud. Finally, an additional problem inherent in the system is the geometrically induced flowing decrease in point density from the central to the lateral areas of the scan, which is responsible for the fact that the level of detail of the representation also decreases analogously. From a methodological point of view, this is equivalent to a necessary compression of the required scan positions with the help of which these problem areas can be kept as small as possible. However, this procedure would be tantamount to an increase in effort and raise the question of more favorable alternatives (e.g. flying with UAVs).

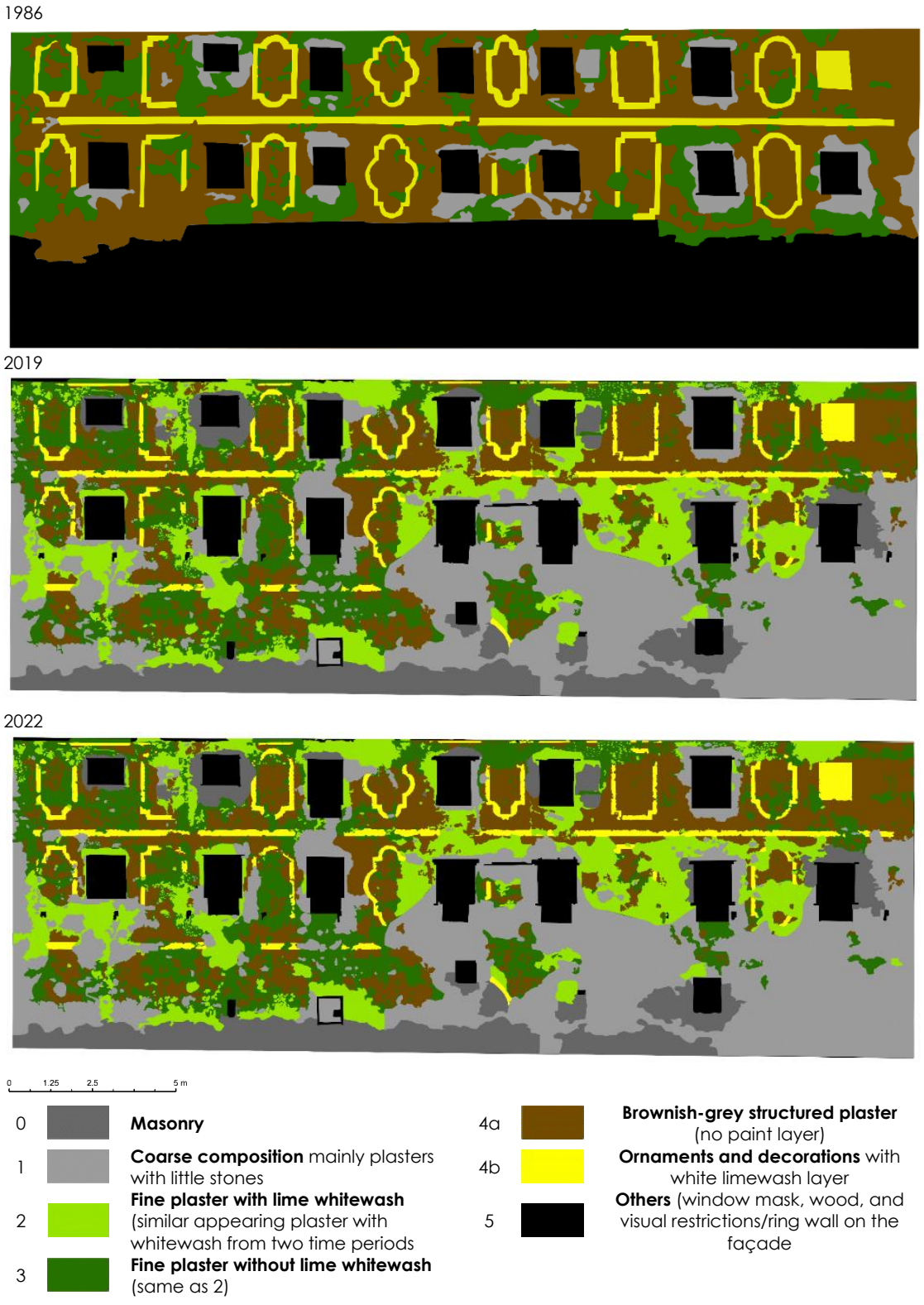

Figure 16. Object-based Classification of the western façade 1986, 2019, and 2022

The comparison (fig. 16) of the years shows, as expected, that the west façade suffers the greatest visible deterioration on the mesoscale (cm to m) (Viles et al., 2011) from 1986 to 2019. However, it shows that the southern part in particular - i.e., the right part of the façade - is more vulnerable, which is particularly illustrated by the appearance of the lower layers such as the masonry and the coarse composition. The comparison of the years 2019 and 2022 also shows that the most significant differences take place in this part and shows that there is a need for action in this area, even if the changes take place on the microscale (mm to cm). Overall, numerous changes in the mm and cm range were determined, bearing in mind that non-visible deterioration on the nanoscale (<mm) cannot be examined with this method.

The comparison of 2019 and 2022 shows that the condition of the façade can only be seen on a small area or in the details. A total of 70 differences (+) were identified, but not all of them are of significant importance (6 of 70 concern significant changes, which are larger and therefore more noticeable; these crosses are marked in fig. 17).

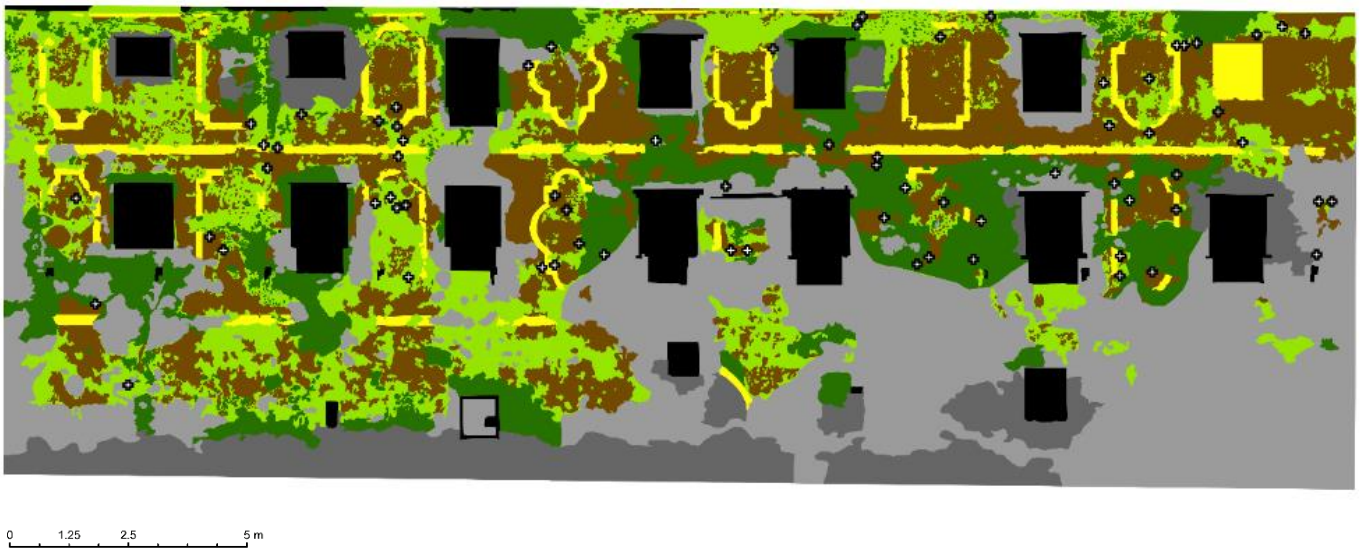

Figure 17. Spots (+) in the western façade, where changes occur between 2029 and 2022

Figure 18 documents a change detection analyses of the obtained object-based image classifications of the orthophotographs 1986, 2019, and 2022. 2022 (green) means, that there are intact layers (ornaments and plaster layers, 4a and 4b in fig. 16) which do not exist in 2022 anymore. Yellow (2019) means the changes between 2019 and 2022, respectively those parts which do not exist in 2022). The red color represents the plaster layers (4a and 4b in fig. 16) which are still intact in 1986. The greyish colored parts were not existent in 1986 and weathered before. Black colored areas represent other not visible parts of the façade like window mask, wood, and visual restrictions such as caused by the ring wall). Figure 19 represents 3 examples (details) from the western façade to enhance the small changes caused by the weathering from 1986 up to 2022.

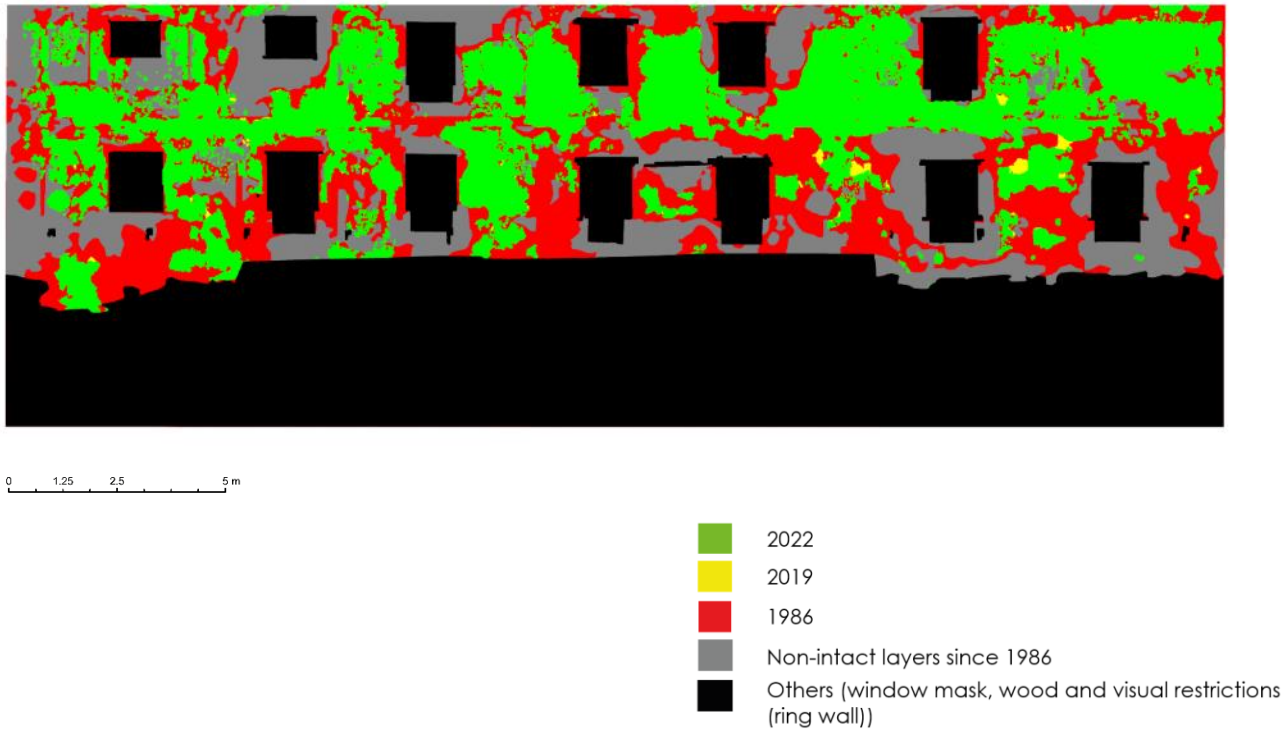

Figure 18. Changes on the western façade between 1986, 2019 and 2022 (explanations see text)

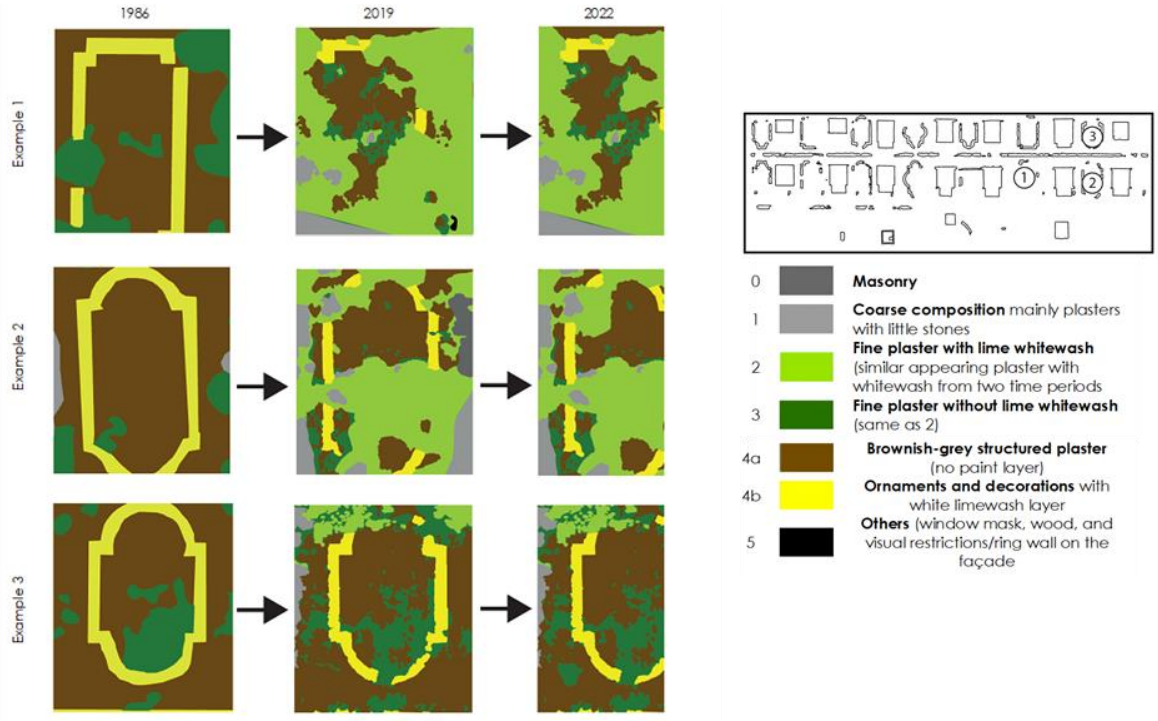

Figure 19. Detailed change on the western façade 1986, 2019 and 2022

5. Discussion

As already mentioned, the collection of methods presented here first serves to create a sustainable data basis, which through its conception (especially method and scale of acquisition, but also integration and possibility of use of the data) eliminates any future limitations as far as possible. This means that the investigations can be repeated almost at will, which is particularly well documented about the multitemporal investigation of façade development presented in this work. In this case the implemented methodologies of Geospatial Technologies proofed very suitable for the data and information acquisition of the western façade of the castle Hanfelden. A multitemporal and multisensorial analyses provides important information about the condition and the almost continuously destruction due to weathering influences. The example discussed here, provides a good estimate of the scale up to which structural irregularities in the building fabric or their changes can be documented using this method.

When looking at the individual 3D techniques (photogrammetry, SfM and TLS), the following can be noted in the specific example of Hanfelden:

The advantage of photogrammetric acquisition is mobile and flexible object capture on site. In the given Hanfelden example, contactless recording of the facade is often not possible due to the proximity of the castle's surrounding wall, and the recording angle is often only dragging. The high geometric resolution and the use of RAW data, however, allow a high level of detail in the images and this benefits the very good documentation of the surface condition. In the processing process of the photos, photorealistic 3D models can be further processed into rectified, dimensionally accurate photos and plans. Terrestrial photogrammetry thus achieved the highest comprehensive geometric accuracy of all methods used. A major disadvantage was the lack of a surface model in 1986, which was not available (fig. 12).

For 3D capture in the SfM process using conventional UAVs, a digital camera is usually used, the quality of which cannot be compared with a full-format camera (Nikon D800). These include, on the one hand, the poorer camera geometry and, on the other hand, irregularities that occur during data acquisition. This primarily includes irregular aerial photo block structures (angled shots, variable image scales at different flight distances from the facade, changing image coverage, etc.). A clear advantage of UAVs is that the geometric resolution of the image data can be increased due to the variable distance to the facade. Due to the proximity of the surrounding wall, the distance of the UAV to the facade must be reduced to approx. 5m (to keep a safe distance from the façade and surrounding wall). However, this procedure leads to a relatively large number of images (around 1200 images for 2022, see tab. 1), which itself has a negative impact on data processing.

Although the use of a terrestrial laser scanner brings undoubted advantages, it is also subject to several potential problems, which - apart from the technical limitations of the equipment - are primarily based on the local conditions. Particularly noteworthy in this context are the shadowing caused by the structural conditions of the object under investigation, which on the one hand prevent optimal placement of the scanner (e.g., minimum distance to the object versus scanning angle) and on the other hand make it impossible to record certain parts of the building (e.g., roof surface sloping towards the inner courtyard).

Another problem of TLS solution results from the (theoretically possible) high sampling density, which commonly leads to extremely large point clouds (30 GByte) and thus requires special resources for further processing (both data management and surface generation and analysis). Finally, a problem typical for these project phases should be mentioned: At the beginning of the search for the optimal workflow, it must be expected that data from other acquisition methods are not yet available.

The orthophotos and Digital Surface Models (DSM) created using Photogrammetry, SFM and TLS represent optimal documentation of the façade surface and allow building research and restoration to

record and map a wide variety of observations on the plastering phases, their dating and materiality, special craftsmanship and various phenomena of damage. It is also possible to monitor changes by regularly repeated photo campaigns and to determine whether the deterioration has been stopped or is continuing after the implementation of conservation measures. The methodologies are suitable to be applied in the context of façade inspection.

A challenge in multisensorial and multitemporal analysis lies in the different resolution and accuracies of the image products used. On the one hand, a balanced compromise must be achieved when integrating historical data that cannot be changed and is not of such high quality, but on the other hand, future technological development of the methods and tools used should demand higher resolution and accuracy. It is precisely these aspects that must generally be discussed with all disciplines involved at the beginning of a monitoring concept (e.g., when analysing facade changes).

With regard to the methods and techniques presented in this document, it has become clear how valuable the cooperation of geospatial technologies can be in the field of historical building research; this applies above all to the different acquisition methods that are seamlessly intertwined here and thus optimize the achievable result. In addition, this type of data acquisition also enables the problem-free transfer to geographic information systems, where the traditional GIS analysis functions are of less use than the storage and documentation of the collected information. Provided that the workflows developed are used to optimize future workflows or to develop sample workflows, the results can serve as a basis for permanent monitoring of the building fabric and thus make a valuable contribution to future research on the Hanfelden property. This could finally achieve a historical cultural heritage building information system (BIM).

6. Conclusion

Within a specific application of Photogrammetry, Structure from Motion (SfM), Terrestrial Laser Scanning and object-based classification tools detailed information about the historical and status of façade from a last middle-aged castle was obtained. New information about the structure and development of façade with the applied methodologies of Geospatial Technologies could be received, by a data homogenization of historical data (1986) and recently recorded data material (2019 and 2022).
This could also be achieved by the application of an automatic, object-based classification of the images. Besides the optical image data, results from the Terrestrial Laser Scanning carried out additional information about the construction history, by visualizing building structures (construction joint). The final benefit was to give valuable data and information to assist conservation and reconstruction activities.
As soon as the knowledge gained allows the recording process to be automated as far as possible, the observation intervals can be shortened to such an extent that, in the sense of the initial intention, the structural changes can be documented for each area of the object in high temporal resolution. This enables researchers from neighboring disciplines to draw valuable conclusions for their research. In addition, the data material is of course also designed so that it can be used - for example in the context of 3D virtualization - in the sense of a science-to-public information transfer.

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Data availability statement
The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

Ethics statements
Studies involving animal subjects: No animal studies are presented in this manuscript.
Studies involving human subjects: No human studies are presented in this manuscript.
Inclusion of identifiable human data: No potentially identifiable human images or data is presented in this study.

Conflict of Interests
The author declares no conflict of interest.

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The Landscape Urban Planning Approach for Improving Urban Air Quality, Case Study of Algiers, Algeria

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ABSTRACT

Gardens and urban parks are areas of great importance for the support of the urban ecosystem, in addition to their psychological and therapeutic values; they provide the urban environment with a large amount of oxygen. Trees produce oxygen through the operation of photosynthesis; one hectare of eucalyptus tree annually produces oxygen for 37 to 80 people, and absorbs 25, 000 kg of carbon dioxide for the same period of time. Wooded zone in urban areas significantly improve and purify the quality of the air that we breathe and make living environments healthier. A recent study carried out by the World Health Organization (WHO) revealed that the MENA region (Middle East and North Africa) is one of the most polluted in the world, air polluted by particulate matter smaller than 2.5µm (PM2.5). For the case of Algiers, measurements were taken during the first two months of the year 2023 by the station of the United States Embassy in Algiers, showed that daily average of 14 µm/m3 for particulate matter less than 2.5 µm/m3 and a daily average of 50 for the IQA, air quality index. According to the US EPA's NAAQS, any measurement above 12.0 µg/m 3 (US AQI 50) may be hazardous to human health. Several factors of an exogenous and endogenous nature act directly on the quality of the air in large urban concentrations, CO2 emissions, modes and nature of urban mobility, uncontrolled urban sprawl. High population densities, urban forms, morphology, the size of cities, which getting larger and larger, the choice of urbanization models, and the surface of wooded areas, all are, factors responsible for air quality. This study will be particularly interested in the contribution of gardens, parks and wooded areas in improving air quality, and consequently on the quality of the living environment in urban areas. In this respect, and to understand the situation, we take the city of Algiers as a case study. The field work will allow us to understand in a qualitative and quantitative way the contribution of the tree and the choice of tree species, understanding co-relation between landscape architecture decision and results obtained on the urban air quality, and try to research on how it would possible to improve air quality in urban areas by using trees new essence.

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1. Introduction

According to the 5th annual report on air quality in the world in 2022, there are only 5% of countries on the planet respecting the WHO guidelines on air pollution, Australia, Estonia, Finland, Greenland, Island and New Zealand. Conversely, the most polluted countries in 2022 in terms of fine particles 2.5 PM, are first Chad with 89.7 µm/m3, which represents 17 times higher than the WHO annual average set at 5 µm/m3, followed in second place by Iraq with 80.1 µm/m3, 16 times the annual WHO recommendations . Pakistan comes in third position with 70.9 µm/ m3, Bahrain in 4th position with 66.6 µm/ m3, (Figure 1) in 5th position of the most polluted countries is Bangladesh with 65.8 µm/ m3, the report also indicates that 90% of the countries of the globe have exceeded the annual WHO PM2.5 guideline value of 5 µm/m3.

Algeria is ranked in 58th place with a rate of 17.8 µm/m3, air pollution in Algeria is mainly due to emissions from the combustion of fossil energy sources generated from industry, urban transport and even residential sector. The disparity of the results taken on the quality of the air, the values of NO2, taken on different places of the capital Algiers, has pushed us to seek to understand the link which can exist between the space in question which is defined by a form and a precise spatial configuration and the value of NO2 taken during a period of time, at this stage, the question that arises; Is there really a relationship between the quality of the air taken in public space and the physical components of the same space?

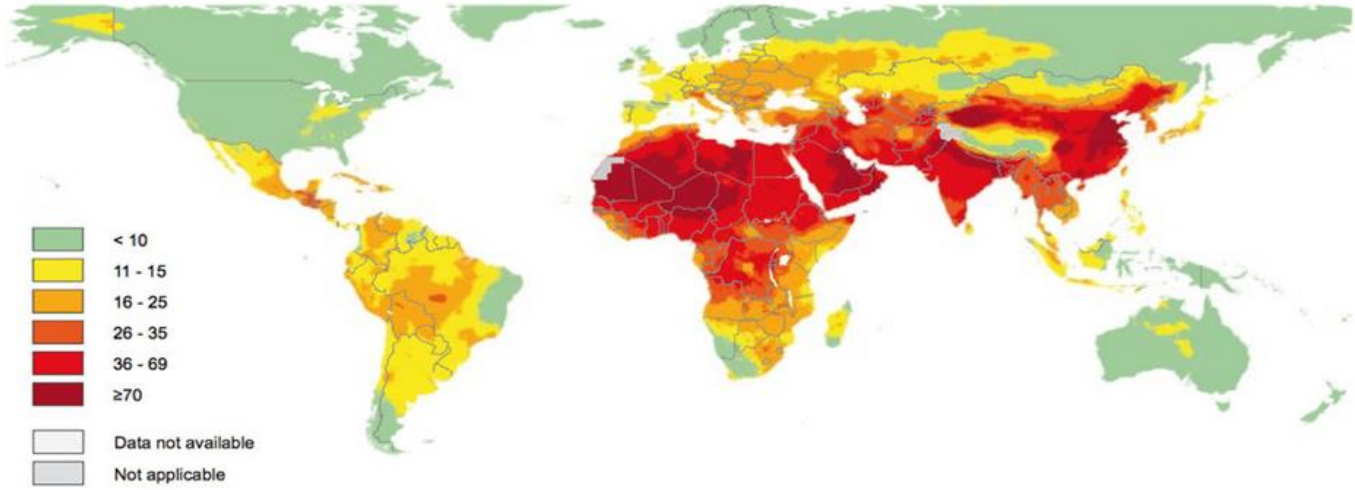

Figure 1. Particulate matters under 2.5, PM2.5 concentration, world map (WHO source 2023)

2. Context of study

The context of study concerns air quality assessment in several preselected site in Algiers, giving interest to study site, not areas not perimeters, is for the master reason that site contains a set of physical attributes that could be defined as the sum of relations existing between container, contents, immediate environment, external acting agents, and emerged reactions.

At that point of view, sites of study, concretely includes physical elements; that are man-made elements, as well as living elements, trees and plantations, mostly these physical contents are delimited by streets, the intersection of streets results up by an urban open space configuration, beyond streets, urban walls came to shape the urban open space.

Air quality assessment process concerns an area of 6 km distance, covering the main three municipality; Bab el Oued municipality, Algiers Centre and Belouezdad, all of them having an opening to the Algiers bay on the Mediterranean sea. Three group of distinct site were selected to procced to air quality assessment, the first group concerns public gardens developed on slopping site, the second group concerns public gardens developed on flat site, and the third group concerns planted streets. The

common characteristics of the study sites, are mostly planted with Benjamin Fig trees, which are first introduced to Algeria in 1864 during the French colonial period. Benjamin Fig tree is native from south East Asia and is known by its good resistance to pollution, and don't need too much maintenance during its long life that can reach 300 years (Figure 2).

Land scape approach in improving the urban quality life, is a concept as old as human being existence, but the real innovation of the 19th century is the appearance and generalization of municipal parks made available to everyone In England, John Claudius Loudon, Scottish botanist was the first to plead in favour of the opening of public gardens, asserted as an "instrument of social reform" (Zeybekoglu Sadri, S., 2020).

During the 19th century the most important program of public parks integrated into an urban plan is French: it is the restructuring of Paris, launched by Napoleon III and orchestrated by Baron Haussmann

The objective is to "ventilate" the capital; it is a question of providing Parisians with fresh air and new leisure spaces by opening up spaces, in particular with the help of major thoroughfares and large public parks.

For the case of Algiers, the city possess many gardens, and got its first garden ; le Jardin d'essai, Test garden in 1832, few time after in 1833 garden Maringo actually named Jardin Sofia took place at the western limit of Bab el Oued, another garden was erected in 1864 in Bab el Oued on a slopping site open to the Mediterranean sea was named le Jardin de la Ferrierre actually Jardin Taleb Abderrahman, the square port said in front of the national Theatre was edified in 1853, years later and after city walls destruction on the eastern direction of the old city le Jardin plateau des Gliere (actually les jardins de la grande poste) was edified in 1889. The early awareness of the importance of gardens in improving urban quality is felt through the city fabric organization, and the position of gardens within the district to which it belongs.

Figure 2. Context of study, 6 kilometre distance area on the Algiers bay

3. Research methodology

The methodology adopted for air quality assessment in urban open space is an hybrid methodology based on two level assessment processing, the first one is a descriptive method which consist on collecting information about physical attributes of the site case of study, the site of study which is

considered as an urban ecosystem in relation with the whole city fabric, in that perception the site of study is constituted of a set of contents, like physical elements end living elements, the sum of contents are framed by a container, which give a specific and a distinct form and configuration for the urban open space, the container which give form to the space, itself is surrounded, and resulted from the cross intersection of streets, the position of streets on the limit of urban open space let us to decide the space use and hierarchy, so then public urban space limits made by streets intersections can be considered as well as boundaries as well as means of transition . the public open space configuration is also made by urban walls; blocks of buildings, facades opened to the public open space case of study, in descriptive methods we interest also to the public space topography, whether is developed on slopping site or on flat one, to the orientation of the space, the sun exposure, and wind ventilation.

Collected data resulted from the descriptive method serve essentially to make decision about the position of points from which air quality, in particular NO2 pollutants will be measured. These points or measurement station are identified on site according to a number of factor, 5 factor may have direct impact on the air quality on urban open space; the first one is the density of trees on studied area, the second criteria is the wind spend and the public space air ventilation, the third factor is the height of the surrounding buildings, the fourth one is the density of traffic in studied area, the fifth factor is the values of NO2 pollutants, NO2 values are quantitative indicators of pollution in a space. For instance the case of the garden of la Grande Poste, the garden is developed on slopping site, designed in sort of cascade, four platform shape the garden, the lower platform situated at 25 meters altitude, the second one at 39 meters, the platform at the middle is situated at 48 meters above the sea level, and it is reserved for the floral clock, and the superior platform is located at 56 meters., here 4 point of measurement were taken in correspondence to each one of the previously cited platform, and Intersection of streets passing by the garden.

4. Descriptive methodology

Descriptive methodology is operated to gather quantitative information about the sites case of study, at this stage of assessment process we need to establish a list of criteria that allow us to well understand the correlation between the space component and space's attributes. for this purpose, 5 criteria are taken in consideration, the first criteria is related to the shape and the space dimension, the second criteria focus on space case of study limits interpreted in term of length and width, the third criteria is about the quality and quantity of plantation, the fourth criteria is related to the surrounding buildings; elevation, the fifth criteria is about the space orientation solar orientation, and sun exposure duration.

The descriptive methodology is exercised on three group of preselected sites, the first group concerns gardens developed on flat site Jardin d'essai and Port Said square are taken as case of study. The second group is constituted of la Grande poste garden and Taleb Abderrahman garden, both of them developed on sloping site.

The third group contains Hassiba Street and Didouche Street (Figure 4). The two street are heavily planted with Ficus Benjamin trees.

4.1. Le jardin d'essai

It was on December 30, 1832 that General Antoine Avisard, acting Governor General, signed the decree creating the trial garden at a place called El Hamma to the east of Algiers. Its first vocation was to be a model farm, but also a testing ground for the cultivation of useful plants and thus provide for public plantations.

In 1837, its area was increased from 5 to 18 hectares and sanitation and construction works were ordered. Thus, the Jardin d'Essai gradually began to take shape under the leadership of Auguste Hardy, appointed director in 1842 "an almost square surface, three main axes which crossed the garden from north to south (allée des Platanes created in 1845, the Allée des Dragonniers and the Allée des

Bambous created in 1847 and the Allée des Ficus created in 1864) and thus delimited the large sectors (the French garden, the English garden, the nursery, the greenhouses).

The acclimatization garden will integrate the municipality of Algiers. In 1914, the Hamma became a public garden intended for walking, but the State remained the owner. From 1913 to 1946, the General Government of Algeria which manages the garden, begins work of reorganization and restoration Also become a place of vacation and walk, works of embellishment are undertaken in 1914 by the architects Régnier and Guion, winners of a competition to whom we owe the perspective of the French garden which extends from the National Museum of Fine Arts (created in 1930) to Hassiba Ben Bouali street over an area of 07 hectares.

The garden during its long history has gone through times of degradation and abundance, the garden closes due to rehabilitation work between 2001 and 2009. Reopened in May 2009, it now houses the premises of the National Research Institute agronomy of Algeria (Figure 3).

The garden in its current state covers an area of 32 hectares, bounded from the north by Belouezdad street for a distance of 570 meters, on the south side by Hassiba Benbouali street for a distance of 590 meters, to the east is bounded by the August 20, 1955 stadium and a residential group, to the east is limited by the national library and the Sofitel hotel. The garden at its creation had more than 6000 species of trees, today there are only 2700 trees in good condition, despite the great loss of several hundred trees, the garden remains one of the privileged places recognized by its quality of air.

4.2. Square Port Said

The square most probably was created in the same period as the national theatre in 1853, the square is of a square shape covers an area of 5000 square meters, occupying the north side of the TNA The square housed benches, chairs and birds appreciated by all those who tasted the charm of gossip.

You could see a population of regulars, engaged in endless conversations under the evergreen trees, the square is planted with Ficus, Magnolias, Palms, and Bamboos.

The square is bordered from the east and west by Haussmann-style buildings with a template of 4 levels, forming urban walls 20 meters high, its position on a platform at an altitude of 20 meters high. Compared to the level of the sea, its fully cleared north facade and open to the Mediterranean, have made it one of the most privileged places for outdoor socialization activities.

During its history the square has undergone transformations in the use and in the quality of the elements which constitute them, today the square is only with 27% of its green cover, of what it was at the time of origin.

4.3. Hassiba Ben Bouali street

Hassiba Benbouali street was created in 1864 to give birth to the lower Mustapha district, it connects the garden of the large post office on the west side and the May 1 crossroads on the east side over a distance of 1180 meters, with its 18 meters wide Hassiba street has a 10-meter floor, offering traffic in 2 lines in the direction of going and a line for the return, sidewalks planted with Ficus on both sides reaching 4 meters wide, along Hassiba Street there are 472 Ficus trees planted at an interval of 5 meters.

The urban walls vary from one sequence to another, at the beginning of the Hassiba urban axis the heights of the buildings on either side, near the garden of the large post office, easily reach 20 meters high, the equivalent of 4 level, the urban walls on the sequence of Mauritania Square rise to 24 meters, on the side of the agha the templates rise to 4 levels with a fifth level set back, the same template is maintained until the crossroads of first May.

The relief of Hassiba Street is of a very low slope, the altitude is 15 meters at the level of the garden of the great post office, and reaches 23 meters at the level of May 1st.

4.4. Didouche Mourad street

Rue Didouche was created in 1907, as an extension of rue Larbi Ben Mhidi (formerly rue d'Isly), giving birth to the district of Mustapha superior, and shortly after to the districts located at the heights of the capital. The Didouche axis extends over a distance of 1220 meters and a width of 20 meters. In its physical configuration, the axis consists of a central roadway with a width of 12 meters and sidewalks on either side with a dimension of 4 meters wide for each. The alignment of 488 Ficus benjamana trees provides shade and protects walkers along the shopping street.

The urban walls of rue Didouche are made up of buildings largely in the Haussmann style, some examples belonging to the art nouveau style, and art deco, built between 1900 and 1930. The size of the buildings reaches 20 meters high, the equivalent of five level with a last floor set back (Figure 4).

Figure 3. View of Jardin d'essai garden

Figure 4. View of Didouche Mourad Street

4.5. La Grande Poste Garden

The law on development, embellishment, and extension plans is made applicable to Algeria by the decree of January 5, 1922. Algiers was endowed with its plan in 1931; it was thus one of the first cities of the French Empire to have them. You should know, on this subject, that the French colonies, especially Morocco (with Marshal LYAUTEY), the Middle east and to a much lesser degree Algeria, have set up a Laboratory for innovative methods of urban planning in plan. The main protagonists of the French school of town planning exercised their expertise in these colonies, like Prost and Danger in Algiers, for the establishment of the town plan.

In 1898, the decision to demolish the Isly gate was taken. The gate being on the place of the current main post office, in 1900 the gardens of the Glières plateau took place of the old rampart and the gate of Isly. The garden is designed in steps opening a beautiful panorama over the port of Algiers and the Mediterranean Sea, The garden is largely planted with ficus trees, Built on a slope, this flower garden offers a very beautiful view of the bay of 'Alger. In its upper part (facing its second entrance overlooking the rue du Dr Saâdane, Ex-Berthezène), a large monument has been erected. On November 11, 1928, Le Pavois, commonly known as 'Le Monument aux Morts', a work created by Paul Landowski and Charles Bigonet, in memory of the Algerians and French who died during the First World War (14-18) was inaugurated (Figure 5).

In 1978, on the eve of the African Games, M'hamed Issiakhem was asked to revamp this stele reminiscent of the French colonial period. The famous visual artist locked the Pavois in a concrete sarcophagus. He adorns the facade of this monument with a sculpture: two raised fists, breaking the chains of the colonial yoke. The Garden covers an area of 11421 square meters, develops in steps opening on the north side on the bay of Algiers, the garden is composed of 4 platforms constituting 4

thematic gardens, the first thematic garden is located at an altitude of 25 meter, exclusively used as a space for relaxing and reading newspapers and also used as a transition space for pedestrians.

The second garden is located at an altitude of 39 meters; a grade part of the surface of this garden is taken to provide the exits of the Algiers metro. The third garden is at an altitude of 48 meters; it is a fenced garden, richly planted with several varieties of plantation and houses the floral clock and the stele of freedom.

The fourth garden is located at 56 meters high, is a space planted mainly with ficus, the garden at the top has about 120 trees for the most part Ficus.

4.6. Taleb Abderahmane Garden

During the visit of Napoleon III in 1861, Princess Eugenie deplored the lack of shade under the omnipresent sun. It is true that the city of Algiers counts in everything and for everything only the Marengo gardens, ex-garden of the condemned built by 300 military convicts under the command of Colonel MARENGO and the TEST garden entrusted to the good care of the English botanist, HARDY. In 1865, during his second visit to Algeria, the Emperor decided to open from the casbah a large strip of greenery that would descend from the Vallée ramp to the sea on the site of the artillery arsenal.

He draws up the plans himself, which will also be used to ventilate the Plateau des Glières. This gap of light will pass through the Place du Général Farre, the only artery wide enough to accommodate the five gardens planned by the architect, Mr. Valentin. The only problem, and it is a major one, is that an old Jewish cemetery dating from the Ottoman era, where the remains of the Jewish victims rest, occupies part of the square. In 1880, after a very difficult politico-religious conflict with the Jewish community, the authorities moved the cemetery to the nearby suburb of Saint-Eugène. Only the koubah of the two saints RASHBAZ and RIBACH, place of pilgrimage and devotion, located on the mount of Sidi EL KETTANI poses a problem.

The Arab workers give up breaking the tomb, which resists any enterprise of demolition. In desperation, the authorities transfer the mausoleum to its entity. Then nothing stands in the way of the company. At first, we are content to plan the land to plant rows of trees in the middle of it at the end of the 18th century, thus responding to the expectations of Empress Eugénie. In the 1930s, the gardens took on their final appearance, to the delight of children and their mothers.

Boulevard Général Farre is renamed in favor of Boulevard Guillemin. The five squares adopt this surname as well as the college, which dominates them and borders them from the top of its string of stairs. These rest and play areas are a delight for the inhabitants of the neighborhood. After Independence in 1962, like many places the garden was renamed Taleb Abderrahmane garden, in memory of the martyrdom of the revolution, the young physicist scientist Taleb Abderrahman.

The stepped garden covers an area of 12, 300 square meters, and opens towards the Mediterranean Sea, forming 5 garden terraces, starting from the level of 20 meters above sea level arriving at 42 meters in its upper part. The garden is planted with 129 trees, several species of shrub trees, and decorative plantations. Ficus Benjamina trees, date palms, Japanese banana trees, pruned junipers, massively populate the garden, this landscape composition forms a microclimate and a place of relaxation for residents on hot days (Figure 6).

The buildings on the east and west side of the garden rise to 5 levels, on the south side a residential group of 12 levels dominates the upper part of the garden. The garden during its long life has seen several maintenance and renovation works, the garden today regains its brilliance and its landscape value.

Figure 5. View of la Grande poste garden

Figure 6. View of Taleb Abderrahmane garden

5. Results discussion

The second stage of work consists on evaluating the rate of NO2 (dioxide of nitrogen) and CO (monoxide of carbon) the two pollutants directly responsible of the increase of PM2.5 and PM10 particular matter in the air, for this reason three group of site were chosen to be made under test, NO2 and CO were taken during a period of 3 weeks in April, from Friday the 04 April to 30 April 2023, for the present paper we have presented the most significant values taken from 07 April to 11 April 2023

5.1. Jardin d'essai garden assessment results

The first group consists of the Jardin d'essai garden and the square of Port Said, for the case of Jardin d'essai 4 points were taken in consideration to evaluate NO2 and CO values, point A is situated at 9 meter of altitude, the point B situated at 13 meter altitude, point C is situated at 22 meter altitude, the point D is the situated at the limit of the hill on the south direction.

In Jardin d'essai garden, we notice that the values of NO2 and CO taken the 08 and 09 April are largely superior to WHO guideline, these values are directly impacted by the wind speed and air ventilation, the plantation density 57% at point D, and building prospect act negatively on the NO2 and CO values.

On the 11 April we notice that NO2 and CO rates are quite responsible, are respectively 5.17, 6.07 at the point A, the two values got increased due to the wind speed at that day, around 20.4 km/h, the plantation density act positively in decreasing NO2 AND CO values. Building prospect acts on the rate of NO2 and CO, when buildings are very close each other, pollutants matter concentration stand longer in the area than when the prospect is flexible and large.

Values of NO2 and CO recorded in square Port Said were very close to WHO guidelines, for example NO2 values range between 3.79 to 14.48 and CO values range between 4.21 to 7.6, so the high values in NO2 and CO are directly related to air ventilation, wind speed and to the surrounding building layout (Table 1).

Table 1. Air quality assessment at Jardin d'essai garden

	07/04		W:	NW		08/04		W:	NE		09/04		W:	NW	
	NO2	CO	WS	GC	Prct	NO2	CO2	WS	GC	Prct	NO2	CO	WS	GC	Prct
A	4.38	7.2	10.8	89	0.05	8.28	7.5	11	89	0.05	8.28	11.3	11.1	89	0.05
B	4.44	7.1	10.8	89	0.05	8.37	7.2	11	89	0.05	8.37	11.2	11.1	89	0.05
C	4.51	7.2	10.8	89	0.05	8.5	7.6	11	89	0.05	8.5	11.3	11.1	89	0.05
D	4.54	6.8	10.8	57	0.28	8.54	7.1	11	57	0.28	8.54	10.9	11.1	57	0.28

	10/04		W:	NE		11/04		W:	NW	
	NO2	CO	WS	GC	Prct	NO2	CO	WS	GC	Prct
A	8.68	8.4	18.5	89	0.05	5.17	6.07	20.4	89	0.05
B	8.78	8.3	18.5	89	0.05	5.23	6.08	20.4	89	0.05
C	8.94	8.4	18.5	89	0.05	5.28	6.1	20.4	89	0.05
D	8.99	8.1	18.5	57	0.28	5.33	6.12	20.4	57	0.28

5.2. La Grande poste garden assessment results

for the case of la grande poste garden, 4 points were chosen to procced to NO2 and CO assessment, the four point are respectively located in the 4 platform constituting the garden ; the point A is located at the garden's first platform at 25 meter altitude, the point B is located at the garden's second platform at 39 meter altitude, the point C is located at the floral garden at 48 meter altitude, the point C is located a the platform at 56 meter altitude.

NO2 and CO values recorded during the 5th day assessment, show that the plantation density has a positive impact on NO2 and CO results; that means the more the are trees and plantation the less NO2 and CO is. The building prospect at the upper part of the garden is 0.36, that means there are more open urban space than built forms, such urban configuration strongly helps air ventilation, so then NO2 and CO values go down (Table 2).

Table 2. Air quality assessment at la grande poste garden

	07/04		W:	NW		08/04		W:	NE		09/04		W:	NW	
	NO2	CO	WS	GC	Prct	NO2	CO2	WS	GC	Prct	NO2	CO	WS	GC	Prct
A	3.98	5.4	10.8	72	0.4	14.92	7.9	11	72	0.4	7.58	5.8	11.1	72	0.4
B	3.98	5.41	10.8	72	0.4	14.92	7.8	11	72	0.4	7.57	5.7	11.1	72	0.4
C	3.97	5.2	10.8	85	0.4	14.93	7.6	11	85	0.4	7.55	5.6	11.1	85	0.4
D	3.96	5.1	10.8	85	0.36	14.87	7.4	11	85	0.36	7.59	5.3	11.1	85	0.36

	10/04		W:	NE		11/04		W:	NW	
	NO2	CO	WS	GC	Prct	NO2	CO	WS	GC	Prct
A	7.71	4.8	18.5	72	0.4	4.56	5.03	20.4	72	0.4
B	7.70	4.6	18.5	72	0.4	4.55	5.01	20.4	72	0.4
C	7.68	4.6	18.5	85	0.4	4.53	4.94	20.4	85	0.4
D	7.65	4.4	18.5	85	0.36	4.50	4.81	20.4	85	0.36

5.3. Hassiba Benbouali street assessment result

The case of Hassiba street, 4 points as well were selected to proceed to air quality assessment, the point A is located at the beginning of the axe at the cross section with la grande poste garden, the point B is located at 350 meter distance from the point A, at the node point of Mauritania place, the point C is located at the intersection of Hassiba street with Victor Hugo street, the point D is located at the 1 st May node.

Two main outstanding values were recorded at Hassiba street, on the 8TH of April at the point D at 1 st May node, we recorded the value of 15.49 for NO2 and 10.6 for CO, point D is a node point which is crossed by large traffic along the day, that explain the high values recorded at the point D.
Low values are recorded on the 11th of April at the point D, the 11th of April was Tuesday, a working day, values were taken at 4 pm, even though obtained results show that the rate of NO2 and CO was largely lower than the others day, this is because of the wind direction which was north west and the wind speed 20.4 km/h, that helped the ventilation of the area (table 3).

Table 3. Air quality assessment at Hassiba Street

	07/04		W:	NW		08/04		W:	NE		09/04		W:	NW	
	NO2	CO	WS	GC	Prct	NO2	CO2	WS	GC	Prct	NO2	CO	WS	GC	Prct
A	3.98	3.29	10.8	50	0.4	14.9	10.34	11	50	0.4	7.58	8.09	11.1	50	0.4
B	4.06	3.31	10.8	33	1.11	15.11	10.37	11	33	1.11	7.72	8.1	11.1	33	1.11
C	4.15	3.5	10.8	33	1.11	15.32	10.41	11	33	1.11	7.89	8.12	11.1	33	1.11
D	4.24	3.56	10.8	0	0.33	15.49	10.6	11	0	0.33	8.06	8.21	11.1	0	0.33

	10/04		W:	NE		11/04		W:	NW	
	NO2	CO	WS	GC	Prct	NO2	CO	WS	GC	Prct
A	7.72	8.01	18.5	50	0.4	4.57	6.03	20.4	50	0.4
B	7.88	8.06	18.5	33	1.11	4.62	6.05	20.4	33	1.11
C	8.1	8.09	18.5	33	1.11	4.71	6.07	20.4	33	1.11
D	8.3	8.11	18.5	0	0.33	4.83	6.09	20.4	0	0.33

Legend:
NO2: dioxide of nitrogen, unit µm/ m3
CO: monoxide of carbon, unit mg/m3
WS: wind speed, unit Km/hour
GC: green covert, percentage
Prct: building prospect

6. Recommendation and conclusion

The contribution of vegetation on air quality improvement is an undeniable fact. However, trees are able to absorb only 7% to 27% of pollutants. The results obtained from the evaluation of air quality operated on the six study areas; show that the urban forms, the layout of the building blocks, the ventilation, and the circulation of the air are also factors that act directly on the duration of concentration of pollutants in an urban space.

Trees are living element that a large part in purifying the air we breathe and affect positively the concentration of air pollutants, directly by removing pollutants or avoiding emissions and secondary pollutant formation in the atmosphere.

We have also found that urban spaces developed on sloping land are less polluted than those on flat land, the orientation of the space in question and its exposure to the sun play an important role in the elimination of pollutants, spaces having clear urban openings present a considerably better air quality. Streets of 18 to 20 meters wide with urban walls 20 meters high forms a sort of narrow canals that retain pollutants longer than larger urban spaces. It is however advisable to design streets no less than 32 meters wide with a planted solid ground, it is imperatively important to choose trees with a high CO2 absorption capacity, such as eucalyptus, ficus and bamboo. The promotion of means of soft mobility and the reduction of the use of fossil energy is an action strongly recommended in order to be able to go towards the reduction of harmful pollutants.

Landscape and greening of urban city is an approach that provide socio-economic and environmental benefits, garden and plated areas are not any more just a place for distraction but presents an urban entities fully fledged highly useful for the urban health.

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Spatial-Functional Organization of a Contemporary Apartment in Serbia

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A B S T R A C T

The expansion of residential construction has marked the last twenty years in Serbia. Contemporary housing construction is popularly called "investor construction", and it is based on the investor's influence on achieving the greatest possible capacity in relation to the area of the plot, the largest possible area for sale, as many apartments as possible per floor, the largest possible dimensions of the building on the plot, and the largest possible number of rooms within the smallest possible total square footage. The research's aim is to discover how the aforementioned effects manifest themselves in the spatial-functional organization of the units. The analysis is performed on the case studies of residential construction in the largest urban areas of Belgrade, Novi Sad, and Nis. The findings of this research show that different authors repeat the same functional organization regardless of the location where they are constructed.

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1. Introduction

The housing construction in Serbia has experienced a significant expansion in the last twenty years. Most apartments have been built in the three largest cities in Serbia: Belgrade, Novi Sad, and Niš. The construction period that took place is called "investor building", and, on a broader level, "investor urbanism". As the name says, the influence of a private investor who funds the construction is involved in the design, construction processes and urban design. This way of construction is a way of conducting an urban policy that often enables the implementation of all the material interests of investors without regard to the real needs of the population and at the expense of the public interest and the real needs of citizens. The aforementioned influences also indirectly impacted the housing organization. As a result, a certain type of organization of a contemporary apartment emerged, which reached the satisfaction of the basic requirements of the market. In practice, these requirements include as many rooms in the

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apartment and as few square meters as possible, while at the level of a residential building, as many apartments on the first floor as possible, or as many square meters for sale. The aim of this study is to observe, that is, to accept certain typological characteristics of a contemporary apartment through the analysis of spatial organization. The paper will investigate the typology of housing based on a case study in Serbia's three major cities: Belgrade, Novi Sad and Niš. Depending on the selected case studies, it will be examined if spatial similarities occur in the modern apartments envisaged in the places listed and designed by different authors. The research of the housing organization will be based on the analysis of examples of new construction in the mentioned cities. The aim of the work is to draw conclusions on the modern spatial and functional organization of the housing unit and adopt a characteristic housing scheme. The paper is structured into six chapters. In the first chapter, introductory considerations on the topic are given; in the second chapter, an analysis of social and housing conditions in Serbia is given. In the third chapter, the methodology for the analysis of urban and architectural factors in the mentioned cities is given. In the fourth chapter, an analysis of the spatial-functional organization of the residential unit was done through selected case studies; in the fifth chapter, the results are discussed based on selected case studies and, in the sixth chapter, the conclusions of the research are reviewed; and the seventh chapter presents a review of the literature.

2. Analysis of housing conditions in Serbia

"During the period of socialism in Serbia the construction of apartments was completely controlled by the state. In addition to being rational and economical, multi-family housing was seen as the ideologically desirable form of housing" (Stoiljković, 2020). "At the end of the last century, the state rejected the system of financing public subsidized housing construction and the housing sector was abruptly and completely left to market forces"(Stoiljković, 2020). New housing conditions in Serbia appeared in the first decade of the 21st century. Changes in the social and political system led to the state withdrawing from the housing sector, the development of illegal construction and, the upgrading of existing residential buildings (Petković-Grozdanović, 2017). The changes in society that occurred in 2012, created different conditions for housing construction, primarily leading to the emergence of new private investors whose main goal is the highest possible income from the sale of residential space. This impact is called investor construction, and on a broader level, it is called investor urbanism. Regarded as a contemporary social change, this impact is regarded as negative since it affects the process of direct collapse of all forms of urban and architectural development (Lojanica, 2019). According to the definition, investor urbanism is a way of conducting urban policy that often enables the implementation of all (material) interests of investors, to the detriment of the public interest and the real needs of citizens (Petrović, Rašković, 2011). Looking through the context of social conditions, the investor has become the most important factor in the process of the creation of architecture while the architect is required to realize the "ideas of the investor" that range from the functionality of the base, through form and architectural style to the choice of materials and color of the object (Jovanović, 2007). The residential normative managed by the designer under the influence of a private investor is a financial normative and refers to the net square of the building sold by the investor, with cause-and-effect links between the gross construction square and the net square that resulted from it. "The former minimum of the apartment has become the optimum and the maximum together, which has become the normative foundation of design standards. (Petrović, 2017). Although the conditions at the site are "primary in the conceptualization of the conceptual solution and undoubtedly affect the architectural design, both in terms of form and in terms of function (Krstić, 2019). In the case of investor construction, they become completely neglected, which leads to the conclusion that all influential factors are reduced to only one influential factor, and that is the requirement of the investor, which is reduced to the greatest possibility of construction of the surface (Petrović, 2021). In the last five years, private investors have built the most residential homes. According to the latest statistics, 28874 apartments were completed in the Republic of Serbia in 2021, with a total area of 2,161,492 m2. It has reached a maximum in the number of

apartments built in the last ten years, with a tendency to increase this number in 2022 and 2023 (The Federal Bureau of Statistics).

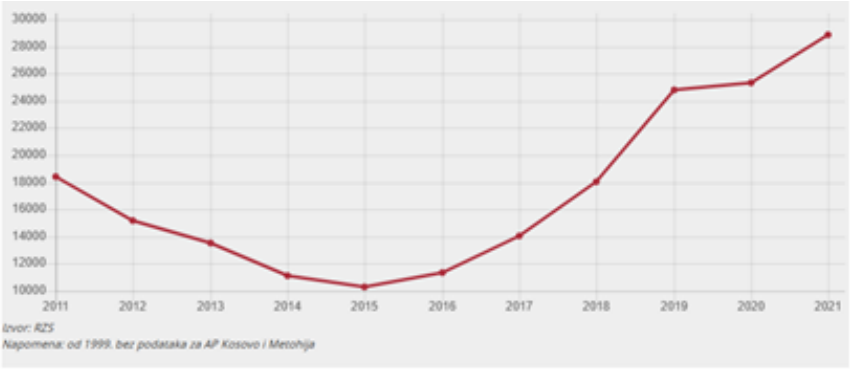


Figure 1. Number of completed apartments in the Republic of Serbia by year (Source: The Federal Bureau of Statistics, accessed 21.3.2023)

During the past twenty years, the development of residential buildings in Serbia can be traced in three directions. The first development direction refers to the creation of new residential neighborhoods in central or peripheral localities by public or private investors. These buildings were purposefully constructed, taking into account the requirements of the users and creating open spaces with the anticipated number of parking spaces, resulting in a certain level of housing quality. An example of investor construction is the residential complex "K district" (Figure 2), which belongs to the first direction of residential construction and is a large block built in the center of Belgrade. This violation blocks the view of the Kalemegdan Fortress and has sparked controversy and criticism from locals and urban planners who argue that preserving the historical and cultural significance of landmarks should be a priority in urban development.

Figure 2. Residential complex "K DISTIRKT"(2022), Belgrade (Source: https://kdistrict.rs/index.html#stanovi/ accessed 21.2.2023.)

Another form of residential construction is developed in the suburbs of cities by private investors. It is characterized by residential lamella construction and high population densities. This type of housing

does not provide shared areas such as playgrounds for children or parks for the community. Parking is limited to the space on the plot and, as a rule, is regulated spontaneously. These residential buildings, shown in Figure 3, are an example of this construction style. They are situated on Somborski Boulevard in Niš.

Figure 3. Residential area on Somborski Boulevard, Niš
(Source: By Author)

The third type of modern investor construction is an adaptation of single-family homes and/or low-story buildings that also entails improving and increasing their dimensions (Živković, 2017). Existing single-family homes are being replaced with brand-new multi-story buildings during this type of construction. There are many issues with this kind of construction. First of all, population density rises markedly, but housing quality frequently deteriorates, city center streets are destroyed, urban views are ruined, open spaces with greenery are lost, and significant parking issues are brought about. In most instances, such buildings' overall aesthetics are diminished. The situation has slowly changed in recent years as a result of the construction of individual structures that, due to their form and design features, significantly improve the aesthetic quality of contemporary residential structures.

Figure 4. Residential building, Takovska Street 14. Novi Sad
(Source: Takovska - Novogradnja Novi Sad, Sajmište - Prodaja Novogradnje Novi Sad | City Expert, accessed 26.4.2023.)

3. The spatial-functional organization of the housing unit

The new conditions created in the construction of residential buildings have had an impact on all spatial levels of the building. As seen through the design process, the investor's request became the only aspect to which the architect had to respond. According to this aspect, "the larger the area to be sold, the more apartments on the floor, the larger the size of the building on the plot, and, most importantly, the larger the number of rooms within the minimum possible total square footage" (Petrović, Rašković, 2011). The fundamental standards for designing an apartment, according to G. Jovanovic, "are reduced to the investor's subjective assessment of which apartment type and size will sell best on the market." The investor's primary concern is making a profit, and the planning measure is now a private plot (Jovanović, 2007). According to the mentioned requirements and the Rulebook on conditions and norms for the design of residential buildings and apartments ("Official Gazette of the RS", no. 58/2012, 74/2015, and 82/2015), the minimum surface areas of the structure of the apartments are defined in Table 1. As well as the minimum areas of residential premises Table 2. Although functional and minimal dimensions are necessary for human functioning, it happens frequently that these dimensions are not adhered to, which results in undersized rooms. The result of that is that the apartment cannot be functionally organized. There may be more rooms than permitted by the regulations within the apartment, depending on the square footage in question.

Table 1. Minimum area of the apartment according to the structure of the apartment (Source: Rule book on conditions and norms for design of residential buildings and apartments ("Official Gazette of RS", no. 58/2012, 74/2015 and 82/2015))

MINIMUM AREA OF THE APARTMENT ACCORDING TO THE STRUCTURE OF THE APARTMENT		
1.	**Studio apartment**	**26,00 m²**
2.	**One bedroom apartment** (living room for sleeping 2 persons)	**30,00 m²**
3.	**One bedroom apartment** (living room for sleeping 2 persons + 1 bedroom for sleeping 1 person)	**40,00 m²**
4.	**Two bedroom apartment** (living room for sleeping 2 persons + 1 bedroom for sleeping 2 persons)	**48,00 m²**
5.	**Two-bedroom apartment** (living room for sleeping 2 persons + 1 bedroom for sleeping 2 persons + 1 bedroom for sleeping 1 person)	**56,00 m²**
6.	**Three bedroom apartment** (living room for sleeping 2 persons + 2 bedroom for sleeping 2 persons)	**64,00 m²**
7.	**Three-bedroom apartment** (living room for sleeping 2 persons + 2 bedroom for sleeping 2 persons + 1 bedroom for sleeping 1 person)	**77,00 m²**
8.	**Four bedroom apartment** (living room for sleeping 2 persons + 3 bedroom for sleeping 2 persons)	**86,00 m²**
9.	**Four-bedroom apartment** (living room for sleeping 2 persons + 3 bedroom for sleeping 2 persons + 1 bedroom for sleeping 1 person)	**97,00 m²**

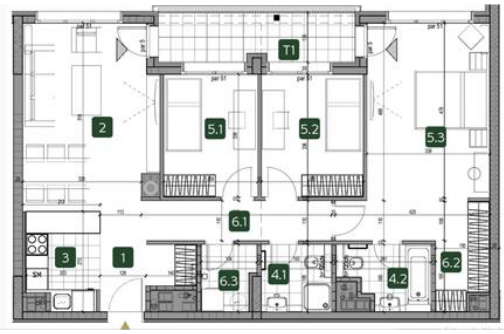
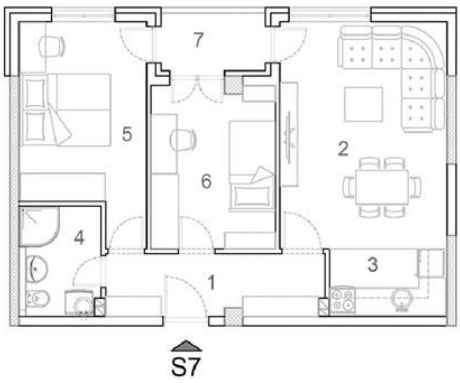
Table 2. Minimum area of rooms in the apartment
(Source: Rule book on conditions and norms for design of residential buildings and apartments ("Official Gazette of RS", no. 58/2012, 74/2015 and 82/2015))

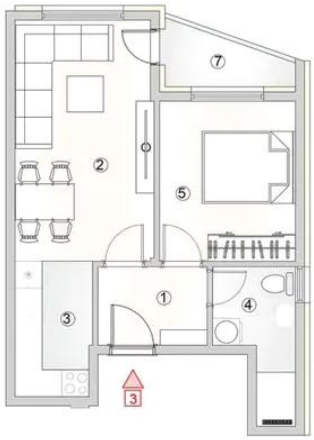
	MINIMUM AREA OF ROOMS IN THE APARTMENT	
1.	Living room	16,00 m^2
2.	Room for two persons	11,00 m^2
3.	Single room	7,00 m^2
4.	A place to eat lunch	4,00 m^2
5.	Food preparation area (kitchen)	4,00 m^2
6.	Closet storage	0,50 m^2
7.	Bathroom	3,00 m^2
8.	Toilet (special room)	1,30 m^2

4. A case study of contemporary housing unit organization

Six residential unit examples were chosen for the case study, two of which were designed in Belgrade, two in Novi Sad, and two in Niš. The case studies are representative examples of apartments with various building types and square, residential typologies and created by different authors. Selected projects are chosen from a large number of analysed examples using the classification and comparison method. Typological analysis has been performed on the basis of the adopted parameters and significant criteria for the spatial-functional organization of the residential unit. Representative examples were examined using the case study approach. A synthesis of pertinent information was found by examining the contents that were available, changes, and various housing unit design concepts.

Table 3. Case studies of spatially-functional organization of housing units
(Source of photos and floor plans: https://cityexpert.rs/a/novogradnja, accessed 18.4.2023)

	TYPOLOGY	FLOOR PLAN	INDOOR SURFACE AREA (M2)	
A	**THE DUKE'S GATES**		Entrance hall	4.03m²
			Kitchen	3.94m²
			Bathroom	3.38m²
			Bathroom	3.79m²
			Living-dining room	20.38m²
			Bedroom	8.67m²
			Bedroom	9.40m²
			Master bedroom	20.38m²
			Corridor	5.58m²
			Wardrobe	3.21m²
	Condominium		laundry room	2.58m²
			Terrace	7.21m2
	Belgrade, Voždovac		**Total area 92.52 m²**	
B	**LIMAN 4**		Entrance hall	8.72m2
			Kitchen	6.85m2
			Bathroom	5.46m2
			Living room	18.77m2
			Bedroom	12.74m2
			Bedroom	13.25m2
			Terrace	5.44m2
	Zatvoreni kompleks sa zelenim površinama i dečijim igralištima		**Total area 71.21 m2**	
	Novi Sad, Telep, Liman 4			
C	**RESIDENTIAL AND COMMERCIAL BUILDING PANTELEJ**		Entrancehall	6.66m²
			Living-dining room	18.58m²
			Kitchen	3.90m²
			Bathroom	4.38m²
			Bedroom	12.18m²
			Bedroom	9.88m²
			Terrace	2.96m²
	Residential and commercial building		**Total area 58.54 m²**	
	Niš, Pantelej			

D	**TELEP HOME**  Interpolacija Telep, Novi Sad		Entrance hall	5.92 m²
			WC	3.06m²
			Bathroom	3.82m²
			Corridor	3.35m²
			Kitchen	6.06m²
			Utility	1.62m²
			Living-dining room	17.30m²
			Bedroom	12.51m²
			Bedroom	8.19m²
			Terrace	5.46m²
			Total area 67.28 m²	
E	**RESIDENTAL BUILDING IN ČUKARICA**  Slobodnostojeći objekat Čukarica, Beograd		Entrance hall	4.07m²
			Bathroom	4.69m²
			Kitchen	5.17m²
			Living-dining room	20.53m²
			Bedroom	11.09m²
			Terrace	3.66m²
			Total area 49.20 m²	
F	**NEW BUILDING NIŠ**  Slobodnostojeći objekat Trošarina, Niš		Entrance hall	4.22m²
			Living-dining room	16.50m²
			Kitchen	5.07m²
			Bathroom	4.75m²
			Bedroom	10.70m²
			Terrace	2.90m²
			Total area 44.14 m²	

5. Discussion

The analysis of case studies is processed through Tables 3 and 4.

Table 4. Shows a comparative analysis of the areas prescribed by the Rulebook and the projected areas in the presented case studies. The problem that occurs in apartments C, D, and F is the area of the living room, which is smaller than the permitted dimensions. Another way to look at these situations is to say that combining the living room and dining room results in a reduction in surface area. Apartment F has an undersized bedroom as well as a total area that is smaller than the prescribed minimum area, which refers to the structure of a two-room apartment. Additionally, the kitchens in apartments A and C are inadequately sized.

Table 4. Comparative analysis of case studies and the areas prescribed in the Rulebook on conditions and norms for design of residential buildings and apartments regulations

MINIMUM AREA OF ROOMS IN THE APARTMENT		A	B	C	D	E	F
Living room	16,00 m2	16.38 m2	14.77 m2	14.58 m^2	13.30m^2	22.53 m^2	12.50 m^2
Room for two persons	11,00 m^2	15.58 m^2 20.38 m^2	13.25 m^2 12.74 m^2	12.18m^2	12.51 m^2	11.09 m^2	10.70 m^2
Single room	7,00 m^2	9.40	x	9.88 m^2	8.19 m^2	x	x
Dining room/ A place to eat lunch	4,00 m^2	4,00 m^2	4,00 m^2	4,00 m^2	4,00 m^2	4,00 m^2	4,00 m^2
Kitchen Food preparation area	4,00 m^2	3.94 m^2	6.85m^2	3.90m^2	6.06m^2	5.17 m^2	5.07 m^2
Entrance hall	4,00 m^2	4.03 m^2	8.72 m^2	6.66m^2	5.92 m^2	4.07 m^2	4.22 m^2
Closet storage	0,50 m^2	2.58 m^2	x	x	1.62 m^2	x	x
Bathroom	3,00 m^2	3.38 m^2 3.79 m^2	5.46m^2	4.38m^2	3.82 m^2	4.69 m^2	4.75 m^2
Toilet (special room	1,30 m^2	x	x	x	3.06 m^2	x	x
Terrace	Is not definition	7.01 m^2	5.44 m^2	2.96 m^2	5.46 m^2	3.66 m^2	2.90 m^2
Corridor	Is not definition	3.21	x	x	3.35 m^2	x	x
DOES THE APARTMENT FULFILL THE MINIMUM AREA REQUIREMENT		**YES 92.52 m^2** (86.00m2)	**YES 71.21 m^2** (64.00 m2)	**YES 58.54 m^2** (56.00m2)	**YES 67.28 m^2** (56.00m2)	**YES 49.20 m^2** (48.00 m^2)	NO 44.14 m^2 (48.00 m^2)

Based on the selected case study examples shown in (**Table 3**) and numerous other examples of modern housing organization, as well as analysis of the same, the following typological characteristics of a modern apartment have been observed:

1. The apartment organization scheme develops linearly, very often without a spatial focus;
2. The position of the entrance does not affect the linear development of the organizational scheme;
3. The living area is characterized by an open space organization plan, based on the integration of the living room, dining room and kitchen;
4. As a rule, the kitchen is positioned in the farthest part of the living space. It is often designed without direct lighting and ventilation;
5. The living room and dining room often lose their dimensionality within the open plan;
6. The use of a strict, functional area into zones for day and night ends;
7. Bedrooms are positioned along linear communication; the existence of internal communications is lost, which conditions the reduced intimacy of bedrooms;

8. The physical size of spatial elements increases linearly within the same design manner;
9. Communications often develop without increasing use value; in a large number of cases there are too long communications, resulting from inadequate organization of space;
10. Absence of auxiliary rooms and storage space even in apartments with a larger structure;
11. The most common is the one-sided orientation of the residential unit;
12. Open spaces are undersized or absent.

6. Conclusion

The last two decades in Serbia have been marked by major turbulence and changes in the social and political system. Residential construction was one of the aspects of society that was affected by the changes. The state, which had previously been the sole investor in housing construction, was replaced by private investors. These changes have resulted in investor interest becoming the most important influence, placing itself above broader social interest. The main objective is monetary gain, which entails maximizing the use of the available space without taking into account the needs of the user population. The direct investment effect changed how the staff unit was organized as well. A contemporary apartment is set up according to a specific housing pattern plan that satisfies market demands. Based on numerous examined examples and selected case studies, it is possible to develop a typical scheme for the organization of a contemporary apartment, as shown in

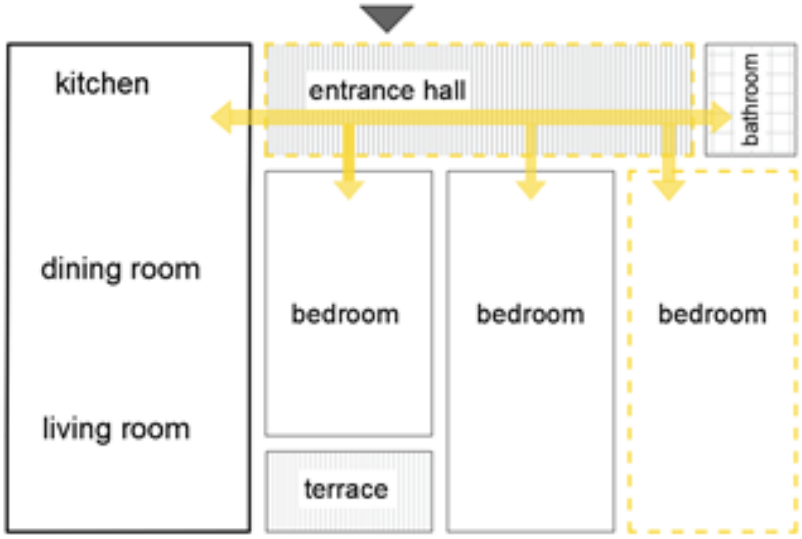


Figure 5. Scheme of the spatially-functional organization of the contemporary apartment (Source: By Author)

According to the presented scheme and previously analyzed case studies, the spatial-functional pattern of a contemporary apartment implies a linear organization without setting a spatial weight. The rooms are "lowered" along the communication, which also represents the entrance zone of the apartment. An open plan is formed where the living room, dining room, and kitchen come together. The kitchen is based on the organization of a working kitchen, often without natural lighting and ventilation. Apartments in larger structures physically increase linearly according to the same design principle. The central position of the entrance hall allows access to the bedrooms, which leads to the loss of internal communications. The apartments are mostly one-sided oriented and almost "as a rule" designed without a pantry. Open areas are very often sub-dimensioned or not designed in apartments in smaller structures. The appearance of certain spatial and functional differences in the residential organization mainly stems from the irregular shape of the plot.

Data availability statement
The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

Ethics statements
Studies involving animal subjects: No animal studies are presented in this manuscript.
Studies involving human subjects: No human studies are presented in this manuscript.
Inclusion of identifiable human data: No potentially identifiable human images or data is presented in this study.

Conflict of Interests
The author declares no conflict of interest.

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Urban Design Impact on Local Climate and its Consequences on Building Energy Demand in Morocco

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ABSTRACT

Urban design has a profound impact on the local climate, which can result in changes in temperature distribution and energy demand. The Urban Heat Island (UHI), a well-documented issue where cities typically experience higher temperatures than the cooler rural surroundings that envelop them, is closely tied to urban design and its geometrical features. This increase in temperature can lead to increased energy consumption, particularly for air conditioning, as populations strive to maintain thermal comfort. Within this framework, this paper seeks to advance our comprehension of the influence of urban design on the Urban Heat Island (UHI) effect and building energy requirements. It makes a valuable contribution to the expanding body of research in this field, offering insightful guidance on optimal urban design strategies tailored to diverse climate zones in Morocco. To achieve these goals, we explore multiple urban design scenarios incorporating variations in building heights, street aspect ratios, building layout configurations, and street orientations. We employ the Urban Weather Generator and EnergyPlus for our analysis, with the former enabling the generation of synthetic weather data that accounts for the UHI effect in urban contexts, and the latter facilitating building energy simulations. The simulation results reveal a wide-ranging hourly variation in Urban Heat Island (UHI) intensity, spanning from 11°C to -5°C across the cities under study. Among these cities, Ifrane, Marrakesh, and Fes exhibit the highest average annual UHI intensity. Incorporating UHI considerations into energy simulations has yielded notable outcomes. Low-rise buildings experience a reduction in total energy requirements, while mid-rise and high-rise buildings exhibit an increase. For instance, adopting an urban design scenario featuring 20-story buildings and a street aspect ratio of 0.33 led to a rise in total energy demands between 8% and 19%. Furthermore, the street aspect ratio (H/W) emerges as the primary driver of UHI, whereas street orientation and building layout exert the most substantial influence on building energy requirements. Inefficient building layouts result in a significant increase in building energy needs, ranging from 106% to 121%, while less energy-efficient street orientations lead to total energy needs escalating by 28% to 76%.

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1. Introduction

Urban design has a profound impact on the local climate, which can result in changes in temperature distribution and energy demand. The Urban Heat Island (UHI), a well-documented form of urban climate modification where cities encounter elevated temperatures in contrast to the cooler conditions found in the rural areas surrounding them. It is closely tied to buildings forms and streets arrangements, thermal properties of surface material and anthropogenic heat release (Arnfield, 1990; Lachir, 2022; Oke, 1981, 1982). The two later non-urban geometrical features are mostly linked to urban forms, since high density urban areas are often associated with more important modification of land surface thermal properties and heat release (Oke, 1988). (Salvati et al., 2017) demonstrated that urban form has the most significant impact, resulting in a relative increase of up to 120% in the average annual Urban Heat Island intensity within the Mediterranean region.

The UHI effect has been studied extensively in various cities worldwide, with a focus on understanding the factors that contribute to its magnitude. More recent Research emphasized the significant effect of urban heat island on thermal comfort and the building energy consumption. (Li et al., 2019), in a review of 24 case studies, reported that UHI in different urban contexts increased the cooling energy needs from 10% to 120% and decreased the heating energy needs from 3% to 45% . Yet, the urban context and its resulting UHI are often neglected in building energy simulations which leads to less accurate building energy estimation and unadapted energy efficient design options.

In Morocco, a North African nation with diverse climate and urban forms, energy-related issues are rising especially in the building sector, a crucial element within the energy system that is responsible for roughly one-third of total energy consumption. A new thermal regulation is introduced for new buildings and several studies are conducted on energy-efficient buildings (ADEREE, 2014). But in all cases, the urban context is often neglected and the climate data driving the Building Energy simulation are generally calculated from weather stations. These are generally located outside the cities and exclude the UHI effect that was shown to be intense in different Moroccan cities (Bahi et al. 2016; El Ghazouani et al. 2021; Fathi, Bounoua, et Messouli 2019). Lachir et al., (2016) conducted a temporal analysis of the monthly electrique energy consumption and corresponding mean air temperature in Marrakech and found that an increase of 1◦C causes a spike in energy needs of 4.4% at city level. This emphasizes the effect of rinsing urban temperatures on building energy consumption, particularly for air conditioning, as populations strive to maintain thermal comfort. However, our current knowledge of the urban heat island impacts on building energy consumption in morocco is very limited. Notable attempts to address this issue focused on investigating the effect of the streets aspect ratio on building energy consumption in a single climate zone and similar urban context (Jihad & Tahiri, 2016; M'Saouri El Bat et al., 2021).

To better understand the impact of urban design on the UHI effect and building energy demand in Morocco, this study simulates the urban microclimate induced by different urban forms and estimates its impact on the energy consumption of a typical residential building. It utilizes a modeling-based approach to forecast Urban Heat Island effects and energy requirements across various urban design scenarios. These are created by combining different values of the urban geometrical parameters. The results will provide valuable insights for urban planners and architects into the most effective urban design strategies for different climate zones in Morocco to reduce UHI effect and energy consumption. This paper makes a significant contribution to the expanding body of literature concerning this subject. Its findings are truly groundbreaking within the Moroccan context, as there have been limited studies addressing the impacts of Urban Heat Islands (UHI) on building energy to date.

2. Material and method

2.1. UHI and energy simulation tools

The urban heat island impact on building energy needs can be defined as the difference in the building energy needs simulated using two types of weather datasets. First, a meteorological dataset that accounts for the UHI effect. This is measured within the urban environment or simulated using urban climate models. Second, a meteorological dataset derived from the weather station at a rural location outside the city (UHI-free weather data). Lauzet et al., (2019) presented an overview of the different methods currently used to take into account the UHI in building energy simulations.

This study employs the Urban Weather Generator (UWG) (Bueno et al. 2013) to generate synthetic meteorological data for different urban settings and climates. This model use neighbourhood scale surface energy balance to transform a typical meteorological year weather files (TMY) into an urban weather file in the same format. The resulting weather file can be used for a more accurate energy simulation for buildings within the urban context (Kamal et al., 2021; Nakano et al., 2015). The model was evaluated against field measurements from different urban sites and showed high accuracy in urban temperature prediction (Salvati et al., 2016).

The UWG predict urban canopy air temperature and humidity as follows: 1) the observed meteorological variables of the weather station are transformed into meteorological conditions at a reference height above the weather station using models of land surface energy balance and heat diffusion. 2) The results are fed to the urban boundary layer model that estimates air temperatures beyond the urban canopy layer. 3) The conditions inside the urban canyon are calculated using the Town Energy Balance (TEB) (Masson, 2000). This model was improved to integrate a building energy model for a better estimation of the heat and mass transfer processes between buildings and the urban canyon.

The building energy simulations are performed using EnergyPlus (Crawley et al., 2001). It is a physics-based model that evaluates the thermal dynamics of buildings based on thermal transfer principles. The simulation software takes into account factors such as building orientation, shading context, envelope properties, HVAC systems, internal loads, usage schedule and meteorological data.

2.2. The study region

The urban heat island and the building energy simulations are performed in different urban contexts to account for the diversity of the climate and the urban forms in Morocco. Figure 1 presents examples of typical urban fabrics in Morocco. The historical parts of cities have a compact urban fabric with low-rise houses and narrow streets while in the modern parts, we find a more open urban fabric with a variable range of building heights and street aspect ratios. Residential areas include detached low rise houses, compact low-rise economic houses and mid-rise buildings (with 6 floors in general). City centres usually have a mixed function and include mid-rise and high-rise buildings.

This study is performed for the six climate zones in Morocco. These are defined by the Moroccan thermal construction regulation according to climate data recorded across the country and the resulting energy needs to achieve thermal comfort in buildings (ADEREE, 2014). The zones from 1 to 6 are represented respectively by the cities of Agadir, Tangier, Fes, Ifrane, Marrakesh, and Errachidia. For each city, typical meteorological data derived from hourly weather data from 2007 to 2021 are used for the energy simulation purposes (ISO, 2005). The calculated daily composites of air temperature are shown in figure 2.

2.3. Urban design scenarios

The urban heat island simulations are performed for a simplified urban fabric of 100 residential buildings with 100m² footprint areas. The buildings have 40% glazing ratio and a well-insulated envelope. The

construction of the building elements and their thermal characteristics are summarized in table 1. Air flows, internal loads and operation schedules are defined according to The EnergyPlus mid-rise apartment reference building. All the buildings are supposed to be air conditioned with heating and cooling temperature set points of 20 °C and 26 °C. All the HVAC waste heat is released in the urban canyons. The streets are supposed to be covered with asphalt with no vegetation and the traffic heat release is estimated according to the urban density. The urban morphology and its geometrical characteristics are the varying parameters of the simulations. These are as follows:

Figure 1. Examples of the urban fabrics in Morocco

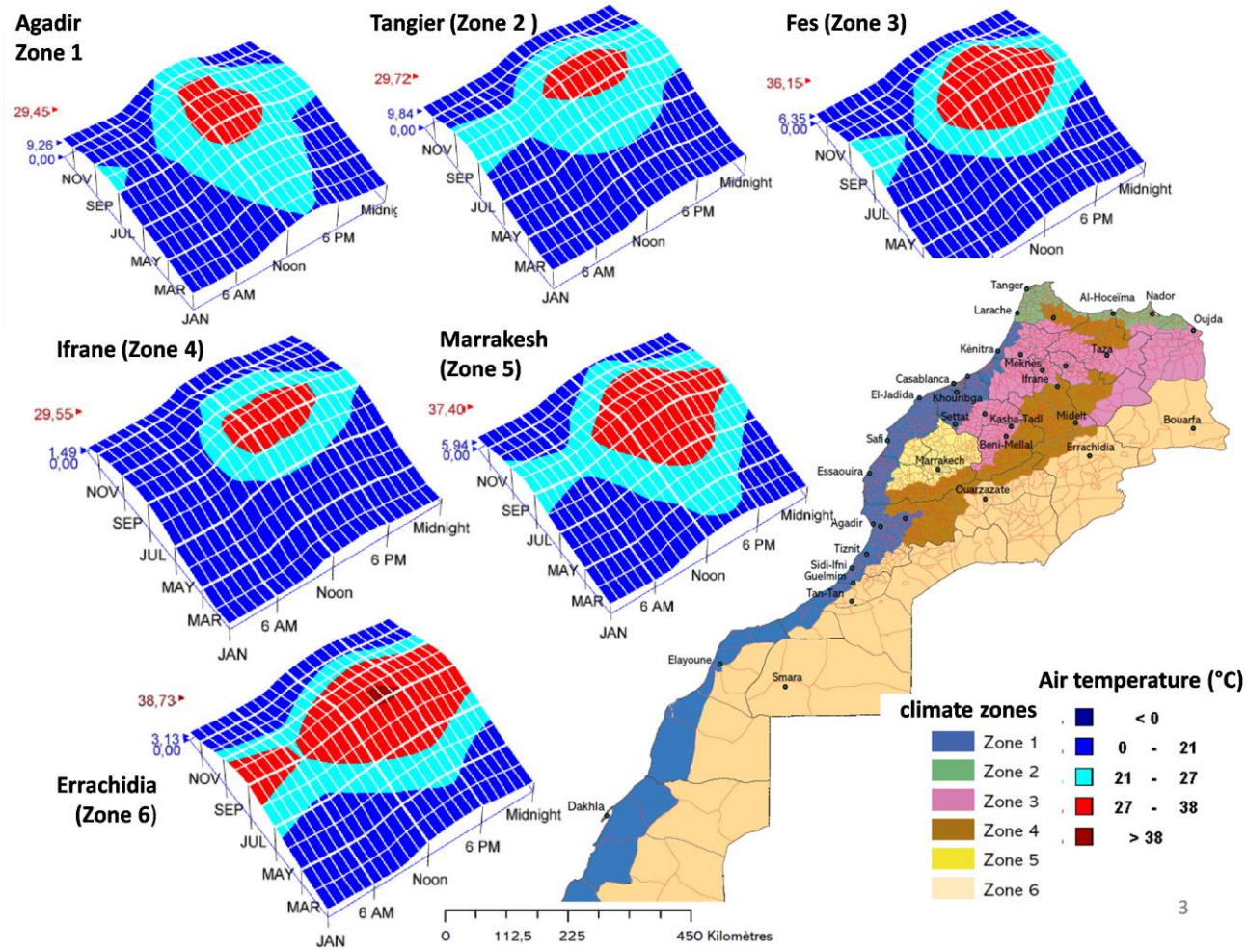

Figure 2. Daily composites of air temperature in the representative cities of Morocco climate zones

- Buildings height: this is indicated by the number of the buildings stories (3.2m height for each story). Considered building heights are between H=1 story and H=20 stories;
- Street aspect ratio (building height-to-street-width): four cases of H/W are considered; 1/3, 1/2, 1, 2 and 4;
- Building layout: four cases for buildings layout are considered. This will help evaluate different ranges of urban fabric compactness and façade areas. The cases are presented in figure 3;
- Street orientation: Four cases are considered: East-West (EW), Northeast-Southwest (NESW), North –South (NS), Northwest- Southeast (NWSE).

Table 1. The building envelope thermal characteristics

Envelope elements	Principal construction	Thermal characteristics
Exterior wall	Hollow concrete bricks of 20 cm with thermal Insulation	U=0.49 W/(m²°C) Albedo=0.5
Exposed roof	Concrete joist floor of 25 cm with thermal insulation	U=0.53 W/(m²°C) Albedo =0.5
Windows	Double Glazing (clear glass) 6 mm airspace	U=3.61 W/(m²°C) Solar heat gain g=0.7

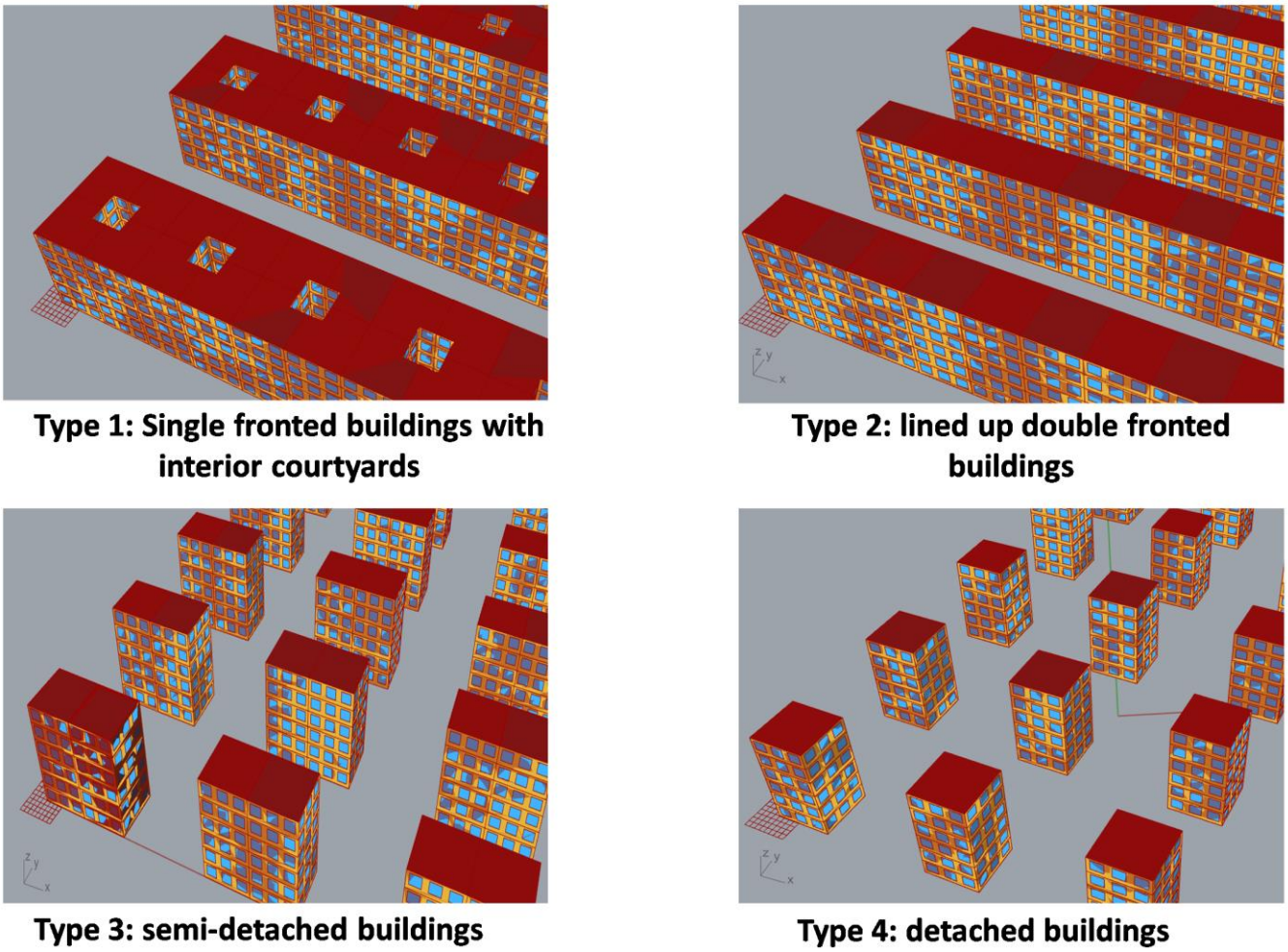

Figure 3. Buildings layout types

Multiple urban design scenarios are developed using the different values of the urban geometrical parameters (table 2). The urban 3D model for all scenarios are created and fed to the UWG and EnergyPlus using Ladybug components through the grasshopper plug-in tool for Rhinoceros (Ladybug Tools, L. L. C., 2021). This provides a parametric simulation module to automatically generate the urban 3D model, to extract the required inputs and to run the simulations.

Table 2. Urban design scenarios

Scenarios type (number of scenarios)	Base Case: (1)	type1 (20)	type 2 (20)	Type 3 (4)	Type 4 (4)
Buildings height (H) Indicated by stories	6	2, 6, 10, 20	From 1 to 20	6	6
Streets aspect ratio (H/W)	1	1/3, 1/2, 1, 2 and 4	1	1	1
Buildings layout	Type 2	Type 2	Type 2	Type 1, 2, 3 and 4	Type 2
Streets orientation	EW	EW	EW	EW	NS, NESW, EW and NWSE

3. Results

The base case urban design scenario represents the most common urban design options in Morocco. This scenario was first simulated in the UWG to compare the UHI effect in the different climate zones in Morocco. The UHI intensity is calculated as the difference in hourly temperature between the weather data generated by the UWG and that includes the UHI effect and the UHI free meteorological data measured at the rural weather station. The results for the 6 climate zones are presented in figure 4.These show that for all regions the maximum UHI intensity occurs during night time and a low negative UHI intensity occurs during midday. This presents an Urban Cool Island (UCI) and can be explained by the important heat storage capacity of buildings and the shadowing effects of surrounding buildings which reduce solar gains during the daytime (Yang et al., 2017). Meanwhile, the night-time UHI intensity is explained by the heat released by buildings and the decreased sky view factor and wind speed around buildings which limits the radiative and convective cooling of the urban area (Svensson, 2004).

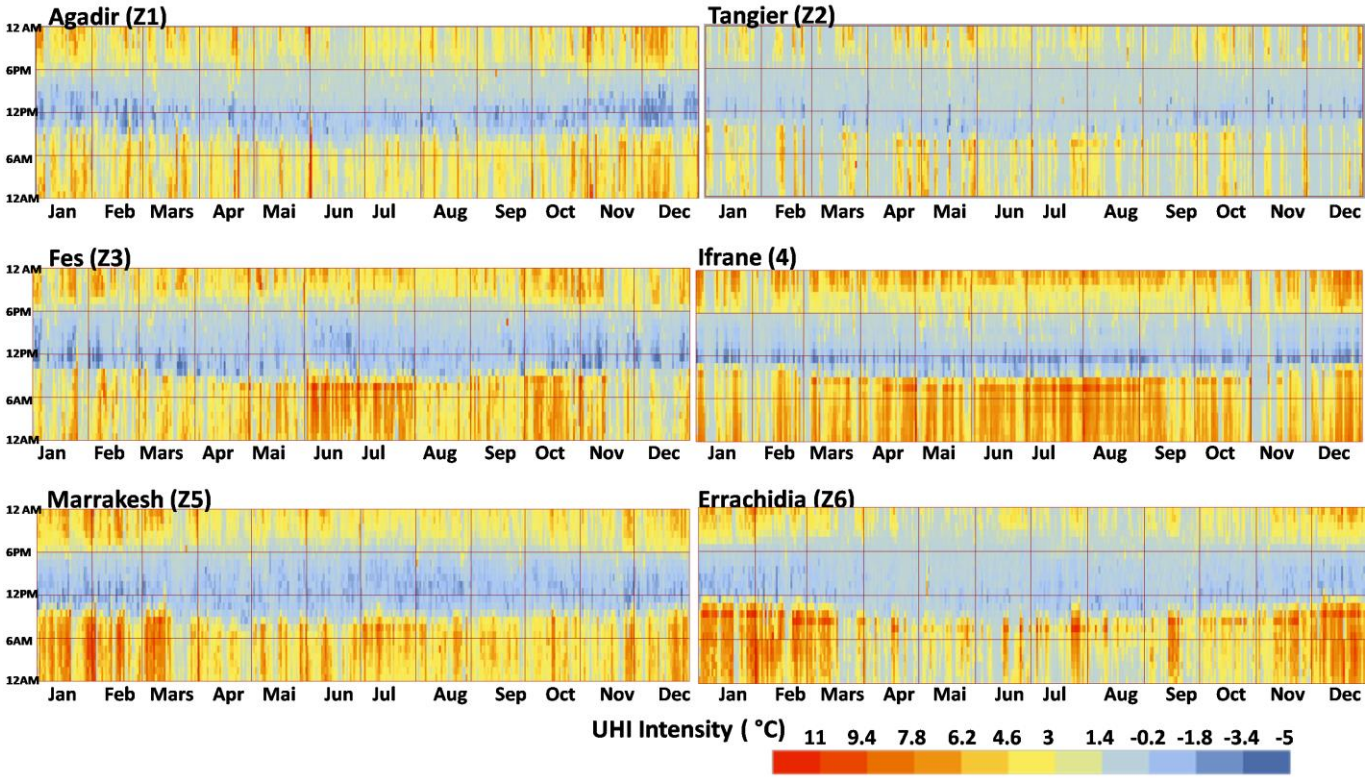

Figure 4. Hourly UHI intensity simulated for the base case urban design scenario in the cities representing the 6 climate zones in Morocco

Low values of UHI intensity are simulated in Agadir and Tangiers representing the first and second climate zones. These cities are located at the coast where sea breeze enhance wind speed and the transfer of cool air in the city. Highest values of UHI intensity are simulated in inland cities. Ifrane, a city with very cold winter and warm summer presented more important UHI intensity during warm months. While In Marrakesh and Errachidia, where the winter is relatively cold and the summer present very high air temperature that often exceed 40°C, simulated UHI intensity are more pronounced during the winter.

For a better understanding of UHI and how it is affected by urban geometry, further analysis of the simulations outputs are performed. For each simulation, the AverageUHI is calculated considering only positive values of hourly UHI intensity. This evaluates the Night-time UHI. The negative values of hourly UHI intensity are averaged to get the AverageUCI that assesses the daytime urban cool island. The

simulations of urban design scenarios type 1 allows to assess the impact of different building heights and street aspect ratios on UHI effect. The results are reported in figure 5 and show a large variation of AverageUHI between 1.9°C and 3.8°C over the 6 climate zones against a less important variation of AverageUCI between -1.3°C and -0.7°C.

Results indicate that street aspect ratios (H/W) have a larger impact on UHI compared to building heights. It is shown that AverageUHI increases with higher values of street aspect ratio. This because the wide and more open urban canyon presents a high sky view factor and allows a rapid radiative cooling during night time. While in deep canyons, the heat is trapped in the urban canopy and also convective cooling is less efficient because of the reduced wind speed in the more compact area. These patterns are more pronounced when building height increases. For a high-rise building of 20 stories, a change in H/W from 1/3 to 4 induced an increase in AvrageUHI of 0.74°C in Marrakesh, 0.55°C in Ifrane and Fes, 0.48 in Agadir and 0.26°C in Tangier and Errachidia.

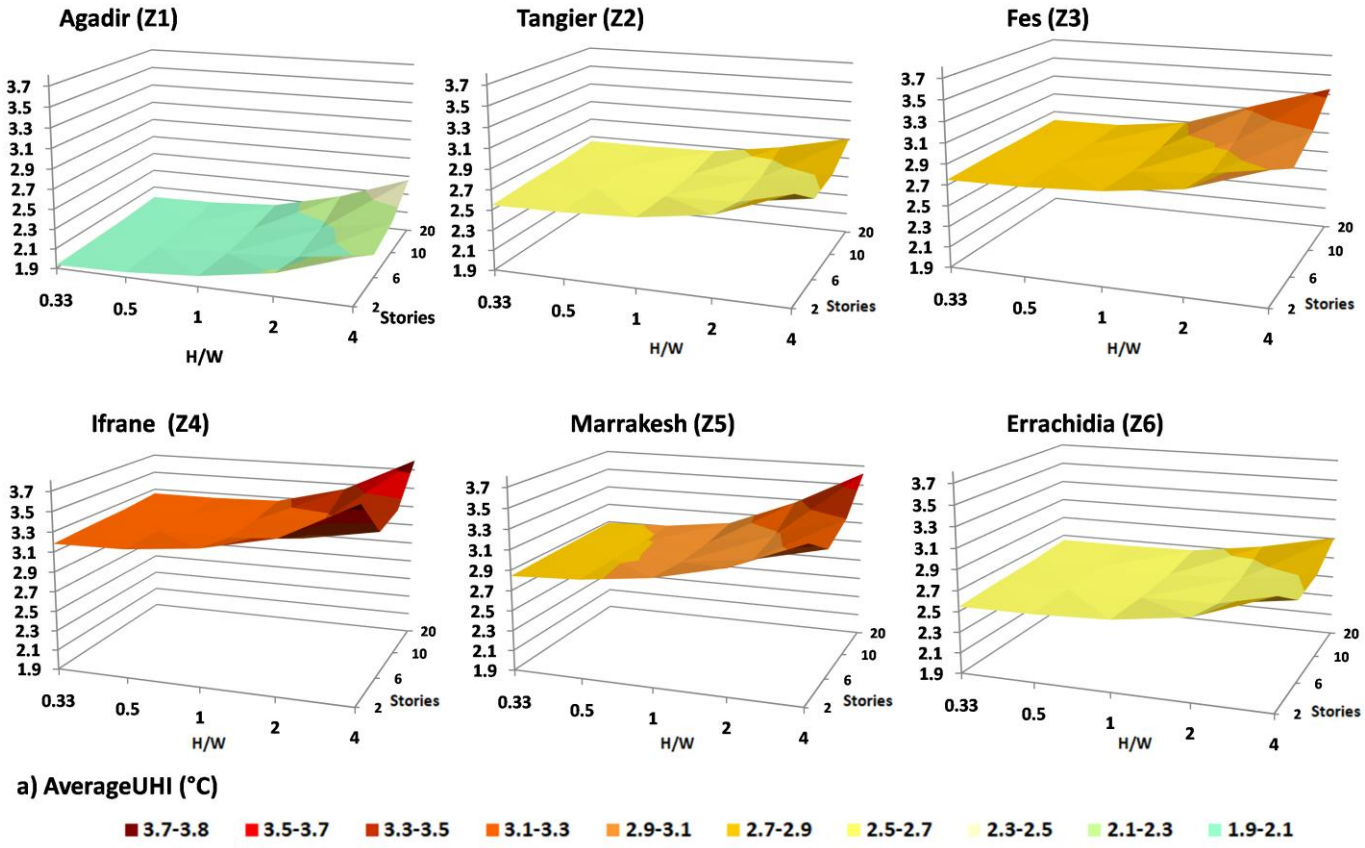

Figure 5.a. Variation of average UHI with buildings height and street aspect ratios for the 6 climate zones in Morocco

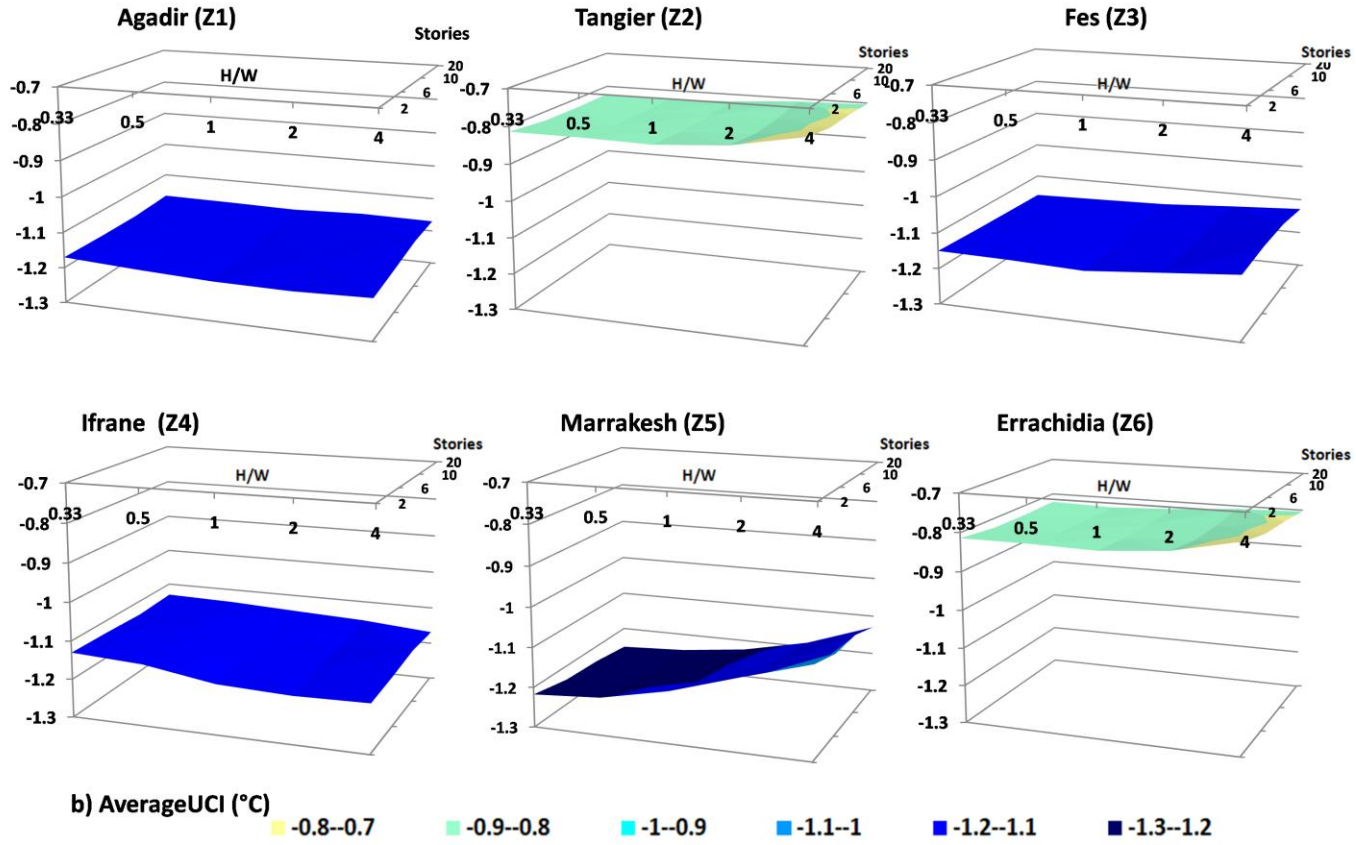

Figure 5.b. Variation of average UCI with buildings height and street aspect ratios for the 6 climate zones in Morocco

The analysis of building energy consumption is more relevant to understand the effect of urban forms on UHI consequences and the thermal behaviour of buildings. This accounts for the cumulative effect of hourly UHI Intensity. In addition, both the negative and the positive effects of UHI are considered. For this, EnergyPuls is employed to simulate the total annual heating and cooling needs for a specific building in the middle of the studied area. The simulations are performed in the 6 climate zones for all the urban design scenarios using 2 different weather data. First, the UHI free meteorological data measured at the weather station is used to calculate the UHI free cooling and heating needs then the weather data generated by the UWG is used to calculate the cooling and heating needs that account for the UHI effect. The analysis focuses on the effect of urban design options on both building energy efficiency and the changes in building energy estimation when UHI effect is included in the weather data.

The energy results for the urban design scenarios Type 2 are given in figure 6. These shows the variation of energy needs in the 6 climate zones when varying building heights from 1 to 20 stories with H/W=1. As expected the consideration of UHI in building energy estimation decreases the heating needs and increases the cooling needs. In all climate zones, the cooling loads of low-rise buildings are generally less important than the heating load because of the low solar access. This trend quickly reverses when the story number is higher than 2, except in Ifrane, the coldest climate zone, where the cooling load prevails for low-rise and mid-rise buildings. The UHI effect on cooling need increases with building heights while the effect on heating needs decreases.

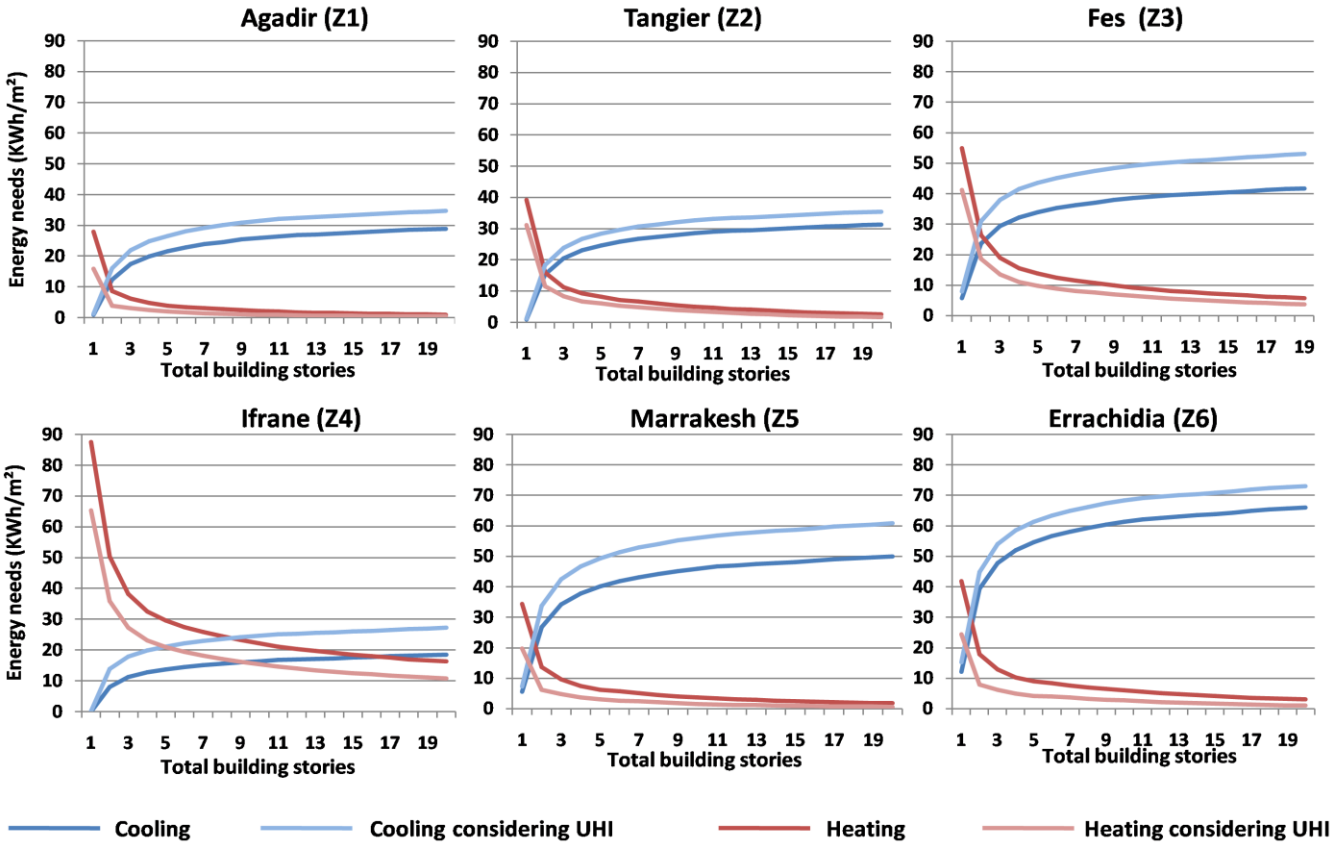

Figure 6. Impact of building heights and UHI on building energy needs for the urban design scenarios type 2 in the 6 climate zones

Figure 7 provides more insight on the effect of building heights and H/W variation on building energy needs. It summarizes the energy results of urban design scenarios type 1. It shows for all cities except Ifrane that low-rise buildings can be more energy efficient with adequate values of H/W. high values of H/W increase the energy needs for a low-rise building as the heating needs increase. H/W=1 is found to be the best design option in Agadir, Marrakech and Errachidia. While H/W=0.5 showed a slightly better energy efficiency in Tangier and Fes. In terms of UHI effect, it is found for low-rise buildings with different H/W values that the consideration of UHI reduced the building energy needs. This reduction is maximal for high H/W and is up to 12.3% in Agadir, 6% in Tangier, 3.8% in Fes, 17% in Ifrane, 4.6% in Marrakech, and 12.5% in Errachidia.

In Ifrane, High-rise buildings with a low aspect ratio are the best design options in therm of energy efficiency. A 20-story building with H/W=1/2 reduced the energy needs by 40% compared to the case of a 2-story building with H/W=4. Meanwhile, in other cities high-rise buildings with a low aspect ratio increase solar exposition and buildings overheat. This adds to the UHI effect that increases the prevailing cooling energy needs and leads to higher energy needs compared to low-rise buildings. The results show that urban design scenario with 20-story buildings and street aspect ratio of 0.33 increases the energy needs compared to the case of a 2-story buildings with street aspect ratio of 1 by: 90% in Agadir, 30% in Tangier, 18% in Fes, 61% in Marrakech and 48% in Errachidia. However, in Agadir, high H/W can enhance significantly the energy efficiency of mid-rise and high-rise buildings.

The negative impact of UHI on total energy need is more important in the case of high-rise buildings. The consideration of UHI in the energy simulations for the urban design scenario with 20-story buildings and street aspect ratio of 0.33 increased the total energy needs by: 13% in Agadir, 8% in Tangier, 19% in Fes, 14% in Ifrane, 16% in Marrakech and 7% in Errachidia.

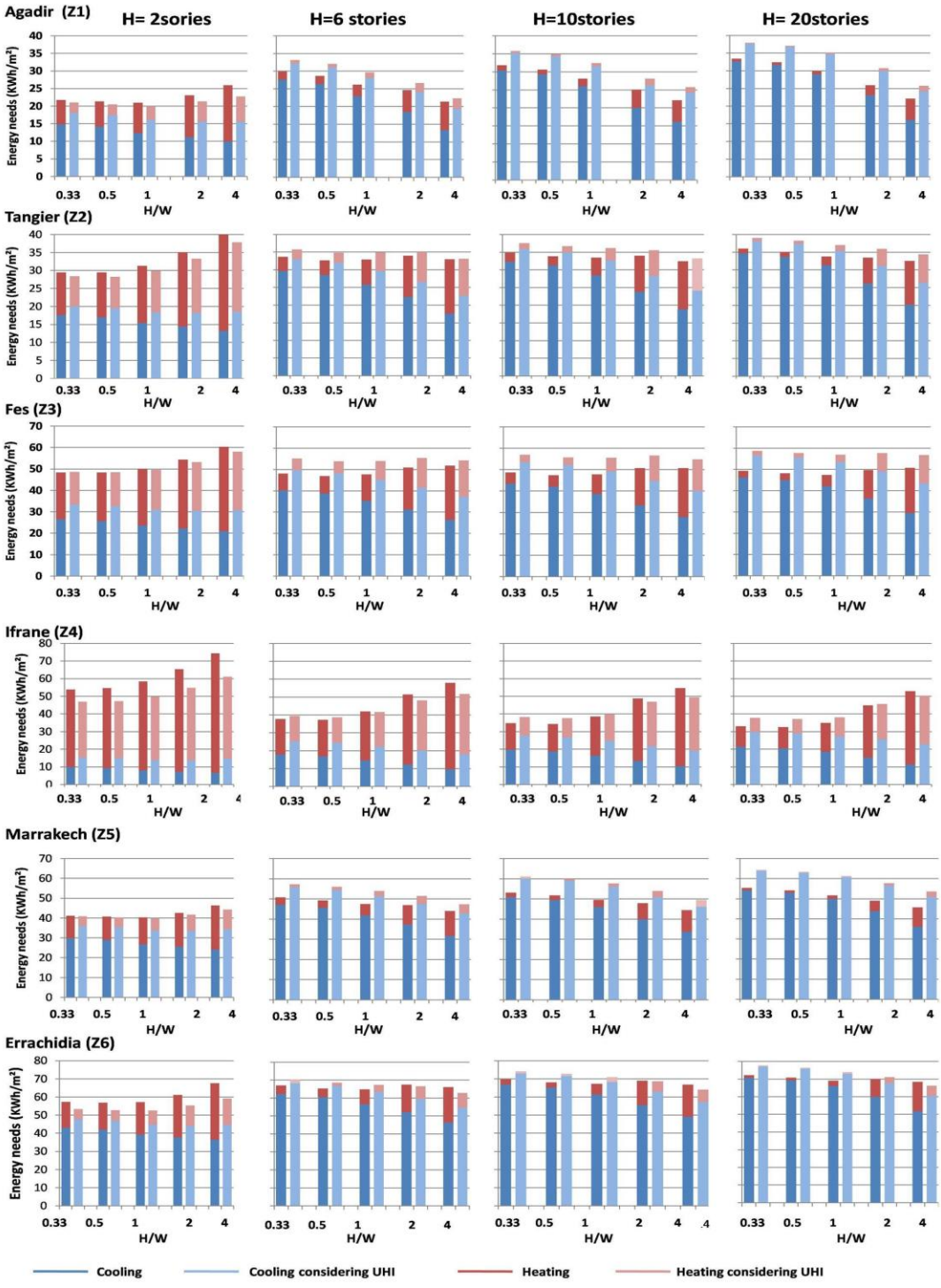

Figure 7. Impact of building heights and street aspect ratios on building energy needs

The variation of street orientation and building layout produced a small change in UHI intensity ranging between 0.1°C and 0.2°C. However the impact on building energy needs is more significant. Table 4 shows the energy simulations results under urban design scenarios type 3. In these scenarios we consider a constant building height of 6 stories and H/V =1 and we change the building layout as explained in figure 2. The results show that the layout type 1 and type 2, representing the single-fronted buildings with interior courtyards and lined up double-fronted buildings are the most energy efficient with a slight difference. The first been the best in all climate zones when the UHI effect is included in the energy simulation. The less energy efficient option is layout type 4 representing the detached buildings. This increased very significantly the cooling energy needs and slightly the heating energy needs and the UHI impact. It results in an increase in total energy needs including the UHI effects of 121% in Agadir, 108% in Tanger, Fes and Ifrane, 106% in Marrakech and 111% in Errachidia.

Table 4. Total building energy needs for urban design scenarios type 3 in the 6 climate Zones

Building layout	Type 1		Type 2		Type 3		Type 4	
Agadir (Z1)	24*	(+1.4)**	26.2	(+3.5)	50.3	(+3.6)	53.1	(+3.1)
Tangier (Z2)	32.5	(-1.1)	33.0	(+2.0)	58.2	(+2.2)	63.3	(+2.0)
Fes (Z3)	47.9	(+1.5)	47.7	(+6.3)	88.4	(+8.1)	94.3	(+8.5)
Ifrane (Z4)	44.7	(-5.8)	41.9	(-0.4)	78.5	(-1.0)	80.9	(+0.0)
Marrakech (Z5)	46.2	(+2.4)	47.5	(+6.5)	88.2	(+8.5)	93.0	(+7.6)
Errachidia (Z6)	64.4	(-3.2)	65.0	(+2.4)	119.7	(+2.6)	127.6	(+1.9)

***Building energy needs in KWh/m² estimated without considering the UHI effect**
****The impact of UHI consideration on energy needs in KWh/m²**

The UHI and energy simulation of urban design scenarios type 4 help to evaluate the impacts of street orientation. The energy simulation results are summarized in table 5 and show that the north-south orientation leads to the best building energy efficiency for all cities except or Ifrane were the street orientation East-West is more efficient for the city cold climate. The North-South oriented streets provide enough shadow, cooler surfaces and less energy demand for cooling. The east-west orientation allows a maximum solar gain through the south façade that is difficult to keep in shade. This is helpful in the case of cold climate cities. Otherwise, the energy needs increases. Also the UHI effect and its impact on the energy need is more important. The most unfavorable street orientation is the northwest-southeast for Ifrane and northeast-southwest for the other cities. Compared to the best options, these orientations increase the total energy needs by 76% in Agadir, 41% in Tangier, 28% in Fes, 29% in Ifrane, 47% in Marrakech and 38% in Errachidia.

Table 5. Total building energy needs for urban design scenarios type 4 in the 6 climate Zones

Streets orientation	East West		Northeast Southwest		North south		Northwest southeast	
Agadir (Z1)	26.2*	(+3.5)**	34.0	(+2.4)	19.8	(+0.8)	24.2	(+0.1)
Tangier (Z2)	33.0	(+2.0)	41.3	(+1.4)	30.5	(-0.3)	34.7	(-0.6)
Fes (Z3)	47.7	(+6.3)	59.2	(+5.6)	48.3	(+2.2)	54.0	(+2.0)
Ifrane (Z4)	41.9	(-0.4)	51.9	(+0.7)	54.0	(-5.4)	57.9	(-4.2)
Marrakech (Z5)	47.5	(+6.5)	59.5	(+5.7)	41.6	(+2.6)	47.6	(+1.9)
Errachidia (Z6)	65.0	(+2.4)	80.9	(+0.5)	61.8	(-2.9)	69.8	(-3.9)

***Building energy needs in KWh/m² estimated without considering the UHI effect**
****The impact of UHI consideration on energy needs in KWh/m²**

4. Discussion

The results of the study showed that urban design exerts a substantial influence on the UHI effect and building energy needs in Morocco. In all climate zones, the results indicated that urban forms has a significant impact on the magnitude of the UHI effect. A first comparison of the UHI effect in the different climate zones in Morocco showed that the UHI is particularly altered by local climates. Its intensity decreases significantly under the convective cooling effect of strong cold wind. For a common urban design scenario, hourly UHI intensity varied between 11°C and -5°C in the studied cities. The highest average annual UHI intensity is simulated in Ifrane, Marrakesh and Fes.

The simulation results showed that the street aspect ratios H/W has the most important influence on UHI intensity compared to the other studied geometrical parameters of the urban design. The compact urban area with tall buildings and narrow streets present more intense UHI during nighttime. However, during the daytime this urban design option might be more advantageous. Although a significant correlation between H/V and the temperature decrease in urban canyons during the daytime was not identified, the important shading in deep urban canyons decreases the mean radiant temperature. This might enhance the thermal comfort during the daytime as suggested by (Ali-Toudert & Mayer, 2006; Mahgoub, 2013).

In terms of building energy needs, it was observed that the consideration of UHI in energy simulation resulted in a decrease in energy needs estimation for low-rise buildings and an increase for mid-rise and high-rise buildings in all cities, except in Ifrane where they consistently decreased. When urban context and its resulting UHI effect were taken into account, it was determined that in cold climates, urban design featuring tall buildings with low street aspect ratios is more energy efficient. Conversely, in hot climates, low-rise buildings with H/W=1 were found to be more adapted.

Streets orientation and building layout have a small impact on UHI intensity but a very significant effect on building energy needs. The building layout is the most important parameter. The results show that detached buildings are the worst option that can increase the energy needs of more than 100% compared to single-fronted buildings with interior courtyards in all climate zones.

Overall, the results of the study provide valuable insights into the most effective urban design strategies for reducing the UHI effect and building energy demand in different climate zones in Morocco. However, a further development of this study is still needed for a more comprehensive understanding of the best design options. This should add other performance criteria such as the thermal comfort and include more urban design scenarios to test the impact of different construction materials, urban land use and more importantly the integration of vegetation within the urban fabric. This is shown to be a very effective solution for UHI mitigation (Gunawardena et al., 2017; Lachir et al., 2016). The biophysical processes of vegetation within the urban canyon are not fully detailed in the UWG. Combining the UWG with a comprehensive land surface biophysical model can enhance our understanding of how integrating green spaces and green roofs into urban design impacts the Urban Heat Island (UHI) effect and building energy demand.

5. Conclusion

The study's results add to the expanding corpus of literature. On the relationship between urban design and the local climate, and its consequences on building energy demand. The results indicate that urban design has an important impact on the UHI effect and building energy needs in Morocco and recommend always including the urban context and its consequent UHI effect in building energy simulation for a more accurate estimation of buildings' energy needs.

The study examined the impact of various factors, including building heights, street aspect ratios, building layout, and street orientation on Urban Heat Island (UHI) intensity. It revealed that the height-to-width ratio (H/W) has the most significant influence on UHI intensity and that an optimal combination of H/W and building height can enhance building energy efficiency. The study suggests that, in Agadir,

Marrakech, and Errachidia, low-rise buildings with an H/W ratio of 1 are preferable, while in Tangier and Fes, an H/W ratio of 0.5 is recommended. However, in cold climates such as Ifrane, high-rise buildings with a low aspect ratio are found to be more energy-efficient.

Regarding building layout and street orientation, these factors were found to have a minor impact on UHI but a notable effect on building energy requirements. Therefore, the study recommends the adoption of single-fronted buildings with interior courtyards and favours an East-West street orientation in Ifrane, while in other cities, a north-south orientation is preferred.

As a final point, the findings of this study shed light on the crucial factors influencing Urban Heat Island (UHI) intensity and building energy efficiency in various climate zones of Morocco. This provides valuable information for urban planners and architects in Morocco to develop more sustainable and energy-efficient urban design strategies in different climate zones.

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Data availability statement
The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

Ethics statements
Studies involving animal subjects: No animal studies are presented in this manuscript.
Studies involving human subjects: No human studies are presented in this manuscript.
Inclusion of identifiable human data: No potentially identifiable human images or data is presented in this study.

Conflict of Interests
The author declares no conflict of interest.

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Standalone University Campuses' Outdoor Spaces: Case of the German International University, Egypt

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ABSTRACT

This paper investigates the nature of university campuses' outdoor spaces and some of the main important aspects and factors that contribute in achieving a successful campus. Through referring to several related researches, observing and mapping, an analysis and study of the German International University has been conducted. These have highlighted different dynamics and complexities. As it is located in a still not yet urbanized area, the German International University is considered one of the leading projects in its surrounding. A new concept was introduced, namely the "standalone" campus, accommodating all needed services, which are missing in its surrounding. This new concept is considered a solution for universities with similar circumstances and nature.

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1. Introduction

A campus outdoor space is a vital and important element of a university that has to be carefully and thoughtfully planned and designed after comprehensively studying the different and diverse aspects and dimensions of such an entity. In the literature on campus design, much emphasis is given to the nature of outdoor spaces as independent social realms. In this paper, the aim is to highlight the role of these spaces as thresholds that define the relation between campus buildings with each other and with the adjacent context.

Special attention has been paid to students' life in these outdoor spaces and the patterns of use, which are considered to facilitate social interactions and benefit the students' welfare and sense of belonging (El-Darwish, 2022; Öztürk, et al, 2016). Understanding these dynamics is vital as students spend most of their time on campus, especially after the corona pandemic and the continuously expanding social media. The global economic slowdown that resulted from the pandemic, followed by the Russian-Ukraine political conflict has also contributed to the changing social patterns. The corona pandemic

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has created isolated personalities, as many people have spent months or even years in their homes, either working remotely or even studying online, with the minimum real one-to-one interaction. It also resulted in the excessive use of social media, where people was more attached to their phones and other electronic devices, as these are the only way to communicate, socialize, and entertain. As for the economic condition, the struggle of many businesses and industries, which led to enormous shutdowns and the loss of jobs, has led to significant changes in some people's lifestyles, routines, and spending patterns.

The study focuses on the case of The German International University (GIU), which was established during the time of the corona pandemic and the current economic slowdown. It investigates the design approaches adopted to accommodate the changing social and economic dynamics. University campuses are usually located inside the city or in its outskirts, which are considered built environments that are reachable, accessible and near all the needed services and facilities. The German International University (GIU) is considered a unique example that should be studied and analysed, as it is located in a not yet urbanized part of a new city that is far away from any services and facilities. For this reason, the GIU's campus is considered as "standalone", as it houses all the services and facilities that might be needed daily by the campus users, since its surrounding is still empty. The campus is self-sufficient and self-contained, designed to accommodate all the needed entertainment and activity options, indoors and outdoors, with consideration of the different conditions and aspects.

This study assesses the performance of the campus outdoor spaces by unfolding the proposed design layer, how users, and the lived experiences that were created have perceived it. It is essential and vital to expedite a better understanding of the constraints during the design phase of the campus and the complexity of the discussion making process to rejuvenate it and tackle challenges by creating a complexion. This complexion aims to enable more interaction between all of the campus users in different ways by offering a variety of activities and possibilities to socialize and enjoy, individually or in groups (Gehl, 1987), as the outdoor spaces are considered as a booster for social interaction and the sense of belonging (El-Darwish, 2022).

2. Theoretical Context

In the context of this study, emphasis is given to literature on outdoor spaces on university campuses. An analytical framework has been developed to analyze the spatial quality of these spaces with the German International University as a case study. Chambers, M. et al. (Welsch, E., et al, 2004) discuss the importance of the "sense of place" and the factors that shape university campuses (Welsch, E., et al, 2004)· Users develop this "sense of place" in diverse modes, and their use patterns feature significant variations (Hillier 2014; Dicle & Ter, 2008; Welsch, et al, 2004; Abu-Ghazzeh, 1999; Hillier, 1996; Marcus, 1990). And since students represent the majority of campus users, emphasis is given to their spatial behavior and perception of space (Tiyarattanachai & Hollmann, 2016; Dönmez, et al, 2015; Aydin & Ter, 2009; Dicle & Ter, 2008; Abu-Ghazzeh, 1999; Hillier, 1996). A very important aspect is highlighted, which is the sense of safety on campus and the ability of users to enjoy their time on campus and create memories (El-Darwish, 2022; Welsch, et al, 2004).

Welsch, E., et al (2004) referred to Richard C. Stedman's article *[Is it Really Just a Social Construction?]: The Contribution of the Physical Environment to Sense of Place*, as he notes that the outdoor space is for movement between places and is also used for other activities, such as studying, socializing, or just relaxing, which is also mentioned by Öztürk, et al. (2016). Many of the outdoor spaces are located along the central axis and routes, to be easily found by the students, as the campus is pedestrian-friendly (Welsch, et al, 2004). The term "gathering space" is defined as "any place where an individual or group engages in any type of activity." (Welsch, et al, 2004).

The components of the outdoor gathering spaces are outlined in the following points: 1. Seating, 2. Access, location, and noise, 3. Green elements, and 4. Sunshine and shade (Welsch, E., et al, 2004).

Seating is categorized into structured and non-structured (Welsch, et al, 2004). Structured seating has to be comfortable to all, even if they do not have back and arm supports, and should be offered and be easily accessible to older people and the handicapped, and should offer sunny and shaded options for individuals and groups (Welsch, et al, 2004). As for the non-structured seating is all about adding chairs and benches that are moveable to provide more options and freedom. As stated by William Whyte, "forced choice is rarely chosen" (Welsch, et al, 2004).

Moving on to the second component, access, location, and noise. Visibility and accessibility should be considered for all campus users, by providing ramps or slopes to ease the movement around the campus and the outdoor spaces (Welsch, et al, 2004). Welsch, et. al (2004) also believed that the gathering spaces that are located along the high-traffic spines are usually highly dense. As for the noise, compared the acceptance of the activities for the level of noise was compared, where spaces that accommodate studying or outdoor classes should have low noise levels and be isolated from streets or construction sites, meanwhile the other recreational or social spaces can accept some noise (Welsch, et al, 2004).

The third component, the greenery, is mainly about providing shading for the seating areas, as well as it is considered one of the campus' strengths that also creates comfort for the users (Welsch, et al, 2004). As for the last component, which is the sunshine and shade, it is highlighted, that a campus should offer both options, as it is important to have sunny spaces during the winter and shaded areas during the hot days in the summer (Welsch, et al, 2004).

Table 1. Example for the seating typologies offered in the Outdoor Spaces on the University of Iowa (Source: Chambers et. al., 2004)

Gathering Space	Seating Infrastructure	Access/Location/Noise	Green Elements	Sun/Shade
Main Library North Entrance	Ledges	A major pathway for most users	Few adjacent trees	Sun
		Close to central campus	Little green space	
		Some noise from Madison Street		
North Hall	One bench	A major pathway for west side residence halls	Trees	Mixed
	Ledges	Sheltered from traffic noise	Hedges	
Burge Front Entrance	Benches	Major pathway for dorm residents	Hedges between ledges and buildings	Mixed
	Ledges	A lot of noise from Clinton Street		
Pentacrest	Fences	The most travelled path on campus	Lots of shade trees	Ideal mix
	Ledges and stairs on buildings	Ideal location – The center of campus	Abundant landscaping	
		Traffic noise from adjacent streets	Open green space	
Philips Hall	Circular Benches	On a major pedestrian path	Shade trees in center of benches	Ideal Mix
	Ledges	Adjacent to the center of campus		
	Stairs	Noise from Clinton Street and Lowa Avenue		

All components and their characteristics that have been mentioned in this paper are valid and should be considered when designing a university campus, but all these points should be studied in depth and detail, as campuses in different countries have different treatments, due to the different characteristics of the different locations. One should not treat a university in the United States the same treatment as one in the Middle East, Europe, or Asia. Each country has its weather, traditions, culture, and even the behavior of the youth. When comparing the numbers and quantities of the components and seating elements, that were mentioned in the paper, to the number of users at the University of Iowa, one will notice, that there are not enough seating elements offered, but they are mainly depending on green spaces and lawns (Figure 1), where students can sit on the ground, instead of chairs or benches (Table 1). Meanwhile, dry and hot countries, such as the UAE or Egypt, cannot depend on large green lawns and fields, since this much greenery will not stand the weather and therefore, more seating elements should be provided.

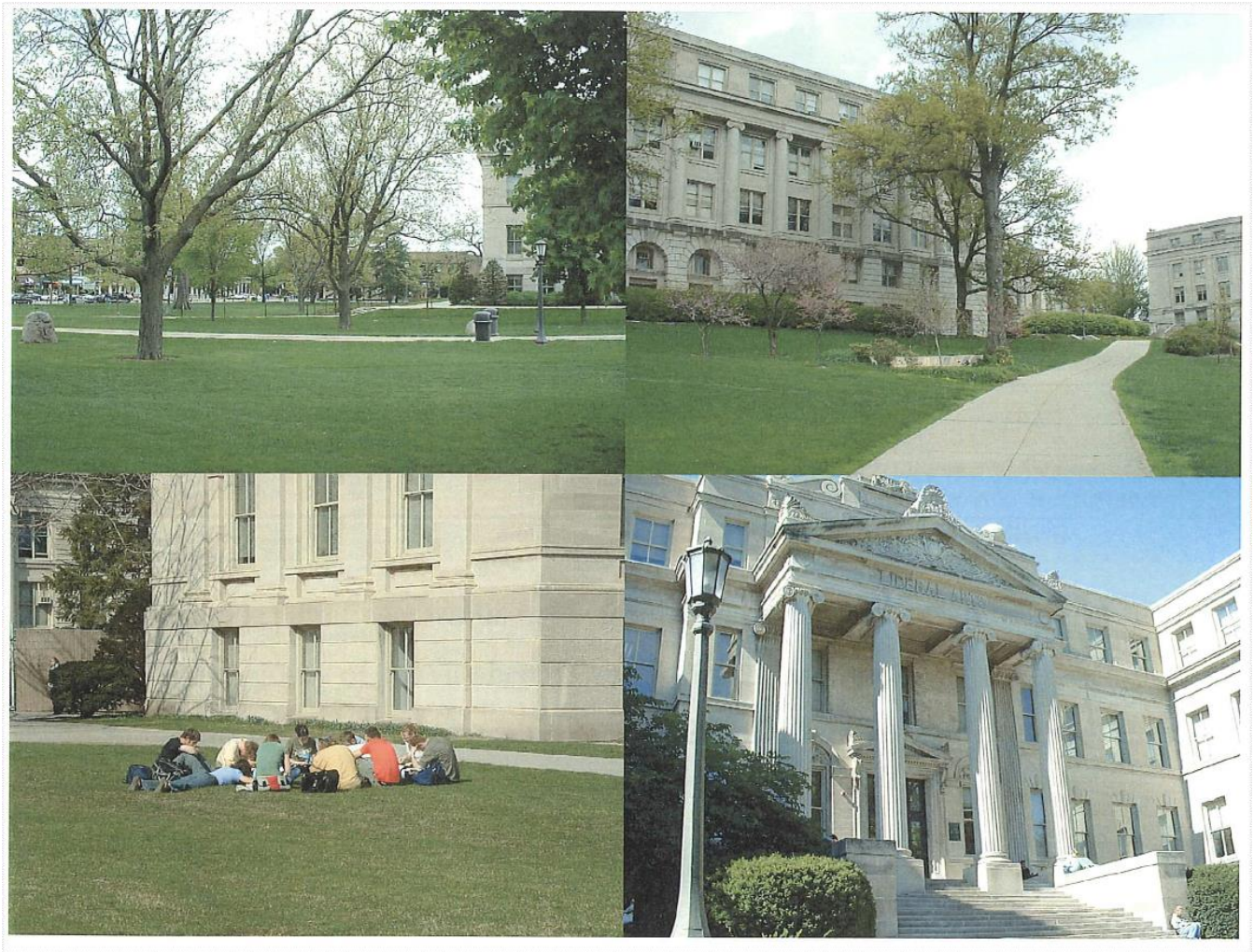

Figure 1. Examples of Outdoor Spaces on the University of Iowa Campus (Source: Chambers et. al., 2004)

In another article by van den Bogerd, et al (2018), emphasis is given to the effect of greenery on people (El-Darwish, 2022; van den Bogerd, et al, 2018; Carrus, et al, 2015; Rapoport, 2005), especially in the universities. The impact of greenery on the different groups of people and how they prefer greenery,

indoors or outdoors, as they find it more beautiful and benefits the emotional, psychological, and physical state (van den Bogerd, et al., 2018; Carrus, et al, 2015; Rapoport, 2005), were highlighted. van den Bogerd, et al (2018) also believe, that it helps people relax and distress themselves, and that greenery will be beneficial for university students, as they are always stressed, due to their studies, assignments, and exams (van den Bogerd, N., et al., 2018). In the article of van den Bogerd, et al (2018) a questionnaire was conducted, which it had some edited pictures of different spaces, showing several options of how these spaces can look like (Figure 2), and one had to select one preferred option per space. The results of the previously mentioned questionnaire, that was conducted by van den Bogerd, et al, 2018, confirm, that greenery is preferred by the majority, in different ways, indoors and outdoors, and that the majority of the university users prefer green and colorful outdoor spaces, than built campuses (van den Bogerd, et al., 2018). This questionnaire was targeting university users in eight Dutch universities. And therefore, not all university campuses can be treated the same way, having huge green and colorful outdoor spaces, due to weather constraints.

The previously published papers and articles were mainly concentrating on the seating and the greenery (van den Bogerd, et al., 2018; Welsch, et al, 2004). These two elements are considered important, but not enough to achieve an acceptable and satisfying student life on campus, as these will not fit or meet the criteria of university campuses in Egypt due to several constraints. The current work highlights the activities that can be offered outdoors, while considering additional elements, as the outdoors enables more flexible possibilities, compared to the indoors. In this study, the triad of Henri is referred to support the analysis.

Henry Lefebvre has divided the production of space into three aspects, creating a triad. These three main aspects are 1. Conceived space, 2. Perceived space and 3. Lived space (Mtolo, 2021; Salama & Wiedmann, 2012) The first aspect or dimension, which is the "conceived space," can be translated into the conceptual design created by the designer or architect of the space, which was designed based on science and can be found in the form of architectural drawings. As for the second dimension, which is the "perceived space", it is considered to be the usage of the space, that is translated into the activities taking place within the space. These activities cover all the needed activities that university users might need, such as studying, socializing, and recreational purposes. It also covers how the users move and interact within the spaces and create new networks. Moving on to the third aspect, the "lived space", is translated into "representational space", which is how the users behave towards the surrounding architectural environment, sculptures and art pieces, within the space. As per Salama & Wiedmann (2012), the users, in our case, the students and staff of the university, are the main factor or element that forms the urban space, the outdoor campus spaces, which creates the quality and identity.

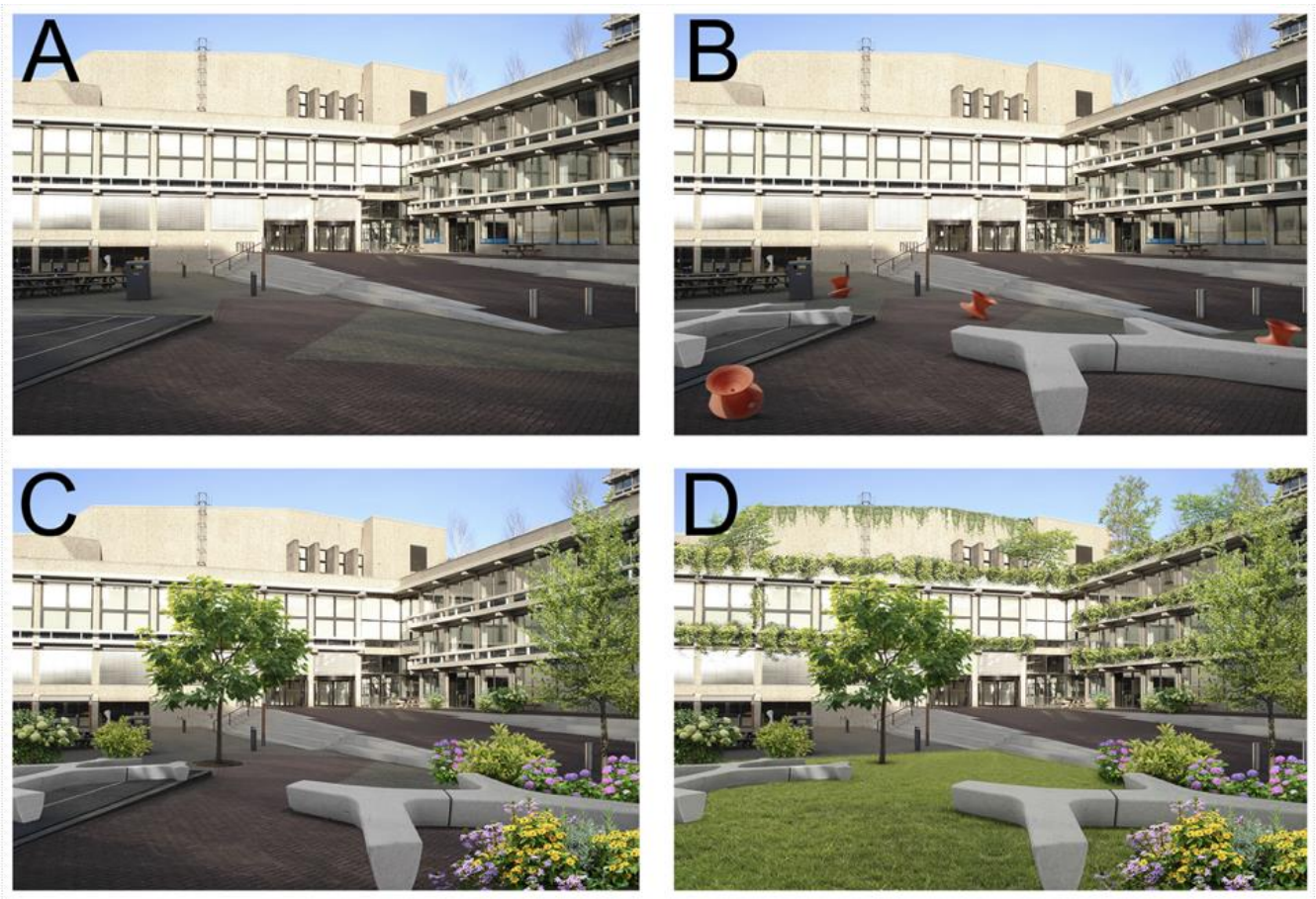

Figure 2. Example for the questionnaire's options for the outdoor spaces (Source: Bogerd et. al. 2018)

3. Case Study of the German International University

The German International University is located in the Egyptian New Administrative Capital (NAC) which is located around 35km east of Cairo and is considered one of the largest urbanization projects in the region. It has a total area of around 688 km22, housing many institutions such as all the ministries, the parliament, several embassies, and their diplomatic residences in addition to several museums and theaters. It also has a large business district, which hosts a group of towers including the Iconic Tower, which is considered the tallest in Africa. The whole city is connected through a 25 km2 green river. The New Administrative Capital is considered to be a well-connected city, as it is directly connected to the Cairo, Al-Suez, and Al-Ain Al-Sokhna, through highways and the currently under construction high-speed train. The construction of the first phase of the New Administrative Capital started in 2016 and is still ongoing, which is around 162 km2 and includes 8 residential districts. The German International University (GIU) was planned and designed following a new approach to university campus planning, which is the "standalone campus", as its whole surrounding area has been under construction. The "standalone campus" concept is based on the idea of being self-sufficient in terms of services and facilities.

The work has been done by Welsch, et al, (2004) characterized the outdoor spaces to be easily found, which is again defined as any place, where individuals or groups can engage in any type of activity. In the current work, the concept of creating "hubs" and "hotspots" was studies and analyzed. This concept accommodates diverse and integrated activities, where these hubs and hotspots are laying in the normal daily cycle of the students and staff so that everyone should pass by them multiple times, every day for several different reasons (El-Darwish, 2022). Accordingly, the university campus planning,

as well as the rooms, scheduling, and real-life operation cycles are studied to be able to plan for the intended outdoor activities, which can serve:

1. The standalone campus or the so-called island concept,

2. The target of socialization, team building, and students and academics networking (El-Darwish, 2022),

3. Integration of normal life needs, such as food, sports, relaxing, working, socializing, etc., in one landscape design containing different hotspots, that are close and integrated with each other, and

4. Integration of seating, shading, and greenery within these hotspots and hubs in one fully integrated concept and campus masterplan. All these aspects have been considered during the designing of the GIU university campus' outdoor spaces. This new approach intentionally aims to enhance the behavior of campus users and their daily routines and activities.

3.1. Methods of Data Analysis

All the above mentioned points are very important to be considered in the design phase to create the master plan. These aspects or points have different sources. Starting with the weather, the data have been retreived from a certified online weather website: meteoblue.com. The exact coordinates have been inserted to generate the weather forcast, as well as the weather history of this specific site. As for the students' behavior, the data has been gather and collected through observation and mapping. These date were later on translated to visual/illustrated maps.

3.1.1. Weather

The weather including the temperature, sun, and wind at the GIU's location has been studied and analyzed carefully during the whole year, paying special attention to the period of the academic calendar and the semesters, to examine the feasibility of which activities to be placed outdoors, when to schedule the classes as well as the gaps per faculty, group, and class through adopting alternating slots, to allow different and alternating groups of students to be outdoors and where the activities and the hotspots can be placed.

During the winter, the campus has at least 12 sunny days and 13 partially cloudy days per month. And during the summer, there are around 25 sunny days per month. As for the temperature, it varies from 37 °C and 16 °C during the summer and from 25 C° and 6 °C during the winter. Moving on to the wind, it mainly comes from the North, North-North-West, and the North-North-East directions. During the summer, the wind speed varies from >12 km/h to >28 km/h, and during the winter, the wind speed can reach >38 km/h. To conclude, the winter season has strong winds, cold but almost sunny days, and during the summer, there is some breeze to be felt, but sunny and hot days (Figure 3). Considering such an important factor, the weather, the masterplan and the design of the university campus are designed to treat such constraints.

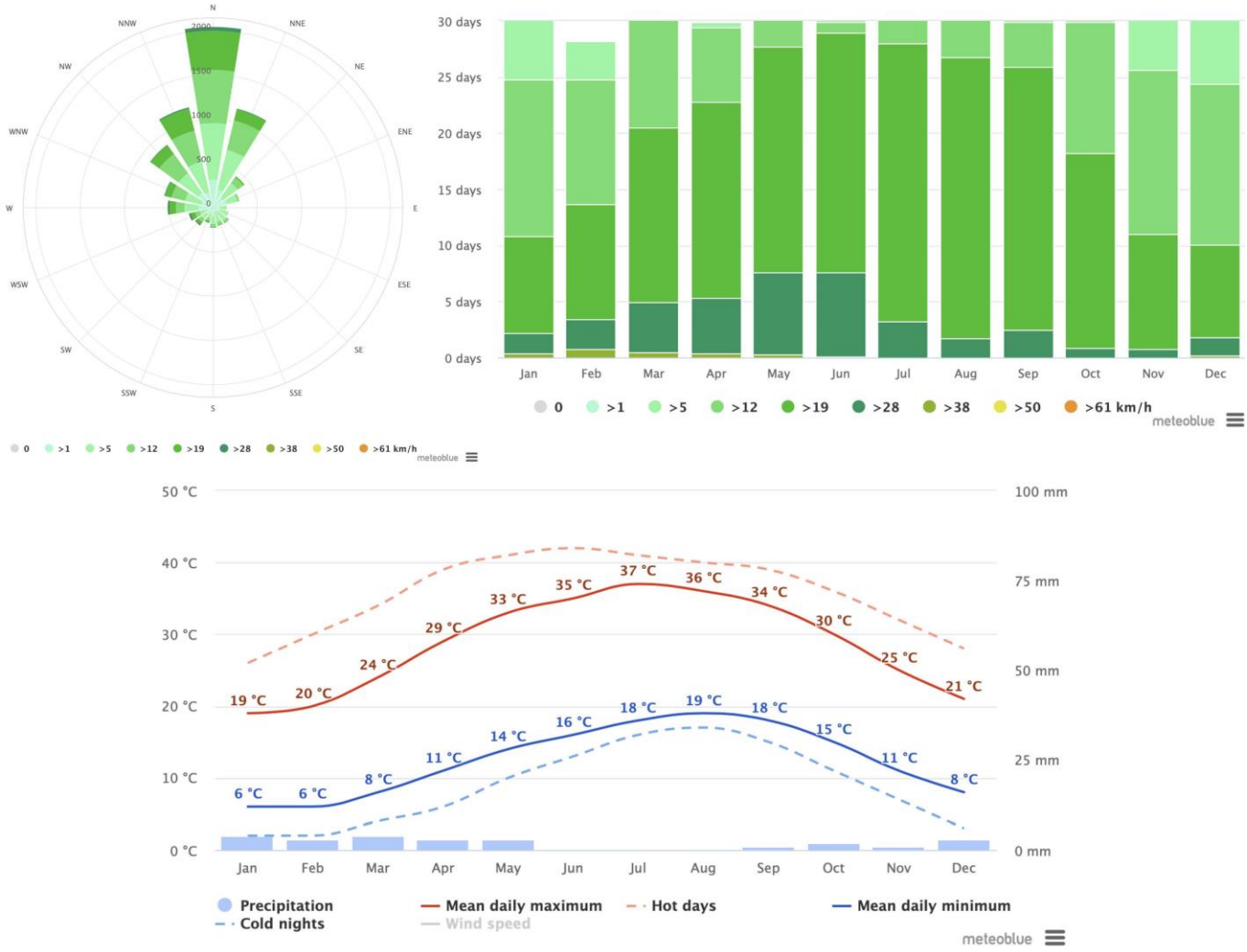

Figure 3. Weather Studies for the German International University (GIU) (Source: Retrieved from meteoblue.com)

To sum up, it can be stated that the GIU masterplan's design has considered both sun and wind screens, which was achieved through the positioning of the buildings within the layout, as shown in Figure 4, where the buildings are placed along two main axes, the southern one to act as a sun shield and offer more shade, and the northern one, which acts as a windbreaker, as it can be extremely windy sometimes.

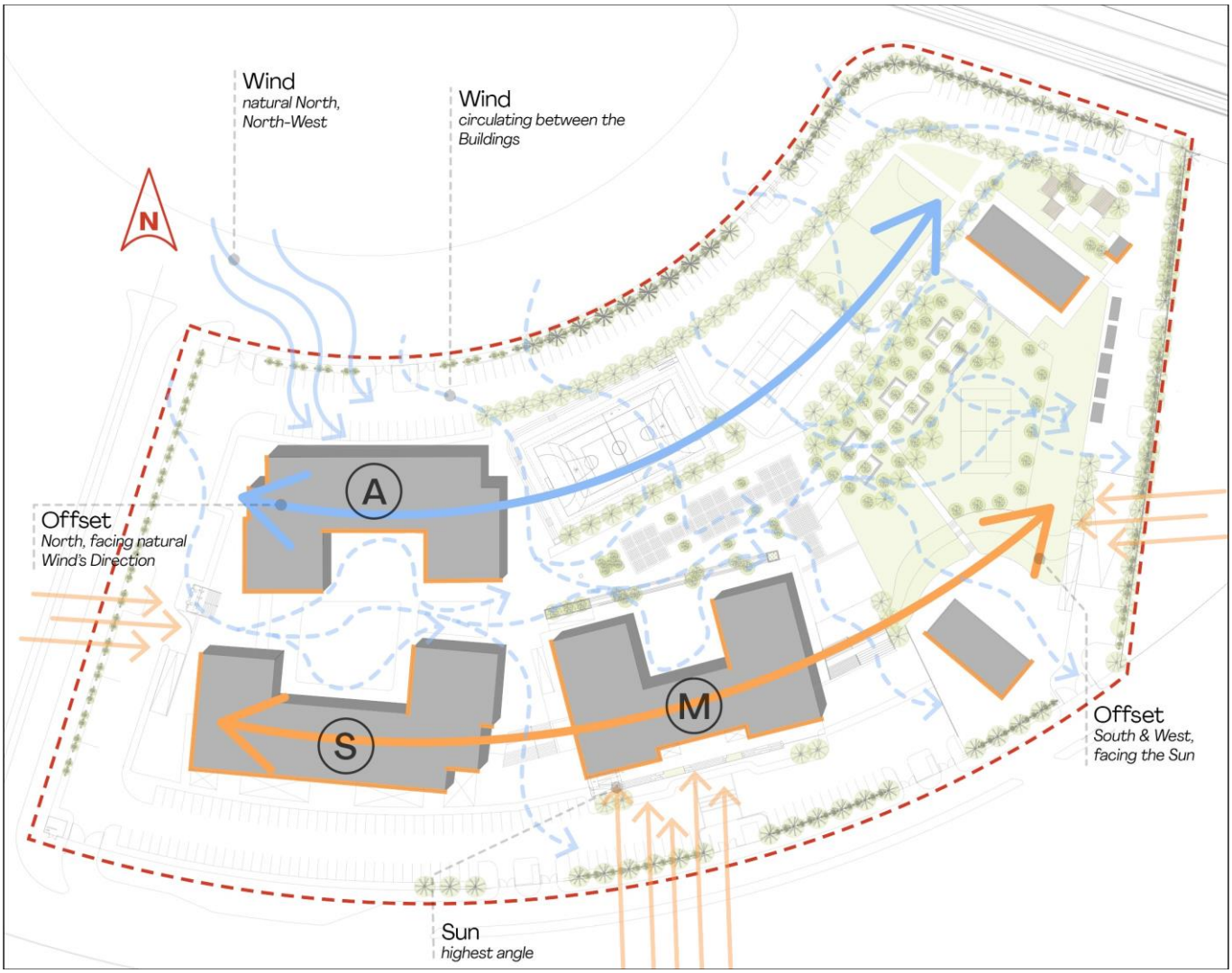

Figure 4. Weather considered in the Masterplan of the German International University (Developed Authors, 2023)

3.1.2. Students Behavior

The previous finding, together with the design mentioned above principle, a big area to accommodate an integrated hub of greenery, food, and sports on the eastern side, and another hub with less noise and distraction to be used for group work, studying, and relaxing, located in the west side by the educational buildings.

The most important aspect of studying is the students' behavior, which can be affected by the offered spaces, namely the "hubs" and their "hotspots." The youth are usually outgoing and like diversity. They dislike repeating the same activities daily and therefore require various options. These options should also be diverse so they do not get bored easily. This well-needed diversity is through offering them several activities distributed throughout the whole campus (Figure 5), as different user groups have different tastes. This aspect has been addressed by creating a new principle named the principle of multi-hubs and hotspots with diverse and integrated activities.

Figure 5. German International University (GIU) Masterplan, showing the buildings, greenery and activities (Developed Authors, 2023)

These activities are divided into five categories: (1) Studying, (2) Playing, (3) Eating, (4) Socializing, and (5) Relaxing or meditating. These categorized hubs were distributed all over the campus with different profiles, which resulted in higher possibilities of encounters between all university users. This serves the primary target, team building and achieving higher degrees of socialization, while serving the different characters and personalities, as well as achieving the campus planning purpose of having a standalone island with a vivid life. Meanwhile, the characteristics, which each hub category and its hotspot'' needs are considered. The spaces for studying need to be quiet areas with low noise levels and minimum disturbances, for instance, the Technology Corridor. They also need to be shaded during the summer and well-ventilated, as well as well equipped with several power sockets and comfortable and moveable seating elements with tables.

As for the playing category, it has been treated by adding several courts for different sports, such as football, tennis, basketball, and paddle tennis. There is also a swimming pool inside one of the buildings that can be considered indoor, as well as outdoor, since three sides are glass elevations that are designed to be foldable and can be completely opened. Having this flexibility in the in-outdoor swimming pool is a great option to have and to use all year long, whether it is summer when the glass doors can be opened or closed or the winter when all the glass facades are closed. It also enables

privacy for the users, as the university offers slots for females only, so all can feel free to swim and have full privacy.

Moving on to the eating category, the campus has many food options. There are several food trucks and containers, which are considered trendy and youthful. These food outlets offer a variety of options and cuisines. There is also a fully equipped, but mobile kitchen, ready in case it is needed, and a cafeteria offering a variety of snacks and drinks. All outlets have seating in front of them, which enables the students to sit, eat and enjoy individually or in groups, while having a nice view of the different and diverse activities, such as the sports courts, greenery, and the beautiful skyline of the towers in the nearby business district. As for the last category, which is the socializing category. This category is mainly about offering the students different areas to sit, relax, and socialize together. Accordingly, the campus enables social interaction all over, whether it is sunny, or shaded, also with a view of the other activities, courts, and towers.

These categories' success is depending on several components (Figure 6), which are the 1. Seating, 2. Shading, 3. Greenery, 4. Food and beverages and 5. The activities. Considering all these components will help in maximizing the outdoor presence and the interactions between the students, with different and various background and boost interdisciplinary connections (Kaya, 2016).

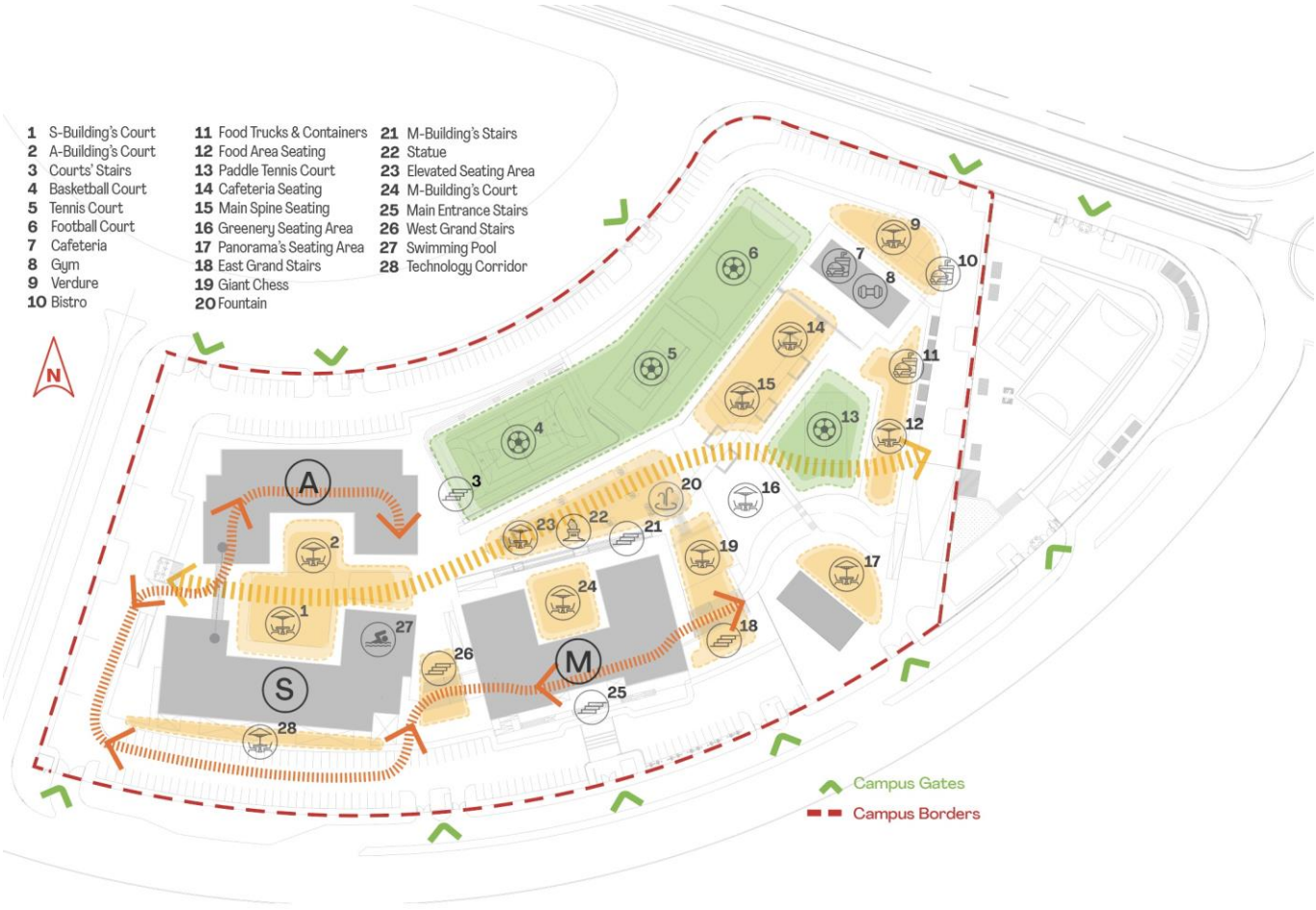

Figure 6. German International University (GIU) Masterplan, showing the buildings, main spines, greenery, activities, and hubs (Developed Authors, 2023)

As mentioned in the previously discussed readings, the seating is an important element that was divided into two categories, which are the structured and non-structured seating. As Whyte stated "forced choice is rarely chosen", several seating options are offered on campus, where most of them are flexible. The non-flexible ones are the ones that are constructed or built, which are the outdoor stairs and stepping. These are mainly located between the buildings and in front of the court of the M-Building, as well as by the courts, to enable students to sit there and watch a game. As for the stairs between the buildings, they have a view of the towers of the business district. Stairs located by the entrance of the M-Building are also designed to be sat on, which are ideal during the winter, while sitting in the sun and protected from the strong winds, as it is located in the south. All these constructed seating, stairs and stepping, can accommodate large groups of 50 to around 150 people or even more at the same time, per stairs. As for the flexible seating, there is a variety of chairs and benches that are distributed all over the campus to offer the highest number of flexible seating possible.

Therefore, the university offers more than 1,230 outdoor seats in different typologies at the same time, which is 1:3 compared to the total number of enrolled students, excluding the structured outdoors seating as well as the indoors seating. And as the scheduling system is set to have different time slots and gaps, the offered seating elements are extremely sufficient during the breaks and gaps. This high ratio of available seating facilitates easier socialization and team or group building, as well as creating friendships. This is also achieved easily, since one can change where he is sitting, depending on the activity he is joining or even watching. There are some concentrations of seating elements that are placed strategically always to have a view of the surrounding activities. For instance, the seating spot by the Panorama Pavilion has a view of the greenery, all sport courts, activities and the towers.

As for the seating area by the food trucks and containers have a view of the paddle tennis, greenery, and other activities. The seating placed along the main spine has a good view to all

Figure 7. *German International University (GIU) Masterplan, showing the flow and concentration of users in the campus outdoor areas in three different timings during the day in winter and summer* (Developed Authors, 2023)

activities, while those in the Technology Corridor see the workshops and their equipment, which can be used by all students and staff for educational reasons, for fun or to build entrepreneurships among the different specializations in engineering, design business, and others. Having flexible and movable seating elements enables the possibility for the students and academics who want to sit in extended, larger groups and for those who want to sit in smaller groups or even individually. All these seating should also have flexible options for shading. During the summer, as the weather gets warmer and sometimes hot, people cannot sit in the sun and require shading. This element has been tackled through having movable umbrellas that the students can move themselves to adjust them next to where they are sitting, as well as a fixed light structure by the "Verdure" next to the cafeteria. It has been observed that the students also sit in the shade provided by the buildings (Figure 7).

According to the questionnaire in the above-mentioned Dutch study, the greenery was found to be not only beautiful, but also has emotional and psychological benefits. Also, it was reported that the majority of university users prefer green and colorful outdoor spaces, however, in Egypt, the weather is quite different than in the Netherlands, where it rarely rains and the climate is relatively much warmer and dry. Therefore, a diversity of trees and plants have been carefully selected to be planted and added to the campus to suit the weather. Since the university's soil is loamy, the options were narrowed down to specific trees and plants, that require small amount of water, as well as stay green most of the year, especially the trees, as they are also used for shading. The concept, as mentioned before, is to have evergreen trees and plants that stay green most of the time and bloom seasonal colorful flowers, so the campus stays green and colorful all year long. The trees used are mainly local palm trees and prosopis trees, as these are considered one of the evergreen trees. As for the plants, a diversity was used, to keep the campus always green and colorful. These plants include geraniums, lantanas, red euphorbias, eucalyptus, Joshua trees, cock's combs, plumeria Albas, jasmine trees, night-blooming jasmine, African daisies, bougainvillea, and paulownias.

Moreover, the campus should offer a variety of food options to serve the different tastes, in order to be a self-sufficient standalone island campus, with all services, including a variety of food options. These options are mainly served through food trucks and containers and the cafeteria in the pavilion. There is also a fully-equipped mobile kitchen and an indoor food court that has all the needed infrastructure ready to be furnished, when needed in the future phase, and is connected to a central kitchen. It has been observed, that the youth always need to have options, to be able to change between them, as they cannot eat the same food every day and as they have different tastes. Accordingly, seven food outlets with different products are available in the Eastern hub, to serve the different tastes and moods of all students and staff members at the same time, where the students can pick their food from the different outlets and sit together to eat and socialize, meanwhile they are being entertained by the different activities surrounding them.

All these previously mentioned integrated components and elements located in the hubs and hotspots are connected together and depend on each other to achieve a successful outdoor space, in addition to the previously mentioned activities offered on campus. These activities are mainly sport oriented, such as the football, tennis, basketball, volleyball and paddle tennis courts, as well as the indoor gym and the in-outdoor swimming pool. But there are also other activities found on campus, such as the Giant Chess area, the fountain, and the newly added giant bear sculpture.

All university campus components, that were previously mentioned, are connected to each other and interlinked, specially through the students' behavior, where the students usually tend to do multiple things during their gaps or breaks or stimulated through the need to study in class or go to eat and therefore, they are crossing the different hubs couple of times during the day. For instance, some students play sports during their gap, and usually head to the food containers afterwards to grab something to eat. Meanwhile, some students go to eat, while sitting in the shade, enjoying watching the others play a football match and also socialize in a spot, surrounded by greenery or have a green

scenery (Figure 8). The activities have been placed in the campus in a way to have a balance between the different kinds offered. Not only has the placement of the different activities, but also the urban topography and the different levels within the campus created a dynamic student life, movement, and visual connectivity.

Figure 8. Picture of the eastern part of the German International University (GIU) campus, showing a part of the main axis, some food containers and trucks, the paddle tennis court, the football court and the greenery, 2022 (Photo by Authors, 2023)

3.1.3. Results & Discussion

Through conducting this research, it has been found, that there are many various aspects, which contribute in creating a university campus. Specific aspects have to be carefully studied and considered during the design phase, as well as during the operation of the campus. These vital and important aspects help and contribute in the success of the different campuses around the world. The main objective was to explore and define the main aspects to achieve successful outdoor spaces in a university campus with similar circumstances as the German International University (GIU). Every campus has its own circumstances that should be addressed, through different variables, such as the climate/weather, location and environment and the culture and the users' behavior within the space. As mentioned before, university campuses in a European country cannot be treated the same way as

campuses in the MENA region, as the weather and the cultures and traditions are not similar. As well as the location and environment, where the campus is located will help define what is needed to be offered by the university.

4. Conclusion

To conclude, there were many papers and articles regarding campuses outdoor spaces, but were limited to only one or two elements, which are considered as important as other elements, but a combination of all is needed and preferred to achieve a livable and enjoyable university campus, specifically for universities with similar situation and backgrounds.

A successful university outdoor area planning, design and operation have a direct connection with its users, in that case the students. It is very important to consider the needs of the students and staff, to create an acceptable campus life, as they spend most of their time on campus. It all starts with the real-life operation and all the needed utilities and facilities, that will allow either the integration with the university campus's surround area or in like the current case of the GIU, to apply the new approach mentioned before, that is called the "standalone island university campus", that should be self-sufficient, starting from the university's full operation and the design of the masterplan. Accordingly, a weather study should be conducted before designing outdoor landscapes and facilities, as the buildings can be used as wind and sun shields by placing them along two main rows positioned in the north and south sides of the land, as shown in Figure 4. Not only the buildings' locations but also their orientations and typologies matter. The orientation will help in the air flow and the shade.

As for the typology of the buildings, it is recommended to have U-shaped buildings to create open, but safe and shielded courts, which can eventually house some of the needed activities. A series of diverse hubs and hotspots are advisable, that should have different characteristics, as well as accommodate different functions. These hubs and their hotspots are recommended to have the following design dimensions:

1. The standalone campus or the so-called island concept,

2. The target of socialization, team building and students and academics networking,

3. Integration of normal life needs, such as food, sports, relaxing, working, socializing, etc., in one landscape design containing different hotspots, that are close and integrated with each other, and

4. Integration of seating, shading, greenery within these hotspots and hubs in one fully integrated concept and campus masterplan.

It is worth noting, that by praxis, this concept is found to be successful and has achieved its goals in both directions, the standalone, self-sufficient, vivid campus, as well as the team building, socialization and the feeling of belonging. In this paper, some important variables and aspects have been mentioned, but there are still many others, that also contribute in the success of a university campus. These aspects should also be analyzed and studied further, such as how the movement and flow of people between the tutorials and slots affect the outdoor spaces within the campus.

Conflict of Interests

The author declares no conflict of interest.

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Comparative Analysis between the Architecture of Bimaristans in Egyptian and Syrian during Mamluk's Era

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ABSTRACT

Bimaristans are a building type which emerged in the Islamic world equivalent to nowadays hospitals. Most of the Islamic architecture studies focus on mosques, then mausoleums. This makes the research field open for more studies on building types like baths, wekalat, etc. Bimaristans remain within the scope of structures that need more studies through comparatives and analytical analyses. This paper introduces comparative analysis between bimaristans in Cairo and Aleppo, with particular focus on those constructed during the Mamluk's era. This comparison highlights the points of similarity between the concepts that influenced the designers by that time with respect to their different locations, surrounding context and historical background. Such factors caused to make distinguished differences that gave each location its unique identity. This research depends on inductive-deductive methodology; inductive by reading and explaining the architectural drawings of both case-studies, and deductive from the theories and researches that justifies the reasons lied behind the end architectural product. Consequently, analyses the comparative results. The study provides architects and scholars with a clear image about the unique private identity of each zone, although they stand on the same believes using analytical analyses of bimaristans. Hence, contemporary architects in the Arab world can recognize the spiritual concepts behind the architectural and planning dimensions of bimaristans' discrete design, that they may use or re-use to regenerate new forms that reflect their local identity and satisfy local cultural needs. Also, the study clarifies the role of local artists in articulating such concepts using carved geometrical reliefs, in addition to the documentation role of decorating relieved texts on those structures.

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1. Introduction

Studies in the field of Islamic architecture focused primarily on religious buildings (mosques and mausoleums). While public or domestic buildings did not receive enough attention from scholars. However, given the tangible reality of the Islamic heritage, we find that during the successive Islamic eras, the community took care of all types of buildings, whether religious or domestic, such as agencies,

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baths, residential buildings, and others. Among the building types that attracted their attention were the bimaristans. As the preservation of public health was an integral part of building the civilization of the Islamic society.

However, there are some few researches that describe and mention the bimaristans along the flourished periods in the Islamic era. The topics covered in the majority of these dissertations include bimaristan's origins, types, and policies. Whereas, the question of the bimaritan's history and the precise date that the first one was constructed has been impossible to determine (Ragab, 2015). Then, more important considerations are about what constitutes a bimaritan and what function this institution served in the Islamic societies. Also, (El-Baba, 2009) in his master's degree dissertation mentioned the various types of bimaristans as follows; leprosy, mentally ill and those for strangers, handicapped, disabled and blind people (Akram Muhammad Yahya, 2018), such types can be considered as public (Elyan, 2002). Moreover there were specialized bimaristans and others for the care of students and orphans (Al-Kubaisi, 2006). In addition of prisoners and military (Abdullah, 2012) bimaristans. Moreover, he classified them into portable and permanent hospitals.

Although the origins of building bimaristans are unknown, some studies suggested that they may have originated in prehistoric Iranian and Iraqi societies (Sherif Kaf, 2007) or may have been passed down as a result of the impact of Western Christian culture (Riva & Cesana, 2013). This is in reference to the plan to construct a hospital-specific structure. Contrarily, some other researchers contend that because of the Crusaders' close proximity to the Muslims in El-Quds, European nations were impacted by this building type (Ragab, 2015).

From the architectural point of view, some authors and scholars used the documented bimaristans to put their analyses from different perspectives. From an environmental point of view (Belakehal et al., 2004) considered sunlight as a crucial component of the architecture of the bipartisanz since it was thought to have medicinal advantages. To prevent warming and glare, control over sunlight admission has to be implemented due to the region's harsh climate. Iwan, screened windows, and partially covered courtyards were thus utilized depending on the type of activities performed in the various sections of the bipartisan. (Alansari & Hirao, 2017) were able to identify the presence of numerous architectural components that consider the environmental aspect in the same context and via their analytical investigation, which helps to enhance medical performance. These components include accounting for the necessary height and providing enough room for natural ventilation. As well as techniques that promote solar exposure, like Iwans, wide windows, or open courtyards. Additionally, (Maraqa et al., 2014) created a system to evaluate the effectiveness of these architectural components in Bimaristan Al-Qaimari - Damascus, emphasizing their role in enhancing the Bimaristan's medical performance. From another angle, and based on the idea of biophilic design, the results of deeper investigation (Abdelaal & Soebarto, 2018) shows a strong association between innovation-generation processes and the built environment in conventional higher education institutions. Where architects can adopt certain lessons from such "timeless" buildings to develop their methodologies to put their design for contemporary hospitals.

The aforementioned research makes it abundantly evident that during the Islamic nations' affluent periods, the bipartisan building type spread throughout them. But its architectural evaluation needs a lot of investigation, which prompts the question; what similarities and differences exist between this architectural product in terms of place and time? And how was the composition and creation of the Bipartisan impacted by Islamic culture? Since the inception of Islam, through the Umayyad era, and into the Ottoman era, many of these bimaristans have been referenced in historical books and academic researches. Few of them have, however, been architecturally recorded, which hinders the process of comparative study between them. The study will therefore be restricted to a comparison between bimaristans in Egypt and Syria during the Mamluk era in order to find tangible results. From another side,

Egypt and Syria were key political capitals of the Islamic caliphate that time, and they were also firmly linked militarily, commercially and culturally.

We can identify the similarities in the composition and formation of this building type through this analytical study of the architectural components found in bimaristans in Egypt and Syria, and we can also realize in concrete terms the intellectual integration between Islamic societies, despite the differences in the architectural product resulting from each society's unique geographic location and historical background.

2. Methodology

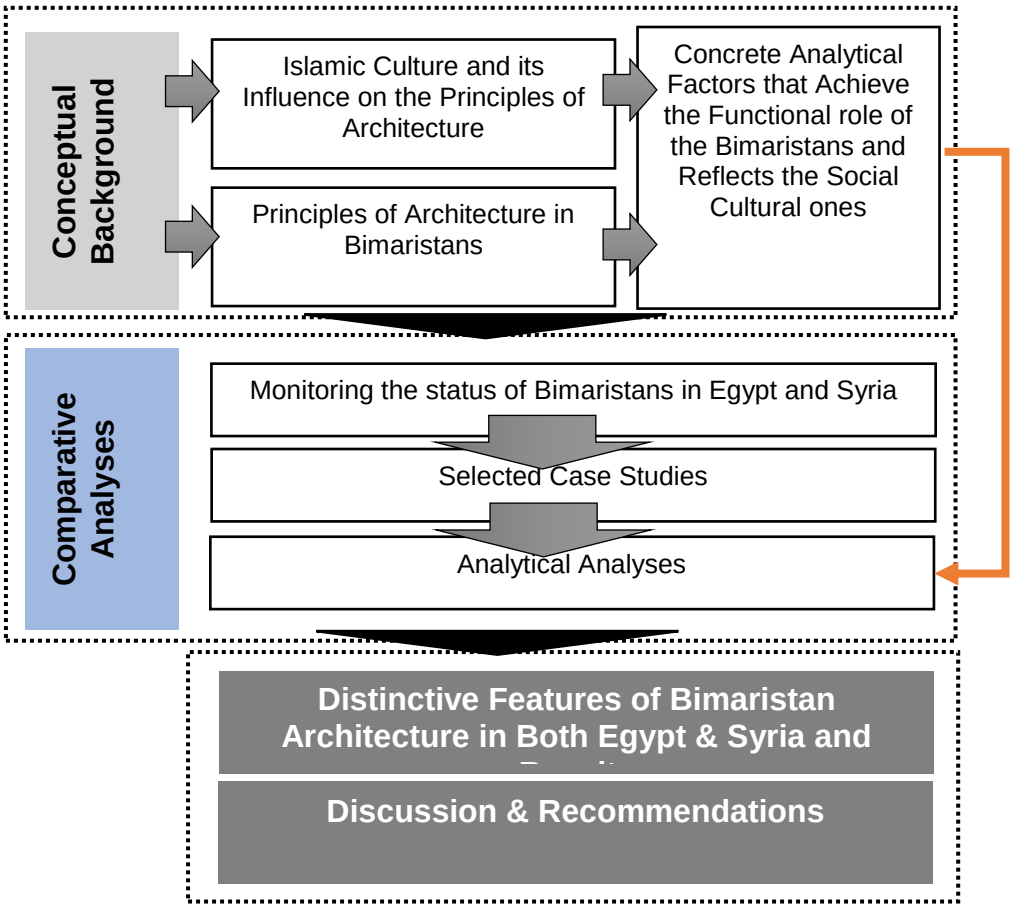


Figure 1. Structure of the Study (Developed by Author)

The research methodology depends on the results of previous studies that dealt with the common concepts of Islamic culture, on which the general principles of Islamic architecture in general are based. It spreads from one Islamic nation to another during the flourishing Islamic Ages. In addition to studying the functional architectural components made mandatory in traditional bimaristans. By examining two models of bimaristans, one in Egypt and the other in Syria during the Mamluk era, it is simple to find the applications of these principles to the two models, these applications are within the scope of the similarities between the two models. On the other hand, by dismantling the architectural elements and comparing them with their counterparts in the other model (portal, iwan, courtyard, healing areas, distribution of functional zones, structural elements, ceilings, and domes), it is possible to elicit differences and identify their causes, whether historical, economic or environmental.

The structure of the research consists of four parts. The first chapter reviews the state of conceptual background of designing bimaristans as a functional building type, for an Islamic community regarding its cultural paradigm. This part provides a tool for conducting an analytical comparison between bimaristans in Egypt and Syria, containing physical factors for the architecture of bimaristans. The second part reviews the aforementioned bimaristans in Egypt and Syria, and provides an accurate description of the selected case studies. Then, the analytical comparison is made according to the architectural design factors derived from the first part of the study. The third part of the research highlights the points of distinction between the Bimaristans in Egypt and Syria during the Mamluk era, to find out the reasons for those differences, whether political, economic, environmental or otherwise. The fourth chapter considers the recommendations and discuss the main contributions of this paper (Figure 1).

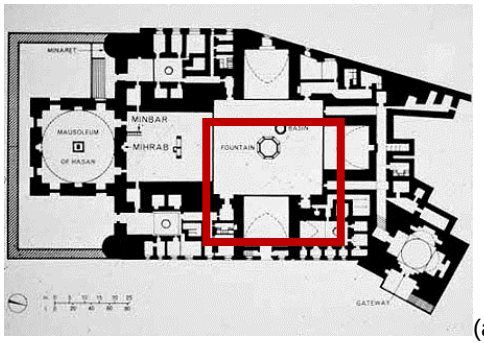
3. Conceptual Background

This section of the research is divided into two parts. The first part is related to the general concepts of Islamic architecture that are derived from Islamic culture. These concepts are typically applied to most building types (mosques - houses - agencies - public baths, etc.) that Islamic societies cared about throughout their ancient historical eras. The architecture of bimaristans and the architectural components they contain to fulfil the required function in terms of health care are the subject of the second half.

3.1. Islamic Culture and its Influence on the Principles of Architecture

Islamic Architecture is characterized by being based on concrete cultural and religious bases that were mainly generated from their interpretation of Qur'an and Sunnah, and that were of significant influence on the Islamic Architecture of almost all building types known by that time. This influence formed a strong character for different building types that had significant features each of which is based on a strong concept generated from the Islamic culture, this applies to plans as well as facades of their buildings.

One of the main features that was always present in most types of buildings is the Courtyard. Most of the Islamic buildings regardless to their types (Residential, mosques, schools, bimaristans……etc.) were characterized by having a central (square or rectangular) court in the center of building, or centralize the building in the correct sense, the court besides the useful environmental role it plays to allow natural lighting into interior spaces and to aid in ventilating these spaces, and the great role it plays in achieving privacy in the interior spaces overlooking it and that are not desired to be exposed to the outer facades, it had also a strong cultural concept which was the main reason for its presence. In the Islamic culture the square is a symbol of earth, while the dome is a symbol of the sky, God's throne is carried by eight angels over the water (و يحمل عرش ربك فوقهم يومئذ ثمانية) (AlHaqqah, verse 17), (و كان عرشه على الماء) (Houd, verse 7). This resulted in the presence of the square or rectangular courtyard referring to earth with a central fountain or water feature referring to the water under God's throne, in many cases the fountain is covered with an octagonal wooden structure referring to the eight angels carrying God's throne and then covered by a small dome referring to the sky in which God's throne is present above all. (Figure 2) (Gabr, 1992)



(a)


(b)

Figure 2. Plan and photo of Sultan Hassan mosque and Madrassah (being a prototype of Islamic Mamluk Architecture) showing the central squared court with its above mentioned featues (Behrens-Abouseif, 2007)

Majaz was also one of the main characteristics of Islamic buildings, simply it is the indirect entrance that creates a clear visual and audio separation between inside and outside of the building, a technique that was innovated to achieve the most possible privacy for the interior spaces, as a privacy is a main characteristic of Islamic culture that is highly valued and always required to be achieved (Figure 3a).

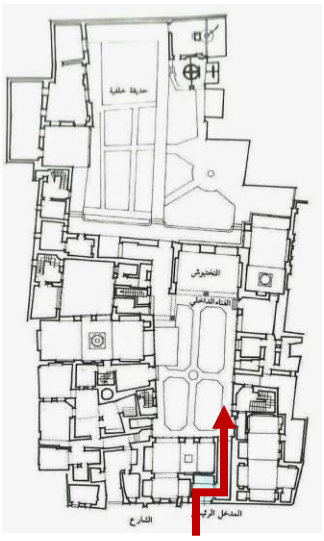


Figure 3. (a) Ground floor plan of Al Sehemy House (prototype of Islamic houses in Egypt) highlighting the Majaz at its main entrance, and showing the central rectangular court (Behrens-Abouseif, 1992), (b) Shot from the court of Al Sehemy house showing mashrabias on windows (*Bayt Al-Suhaymi ("House of Suhaymi"*, n.d.)

At the same time facades of Islamic buildings also had certain features and characteristics that were also generated from cultural concepts. Pointed arches were the main shape used for the openings of Islamic buildings either for windows or doors. The pointed arch apart from being an appropriate structural system for openings in stone structures, they also had a cultural concept pointing to the sky creating a virtual spiritual bond between the building and the sky. The same applies to vaults which

were always pointed arches and were used excessively especially in constructing Iwans in mosques and madrassahs as those shown in the above photo of Sultan Hassan complex.

Also, Mashrabia (Figure 3b) is among the main known features of Islamic building facades, a wooden mesh of designed with respect to Islamic ornaments always used as a shutter on most windows playing an environment role to allow indirect sunlight into the interior space but at the same time plays a more important role in achieving privacy and expressing the Islamic art.

3.2. Principles of Architecture in Bimaristans

Bimaristans were designed in traditional Islamic times to achieve their primary functional purpose, which is complete health care. This is in accordance with the culture of society emanating from the Islamic faith. Where the designer was keen to prepare the healing spaces so as to achieve complete physical and psychological comfort for the patient, and simultaneously support the employees and medical professionals in their efforts to complete their duties fully and to practice charity in their work to the best extent possible. In terms of functionality, the bimaristans included the following seven functional areas: Services and security areas, medical services, administration area, religious zone, educational zone, residential area, charitable services (Akram Muhammad Yahya, 2018).

Table 1. The main zones of the traditional bimaristans and their contents

Services zone/s	**Medical zone/s**	**Administrative zone**	**Religious zone**
Portals, doors, and walls surrounding the bimaristan. Control and guard rooms. Internal corridors. The foyer and the corridors of the Bimaristan and its bays. Kitchens, pantries, and food preservation. Baths and rest house. Stone clock tower. Vehicle parking.	Outpatient clinic. Iwan of Bimaristan. Pharmacy. Mortuaries and affiliated cemeteries.	Diwan of Bimaristan. (office) Manager office (Nezara).	Mosque.
Educational zone	**Residential zone**	**Charity zone**	**Recreational areas**
Medical schools. Library.	Residences for doctors, teachers, and workers. Residences for scholars	Watering, sabil, and Almzamliyah.	Courtyards. gardens

4. Comparative analyses between Egyptian and Syrian Bimaristans

This part of the study includes basic information - about those bimaristans – that must be collected in order to create an analytical comparison between those in Egypt and Syria. This allows us to select case studies from them. Those case studies that allow us to evaluate the analysis tool, which components were taken from the previous section of this study. This information includes the name of the bimaristan,

its founding date, the Islamic era in which it first emerged, the current construction state, and whether any architectural drawings have been documented for it that allow us to perform analyses.

4.1. Monitoring the status of Bimaristans in Egypt and Syria

4.1.1. Bimaristans in Egypt

Numerous references make it abundantly obvious that Egyptian society has a strong health care culture that dates back to ages before the Islamic eras (Metwaly et al., 2021). Consequently, the practice of medicine has continued to exist from the early Islamic era. In the beginning of the early Islamic era in Egypt, spaces were provided for it inside the mosques, because it was a public structure that attracted visitors from all over and was located in the center of the city (Hosney Radwan, 2021). Hence, up until the early Umayyad era, when the bimaristans arose as a center for healthcare. Then the bimaristans began to develop until they witnessed continuous flourishing, until Cairo became, in the twelfth century, a beacon for the countries of the East. It has annexed by schools of medicine. And it kept growing until the Ottoman era, when this building type experienced significant changes. The following table lists mentioned bimaristans in Egypt.

Table 2. A list of Egyptian bimaristans throughout the different Islamic eras

The Name of the Bimaristan	Construction Date	Islamic Era	Currently Construction Condition	Documented Architectural Drawings
Bimaristan Zoqaq El-Qanadil	a. 690 C.E.	Ummayid	Does not exist	X
Bimaristan Al-Maafer	a. 850 C.E.	Abbasid	Does not exist	X
The Ancient Bimaristan or The Supreme Bimaristan or The Tulunid Bimaristan	872 C.E.	Tulunid	Does not exist	X
The Lower bimaristan or Bimaristan Camphor Al-Ikhsheedi	957 C.E.	Ikhshidid	Does not exist	X
Bimaristan Al-Qashshin		Fatimid	Does not exist	X
Bimaristan Al-Saqqatiyin			Does not exist	X
The Nasserite bimaristan or El-Salahy or Bimaristan Salahuddin	1181 C.E.	Ayyubid	Does not exist	X
Bimaristan Alexandria	1181 C.E.	Ayyubid	Does not exist	X
El-Mansouri Bimaristan or Dar Rl-Shefaa or Marstan Qalawun	1284 C.E.	Bahriyya Mamluks	Exists and still operating as an ophthalmology hospital	√
Bimaristan Al-Moayyed	1421-1423 C.E.	Circassian Mamluk	Exists and is operating as a tourist attraction	√

According to the illustrated table (Table 2), the bimaristans built during the Mamluk era are still the ones that have architectural documentation, allowing for their study and analysis in the following section of the study.

4.1.2. Bimaristans in Syria

Agricultural policies like the Common Agricultural Policy of the European Union have been insensitive to the rural world's complex, multicultural and densely populated tapestry. A situation similar to the design

of new capitals that emerged in the mid-twentieth century with principles far removed from the local reality, such as Brasilia or Chandigarh. The project The City of a Thousand Cities by Perea (2012) was winner of the New Multifunctional and Administrative City for 500,000 inhabitants' competition in Korea. It makes an interesting reflection on preserving a large central productive agricultural space, and building around it a ring of intermediate cities, where citizens can interact without the need for a motor vehicle, and count on the presence of the landscape. Perea (2012) affirms that the complex and intense sustainable city is not a consequence of zoning, but of "meshing in space, function and building matter" and where the net sphere must be superimposed on the natural and urban spheres.

4.2. Analyses of the Bimaristans Elements in Egypt and Syria during the Mamluk's era

It was recorded that in Damascus hospitals existed as early as 706 CE at the time of Umayyad Caliph Al-Walīd. Several countries in the middle east witnessed the presence of bimaristans by that time but most of which were destroyed either totally or partially and the only traces of them are documented in the books of history. In Syria specifically there are main four Bimaristans that still exist nowadays, two of them are in perfect condition while the others are in deteriorated conditions. Two of them are found in Damascus while the others are in Aleppo. (Naqvi, N., 2012) The following table lists the four Bimaristans.

Table 3. Documentation of the most important Bimaristans in Syria

The Name of the Bimaristan	Construction Date	Islamic Era	Currently Construction Condition	Documented Architectural Drawings
The Nuri hospital, Aleppo.	12th century	Ayyubid	Deteriorated condition	X
The hospital Arghun Al-Kāmilī, Aleppo.	1354 C.E.	Mamluk	Well maintained and open for public witnessing frequent cultural events.	√
The Nūrī Hospital, Damascus.	1154 C.E.	Ayyubid	Well maintained and functions as a museum.	√
The Qaymārī Hospital, Damascus.	1248 C.E.	Ayyubid	Deteriorated condition	√

The crucial section of the study begins here, as the chosen case studies from the Bimaristans of Egypt and Syria are studied in accordance with the data compiled about them. Wherein their architectural components are analyzed in relation to design concepts derivate from Islamic culture and the elements of functional formation of Bimaristan. They were discussed in the study's earlier section.

4.2.1. El-Mansouri Bimaristan/Marstan Qalawun/ Dar El-Shefaa as an Example of Egyptian Bimaristans During Mamluk'd Era

Al-Mansour Qalawun, the seventh Mamluk sultan after the Mamluk emirs seized the throne from the Ayyubids of Cairo and established control of the greatest region of the Ayyubid Empire, inaugurated al-Bimaristan al-Mansour in 1285 C.E. Although Qalawun's complex included a madrasa, a bimaristan, and a mausoleum, the location of these buildings gave the bimaristan more prominence and emphasized its significance (Ragab, 2015).

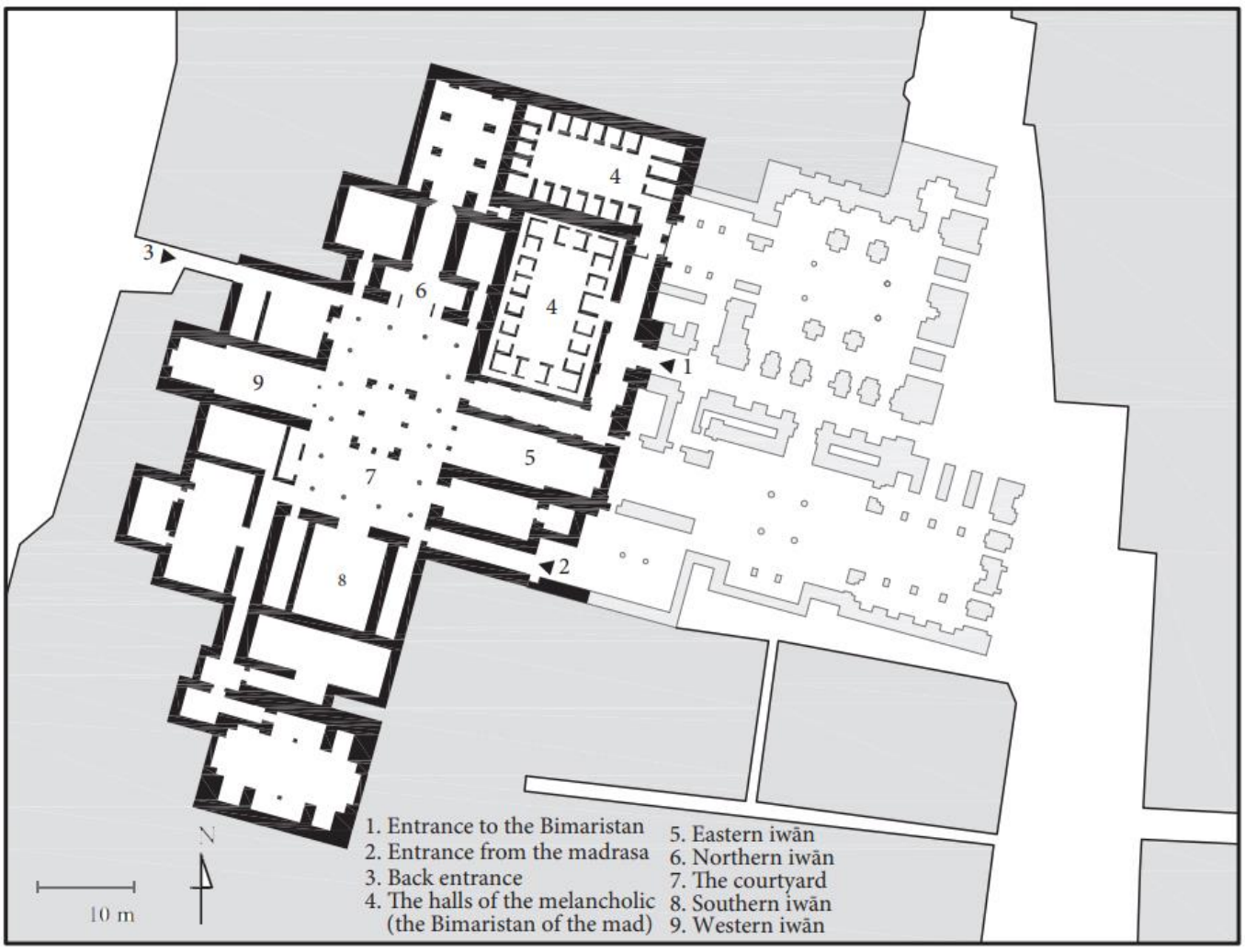
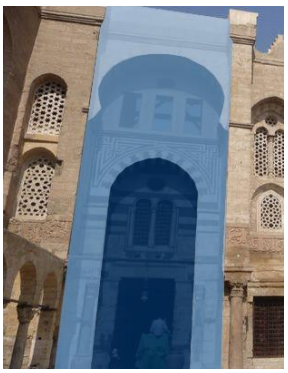
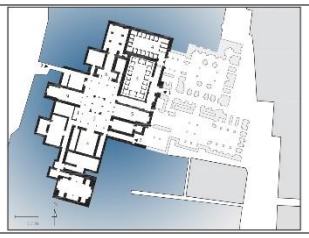
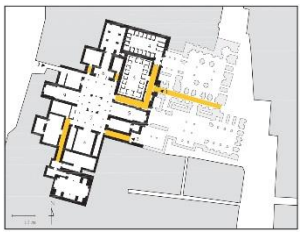


Figure 4. Floor plan of El-Mansouri Bimaristan. (Ragab, 2015)

Table 4. Analysis El-Mansouri bipartisan according to the main zones of the traditional bimaristans and their contents (Table 1)

Functional Zones	Architectural Elements	Location in Floor Plan
Services zone/s	Portals, doors, and walls surrounding the bimaristan. No entry immediately overlooks the main street; all entries are indirect. The mosque and mausoleum must be passed in order to access the main entrance. Two effects are obtained by treating the portal as a series of three layers. It does two things: first, it reduces the scale of the doorway as it climbs to the height of the building; second, it is a kind gesture that creates inward visual flow and strengthens the continuity between the street and the main corridor. The bimaristan is unenclosed by walls. Al-Nassir Muhammad Ibn Qalawun's complex is located on the northern side, and other structures can be seen on the southern side. Al-Mansur Qalawun's mosque and mausoleum are located on the eastern side, with a view of the front façade. While the bimaristan takes up the majority of the area of the complex. There is a western entrance that can be reached by passing through a passageway between the neighboring structures.	 The Portal of Qalawun complex. Layered entrance (by author, 2022)
	Control and guard rooms. Guard rooms for the building are not specified in the plan or mentioned in any references. However, we can see that the Bimaristan is hidden behind the school and the mausoleum and is completely surrounded by guarded structures.	
	Internal corridors. After passing through the gateway, the mausoleum, which was on the right/north, and the madrasa, which was on the left/south, both had windows that opened to the hallway, whose level was lower than that of both buildings. This created the effect of resembling the exterior street running up to the building in the corridor. At the further end of the corridor, facing one another, were the entrances to the mausoleum and the madrasa, which served as a signpost for the main corridor's end and the entry to the bimaristan. When approaching the building, a row of domes directed visitors to their left and then to their right along an L-shaped pathway, which in turn opened into the building's main courtyard next to the east iwan. The rather lengthy L-shaped pathway effectively blocked out street noise and gave the impression that there was only one little area within the bimaristan that was neatly organized. The patient or visitor would have	

travelled from the sunny street to yet another bright courtyard inside the hospital via the lengthy pathway between the mausoleum and the madrasa as well as the L-shaped corridor leading to the bimaristan courtyard.

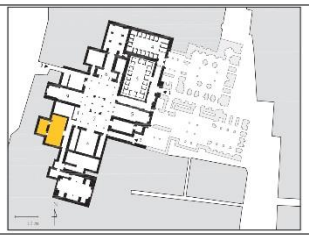
The foyer and the corridors of the bimaristan and its bays.

There would have been a big wooden gate at the start of the L-shaped domed corridor to the right of those entering the bimaristan, essentially forcing them to turn left along the L-shaped passage. The L-shaped passage continued straight behind the mausoleum, separating it from another area of the building that was divided from it by the gate. The section consisted of two halls, one of which opened onto the main corridor and had a door facing the back of the mausoleum; the other, which was entirely separate from the first, opened at the end of the corridor and had a smaller gate, and it was positioned perpendicular to the corridor so as to shield its occupants from view (Ibn Habib, 1976). That one serving men and the other serving women, these two halls were reserved for the melancholics (or the insane).

Ceiling and lighting system in the corridors (Saad, 2021)

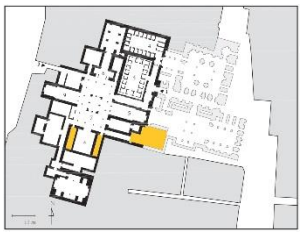
Kitchens, pantries, and food preservation.

Other than Pascal Coste (Troelenberg, 2015), who places the kitchen on a horizontal design, there are not enough sources to adequately describe the kitchen (Ragab, 2015).



Baths and rest house.

The floor plan makes it apparent where the restrooms for the Qalawun complex are located. The restroom for the school is at the Bimaristan's entrance, which is accessible from the school. For the Bimaristan, bathrooms which are separated into two sections flanking the southern Iwan, one for men and one for women, also has another area for servicing patients. The school's restrooms, which are positioned around an open courtyard, have received particular interest. Such composition to complete the cosmological Islamic concept.

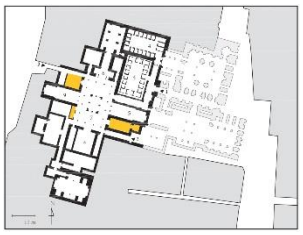
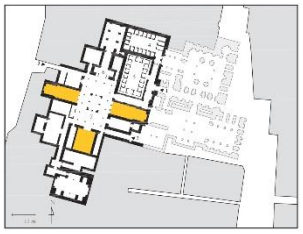
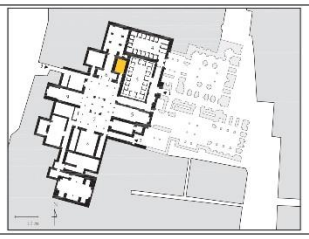
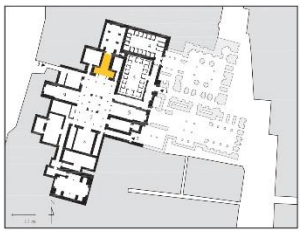
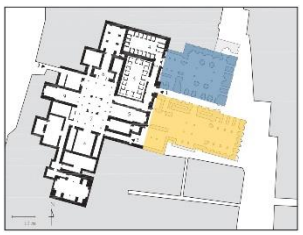


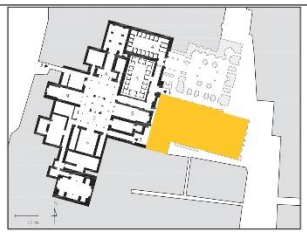
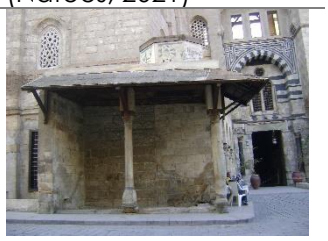
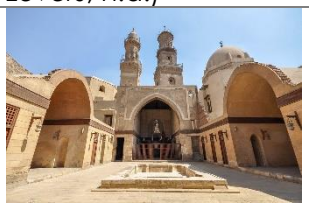
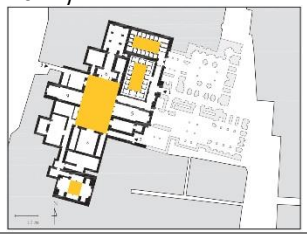
Stone clock tower.

Nothing on the site or in the literature suggests that this bimaristan has a clock tower.

Vehicle parking.

Nothing on the site or in the literature suggests that this bimaristan has a vehicle parking.

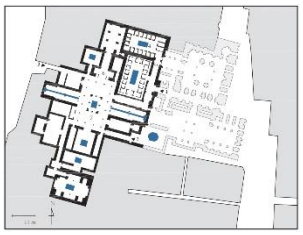
Medical zone/s	Outpatient clinic. Outpatient clinics are located near the entrances and around the courtyard. It is dedicated to ophthalmology and general surgery. Pharmacy. As for the room, which is located on the western side, near the back entrance of the Bimaristan, it is used to install medicines, as well as to support patients with quick medical advice.	
	Iwan/s of Bimaristan. There are four iwans in Bimaristan Qalawun. The eastern and western iwans are used as halls for convalescent men with beds. As for the southern iwan, it is used as a hall for male patients. As for the halls designated for women, they are located in the southern part of the main courtyard and its iwans, and private bathrooms for women are annexed to it. This is to provide the greatest degree of privacy for female inpatients.	
	Mortuaries and affiliated cemeteries A hall designated for ritual washing and encasing corpses. However, there is no proof that the Bimaristan is connected to a private cemetery.	
Administrative zone	Diwan of Bimaristan The front columns separating the northern iwan from the courtyard allow for visual connection. It is intended for the bimaristan's gradians and the nurses. There is a hall to the north of this iwan that might have been used for patients in intensive care. The physicians and employees accommodate in the next floors, which are accessible from this hall through a stairway. Manager office There is also a place reserved for the nazir (director) of the bimaristan in a corner of the courtyard.	
Religious zone	Mosque As mentioned above, this complex includes religious elements. The mosque, which is a religious element, has a significant area in the complex. It is of the iwan type mosques. Mausoleum There is also a mausoleum covered with a dominant dome on the facade of the complex. Only those religious elements overlook the main façade.	

Educational zone	The educational component was of particular significance in Qalawun complex. Where the sciences of jurisprudence and religion are taught, in addition to the sciences of medicine and pharmacy, due to the presence of the Bimaristan, which provides the practical part of the study. Like any other teaching hospital nowadays. The school is located in the upper floors of the mosque.	
Residential Zone/s	<u>Residences for doctors, and workers</u> The physicians and employees accommodate in the upper floors, which are accessible from the northern hall above the northern iwan through a stairway. <u>Residences for scholars</u> The mosque's upper floors house the school and the rooms where students and teachers accommodate.	 Entrance from the mosques's courtyard to the schools and accommodations (Nafees, 2021)
Charity zone	<u>Sabil</u> The whole complex is considered as a charity work. It serves religiously, educationally and medically. However, we can notice infront of the building a sabil. It was a basin for drinking animals, it was deep and paved. But Al-Nasser Muhammad rejected the ugly image of animals in front of this huge complex building, so he converted it into a water sabil for people. It is considered one of the oldest sabils after the sabil of the Zahiriya school.	 The Sabil at the entrance of the complex (*Qalawun Complex | Civilization Lovers*, n.d.)
Recreational zone	<u>Courtyards</u> In this complex, specifically, and in Islamic design in general, courtyards are a crucial component. As can be seen, the center of each zone in the bimaristan is an open courtyard. It aids in providing natural lighting and ventilation. This creates a sense of comfort for the patients and that they are not isolated or locked in a closed building. These yards usually contain plants and greenery, such as basil and plants that improve the psychological state of the patient and fasten the recovery process.	 Main courtyard in the bimaristan (Nafees, 2021) 

Fountains

Each courtyard has a water fountain. Which helps in the same mentioned process, as courtyards, and also completes the cosmological Islamic concepts.

There is a water fountain not only in the courtyards, but there are also some other areas that needed to be covered, such as the areas reserved for the care of female patients. It was designed so that the fountain is situated in the center of the space, in order to achieve the principle of centralization in Islamic architecture.



4.2.1. Araghun Bimaristan as an Example of Syrian Bimaristans During Mamluk's Era

Generally, in Syria, the sources that chronicled the history of medicine in the Islamic state mention that the first fixed hospital established in the Levant was in Damascus, and its establishment dates back to the caliph Al-Walid bin Abdul-Malik. Then the Bimaristan of Antioch, which was built by Al-Mukhtar bin Al-Hassan bin Batlan, who died in 1063 C.E. Then the great al-Nuri bimaristan built by the king "Nur al-Din Mahmud ibn Zangi" in Damascus.

1. Main entrance. 2. Main corridor (entrance lobby). 3. Central court. 4. Southern and Northern Iwans. 5. Corridor. 6. Corridor. 7. Service entrance corridor. 8. A main unit consisting of rooms. 9. Another unit consisting of eleven small rooms. 10. Court.

Figure 5. Floor plan of Arghun Bimaristan Aleppo, Syria (Asslan, 2023)

In this section, we analyse a historical mediaeval hospital called Arghun Al-Kamli (Figure 5) or Bimaristan al-Arghuni, also known as Argun Bimaristan or Arghun al-Kamili Bimaristan, is situated in Aleppo, Syria. It was constructed in 1354 C.E.by Arghun Al-Kamli, the Mamluk sultanate's representative in Aleppo. The bimaristan has three primary wards: one is for serious cases, one is for cases of common diseases, and one is designated for ladies and also has a portion for convalescence. The historic city of Aleppo, which

includes the Bimaristan of Arghun Al-Kamli, one of the most significant hospitals ever constructed in the Islamic world, was included as a UNESCO World Heritage Site in 1986 C.E. (Abou-Saleh & Salloum, 2020).

Table **5** includes the architectural analyses of Arghun bimaristan at Apollo.

Table 5. Analysis El-Arguni bipartisan according to the main zones of the traditional bimaristans and their contents (Table 1)

Functional Zones	Architectural Elements	Location in Floor Plan
Service/s	 <u>Portals, doors, and walls surrounding the bimaristan.</u> Main entrance on the main road leading to the entrance lobby which apart from its role in inner circulation was also used for patients and inspection and medicines distribution. The entrance is protected by a wrought iron fence. Islamic ornaments on the main entrance facades (Nizamoglu, 2012)   (David & Degeorge, 2002) An internal door covered in ornamented copper sheets. <u>Service entrance</u> on the lower right side of the plan leading to the main service corridor which intersects with the above-mentioned corridor in a covered squared lobby.	 

Control and guard rooms.

Guard rooms for the building are not specified in the plan or mentioned in any references.

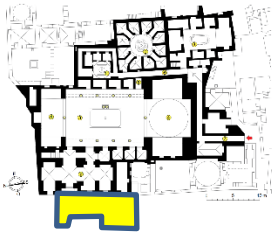
Internal corridors.

Small corridor on the upper right side of the court leading to the internal zones specialized in medical uses, accommodation, and services.

Main corridor reached from the above mentioned one and leads to the three main zones specialized in medication and accommodation.

The foyer and the corridors of the bimaristan and its bays.

The main entrance lobby leading to the central court was being used for patients' inspection and distributing medicines among non-resident patients (pharmacy).



Kitchens, pantries, and food preservation.

On the right side of the plan next to the service entrance, linked with other zones through the service corridor.

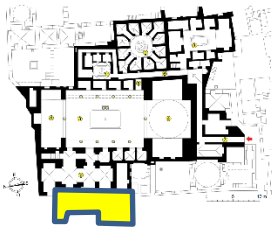
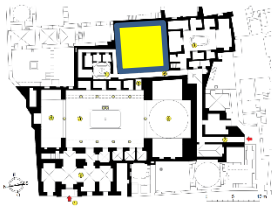
Baths and rest house.

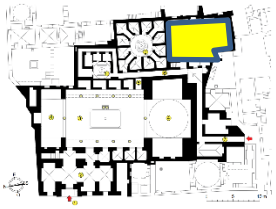
There is not enough data documenting their location.

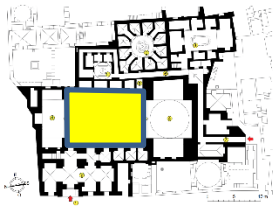
Stone clock tower.

Nothing on the site or in the literature suggests that this bimaristan has a clock tower.

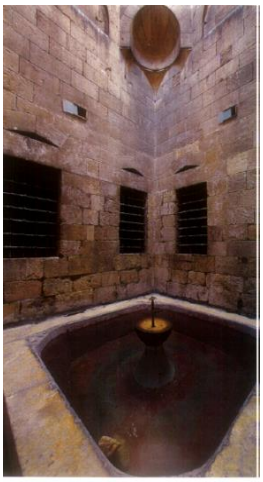
Vehicle parking.

	Nothing on the site or in the literature suggests that this bimaristan has a vehicle parking.	
Medical zone/s	Outpatient clinic. The main entrance lobby leading to the central court was being used for outpatients' inspection and	
	Pharmacy. The main entrance lobby leading to the central court also played the role of a pharmacy distributing medications among non-resident patients.	
	Iwan/s of Bimaristan. The two Iwans were used for several functions among which was for organizing meetings. (Naqvi, N., 2012)	
	Mortuaries and affiliated cemeteries There is not any evidence on the presence of either of them.	
	Five treatment rooms accessed through a rectangular central court having a water fountain in its center.	
	Nine small treatment rooms with a central court with a water fountain in its center.	
	Accommodation zone consisting of a central court with a centralized water fountain and four accommodation rooms overlooking the court through windows covered with steel mesh, the four rooms are not accessed from the court but through the surrounding corridor on the outer perimeter of the four rooms. This zone was devoted to patients with psychological or mental problems. The court is covered with a dome having a square wide	

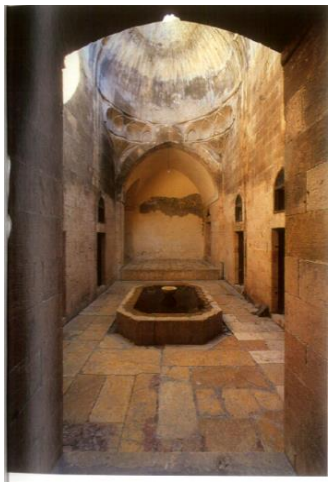
	opening. (Naqvi, N., 2012)  Steel mesh covering accommodation rooms' windows overlooking the court. (David & Degeorge, 2002)	
Administration	Diwan of Bimaristan The two Iwans were used for several functions among which was for organizing meetings. (Naqvi, N., 2012)	
	Manager office This area played several roles among which was arranging meetings within it. (Naqvi, N., 2012) But still the manager's office is clear whether existed or not.	
Religious zone	Mosque No evidence.	
	Mausoleum No evidence.	
Educational zone	The two Iwans played also an educational role in the building. (Naqvi, N., 2012) This central court and surrounding rooms were reportedly used in educational functions. (Naqvi, N., 2012)	 

Residential zone	Residences for doctors, and workers Not defined.	
	Residences for scholars Not defined.	
Charity zone	Sabil There is no evidence of its presence, but the whole building could be considered as a charity zone because it provided medical and educational facilities free of charge for all clients regardless to their origins or status.	
Recreational zone	 Courtyards A large central open courtyard with a centralized rectangular water fountain, leading to two Iwans which are covered with domes (David & Degeorge, 2002). A composition that reflects clearly the influence of Islamic Architecture being explained in the previous section of the research. The two Iwans were reportedly used in several functions among which were recreational activities as playing music and singing as it was well known in Arabic culture that music was used for treating some sorts of diseases. (Naqvi, N., 2012) Three other smaller courts with central fountains are the main core of the three treatment zones. The main central court with aisles and water fountain (David & Degeorge, 2002)	 

Fountains



Water fountain in the center of the court (David & Degeorge, 2002)

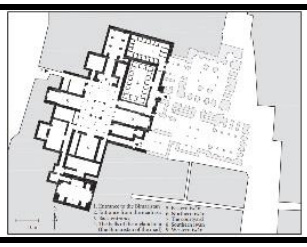


Internal court with a centralized water fountain.(David & Degeorge, 2002)

5. Results

From the previous analyses we can stand on a number of results. The chosen Egyptian case-study was built after that from Syria. Accordingly, the founder considered some elements that was missing in the Syrian bimaristan. That in addition of political and economic reasons. The following table illustrates the between El_Mansouri bimaristan at Egypt and El-Arguni Birmaristan at Syria.

Table 6. The difference between El_Mansouri bimaristan at Egypt and El-Arguni Birmaristan at Syria according to the architectural principles of designing traditional bimaristans in Islamic communities

			
Services zone/s	Portals, doors	√	√
	walls surrounding	X	X
	Control and guard rooms	X	X
	Internal corridors.	√	√
	The foyer and the corridors of the Bimaristan and its bays.	√	√
	Kitchens, pantries, and food preservation.	√	√
	Baths and rest house.	√	X
	Stone clock tower		
	Vehicle parking.		
Medical zone/s	Outpatient clinic.	√	√
	Iwan of Bimaristan	√	√
	Pharmacy.	√	√
	Mortuaries and affiliated cemeteries.	√	X
Administrative zone	Diwan of Bimaristan (office)	√	X
	Manager office (Nezara).	√	X
Religious zone	Mosque	√	X
	Mausoleum	√	X
Educational zone	Medical schools.	√	X
	Library.	√	X
Residential zone	Residences for doctors, teachers and workers	√	X
	Residences for scholars	√	X
Charity zone	Watering, sabil, and Almzamliyah.	√	X
Recreational areas	Courtyards.	√	√
	Gardens	X	X
	Fountains	√	√

From this table we can notice that the service zones in both bimaristans are almost equal. Both of them didn't include security walls or boundaries or guard rooms. Since each of them derived the element of protection from the being adjacent to other buildings of importance. Therefore, the fronts of the bimaristans were not directly overlooking the streets, and therefore were not exposed to any direct attack.

The presence of a tower clock on one of the Bimaristan's wall towers served to identify the Islamic Bimaristans. Usually, it was located at the main entrance, like the minaret for the mosque. Where it was erected, to remind the times of prayer and working hours and official works within the Bimaristan.

Additionally, given how crucial it is for patients to receive medication and therapy in accordance with the doctors' recommendations, it is vital to know the precise time (Akram Muhammad Yahya, 2018). However, the study reveals that the bimaristans that were examined and studied for this research lack this stone clock tower as an architectural feature. This is most likely caused by the fact that the bimaristan is a part of a larger structure that includes a mosque. Large minaret in this mosque provides the same function, and locals are aware of the appropriate times for their diverse needs.

The only difference between the two case studies in the service zone is the absence of rest rooms in the Syrian bimaristan, despite, bathrooms are important because the Islamic culture requires and enforces their constant hygiene, so that believers can perform the other aspects of devotion. This is in addition to the fact that bathrooms are vital for hygiene and sanitation purposes in the bimaristan.

Also, bimaristan Argun did not include an area for ritual washing for dead bodies, however this service is provided in the Mansouri bimaristan. The service of ritual washing for dead bodies, as well, must had been provided in another structure nearby the place.

In addition, we can notice that administrative, religious, educational, residential and charity zones are not considered in Argun bimaristan, while they are considered in El-Mansouri one.

Concerning recreational areas both of them included, where they have open courtyards and water fountains, but both of them missed open gardens. However, they used greeneries inside the courtyards.

From the cosmological point of view, we can notice that the design of both bimaritans followed the spiritual and cultural aspects of Islamic communities. Both buildings are iwan type building that achieve unity and multiplicity principle. Also, they used courtyards as the core of central point for the internal zones. Eventually, we can claim that both of them can be considered as a model of the domestic Islamic architecture.

6. Discussion

The purpose of the study was to study the architecture of bimaristans in communities that adopt Islamic culture, by making a comparative analysis between that in Egypt and in Syria during the Mamluk's era. That building type, in the studies of traditional Islamic architecture is very few. This paper focused on Egypt and Syria because those illustrated case studies are documented and still intact. The methodology helped in reaching the findings by introducing the mentioned or studied bimaristans to choose from them the most suitable case studies. Then, introduced the elements that mostly included in that building type. Finally, compare between those architectural elements from the formal point of view and justify points of similarities or differences.

From the previous architectural analyses of the bimaristans *Al-Mansouri* and *Argun,* that were built during the Mamluk's Era, we can notice obviously that both of them were following an architectural prototype, similar to that mentioned by Akram Yahya (Akram Muhammad Yahya, 2018). Such a prototype is a reflection of the impact of the Islamic culture of both communities. For example, considering having a core or center to achieve the idea of interiorization in Islamic architecture. This core is surrounding by iwans, and iwans are surrounded by the functional spaces to achieve the idea of unity and multiplicity in Islamic architecture (Gabr, 1992). However, each of Egypt and Levant has it own architectural character that cast it shadow in their bimaristans. That appears on the detailed architectural elements more that the form of the building as a whole. For instance, the domes see Figure 6, we can notice from the interiors that the dome in Syria still influenced by the roman characteristics. The dome in Arghun bimaristan is semicircular with an oculus in the top middle. That feature cannot be seen in the Egyptian territory. However, structurally wise the architect used tiered squinches to transfer the squared space into a circular cover. That treatment flourished during the Islamic consequent eras especially since the Ayyubid dynasty. Here we can physically distinguish the Islamic cultural influence on the layers of civilization that passed by Syria.

Such details confirm that each Islamic region keeps beneath its details its regional features and forces of influence that formulate its architecture.

From another point, many academics believe that Bimaristan al-Mansouri was placed behind the mosque and mausoleum because of political considerations. They explain that the founder was determined that the bimaristan be linked with name as a charitable institution, in order to enhance his political influence both while he was alive and after his passing. Without sacrificing any of the façade's significant political importance, the bimaristan would be annexed to his cemetery and school. In their perspective, it was not a coincidence that the bimaristan was hidden behind the mausoleum and the school; rather, it was done with political purpose. No one would be able to enter the bimaristan without first passing through the school and the mausoleum (Rabbat, 1992).

(a) ("Sultan Al-Mansur Qalawun Collection," 2023)

(b) Interior of the dome (by author, 2017)

Figure 6. (a) the dome of El-Mansouri complex, (b) the dome of Arghun bimaristan.

While the designer's technique supplied the factors of safety and calm, which are typically considered in Islamic bimaristans. The technique is to completely surround the Bimaristan with less significant structures, with no emphasis whatsoever placed on the entrances.

Concerning missing the rest rooms in Argun bimaristan, this is a very strange information, and our assumption is that, either it already exists but has not been registered, or there is a nearby bath area that serves the Bimaristan, or this point was not taken into account in the design of this building.

That theories provide practicians and scholars in Arabian or Islamic communities with the architectural tools from the traditional treatments whether for the building as a whole or its details. Architects who work with such communities

7. Conclusion

During the course of this investigation, information collection proved quite challenging due to the dearth of references addressing the architecture type of bimaristans. Many of them also physically vanished owing to environmental and social circumstances, in addition to their bodily departure.

On the other hand, in order to chronicle what has been destroyed as a result of environmental and human factors, research into the history and architecture of bimaristans must be expanded, especially in terms of tracing their archeological traces. Consequently, it can be examined, analyzed and creative hypotheses can be drawn to support historical, and architectural research can be developed.

From this analysis we can state that the bimaristans in Egypt and Syria have their prototype, unless each territory keeps between its architectural elements details that reveal its identity and tell about each layer of civilization that this region passed through. This research is considered as a piece of puzzle in the field of research concerning the architecture of Islamic bemaristans. This field needs efforts for documenting architecturally bimaritans that demolished, however described and mentioned by many historians. We need to make a reconstruction for each of them. Also, by comparing between bimaritans in different regions in the Islamic world that helps to complete the picture of this place that time, recognize and link more circumstances that occurred.

Studies concerning the existing bimaristans, need to be more precise, as we assume that there are some zones must have been considered in Argun bimaristan but not documented.

Contemporary architects, who deal with this type of heritage building, must take into account what has been mentioned regarding the initial principles of design, which have been extrapolated from what has been inherited through different eras, taking into account the cultural and social aspects, when making any renovations for the continued use of the building.

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The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

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Studies involving animal subjects: No animal studies are presented in this manuscript.
Studies involving human subjects: No human studies are presented in this manuscript.
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Conflict of Interests
The author declares no conflict of interest.

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Networks, Cycles and Urban Metabolism. Mapping Critical Environment: Giugliano in Campania (Naples) as a Case Study

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ABSTRACT

The waste areas in Giugliano intercept the continuity of infrastructure networks and the reticular dimension of ecological connections, returning a porous structure that crosses the urbanized areas. This condition inevitably overlaps the processes of land consumption still in progress. The process aimed to map this critical condition was based on the interaction of some analytical-specialist readings from different sources using multiple GIS tools. The process results are represented in a system of integrated maps that provide data relating to the crisis of five life cycles (ecosystems, production cycle, waste cycle, infrastructure and urban fabrics). These dynamics give us a heritage of socially, ecologically and economically disadvantaged landscapes with immense potential for adaptation, reuse and recycling projects. The research has revealed a distinctive geography of place, even at a larger scale, where materials and relationships constitute the structure of the territory. The contribution presented was intended to recount a process of knowledge and planning for an emblematic territory such as Giugliano in Campania, in which the role of mapping critical landscapes that become potential materials for a project of adaptation, reuse and recycling is central. To overcome the current critical situation, it is essential to recover the environmental frames still capable of narrating the territory and use them as a strategic resource for the creation of new urban landscapes and for a Strategic Plan focused on regeneration.

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1. Introduction: The Landscape of Giugliano as an Interpretive Device

The Domitio-Flegreo Coastal Plain plays an important role as a connecting link between the conurbation north of the Metropolitan City of Naples and the dispersed city (Indovina, 1990) to the south of Caserta. The city of Giugliano in Campania is strategically located right in the center of this vast territorial nexus. The municipality is home to 123.697 inhabitants and covers an area of 94.62 square kilometers. It is the second-largest municipality in the Province of Naples in terms of population size and

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the third largest in the Campania region, following Naples and Salerno. Nationally, it is the most populous non-capital municipality after Cesena in Emilia-Romagna.

From a morphological perspective, the Coastal Plain slopes gently towards the extensive coastal strip from east to west, where significant archaeological and natural heritage sites are concentrated, and sporadic low-density settlement expansion has occurred. In contrast, the eastern quadrant features a highly urbanized and infrastructural territory, characterized by distinct environmental and functional diversities. In between lies the vast plain, marked by the strong grid pattern of historical agricultural design.

Within the area of the city of Giugliano, three major urban areas can be distinguished, each with distinct landscape and settlement characteristics: (1) the consolidated urban center, (2) the extensive central agricultural plain, and (3) the coastal strip corresponding to the Licola Mare fraction:

1. The first area, the consolidated urban center, is one of the most densely populated portions of the northern peripheral expansion of Naples, characterized by a fragmented fusion of urban centers from different municipalities. These centers predominantly serve residential purposes with limited urban features, face significant problems of insufficient internal infrastructure and service provision and exhibit a strong dependence on the regional capital. In this context, the settlement of Giugliano, in line with the typical urban growth process of rural nuclei in the province of Naples, is structured around its historic urban center, which is based on certain strong traces of Roman centuriation. The settlement has experienced recent expansions along the main communication routes radiating from it towards Naples, Caserta, Acerra and Casoria, Quarto, and the coastal areas, incorporating some important former administrative fractions.
2. The second identified area is part of the agricultural plain of Aversa, to the east of the populous fractions of Qualiano and Villaricca. It corresponds to an extensive, fertile, sparsely inhabited agricultural plain punctuated by farmsteads, rural buildings, and single-family residential structures. It is crisscrossed by a dense network of drainage channels and artificial canals inherited from ancient and recent water reclamation and regulation processes. This network extends up to the coastline, traversing a significant portion of the Giugliano territory and guiding the layout of its agricultural patterns (farm roads, inter-farm roads, cadastral plots, boundaries). After reaching certain artificial watercourses and the Regi Lagni, this network flows north of the Lago Patria coastline, while to the south, after intersecting the main drains of the "Canale di Quarto" and the "Alveo dei Camaldoli", it reaches the sea between the Varcaturo estuary and the Lido di Licola, at the center of the Domitio coast. This landscape is characterized by sequences of cultivated fields (orchards, tomatoes, legumes, artichokes, beets, and other fresh produce) and intensive greenhouse production (strawberries, kiwis, early crops), representing fertility, productivity, and intensity in agricultural production cycles, which are now at risk due to the pervasiveness of water and soil pollution processes.
3. The third area, the Domitio coastal strip, although smaller in size compared to the previous ones, is characterized by its distinctive natural and historical-settlement features. Morphologically, it is defined by the presence of dune systems and the historical water patterns that have shaped it. Within this area, the main archaeological resources are concentrated, such as the remains of the ancient Roman city of Liternum near the southern shore of Lake Patria, as well as the historic-architectural resources, consisting of a significant number of farmsteads scattered throughout the territory. From a naturalistic perspective, the coastal area is primarily characterized by a low, sandy coastline, where surviving sections of the coastal dune coexist with extensive pine forests and dense Mediterranean scrubland, albeit suffering from progressive soil erosion, abandonment, and frequent fires. This area has experienced widespread residential expansion with villa and apartment subdivisions, creating isolated and single-function settlements, such as Varcaturo, during the 1980s and 1990s. Over time, these settlements have been subject to real estate dynamics and social transformations that tend to exacerbate phenomena of

degradation. The northern sector of this area is characterized by the presence of the natural water body of Lake Patria, with its interesting ecosystem now compromised by significant water pollution and the presence of low-density residential development occupying a large part of the south-eastern shoreline.

By crossing and observing this vast area today, one can notice that it is the result of a long process of alteration and stratification, which experienced a rapid, diffuse, and confused development on the territory in the second half of the 20th century, lacking any political and design strategic vision. This process has inevitably led to the growth of new and dramatic inequalities, giving rise to new forms of social injustice that increasingly overlap with spatial injustice (Secchi, 2013). The consequences of these dynamics dangerously intertwine with the outcomes of the waste cycle crisis, land consumption, disposal and abandonment of tourist-accommodation properties, etc., resulting in a sudden and structural change in the urban metabolism of these places. They have moved away from the images of Campania Felix and are now represented in the media through the stigma of the "Land of Fires".

The reflections presented in this contribution were developed during the preparation process of the Preliminary Urban Plan (PUC) of the City of Giugliano in Campania. This process necessitated a multiscale approach, attempting to bring together the multiplicity of information and resources present in such a stratified and complex landscape, one that encompasses many of the issues that can be found in cities today. The complexity of these territories requires a transformation in the approach to knowledge for those who observe them, in which the landscape plays a central role as an interpretive device. This involves intersecting various modes of investigation, such as field visits and direct experiences, engaging with the communities that inhabit these places without prejudice, as well as collecting data through digital platforms provided by specialized studies, systematized within a GIS environment and processed using other digital tools (Terracciano, 2017). For these reasons, this study is part of a much broader spatial planning context, with the ambition to contribute to the ongoing debate in the field. These reflections can have a tangible impact on spatial planning processes in other urban settings. Through a multidisciplinary approach and in-depth case study analysis, this research offers new perspectives and practical solutions to contemporary urban and environmental challenges.

2. The context: Ecological-environmental and social impairment

The territory of the municipality of Giugliano is completely contained within the Site of National Interest (SIN) "Litorale Domitio Flegreo e Agro Aversano", established by Ministerial Decree of 10 January 2000 according to Law 426/98 and comprising 59 municipalities, to which a further 18 were added by two subsequent Decrees (Ministerial Decrees of 8 March 2001 and 31 January 2006), in the Provinces of Naples and Caserta.

As also reported by ARPAC, based on the provisional perimeter Decrees, within the perimeter of a SIN the surface area, regardless of the exceeding of the Contamination Threshold Concentrations (CSCs) in the individual areas, is potentially contaminated and as such, subject to the clean-up procedure. This site has identified about the danger of exposure to health and ecological risks about the extension and population density of the area and provides for sub-perimeter, characterization and reclamation procedures according to the laws in force (Title V "Remediation of Contaminated Sites" of the Fourth Part of Legislative Decree 152/06, art. 252). The spatial consequences of the previous economic crises are still clearly visible today, and here more than elsewhere they also intercept the crisis of the waste cycle and land consumption. For years, this area has not only been at the center of the state of emergency for the waste cycle crisis - declared in Campania on 11 February 1994, which lasted until 31 December 2009 and was led by no less than ten different extraordinary commissioners - but has also been the subject of illegal disposal operations of special waste, leading to the deep and widespread pollution of the territory. The data reported by studies are alarming: in the last 30 years, 13 million tonnes of waste have been disposed of in Giugliano, either legally or illegally.

This system of deep pollution is intertwined with widespread practices of abandoning waste that invades agricultural fields, road junctions, canals and infrastructure buffer zones and whose disposal has taken place and continues to take place through fires in various parts of the territory, producing large quantities of dioxin that spread through the air and surface waters to neighboring lands. In addition to these compromises to the environmental quality of the agricultural landscape, there are also unplanned urbanizations that contribute to the fragmentation of the agricultural matrix.

Following the entry into force of Ministerial Decree 11/01/2013 (Approval of the list of sites that do not meet the requirements of paragraphs 2 and 2-bis of Article 252 of Legislative Decree 3 April 2006, no. 152 and that is no longer included among the remediation sites of national interest, GU Serie Generale no. 60 of 12-03-2013), the "Litorale Domitio Flegreo and Agro Aversano", the "Bacino Idrografico del Fiume Sarno", the "Litorale Vesuviano and Pianura" areas were excluded from the list of SINs. Thus, the "Litorale Domitio Flegreo and Agro Aversano" site to which the municipality of Giugliano in Campania belongs has become a regional site and is therefore designated as a SIR (Site of Regional Interest) .

For the sub-perimeter sites within these ex-SINs, which have not yet been subjected to environmental investigations, the Campania Region has established the obligation to carry out preliminary investigations (Executive Decree no. 796 of 09/06/2014). With D.G.R. no. 417/2016 (Approval of the Technical Implementation Regulations (NTA) of the Regional Land Reclamation Plan) the "Guidelines for the preparation and execution of preliminary investigations" were defined, aimed at ascertaining the presence of pollution in the environmental matrices affected by an event that could contaminate them. As reported in the 2013 and 2019 Regional Remediation Plan, the criteria for carrying out preliminary investigations are differentiated according to the type of sites and the size of the areas to be investigated and concerns:

- Landfills.
- Disused or abandoned mining activities.
- Waste treatment plants; active and abandoned production activities; RIR industries.
- Hydrocarbon storage sites, active and abandoned fuel outlets.

The geographic location of the census of potentially contaminated CSPC sites in the former SIN allows the identification of a series of areas, defined as Vast Areas (AV), in which the existing data suggest that the environmental situation is particularly compromised due to multiple polluted and/or potentially polluted sites. Within the 2013 and subsequent 2019 Remediation Plan, no. 7 Large Areas, including one in the territory of Giugliano in Campania: Area Vasta Masseria del Pozzo-Schiavi, for which, as for each vast area, within the 2019 Land Reclamation Plan, a sheet was drawn up in which the identification data of the site, the cartography with its location, the description of the component sites of the area, a summary of the available past investigations, the current state of the activities and the interventions to be implemented are reported, from which the simultaneous presence of two or more waste disposal sites, for which the various investigations carried out over time have highlighted contamination situations, can be inferred.

«The territory of the municipality of Giugliano is affected by 113 potentially contaminated sites covering a total of 6.75 km2, which represents approximately 8% of the Giugliano territory. The most impactful potentially contaminated sites from an area viewpoint are the quarries and landfills in the area. Among the contaminated sites at Loc. San Giuseppiello, Masseria del Pozzo - Schiavi dumps, the former Resit dump (Quarry Z, Quarry X) and Novambiente S.r.l., remediation work has been started but has not been completed. Of the entire potentially contaminated area, the only site with advanced reclamation works is the one in the San Giuseppiello area». In addition to these contents, which mainly affect the areas of the large agricultural plain and those of the coastal strip, there are also critical issues related to soil subsidence phenomena mainly present in some areas of the Historic Centre.

As several recent studies testify (Greenpeace, 2019), agriculture itself is not only a victim of this serious environmental situation, but is also partly responsible for it, not only because of the excessive use of synthetic chemicals, not entirely absorbed in the vegetative cycle, contributes to the contamination of air, water and soil, but also because the actions aimed at improving the usable agricultural species have in many cases forced the dynamics of regeneration of natural resources.

As regards the surface and underground water systems in the municipality, they too are characterized by a rather evident level of pollution. For the surface water system, the main critical issues are related to the Quarto canal, the Camaldoli bed and Lake Patria. For the Quarto canal and the Camaldoli bed, the presence of sewage and wastewater spills are proven, while for Lake Patria, the level of pollution is defined by the poor state of the waters in the classification for transitional waters that emerged from the surveys conducted by ARPAC. Moreover, the criticality of surface waters is not only related to their quality but also to flooding phenomena that characterize the Camaldoli riverbed in some places. This criticality is evident in the hydraulic risk tables contained in the "Piano Stralcio per l'Assetto Idrogeologico" of the former Central Campania Basin Authority, now merged into the Southern Apennines District Basin Authority.

The critical issues related to the groundwater system emerged through various measurement and monitoring campaigns of well water, which found exceedances of the permitted levels of certain pollutants, especially in the vicinity of landfills in the area. To summarise, the entire system of groundwater and surface water, of the soils directly exposed to polluting factors and those in any case affected by the transport of these factors through run-off, emunition and water absorption, to be affected by this general impairment process.

In addition to these crisis conditions of the water and soil system, there is also a particularly critical condition of erosion for the coastal strip, which is extremely anthropized due to the uninterrupted presence of bathing facilities and residential structures (Marina di Licola), which have contributed considerably over time to make the dune and back-dune ecosystem and the connected wetlands extremely fragile. The study of the evolutionary trend of the coastal sector, carried out within the framework of the "Piano Stralcio per la Difesa delle Coste" PSDC of the former North-Western Campania Basin Authority 2008 and the Coastal Erosion Plan of the Liri Garigliano and Volturno River Basin Authority, testifies to the evolutionary dynamics of the coastline and its progressive and inexorable erosion.

In this framework, the levels of vulnerability of urban areas due to the impacts of climate change (intense rains, heat waves, sea storms, etc.) remain to be investigated. Among the main factors that certainly need to be pointed out and analysed are the limited permeability of urban soils, due to the prevalence of asphalt surfaces over permeable ones, the lack of maintenance of current drainage and rainwater collection systems, as well as the meager and fragmented presence of green areas, and the poor quality of the construction materials used. An effective knowledge of the characteristics of the vulnerability of urban settlements to the various hazard factors induced or increased by climate change is indispensable not only to assess effective measures to guarantee their safety, but also to orientate choices in terms of regeneration and improvement of living conditions in urban contexts.

For these reasons, risk prevention and mitigation strategies must be based not only on the knowledge of the single factors of impairment, vulnerability and danger of natural and anthropic origin, but also on their reciprocal and possible interactions (See all the analysis papers of the Giugliano Environmental System: Water, geomorphology and natural and anthropised landforms; Water and evolutionary dynamics in land design; Land consumption and dynamics of vegetation cover; Urban metabolism and waste areas; Aggregate risks.

3. Material and Methods: methodology and objectives of the case study

This contribution aims to show the outcomes of the narrative of the Giuglianese landscape features. This work has been a complex process, characterized by a multi-scalar dimension, the outcome of the interaction and multi-disciplinary convergence between different areas of knowledge that have made it possible to construct an up-to-date picture of the territorial structure, the vegetal landscapes, the evolutionary dynamics of land use and consumption, the areas of environmental criticality and, more generally, the outcomes of urban metabolism and the more or less virtuous functioning of the city itself.

3.1. Tools

In planning processes, one must deal with the management of an imposing and heterogeneous mass of data to be superimposed and intersected to identify areas suitable or not suitable for a particular type of resource management and to understand where to implement certain plan choices. This method made a big breakthrough in the 1970s, when landscape architect and planner Ian L. McHarg developed a suitability analysis using a thematic overlay mapping technique he called Overlay Mapping (McHarg, 1969). Although this operation allows for the measurement, mapping, monitoring and modeling of land, as well as having the capacity to generate new data as a product of existing layers - particularly with the advent of GIS, which ushered in the era of computer-aided mapping - the maps and mappings obtained are very often inaccurate or incapable of capturing significant data streams leading to imperfect or false conclusions (Bailey, 1988). The overabundance of information, using super-clear and dense maps, in the superimposition of measurable and integrable thematic maps, however, generates problems for which the excess of certainty generates a simplification of the map, up to the construction of passive cartographies produced automatically by remote sensing, which however lack a critical reading, so that in the absence of a selection, these maps end up returning a selective and incomplete view of reality (Monmonier, 1991).

It is from this awareness that this research has endeavoured to build a methodology that involves a constant interaction between the virtual database in a GIS environment and the physical space of places. A continuous oscillation between the technical control of the data and the verification in the field, through visits and dialogue with the local communities. This method allowed us to organise and control all the information bases useful for the development of the research work, starting from the open-data portals to the incorporation of the geographic information layers by the competent bodies in the area, up to those of the specialised studies drawn up expressly for the Urban Plan of Giugliano. This procedure allowed us to combine different techniques and languages within a process of construction and manipulation of data, at different levels and scales, to bring out a drawing with a dry and essential language, capable of highlighting the characterised materials and latent questions of this territory that finally find form within evocative figures. The drawn figures tell some of the stories and dynamics of the landscapes of the Litorale Domitio-Flegreo and the Giuglianese area. These narratives convey not only the processes of territorial transformation from an environmental and morphological point of view but also and above all the socio-economic changes that have led to the crisis of certain cycles of life, such as that of production, waste, infrastructure and urban fabric. These dynamics are investigated in the form of layers of the GIS database, which constitutes a container of information in constant relation to each other, whose convergences and dissonances proactively suggest an opportunity to rethink these places.

3.2. Method

The knowledge process for the construction of the Environmental System of Giugliano (Figure 1) was based on the interaction of several analytical-specialist readings from different sources such as:

- The studies that supported the drafting process of the PUC: (1) the Geological Study, (2) the Agricultural-Forestry Study and (3) the Environmental Study "Main environmental criticalities of

the municipal territory of Giugliano in Campania, (4) the Municipal Census of abandoned (art. 30 L.R. 54/85), closed and active quarries (2018).

- The information coming from some digital databases: (5) the DEM Digital Elevation Model from NASA's Shuttle Radar Topography Mission SRTM (2014), (6) the Nature Map of the Campania Region: Habitat Map at the scale 1:25.000 (2009), (7) the Corine Land Cover in Campania updated by ARPAC Campania in agreement with ISPRA (2018) , (8) the Geoportal of the Regione Campania, (9) the CTR Regional Technical Map of Campania (2017), etc..
- The forecasts of supra-municipal and sector plans: (10) the PSAI-RI Piano Stralcio per l'Assetto Idrogeologico dell'Autorità di Bacino Campania Centrale (2015), (11) the PRB Regional Reclamation Plan (2013, 2017, 2019), (12) the PSdC Coastal Defence Stralcio Plan of the former North West Campania Basin Authority (2008), the (13) Piano di Tutela delle Acque Ciclo 2015-2021, (14) the Domitio Coast Master Plan by the Campania Region, (15) the Piano Regionale per la Gestione dei Rifiuti Urbani PRGRU (2016), (16) the Water Protection Plan (2017), (17) the Characterization Plan of the Giugliano Wide Area (2014), etc.
- Several sector studies such as: (18) the studies drawn up for Polluted, Contaminated and Potentially Contaminated Sites by ARPAC in SIN and ex-SIN sites, (19) the Italian Atlas of Environmental Conflicts18, (20) the Municipal Census of Abandoned Quarries (art. 30 L.R. 54/85), (21) the Studies of the General Reclamation Consortium of the Lower Volturno Basin, etc.
- The field surveys and virtual surveys through the Google Earth and Google Maps platforms, including the platforms: (22) Google Maps Digital Landfill Map, (23) the "Terra Dei Fuochi" Geoportal, etc.

The collection, elaboration and systemization of these data in a GIS environment have resulted in some interpretative readings contained in some of the Preliminary Drafts of the PUC of Giugliano which we will illustrate below, namely: Water, geomorphology and natural and anthropised landforms, Water and evolutionary dynamics in the design of the territory, Soil consumption and dynamics of vegetation cover, Urban metabolism and waste areas, Aggregate risks.

The realization of these analytical-interpretative maps constituted the starting point for the definition of an updated framework of Strategic Objectives and Project Actions that find their spatial precipitate in the Strategic Synthesis Framework and the Strategic Projects (Figure 8), aimed at defining the guidelines for a more overall requalification of Giugliano.

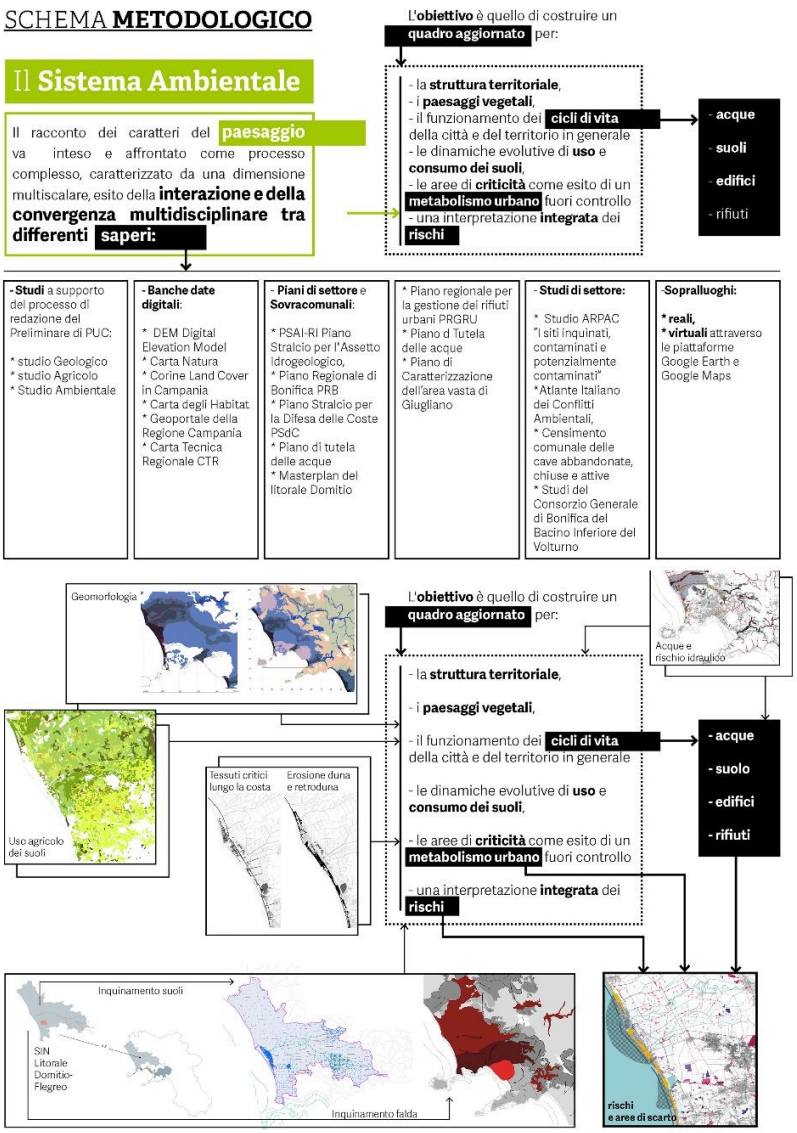

Figure 1. Methodological outline of the interactions between the objectives, sources and characteristics of the Giugliano Environmental System (Developed by Author, 2022)

4. Results: integrated maps with an analytical-interpretive character

This mapping process has returned a geography of places, endowed with a strong recognisability even at a vast scale, in which the materials that compose them and the relationships that exist between them constitute the structure of the territory itself and are of fundamental importance not only for its own understanding but also and above all for understanding the relationships that exist between the hydro-geomorphological and vegetation aspects, between the consolidated and recently expanded urban settlements and the agricultural contexts and coastal areas. In addition, the reading of the evolutionary dynamics and persistent features that have qualified the environmental structure over time provide an important opportunity to understand the criticality and vulnerability factors of the environmental and landscape systems in Giugliano, which are represented in the following maps.

4.1. Water, geomorphology and natural and man-made landforms

For the construction of this map, we started with the codification of some of the emblematic features of the Giugliano landscape, through the synergic use of different multidisciplinary knowledge that made it possible to update the territorial structure of the water network, geomorphology and landforms. These materials are superimposed on the dynamics of soil loss due to anthropogenic action and the identification of environmental criticalities such as hydraulic risk, the mapping of quarries and mining areas, landfills and storage sites, the survey of unstable and potentially unstable areas, geological and subsoil instabilities, and the study of soils saturated with water or potentially saturated due to the rise in the water table in the back dune areas where the soil level, in some places, is below sea level.and building matter" and where the net sphere must be superimposed on the natural and urban spheres.

Figure 2. Water, geomorphology and natural and anthropized landforms (Developed by Author, 2022)

4.2. Water and evolutionary dynamics in the design of the territory

The development of this map starts from an in-depth study of the cartographies and historical texts that have dealt with the evolution of water and its role in the territorial design of the Domitio-Flegreo coastline. Over the centuries, this great plain south of the Volturno River has seen a multiplicity of uses and different economies that have shaped and profoundly modified its landscape. In particular, the imposing work of land reclamation of the Regi Lagni, the largest hydraulic infrastructure in Campania

completed between the end of 1592 and 1616 under the direction of Giulio Cesare Fontana, made the typical alluvial lands of this area particularly fertile, thus dedicating them to agriculture. The post-reclamation landscape took the form of a complex system of canals that crossed the historic wetlands down to the sea, while at the same time building an articulated network of connecting tracks that encouraged the repopulation of the plain. The large number of farms and farmhouses present flanked the historic urbanization of the centers that had sprung up along the Roman centuriazioni, thus initiating an epochal change that transformed the nature of social and economic relations in these places. This great water machine, which has been capable of governing territorial development since the 17th century, has, however, in the last hundred years progressively become, in the media dimension, the skeleton of a territory sadly subjected to a widespread condition of degradation, abandonment and pollution. To superimpose the different layers of the water network, it was decided to photograph the territory in four different periods to highlight the territorial transformations following the manipulation and regimentation of water, in particular, reference is made to the "Map of the Naples environs" (1818) by the Royal Topographical Office, to the "Carta Idrografica e delle Bonifiche" (1889) edited by the Istituto Geografico Militare IGM, a mapping of the water network from the "Carta d'Italia" (1950) edited by the IGM, finally a restitution of the current state using the work edited by the Autorità di Bacino della Campania Centrale updated to 2017, in which the criticality of the areas subject to hydraulic risk is also highlighted.

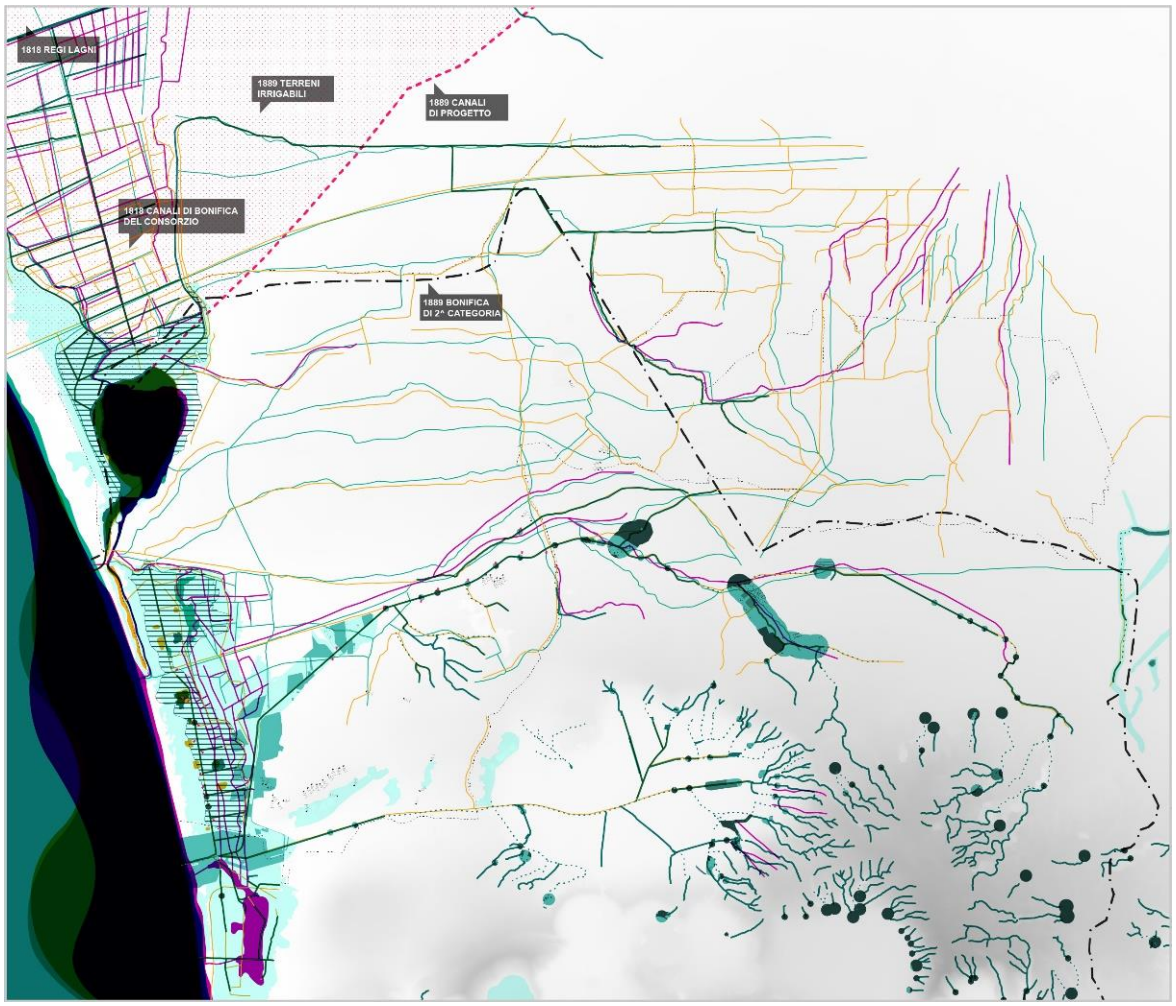

Figure 3. Water and evolutionary dynamics in land use design (Developed by Author, 2022)

4.3. Soil consumption and land cover dynamics

From this map emerges a territorial structure of fundamental importance not only for its own comprehension but also and above all for understanding the relationships that exist between the hydro-geomorphological and vegetation aspects, between the consolidated and recently expanded urban settlements and the agricultural contexts and coastal areas. In addition, the reading of the evolutionary dynamics and persistent features that have qualified the environmental structure over time provide an important opportunity to understand the criticality and vulnerability factors of the environmental and landscape systems in Giugliano. In this drawing, we can recognize the "Rural landscape matrices" composed of agricultural soils in particular arable land and orchards, the "Linear coastal landscapes" with beaches and the dune and back-dune vegetation system, and the "Urban ecological constellation" where the minute system of green pores, green spaces of historical and ornamental value, designed gardens, greenery and street furniture, outdoor and permeable recreational and sports facilities, and even the mapping of tree rows emerge. Superimposed on these landscapes characterized by the green system are drawn the "Landscapes of waste and compromise", i.e. an archipelago of materials in which the largely rural areas and consolidated urban nuclei fade towards an incessant and pervasive settlement dispersion, which generates discontinuities between the environmental networks with which it inexorably seeks to overlap. An image that we can reconstruct by broadening the horizon of our observation within a necessarily metropolitan dimension, in which the forms that these structures take on the territory transcend administrative limits. Specifically, the system of compromised and polluted soils, quarries and mining areas, landfills, specialized production and trade enclosures, areas that intensively exploit agricultural soils, and abandoned and degraded areas are restored.

Figure 4. Soil consumption and land cover dynamics (Developed by Author, 2022)

4.4. Urban Metabolism and waste areas

This map depicts the pervasiveness of pollution and the multiplicity of contamination factors, ecological degradation, the pervasiveness of land consumption and the consequent hydro-geomorphological fragility, the scarcity and vulnerability of water resources, the lack of adequate management of the waste cycle and, more generally, the spread of waste produced by partially or totally abandoned industrial supply chains, the seismic vulnerability of the built heritage and its energy inefficiency, are just some of the factors that are stressing Giugliano and, more generally, all the cities in the world at this historical stage, dangerously intercepting also the risks arising from climate change. In addition to the environmental issue, there are also the visible effects of the economic crisis and traditional development models, along with the social crisis expressed above all by the absence of fair access to resources and the right to the city. These dynamics hand us a legacy of landscapes that are socially, ecologically and economically disadvantaged but which return an immense capital of opportunities for adaptation, reuse and recycling. The areas of waste and abandonment in the Giugliano context also intercept the continuity of infrastructure networks and the reticular dimension of ecological connections, restoring a porous structure that crosses with the urbanized areas, inevitably overlapping with the processes of soil consumption still underway. In this sense, what we want to return with these readings is a geography of places that do not only configure a traditional critical porosity made up of disused areas and buildings, brownfields and residual spaces, but rather to broaden and specify a taxonomy capable of involving further urban and landscape materials affected by the exhaustion of economic, productive and ecosystemic life cycles to return more effectively not only the complex dimension of waste areas but also and above all the mechanisms and outcomes of an urban metabolism out of control. The outcomes of this process can be seen in this paper and can be mainly traced back to the crisis of five life cycles: (1) compromised ecosystems, (2) crisis of productive cycles, (3) critical tissue, (4) compromised infrastructure and (4) waste cycle.

Figure 5. Urban metabolism and waste areas (Developed by Author, 2022)

4.5. Aggregate risks

The investigations, studies and interpretative readings represented above give us for Giugliano a territory characterized by a multi-hazard dimension, affected by a multiplicity of hazard factors that have undermined and continue to make vulnerable a very complex territorial system. Although anthropic hazard factors constitute a threat that is sometimes less evident than natural hazard factors, they risk profoundly compromising not only the existence but also the possible use of the natural and anthropic resource heritage by future generations (Magnaghi, 2015). In the case of Giugliano, the greatest evidence is represented by the risks linked to waste flows that have constituted, over time, one of the main causes of long-term changes to landscapes, even with very significant impacts of alterations to natural resources and damage to the health of inhabitants. In addition, ineffective land-use controls have led to the development of vast residential settlements in high-risk areas.

This map is the result of the relationships and overlaps between two large families of hazards, viz: those deriving from (1) geological vulnerability factors, such as hydraulic vulnerability and hydraulic crisis points, areas subject to subsidence risk, landslide vulnerability, unstable soils, geological and subsurface instabilities, coastal strip vulnerability and seismic vulnerability and those arising from (2) anthropogenic vulnerability factors, such as impaired waters, marine coastal water quality, well water quality, mapping of sewage treatment plants and fugitive canals, mapping of risks from land consumption and fragmentation of ecosystems, in particular peri-urban sprawl and greenhouse areas, mapping of waste cycle management, highlighting landfills, storage sites and illegal disposal practices. For these reasons, risk prevention and mitigation strategies must be based not only on knowledge of individual natural and anthropogenic hazard factors but also on their mutual and possible interactions.

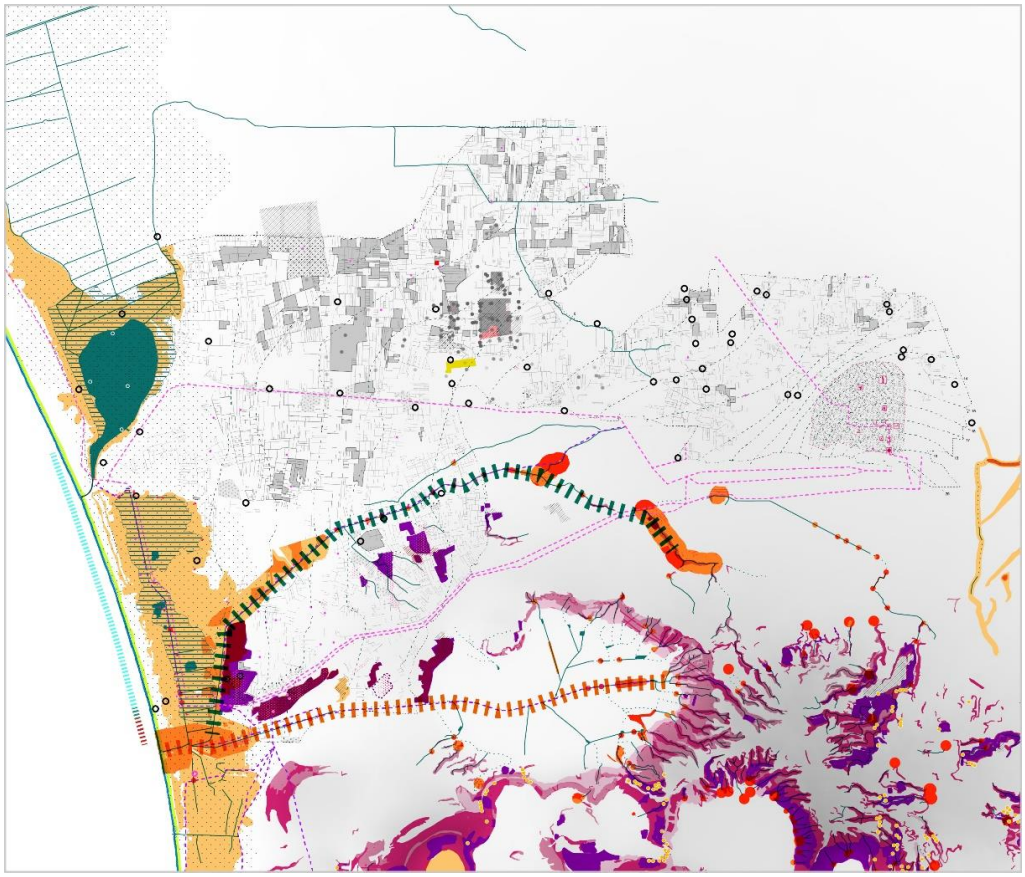

Figure 6. Aggregate risks (Developed by Author, 2022)

5. Discussion: the role of blue and green infrastructure in Giugliano as prospects for sustainable development

It is from a reading of the historical territory of Giugliano and the succession of settlement processes according to several significant temporal scans, that the degree of permanence and persistence that the networks of environmental infrastructures retain to this day as a load-bearing structure capable of innervating the entire dimension, while profoundly modifying itself through the urban, peri-urban and natural contexts, can be deduced. This founding, structuring dimension, endowed with enormous potential in terms of regeneration and rethinking for the multiplicity of Giugliano's landscapes, is conveyed through the synthesis framework contained in the blue and green infrastructures (Figure 7) which, crossing transversally all the analysis papers of the Environmental System, constitutes its inevitable outcome. To overcome the current critical scenario, it appears necessary to recover the life cycle of those environmental frames still capable of narrating the territory, revealing themselves as a strategic resource for the new landscapes of town planning and for the elaboration of a Municipal Urban Plan that proposes their regeneration. The historical landscape of the hydraulic reclamation devices becomes inescapable for the construction of landscape networks at different scales that can have the strength to propose new figures and new narratives for the Giugliano of the future, but also to redesign the territory incrementally, crossing the city along the environmental and infrastructural networks and building a generation of multiform and multifunctional spaces within which to place a qualified, updated and dynamic offer of welfare places, passing from a perspective of regulatory resistance to soil consumption to a strategy of production of new soil.

Through blue and green infrastructures, it is indeed possible to imagine working on a double level:

- A first level could concern the great territorial fixed capital consisting of the hydrographic network, the great agricultural plain and areas of naturalness, characterized by phenomena of environmental compromise and alteration, opening it up to new life cycles and focusing on resilient and adaptive systems capable of responding, at different scales, to changing context conditions. These are performance and structuring systemic interventions that inevitably overflow the municipal dimension and therefore also require new forms of inter-municipal cooperation (e.g. for the reclamation of the Regi Lagni and contaminated agricultural soils, the nourishment of the coastal strip, etc.) capable of defining new territorial development figures, linked to the coordinated action of institutional subjects and priority and long-term redevelopment and investment objectives.
- A second level could concern micro-interventions also linked to temporary practices in land use to give immediate answers to extremely fragmented territorial situations with two important purposes: the ecological one, to reconnect natural resources in support of large-scale interventions (e.g. the creation of river filter belts, phyto-purification areas, punctual biological reclamation interventions, etc.) and the social one, because micro-interventions are not only a way to improve the quality of life of the population, but also to improve the quality of life of the population) and the social one, because micro-interventions can be rapidly activated in confrontation with actors operating on the territory and involving a multitude of private subjects (farmers, small leisure entrepreneurs, dispersion inhabitants, occasional users of leisure spaces, niche tourists, etc.) and unusual geography of public subjects to implement and guarantee continuous maintenance of the interventions and the landscape itself.

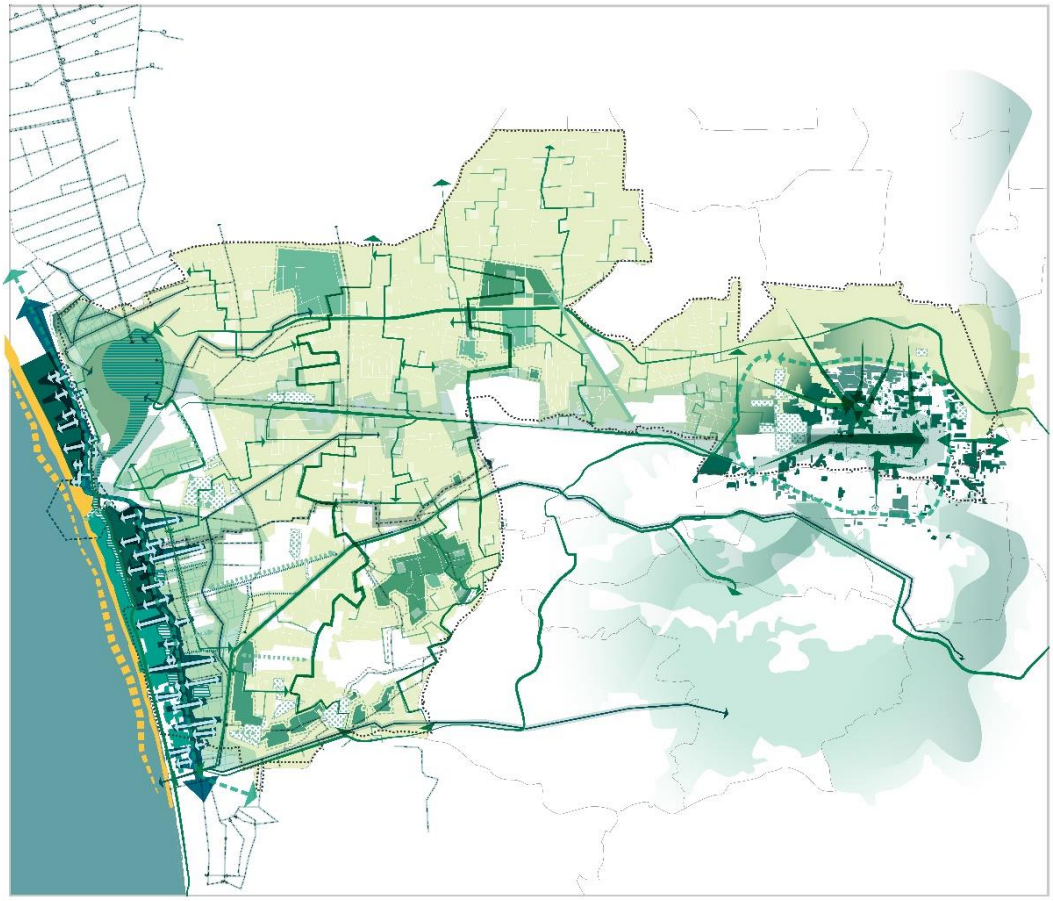

Figure 7. Blue and green infrastructures (Developed by Author, 2022)

6. Conclusions: Waste landscapes as a potential heritage for a reuse and recycling project

Taking into account this complex condition and the extreme fragmentation of this territory, starting from the synthesis of the fundamental cognitive-interpretive representations described up to now, considering the dimension of risks and the role played by blue and green infrastructures in this territory several urban and environmental regeneration perspectives have been outlined to try to hold these materials together while awaiting regeneration and redesigning, defining actions to stitch together pieces of territory, promoting public and alternative mobility to road transport and orienting risk mitigation to favour a polycentric network of services for greater social inclusion and interaction. The main strategic guidelines are outlined by referring to the co-presence and interaction of different declinations of the city's future the virtuous adaptation to the multiple conditions of natural and anthropic risk, also as an opportunity to qualify the coastal landscape for sustainable tourism; the consolidation of the agrifood production heritage of the vast Giugliano countryside and of a food chain linked to the growth of agro-biodiversity the prospect of hard and soft infrastructures aimed at consolidating sustainable urban mobility at the service of the entire urbanised territory, in close connection and integration with the rail and road network of the metropolitan area, also supported by new digital and energy networks; finally, the concrete start of a concentrated and widespread process of urban and environmental regeneration, to be accompanied by an economy based on recycling and a new urban metabolism, as well as a profound renewal of the building cycle centred on the regeneration of the existing city.

Based on these considerations, a system of strategic objectives and project actions was developed and graphitized in an Overall Vision (Figure 8). The strategic perspective is also completed by the identification of four Guide Projects (Figure 8) that correlate the priority project actions within specific narrative schemes structured around great signs of nature, history and urban and territorial infrastructures.

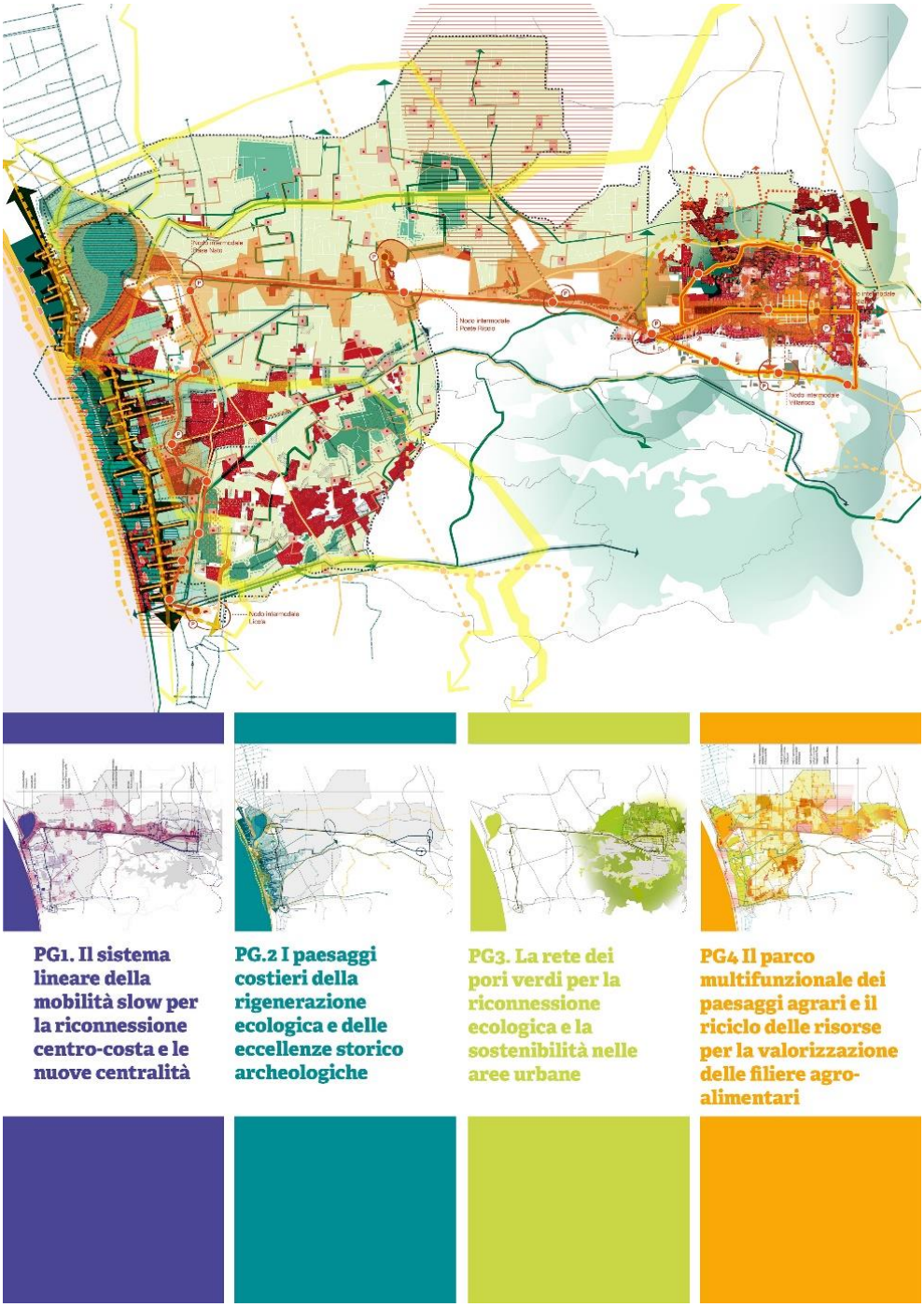

Figure 8. The Framework of Strategies and Thematic Strategic Projects (Developed by Author, 2022)

Overall, the contribution presented was intended to narrate a knowledge and planning process for an emblematic territory such as Giugliano in Campania, in which the role of mapping critical landscapes that become potential materials for a project of adaptation, reuse and recycling is central. The process aimed at mapping this critical condition was based on the interaction of several analytical-specialist readings from different sources, using multiple GIS and graphic post-production tools to be able to represent the complexity of these data and issues, which are often intangible or untraceable with conventional tools and methods. Of fundamental importance were the in-situ surveys that made it possible to recount these layered landscapes more closely, without any bias.

The results of this process are represented in a system of integrated maps providing data on the crisis of five life cycles (ecosystems, production cycle, waste cycle, infrastructures and urban fabric), which are fundamental for the construction of a vision of the future for the city of Giugliano in Campania represented in the Strategic Synthesis Framework of the Preliminary Municipal Urban Plan. Looking forward, it is critical to explore opportunities for regeneration of these landscapes and develop specific strategies for redevelopment. In addition, further insights and studies are desirable to better understand the interplay between these critical landscapes and urban planning, in a never-ending process that fosters continuous updating of both cognitive and strategic papers. This study is intended to provide a solid and integrable basis for future research aimed at promoting sustainability and resilience in urban areas undergoing continuous transformation, as well as a useful tool for local government.

In the presence of such complex and stratified places, it is necessary to rethink the methods of representation for this condition of complexity and uncertainty, to orient the project towards an open incremental process, with particular attention to the use of languages and communication, keeping in mind that to draw is to select, to select is to interpret, to interpret is to propose (Solà-Morales, 1979), in a collective path, maintaining the complexity and roughness of the territory (Poli, 2019). This is how some 'territorial figures' emerge, capable of capturing the shapes and dimensions of this territory, giving back evocations and conditions, represented in the Guiding Projects of the Preliminary Municipal Urban Plan. What emerges in these drawings is a series of landscape materials, new and sedimented, that merge with the practices and uses produced by different forms of interaction between environmental transformation and social re-appropriation, and that infuse a greater concreteness to the strategic dimension, producing a series of projects of open spaces for the community capable of meeting a need that has so far been largely unfulfilled.

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Data availability statement
The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

Ethics statements
Studies involving animal subjects: No animal studies are presented in this manuscript.
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Conflict of Interests

The author declares no conflict of interest.

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City Sediments in Beirut: An Urban Ecology Perspective

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ABSTRACT

Cities are products of urbanization processes, economic changes, technology and climate change. Adversely, in specific contexts, they are affected by wars' enduring physical effect, long after armed conflicts are over. Hence cities are perceived as dynamic organisms, in continuous change of spatial abandonment, neglect and regeneration process, unfolding a continuum of space and time. In tandem between urban ecology and the urban history specificities, this paper addresses Beirut as a case study in its actual condition, and the different representations of the informal resurgence of green areas. It follows a methodology of identification and mapping of the different urban sediments which constituted over time potential reservoirs for urban ecology. These include previous war demarcation line, train tracks traces, cemeteries, destroyed wheat silos following the 2020 port explosion and other liminal spaces. This approach brings in a new perspective for approaching urban ecology differently according to the urban contexts historiography.

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1. Introduction

The prevailing notion on urbanization has long been, that as cities grow, nature shrinks. While more than half of the world's population lives in cities, a ratio expected to reach 68% by 2050 (UN, 2018), cities represent the direct threat to nature. Lately urbanists are concerned with the increasing consumption of energy with gas emissions reaching 75% of global CO2 emissions (UNEP). Therefore, beyond representing the antipode of nature, cities, as a scientific fact, became mainly responsible of climate change. With these facts in mind, the discourse is shifting away from the nature-city perspective to further exploring underpinning notions and principles between ecology and city. Over a decade ago, Mostafavi and Doherty (2010) first coined the term '*ecological urbanism*', tapping into ecological matters in urban contexts. Linking the urban discipline with the science of ecology became an increasingly important discourse across various disciplines. While some discourses address the fluid expansion and flows of natural ecosystems and the urban patterns changes over time (Beck, 2013; Forman, 2014), many discourses focus on the development between human and natural ecosystem processes in urban contexts (Corner, 2006; Danilo and Steiner, 2011). Setting principles and guidelines for the link between

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urban ecology and the built environment became an important objective in many works (Niemelä et al. 2011; Pickett and Cadenasso, 2017). Forman (2008) first published in his book a roster of urban ecology principles linking the science of ecology to the spatial constituents of the city. This link was further elaborated into a more extensive list of principles in his subsequent book (2014). The latter were further synthesized to other authors' scholarly work in the same field and consolidated into a fully comprehensive list of 90 principles in Forman (2016). These principles were inspiring for this article and as further described in the methodology section, will serve as a benchmark for the findings. Concurrently, rather than studying the shrinking or growing boundaries between the urban environment and the natural ecosystem as antagonistic systems, *Ecological urbanism* (Mostafavi and Doherty, 2010) is a mind-opener concept for delving into the city resources and the opportunities they could bring forth to an ecologically balanced urban life. A major role of *Ecological urbanism* is to explore the relationship between the spatio-temporal patterns of urbanization and the ecosystems processes. This forms a point of departure for this present article, by stretching the limits into the different systems in the city that are formed over time.

Cities are perceived as dynamic organisms, in continuous change and regeneration process, unfolding a continuum of space and time. Following the industrial revolution, they were mainly shaped by factors such as population growth and infrastructural development. The factors affecting cities' metabolism and transformation changed over time. Contemporary cities and metropolises are products of processes and changes, including economy, technology and climate change. Though cities share common factors affecting their urban fabric, similar to the industrial revolution, other circumstances have deep impacts such as the man-made and natural disasters. The resulting unused and under-managed areas, become obsolete urban spaces subject to the informal recovery of nature over the course of its time. This article refers to them as urban sediments and addresses their potential from an urban ecology perspective. It also considers the formation of these urban sediments as intrinsically related to the historic trajectory of each urban context. The objective of this article is to highlight the urban spaces subject to abandonment and neglect in Beirut. It considers them as urban sediments, where nature resurged informally over time, and addresses them as potential spaces from the perspective of urban ecology. In tandem between urban ecology and the urban history specificities, this approach brings in a new perspective for approaching urban ecology in relation to the urban contexts historiography.

2. Methodology

While climate change and natural disasters constitute global and common threats to nowadays cities, man-made disasters affect cities otherwise. In contexts of conflicts and urban violence, armed hostilities affect the urban fabric in different forms. Cities which underwent an armed conflict, go through a different metabolism during the wartime years, and in some cases long after the conflicts are over and the peace established. Beirut is no exception to cities which went through a conflict situation. In addition to the post traumatic sequels of the war time, other abandoned and under-used spaces constitute sediments accrued different periods of the city history. Deterioration and neglect are not the only factors marking spatially these areas over time. In that context, the natural recovery phenomenon represents opportunities rather than threats. Reconciling ecology with urbanism in Beirut, a city with different historic sediments, requires a particular perspective, acknowledging that the presence of an informal type of ecology can form the basis for a symbiotic relation with the built environment. Departing from the body of literature on ecology and the built environment in the introduction, as a framework, this article aims at approaching urban sediments from an urban ecology perspective. It follows a methodology of identification and mapping of the different urban sediments spaces which constituted over time potential reservoirs for urban ecology. A comprehensive combination of a map, some photographs and a historic narrative constitutes the basis of the work.

Two urban sediments form the basis of this article, namely the previous war demarcation line and the train tracks traces. They are identified and represented on the map of Beirut in the case study, based on a first-hand knowledge of Beirut's urban context and its urban history. The identification of both spaces is done in a representational scale on the map. The methodology extends beyond these two urban sediments to include cemeteries, destroyed wheat silos following the 2020 port explosion and other liminal spaces, as potential ecological reservoirs. This approach brings in a new perspective for approaching urban ecology differently according to the urban contexts history. The methodology further identifies and summarizes the different urban receptacles which constituted the tools for the informal return of nature to the different mapped urban areas. Following this identification and mapping, the receptacles are enumerated and described inductively. They are further benchmarked with the broader principles of urban ecology set forth by Forman in 2014, in the form of brief guidelines aiming at improving the existing balance between the built environment and the growing ecosystems. Moreover, the paper concludes with the identification of urban attributes specific to the case study context.

3. Case study: Beirut

3.1. Urban sediments over time

As cities grow and decline over their course of history, they expand horizontally and vertically under different forms. The growth of cities determines the complexity of their systems. The more complex a city becomes, the higher the need to supply its different systems gets (Tainter, 2011, p. 86). The need for sustaining the city and its population implies an increasing supply chain under different forms, not limited to food, energy, materials and products. In common discourse, cities increasingly established physical connections beyond their boundaries to constantly sustain their systems. Starting the 19th century, links and urban growth became increasingly visible on the urban landscape with the significant development of infrastructure and train tracks. In other terms, a substantial part of the infrastructure is becoming irreversible, as their traces often remain on the urban landscape for years following the end of each period. Beirut was no exception to such urban changes. However, the industrial revolution is not the only era that significantly marked its territory. Over the course of the twentieth century, it underwent a distinct form of urban mutation following a fifteen years' civil war (1975-1989) which divided it into two parts, East and West. Similar to other cities affected by the industrial revolution and acts of war, both the post-industrial infrastructural remains and the traces of war, were further subjected to abandonment and under management over time. Time itself implies an evolutionary process that is intrinsic to the city, manifested in the form of informal greenery wildly growing and spreading in the abandoned and unused areas. In tandem between time and neglect, the city becomes a reservoir and a receptacle for the action of diverse ecological factors. The railway network and the demarcation line, both of a linear morphology, constitute two distinct urban moments, reminiscent respectively from the 19th and the 20th centuries. Their abandoned condition turns them into urban sediments subject to the potential expansion of ecological factors. This case study is centered on these spaces in their potential of acting as reservoirs for urban ecology, however it also enumerates the different categories of existing green areas (Figure 1).

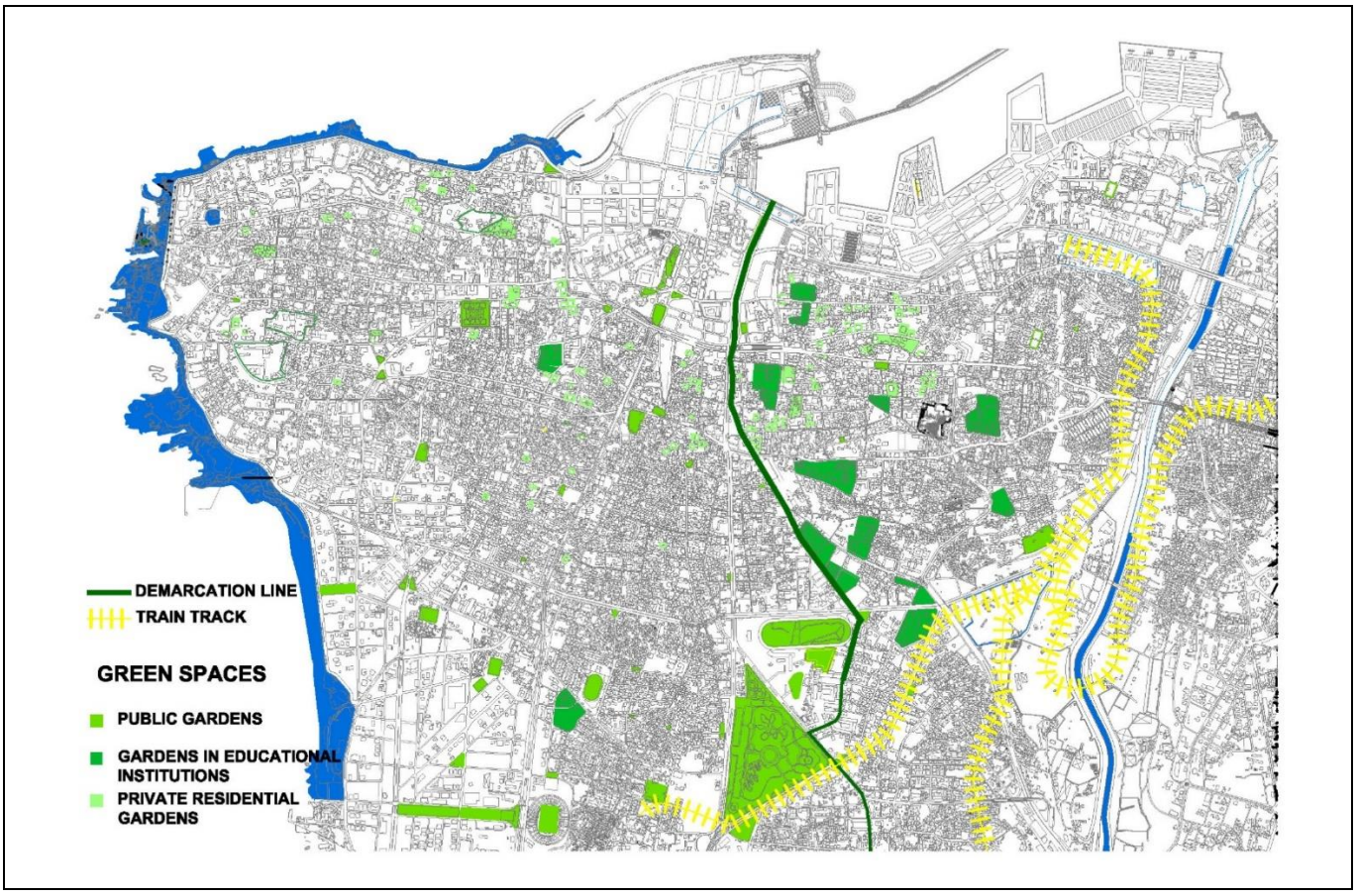

Figure 1. Map of Beirut showing the demarcation line, the train track and the different green spaces – (Developed by Author).

3.2. Potential ecological reservoirs

These two linear urban strips, related to two different urban moments, constitute the backbone for this case study in Beirut. The following sub-chapter will unfold a spatio-temporal narrative for the natural and formation of green areas along each one of them. The gradual and informal growth of nature ultimately led to their consequent transformation into natural reservoirs for urban ecology. The elaborate train network constitutes in Lebanon one of the main legacies of the industrial area and the late Ottoman period. During the 19th century, the expansion of the railway system deeply marked Beirut's territory, connecting it to Damascus and to other cities of the Ottoman territories[1]. With the announcement of Greater Lebanon in 1921, the Lebanese Railway network was reorganized in 1960 by CEL, (*Chemin de fer de l'État Libanais)* and lies on public domain. The train remained operational within the state borders until the early years of the civil war when most of the railway tracks were subject to the vandalism of the armed forces and militiamen. They remained under-maintained and neglected ever since they stopped operating. In the absence of a constant maintenance from the municipality, their status as public domains and state-owned land plots accentuated their neglected condition. Nature recovered slowly but surely, as shrubs and green patches grew all along the train track traces and

[1] Inaugurated in 1895, the railway linking Beirut to Damascus formed part of a larger train network implemented during the late Ottoman period to connect the Empire territory. This inauguration placed it along Al-Hijaz railroad network, the larger Muslim pilgrimage.

within every building along its path, which was abandoned and deserted by its original occupants. The increasing neglect to these trails, over the past decade and a half, accelerated the process of natural ecological recovery (*Figure 2*). Consequently, the potential of this urban slice could be seen in its actual neglected condition. The informal and contagious spread of urban ecology, brings in a natural balance between urban spread and the absence of it. The informal growth of nature on this public domain, rather represents a real opportunity out of this actual urban threat for transforming it into a green corridor. Observed from that angle, the detrimental effect of time in abandoned areas, acts as a metabolic agent for a natural recovery and the basis for providing linear public space in the city.

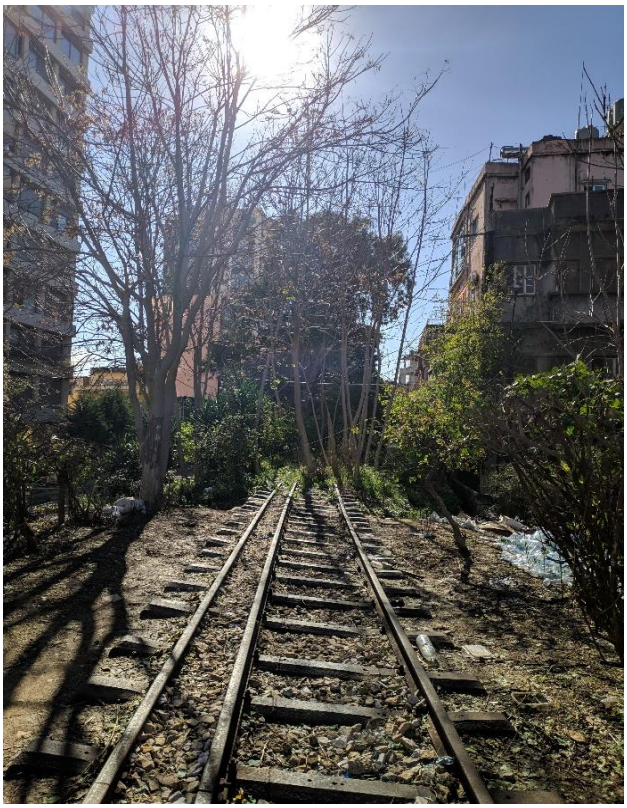

Figure 2. Nature resurgence on train track remains in Beirut – Photo Credit: Students ARP 556 - March 2019.

Figure 3. Nature recovers a war-damaged building along the demarcation line – Photo Credit: by Author – Jan. 2020.

Viewed from that same perspective, the demarcation line, commonly known in Arabic as *Khatt al-Tamass*[2], which divided Beirut into East and West fractions, constitutes another potential receptacle for an urban green corridor. The demarcation line was not a wall, but rather a space with no physical boundaries which persisted as fighting grounds, during the civil war. While it caused the displacement and almost desertion of the first row of buildings of both sides, nature resurged over time, and accordingly was referred to as *Green Line* in some academic literature. In the absence of residents living in the buildings or passing in the streets, nature was emerging in the midst of empty streets and within the nearly demolished and destroyed buildings. Time during war acted like an accelerator to the natural processes, just *'like cancer makes cell-formation visible'* (Moystad, 1988, p. 421). All along it,

[2]Khatt at-tamas which literally means: 'contact line' is the Arabic term for the front line, confrontation or demarcation line.

empty plots of land and abandoned buildings as war remnants constituted the receptacles for wild greenery to grow during the years of civil fighting and for decades after the conflict is over (*Figure 3*). Even though the demarcation line, was dissolved by the end of the war, some green patches remaining in empty plots lands, took over the war-shelled buildings.

In addition to the potential urban reservoirs, the train tracks and the demarcation line, other forms of greenery and ecological receptacles are identified in the city as follow. The identified green spaces consist of public gardens and parks, private ones, and the green spaces within the educational institutions. Several cemeteries along the demarcation line, contain a significant green area. The location of several cemeteries, dating back–to the 19th century, along the demarcation line[3] further fostered the spread of the green ecological system during the wartime. Last and not least, the grain silos of the port, which were partially demolished during the August 2020 port explosion, could be considered from this same lens, as potential urban containers for the spread of urban ecology. The remaining standing silos still containing grains, ironically blossomed and flowered in the seasons subsequent to the tragic port explosion.

4. Discussion of results

As its name suggest, urban ecology consists of this symbiosis between *ecology* and the *urban environment*. This symbiosis informally created between nature and the urban sediments, forms the basis for an inter-disciplinary study of urban ecology based on the existing urban elements. In their book on ecological urbanism, Mostafavi and Doherty highlighted an approach for an urban ecological balance based on the existing urban resources, in the form of traces and remnants from previous eras. Their reference to '*an urban recycling of the remnants of the industrial city*' (Mostafavi and Doherty, 2010, p. 28) brings the attention of urban designers to consider urban traces remaining from the last century, as potential reservoirs and receptacles for the urban ecology flow. Inspired from this perspective of urban sediments' recycling and far from the mainstream principles of urban ecology, the objective of the studied cases in Beirut is to highlight the tools which acted as receptacles for a natural ecological formation. The urban receptacles are identified into the following six points:

1- War-damaged buildings: the remaining war-damaged buildings along the demarcation line were subject to a gradual natural recovery. While the majority of the war damaged buildings were either restored or demolished in favour of newer construction, nature found its way into the remaining ones. Abandonment coupled with a lack of maintenance gave ground to the green foliage growth. Holes resulting from war shells, and factors of neglect like broken glasses and doors allowed nature to infiltrate inside them (*Figure 4*). This can fit under principle 78 (Forman, 2016, p. 1659), in relation to biodiversity in informal spaces.

2- Unused train tracks: laying on public domain, construction is prohibited on the train tracks plots, including a setback limit for construction on both sides[4] (*Figure 5*). This was a key factor for the return of nature along it. Furthermore, the neglect of the authorities in maintaining the tracks, rather constituted an opportunity for an ecological growth. In line with principle 72 (Forman, 2016, p. 1659), this train railway represents an opportunity for a continuous *vegetated corridor*.

3- Private gardens: their presence in adjacency to the demarcation line and the train track domain, facilitated pollination between the different florae species. Pollination introduce a variety of plants and flowers to the privately inhabited properties. This aligns with both the

[3]Beirut intramuros city had its cemeteries outside the walls. Located accidentally along the war demarcation line, those cemeteries once existed outside the city walls boundaries. The demarcation line is partially along Damascus Road, a major road which connected intramuros Beirut to Damascus, since the 19th century.

[4]As per Decree Law No. 148, dated 16/9/1993, the setback from the train track lot property (Chemins de Fers Libanais) is a minimum of 2 meters from the lot limit, from each side, unless another law determines a higher setback.

principle 16 under the *Plants and vegetation* category and principles 68 and 69 of the urban *Greenspaces* category (Forman, 2016, p. 1657).

4- Vacant plots: dispersed vacant plots and unbuilt stretches of land constitute receptacles for plants and vegetation seeds. Regardless of their size, their condition and the connection between them, these disconnected patches of land allow the natural and informal growth of shrubs and vegetation without maintenance all year round. This point aligns with Forman's principles 68 and 74.
5- Existing green patches: of different forms and categories, the identified urban green patches could be categorized as private and public plots. Different green patches were mapped in form of public garden/park (mainly Horsh Beirut and the Sanayeh Garden), and the adjacent several cemeteries pertaining to different religions and sects located along the demarcation line. On the other hand the green spaces within the educational institutions and the planted ground floors of the heritage buildings constitute the main components of green areas in private plots (Forman principles 67, 68).
6- Vacant grain depositories: inspired from principle 90 (Forman, 2016, p. 1660) with the following description, *Major natural and human-caused disturbances are often ecological and human disasters, due to intensive development plus limited resistance and resilience of a large dense population,* the port silos which were partially destroyed during the 2020 port explosion are currently being reclaimed as a heritage place all the whilst they still contain the wheat grains.

Figure 4. War-damaged building on Beirut's previous demarcation line – Photo Credit: Author N. Hindi – Jan. 2023.

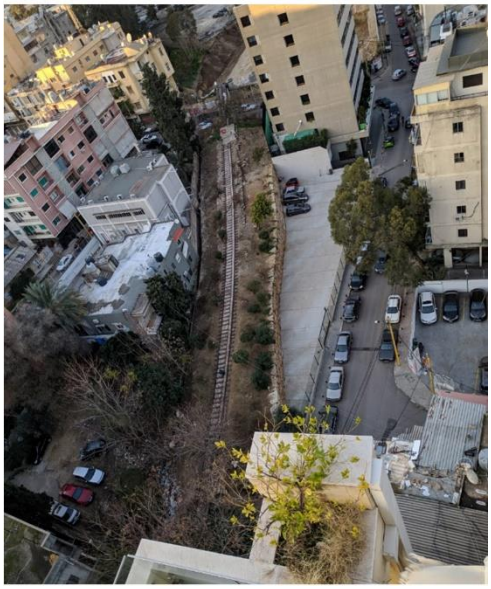

Figure 5. Train track remains in Beirut – Photo Credit: Students ARP 556- March 2019

As different city sediments represented opportunities for urban ecology to find its way without previous planning, three urban attributes can be identified as result of this work:

1- Identify the existing ecology that grew informally and without maintenance. This represents an opportunity for learning lessons and categorizing the flora type which grows with the least maintenance in the city's coastal Mediterranean weather. The wind direction, seasonal growth are factors that further give indications on the naturally growing ecosystems in densely populated urban areas.

2- Both the war demarcation line and the train tracks represent linear forms as a case study with all the potential they represent to become green corridors and linear urban public spaces.
3- The presence of some identified spaces, like the train tracks, on public domains is an asset at the scale of the city. This represents an opportunity for the planning and a step forward in the implementation process.

5. Conclusion

The article identifies the traces in the city from different periods as *urban sediments* and considers them dynamic layers which were subject to the informal interaction of the ecological systems over time. Slowly but surely, nature recovers its original territory, and time constitutes a key factor in this process. The urban sediments highlighted in this article date back to the late nineteenth century and the recent urban history, including the traces of the industrial age, the civil war traces and recipients of the urban violence, i.e. the port explosion. Those latter spaces represent the most neglected part of the city. Following the methodology of mapping and identification of the urban sediments, it was important to understand, identify and categorize the urban receptacles which acted as tools for the nature recovery and the ecological system flows in a dense inhabited environment. The urban attributes highlighted in the discussion of the results, provide a conclusion on the qualities inductively observed in the case studies. As a result of the case studies mapping, the descriptive enumeration of urban receptacles and attributes aims at learning lessons for future planning to accelerate and organize the urban ecology flow and balance. The planning of urban ecology has the possibility achieve a certain level of territorial cohesion in traumatized and under-managed contexts by creating green linear corridors and public spaces across the city and along post-war areas. Though not in the scope of this article, this last point opens the brackets to unravel the potential of highlighting urban ecology in co-relation with the urban history specificities.

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Conflict of interests
The authors declare no conflict of interest.

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