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# What do we visually focus on in a World Heritage Site? A case study in the Historic Centre of Prague

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Since socio-economic development is associated with artificial construction, heritage environments must be protected and renewed while adapting to such development. Many World Heritage Sites' visual integrity is endangered by new construction. The paper aims to explore people's visual focus patterns concerning the integrity of heritage to ensure that traditional culture is not endangered by the construction and development of modern life, and to protect Outstanding Universal Values. In this study, visual heatmaps are generated to investigate people's visual integrity in the Historic Centre of Prague from micro to macro viewpoints using an eye tracker. We found that humans' perspectives are unobstructed or concentrated, and the view of main attractions is generally maintained by a buffer zone. However, newly constructed high-rise buildings can result in major visual concerns. Therefore, new buildings with large heights and strong contrasting colours should be restricted to World Heritage Sites. Moreover, complex artistic effects (facade midline, domes, mural painting, faces of sculptures) will likely attract people's attention. In contrast, visual focus is not concentrated on greenery, roofs and floors. Accordingly, greenery could become a flexible space to serve as a background for buildings and landscape nodes. Furthermore, visual focal factors are associated with two significant aspects: people and the environment. Since people and transportation could pose visual concerns, tourism managers should optimise for characteristics such as controlling the density of pedestrian flow and planning parking spaces. The visual patterns identified could be useful for the design, conservation, and management of visual integrity in cultural heritage sites to avoid the spread of artificial constructions within the boundaries of heritage sites, which may lead to their being endangered or delisted.

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## Introduction

Significant growth in the number of World Heritage Sites (WHS) has been witnessed since the first list in 1978 (Pendlebury et al. 2009). Nevertheless, the concept of heritage is not easy to define precisely since it is composed of multiple elements (Graham et al. 2016). Conventionally, ancient monuments are considered a significant part of the heritage, including great historic architectural work and the urban or rural location where a historic event was witnessed (Gazzola 1964). UNESCO's World Heritage Convention (UNESCO. 1972) stipulates that monuments, buildings, or groups of buildings must have Outstanding Universal Value (OUV) based on historical, artistic, or scientific criteria and considering sites from the, aesthetic, ethnological, or anthropological perspective (UNESCO. 1972). Human activity can affect the function and cultural-heritage values of WHS. For example, the visual integrity of WHS is under the threat of urban development (Short 2007). Many modern buildings around or next to cultural heritage sites whose shape, colour, and style can impact tourists' visual concerns, belong to the Heritage Impact Assessment (Tavernor 2007, Ashrafi et al. 2021, Dupont et al. 2016). In particular, large-scale development close to the site (e.g., tall buildings in London) seriously impacted subjective visual satisfaction (Tavernor 2007). For sustainable development, historic cities face challenges, including protecting their cultural heritage value, constructing new buildings for modern life, and integrating the built and natural environment. In this regard, urban planning should find solutions to balance protection and modernisation. Although great achievements have been made in protecting Form and Links, Vitality such as visual integrity is under threat of new construction for many WHS (Short 2007). The World Heritage List (WHL) has no national boundaries as it is an international list. One of the most frequent reasons for rejection of Heritage site is the lack of integrity and authenticity. The definition of integrity must be based on the definition of OUV: (1) to represent a masterpiece of human creative genius; (2) to exhibit an important interchange of human values, over a span of time or within a cultural area of the world, on developments in architecture or technology, monumental arts, town planning or landscape design; (3) to bear a unique or at least exceptional testimony to a cultural tradition or to a civilisation which is living or which has disappeared; (4) to be an outstanding example of a type of building, architectural or technological ensemble or landscape which illustrates (a) significant stage(s) in human history (Jokilehto 2008).

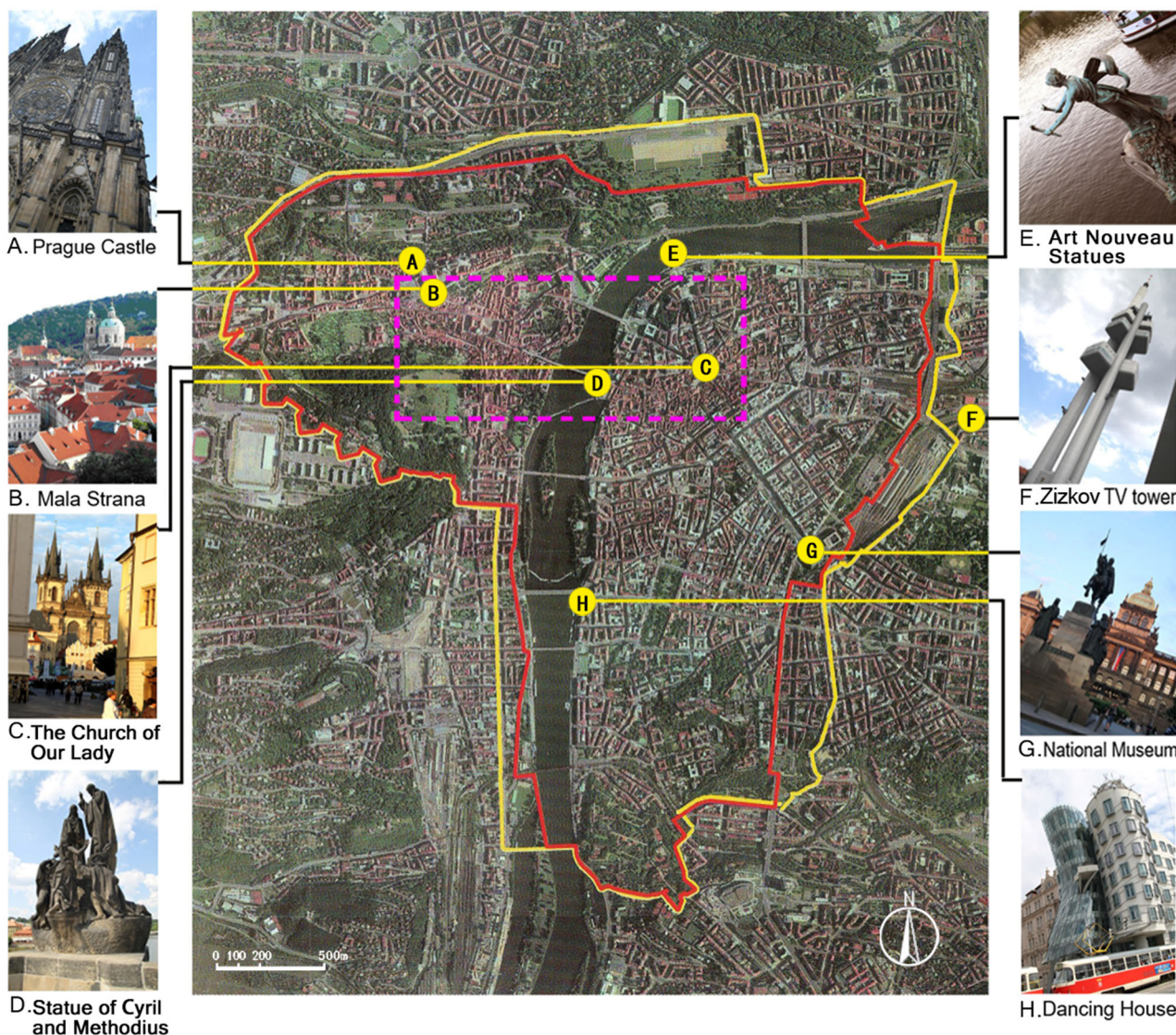
Examining the conditions of integrity, therefore, requires assessing the extent to which the property: (1) includes all elements necessary to express its OUV; (2) is of adequate size to ensure the complete representation of the features and processes which convey the property's significance; (3) suffers from adverse effects of development and neglect (UNESCO 1972). For example, the historical city of Esfahan in Iran would have been removed from the WHL if the height of the Jahan Nama Tower nearby was unreduced (Ashrafi et al. 2021). In another case, the Dresden Elbe valley was removed from the WHL due to a modern bridge that is detrimental to the universal cultural-heritage value of the landscape. Therefore, human factors should be evaluated for the protection and planning of buildings on WHS (Jerpäsen and Larsen 2011; Ashrafi et al. 2021). The issues of authenticity and integrity have been reflected in the conclusions concerning the various criteria (Jokilehto 2008). However, the identification and evaluation of the OUV is a complex process that can only be accomplished by thorough topic investigations based on a scientific study which profoundly depends on expert knowledge at local and global levels, the time allocated for which also usually remains quite limited. Based on previous literature, there are few

case studies related to WHS, and most of them are about management studies, however, few studies from people explored their visual perceptions (Ashrafi et al. 2021). Therefore, we need to know more about the visual patterns related to the integrity of heritage conservation in order to deal with the balance between heritage conservation and new project.

As for the visual study, video-oculography has become one of the most widely used eye-movements assessment methods (Gobster et al. 2019). An eye-tracking apparatus captures the pupil fixation point information for a particular image (including location, watching time, and order). Then, the visual information is extracted, and statistical data analysis is performed to reflect the visual appearance of a regular series for visual features analyses (Ooms et al. 2012; Wojciechowski and Fornalczyk 2014; Darwish and Bataineh 2012; Umesh et al. 2018). In another study, objects of interest were obtained by exploring natural and intelligent interactions between tourists and the environment in a small museum using mobile eye-tracking technology (Mokatren et al. 2018). Moreover, a relationship comparison of integration and other metrics of space syntax and walking has been revealed using methods based on the space syntax theory (Koohsari et al. 2017; Baran et al. 2008; Wineman et al. 2014). Meanwhile, visual information such as size, shape, colour, architectural style, and tourist density can be derived for assessing subjective visual attention (Shang and Bishop 2000; Tweed and Sutherland 2007; Gobster et al. 2019). For example, the landscape signature of the most appealing views can be identified through the panorama level approach using geotagged photos and visibility modelling for detecting the potential of visual amenities (Foltête et al. 2020). Consequently, services could be optimised by understanding the gazing profile and visual attitude of tourists on WHS.

Herein, we have chosen the Historic Centre of Prague as a typical WHS and conducted field investigations to study the progress and effect of its urban planning system with an emphasis on the visual quality of humans. The Historic Centre of Prague is the first site of the Czech Republic on UNESCO's WHL. According to OUV, the Historic Centre of Prague meets the criteria compendium of WHS (i-vi) (Jokilehto 2008). Prague ranked among the largest European cities as early as the twelfth and thirteenth centuries (Beránková 2001). We chose the Historic Centre of Prague for our investigation, Central-European cities, Prague, the Czech Republic's capital, because of its diversity of architectural styles, Prague's climate is mild and transitory between maritime and continental, with a thermal continentality of 26–27% according to Gorczyński (Květoň and Žák 2007). Prague is a typical city where historic buildings are integrated into modern life, city is not as big as London or Paris. However, the densely built-up historical area is surrounded by scattered houses having between four and eight floors, partly modern, partly older than 100 years (Květoň and Žák 2007). Importantly, cultural buildings and landscapes in Prague nowadays are not merely preserved to attract tourists, as displayed in Fig. 1. In addition, it has research value on the coexistence of modernity and classics represented by the world cultural heritage. The heritage site is located in the core zone of the city in the context of urban areas with modern life (Fig. 1) (Beránková 2001). Verifying integrity is particularly important; the OUV or significant assessment is integral to visual assessment.

Whether visual integrity has been affected in the Historic Centre of Prague, which is the state of the problem, consequently, this study aims to explore people's patterns of visual focus related to the integrity of WHS to ensure that traditional culture is unthreatened by the construction and development of modern life.



**Fig. 1 Main attractions in Prague Historical Reserve.** Old Town and Malá Strana (Lesser Town) are highlighted with a purple rectangle.

Therefore, the main research questions are depicted as follows:

- (1) What are the characteristics of the visual concerns for landmark buildings in the city in context of heritage conservation planning practices (from human visual macro-perspectives)?
- (2) What are the patterns and characteristics of visual concerns on street scenes in areas with high visual connectivity (from human visual meso-perspectives)?
- (3) What are the characteristics of the visual concerns of typical architecture and sculptures (from human visual micro-perspectives)?

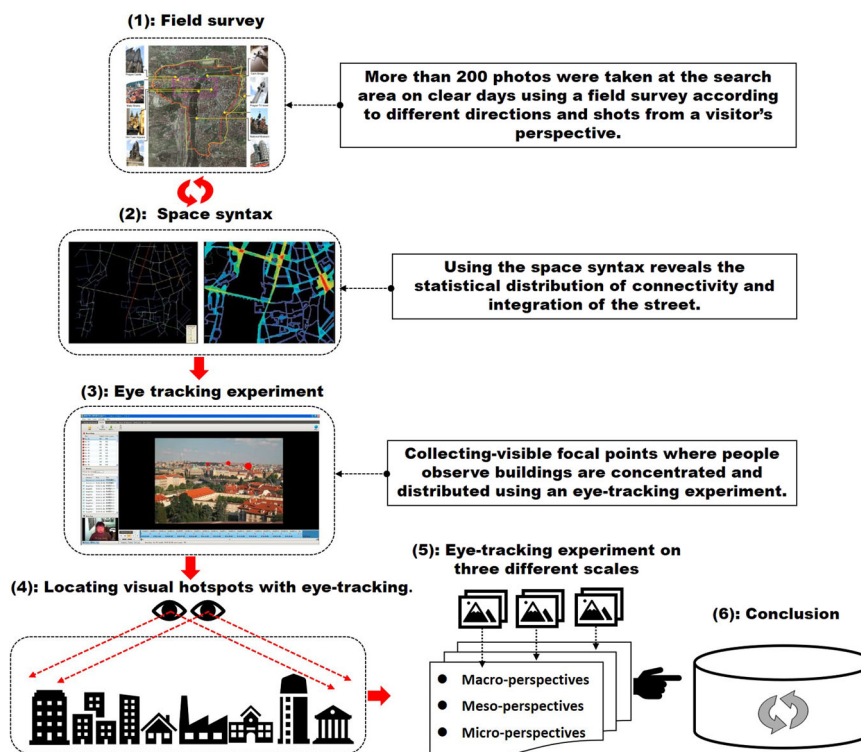
Hence, the results in this paper provide evidence that collecting visible focal points and the objectives are to identify visual patterns to understand the characteristics of the visual concerns from micro to macro viewpoint levels of humans using an eye tracker in the Historic Centre of Prague.

**Methods**

As shown in Fig. 2, we need to collect primary data using a field survey and the space syntax to reveal the statistical distribution of connectivity and integration of the street. Then collecting, visible

focal points where people observe buildings are either concentrated and distributed using an eye-tracking experiment. Therefore, the methodological part of our study is organised as follows: (1) Field survey, (2) Case study site, (3) Space syntax, (4) Eye-tracking experiment. All methods above are designed to realise these three scales of research:

- (1) On the city scale (from human visual macro-perspectives), integrity is paramount for major attractions, and a lack of integrity may result in delisting from the WHL. Therefore, we explored the role of planning strategies and discussed the visual integrity according to the distribution patterns of visual concerns derived from data based on an eye-tracking experiment.
- (2) As for the street scale (from human visual meso-perspectives), where the dynamic walking behaviour of visitors occurs, we used space syntax to reveal the statistical distribution of connectivity and integration of the street. Next, the sight-intensive and sub-intensive areas were selected for oculomotor tests to reveal the visual attentional features.
- (3) On the building scale (from human visual micro-perspectives), we collected visible focal points where people observe



**Fig. 2 Schematic illustration of the methodological path Field survey Space syntax.** (1) Field survey, (2) Space Syntax, (3) Eye tracking experiment, (4) Locating visual hotspots with eye-tracking, (5) Eye tracking experiment on three different scales, (6) Conclusion.

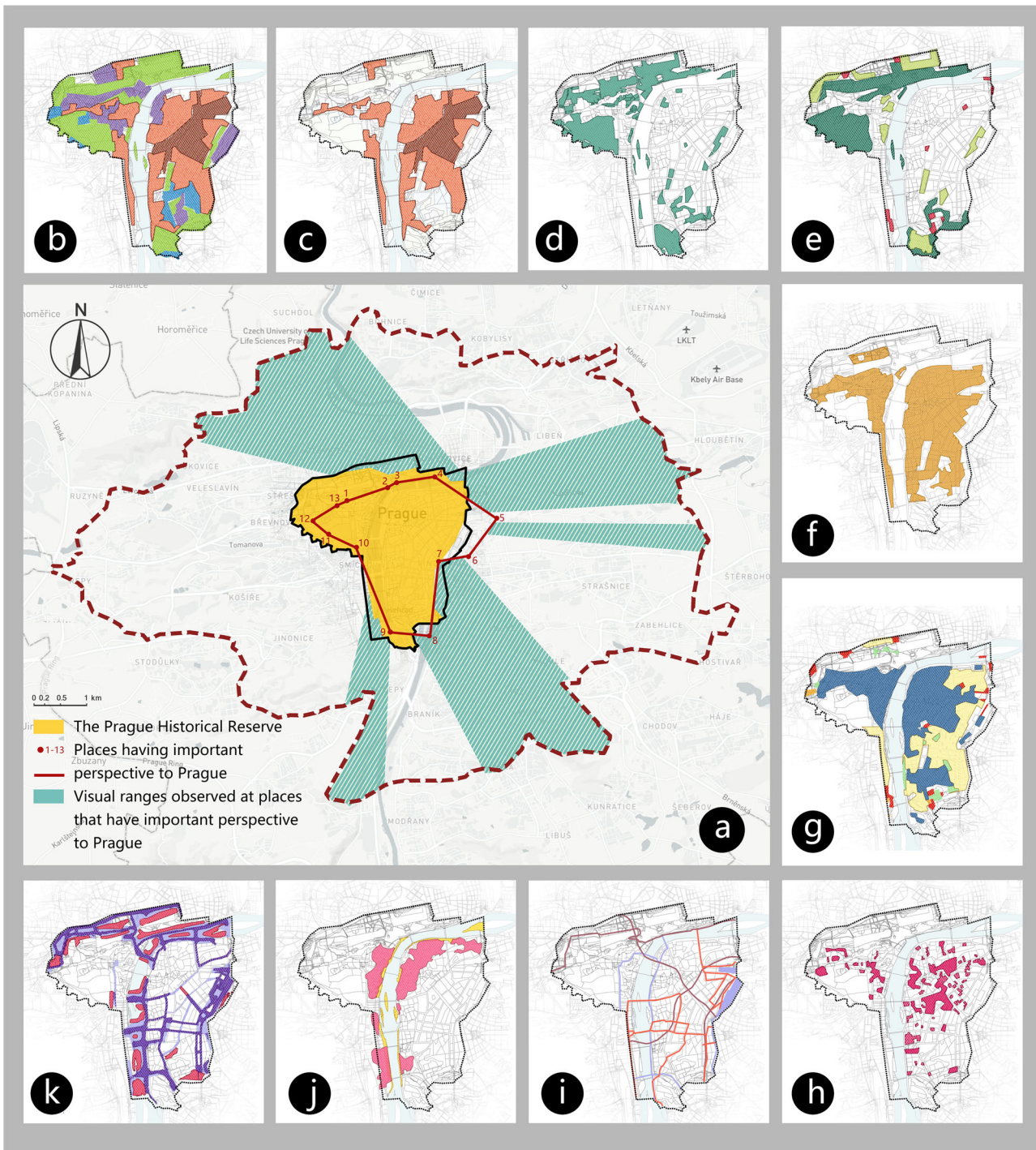
buildings and sculptures are concentrated and distributed using an eye-tracking experiment.

**Field survey.** The field survey has been used extensively in environmental research, geobiology, and heritage conservation (Jo and Jeon. 2020a, b; Liu and Kang. 2018; Maristany et al. 2016; Liu et al. 2020). This study conducted the field survey with a digital camera (Canon 500 D). This study aimed to identify distribution of visual focus on an assessment of the visual impact, primarily based on key observation points (KOP) (Palmer 2019; Hollands and Marple-Horvat 2001; Goodworth et al. 2015). The representative images of each space from different directions and KOPs shots from a visitor's perspective were chosen based on the images of eight associate professors of landscape architects, quality photography was a criterion for selection (e.g., clarity) and variation according to different directions and shots from a visitor's perspective (Liu et al. 2022). More than 200 photos were taken at the search area on clear days. These photos include holistic perspective shots from different directions and shots from a visitor's perspective of the streets, architecture, sculptures, and river landscape covering the typical urban visual landscape.

**Case study site.** Open areas are related to the surrounding buildings, in these areas, architecture should be cautiously built and maintained (Ministry of Regional Development, C. Z. 2015). Planning for various aspects, including residential areas, traffic and transportation, and the landscape of roofs, has been performed according to the Department of Prague City Development (Ministry of Regional Development, C. Z. 2015; Spilková and Vágner 2016). As shown in Fig. 3a, the Prague Historical Reserve is highlighted in yellow, and places with important perspectives on Prague are illustrated with numbers on the red line surrounding the protected area. Both values of the Prague Historical Reserve and its spatial context are protected by a buffer zone (green areas

in Fig. 3a). In Fig. 3b, green highlights the public green area, purple indicates the special area, red denotes the residential area, and blue represents a public building area. In particular, the distribution of new establishments, including the president's office, houses of parliament, other government facilities, embassies of foreign countries, universities, theatres, and hospitals, are shown in Fig. 3c. Greenery and some ancient parks and gardens are listed in Fig. 3d. In Fig. 3e, deep green highlights the important place, light green represents the composite green space, and red denotes the transformation of an area that is possible for future development. For the planning of landscape and urban systems, the roof landscape design is based on the present situation of architectural heritage in the existing historical block (Fig. 3f). In Fig. 3g, five planning concepts, including protection, maintenance, decoration, transformation, and new design, are highlighted in blue, green, yellow, orange, and red, respectively. Underground protected areas are shown in Fig. 3h. Important archaeological sites are highlighted in red according to the Archaeological Dept. of the Prague Heritage Fund (Beránková 2001). The traffic planning map, including land, waterway, and underground transportation, is shown in Fig. 3i. Railroad, light rail, arterial road, and steamer lines are highlighted in purple, red, orange, and blue lines, respectively. Traffic planning helps to improve transit and encourage pedestrians. The air quality is expressed in red and yellow, as shown in Fig. 3j. The sketch of the average pollutant concentration shows that the most polluted areas are around busy roads and major intersections and at the entrances of tunnels. Floods and dampness have caused tremendous damage and frequent floods in historic areas in recent years (Ortiz et al. 2016). Flood forecasting based on Geographic Information System demonstrates a visual approach to flood risk analysis, including flood forecasting, flood impact, and vulnerability (Li et al. 2017). As shown in Fig. 3k, the flood areas that require special attention are highlighted in purple and red.

Although the overall planning has considered the protection scope of architecture in terms of function, size, and spatial



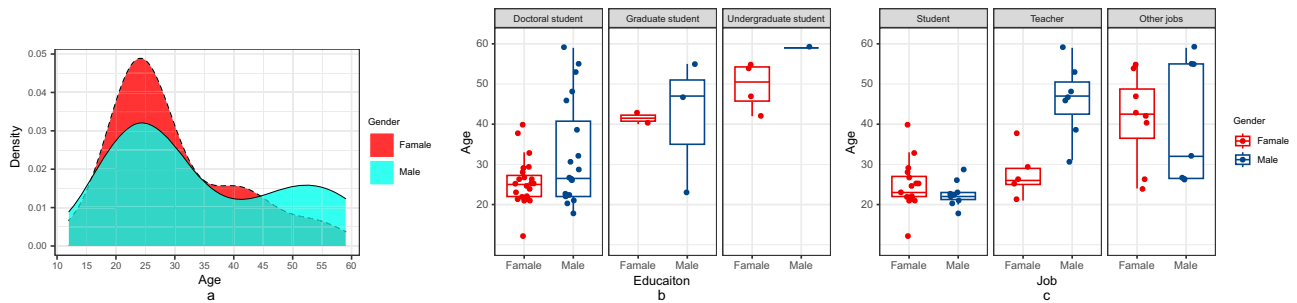
**Fig. 3 Urban planning for the Prague Historical Reserve and the Cultural Heritage.** The buffer zone (a), residency areas (b), functional utilization areas (c), green areas (d), regulation of space (e), landscape of roofs (f), variety of planning (g), underground protected areas (h), traffic planning (i), air pollution areas (j), flood marks and flood areas (k). Adopted from (Beránková, 2001).

composition, the visual experience from the perspective of tourists should also be considered for the protection of the objects and the scope of sustainable protection design. However, no other protection strategies for streets and buildings are given from the perspective of tourists, which is the main focus of this study.

**Space syntax.** Space syntax is a collection of theories and techniques for analysing spatial configurations. Axial lines represent lines of sight, and the configuration of axial lines can be used to

estimate street integration (Hillier and Hanson 1989). Axial map (1061 m × 802 m) and visibility graph analysis (VGA) were implemented based on the satellite imagery using the Space Syntax technique from UCL in Depthmap software. The axial map represents the uninterrupted impression of visibility and permeability as visitors walk on the streets and look at a distance in various directions.

The space syntax simulation in this paper refers to methods such as the axial map method and the VGA method, both of which are based on space syntax theoretically. VGA is a



**Fig. 4** Age variation was based on different jobs and genders in the eye movement experiment. **a** The gender characteristics of participants, **b** The education characteristics of participants, **c** The occupation characteristics of participants.

technique in architecture that analyses inter-visibility connections within buildings or urban networks. VGA was developed from the architectural theory of space syntax and is applied by constructing a visibility graph within the open space of a plan. VGA was used to analyse visual connectivity. It was represented using colour codes from separate points within the space (Fathy Alagamy et al. 2019).

**Eye-tracking experiment.** Planners need tourists' opinions and intentions to better understand their visual attitudes, depending mainly on their eye-movement behaviour patterns (Duchowski 2003; Gompel et al. 2007; Henderson and Ferreira 2013; Galdi et al. 2016). Eye trackers are devices that track a user's eye positions and movements. They use a tiny, unnoticeable infrared light and its reflection on the user's eyes to infer the location or direction of the user's gaze (Mokatren et al. 2018). Therefore, the eye-tracking test is an important method for planners to design and preserve landscapes with historical and artistic value (De Lucio et al. 1996). Devices that track the movements and positions of the eyes are known as eye-trackers. By using infrared light and its reflection on the user's eyes, they can determine where or in which direction the gaze is directed. (Ruiz Fernández et al. 2011). Eye-tracking tests have been used in ophthalmology, cognitive science, neuroscience, human-computer interaction, etc. (Chen et al. 2015; Pastoor et al. 1999; Loboda and Brusilovsky 2010; Kübler et al. 2014; Amir et al. 2001). The intuitive methods can identify human movement decision-making on street integration (Cutumisu and Spence 2009; Koohsari et al. 2014; Karimi 2012). For designers and planners, monitoring eye movements can provide significant results from the perspective and intention of the human mind to obtain important information for landscape design (Pettersson and Falkman 2020; Cáceres et al. 2018).

This test is based on the principle of visual information processing and eye movement. Visual focus refers to visual targets that stabilise the participants' gaze in one specific area (Lucas-Cuevas et al. 2018; Hollands and Marple-Horvat 2001; Goodworth et al. 2015). Therefore, we used the Eye-tracking experiment to investigate visual evaluation. The total number of participants was 54 (24 male, 30 female) based on previous studies on the visual evaluation of landscapes (Daniel 2001; Liu et al. 2019; Motoyama and Hanyu 2014; Liu et al. 2020; De Lucio et al. 1996). All participants showed regular or corrected-to-normal vision, and their age and occupation distribution are illustrated in Fig. 4. In the eye-tracking experiment, photos taken in the field survey were presented on the screen to participants, and pupil focus was monitored by Eye Tracker (Tobii TX300). To catch the visual attention of subjects, each image was displayed for 10 s. Then, the screen was randomly switched to the next image. Figure 5 displays one subject undergoing testing. The lower left corner is the camera view of the participant. Eye movements, including the focusing site, pupil fixation time,

and pupil rotation, were collected in real-time by Eye Tracker and illustrated with red lines and spots on the right side of the screen. SPSS was used for statistical data analysis.

## Results

Although long-term concepts have been developed to define, protect, and develop architecture based on function, size, and spatial composition, subjective attitudes such as visual integrity should be investigated from visitors' perspectives. Hence, the results included verifying the protection strategies for the Historic Centre of Prague from the macro-perspective of spatial planning as well as the visible focus on objects, including streets and architecture, from the perspective of visitors.

The research framework is as follows:

- (1) The city scale (from human visual macro-perspectives).
- (2) The street scale (from human visual meso-perspectives).
- (3) The building scale (from human visual micro-perspectives).

**The city scale (from human visual macro-perspectives).** Previously, the combination of eye-tracking and factor analysis has been used to identify characteristic patterns of visual exploration in the natural landscape. For example, a landscape scene including traditional houses, pastures, and trees surrounded by fences and orchards was used as the visual stimulus for the investigation of visual attraction (De Lucio et al. 1996). In contrast, the visual stimulus is a typical urban landscape in the present study.

To determine how main visible attractions are perceived from several established points of view, the distance of observation is an important criterion, ranging from several hundred to several thousand miles. In this study, visual heatmaps generated from the eye-tracking experiment were used to determine the progress and effect of planning on the visual quality of landscapes. In the Historic Centre of Prague, seven places with important perspectives on Prague were selected for the eye-tracking study, and 54 samples were successfully collected. Figure 6 showed that historic buildings keep their original colours, structures, and architectural appearance. Moreover, heatmaps indicated that the seven perspectives were unblocked, although new buildings such as Zizkov TV Tower (highlighted with a red arrow in Fig. 6) attracted a high degree of visual concern. All these results suggested that the degree of authenticity of the WHS was high, and the buffer zone effectively maintained its visual integrity on the periphery of the heritage.

Furthermore, it was observed that the visual focus was concentrated on the highest points of the skyline, the top of the buildings, and prominent architecture and landscape nodes showing different colours or styles. For example, most attention was paid to the Church of Our Lady in front of Týn (highlighted with a blue arrow in Fig. 6). In contrast, little attention was paid to greenery and large areas of roofs displaying the same colour.

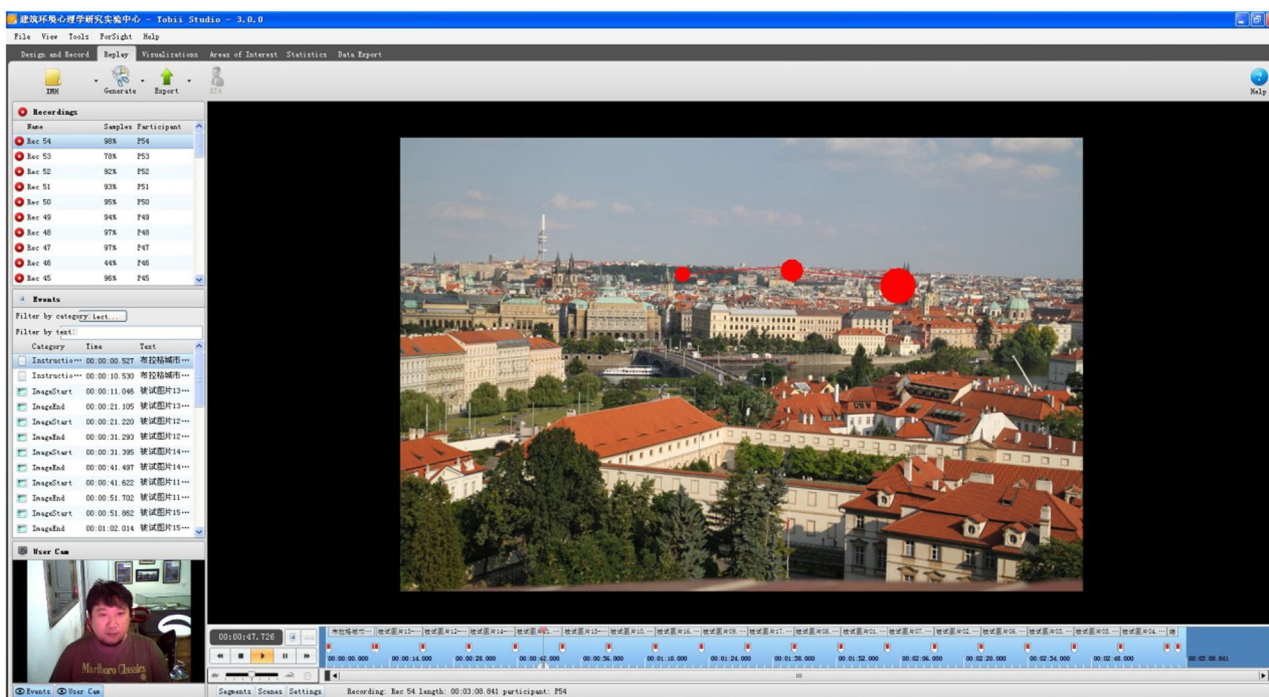


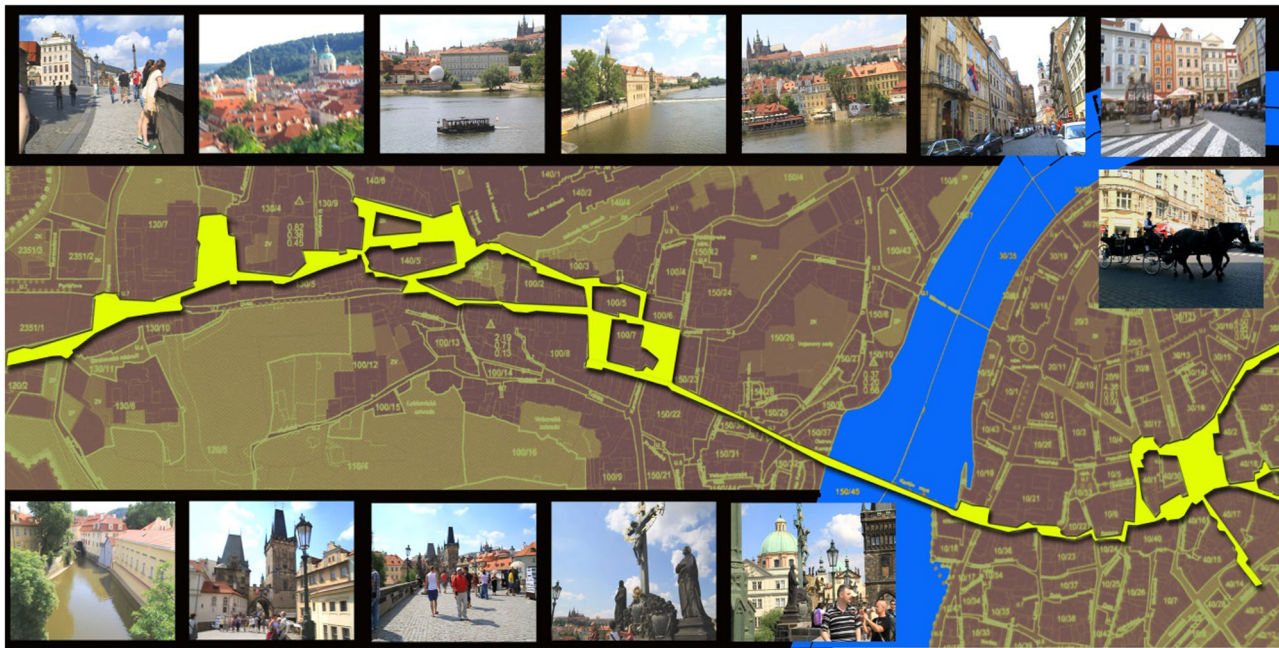
Fig. 5 The 54 test subjects were used in the eye-tracking experiment.



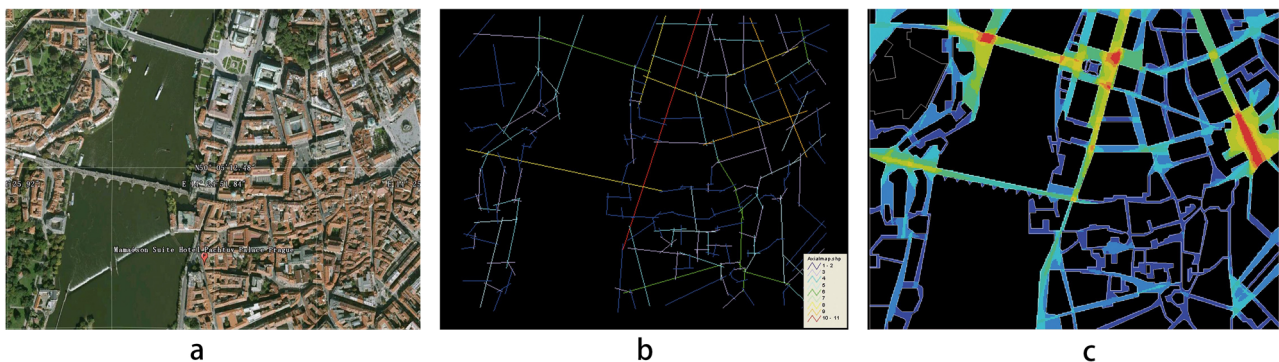
Fig. 6 Heatmaps were derived from eye-tracking studies at seven established points.

The street scale (from human visual meso-perspectives). The built urban environment significantly impacts people’s daily life experiences, and the interaction between the built environment and people is complex (Tweed and Sutherland 2007).

Figure 7 displayed the winding streets in both Old Town and Malá Strana (Lesser Town), highlighted with a purple rectangle in Fig. 1. The diversity of street views was preserved in urban areas of Braque. Unlike urban squares, whose shapes and enclosing



**Fig. 7** Urban landscape perception impression sequence from Old Town Square, Charles Bridge, and Malá Strana (Lesser Town).



**Fig. 8** The satellite image (a) the aerial map (b) and the VGA map (c).

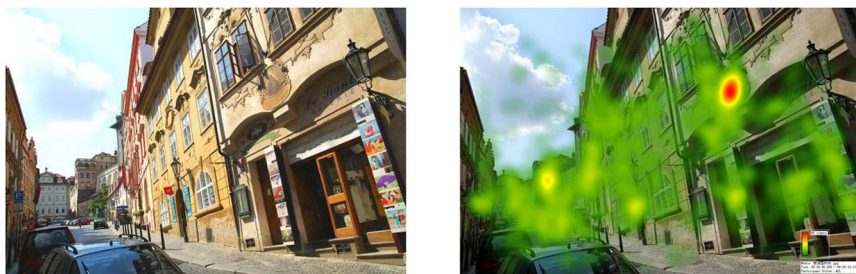
characteristics usually give a static sense to people, streets can cause a variable and dynamic feeling. In addition, winding streets improved the space enclosing characteristics and provided varied perspectives for moving observers, resulting in a mysterious sense that can satisfy people's desires to explore an unknown world. Many commentators, including Sitte and Cullen, have endorsed people's happiness caused by varied perspectives on the street (Carmona et al. 2021).

In this paper, the street space syntactic simulation referred to the street in which the space syntax simulation was conducted using the axial map and the VGA method, both of which used the space syntax as a theoretical basis (Axial map and VGA methods fall under the space syntax simulation). Figure 8a is a satellite image corresponding to the centre area of the heritage site. Based on Fig. 8a, the axial map and VGA were generated using the syntactic simulation, as demonstrated in Fig. 8b, c. In Fig. 8b, the axes' connection level decreased as the colour became cooler. Figure 8b showed one red axis (10–11 range scale), six yellow axes (8–9 range scale), six green axes (6–7 range scale), and many axes with cool colour (<6 range scale), suggesting that the integration was low for the majority of streets in this area. However, Fig. 8c showed the VGA in which the red areas had the most concentrated vision, followed by the yellow and green areas, while the blue areas had the least concentrated vision.

Dense sight lines were located at Parizska Street in Old Town Square, Krizovnicka street on the east side of the Faculty of Arts, Charles University, and the two bridges across the Vltava River. Streets in these hotspots were thus selected for visibility analysis, as discussed below.

Residency is an important functional element of the city since it is the basic condition for maintaining an entire life and living atmosphere. Despite the long-term trend that pushes residential areas away from the commercially attractive downtown areas, people still live here without significant disturbance in the Old Town of Prague (Ministry of Regional Development, C. Z. 2015). A typical residential street scene and its corresponding eye motion heatmap were displayed in Fig. 9, where commercial areas were on the ground floor, and residential rooms were on high floors. People's attention was attracted by the facade of the buildings with elevation frescoes and shop decorations (Fig. 9). In particular, the results indicated that people's attention was easily attracted to the most complex location of the store on the street, such as the mural Wall painting in the middle of Fig. 9. These places have high artistic and appreciation value, which can meet people's need for cultural exploration and relieve the aesthetic fatigue of visiting urban areas. Moreover, the end of the street can attract people's attention. In contrast, the sky, ground, and vehicles nearby attract little attention. As a result, planners should

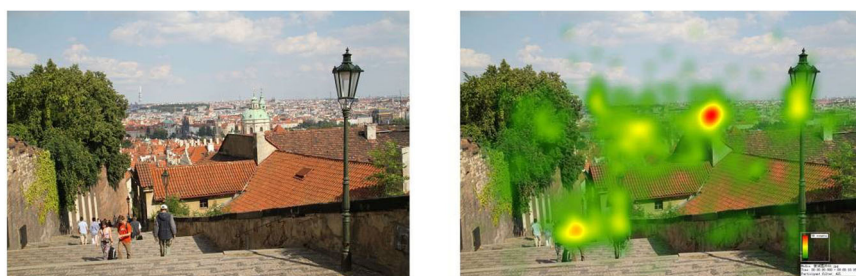




**Fig. 9** The eye motion and heatmap comparison for a typical residential street scene.



**Fig. 10** The comparison of eye motion and heatmap for Old Town Square.



**Fig. 11** The comparison of eye motion and heatmap for a street scene having greenery.

pay special attention to facades for the maintenance and protection of historic buildings. In addition, the end of the street can be the visual focus, which should be elaborately planned for preservation. It is suggested that the maintenance and refurbishment of streets should be respected by the existing facades and based on their original value.

Compared with the residential street depicted in Fig. 9, the population density in Old Town Square was high. Many visitors can be seen, and both the living and tourist atmospheres become strong near the old city hall, as illustrated in Fig. 10. This was consistent with the urban planning that buildings surrounding the Old Town Square have various functions that can be classified as public, special, and residential areas (Fig. 3b, c). The heatmap in Fig. 10 showed that the old town hall was a centre of visual concern (Fig. 10). Moreover, people’s faces nearby and at the end of the street were easily noticed. Although the floor showed a delicate pattern in the Square, it draws little attention, consistent with the fact that the visual attraction is uncaptivated by the ground (Fig. 10). These results suggested that classical or important buildings attract visitors’ attention. As such, the construction of commercial or business establishments should be restricted so that the population density is well controlled to obtain a satisfactory visual experience.

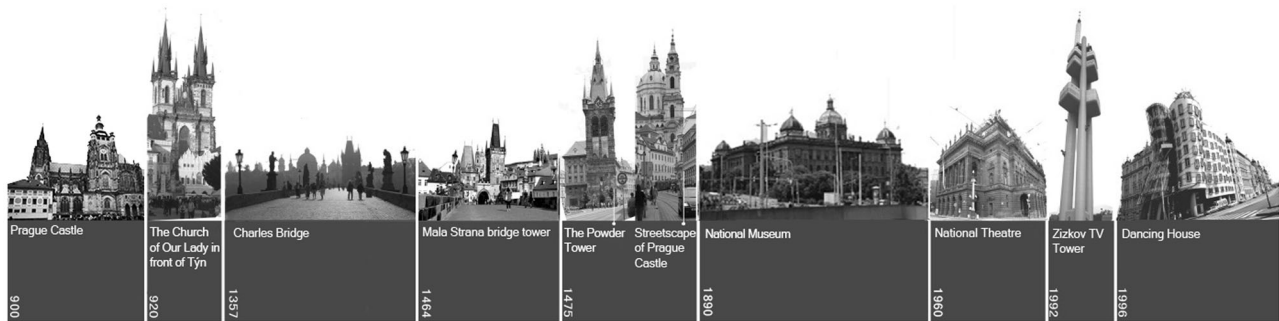
The Historic Centre of Prague has much greenery. Many belong to public spaces such as public courtyards, gardens, and ancient parks. Figure 11 showed a typical urban green space in the courtyard of the blocks of buildings and its corresponding

eye motion heatmap. It was observed that people focused on the commanding heights of buildings or domes with prominent forms and visitors nearby (Fig. 11). In contrast, the focus was not on greenery, even when it was obvious. In addition, the sky, ground, and roofs of the same colour attracted little attention, consistent with the analysis of landscapes viewed from long distances (Fig. 6). Since people overlook greenery, in most cases, it becomes a flexible space in this historic city, which can serve as a background for the architecture and landscape node. As such, the planning and the design of public spaces, including greenery, should be done in a comprehensive, integrated, and coordinated, and solutions for public spaces must be based on the overall design. Since the possibility of establishing new green areas is minimal in the historic city, the priorities of the planning are the maintenance and protection of the existing green spaces and vegetation.

The eye motion heatmap of the walking area in pedestrian zones leading to the famous Charles Bridge was displayed in Fig. 12. While the ground did not attract people, their visual attention was focused on the end of the street, pedestrians’ faces and the nearest bicycle, since no cars or large vehicles are passing by. Restricting cars or large vehicles is a good method to protect the quality of the visitors’ audio-visual comfort. However, pedestrian street traffic includes bicycles and pedestrians. In contrast to the standing vehicles that attract little attention on streets, bicycle shape and placement can affect the gathering visitors’ vision. As such, bicycles should be placed properly in the



**Fig. 12** The comparison of pedestrian 'zones' eye motion and heatmap.



**Fig. 13** The evolution of Prague architectural form.

overall planning of a pedestrian street; otherwise, bicycles will affect the entire visual effect.

#### The building scale (from human visual micro-perspectives).

The landscape of nodes can best reflect the spatial quality and spatial attributes of the urban landscapes. The effect and connotation of the urban landscape are embodied in the design of the nodes. While respecting the principles of sustainable development, the building must meet its high functional and aesthetic requirements and maintain a good relationship with the environment, cultural and natural values, and the surrounding landscape. Architecture is an important node of the landscape. The evolution of urban architecture is revealed by the distribution of buildings in terms of age. If old buildings disappear, memory will fall into oblivion in the landscape. Therefore, it is important to maintain historical continuity. As illustrated in Fig. 13, buildings on the right are younger than those on the left. This distribution pattern is important since a previous study suggested that the consciousness of the past, present, and future correlation would positively affect people's behaviour and mental health (Farina 2009).

Figure 14 showed an image and its corresponding eye motion heat contrast diagram for the building facade. We found that people's concerns were symmetrically located on the most complex centre line of the building facade and the entrance of the building. Figure 15 presented a heat contrast diagram for the city bridge sculpture. It can be seen that the focus was on the face of the sculptures. In contrast, the sky, ground, and greenery had attracted little attention. These results suggested that people focus on the most complicated part of the body. Therefore, the design and quality in the most complicated part of the body and aesthetics of building or sculpture are crucial.

Figure 16 depicted a photograph and its corresponding eye motion heatmap for a typical roof landscape in an old town. People's attention was focused on the changes in dome shapes with complex shapes, while the sky attracted little attention. Consequently, whether it was roofs, buildings, or sculptures, people's attention was the most complex part. Therefore, the aesthetic quality of a building forms a part of its architectural

quality and mainly represents the visual and compositional quality of the building with its symbolic and cultural importance.

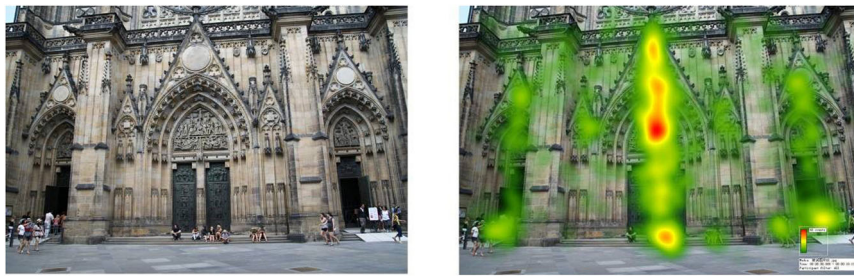
Similar results were demonstrated in Fig. 17, which presented an image and its corresponding eye motion heatmap for a typical building in the centre of Old Town Square. The focus remained on the most complex figures (mural painting) and garlands on the facade. Therefore, it is crucial to protect the aesthetic and visual quality of complex landscape points in the field of vision.

Among rivers and streams, the most significant waterway of the Prague territory is the Vltava River. Its course has determined the layout of the historical centre. A photo was taken in the Vltava River area, and the corresponding eye tracker heatmap presented in Fig. 18. We observed that people focused on the farthest position of the space for bridges and the highest point of a nearby boat. In contrast, the sky, the surface of a river, and greenery attracted little attention. As a result, the protection of historic blocks and historic cities should pay attention to protect the highest point of these nodes, including but not limited to the boats and bridges.

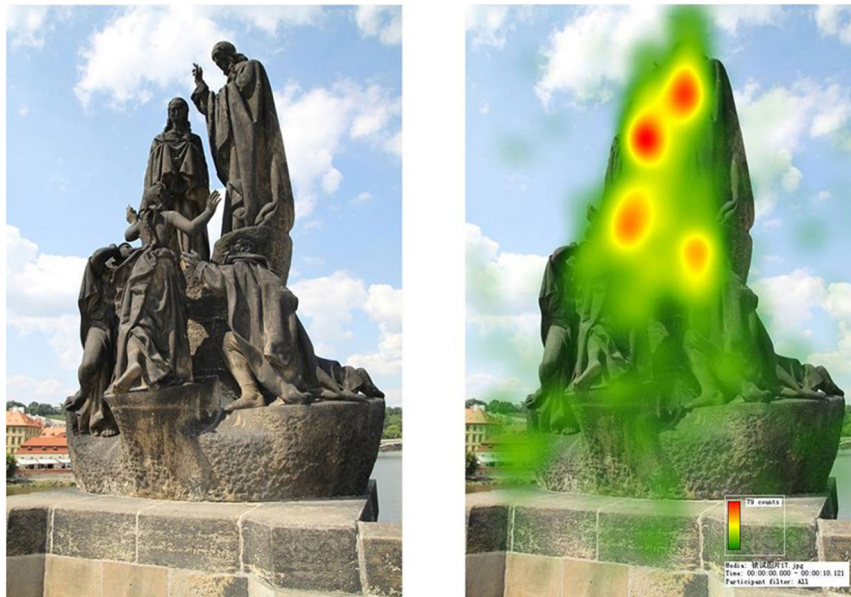
## Discussion

**Relationship between different scales (the city scale\street scale \building scale).** For sustainable development, historic cities face challenges, including protecting their cultural heritage value, constructing new buildings for modern life, and integrating the built and natural environment. To this end, urban planning should find solutions to balance protection and modernisation.

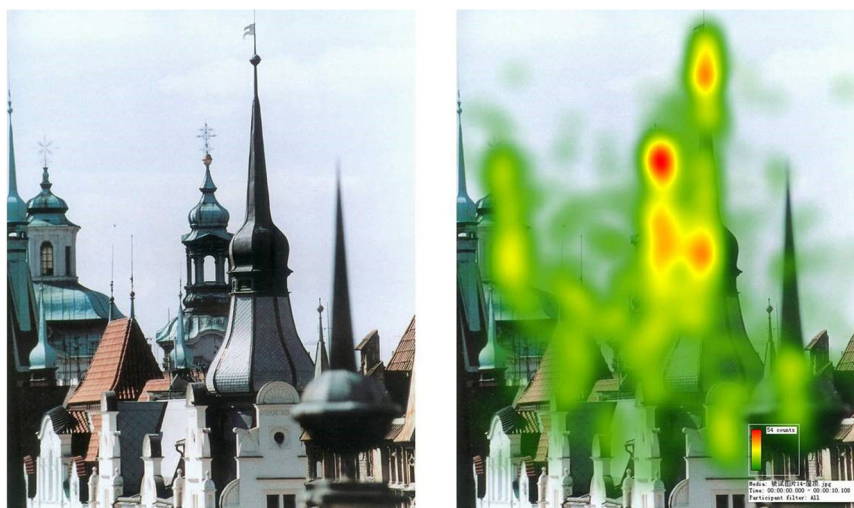
As individual buildings make up streets and individual streets make up cities, there is a logical sequence from micro to macro viewpoint levels to understand the characteristics of the distribution of visual focus for visitors using an eye tracker. Our results revealed that those elements, including tall buildings, the street ends, and the centre lines of building facades, tend to attract visual attention. The human brain tends to understand the visible detail and the direction of the centre of visual attention. Human eyes could be viewed as biosensors connected to the human brain. In particular, the eyes play an important role in understanding surrounding objects through visual information



**Fig. 14** The comparison of eye motion and heatmap for the Prague Castle façade.



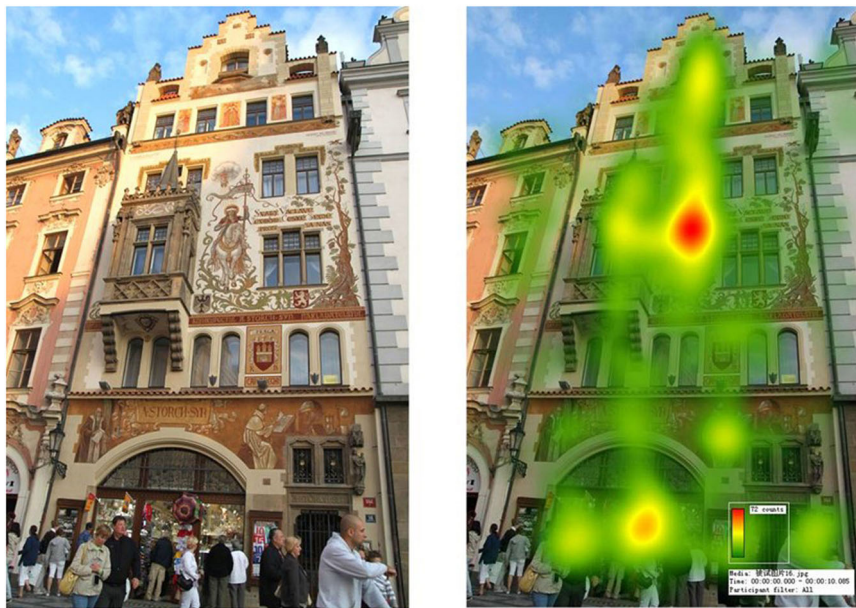
**Fig. 15** The comparison of eye motion and heatmap for the city bridge sculpture of Cyril and Methodius.



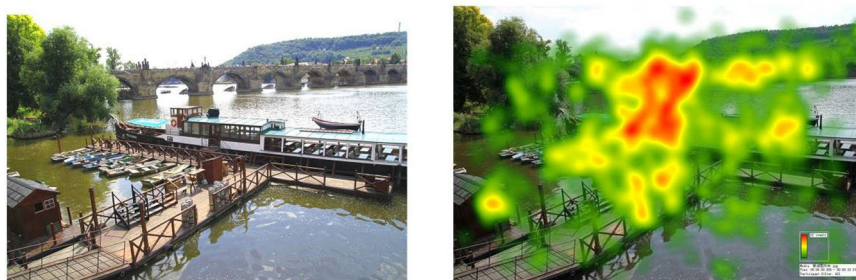
**Fig. 16** The comparison of eye motion and heatmap for the roofs.

processing. (This process involves a complex neurocognitive mechanism combining many potential processes in the human brain, such as active vision, awareness, and other processes). Active vision focuses on specific parts of the visible region from the focal point of vision (Shevlin 2020). It can provide important information for building maintenance and construction by understanding visitors’ visual focus patterns.

**Results of applications.** We now return to the main questions in the introduction and discuss the characteristics of places and objects that should be visually protected on WHS. This study belongs to Visual Impact Assessment (VIA), which could assist planners and tourism managers in refining the planning of rooftops and urban skylines, building facades, streets, greenery, and architectures to preserve their primary forms and to protect OUV further.



**Fig. 17** The comparison of eye motion and heatmap for a typical building nearby Old Town Square.



**Fig. 18** The comparison of eye motion and heatmap for the river area.

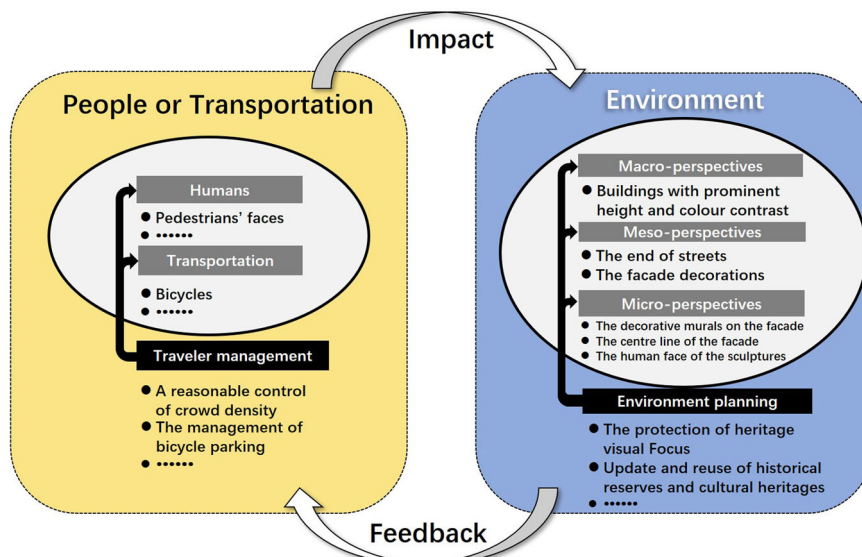
First, understanding the characteristics of the visual concerns from macro-perspectives can avoid interference due to new construction. Since cultural buildings on WHS are located in the urban centre of Prague, the vitality is strongly influenced by both modernisation and tourism. Therefore, the Historic Centre of Prague is selected as a typical WHS for the evaluation of the visual integrity in this study. According to UNESCO's State of Conservation Report, urbanisation has many adverse effects on the visual integrity and aesthetic values of cultural properties due to high-rise buildings (Meskell 2014). Our study showed that the buffer zone on the periphery of the cultural site can effectively protect the skylines and characteristics of the visual landscape. However, tall buildings (e.g., Zizkov TV Tower), as well as prominent architects and landscape nodes, can attract visitors' attention. The results from the field survey in the present work were consistent with previous studies that depicted that salient objects with high contrast in shape, colour, or texture in indoor scenes could attract a high degree of visual concerns (Underwood and Foulsham 2006; Dupont et al. 2016). Therefore, new buildings with prominent heights and strong contrasting colours should be restricted to WHS.

Second, our results indicated that subjective visual concerns could be attracted by the end of streets, facade decorations, bicycles, and pedestrians' faces. In contrast, little attention is paid to the sky, ground, and greenery, following a previous study suggesting that participants preferred to dwell on artificial objects relative to trees and bushes in parks based on their eye-tracking response (Amati et al. 2018). Intrinsically, greenery

becomes a flexible space to serve as a background for buildings and landscape nodes. Since the planning of new green areas is restricted, efforts should be made to retrofit existing green spaces and vegetation to enhance the ecological effect without compromising the visitor's experience of heritage value. Deteriorated pavement floors can be renewed if an intense colour or contrast is avoided. Furthermore, visual conservation requires reasonable control of crowd density and conscious management of bicycle parking.

Third, visual hotspots are concentrated on complex parts of buildings or sculptures, such as the decorative murals on the facade, the centre line of the facade, and the human face of the sculptures. Since facades and sculptures attract visual attention, crowds are frequently observed near these places. As such, sufficient stopping and resting places should be provided for tourists.

The above results were displayed in Fig. 19. The left part depicted people and transportation, while the right showed an environment divided into three perspectives (macro, meso, and micro). It is worth mentioning that one study presents Prague's participatory emotional mapping data. There are 98,364 points, accompanied by 30,941 comments from 5973 respondents in the city of Prague (1,335,084 people). The question about traffic hazards has received the most comments (in relative numbers) (Pánek et al. 2021). Since people and transportation could be visual concerns, optimisation for the characteristics, such as controlling the density of pedestrian flow and planning parking spaces, should be considered by tourism managers. In addition, the discovery of three perspectives on visual concerns can help



**Fig. 19** The diagram of the application of the distribution of visual focus for WHS visitors.

environment planners to update and reuse WHS according to these findings.

Visual impacts have recently been addressed as an essential factor to consider when conducting an Environmental Impact Assessment (EIA) to protect cultural heritage. In this case, Directives 2014/52/EU of the European Parliament and the Council on assessment of the environmental effects of certain public and private projects (2014) identified that to preserve historical and cultural heritage as well as landscapes, a project’s visual impact must be considered, changes in the appearance or view of a built or natural landscape or urban area in EIA. In 2009 the Elbe Valley in Dresden, Germany, was deleted from the WHL, while the Liverpool-Maritime Mercantile City was removed from the WHL in 2021. This is attributed to the visual fragmentation of various dock areas and alterations of the skyline as well as the contours of the Maritime Mall. The OUV of the heritage has been irreversibly damaged. Therefore, two of the three de-listings were due to the destruction of the visual integrity of the site as a result of development. Following the 1972 World Heritage Convention, each state party must protect its cultural and natural WHS (UNESCO 1972). During the Meidan Emam incident in Esfahan, Iran, the state party failed to recognise the threat and act immediately in response; in this case, UNESCO was informed too late after the tower had been mostly constructed. Even though the Iranian government started its collaboration with UNESCO to minimise the impact of the high-rise building on the WHS property’s visual integrity, it was impossible to accurately identify and analyse the existing threats and associated impacts on the site with an adequate impact assessment methodology. Government expenditures on reducing building height exceeded three million dollars (Ashrafi et al. 2021). In addition to demolishing the additional levels of the tower, compensation to the owners was required.

Elucidation of the impact of human construction on the overall visual focus of heritage is necessary for applications of conservation renewal to actual natural and cultural heritage sites. As of 2021, the total number of cultural heritage sites were depicted in Fig. 20. Blue squares represented 897 World Cultural Heritage sites; green triangles represented 218 natural heritage sites; yellow circles represented 39 World Heritage mixed sites (Cultural and Natural Heritage sites); red represented the 52 cultural heritage sites that are in danger of extinction. Among the 52 sites, 36 squares represent cultural heritage sites, while the 16

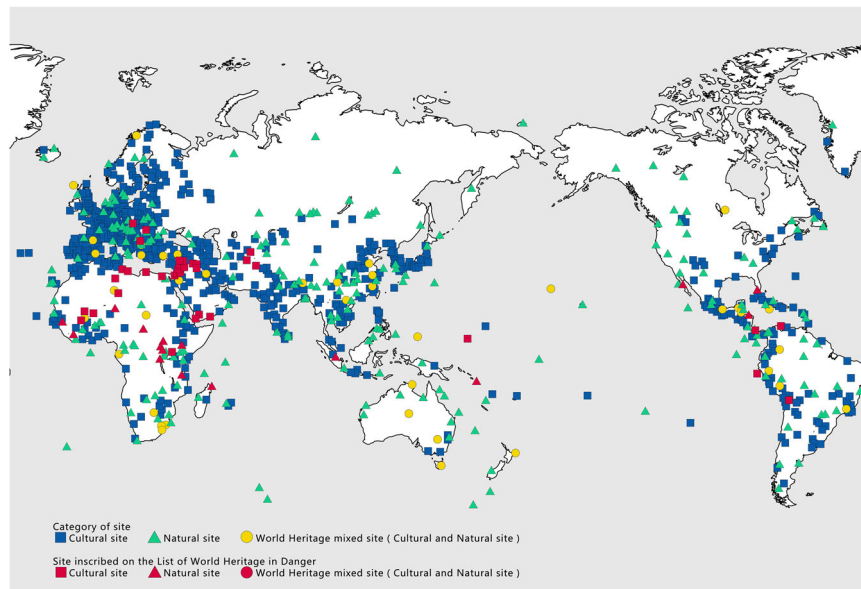
triangles represent natural heritage sites. Apart from the three sites delisted, UNESCO (<http://whc.unesco.org/en/list/>) has strict requirements for WHS, each of which must maintain as much of its original beauty as possible and avoid the construction of modern facilities. Therefore, VIA is needed on WHS to avoid a huge loss of economic and cultural value and OUV.

Since socio-economic development is associated with artificial construction, heritage environments must be protected and moderately renewed while adapting to this socio-economic development. There are three core attributes of a cultural object: physical form (Form), links to the cultural and historical significance (Links), and vitality to actively transmit meaning (Vitality) (Farrelly et al. 2019). Similarly, heritage should be considered a dynamic process that recognises the established meanings and creates new ones (Roders and van Oers 2011). To ensure that traditional culture is unthreatened by the construction and development of modern life, to save and preserve their main forms, and to further protect OUV, we propose that it is necessary to understand the pattern of visual focus in typical examples, which may allow us to prevent the loss of cultural heritage at risk of extinction and to acknowledge its established historical significance.

The present study explored the visual focus of humans on a heritage site, which would be beneficial for planning and protecting historical cities. However, the study had a limitation that should be discussed: this research is only limited to visual perception. In addition to visual attention, a city has a distinctive soundscape. For example, the famous Prague Music Festival brings much musical culture to this city. Recent studies indicated that subjective attitudes are related to multiple sense channels, including olfaction movement, and sound (Small et al. 2012; Liu et al. 2019, 2022; Meng et al. 2020; Xiao et al. 2020). In particular, the audio-visual interactions can affect the overall environmental quality (Liu et al. 2019, 2022; Jeon and Jo 2020). Physiological measurements for landscape in combination with soundscape will be investigated for more thorough assessments, and a comprehensive audio-visual study will be performed with wearable devices based on techniques including field filming and virtual reality in our future study.

**Conclusion**

Although significant efforts have been made to assess visual impact in the preservation and documentation of cultural



**Fig. 20** The map of World Heritage Sites.

elements, there is a lack of in-depth analysis to quantify the visual integrity of outdoor buildings and landscapes on WHS (Ashrafi et al. 2021). Understanding visual concerns would be beneficial for heritage management and future planning. A key factor to consider for the protection and planning of urban heritage is preserving the original value of the landscape and architecture. In addition, the visual focus from the perspective of tourists should be considered for sustainable protection of design, which can help planners and designers to avoid the homogenisation of urban landscape features. As far as the planning for the Historic Centre of Prague is concerned, this work demonstrated the characteristics of visual focus distribution for the typical urban landscape, including streets, architecture, sculptures, and river landscape.

- (1) The city scale (from Human visual macro-perspectives): humans' perspectives are unblocked or attracted, and the view of main attractions is generally maintained by the buffer zone, although new buildings such as Zizkov TV Tower attract a high degree of visual concerns. In fact, people's attention is focused on the highest points of the skylines as well as architecture and landscape nodes that show a prominent difference in colours or styles, while the sky, ground, and greenery are less likely focused. The buffer zone is important for protecting heritage in all sustainable conservation methods. Within the buffer zone, each section defined by places having important perspectives has significance in protecting visible ranges of the main historical objects. Planning for the protection of these sections is verified in the eye-tracking study. As such, it is essential to keep the integrity of the outer contour of historical architecture. It will be necessary to keep the height of new buildings below the average height and the colours less prominent.
- (2) The street scale (from human visual meso-perspectives): the end of streets and standing bicycles are the focus of people's attention in street scenes. Therefore, bicycles should be placed in a reasonable position. Furthermore, the faces of pedestrians nearby affect visual concern, indicating that the visual quality can be enhanced by controlling tourist density and behaviours. Although well-designed greenery,

- roofs, and floors might enrich the aesthetic quality of architecture, they attract little visual concern.
- (3) The building scale (from human visual micro-perspectives): it is observed from a series of heat contrast maps that the features of historical cities, such as the facade midline, domes, the face of sculptures, and the middle of murals, which have complex artistic effects, are the focus of people's attention. Protection of these features should be strengthened.

Although this is a cultural heritage case study, the identified visual focus patterns reflect common human visual patterns. The case meets Criteria Compendium of WHS: (i–vi) (Jokilehto 2008). The study images include holistic perspective shots from KOP, different directions, and shots from a visitor's perspective of the streets, architecture, sculptures, and river landscape covering the typical type of urban visual landscape (Palmer 2019). Hence, the research results have a certain universal application value. From our research, tourism and transportation impact assessments should be incorporated into heritage management plans. We hope that the identified visual patterns will contribute to the design, conservation, and management of the visual integrity in cultural heritage sites and that the number of endangered heritage sites worldwide will decrease.

#### Data availability

Datasets generated during the current study (interview transcripts) are not publicly available due to a confidentiality agreement with the interviewees. However, they are available from the corresponding author upon reasonable request.

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### Competing interests

The authors declare no competing interests.

### Ethical approval

Considering that this study does not involve medical research on human participants, ethics review and approval were not required in accordance with the local legislation and institutional requirements as well as the Declaration of Helsinki (World Medical Association Inc, 2009) guidelines.

### Informed consent

All participants in this study signed a written informed consent prior to the interview and survey processes. Moreover, individuals signed written informed consent for publication of any potentially identifiable images or data included in this article.

### Additional information

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