POLITECNICO
MILANO 1863

SCHOOL OF ARCHITECTURE, URBAN PLANNING AND CONSTRUCTION ENIGNEERING

POLO REGIONALE DI LECCO

MASTER OF SCIENCE IN BUILDING AND ARCHITECTURAL ENGINEERING
ARCHITECTURAL ENGINEERING TRACK

ACADEMIC YEAR 2021 - 2022

PERCEPTION ASSESSMENT USING A MULTIDISCIPLINARY APPROACH: THE CASE OF POLITECNICO DI MILANO LEONARDO CAMPUS

SUPERVISOR
BARBARA ESTER ADELE PIGA

CO-SUPERVISORS
LUCA MAINARDI
NICOLA RAINISIO
GABRIELE STANCATO

AUTHORS
KANISA ATIPAS 927111
NAPISA NAKVIROJ 938767

ACKNOWLEDGEMENT

First of all, we would like to express our gratitude to our supervisor, Professor Barbara Ester Adele Piga, who guided us throughout this project. we could not have undertaken this journey without the invaluable patience and feedback.

We would like to extend our sincere thanks to Gabriele Stancato and Nicola Rainisio from Laboratorio di Simulazione Urbana Fausto Curti (LABSIMURB), as well as Professor Luca Mainardi, Rita Laureanti, and Chiara Maninetti from Department of Electronics, Information and Bioengineering, Poltecnico di Milano, who generously provided knowledges and expertise.

Lastly, we would be remiss in not mentioning our families and friends for all the support and encouragement.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The effect of the built environment's characteristics on perceptions is fundamental to architectural and urban design. Urban scholars have used traditional and contemporary observation-based methods to evaluate the environment. Therefore, many design theories and principles for urban spaces have been centered around intuition or personal experiences without considering users' perceptions. This contribution introduced user-integrated technology, including interactive mobile applications and body sensors, to assess the built environment. The experimental procedure was developed and applied on a path that provides different walking experiences with a particular target of users who work or study at the Politecnico di Milano's Leonardo Campus. The comparative study was conducted between the conventional method of urban study and the sensory-based approach, which include psychological data collection using the exp-EIA© method with the integration of the CitySense application, and physical appraisal to gather biofeedback from sensory devices.

Keywords: perception assessment, sense of place, walking experience, environmental perception, architectural analysis, urban design, sensory device

ABSTRACT

L'influenza dovuta alle caratteristiche dell'ambiente costruito è un tema centrale in architettura e urbanistica. I ricercatori hanno utilizzato nel tempo metodi tradizionali e ed empirici basati sull'osservazione diretta al fine di valutare le peculiarità dell'ambiente circostante. Conseguentemente, numerose teorie e approcci alla progettazione di spazi urbani sono stati costruiti attorno all'intuizione o alle esperienze personali di chi le ha pensate senza considerare la percezione degli utenti finali. Questo studio propone un metodo di integrazione dell'utente nel processo attraverso l'uso della tecnologia, avvalendosi di applicazioni digitali e sensori corporei atti a valutare la percezione dell'intorno in ambito urbano. L'esperimento è stato pensato e svolto su di un percorso avente diverse esperienze di attraversamento con uno specifico campione di utenti che lavorano o studiano all'interno del Campus Leonardo del Politecnico di Milano. Lo studio comparativo è stato condotto tra il metodo tradizionale di analisi urbanistica e l'approccio basato sui sensori, il quale include la raccolta di dati psicologici attraverso l'impiego del metodo exp-EIA© integrato con l'applicazione CitySense e il monitoraggio dei dati biometrici derivanti dai sensori.

Parole chiave: valutazione della percezione, genius loci, ambiente costruito, urbanistica, analisi del costruito, sensori indossabili

01 INTRODUCTION

Architectural and urban studies have embraced the idea of the 'sense of place' (Waller & Flader, 2010). Sense of place may be defined as symbolic and memorable perception of the urban environment (Lynch, 2008), or recognition created through experiences with physical settings, which can be understood through holistic studies of lived experiences (Tuan, 2011). However, it has rarely considered the comprehensive instrument literature to measure the quality of public spaces.

'Senses of place' and walking practices are fundamentally related since walking is an unconscious way of moving through urban space, enabling us to sense our bodies and the features of the environment. (Matos Wunderlich, 2008) Although walking constitutes an embodied everyday practice and a self-evident, it often represents unconscious sensory activity. One critical concern is its practice. As realized by Piga in the Experiential Walk, it is difficult for the individual to evaluate the effect of one single sense separately from the others and correlate it to a single facet of the global personal impressions of a place (B. E. A. Piga, 2021). Kim & Kim's observation supports this argument.

Rather than being based on objects, normally, design principles and theories for urban spaces have been derived from urban theorists' intuition or personal experiences (Kim & Kim, 2019). Moreover, existing literatures do not properly quantify the assessment of the built environment (Mehta, 2014). This study addresses the challenge of creating multimodal assessments to evaluate pedestrian satisfactions with the built environment based on psychological and physical data.

Many research and scholarships reflect diverse perspectives around the relationship between place and learning, which are relevant to urban environmental education (Russ & Krasny, n.d.). Due to the importance of perceptions in education context, the new campus of Politecnico di Milano – Leonardo has been chosen as a case study of this research. The new campus of Politecnico di Milano was newly designed based on the idea of Renzo Piano and the development of an original idea by the ODB-

Research question:
What are possible approaches to assess pedestrian perception on the built environment?

Objectives:
- Assess the pedestrian satisfactions with the built environment using multisensory approaches based on the psychological and physical data

- Develop the experimental procedures and apply on the case study, the new campus of Politecnico di Milano-Leonardo

OTTAVIO DI BLASI & Partners studio (Politecnico Di Milano: New Architecture Campus, n.d.).

A multidisciplinary methodology has been specifically designed for assessing the perception of students and university staff, who are the primary users of the campus. Observation and simulations using software are considered as ‘conventional approach’, while data of ‘sensory based approach’ has been collected through the walking experiment. The comparison investigation was conducted as a conclusion.

02 LITERATURE REVIEW

2.1 Perception and Satisfaction Factors

2.1.1 Environmental Perception

For empirical environmental and psychological hypotheses, scholars typically construct human-environmental perception and behavior processes using an ‘exposure–cognition–behavior response framework’ (Steg & de Groot, 2018). The first phase concerns how humans are exposed to their surroundings, such as sounds or visual stimuli. The second phase, namely human cognition of the exposure, is primarily influenced by individual differences in age, gender, socialization, and adaptive capacity. The final part referred to as human behavior responses, entails emotional arousal, stress reduction, or evaluation of the current circumstance (Zhang et al., 2021).

How do people interpret their surroundings through three steps of responsive mechanism? While human sensory experience can be understood as being embedded in material environments and provoked by specific aspects, urban spaces do not create experiences in a straightforward manner (Degen & Rose, 2012). As is well known, humans receive things simultaneously through their senses, yet the two further hypotheses can explain how our perceptive mechanicals work.

Perception in Motion

The primary justification for this topic is related to motion and how people perceive their environment while walking. Degen and Rose suggest that we have to take account not only of the sensing body but also how the sensory body is moving through urban space (Degen & Rose, 2012). As explained by Winkler, 'motion' is a fundamental attribute of our bodies and a particular aspect of walking. Together with touch, it influences the perception and appropriation of environmental features, landscape appreciation, and social participation (Winkler, 2010). As stated by Tilly, "Through walking, landscapes are woven into life, and lives are woven into the landscape in a continuous and never-ending process" (Tilley, 1994). Consequently, everyday walk creates paths during which sensorial engagement and interaction with the environment take place—'perception paths' (Gibson, 1979) where body and mind act together in living the experience in motion (Kanellopoulou, 2017).

Concept of Affordance

The impression of the environment can also be influenced by an object's affordance quality. As concluded by Degen and Rose's second notion of the walking experiment in Bedford and Milton Keynes, the experiences of urban built environments can be mediated by certain sort of remembering which related to the affordance of environmental objects. For example, regular users of the town centers were both highly engaged in and articulated about the sensory qualities of the built environment; yet they did not notice their surroundings (Degen & Rose, 2012). This conception implies that specific forms of the built environment afford the specific sensory experience.

Additionally, this hypothesis can be clarified by Gibson's theory of affordance (Gibson, 1979). In his concluding, significant work, The Ecological Approach to Visual Perception, Gibson describes how he came up with the phrase:

"The affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill. The verb to afford is found in the dictionary, but the noun affordance is not. I have made it up. I mean by it something that refers to both the environment and the animal in a way that no existing term does. It implies the complementarity of the animal and the environment (Gibson, 1979).

Gibson defines affordances as characteristics of environmental features or perceivable information that offer cooperating organisms' possibilities for action (Golonka & Wilson, 2019). Hinton clarified this notion with some illustrations and examples. He explained that the way sunlight and other substances interact with the shape and texture of a tree branch in nature allow us to detect the structural characteristics of the branch. Even when we are static, we are constantly in motion and can view the branch from many perspectives. Our bodies unconsciously identify affording qualities as a result of the dynamic between the brain, body, and environment (Hinton, 2014).

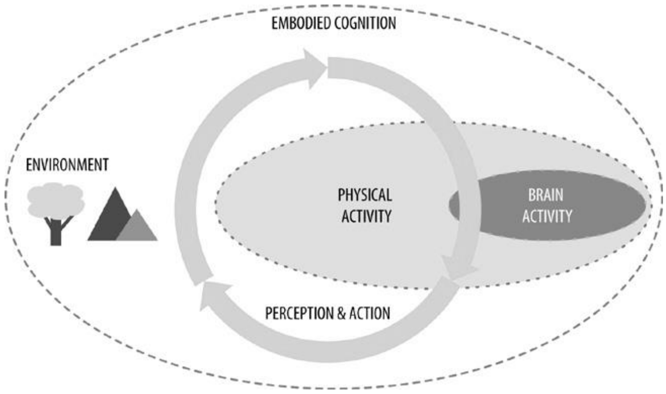


Fig. 1. A model for embodied cognition: brain-body-environment relationship.
(Hinton, 2014).

2.1.2 Restorative Environment

Environmental psychologists have long recognized that research on restorative environments is a crucial complement to studies on stress and coping (Saegert & Winkel, 1990). The idea of restricted restoration acknowledges that failure to restore efficiently may occur for causes other than those directly resulting from stressor exposures (von Lindern et al., 2017). Chronic stress results from repeated exposure to stressors, a person's inability to learn new coping mechanisms or resources, a person's inability to use the resources at hand effectively, and a person's failure to replenish the resources that have been sufficiently exhausted.

For instance, Hartig.'s initial research on this idea considered chilly summer weather as an environmental condition that people could avoid by staying indoors but that would restrict access to outdoor spaces with a reasonably high level of restorative quality (Hartig et al., 2007). The varied viewpoints on adaptation to shifting environmental conditions have been used to frame this complementarity (Hartig et al., 2001; Hartig, 2008, 2021). The fundamental theoretical and practical tenets of each of these views are defined in the Table below.

Table. 1. (below) Perspective on Human Adaptation to the Environment.
Source: Chapter 19The Restorative Environment: A Complementary Concept for Salutogenesis Studies (von Lindern et al., 2017).

	Stress Perspective	**Coping Perspective**	**Restoration Perspective**
Theoretical premise	Heavy demands can undermine adaptation	Readily available resources support adaptation	Adaptation requires periodic restoration
Practical premise	Interventions can eliminate or mitigate demands	Interventions can enhance the availability of resources	Interventions can enhance opportunities for restoration
Relation to salutogenic perspective	Contrast: comparable to the pathogenic perspective	Congruent: subsumes the salutogenic perspective	Complement: calls attention to issues of resource depletion and renewal

Accordingly, 'restorative environments' might be characterized as situations that permit and promote restoration (Ulrich, 1983). Two well-known theories in environmental psychology—the psychophysiological stress recovery theory (Ulrich, 1983; Ulrich et al., 1991) and the attention restoration theory—discuss the environmental conditions that enable and encourage restoration (S. Kaplan, 1995; R. Kaplan & Kaplan, 1989).

The psychophysiological stress recovery theory (Ulrich, 1983; Ulrich et al., 1991) is concerned primarily with environments as people see or view them. It focuses on the affective response to stimulus patterns and contents in the visual stimulus array. The theory assumes that some visual characteristics support stress reduction and that this has an innate basis. Stress is one manifestation of the operation of an evolved affective system that directs approach and avoidance behavior (von Lindern et al., 2017).

Another prominent theory concerned with restorative environments is the attention restoration theory (ART) (R. Kaplan & Kaplan, 1989; S. Kaplan, 1995). Effective functioning is construed as being primarily dependent on the capacity of the mind to focus attention. For instance, to deliberately concentrate on what is required or pertinent to complete a certain task (such as writing a report) and to block the processing of extraneous inputs and inappropriate behaviors (e.g., angry outbursts) (von Lindern et al., 2017).

2.1.3 Multi-Sensory Approaches

The actual experience of urban spaces while navigating in the city is based on the overlapping of sensory experiences, presenting an array of methodological problems in its assessment and evaluation (Vasilikou, 2016). From the previous perspectives, we can imply that the built or urban environment elements are significantly relevant to pedestrians' view, as the walking experience is 'multi-sensory' (Matos Wunderlich, 2008). In other words, sensory experience is defined by Edward Ralph as a synesthetic faculty that combines sight, hearing, smell, movement, touch, imagination, purpose and anticipation and is strongly connected to sense of place (Anemogiannis & Theocharis, 2021). As clarified by Mehta, pleasure experience was derived through various stimuli perceived from the environment; lights, sounds, smells, touches, colors, shapes, patterns and textures of the natural and artificial fixed, semi-fixed and movable elements (Mehta, 2014). Although spatial qualities are evaluated by users as a combination of the different senses, research on the sense-scape of outdoor urban spaces has shifted its focus from the visual quality of the designed environment to studies of sound, olfactory, taste, haptic and thermal perception (Vasilikou, 2016).

According to Vasilikou, the combination of sound in architecture and psychology has the ability to manipulate the acoustic environment in changing an individual's feelings and behavior, which could trigger memories, familiarity, arousal, tension, comfort, discomfort, warmth, and relaxation (Vasilikou, 2016). This acoustic environment of a place or an architectural context can be referred to as 'soundscape.' Secondly, "The identity of an architectural space is also linked with scent" (Henshaw, 2013). This notion highlights that both sound and smell-taste perception can capture and preserve the memory of any given space, and every space can have its own smell. Moreover, smell-taste perception and long-term memory are closely related and often last longer than visual images (Engen, 1991).

In contrast to olfactory, the haptic sense creates a strong link between the body and the built environment by leaving an immediate physical mark. The acknowledged advantage is its ability to incorporate not only one quality but many and those of different kinds; sensations of pressure, temperature, pain, and kinesthetic, as well as all of the aspects of sensual detection that involve physical contact internally and externally (Vasilikou, 2016). Lastly, the temperature sense (or thermal sensation and comfort), recognized as a part of haptic perception, has recently attracted growing attention from interdisciplinary researchers with its dynamic aspect of thermal perception. While visual, sound, and olfactory quality studies have focused on user experience during bodily movement in outdoor urban spaces (Payne, 2010).

2.1.4 Visual Perception: Isovist

Visual perception still prevails on top of the hierarchy of the senses and architecture remains a visually oriented discipline

(Vasilikou, 2016). Isovist analysis is an efficiency method for quantifying the visual perception on the environment.

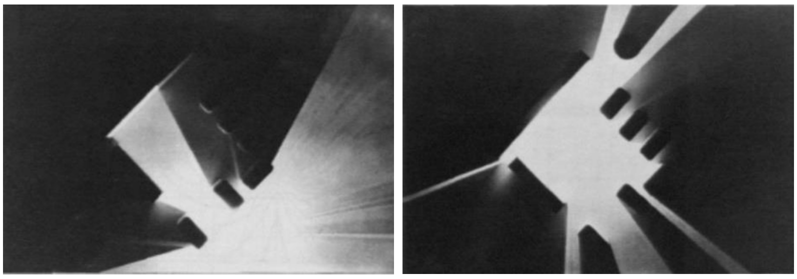


Fig. 2. Analog production of isovist by point-source illumination of a model (Benedikt, 1979)

Although the idea of an isovist has been around since 1970, Benedikt popularized it in 1979. By quantifying the geometry of space seen from the defined vantage point, isovists were designed to aid in the prediction of spatial behavior and the perception of building visitors. Benedikt defined the isovist as a polygon that encloses the area of the environment that is seen from a single vantage point when viewed from above. In order to define the geometry of the isovist, he deduced a variety of metrics, some of which are relevant to a building user's spatial experience. (Benedikt, 1979) In other words, the set of all points that may be seen from a specific place in space. Despite the fact that it is now more practical to calculate isovists in three dimensions, isovists have generally been implemented in two dimensions (Krukar et al., 2021).

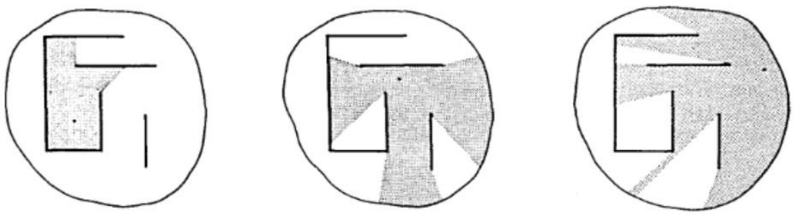


Fig. 3. An original concept of the isovist from points (Benedikt, 1979)

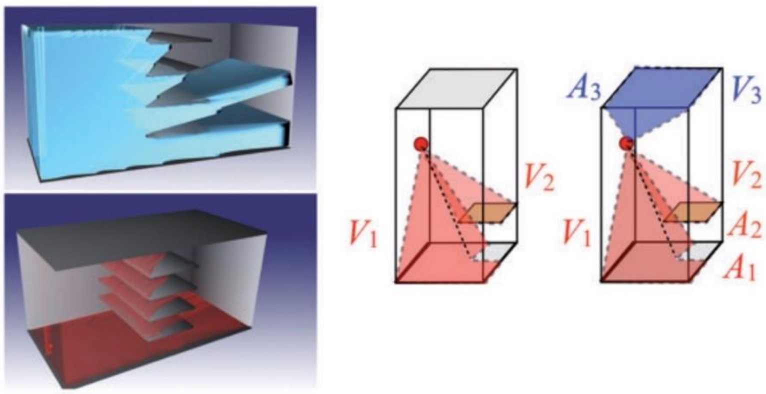


Fig. 4. Examples of 3D isovist
(Krukar et al., 2021)

Many researchers have used isovist indicators to evaluate built environment, urban space, and architecture. Franz tested ideas of behavior and emotion in response to surroundings by measuring environmental configurations using isovist indicators (Franz & Wiener, 2008). Xiang considered isovist indicators as a means to relieve pedestrian psycho-physiological stress (Xiang et al., 2021), while Amoozandeh used it for the space decomposition in an indoor environment (Amoozandeh et al., 2022).

Fig. 5. Xiang considered isovist indicators for pedestrian perception study (Xiang et al., 2021)

A graph may be used to illustrate the isovist along the path to make it easier to grasp. Dalton asserts that we may "unfurl" an isovist and display the distribution of its radial lengths if we think of an isovist as having a large number of lines of sight radiating from a single point in space. The graphs demonstrating the distribution of the radial lengths of three isovists are shown in the figure below (Dalton & Bafna, 2003).

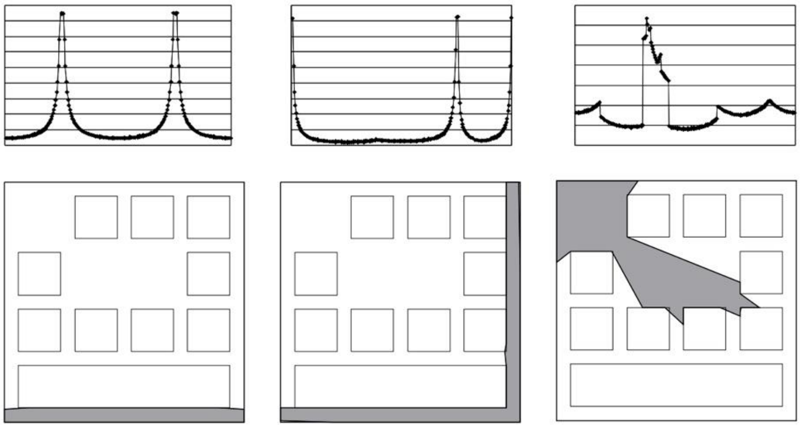


Fig. 6. Graphs of isovits along paths (Dalton & Bafna, 2003)

Despite isovist analysis can measure the visual perception effectively in term of quantities, visual perception is not only sensory but involved with past experiences. “There is no perception which is not full of memories. With the immediate and present data of our senses; we mingle a thousand details out of our past experience” (Bergson, 1911, as cited in (Degen & Rose, 2012). Environment exposes on humans first, and then humans cognize of the exposure. Cognition is varied with many factors, such as age, gender, social, adaptation ability, etc. (Zhang et al., 2021).

2.2 Walking Experience

2.2.1 To Experience

Numerous academics have described walking as a habit that people engage in on a daily basis unconsciously and effortlessly that incorporates both their physical movement and mental states. Conceptually, the term 'walking experience' is complicated and difficult to grasp.

For Wunderlich, 'to walk is to experience'; we utilize all of our senses compulsively while we move through spaces; therefore, the act of walking is seen as a condition of perception and thinking in constant flow (Matos Wunderlich, 2008). Wunderlich suggested that we must separate walking from context and reality as if we could objectify it in order to reflect on it as a lived experience (Matos Wunderlich, 2008). We view objects in real life by wandering about them rather than from fixed places. While doing so, we understand their depth, size, scale, and function (Ingold, 2004).

However, how can we experience things? It is imperative to first consider what is implied by experiencing and how we perceive things. The definition of experience should be examined first. As Yi-Fu Tuan 11/29/2022 11:06:00 AM explained, 'to experience is to learn'; it means acting on the given and creating out of the given. The given cannot be known by itself. What can be known is a reality that is a construct of experience, a creation of feeling and thought (Tuan, 1977).

Furthermore, by unconsciously moving through urban spaces, walking enables us to sense our body and the environment (Seamon & Mugerauer, 1986). Tuan interpreted 'experience' as a combination of feelings (reporting on subjective states) and thought (reporting on objective reality), the latter two being connected ways of knowing (Tuan, 1977). Anemogiannis & Theocharis concluded that the walking experience is also 'multi-sensory' because it creates and re-creates new intellectual and physical connections over distances and through time (Anemogiannis & Theocharis, 2021).

Our experience of the environment differs if we are alone, in a couple, or in a group (Staats & Hartig, 2004). As suggested by Piga (B. E. A. Piga, 2021) for the experiential-walk method, an individual experience is preferable due to the need for attention to the relationship between person, environment, and mutual influence in order to investigate the ambiance of places. A person should activate and pay attention to all senses while walking by immersing and concentrating on experiences in a specific environment.

Sense of Place

As mentioned earlier, walking compels us to use all our senses, emotions, and cognitive processes through urban spaces. Thus, walking is a way to experience urban space that is inextricably linked to the notion of ‘sense of place’. According to Lee's theory, walking is instead constitutive of the place itself and is a particular way of engaging with the world (Lee, 2004). For Tuan, sight, touch and the kinesthetic experience are identified as facets that enable human beings to develop a strong ‘sense of place’ and spatial attributes (Tuan, 1977). While Matos referred the acoustical, olfactory, visual, tactile and even taste are occasionally as contributing to retaining a ‘sense of place’ (Matos Wunderlich, 2008). To conclude, the sense of place is articulated simultaneously as a form of emotional attachment, which means a process of signification and codification of social and personal sensory experience. It can be referred to as the psychological interconnections between a place and its inhabitants (Anemogiannis & Theocharis, 2021).

Ambiance of Place

While ‘sense of place’ is centered around the human perception, ‘ambiance of a place’ is more sensitive to environmental conditions or what the physical spaces offer to humans. As concluded by Piga and Morello, the environment emits sensory data, received, and processed by individuals. Within this process, we recreate our personal understanding and give value to the environment (thus deriving the ambiance of the place). Consequently, the ‘ambiance of a place’ is intended as the physical atmosphere processed through human senses, culture, and personal experience (B. Piga & Morello, 2015).

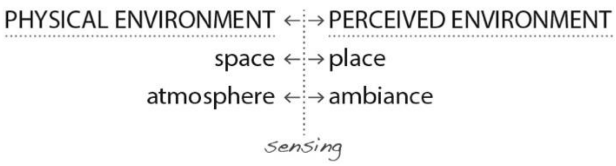


Fig. 7. Physical Versus Perceived Environment. (B. Piga & Morello, 2015).

2.2.2 Three Types of Walking Practice

Following these concepts, three distinct forms of contemporary walking practices in everyday life are outlined. Purposive, discursive, and conceptual walking are inherent temporal practices supported by Wunderlich's literature on the phenomenological fieldwork (Matos Wunderlich, 2008).

The first category, 'purposive walking', is task-oriented, unconscious, instinctive, or even automatic most prevalent type of walking. It is a 'necessary activity' (Gehl, 1987) that connects A to B to C and further on and is normally of a constant rhythmical and rapid pace (Matos Wunderlich, 2008). This type includes walking to work routinely or taking a child to school.

The term 'discursive' is inspired by Michel De Certeau's account of urban walking: "The act of walking is to the urban system what the speech act is to language" (Certeau & Certeau, 2002). This second type of walking practice represent the rhythmicity and harmonic affinity between the pedestrian and the environment, which is done for its own sake, or the joy of being immersed in it. In this way, our familiarity with the environment is deepened. In contrast to the previous walking practice, the journey is more noteworthy than the destination, as are the sites on route (Rendell, 2003).

Under the category of discursive walks, 'memory walking practices' are referred to as spontaneous, meticulously choreographed, and enhance the subconscious mind. As inspired by the practice of flâneurs, memory walking enables the walkers to look for, intensify, and enrich a personal rhythm with the past with new meanings acquired from sensorial experience (Anemogiannis & Theocharis, 2021).

‘Conceptual walking’ is the last classification of all these forms of walking and is usually scripted, carefully planned, and highly performative. The walkers forthright and manipulate the creation of the sensory and cognitive experience through a given concept, following specific walking patterns and contesting the common perception in places instead of synchronizing their walk practice with the place's rhythms (Anemogiannis & Theocharis, 2021). This form of walking inspires and influences creative responses to places; it is a process of becoming acquainted with a space or even a form of intervention in itself (Matos Wunderlich, 2008).

Fig. 8. Purposive walking practices observed at Charing Cross Road, London, Winter 2005. (Matos Wunderlich, 2008).

Fig. 9. Examples of Discursive Walking Practices; Observed in Oxford Street, London, Winter 2005. (Matos Wunderlich, 2008).

Fig. 10. Examples of Conceptual Walking Practices; Walking Arts and Performance Workshop, and Mis-guided in Zurich Workshop, Summer 2005. (Matos Wunderlich, 2008).

2.2.3 Urban Rhythm

Urban rhythm is closely connected to the practice of walking Lefebvre (Lefebvre, 2004) describes walking as a rhythm that explicitly relates to individuals and social groupings and is influenced by certain spatial and cultural settings, for instance, when referring to tourist crowds. Thus, walking can be described as a temporal method of engagement connected to ‘place rhythm,’ which is a multilayered dynamic complex of time-space rhythms arranged in one area (“Buttimer, A., 1976,” 1994). ‘Rhythm’ alone refers to “variation in a pattern in a specific structure” – Marli Huijer. It associates broadly with the fundamentals of life and cultures and can be perceived from the motion of the sun, moon, and stars to the rhythmic movements of a microbe (Nevejan et al., 2018).

Urban life is influenced, shaped, and characterized by social, spatial, and natural rhythms, which also determine how people perceive time and place and their sense of identity (Matos Wunderlich, 2008). According to Wunderlich, another sort of rhythm that can be observed in public spaces is ‘cultural rhythm.’ It alludes to ritual, dressage, etiquette, and gestures. This idea can be related to the urge to exhibit one's identity or the sixth need in public settings identified by Franck & Stevens (Franck & Stevens, 2006). This can be observed, for instance, in mixed-ethnic groups and families walking together while dressed appropriately for church on Sunday mornings.

Fig. 11. Crowded crosswalk.
Photo by Ryan DeBerardinis.

2.3 Pedestrians and Urban Spaces

Walkability is one of the qualities to evaluate the city's livability (Kaal, 2011). Walkable cities can encourage the physical activities of the habitants. On a smaller scale, walkability promotes students' sense of connection to their university's open areas (du Toit et al., 2007). Moreover, Residents' perceptions of their neighborhood environment and the quality of its walkability have also been reported as essential for strolling or recreational walking in the neighborhood (Owen et al., 2004). A variety of factors influence walkability. For Forsyth & Southworth, the walkable environment retains the complete pedestrian infrastructure; sidewalks or distinct paths, designated pedestrian crossings, street furniture, and street trees (Forsyth & Southworth, 2008). Alhusban also identified a number of factors that contributed to a multi-sensory walking experience, including safety, light, shade, landscape, a variety of comfortable open spaces, street connectedness, public seating, the ease of the trip, the quality of the routes, pedestrian crossings, severance, visual amenity, and pavement congestion (Alhusban et al., 2019).

2.3.1 15-Minute City Concept

“Walking is the best way to explore and exploit the city” (Sinclair, 1997). The 15-minute city was well renowned for its unconventional take on a walkable city. It was adopted worldwide in Ottawa, Melbourne, Seattle, and Portland before it became popular in Europe when Paris' mayor unveiled the "Paris Ville du quart d'heure" proposal at the height of the Covid emergency in 2020. Reinforced by Moreno's theoretical discussion (Moreno, 2020),(Moreno et al., 2021), this political agenda established a model for accessibility to urban life experiences within a quarter-hour of one's residence via walking or cycling.

The level of walkability of an area is determined by a number of factors, including ‘safety, comfort, and attractiveness of the walking environment, according to Speck's General Theory of Walkability (Speck, 2012). In order to achieve this, the 15-minute city revaluates the neighborhood scale and prioritizes accessibility to daily services majority based on walking or cycling. Furthermore, by defining the degree of 'essential services' to the local micro-centers, this radical approach endorses function-mix areas, local diversification, and neighborhood-scale living.

Case Study: 15 Minute Walk Model of Milan

Regarding the study of the 15-minute city as a hybrid model for Milan (Abdelfattah et al., 2022), the walk score analysis results set at a 15-minute radius based on walkability from the demand and supply side as shown in the maps below. The supply side is derived from the distribution of the work population, whilst the demand map is drawn by the pedestrian access from residents based on population density.

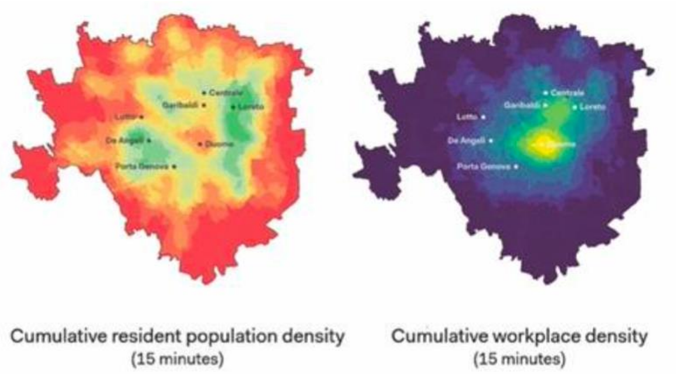


Fig. 12. Pedestrian Access of the Milanese Resident Population (Left) and The Distribution of Workplace Population (Right) in 15 Minutes. (Abdelfattah et al., 2022).

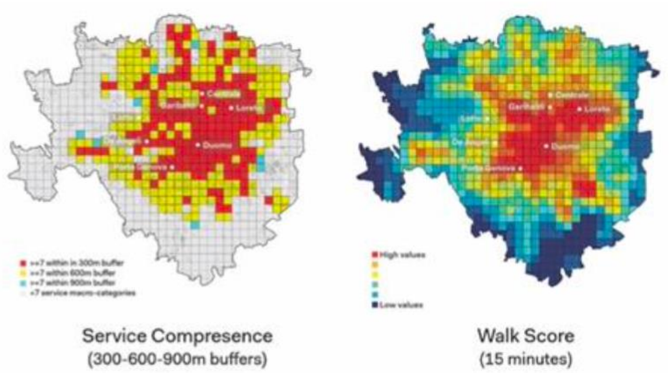


Fig. 13. Service Compresence (Left) and Walk Score (Right) Based on NILS in 15 Minutes. (Abdelfattah et al., 2022).

By considering both sides of the equation, the combined series of maps confirm the static findings of the service compresence, which is concentrated around the central area, and also highlights additional lower-scoring areas in the north of Milan, which can be influenced by adequate service density despite a lack of support of the urban structure for comfortable and efficient walking trips (Abdelfattah et al., 2022). The subsequent discussion recommended that in order to address the issue of inadequate pedestrian infrastructures, the public realm should be seen from a wider perspective and approached holistically, using the walkable "urban living" approach (Sinclair, 1997).

From the walk score scheme, we decided to investigate further some NILs (Local Identity Nuclei as institutionally defined by the Milano City Plan for spatial planning of public interest facilities), which are specific spatial units identified in a spatial grid of 150m. The two NILs of two Politecnico campuses—Citta Studi for the Leonardo Campus and Villapizzone for the Bovisa Campus—were chosen to compare with the NIL of the Duomo di Milano which represent the city center context.

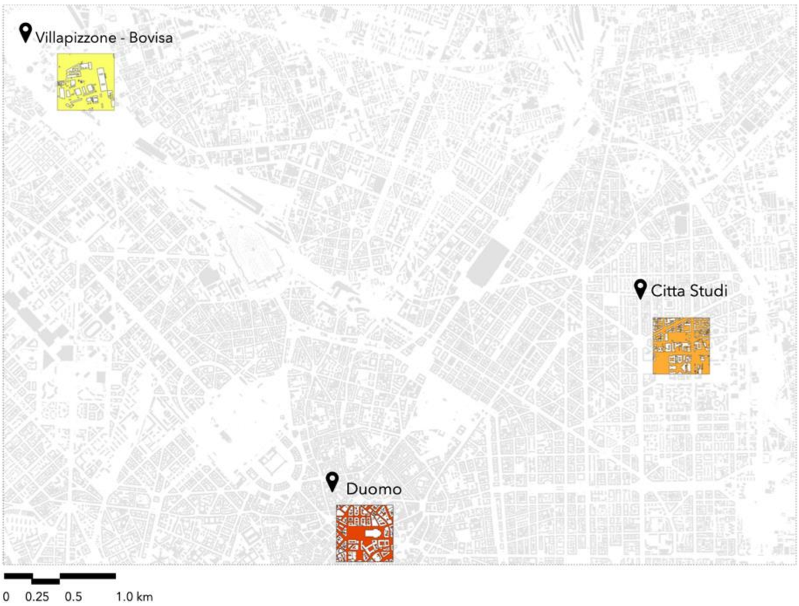


Fig. 14. Comparison Between Campuses and City Center Parameters – Spatial Grid of 500m. Map by Authors.

As shown in the figure-ground schemes below, the Duomo neighborhood owned the highest walking score and the most densely packed constructed area, whereas Leonardo and Bovisa Campus had lower walking scores and smaller built areas, respectively. This finding can be taken to mean, broadly, that the continuous urban fabric, pedestrian environment, facade patterns, facilities, and attractions can affect pedestrian demand and accessibility for walking.

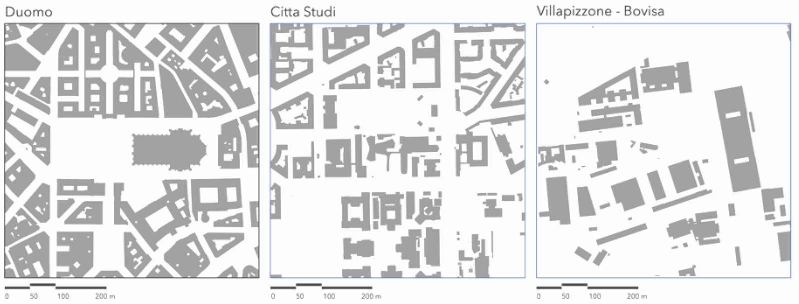


Fig. 15. City Center's Figure-Ground Plan (Left) Compared to Citta Studi – Leonardo Campus (Middle) and Villapizzone – Bovisa Campus (Right).
Maps by Authors

2.3.2 5-Minute Walk Approach

A 5-minute walk measure, widely used to calculate public transportation catchment areas or identify access to destinations inside neighborhoods, was used to determine the research area in block analysis. According to Perry's neighborhood unit diagram (Perry, 1929), the 5-minute walk commonly referred to as the "pedestrian shed," or the maximum distance a person is willing to walk before choosing to drive, is initially represented by a radius measuring ¼ of a mile which equals 400 and 500 meters based on the typical walking speed.

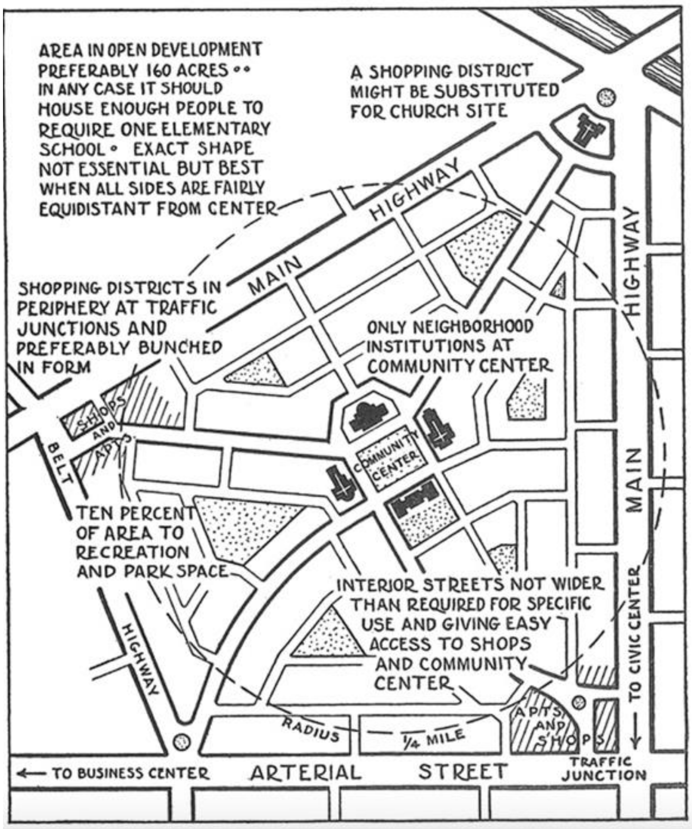


Fig. 16. Clarence Perry’s Neighborhood Unit Diagram . (Perry, 1929).

In urban planning, the 5-minute walk sets a scope for collecting data on a human scale and was adopted by many scholars. An example is an investigation carried out by Peter Bosselmann (Bosselmann, 1998) in which a dotted line representing each path on the the plan view in the form of 4-minute walks was used to compare the experiences along various routes. He found that a 4-minute walk can cover various distances depending on walking speed. Moreover, according to Jan Gehl (Gehl & Svarre, 2013), age, mobility, tasks, and whether the pedestrian is alone or with a group can all affect walking speed, as he noted in his study on the effect of the seasons on walking tempo for the Strøget pedestrian's in Copenhagen.

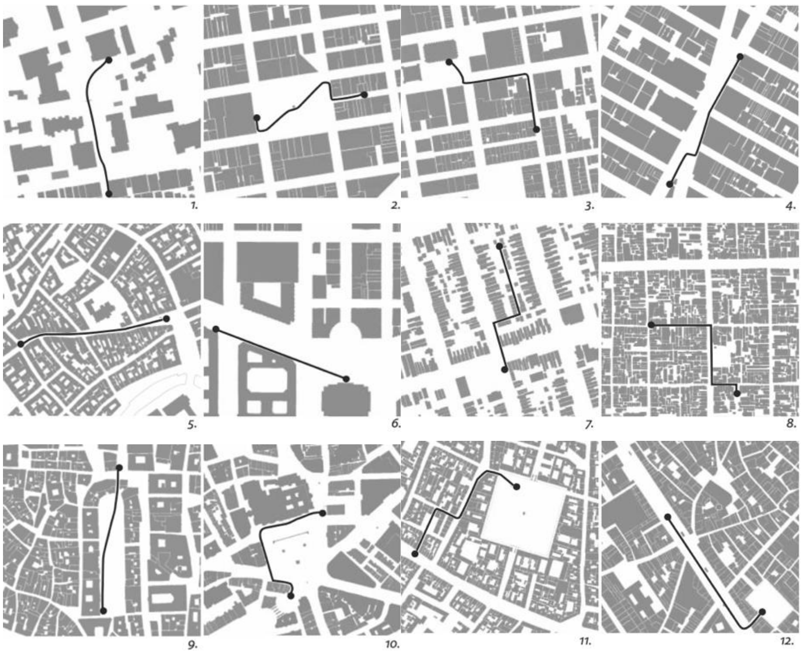


Fig. 17. Bosselmann Comparison Maps of 1. Berkeley Campus, University of California; 2. Downtown San Francisco, California; 3. Chinatown, San Francisco, California; 4. TimesSquare, NewYorkCity; 5. Strøget,Copenhagen, Denmark; 6. Pennsylvania Avenue, WashingtonDC; 7. Old quarter, Toronto, Canada; 8. The old part of Kyoto, Japan; 9. Piazza Navona, Rome, Italy; 10. Trafalgar Square, London, England; 11. Marais, Paris, France; 12. La Rambla, Barcelona, Spain. (Bosselmann, 1998)

2.3.3 Urban Observation

As encouraged by city-life study scholars such as Jane Jacobs, William H. Whyte, and Jan Gehl, the observation of interaction between city life and space should be conducted with own eyes because it will provide a greater understanding. Two examples of this are the series of 'serial visons' sketch techniques by Gordon Cullen (Cullen, Gordon, 1971) and Peter Bosselmann (Bosselmann, 1998), which can capture vital optical elements and give a general impression of the journey through informative illustrations of spaces. The general lines shape the space and give it its main character, while the details; texture, trees, and people, illustrate the environment and how active the spaces are. Additionally, the visual cues that are presented along the way can be used to tie this straightforward drawing method to user experience and spatial navigation.

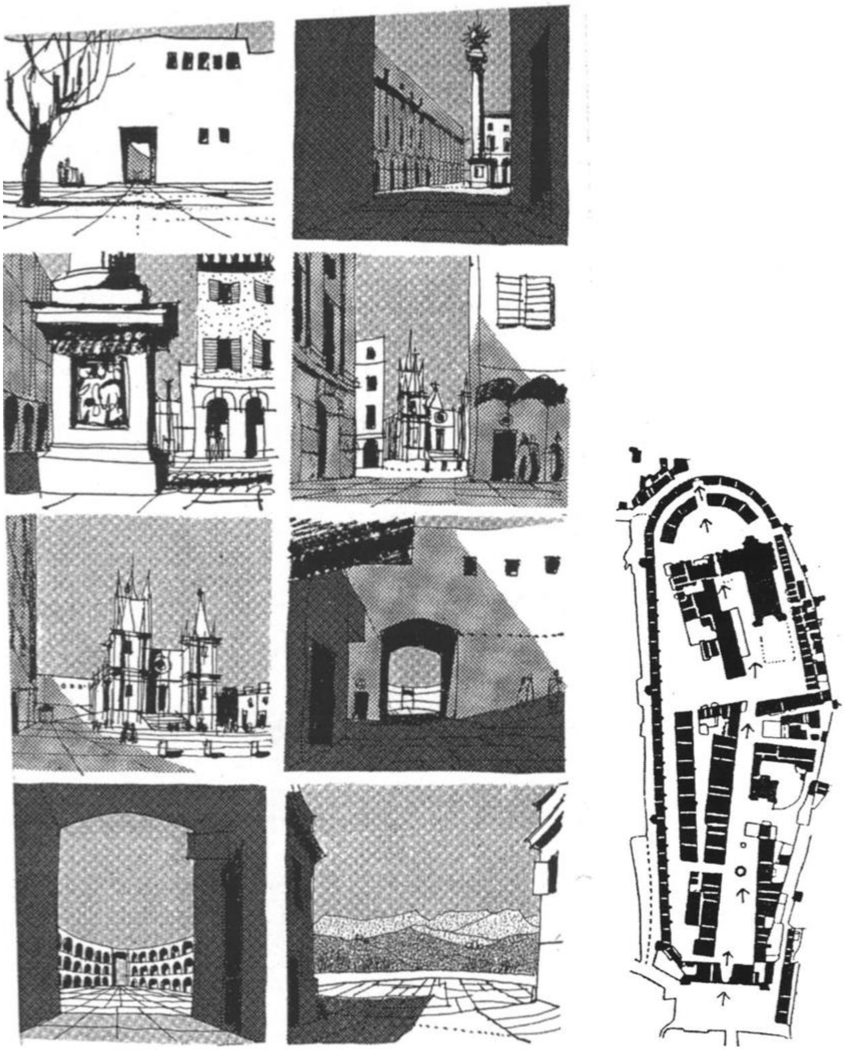


Fig. 18 Cullen's Serial Sketches provide the intriguing sequence of visual revelations from walking experience. (Cullen, Gordon, 1971)

Fig. 19 Bosselmann's Image in Motion Serie represents his impression of regular walk in Venice. (Bosselmann, 1998)

2.4 Campus Space

Campus open spaces are defined as 'accessible urban ecosystems' (US EPA, n.d.), between buildings and functioning as joints of surrounding surroundings, creating a sense of direction in a campus by integrating and arranging various locations and features. Not only physical, but several studies have also recognized the quality of the physical aspect as one of the intricate characteristics of the campus environment. As shown in the figure below, Alhusban defined that the core principles of the campus design include site and context, viability and vitality, accessibility and connectivity, public realm, density, safety, character, mental maps elements, walkability, urban structure, mix use, richness, continuity and enclosure and sense of spaces (Alhusban et al., 2019). Tudorie characterized 'campus open spaces' as multifunctional landscape service providers that provide critical advantages such as increasing air quality, providing good climatic conditions, habitats for biodiversity, outdoor areas to play, do sports, rest, and give psychological benefits (Tudorie et al., 2020).

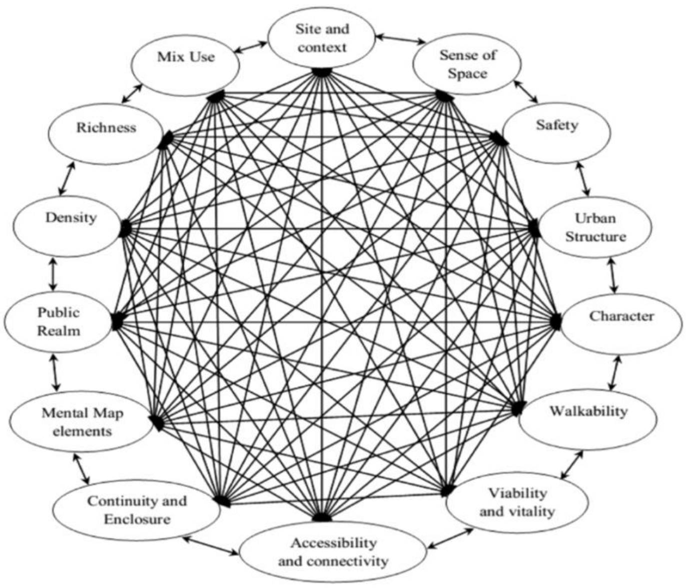


Fig. 20. The Pool of Relationships/Interrelationships between the Campus Urban Design Principles. (Alhusban et al., 2019).

Thus, a well-designed campus creates 'multifunctional places' for students' activities, encourages them to socialize and enhances their academic performance and Experience, increases their feeling of belonging, enhances the sense of well-being, and supports outside learning activities and experiences (Alhusban et al., 2019). The presence of open spaces on campus help to generate a ‘sense of spaciousness’. In most cases, students recall open areas more than their university's structures (B. Piga & Morello, 2015). Good campus-open space designs can also boost the formal indoor learning process through casual encounters, resulting to social interactions amongst users (Tudorie et al., 2020). Furthermore, the importance of campus is more emphasized and has become a critical criterion for evaluating and ranking the campuses (Marrone et al., 2018).

However, how to define what a good campus space is? One option is to consider student preferences, needs, satisfaction, and perception as criteria for campus urban design (Alhusban et al., 2019).It is important to figure out the factors that influence the students’ satisfaction with their campus design during their course of study (Insch & Sun, 2013). The criterion for the campus' urban design and its enhancement can be based on the students' overall sense of pleasure. Another method is to obtain public decisions. The design team may give realistic visuals of various designs integrated inside the actual setting for users to make collective judgments (Al-Kodmany, 1999).

Politecnico di Milano, Leonardo Campus Context

For cities, universities have long been important strategic assets. Cities that host universities benefit from them and live in harmony with universities; in return, the cities receive special and distinctive rewards in a variety of ways, including the economy.

The Politecnico di Milano's Milano Leonardo campus is the oldest, having been inaugurated in Piazza Leonardo da Vinci in 1927. It has been a strategic institution of Milan from the beginning. A genuine university quarter reputed as "Città Studi" or "City of Studies" was created as a result of the campus' expansion to include other campuses throughout the years.

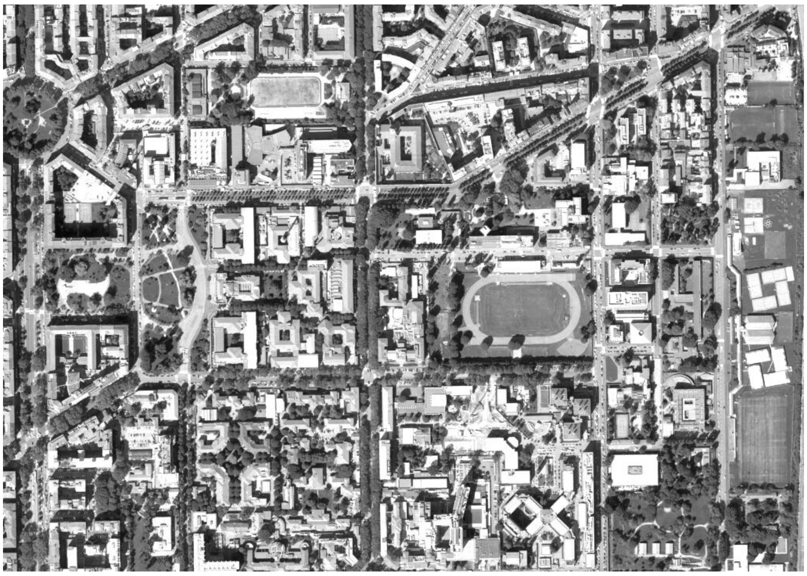


Fig. 21. Top Perspective of Politecnico di Milano, Leonardo Campus. Source: VIVIPOLIMI.

Today, Città Studi is known as a distinctive area of Milan where varied urban activities and academic activities coexist harmoniously. The campus is primarily home to the University's core managerial and administrative structures as well as the facilities for the Schools of Engineering and Architecture. The district hosts the historic buildings of POLIMI and UNIMI, two hospitals, the National Cancer Foundation IRCCS, and the Carlo Besta Neurological Institution. The university campus links with the city effortlessly and openly, making it populated and frequented by researchers, professors, and students (over 20,000 people daily). Moreover, it is surrounded by neighborhoods with great potential for residents. The university spaces are accessible to the public and the city as a whole, providing unique opportunities for recreation and education to people who live and work there.

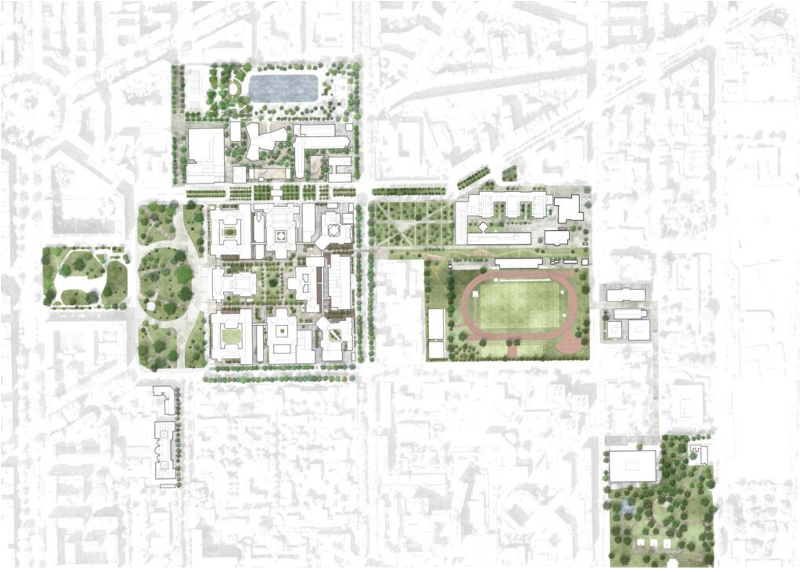


Fig. 22. Masterplan of Politecnico di Milano, Leonardo Campus. Source: VIVIPOLIMI.

Originating from an idea of Renzo Piano, the new University Campus was developed by ODB-OTTAVIO DI BLASI & Partners studio with the idea to rethink the Via Bonardi Campus spaces to increase the provision of study-spaces, teaching spaces, and open spaces. The new design proposed three major transformations: increasing tree and green spaces, restoring the old building, and using roofs as terraces.

Fig. 23. Render of New Campus Space. Source: ODB-OTTAVIO DI BLASI.

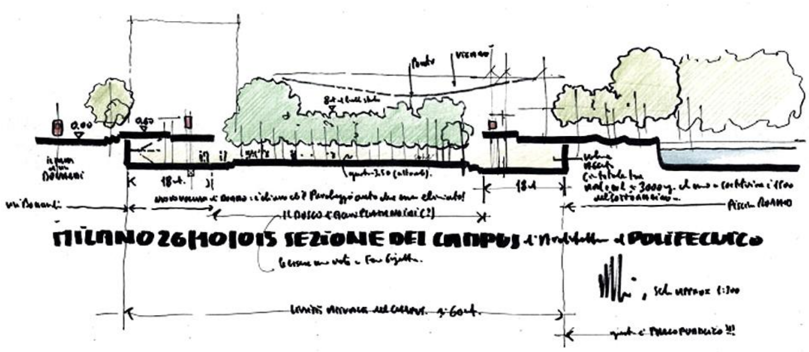


Fig. 24. Section of New Campus, Original Design Drawing. Source: Politecnico di Milano.

03 CASE STUDIES

In order to design the experimental procedure, the authors have studied and analyzed a number of similar projects and research. Ultimately, three case studies with different focuses were selected to be presented based on the methodologies use and the site context.

The first case, the walking experiment by LABSIMURB, is dominate in the objectives and walking practice which is individual walk with the focus on place's multisensory aspects on post-evaluation phase. The experiment was conducted in the center area of Milan which is not far from Citta Studi. The second case is similar to our research in term of context since is also focus on the pedestrian experience in university campus in Chile. This case relates to the use of sensory encounter to observe the environment. The last case shows us an example of applying wearable sensors for data collection, with the clearly defined framework of the method. Below are the summary details of the three case studies

3.1 Experiential Walk Diary Tool

Research title: The experiential walk diary. Mapping urban experience combining architecture and psychology (Piga et al., 2020)

3.1.1. Overview

The case study application is on The Porta Nuova project, located in the center of Milan. The specific focus of the experiential walk was on the 'Gae Aulenti' square, in the middle of the Pelli Clarke Pelli Architects project. However, it is crucial to note that the 'Library of Tres' Park, designed by Inside Outside, was under construction at the time.

The 'experiential walk diary', developed by the 'Laboratorio di Simulazione Urbana Fausto Curti' (LABSIMURB), was a part of multimodal methodology used in at post-monitoring the urban transformation's actual outcomes. Its main scientific goal is to reach a first recognition of the local emotional landscape and trigger at the same time, its punctual reconnection with on-site specific environmental features through the experiential walk modality (Piga, 2021).

This methodology was conceived to be adaptable to different targets and can be used in the initial stages of a research or co-design process in a specific area:
(1) Collect preliminary data on the shared imagination of the place under consideration
(2) Encourage the development of a more structured group discussion, or inform the design of a more focused analysis
(3) Mobilize the target through the exploratory dimension and movement, also favoring mutual knowledge and an essential exchange of opinions
(4) In the case of experts, facilitate an interdisciplinary encounter based on an open platform, which draws inspiration from different disciplines

3.1.2. Methodology

The experimental procedure was simply initiated by allowing each participant to take a 30-minute individual walk through the designated path. While moving through the space, each participant must pay attention to its multisensory elements and ambiance. After the walk, they were asked to reflect on their experiences using the experiential walk diary, which was developed and later interpreted into collective results by the psychologists.

The walk diary structure was broken down into three following sections, aligned from an open compilation to questions with more interlayer.
(1) Free compilation of verbal or visual thoughts and impressions regarding the location.
(2) Gathering information on the psychological experience of being in space utilizing a combination of techniques to capture the complexity of the full place-related emotional image, such as:
(a) A free list of location-related adjectives (b) Gathering information on the psychological experience in space
This section comprises in-depth closed questions based on opposing adjective pairs representing the emotional, cognitive, and social aspects of an urban psychological experience, remarkability-ordinariness, the prevalence of positive-negative

feelings and perceived emotional attuning with the local ambiance, aesthetic pleasure and thought stimulation, perceived affinity with local groups, and space impact characteristics on the interactions within the group of participants.
(3) The participants were primarily guided in responding to the question concerning their psychological experience by collecting textual or graphic data describing environmental elements.

Fig. 25. Researchers are filling the experiential walk diary on-site (left), Researchers discuss the outcomes of the diaries' analysis (right) (Piga et al., 2020)

3.1.3. Outcome

The emotional, cognitive, and social experiencing components were considered and translated into quantitative. As others remark, the location can also be considered an 'oasis,' which is isolated from the city's typical chaos and is entirely pedestrianized; the outcome revealed that it was challenging to develop an emotional connection with the location. It can be characterized as having well-defined architectural and design features, such as a complete lack of green space, the appearance of sterility in the building materials, and the preponderance of the color grey.

However, there are some reservations regarding the validity of the findings, the limited scope, and the stringent requirements. These factors must be considered in order to connect imaginaries with psychological characteristics. Since the survey was conducted with academics at a given time-space, it may not have taken into account other aims or external conditions like weather and the 'Library of Trees' construction phase. The discussion suggests expanding the study's target demographics and repeating it at different times of the year or under various environmental conditions.

3.2 Walking as the Participatory Tool

Research title: A Walking Methodology as the Participatory Tool for a University Master Plan Design (Andersen & Balbontín, 2021)

3.2.1. Overview

This study considered walking as an exploration tool with cognitive and critical objectives about the space, as well as a device for citizen participation. The main objective is to expand theoretic and practical elaborations of urban planning by including citizen engagement in the development of an urban diagnostic.

The research was conducted at the University of Magallanes, Punta Arenas city, Chile, to diagnostic of the present state of the area, which included sensory data for the urban design concept for the developing a master plan for the Punta Arenas Campus. The participatory method aims to include identity, experience, and perception-related elements, to identify the primary issues and needs of the university community, to include this community in practical decision-making, and to provide updates on project progress.

3.2.2. Methodology

There are three main steps for the participative methodology
(1) The meeting of focus groups, which are the users of the campus, with diverse actors (key informants) from the university community, with the intent of representing different interests.
(2) One full day of fieldwork on the university campus, where freely and anonymously different actors were invited to respond to four questions and place their answers on a campus map with post-it notes.
(3) 'Commented walks' with a group of users from the campus.

The chosen route included a first stage through the center of university activity, where participants gathered, and a subsequent path that ran end to end in a straight line across the campus. To capture the thoughts of each participant in each location visited, the entire action was documented using video and images.

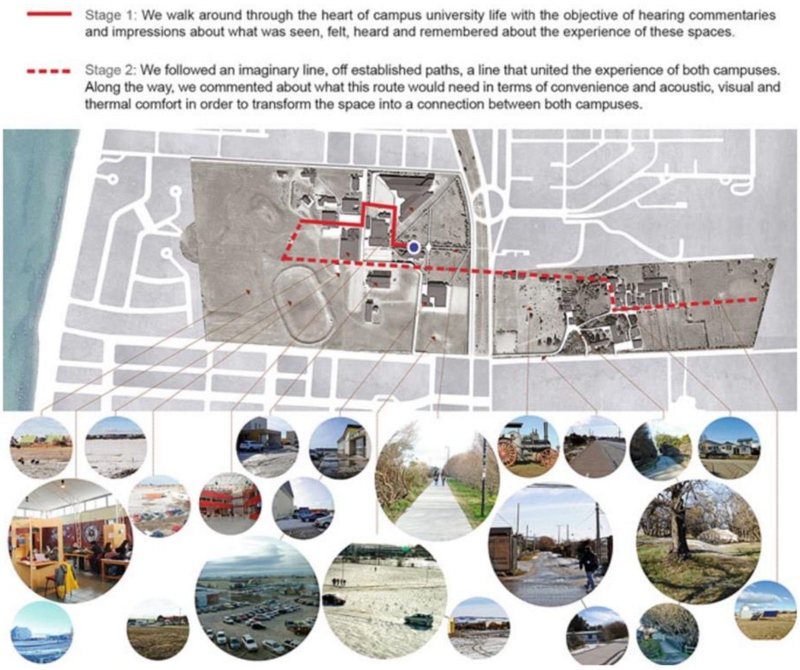


Fig. 26. Map of the chosen route (Andersen & Balbontín, 2021)

3.2.3. Outcome

From the "commented walks", the data regarding forgotten locations that evoke sentiments and ideas based on sensory encounter with these locations was gathered. Direct touch with reality also reveals areas or features of the environment that are overlooked by users and are not stored in their memories. The result has been processed and displayed as a diagnosis map, depicting 4 key zones according to the participants' opinions.

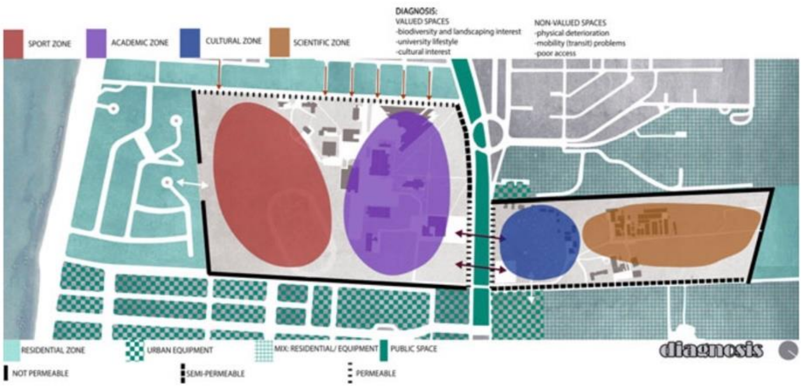


Fig. 27. Diagnosis Map depicting 4 key zones: sport, academic cultural, and scientific (Andersen & Balbontín, 2021)

from observations to strategies, all the comments were translated under six themes, which are design problems, lack of urban furniture, lack of identity, unconsolidated public space, natural heritage, and historical heritage. For the purpose of suggesting strategies, each appreciation is noted under these six themes.

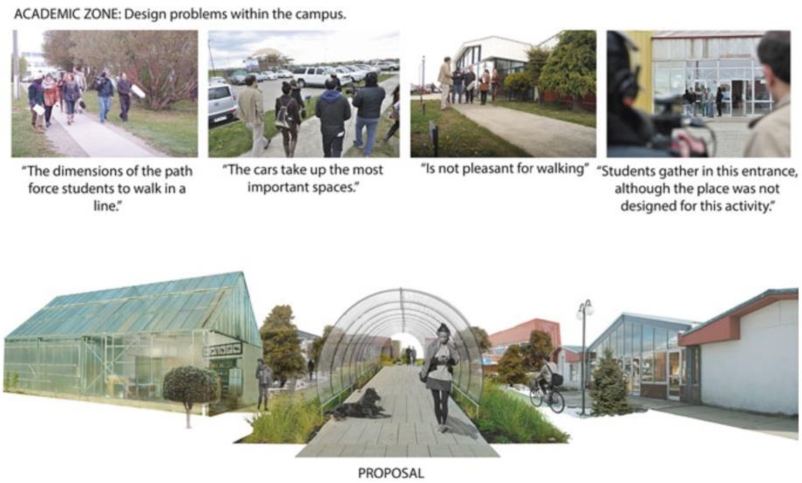


Fig. 28. Example of the outcome: Observations about different places during the “commented walks” and objective image (Andersen & Balbontín, 2021)

3.3 Urban Features and Physiological Response

Research title: Assessing the association between urban features and human physiological stress response using wearable sensors in different urban contexts (Zhang et al., 2021)

3.2.1. Overview

The study combined a wearable camera, a biosensor wristband, and GPS as a package to track changes in people's physiological stress response continuously during their exposure to urban features in various contexts. Its objectives are to: identify significant indicators in various contexts; examine the relationship between urban indicators and human physiological stress response; and pinpoint crucial indicators in study sites to assess urban features on an individual level.

In order to assess the outcomes in various urban environments, six distinct sites in Copenhagen's central business district were chosen. The locations include Sortedams Sø (water area), Nørreport station (transit area), Copenhagen Botanical Garden (green area), Købmagergade (commercial area), Børsgade (motor traffic area), and Christians Kirke surroundings (mixed office and residential area).

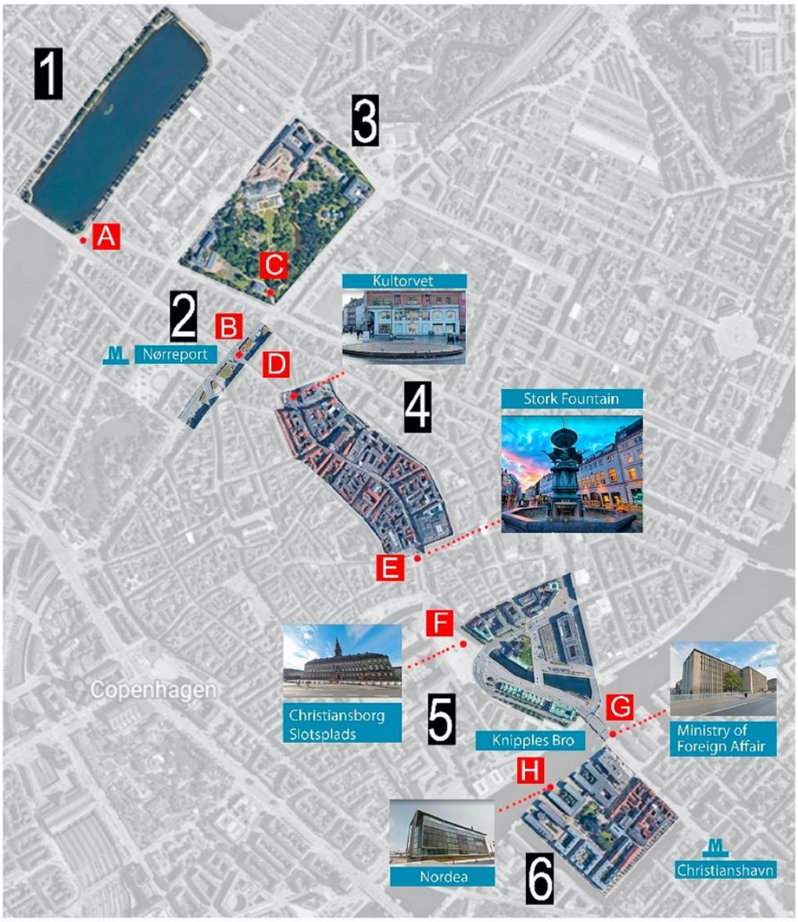


Fig. 29. Six specific sites in the core area of Copenhagenn with different characteristics are selected (Zhang et al., 2021)

3.2.2. Methodology

The study employed three devices:

(1) FrontRow wearable camera: a camera supports time-lapse shooting with different intervals. Participants wore the camera front-facing on the chest so that it could take photos of the front views

(2) Empatica 4 (E4): a medical-standard wristband equipped with an electrodermal activity sensor and infrared thermopile to measure galvanic skin response and skin temperature. E4 was worn on the wrist of the non-dominant hand.

(3) GPS device: Qstarz BT1000XT

Fig. 30. Wearable sensors: (left to right) wearable camera, a biosensor wristband, and GPS (Zhang et al., 2021)

86 participants were recruited for this study. Before the experiment began, participants had a 10-minute training session on the sensors utilized in the investigation. The procedure is depicted in the diagram below.

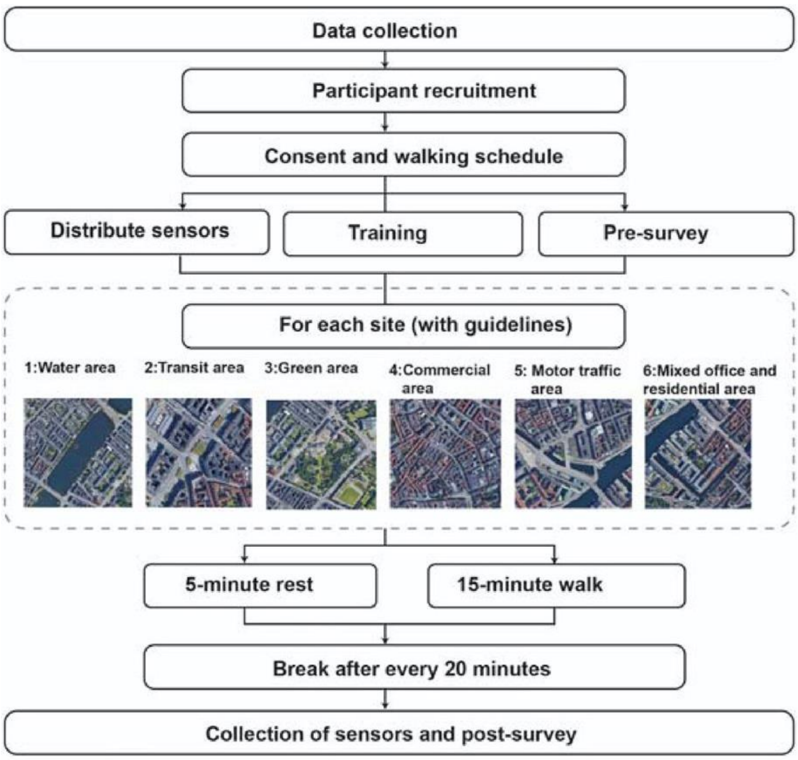


Fig. 31. Experiential method (Zhang et al., 2021)

In terms of data processing, urban characteristics were discovered using Microsoft Cognitive Services (MCS) and a change score was produced to quantify human physiological stress reactions based on galvanic skin response (GSR) and skin temperature from the wristband. The researchers used a random effect model and spatially weighted regression analysis to investigate the association between urban indicators and human physiological stress responses.

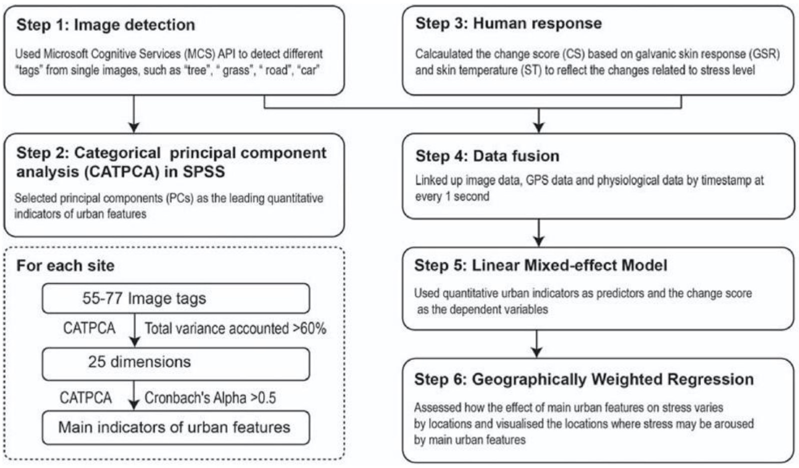


Fig. 32. Framework of data analysis (Zhang et al., 2021)

3.2.3. Outcome

Geographically weighted regression (GWR) was used to determine the local spatial association between selected variables and the change score. The GWR findings indicated the changes in coefficients between indicators and the change score by location, allowing us to compare the places where the change scores were impacted to varied degrees by the indicators.

Fig. 33. Example of the results: GWR analysis between the change score and urban indicators (Zhang et al., 2021)

The study found that human physiological stress response increased significantly when exposed to an urban flow of people, bicycles, autos, waterbodies, greenery, and seating facilities in various contexts. The impact of urban elements on stress relief vary depending on location and context. The result has emphasized the need of urban setting in studies on connections between urban characteristics and stress response.

04 RESEARCH OUTLINE

The main focus of this study is on the procedures. Starting with our research topic, we reviewed several papers on pedestrian perception of the built environment and created our own methodology under a number of limitations.

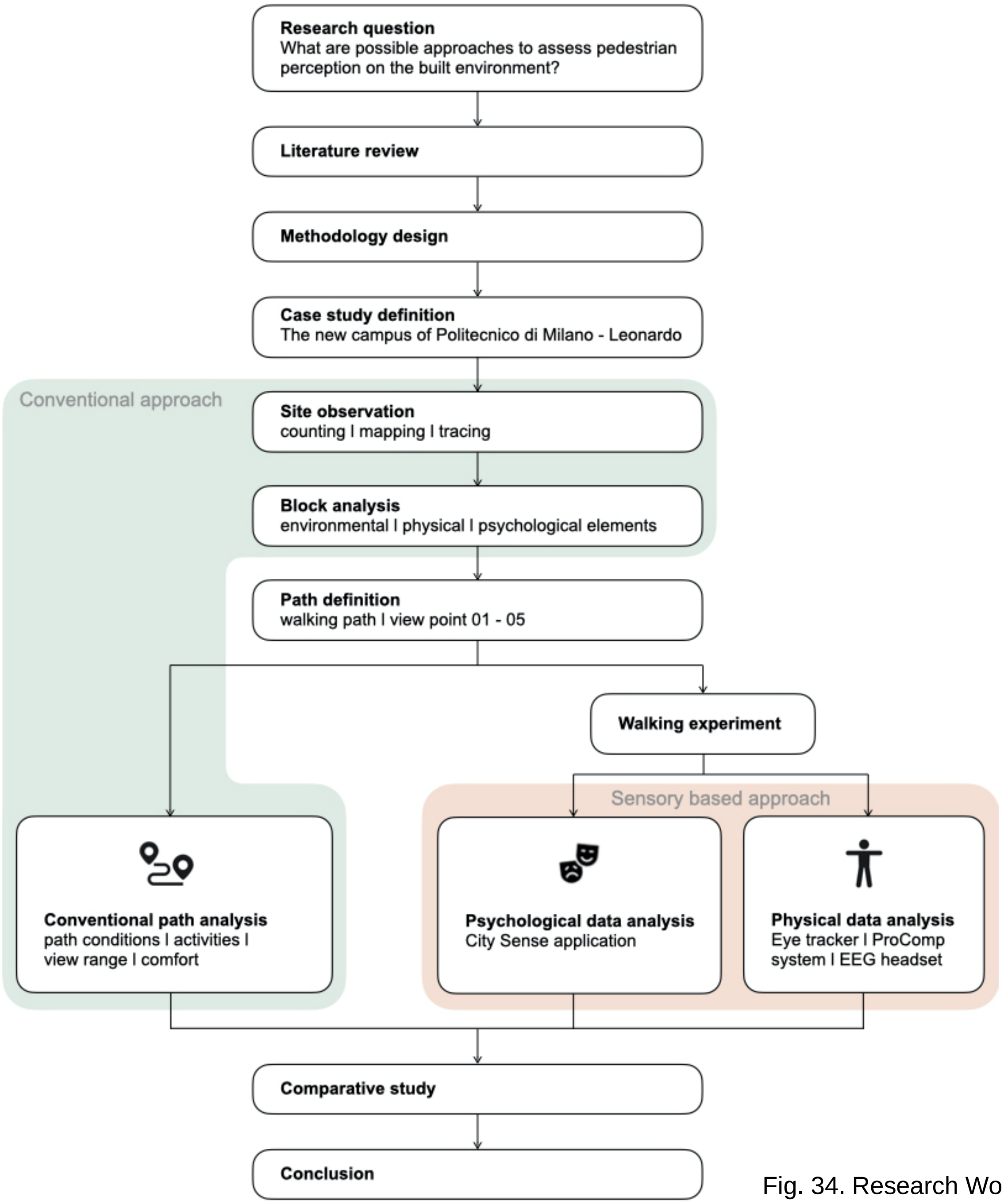


Fig. 34. Research Workflow

The new campus of Politecnico di Milano - Leonardo has been chosen as the case study site to put the methods into practice. The pre-analysis stage was initially carried out on the site; the protocols involve observation and analysis of the entire block. These steps are likewise regarded as conventional approaches, but their primary purpose is to determine the course of the study rather than to conduct a comparative analysis.

Following the path's determination, we carried out path analysis, a conventional approach yet included more details. The walking experiment also took place on the same route. We used CitySense application and sensors to gather both psychological and physical data throughout the walking experiment.

As a conclusion to the thesis, comparisons of these three approaches—conventional path analysis, physical data analysis, and psychological data analysis—were made.

05 CONVENTIONAL APPROACH

5.1 Scope of Analysis

Leonardo Campus settlements are the large single urban block surrounded by fences in an existing Città Studi neighborhood. According to Jane Jacobs' Border Vacuum definition, large single-use institutional areas can be classified as one of the borders as they tend to dull people's desire to cross them to get to another urban district. (Jacob, Jane, 1961) For Jacobs, a border vacuum emerges when some kind of barrier seals what otherwise be accessible space to pedestrians. However, good campus-open-space designs can turn an urban vacuum into a desirable border and offer the potential to activate and support pedestrians.

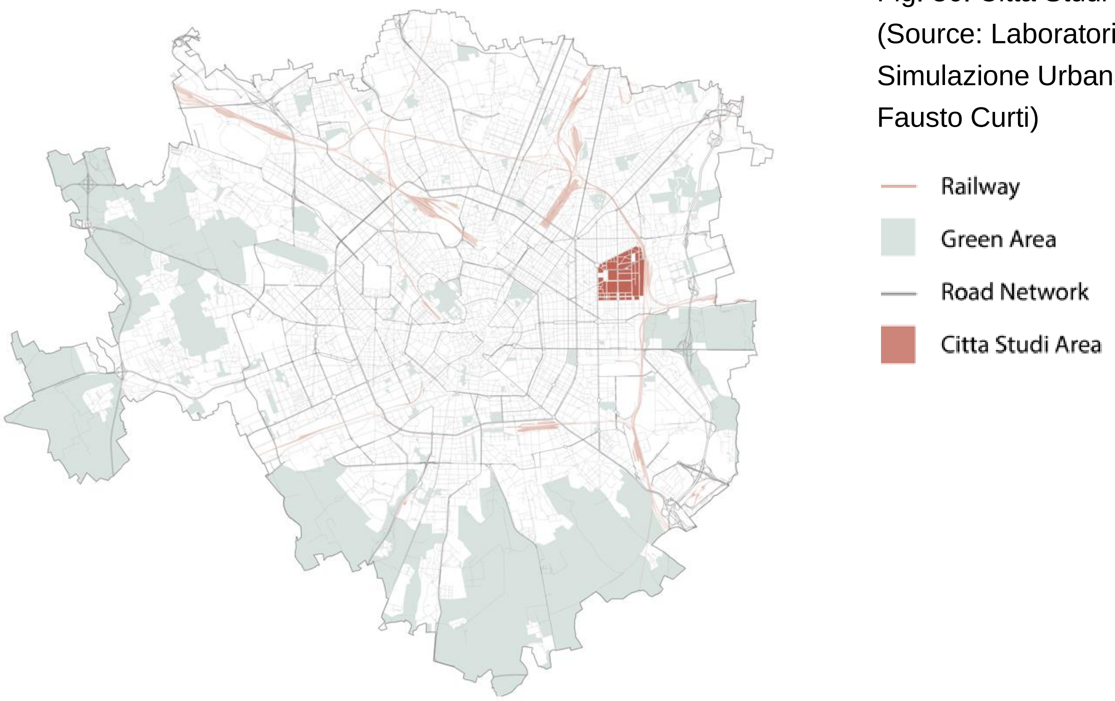


Fig. 36. Città Studi Area (Source: Laboratorio di Simulazione Urbana Fausto Curti)

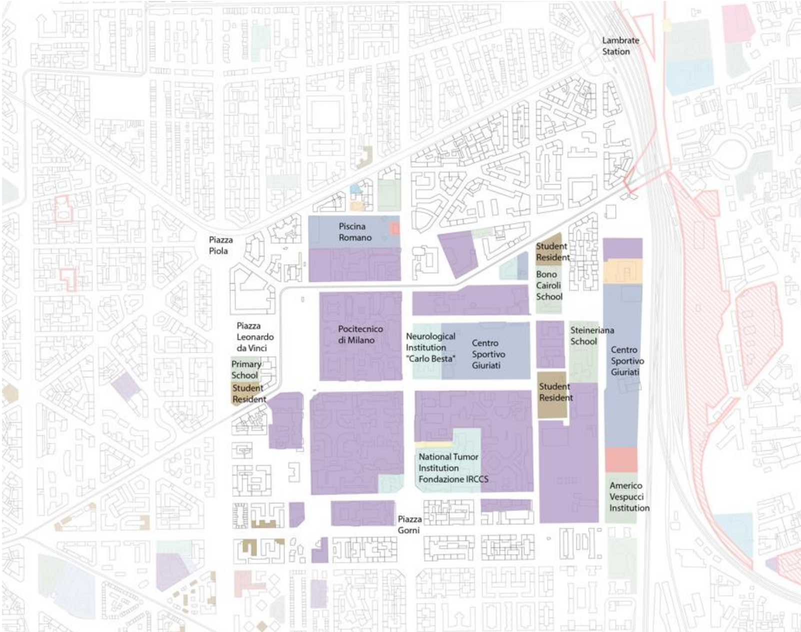


Fig. 36. PGT S01I Public or general interest services (Source: Comune di Milano)

Area Under Transition
- Scope or Partial Implemented Area
- Scope Not Implemented Area

- Administrative Area
- Commercial & Productive Area
- Cultural Area
- Institution
- Health Care
- Social Services
- Sport Area
- University & Research Area
- Technological Infrastructure & Environment (Art. 8.3.1.b)
- Mobility & Public Transport Infrastructure (Art.8.3.1.a)
- Security & Civil Protection
- Housing Services

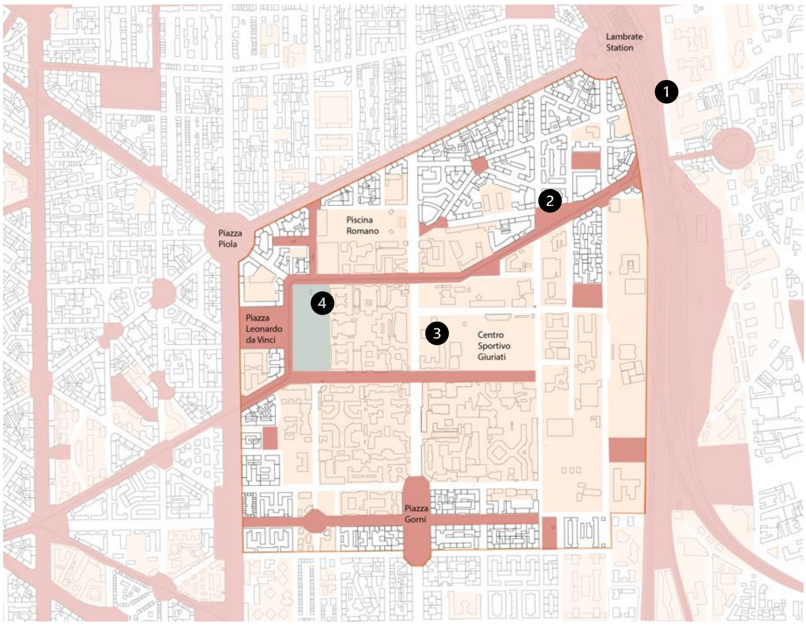


Fig. 37. Città Studi Border

- Geographical and Transportation Borders
- Institutional Borders
- Desirable Borders

Fig. 38. Examples of Borders in Città Studi
1. Transportation Border Railway Infrastructure, Via Rodano
2. Geographical Border Parco pubblico Bassini, Via Afonso Corti
3. Institutional Border Istituto Neurologico Carlo Besta, Fondazione IRCCS, Via Ponzi
4. Desirable Border Piazza Leonardo da Vinci. (Photo by Google Street View)

Emerged an idea of Renzo Piano and ODB-OTTAVIO DI BLASI & Partners studio, the new university campus proposes a solution to demolish undesirable border by opening up urban living areas and sharing the campus with the city. Three pivotal characteristics of the design are highlighted: adding ample green space, preserving the original buildings, and creating accessible terraces to accommodate the students' need. (Politecnico Di Milano: New Architecture Campus, n.d.)

Fig. 39. University Campuses in Città Studi (Source: Laboratorio di Simulazione Urbana Fausto Curti)

As illustrated in the Map of Level 1 below, the new development area and the existing university context are connected through the pedestrian and open space on the street level. In contrast, as represented in the Map of Level 0, the open spaces within the new campus area are located approximately 3 meters below the street level. In order to use those public spaces, students must enter from certain entrances or buildings and take the stair down to reach the destination. The motion transformation obstructs them from using the new campus spaces and induces various physical and sensual experiences.

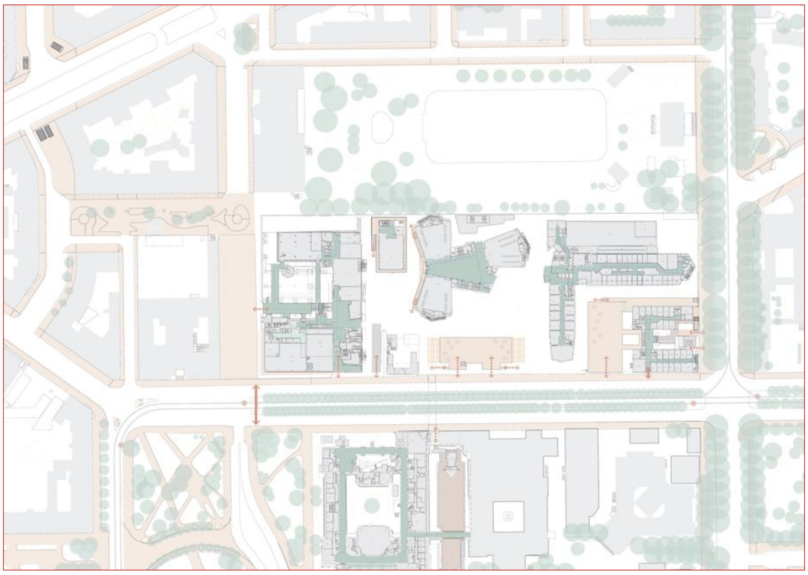


Fig. 40. Map of Level 1 – New University Campus

interior pedestrian
exterior pedestrian
building entrance
crosswalk

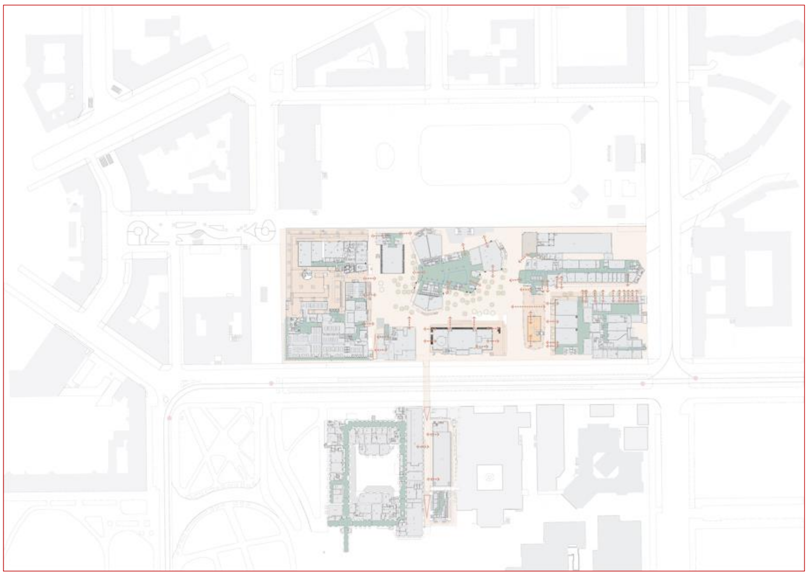


Fig. 41. Map of Level 0 (-3.00 m) – New University Campus

interior pedestrian
exterior pedestrian
building entrance
crosswalk

Fig. 42. Cross Section – New University Campus (Source: Politecnico Di Milano)

5.1.1. The Pedestrians Observation

The observation method was applied at the very beginning of the analysis. According to Jan Gehl and Birgitte Svarre from How to study public life, direct observation is the key tool of the sort of public. As a general rule, users are not actively involved in the sense of being questioned, rather they are observed, their activities and behavior mapped in order to better understand the needs of users and how city spaces are used. The direct observations help to understand why some spaces are used and others are not. (Gehl & Svarre, 2013)

To understand the pedestrian behaviors at the new campus of Politecnico di Milano, three observation modules were carried out in this study: counting, mapping, and tracing.

Counting: Numbers of pedestrians

Counting is basic to public life studies. What is often registered is how many people are moving (pedestrian flow) and how many are staying (stationary activities). Counting provides quantitative data that can be used to qualify projects and as arguments in making decisions (Gehl & Svarre, 2013).

The quantitative data on how many people pass through each space is required in order to identify which points on the new campus of Politecnico di Milano are pedestrian nodes. Since the recreational walk is the main focus of this study, the counting was done during lunch break at 13:00 to 14:00 between 21 to 23 March 2022, using the Clicker Counter application on IOS.

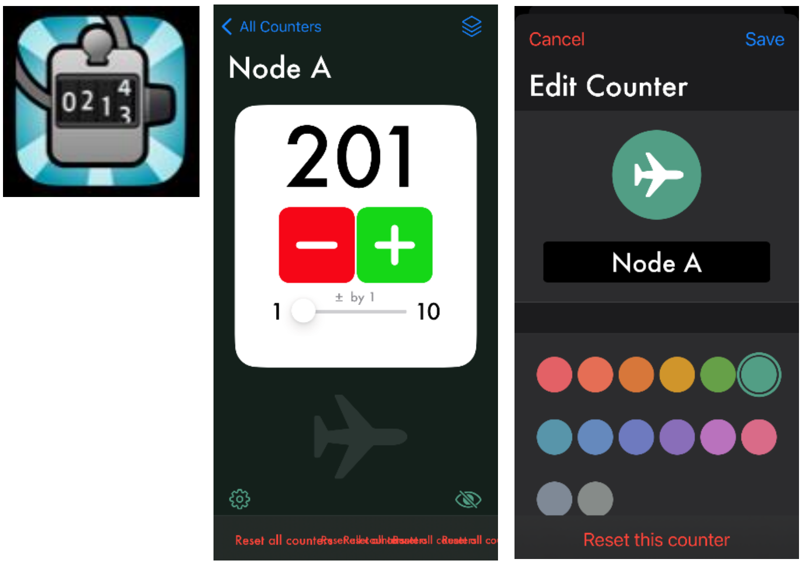


Fig. 43. Clicker Counter application with examples of the interface

There are a few considerations for the counting. Entrances, doors, and passages are the potential pedestrian node points, so they are the priorities of this counting. In case of the double doors or multiple doors next to each other, they are considered as one observation point. The same also applies for building entrances that are situated on different levels but at the same position.

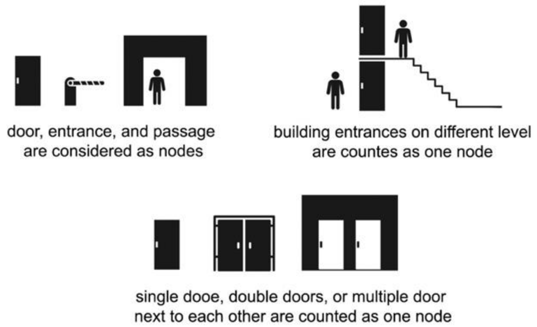


Fig. 44. Considerations of the pedestrian counting by authors

The pedestrian counting result is used for the 'Mapping' in the next step

Mapping: Node points

Mapping behavior is simply mapping what happens on a plan of the space or area being investigated. (Gehl & Svarre, 2013) In this case, the points with more than 300 people pass through during 13:00-14:00 from the count mentioned before. These six points, two points on level 1 (street level) and four points on level 0 (campus level), are considered as pedestrian nodes and are mapped on the campus layout below.

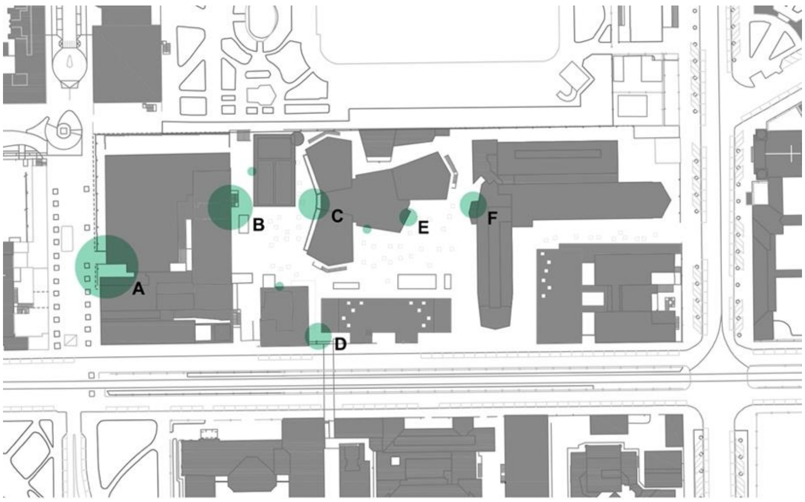


Fig. 45. Pedestrian nodes at the new campus of Politecnico di Milano

Number of pedestrians passed through each node points at Politecnico di Milano new campus between 21 to 23 March 2022, 13:00-14:00:
(A) 1,567 people/hour
(B) 1,241 people/hour
(C) 889 people/hour
(D) 877 people/hour
(E) 436 people/hour
(F) 687 people/hour

Tracing: Pedestrian flow

Tracing means drawing lines of movement on a plan. Registering movement can provide basic knowledge about movement patterns as well as concrete knowledge about movements in a space site. (Gehl & Svarre, 2013) The goal of this tracing is to gather information of the pedestrian flow around and within the Politecnico di Milano new campus. The flows are represented in graphical lines, which thicker lines means more pedestrian flows. The result confirms the presumption that the main movements are between the pedestrian nodes and public transportation nodes.

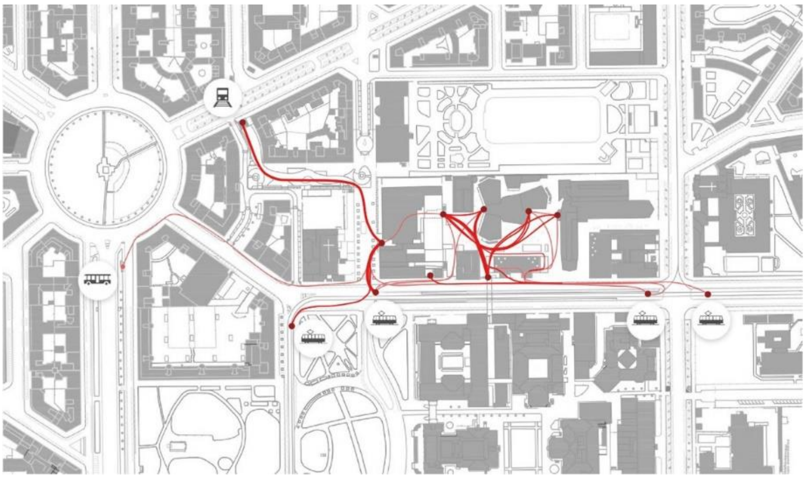


Fig. 46. Pedestrian flow at the new campus of Politecnico di Milano

5.1.2. The Study Area

Study Perimeter

Isochrone maps are a terrific method to visualize all the places individuals may reach using a specific mode of transportation at a particular time. Based on the six primary nodes students regularly engage in, the Isochrones were generated using QGIS to provide a framework for additional block analysis. The map shows the polygons representing 5, 10, and 15 minutes of walking. Adapted from Bosselmann's studying approach (Bosselmann, 1998), the boundary of 500x500m was eventually adopted as the research perimeter to simplify the complex margins and align with the 5-minute Isodistance. The catchment area includes residential neighborhoods and campuses close to the polygon's edges.

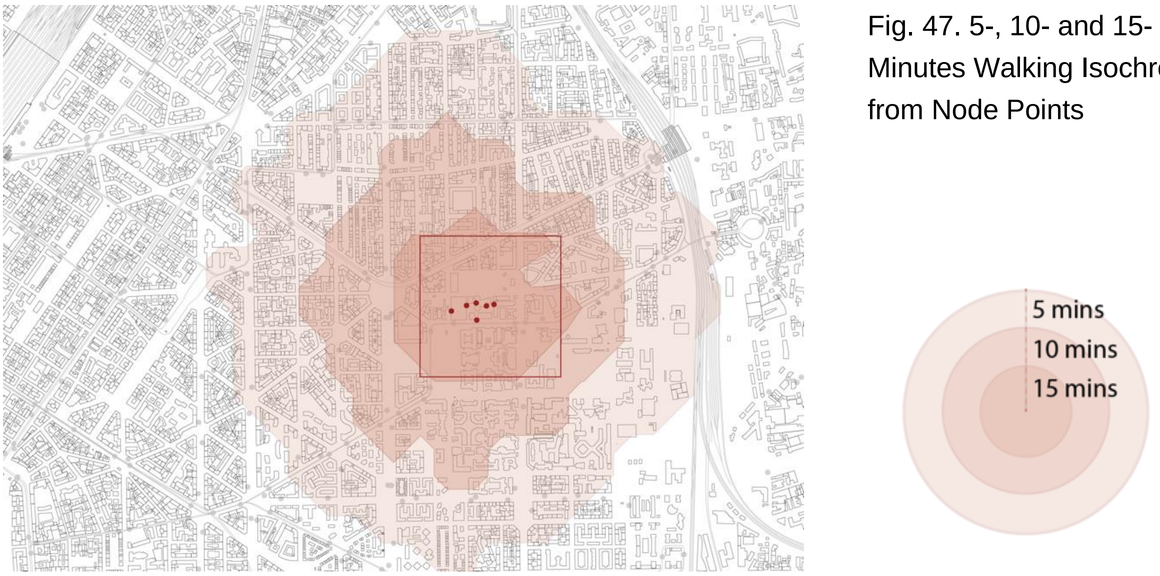


Fig. 47. 5-, 10- and 15-Minutes Walking Isochrones from Node Points

5.2 Block Analysis

Ichnography is always employed in the urban methodological approach to portraying the current circumstances since it is the most straightforward and indicates the dimensions in conventional 2D visuals. According to How to Study the Public Life (Gehl & Svarre, 2013), direct observation is the primary method for such kinds of public life studies. The study approaches include pen-paper sketching, counting, tracing, tracking, and photographing.

Despite the rapid visualization of both existing and imagined urban environments and three-dimensional representation using perspective projection, it has limitations such as imprecise expression (Al-Kodmany, 2002), constrained viewing angles, and perspective projection (Kim & Kim, 2019). However, utilizing computer visual simulation can help solve some of these issues.

A research protocol based on campus blocks serves as the foundation of the mixed-methods methodology. Users' activities and behavior are mapped traditionally to understand their needs and how city spaces are used. Simulation methods such as Geographic Information Systems (GIS) or Grasshopper software for Isovist rendering can serve as effective solutions. Before undertaking the conventional urban spatial investigation, the study criteria will be exemplified in the following topic.

Criteria

Three criteria were identified in the public space sphere of perception: environmental, physical, and psychological elements. The first criterion, the environmental component, is perceived in external circumstances as it affects people's aesthetic sense, comfort, tranquility, and safety. The physical and psychological elements, represented by the orange and blue colors, are subjective since they are based on personal impressions and feelings rather than the nature of the objects.

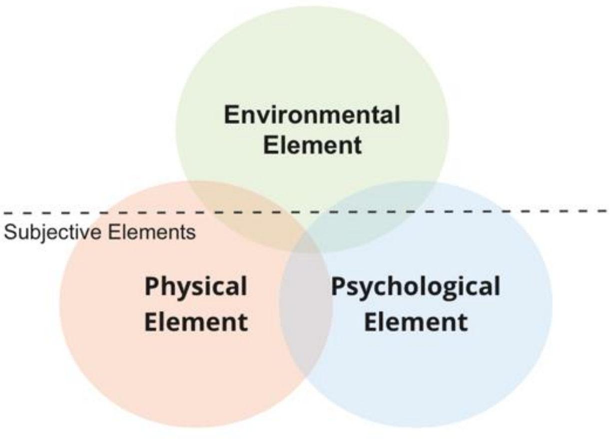


Fig. 48. Criteria for Block Analysis

These criteria emphasize the personal and temporal contexts in which people interact with their surroundings. They relied on two literatures related to activities in public space, Carmona (Carr et al., 1992) synthesizing research and ideas on the use and design of public space based on firsthand observation, and Gehl's Space Between Buildings: Using Public Space (1971) on observations in Scandinavia (Gehl, 1971).

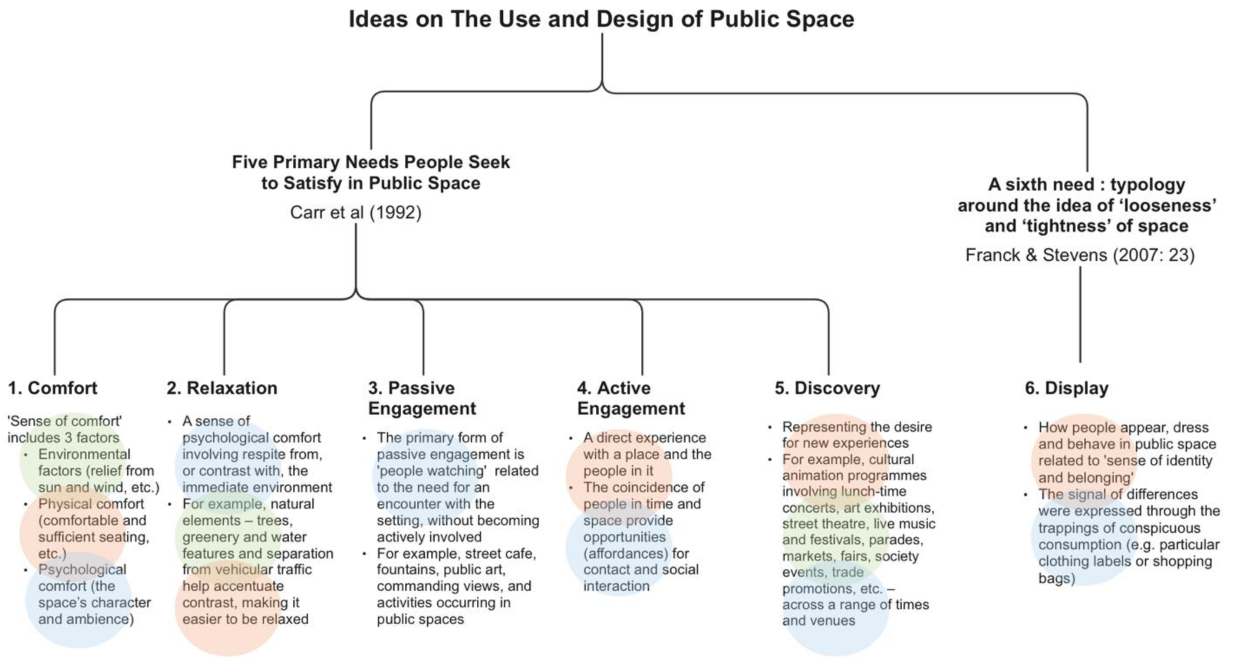


Fig. 49. (above) Carmona's "ideas on the use and design of public space"

As shown in the chart above, Carmona (Carr et al., 1992) identified the primary needs people seek in public settings: comfort, relaxation, active engagement, passive engagement, and discovery. The urge for comfort, relaxation, and discovery possesses all environmental, physical, and psychological criteria (represented in green, orange, and blue respectively) since those sensorial experiences can achieve from the natural elements and climate. Meanwhile, active, and passive interactions are mainly centralized around subjective aspects and interaction between 'people' - with and without physical contact.

In addition to Carmona's facet, Franck & Stevens (Franck & Stevens, 2006) identified the need for display as the sixth need people have toward public space, which represents the subjective criteria. This concept revolves around a 'sense of identity and belonging' and the idea of looseness and tightness of space. Moreover, it is related to 'rhythm as an urban territory'; for instance, people might wear apparel that stands out in color to define the boundaries of a joyful gathering (Nevejan et al., 2018).

Many animals, including birds, mark their territory with rhythmic motions or behaviors, and rituals sometimes involve rhythm (Deleuze & Guattari, 1987).

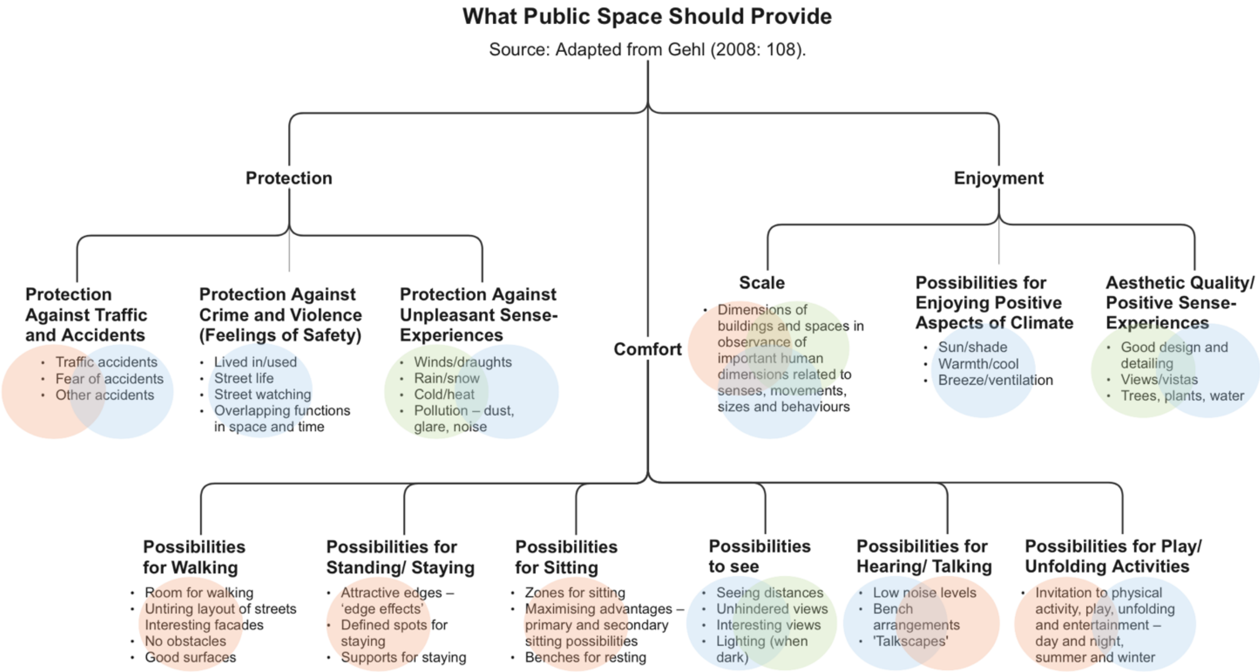


Fig. 50. (above) Gehl's observation on "What public space should provide?"

From Gehl's observation (Gehl, 1971), the three pillars that public space should offer are protection, enjoyment, and comfort. As identified by Injury prevention researchers, 'safety' means a state or situation characterized by adequate control of physical, material, or moral threats. Considering the 'sense of safety,' the protection concept embraced all three dimensions, similar to the enjoyment aspect. Scale, climate, and aesthetic are complex terms involving subjective and environmental contexts. Compared to Carmona's, the comfort from Gelh's perspective is more engaged in subjective and physical elements such as facilities that support bodily motions - walking, standing, and sitting or the psychological state of seeing and hearing.

5.2.1. Environmental Element

According to Gibson's theory of affordances and Carmona's notion of soft landscaping configuration, the proportions of trees were considered to be a crucial factor in the study of environmental factors.

Gibson (Gibson, 1979), uses the term "Affordances" to describe the interactions between creatures and their environments which is essential to many contemporary theories of landscape preference. Affordances, also known as environmental cues, are instantaneous, unprocessed perceptions of the environment that point to potential courses of action without any sensory processing. In the ecological context, what trees possess influences how people perceive them. Therefore, the size of trees or ecological objects was presumed to be one of the optical information acquired by visual perception.

In the study regarding soft landscaping (Nevejan et al., 2018), urban trees have consistently played a significant aesthetic role in bringing some sense to urban spaces and hardscapes. Trees and plants can enhance a place's character, personality, and identity by adding a sense of human scale, reinforcing a sense of enclosure, and being strategically placed. Additionally, landscaping can convey the passing of the seasons and improve temporal intelligibility.

Study of Plants and Green Network

In order to investigate the affordance and accordance of ecological elements, the investigation was conducted on two different scales. The green network map shows the position of trees and parks on a neighborhood scale. The trees are typically grouped linearly along some main streets, and a few green parks are scattered around the area. However, the green area in front of Piazza Leonardo, one of the largest parks found, has a variety of tree sizes and presents as a placemaking in the neighborhood.

On the block scale map, trees' density, height, and canopy breadth were portrayed along with the specifics of three different viewpoints that exemplify the human-tree scale contrast and the coherence between trees and the urban environment.

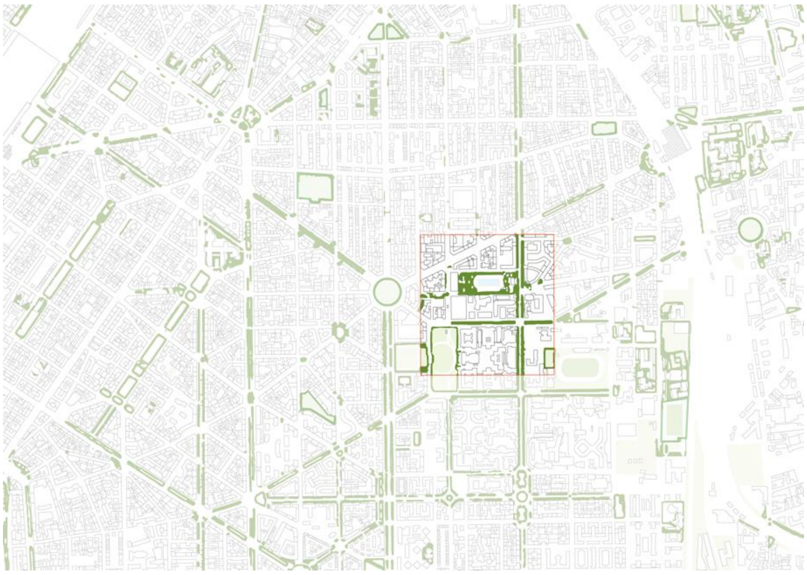


Fig. 51. Città Studi Green Network (Source: Commune di Milano)

Fig. 52. Tree Positioning and Dimension

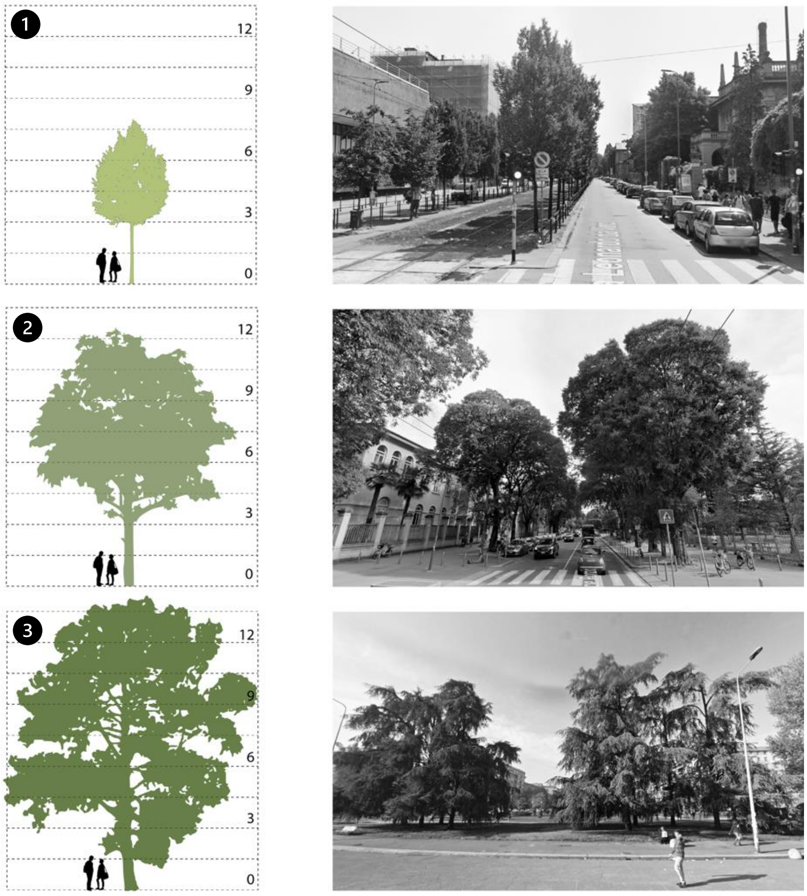


Fig. 53. Examples of three positioning and scale in 3 locations
1. Via Edorado Bornadi — For the comfort and safety of pedestrians crossing the carriageways, trees that aren't very tall were chosen to be planted in a straight line along the road and tram line.
2. Via Giuseppe Ponzio — The 8 to 12-meter-high plants with the rather wide canopy were formally placed in this street to increase the sense of enclosure and continuity.
3. Piazza Leonardo da Vinci — The various tree sizes were chosen to add drama and visual appeal despite the lack of a clear sense of human scale. Additionally, the picturesque
clusters provide as a counterpoint to the formal architecture and general

5.2.2. Physical Element

The physical aspect is an essential facet of subjective experiences that cannot be isolated from psychological conditioning. According to numerous Human Kinesis research, subjective experience refers to the full spectrum of feelings, thoughts, attitudes, knowledge, and meanings that one acquires from engaging in physical activity rather than the actual performance itself.

Moreover, a visually appealing public space is one of the crucial physical factors influencing urban social sustainability. (Dempsey et al., 2011)

This research places a strong emphasis on the pedestrian experience, including physical activity, accessibility to modes of transportation and the effect of facilities on people's willingness and need to walk along the path.

5.2.2.1. Transportation Accessibility

Travel time or distance is the critical determinant of route choice that impacts pedestrians' behavior and physical activities. Pedestrians always select the route that takes them from their starting point to their final destination in the shortest amount of time, according to research on this topic (Huang et al., 2020).

By utilizing isochrones to show how far individuals can walk or access from the specific points, this analysis takes into account the trip time from the transit nodes including train, metro, tram and bus. The isochrones were generated using the 3.0 to 3.04 miles per hour (MPH), or about 4.8 kilometers per hour, the average walking pace of people aged 20 to 29 (Schimpl et al., 2011). The 5, 10, and 15-minute polygons offer varying degrees of accessibility based on the urbanist's criterion.

The center, facilities, and daily needs are all demonstrated by the 5-minute walkshed (generally a public square or main street with minimal mixed use). The 10-minute walkshed indicates the typical travel time for a person to reach a domestic transit destination (metro, tram, bus), whereas most people will only walk a distance of up to 15 minutes access to intercity transportation (train). Moreover, a variety of purposes, including a grocery shop, pharmacy, general commerce, public schools, should be located within this shed.

Fig.54. 5 and 10-Minute Walking Isochrones from Train Stations

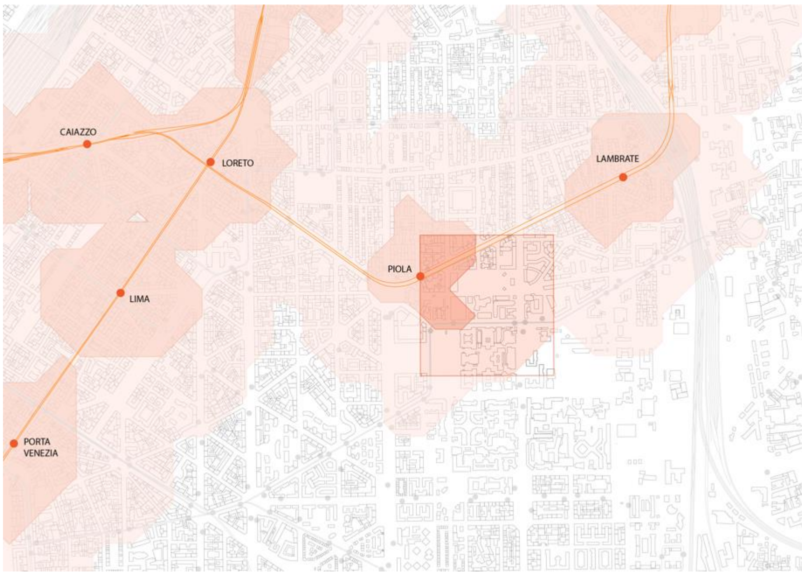


Fig. 55. 5 and 10-Minute Walking Isochrones from Metro Stations

metro stations
metro lines
study area
walking distance
from metro stations
5 mins
10 mins

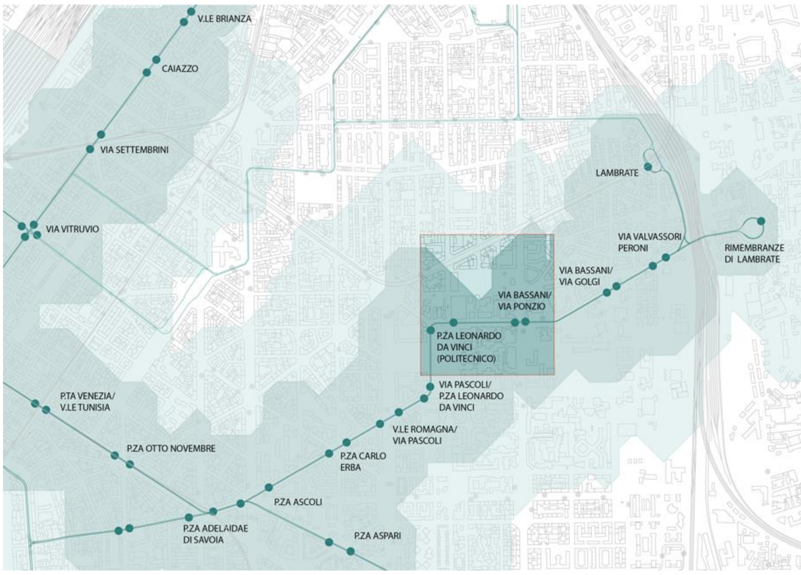


Fig. 56. 5 and 10-Minute Walking Isochrones from Tram Stations

metro stations
metrolines
study area
walking distance
from metro stations
5 mins
10 mins

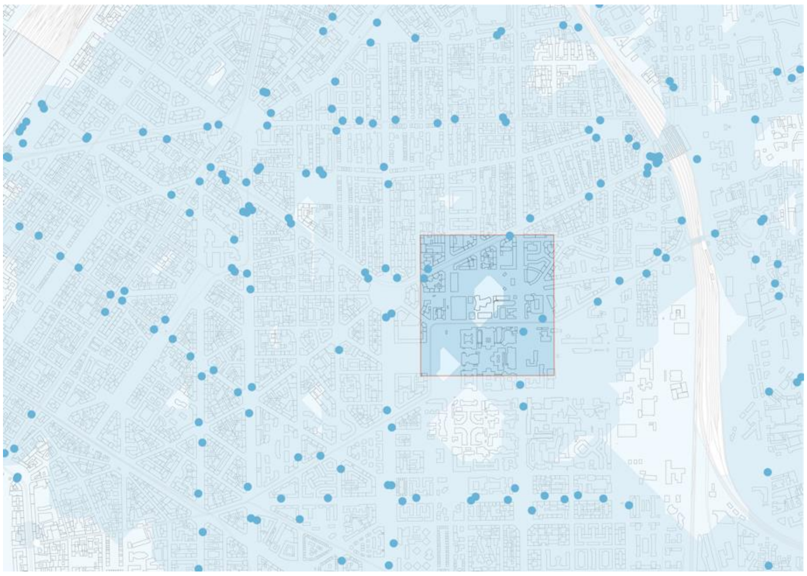
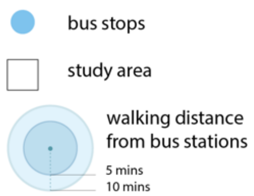


Fig. 57. 5 and 10-Minute Walking Isochrones from Bus Stops



Walking Demand

The volume of transit reflects the demand for pedestrian use in specific locations and indicates the number of persons who reach the stops or stations. By computing the average daily trips per public transportation stop, public transportation efficiency determines how frequently services are provided. The following maps' various-sized circles depict the typical trips to illustrate how likely it is that individuals will use transportation in each location on weekdays and weekends.

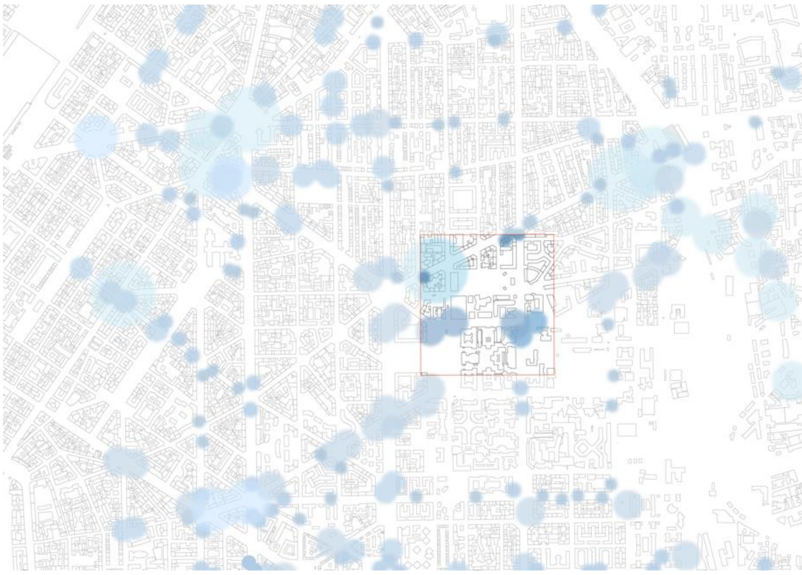
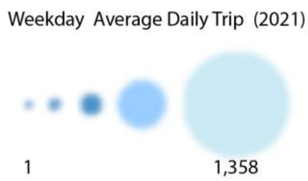


Fig. 58. Weekday Public Transport Frequency (calculated from average number of trips per public transport stop per day, from 6AM-8PM) (Source: https://urbanmobilityindex.here.com/city/milan/)



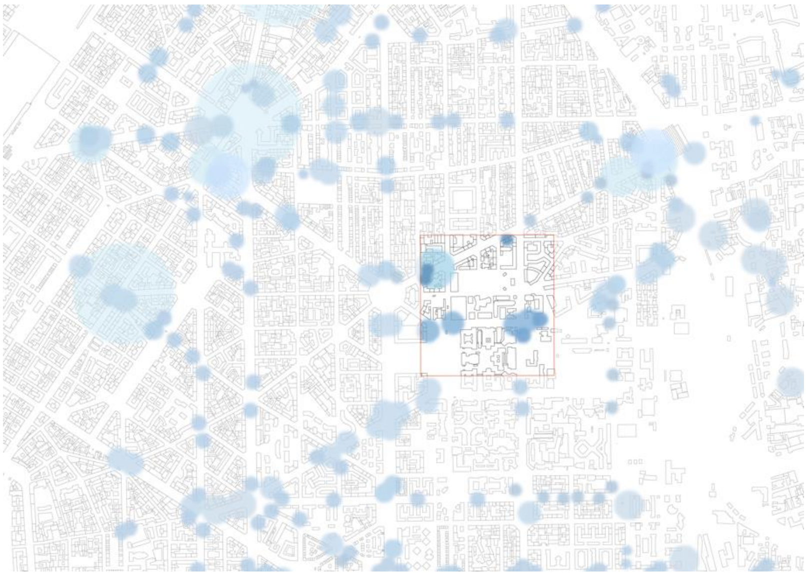


Fig. 59. Weekend Public Transport Frequency (calculated from average number of trips per public transport stop per day, from 6AM-8PM) (Source: https://urbanmobilityindex.here.com/city/milan/)

5.2.2.2. Pedestrian Facility

According to the research on factors associated with pedestrian route choice (PRC), street facilities encourage physical activity and the desire to explore. In particular, pedestrians' likelihood of selecting a route increases with the provision of street crossing facilities like traffic signals, pedestrian signals, crosswalks, and zebra crossings (Shatu et al., 2019).

In some regulations, the term "street facilities" refers to the infrastructure of the sidewalk, such as the walking lane and its components, curb ramp, crosswalk, overpass, underpass, transit stop, lighting, and street furniture that provide pedestrians with comfort, security, and safety (ocpcrpa.org). In contrast, pedestrian facilities can be thought of as areas where people can go that are meaningful or destinations within their "walkshed" (ppms.trec.pdx). Retail stores, bars, restaurants, public gathering spaces parks, hospitals, sporting venues, transportation hubs (like train stations or airports), and houses of worship are a few examples.

The following maps show the two types of infrastructure exhibited while assessing the campus' pedestrian amenities. The first map locates routes, entrances, and crosswalks around the University Campus. The second map, the Spatial Distribution of Public Facilities, reveals the location of comfort facilities that enrich the possibilities for walking, staying, sitting, seeing, hearing, talking, and playing regarding Gehl's (Gehl, 1971)comfort in public space.

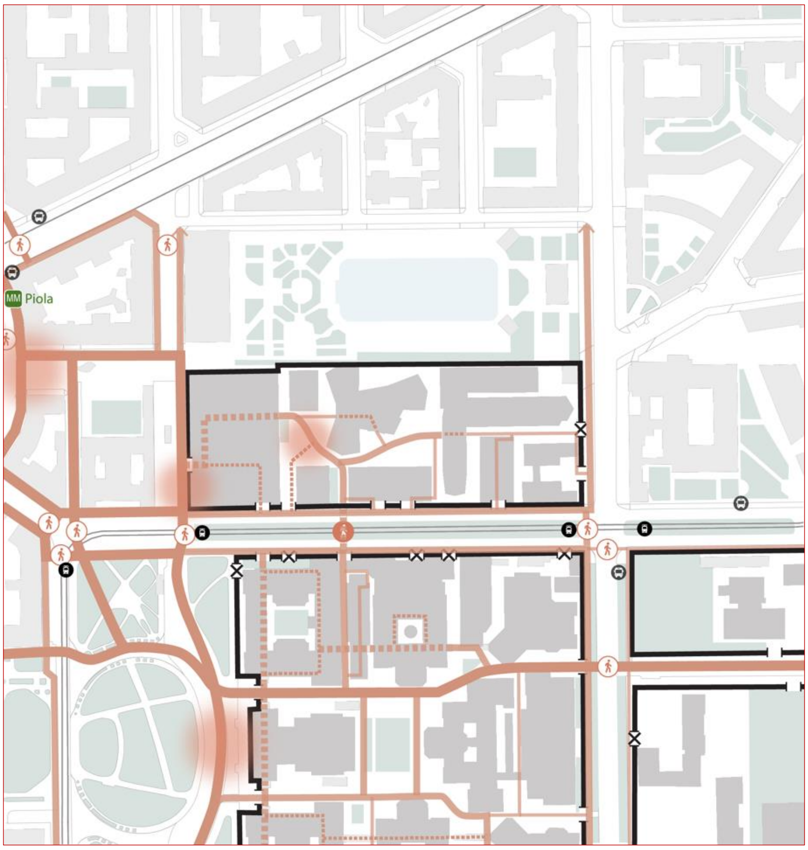


Fig. 60. Routes, Entrances and Crosswalks around the University Campus (Adapted from: Laboratorio di Simulazione Urbana Fausto Curti)

- primary pedestrian route
- secondary pedestrian route
- tertieri pedestrian route
- covered route
- opened gate
- closed gate
- square
- crosswalk
- underground crosswalk
- metro station
- tram stop
- bus stop

Fig. 61. The Spatial Distribution of Public Facilities around the University Campus

living facility
- seating area/ bench
- drinking water
- sport facility/ playground
- bar/ restaurant/ stall/ vending machine
- supermarket
- bank/ATM

studying facility
- biblioteca/ study area
- printing shop

others
- historical/architectural visual landmarks

Fig. 62. Facilities for Sitting and Resting in the main plaza and new development area of University Campus (Taken by Authors)

5.2.3. Psychological Element

5.2.3.1. Spatial Visibility

At any dimension of time and space, there is numerous information ones receive through the perception modes: vision, touch, sound, taste, smell. The dominant mode is vision because it gives two-thirds of all the information (Cafuta, 2015; Gregory, 1997). That makes visual perception one of the key issues in developing good design. (Batty, 2001)

Different environments provide different levels of comfort. One key factor is the enclosure. In general, humans are more comfortable in enclosed spaces; for example, when looking for a spot to sit outside, a person usually looks for a tree or other features to partially surround and shelter him (Carmona et al., 2010). One indicator that can be used to explain the enclosure of spaces is ‘Isovist’.

Isovist is the quantity of viewing space. Batty defined an isovist as a field of vision from which various geometrical properties, such as area and perimeter, can be calculated. (Batty, 2001) Isovist is inversely related with enclosure. In other word, the space with higher isovist will has lower sense of enclosure and the space with lower isovist will has higher sense of enclosure.

Visual field from points

Isovist can be defined for every vantage point constituting an environment, and the spatial union of any geometrical property defines a particular isovist field. (Batty, 2001) On the maps below, green lines demonstrate the Isovist fields from the pedestrian nodes mentioned in 5.1.1., which means the area ones can see without any obstacle from each point.

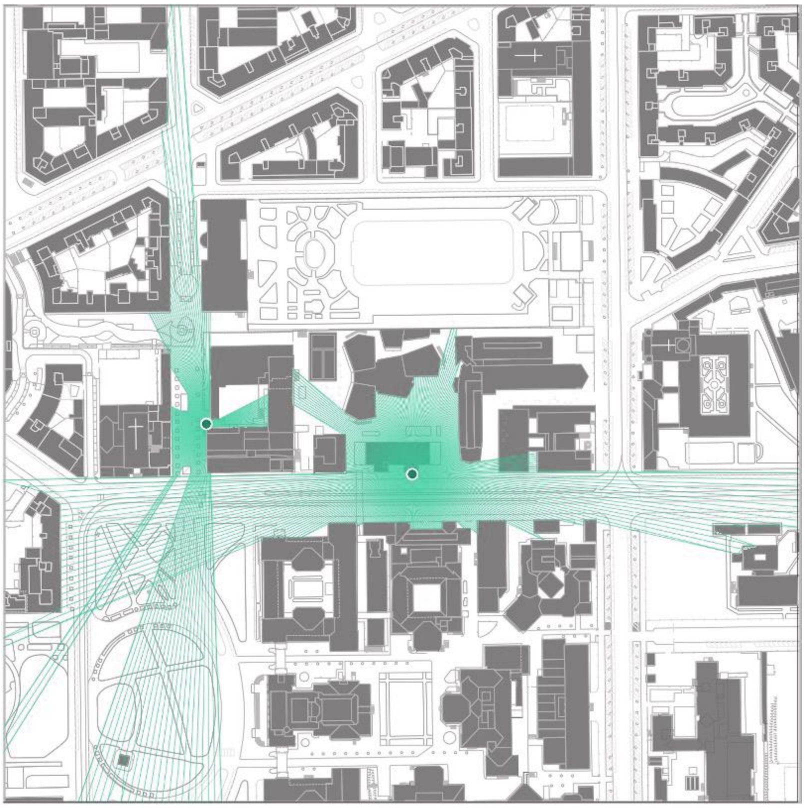


Fig. 63. Isovist field from two pedestrian nodes on level 1 (+0.00 m)

field of visual

Fig. 64. Isovist field from four pedestrian nodes on level 0 (-3.00 m)

field of visual

Isovist map

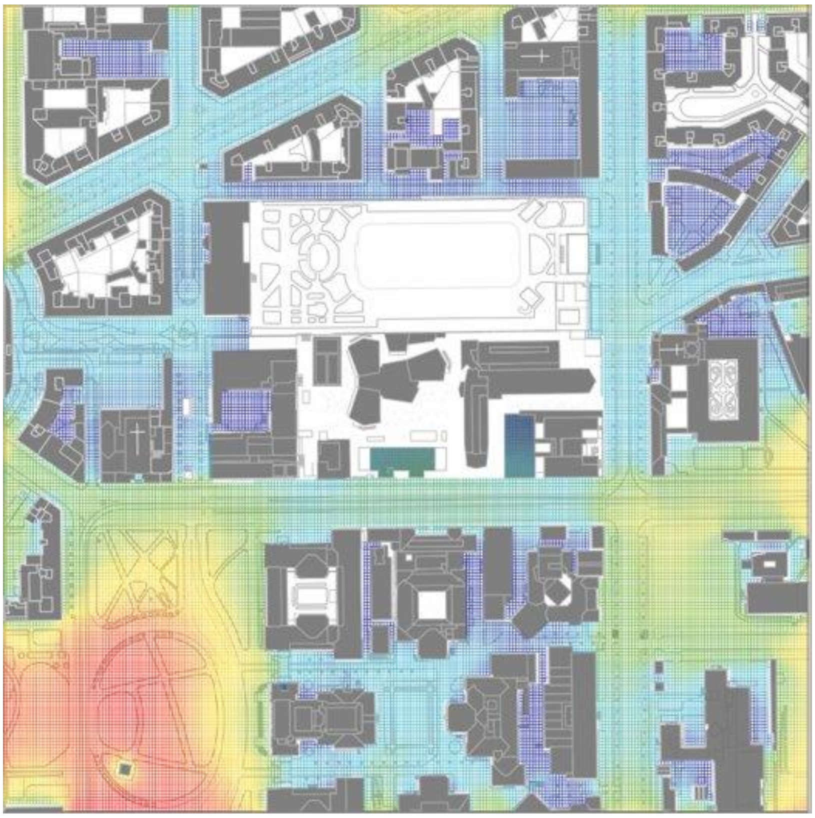


Fig. 65 Isovist map of the study area level 1 (+0.00 m), considered the overall study area on both level

low high

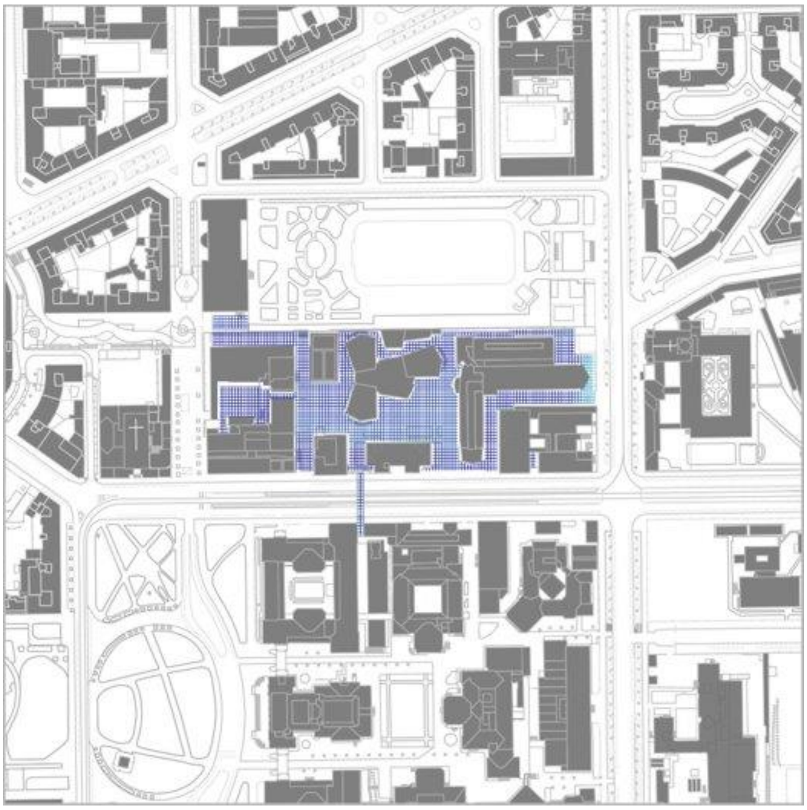


Fig. 66 Isovist map of the study area level 0 (-3.00 m), considered the overall study area on both level

low high

In isovist maps, areas of visual field of each point are presented in colors. Higher Isovist is presented in red color, which means that the area ones can comparatively see from that specific point is higher than from others. On the contrary, the area shown in blue color means a comparatively smaller area of visual field.

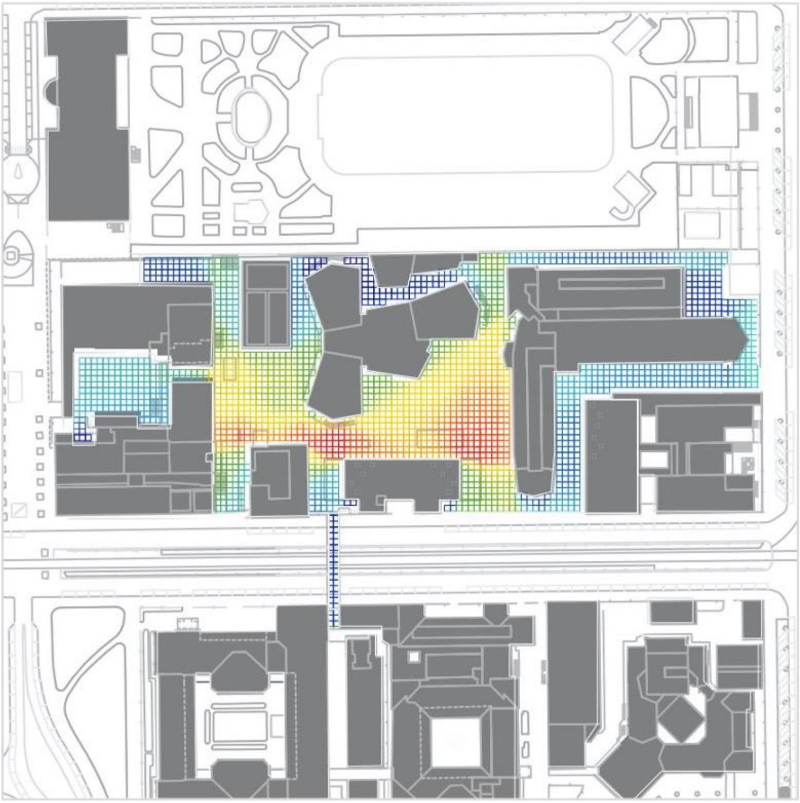


Fig. 67 Isovist map of the study area level 0 (-3.00 m), considered only the study area on level 0

Perception map from node points

The perception maps show visual perception levels on buildings from two and five selected node point. The area in red on the map means the best perception, followed by yellow, green, and blue, while the area in grey means no visual perception from those points.

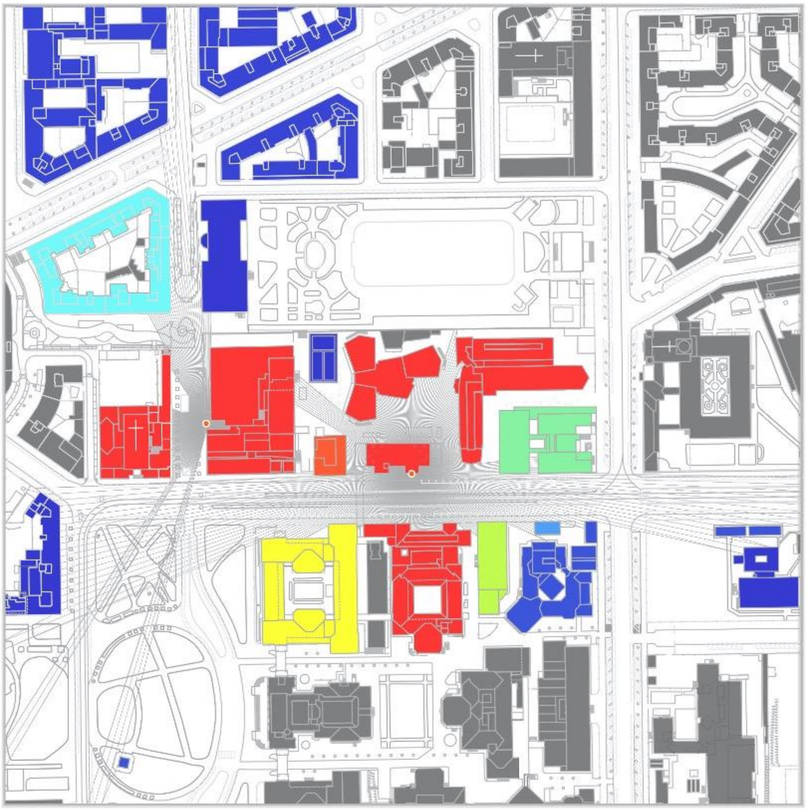


Fig. 68 Perception map from two pedestrian nodes on level 1 (+0.00 m)

low high

Fig. 69 Perception map from four pedestrian nodes on level 0 (-3.00 m)

low high

5.2.3.2. Thermal Comfort

Climate has impacts on pedestrian behaviors and it is one of conditions that support social life (Jacobs, 1993). Thermal comfort can affect humans both physically and psychologically; however, since the study is focused on perceptions and satisfactions, thermal comfort is classified as a psychological element in this research.

Macro climate

Macroclimate analysis is the initial stage in determining thermal comfort. Even if it does not provide detailed information, it can aid in understanding the overall climate conditions of the study area.

In this study, the climate of Milan is considered in the macroclimate analysis. Milan has a Mediterranean climate, however, as usual for metropolitans, built environments and human activities have influenced the local climate. This makes the weather more extreme. Spring (March to May) through early summer (June) and fall (September to November) are normally the best periods to stay comfortably without heating or cooling systems. Late summer is hot and humid, particularly in August, in which the temperatures can exceed 30°C during the day. While winter is too cold to the normal thermal comfort range. The mountains behind the city shield Milan from the harshness of winter, but the weather is still too cold for the normal thermal comfort range.

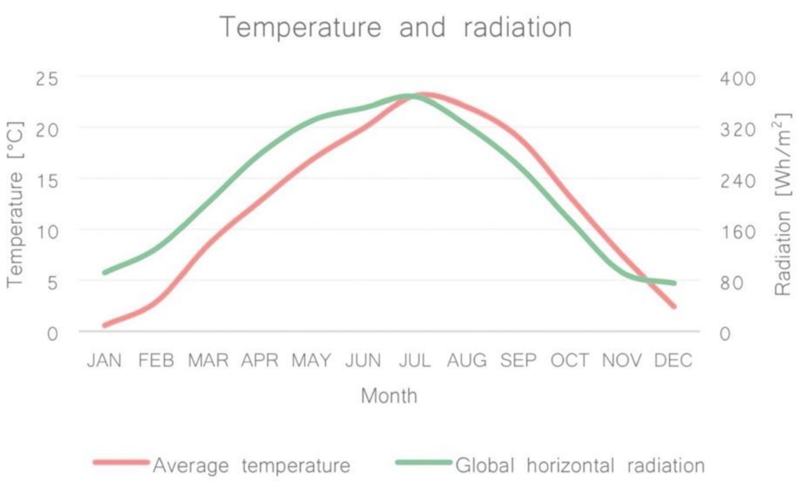


Fig. 70. Average temperature and radiation of Milan (Source: https://world-weather.info)

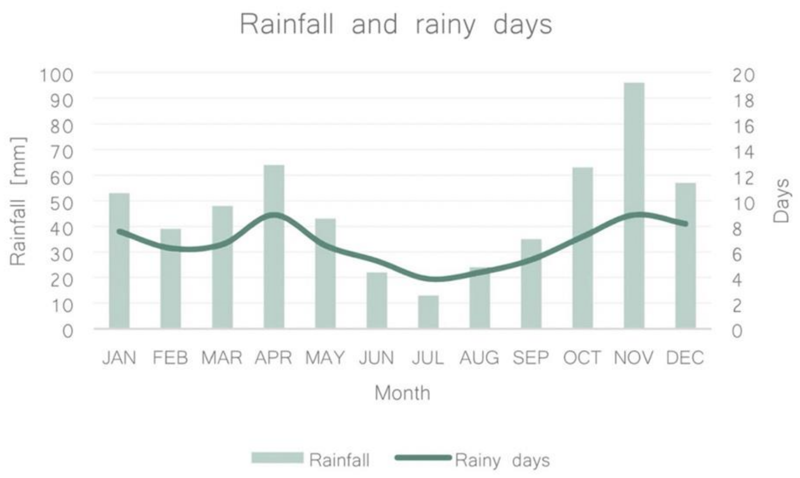


Fig. 71. Average rainfall and rainy days of Milan (Source: https://world-weather.info)

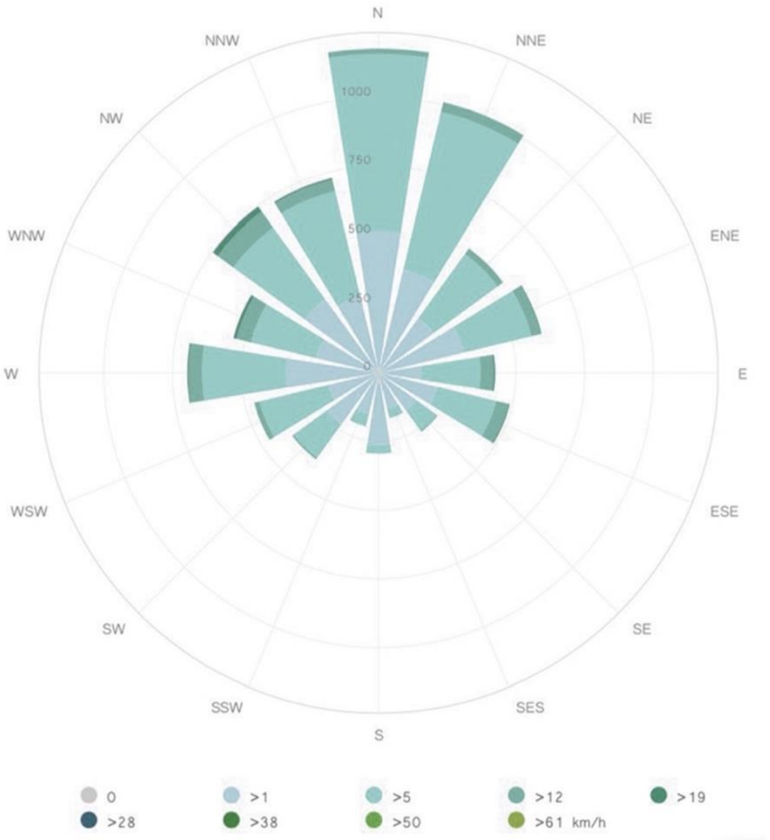


Fig. 72 Wind rise diagram (Source: https://world-weather.info)

Microclimate: Sunlight hours (shadow analysis)

Microclimate analysis is the further step of the thermal comfort assessment. Sunlight hours and cumulative solar radiation are included in the study. As for shadow analysis, due to the significant differences among seasons, the analysis has been done on each equinox date, which are: 21st June for summer, 20th March and 23rd September for midseason, and 21st December for winter

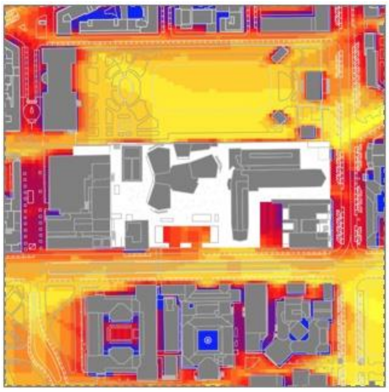


Fig. 73. (left) Sunlight hours map of the study area level 1 (+0.00 m) in summer

Fig. 74. (right) Sunlight hours map of the study area level 0 (-3.00 m) in summer

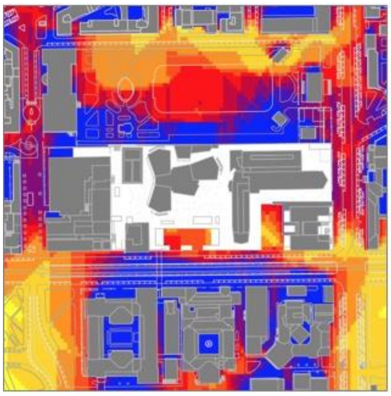


Fig. 75. (left) Sunlight hours map of the study area level 1 (+0.00 m) in midseason

Fig. 76. (right) Sunlight hours map of the study area level 0 (-3.00 m) in midseason

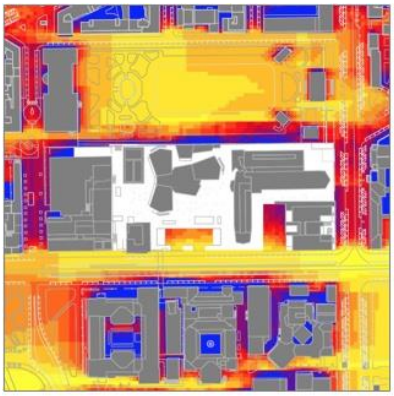
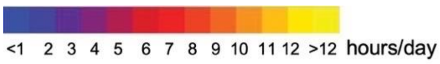


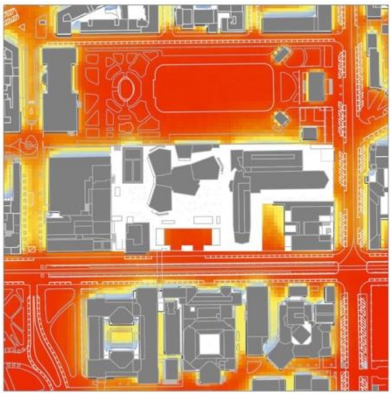
Fig. 77. (left) Sunlight hours map of the study area level 1 (+0.00 m) in winter

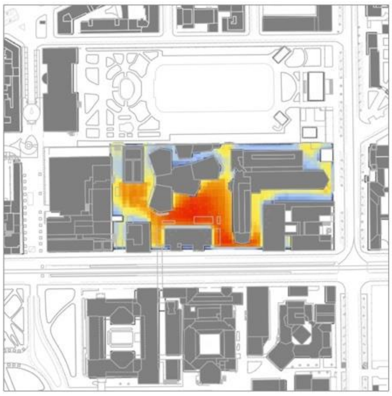
Fig. 78 (right) Sunlight hours map of the study area level 0 (-3.00 m) in winter



Microclimate: cumulative solar radiation

The maps present annual cumulative solar radiation values in the unit of kW per square meter**.**





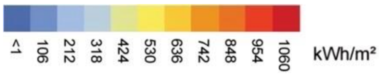


Fig. 79. (left) Annual cumulative solar radiation map of the study area level 1 (+0.00 m)

Fig. 80. (right) Annual cumulative solar radiation map of the study area level 0 (-3.00 m)

5.3 Path Analysis

Observation as a tool

The quality of the path context is considered one of the walkability criteria. Regarding Southworth's Designing the Walkable City, many aspects of the path context can contribute to a positive walking experience; visual interest in the built environment, design of the street as a whole, transparency of fronting structures, a visible activity, street trees and other landscape elements, lighting, and views (Southworth, 2005). However, evaluating the quality of the path context is complicated since the walking impression depends on subjective perception, and there are several ways to represent a person's impression (Piga & Salerno, 2017).

As employed by many public life studies, observation is considered a tool that aids in collecting and systematizing information (Gehl & Svarre, 2013). Direct observations help to understand why some spaces are used and others are not, while indirect observations include using cameras or other technical devices to register or look for human activity traces (Gehl & Svarre, 2013). In this chapter, the result of the path context observation was interpreted and represented in three ways regarding Barbara's observation and interpretation approaches based on Bosselmann's methodological key actions of environmental design and simulation (Piga & Salerno, 2017). The methods introduced here are traditional technical drawing, imaginative or artistic representation, and the comparative qualitative approach.

Path Definition

From observation (tracing) in 5.1.1. and study area definition in 5.1.2. The major pedestrian paths within the study boundary are selected as the study path.

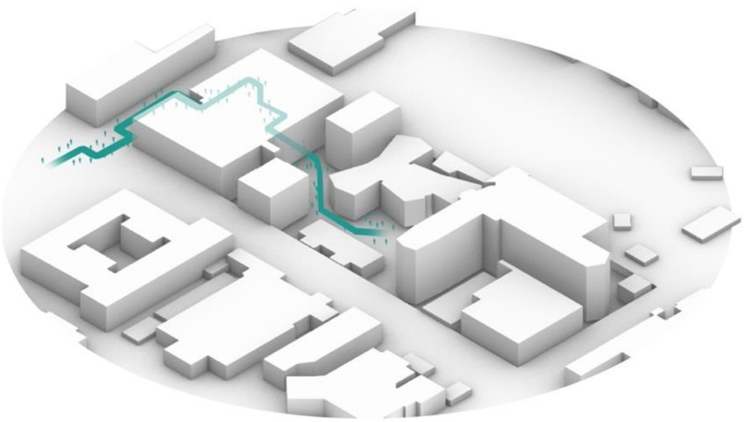


Fig. 81. Diagram of the selected path for the study

The path begins at Piazza Leonardo da Vinci, continues past building 11, and ends at the courtyard of the new campus of Politecnico di Milano. This research focuses on what pedestrians may perceive through this path in the 124° visual range, often known as the 'Optimal eye rotation area'. Some further explanations on a person's flat visual angle are illustrated in the diagram below. From the centerline, the focus recognition area is 10°, the text recognition area is 15°, the color recognition area is 30°, the eye's optimal range of rotation is 62°, and the visual range of a single eye is 94°~104°(Zhisheng et al., 2019).

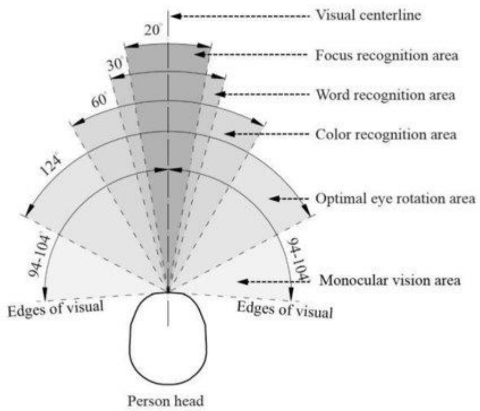


Fig. 82. Human's field of visual (Zhisheng et al., 2019).

The visual field directions are indicated toward walking directions and the activities that occur in those locations, similar to how individuals instinctively turn.

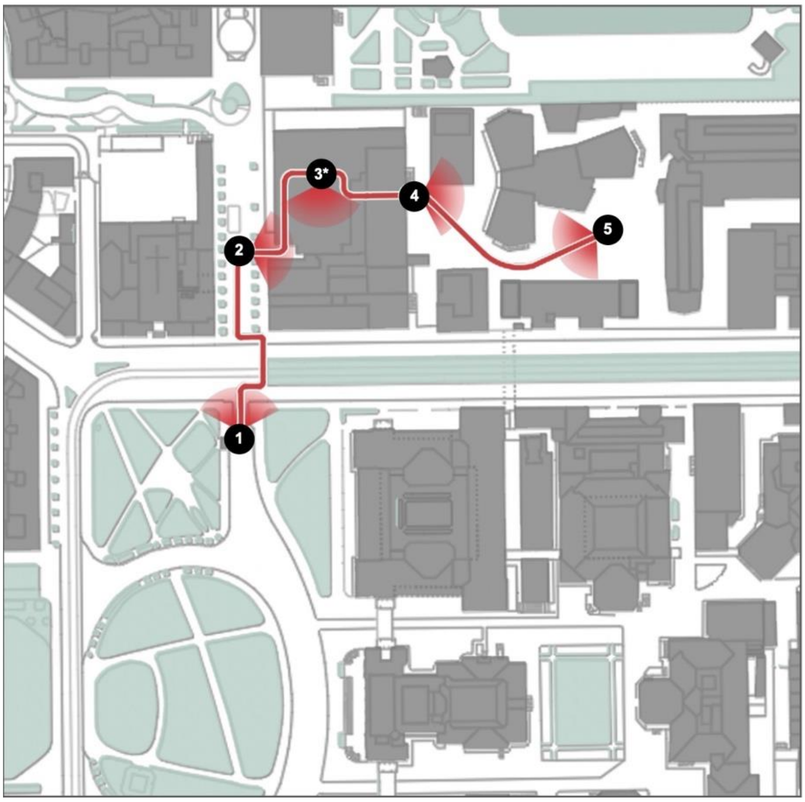


Fig. 83. Selected path and five viewpoints

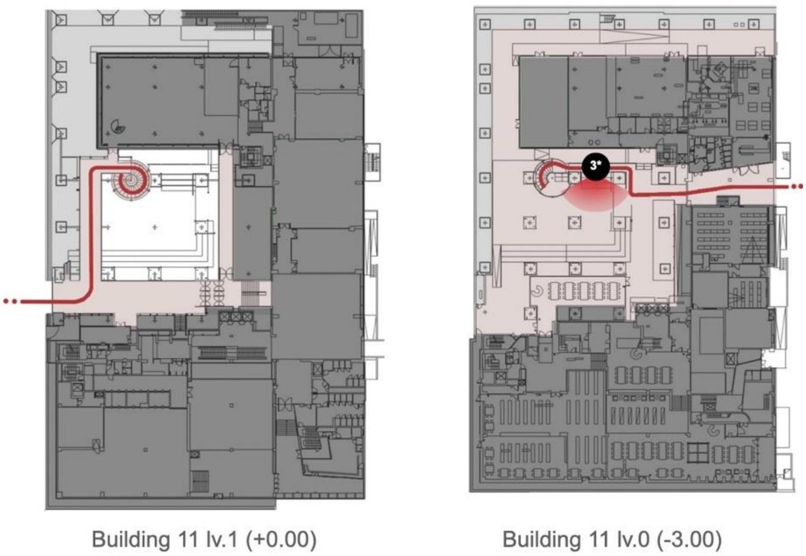


Fig. 84. Selected path inside building 11 with viewpoints 3

Viewpoints are determined along the path based on the change of spaces which significantly influence the change of perceptions. These viewpoints are also applied in the walking experiment as points to collect data. The five viewpoints are listed below.

Viewpoint 1 - **Piazza Leonardo da Vinci**: outdoor open space

Viewpoint 2 - **Entrance of building 11 from Piazza Leonardo da Vinci**: transition space from outdoor to indoor

Viewpoint 3 - **Inside building 11**: open-air indoor public space

Viewpoint 4 - **Exit of building 11 to the courtyard of the new campus**: transition space from indoor to outdoor

Viewpoint 5 - **Courtyard of the new campus**: outdoor semi-enclosed space

5.2.1. Technical Drawing: Serial Visions

The pedestrian observation adopts Cullen’s and Bosselmann’s sequential sketching method to transfer the authors' impression of the walk along the university's defined path. Apart from the space characters and the environments during the transect walk, the sketches display several transitional experiences and contrasts, which include the change in topography, activities, and the enclosures of spaces.

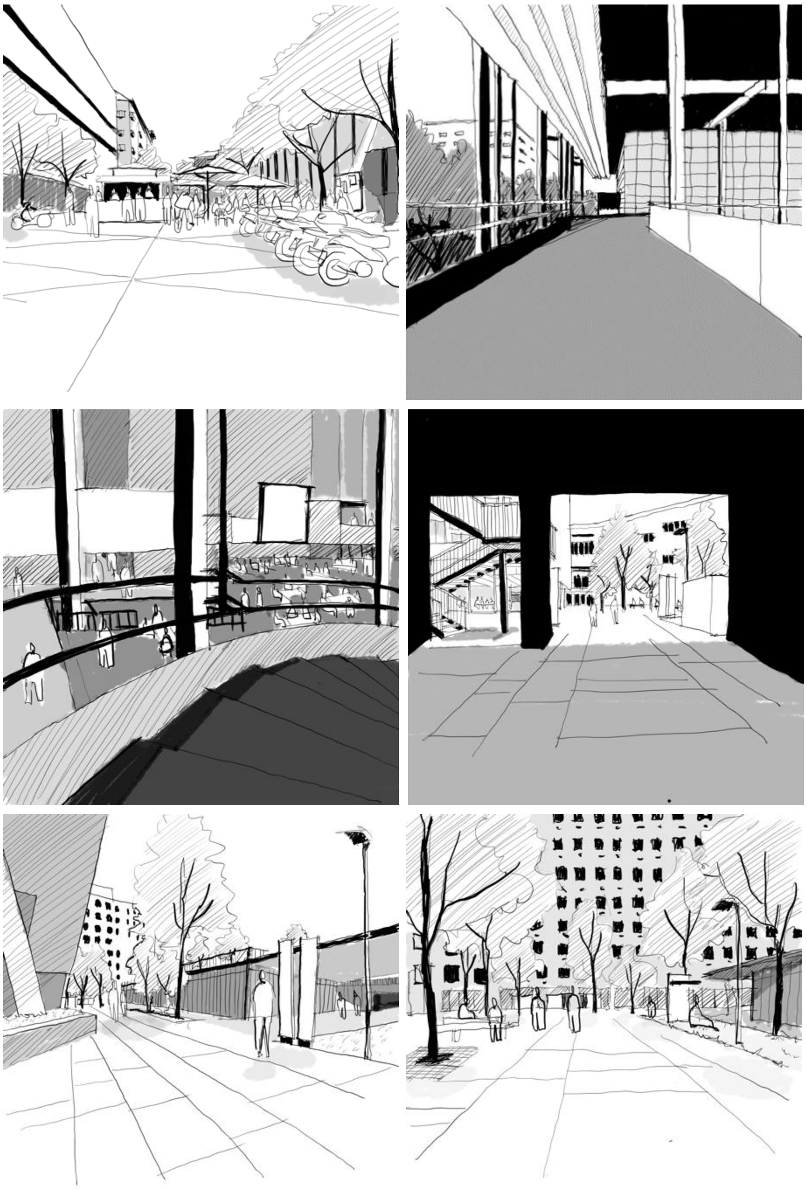


Fig. 85. Visual Sequences of Transect Walk in Leonardo Campus (Sketch by Authors)

5.2.2. Comparative study: View Range Analysis

Following the 'observation and interpretation' theory, the comparative approach works as a contrast method, enabling one to focus on the change (Piga & Salerno, 2017). In addition, the comparative analysis can be conducted in several ways; comparison of similar case studies, different alternatives of design schemes, and the current condition to the future one (Piga & Salerno, 2017). In this study, the comparative approach is centered around transforming the visual field range of the five viewpoints along the designated path. The synchronization between the viewpoints was presumed to be controlled by the brain and body motion state as they received information from the environment via the optic nerve and thalamus.

The newly designated five viewpoints are subjected to additional isovist assessment. The outcome of this analysis will be compared to the result from the walking experiment.

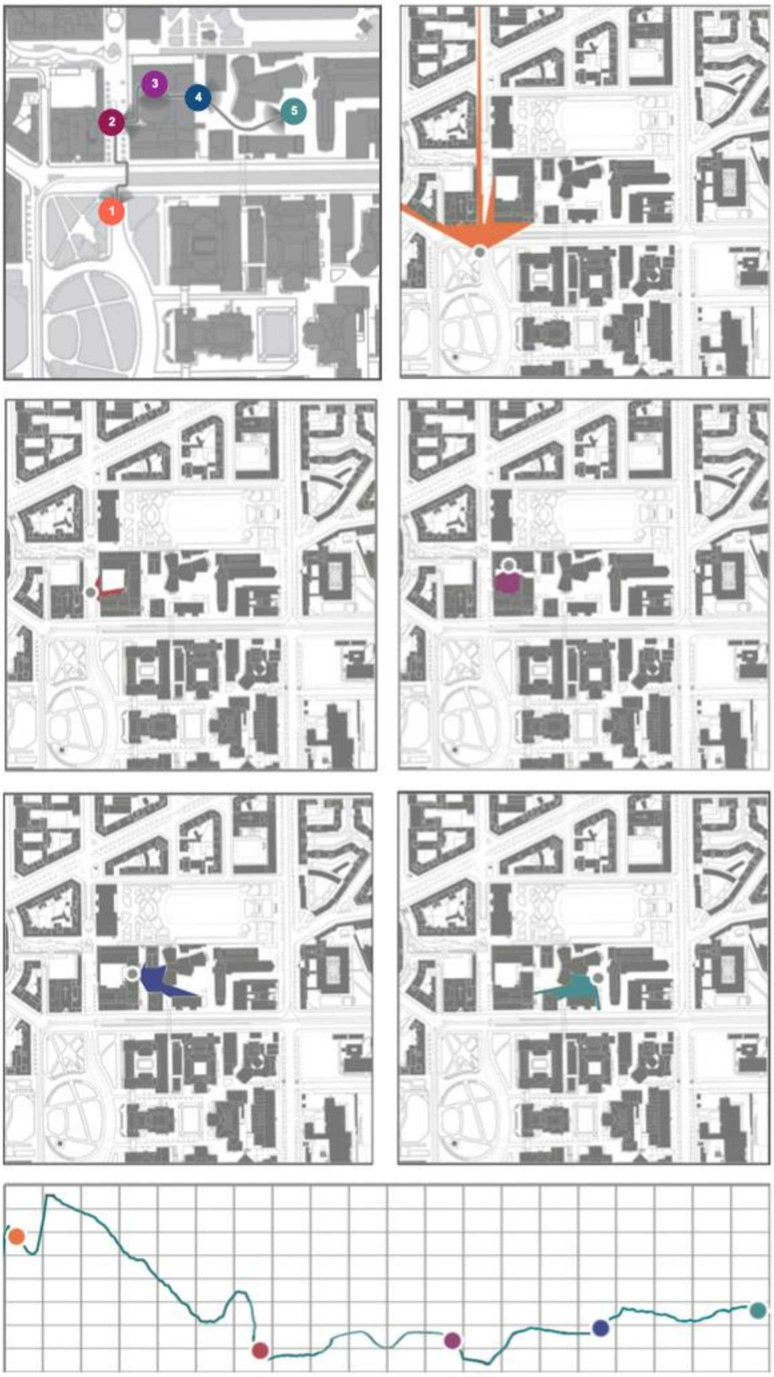


Fig. 86. View range analysis from five visual points

5.2.3. Path analysis summarize - Imaginative Representation: Experiential Walk Illustration

In psychology, the term 'imagination' describes a cognitive process that involves creating mental representations from memories without immediate input from the senses. As a result, imagination representations are built using the data from prior perceptions and their more or less inventive processing. Additionally, imaginative or artistic depictions can more effectively achieve a communicative purpose than technical drawings when it comes to researching and communicating a sense of place (Piga & Salerno, 2017). The subsequent drawing illustrates the subjective walking impression from the authors' imagination along the defined path. The nine linear diagrams represent the 'notion of urban rhythm' including component and environment perceived during the walk.

Fig. 87 Imagination Representation of Transect Walk (Sketch by Authors)

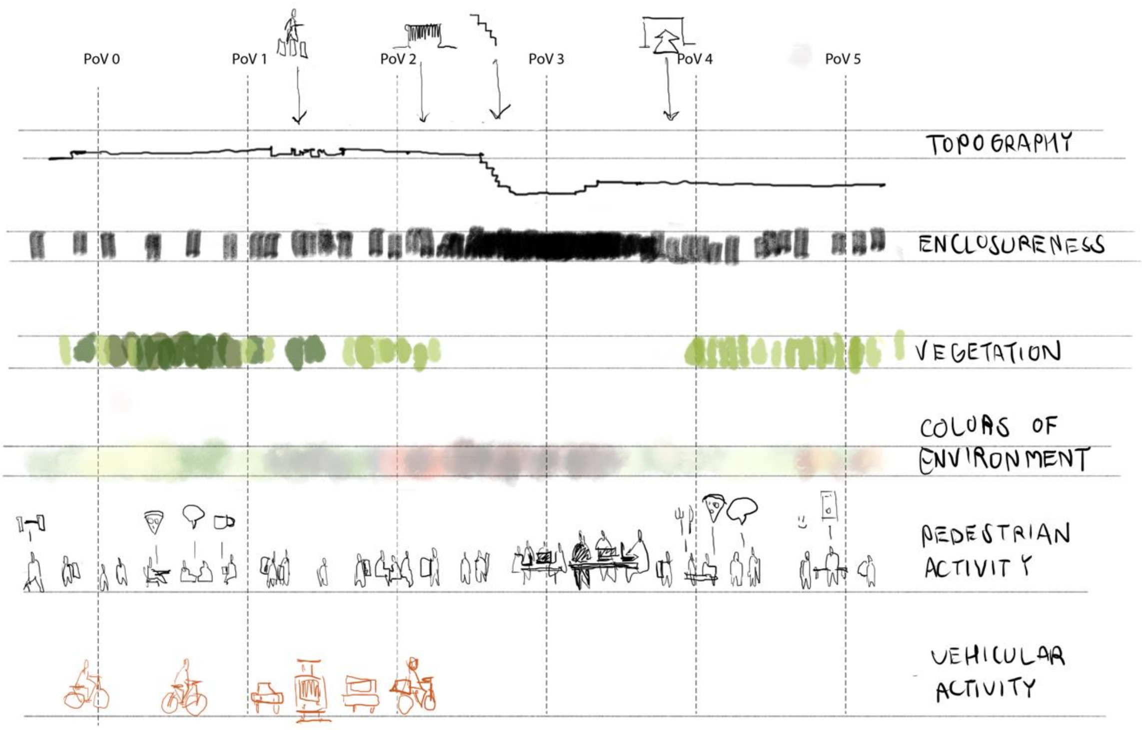


Fig. 88 (above) Imagination Representation of Transect Walk in Leonardo Campus – from PoV 0 to 5 (Diagram by Authors)

06 SENSORY BASED APPROACH

In terms of the sensory approach, we created and designed the protocols to collect Psychological and Physical data from participants in the 'walking experiment' along the predetermined course. Both sorts of data come from the same experiment.

During the walk, at each point on the path, numerous sensations are supplied by the environment and goes into the brain through five sensation modes: vision, touch, sound, taste, smell. Humans' brains automatically select only important information to process (Wilson & Soranzo, 2015). What we can process and perceive is perception.

Because visual perception is the primary mode and it normally accounts for two-thirds of the information humans receive (Cafuta, 2015; Gregory, 1997), we employed a **pupil invisible eye tracker** to monitor it. Additionally, it is the most convenient information to process. We also used this vision record to synchronize the data from other tools to indicate the position on the path.

Once the information has been processed by the brain, psychological data may be gathered. Participants are asked to stop at designated node sites, snap a photo, and complete the surveys on the **CitySense application** in order to collect the data. The analysis of the emotional reactions will be done using this data.

Environment exposes on humans first, and then humans cognize of the exposure (Zhang et al., 2021). At this stage, after receiving and processing the environmental information, humans' bodies unconsciously response back to the environment. We used **ProComp Infiniti System** (ECG, skin conductance, and respiration sensors) and **Bitbrain EEG headset** to collect these physical signals to translate them into perceptions.

The ambient factors also affect perceptions. Throughout this walking experiment, Environmental conditions are continuously captured utilizing a **360-degree camera** and **PASCO environmental data sensor**.

The graphic below shows the connection between the tools and the data gathered, and 6.1 provides further information on each tool.

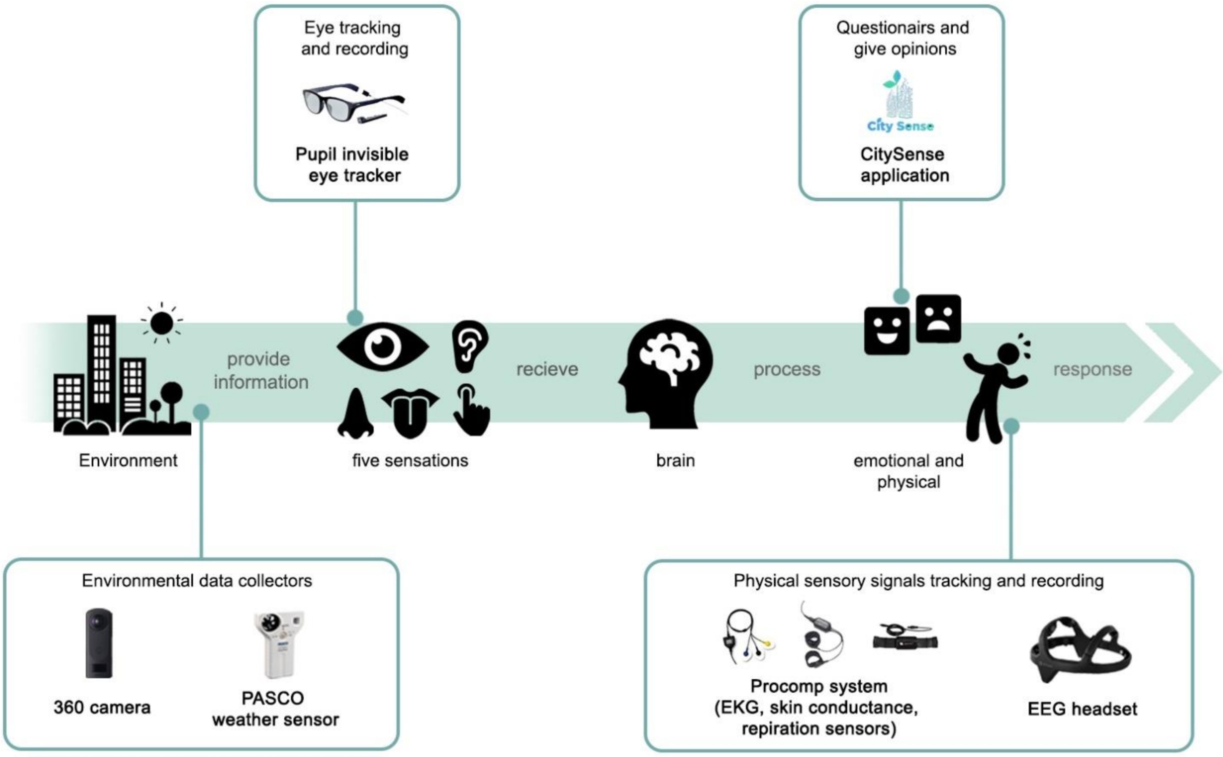


Fig. 89. (above) Relationship between tools and the data collection

6.1 Tools and Equipment

6.1.1. Tools for psychological data

CitySense application

CitySense is the interactive and innovative engagement application that allows users to visit the project site and take into account their experiences with a real-time tour and on mobile accessibility (*Citizen Features* | *City Sense*, 2022)

For general users, CitySense currently has four major interactive functions: discover settings around the current location, take photo, visualize consultations through the questionaries, and give opinions on the type of activities a place should have. Since our participants in this experiment are students and staff of Politecnico di Milano, who are already familiar with the setting, we mainly use the last three functions mentioned above.

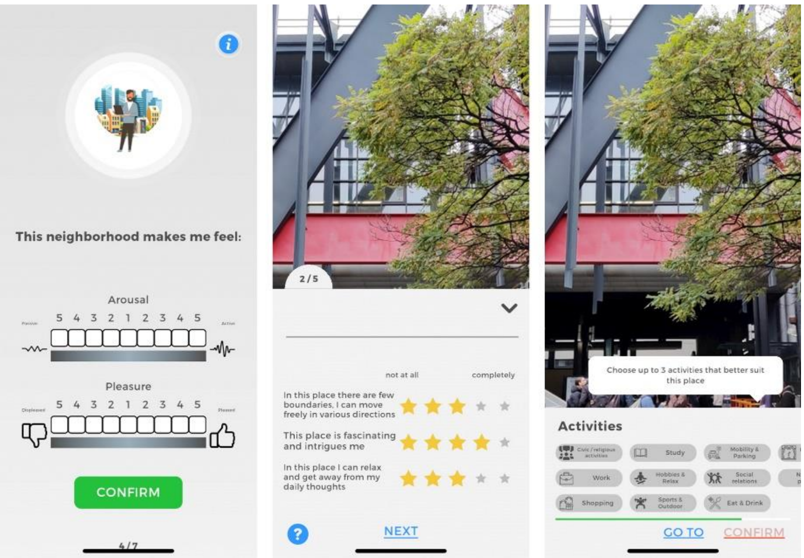


Fig. 90. Examples of Interfaces of CitySense: questionaries, and opinions on the type of activities a place should have

Examples of the questions included in CitySense:

- From this perspective, this place makes me feel? (Arousal and Pleasure aspects, rate from scales)
- This place is visually varied and full of elements? (Rate from 'not at all' to 'completely')
- It is easy to understand this place and orient yourself in? (Rate from 'not at all' to 'completely')
- In this place, I can relax and get away from my daily thought? (Rate from 'not at all' to 'completely')
- Choose up to 3 activities that better suit this place (Drag the icons of activities to the photo)
- From this viewpoint, do you see remarkable element that characterizes the place and make it recognizable (Yes/No, drag and drop the pin on the photo and name it)

The application may be downloaded and installed on both smartphones and tablets, However, we decided to use it on a smartphone to make it more portable for the participants.

6.1.1. Tools for physical data

Pupil invisible eye tracker

Pupil invisible eye tracker is a mobile eye tracking glasses that come up with a wide-angle camera records, swappable lenses, and companion application.

Fig. 91. Pupil invisible eye tracker connected with smartphone

The glasses have two cameras. The front camera is a wide-angle camera to record a full field of view, while the one at the back tracks the pupil to analyze where exactly the users are looking and focusing at.

Fig. 92. Front camera (left) and back camera (right) of Pupil invisible eye

ProComp Infiniti System

ProComp Infiniti System is a set of physiological sensors and channel encoder that can be used for computerizing and acquiring human’s physiological responses and biofeedback.

The channel encoder may be linked to a laptop through a USB connection. Many physiological markers utilized in clinical observation and biofeedback in any situation are covered by the system. The ones we used in the experiment were as follows:

Fig. 93. ProComp Infiniti system

(1) ECG sensors

ECG or electrocardiography is used for heart rate, RSA & HRV (heart rate variability) biofeedback. The sensor measures and amplifies the tiny electrical voltage produced by the heart muscle during contraction.

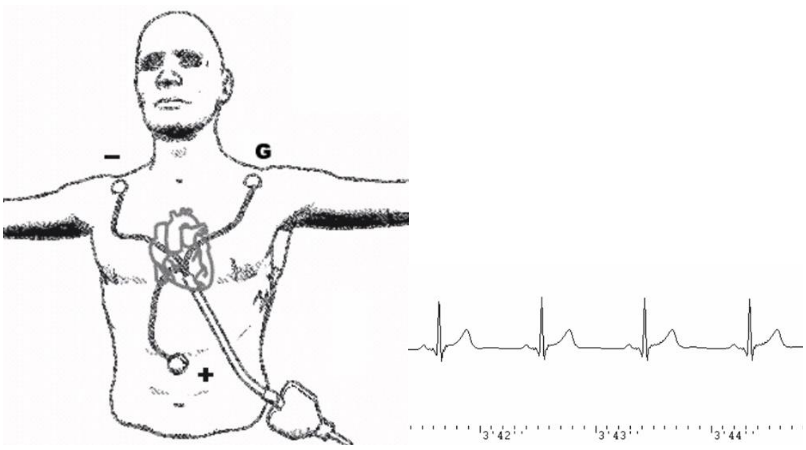


Fig. 94. ECG sensors with example of the signal *(ProComp Infiniti System w/ BioGraph Infiniti Software - T7500M, n.d.)*

The standard ECG electrode placement requires that the negative electrode be placed on the right shoulder, the positive electrode be placed on lower center or left side of the chest (xyphoid process) and the ground electrode, on the left shoulder (*ProComp Infiniti System w/ BioGraph Infiniti Software - T7500M*, n.d.).

(2) Skin conductance sensors

Skin conductance is a measure of the skin's ability to conduct electricity. A tiny electrical voltage is applied through two electrodes, usually strapped to two fingers of one hand, in order to establish an electric circuit where the client becomes a variable resistor. The real-time variation in conductance, which is the inverse of the resistance, is calculated.

The signal from the sensors represents changes in the sympathetic nervous system. As a person becomes more or less stressed, the skin's conductance increases or decreases proportionally. Skin conductance, galvanic skin response and electro-dermal response are different terms for similar physiological measures (*ProComp Infiniti System w/ BioGraph Infiniti Software - T7500M*, n.d.).

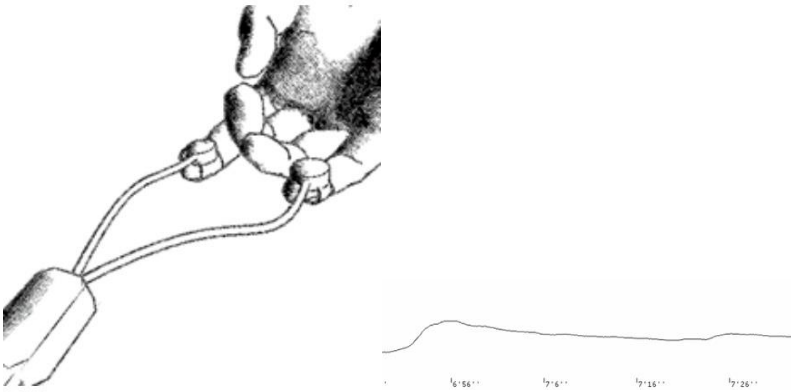


Fig. 95. Skin conductance sensors with example of the signal (*ProComp Infiniti System w/ BioGraph Infiniti Software - T7500M*, n.d.)

A skin conductance sensor's signal type exhibits comparatively quick rises and more gradual declines.

(3) Respiration sensor

Respiration Sensor Measures respiration amplitude and rate with an electronic sensor installed on a self-adhesive belt. The sensor is mostly made up of a long Velcro strap that is wrapped over the participant's chest or abdomen. The sensor can be worn on top of clothing; however it should not be too loose.

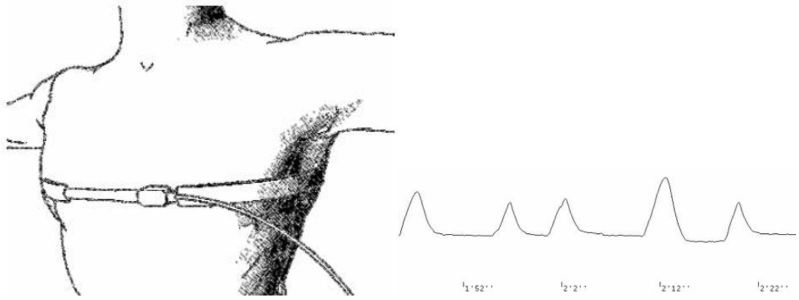


Fig. 96. Respiration sensors with example of the signal (*ProComp Infiniti System w/ BioGraph Infiniti Software - T7500M*, n.d.)

There are several breathing patterns that may be identified, but there is no standard waveform for the respiration signal. A quick rise that slows towards the top of the breath is usually followed by a fast fall that slows near the end of the breath. The breathing rhythm will change depending on the activity.

Bitbrain EEG headset

Bitbrain EEG headset is a portable EEG device designed for real-world applications. The system can be used for evaluating the natural human behaviors of people when interacting with new experiences or measuring attention and stress levels in natural conditions.

Fig. 97. Bitbrain EEG headset and the EEG electrodes

The headset has 12 dry EEG electrodes over specific brain areas, it is optimized to estimate emotional and cognitive states (pre-frontal, frontal, parietal and occipital brain areas).

This equipment sends data to computer using Bluetooth wireless. The acquisition software shows the EEG signal captured by the device in real time. Since the sensors are sensitive, after wearing the headset and place the clip on the left earlobe, it is important to monitor the signals to check if all the sensors have well contact with the skin.

Fig. 98. Bitbrain EEG headset with example of the signal (*Diadem | Wearable Dry-EEG Headset*, n.d.)

Monitoring devices
The pupil invisible eye tracker requires a USB-C connector on a **smartphone**. ProComp Infiniti system and Bitbrain EEG headset are linked to a **laptop** through Bluetooth and USB ports, respectively.
In order for the organizers to remotely access the laptop and monitor the signals without interfering with the participants' walk, we installed VNC Connect on a **tablet**.

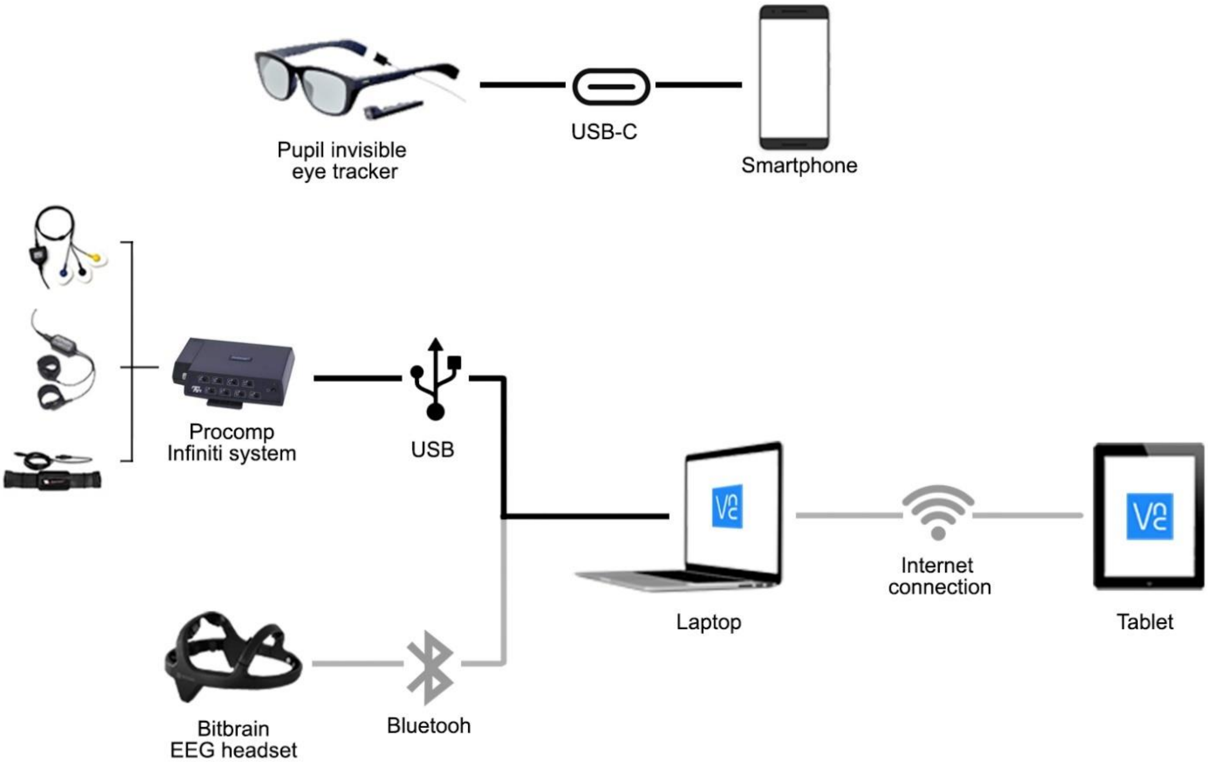


Fig. 99. (above) Devices connected with smartphone and laptop

6.1.5. Tools for Environmental data

RICOH 360 Camera

360 camera has a 360-degree field of view and can catch almost everything surrounding the sphere. When wide visual areas must be covered, such as when taking panoramas, 360 cameras are required. This camera was used to capture the walking experiment.

PASCO weather sensor

The Wireless Weather Sensor is a comprehensive tool for keeping track of challenging environmental conditions. It may be used as a portable tool to track environmental phenomena-related ambient conditions and analyze microclimates. The device has built-in GPS to collect location data and can measure weather conditions and lighting information.

Fig. 100. (left) RICOH 360 camera

Fig. 101. (right) PASCO wireless weather sensor

6.2 Context

In this walking experiment, the same path from the conventional path analysis (chapter 5.3) is used once more. However, point 0 was added to the route. The purpose of the walk between points 0 and 1 is for participants to become used to the different walking conditions while wearing the sensory devices.

The stopping points are:

Point 0 - Participants start by sitting on the bench at Piazza Leonardo da Vinci.

Point 1 - between benches and the bar at the other side of Piazza Leonardo da Vinci

Point 2 - at the entrance of the building 11 from Piazza Leonardo da Vinci
Point 3 - inside building 11, after walking down the spiral stair.
Point 4 - at the exit of building 11 to the courtyard of the new campus
Point 5 - the courtyard of the new campus, for this stopping point, participants are asked to sit on a specific bench.

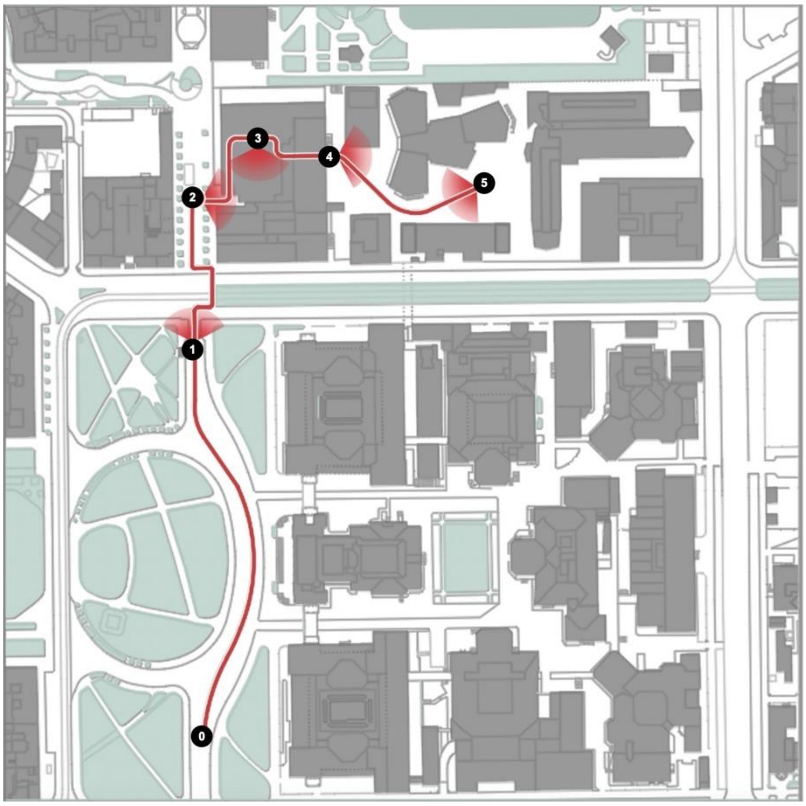
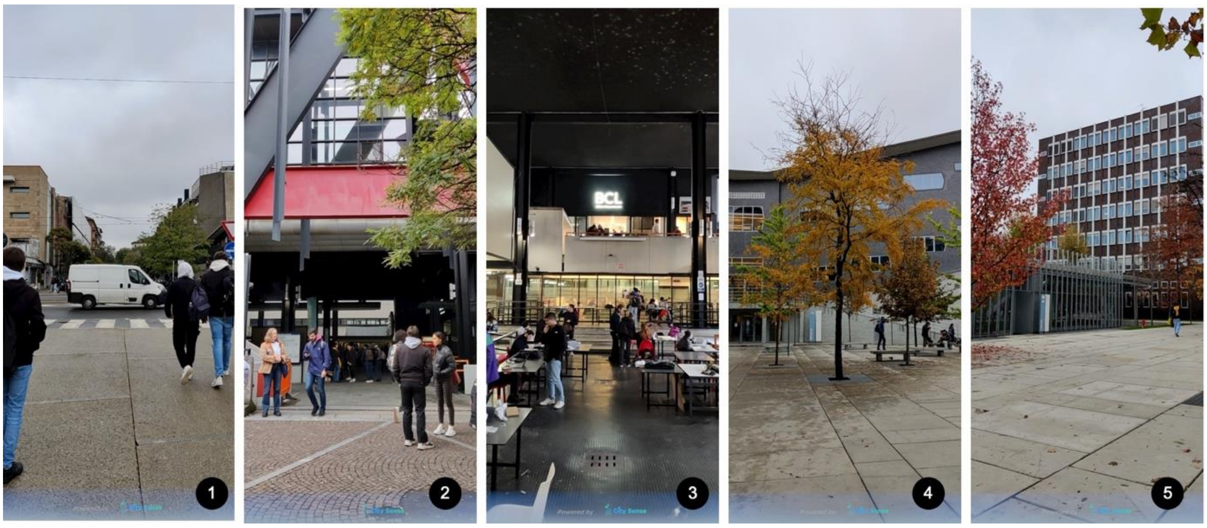


Fig. 102. Path and stopping points of the walking experiment

Fig. 103. (below) Photos taken from each viewpoints using CitySense application



6.3 Implementation

6.3.1. Preparations

Preparation of tools and place

Every device has to be fully charged in advance. Before the participants arrive, the organizers must ensure that all the software and programs are correctly installed.

It is necessary to reserve the room allotted for the experiment subject's preparation. The team leader is responsible for keeping the room's key and making sure it is locked while no one is there. All personal property should be secure throughout the whole experiment.

Fig. 104. Preparation of tools

Preparation of participants

The volunteers are expected to arrive one at a time because the experiment lasts for around 2-3 hours for each one. In order to participate, participants must first provide personal information and register for an account on the CitySense application.

It is crucial that the route and task be well explained because the team tries not to communicate with the participants while they are walking. The organizers illustrate the walking experiment using pictures, maps, and infographics.

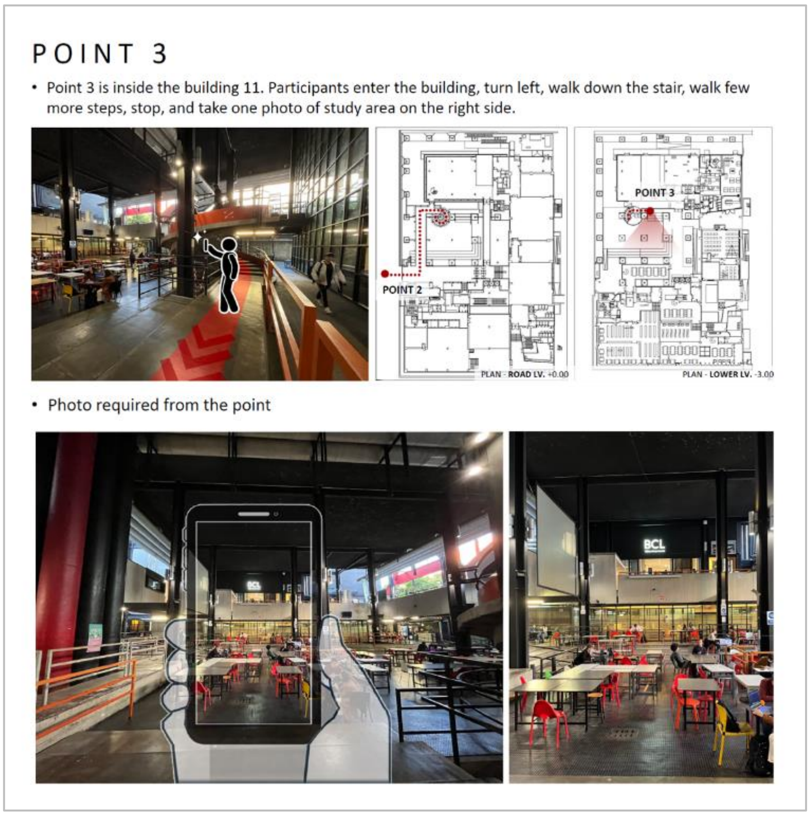


Fig. 105. Examples of the brief

6.3.2. Protocol

The procedures are listed in the following order according to the tools:

Laptop and tablet

- Make sure that when the laptop has the lid close, it still operates and does not switch into sleep mode
- Sync the clock
- Open VNC on the tablet and connect to the laptop

Procomp Infiniti system

- Connect the receiver to the laptop and connect the optical fiber to the receiver Procomp hub and the sensors
- Remove the subject's sweater, pullover, or any item of clothing that could make the sensors placing procedure difficult.
- Put all the sensors on the participants
- The subject should dress up before wearing the headset in the next step

Bitbrain EEG headset

- Connect the headset to the transmitter and insert the SD card
- On the laptop, open the BitBrain software and connect the headset

- Wear the headset on the participants
- Start the recording session to check the quality of the signals.
- Adjust the headset until the quality is acceptable.

Pupil invisible eye tracker

- Turn on the smartphone and open the Invisible Companion app, then connect the glasses to the smartphone
- Ask participants to wear the glasses
- Check the correct positioning of the glasses, which shouldn't move while the subject is walking.
- Start the record

The laptop and the ProComp box are kept in a backpack bag for the participants to carry

Fig. 106. The organizing team assists the participant to wear the sensors

6.3.3. Walking experiment

Once all of the equipment is set up and appropriately worn, the walking experiment may begin. The entire team moves toward the point 0 , at the bench at Piazza Leonardo da Vinci. The participant takes a few minutes to sit on the designated bench to get used to the wearable devices. The participant is instructed to begin the walk as soon as the organizer determines that they are ready.

To conduct the walking experiment, at least two organizers are required. The first one monitors the signal on the tablet and carries personal hotspot device, and the other one collect environmental information. However, it is advised that the organizing team include more than two people.

Fig. 107. The organizing team must maintain the distance from the participant

In order for the participant to walk organically without the distribution, the organizers must maintain the distance from them. The participant must follow the prescribed route, stop at the designated location, take a photo, and then respond to the questions on the CitySense application.

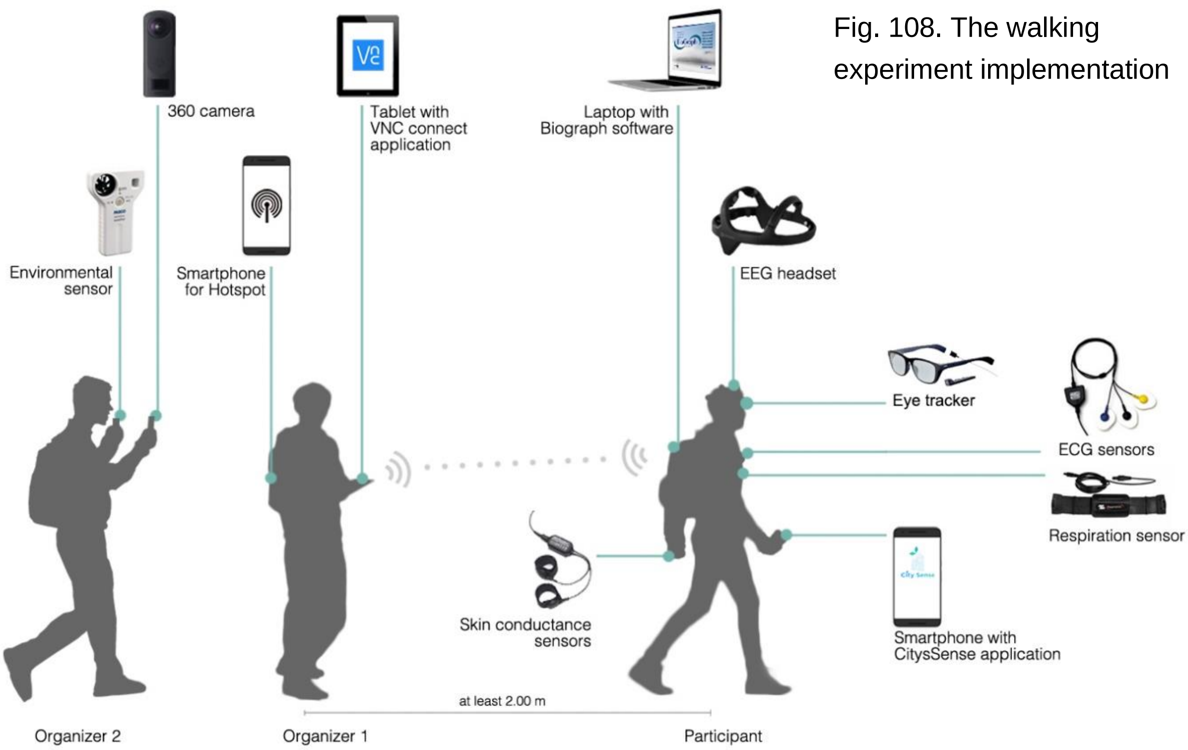


Fig. 108. The walking experiment implementation

Before employing the same instruments for another individual, all the objects that came into touch with the subject's skin during the session must be cleaned.

The gathered psychological data from CitySense application was analyzed with the guidance and methodology if of Laboratorio di Simulazione Urbana Fausto Curti (LABSIMURB), Department of Architecture and Urban Studies, Politecnico di Milano, while the physical signals processing was assisted by Department of Electronics, Information and Bioengineering, Poltecnico di Milano.

6.4 Results

Due to several constraints, we were unable to use all of the participants' data. The psychological data was collected from the *CitySense* Application and represented the average of two female participants who completed the experiment on the same day. While only *Empatica* and *ProComp* Sensors were used to determine the physical results, provided by one male and one female participant.

6.4.1 Walking Conditions

As demonstrated in the table below, the experiments were conducted on four days (including the equipment trial session) within different weather and surrounding conditions.

Table. 2. (below) Experiment Details and Sessions

Date	Session	Participant(s)	Time	Weather Condition*	Average Temperature*	Average Humidity*
3/11/2022	Trail	1 male	(No walking experiment conducted)			
8/11/2022	1^{st} walk	1 male	11:46 - 12:24	Scattered Cloud*	14 - 16 °C	63%
16/11/2022	2^{nd} walk	2 females	11:05 - 11:20 12:20 - 12:53	Partly Sunny	11 - 12 °C	89 %
21/11/2022	3^{rd} walk	1 female	10:58 - 11:29	Passing Clouds	9 - 13 °C	63%

Trial Session

1^{st} Session

2^{nd} Session

3^{rd} Session

6.4.2 Psychological Response

The emotional response data of two participants were collected from the *City Sense* application and were clustered for each point of view using the DBSCAN algorithm (Birant & Kut, 2007; Stancato & Piga, 2020), Scikit-learn 0.22 and Python 3.8 libraries. Using the *Copyright exp-EIA—Experiential Environmental Impact Assessment*, descriptive statistics containing users' geographic information were analyzed to locate the emotional state on a Russel Circumplex quadrant and the subsequent charts.

Emotional Appraisal of the Campus Spaces

Emotions are products of how people appraise their ongoing transactions with the environment (Schmidt et al., 2010). Therefore, emotions possess tremendous diagnostic value because their intensity and quality reveal how people think they manage what is important to them in a particular context. The emotional appraisal analysis depicts the relationships between different emotional states and perceived environmental factors encountered during the transect walk.

As shown in the Russell circumplex quadrant, the numbers from 1 to 5 indicate the points of view where the observers stopped, and the red dot line represents the path taken during the experiment. The overall emotional response shifts throughout the path from the tense experience to the alert, enthusiastic, delighted, and contented experience at the last location. This process made it possible to spatialize the observers' emotions in a georeferenced way. The bar chart below showed the lowest intensity at the first point of view (at 61%), which consider as the only displeasure emotional state (tense feeling) regarding Russel's model before shifting to a range between 86.4% and 87.6% for the other 4 points of view.

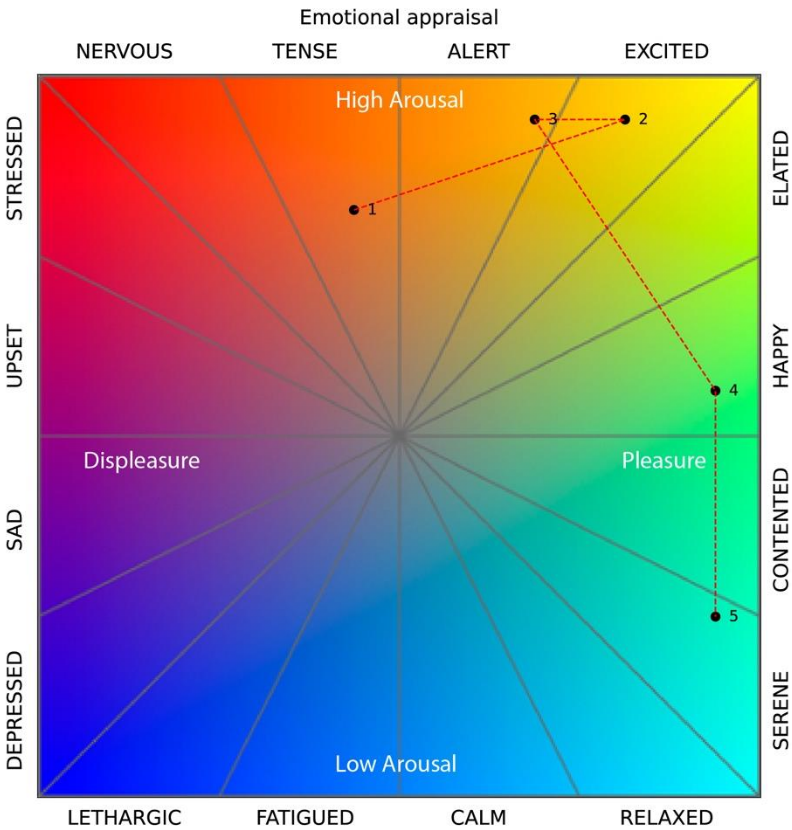


Fig. 109. Russel Circumplex Chart Showing Emotional Appraisal of PoVs along the Path and Polimi Leonardo Campus

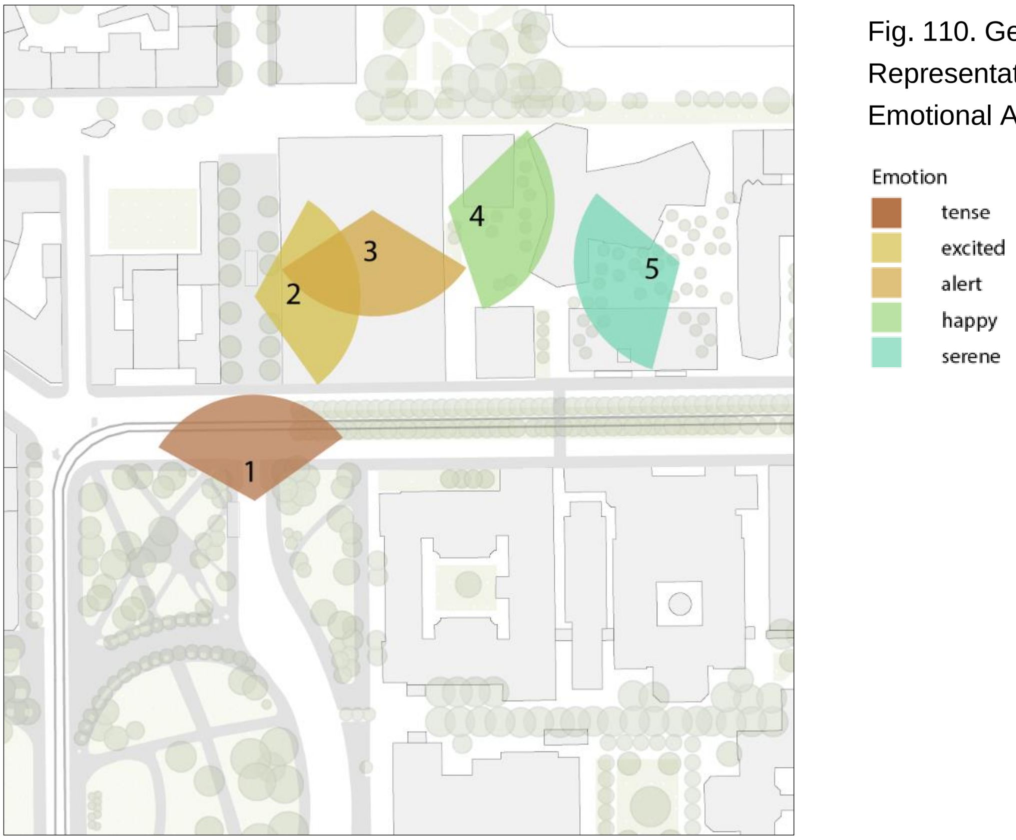


Fig. 110. Geographical Representation of Emotional Appraisal

Fig. 111. Emotional Appraisal Intensity for Viewpoints and Polimi Leonardo Campus

Both patterns demonstrate how emotional states and spatial characteristics correspond geographically, despite not being able to directly convey the quantitative results of emotional reactions. We infer from the low intensity level of emotional evaluation that the participants tended to feel anxious when they reached the formal plaza and halted beside the busy street. Then, when the observers moved inside the building before making their way down to the patio area, which was crowded and emanated a particular atmosphere, the intensity of their enthusiasm intensified. At the end of the stroll, an open area with some greenery provoked the participants' feelings of pleasure and contentment with a consistent high intensity.

Restorative Appraisal of the Campus Spaces

In contrast to the intensity of emotional appraisal findings, the restoration appraisal bar chart displays relatively low opacity for the second and third points of view (alert and exited emotional state), both equal 60%, and relatively close to the first point of view, which is 57.5%. The therapeutic appraisal level of the last two stops also climbed significantly at the same time.

From the observations, we may assume that the restoration intensity is influenced by the degree of excitement, as shown in Russel's model. The more active a place is, the less restorative effects it has. This trend corresponds to spatial attributes. As the last two locations are calmer and contain more vegetation, the observer may experience less psychophysiological tension and greater relaxation.

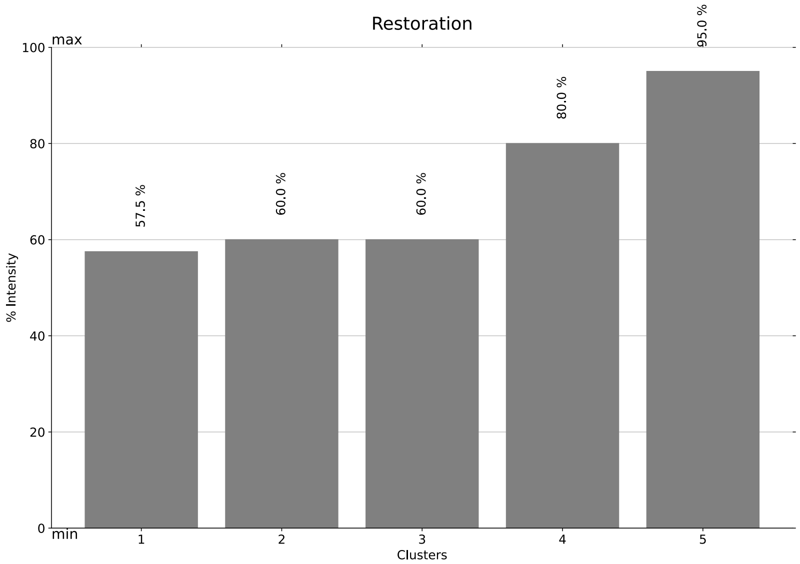


Fig. 112. Restoration Appraisal Intensity for Viewpoints and Polimi Leonardo Campus

Cognitive Appraisal of the Campus Spaces

Cognitive appraisal describes a cognitive process in which an individual subjectively interprets environmental inputs by assessing an emotional situation and determining how the experience will affect them. The cognitive evaluation chart below revealed how likely it was that the two observers evaluated and responded to their surroundings from five different angles.

According to the graph, the first point of view has the lowest intensity of cognitive aspects, with a 70% score for both nudging exploration and ease of understanding categories. At this point, participants were unable to recognize and locate themselves within the setting due to its spaciousness and bustling character.

However, the level of nudge investigation at the second and third points dramatically increased to 90% in accordance with the alert and excited emotional state. This finding can be explained by the building's remarkable characteristics, which are more enclosed and darker. In contrast to nudging exploration, the degree of understanding remains roughly the same from the initial point, ranging between 70% and 75%.

The last two points received the same score for both criteria; the level of understanding is 85%, which is comparatively high due to the attractiveness and visual landmark, and higher than the degree of nudging exploration, which dropped 10% from the second and third points of view.

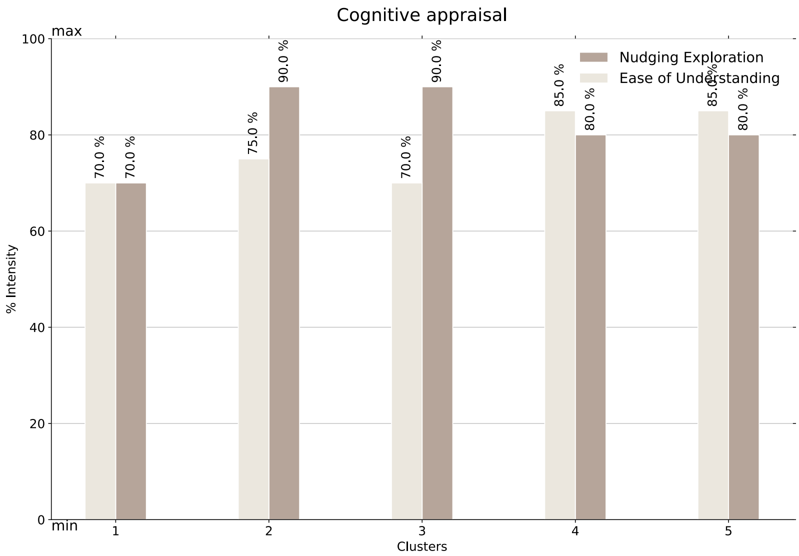


Fig. 113. Restoration Appraisal Intensity for Viewpoints and Polimi Leonardo Campus

6.4.3 Physical Response

With assistance from the Department of Electronics, Information, and Bioengineering at the Politecnico di Milano, the complex statistical data gathered from wearable sensors were interpreted and visualized into various shape plots. After the conclusion of five experiential walks (the first one is a trial walk without data record), the sensory data were selected from two devices (4 sensors) and divided into four groups: electrodermal activity and skin temperature, respiration rate, electrocardiogram (ECG or EKG), and blood volume pulse (BVP) and heart rate (HR). Each criterion displays two plots with two signals: the complete signal and a zoomed-in snapshot of a particular signal section.

Additionally, due to various experimental limitations, data from a few subjects were insufficient to support an explanation of the outcome. For instance, the sensor may have recorded the incorrect value, the electrodes may have shifted while the individuals were walking, or other scenarios that will be discussed in more detail later. The final dataset that served as the prototype for each criterion was thus provided by the participant, who provided the lowest error and best quality data.

Blood Volume Pulse (BVP) and Heart Rate (HR)
Derived from PPG Sensor Sensors (Empatica E4)
During each stage of the cardiac cycle, the amount of blood flowing through vascular system varies, and the blood volume pulse calculates these variations. We may utilize the signals from cardiovascular mechanisms to determine the subject's heart rate, beat-to-beat interval (the amount of time between two consecutive beats), and how this interval fluctuates (heart rate variability). As a result, all these signals contain important information about the autonomous nervous system's activity, which is also influenced by the subject's emotional or mental states, tension, concentration, exhaustion, and enthusiasm.

The heart rate plots below show the trend of emotional state based on the Blood Volume Pulse (BVP) signals. As seen in the zoomed-in graph, positive emotions were produced while walking and were reflected by an increase in Heart Rate (HR) relative to the subjective baseline, while negative emotions were generated upon entering the resting state and were subsequently correlated with a decrease in Heart Rate (HR).

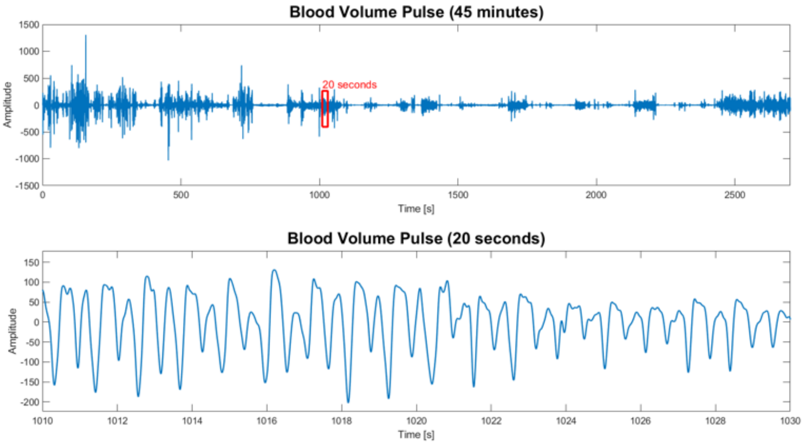


Fig. 114. Blood Volume Pulse (BVP) Variability from Male Participant (upper) and its Zoom-in Section (lower)

Fig. 115. Heart Rate Extraction from Blood Volume Pulse (BVP) Signal from Male Participant (upper) and its Zoom-in Section (lower)

Respiration Rate

Derived from Respiration Sensor (ProComp Infiniti System)

The subject's breathing movement's amplitude can be seen in the respiration signal. The signal has a wave-like pattern because each breath has an inhalation phase (rising amplitude) and an exhalation phase (declining amplitude). Depending on the subject's breathing frequency (how quickly they breathe), the waves will be dilated. However, some of the variations in the total signal could be the result of a recording error brought on by the movement of a sensory device.

According to the zoom section, the subject's respiratory rate increased from shallow breaths to deeper breaths at a pace that exceeded 20 times per minute (about 22 times per minute). This pattern can be used to describe the transition from a condition of regular breathing (Eupnea) to hyperventilation breathing (Hyperpnea) state. Exercise, anxiety, or an increase in metabolic rate related to the weather temperature can all contribute to the condition.

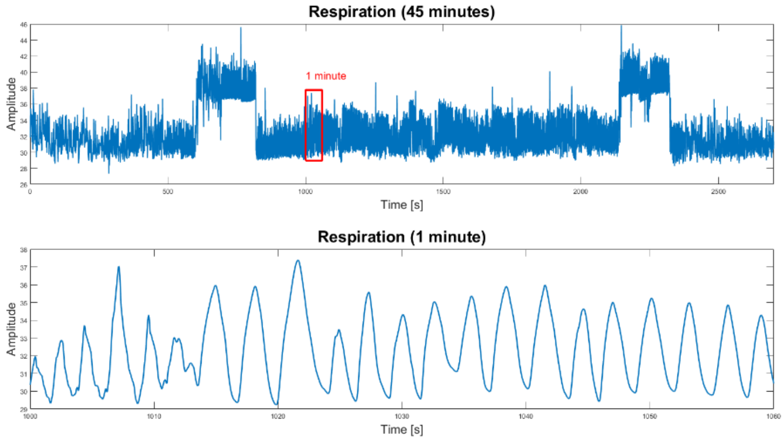


Fig. 116. Respiration Rate Variability from Female Participant (upper) and its Zoom-in Section (lower)

Electrocardiogram (ECG or EKG)

Derived from EKG Sensors (ProComp Infiniti System)

The electrocardiogram measures the electrical activity of the heart by attaching temporary electrodes on subject's skin to monitor, track and document her heart's electrical activity. In this research, we chose a portion of the clean signal from the entire plot to show the spectrum over a period of 20 seconds. We need to reduce noise and further investigate the properties of the histogram in order to associate the emotional state of the subjects in patterns.

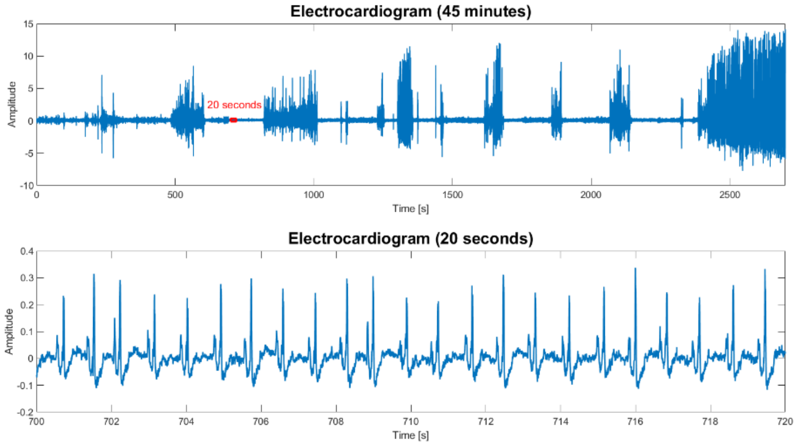


Fig. 117. Electrocardiogram (ECG) Spectrum from Female Participant (upper) and its Zoom-in Plot (lower)

Electrodermal Activity (EDA) and Skin Temperature

Derived from Skin Conductance Sensors (ProComp Infiniti System)

The electrodermal activity, defined as the skin's capacity to carry electrical currents, is influenced by the activity of the sweat glands. The amount of perspiration that these glands secrete is influenced by emotional states, which in turn affects the skin's electronic properties. However, it is challenging to pinpoint and confusing to interpret the outcome.

The total signal plot shows that some variations in the signal could be the result of a recording error. In order to see the relationships, we may also need to overlay the data with additional biofeedback. The zoom segment reveals some variance in sweating or electrodermal activity, which may be brought on by changes in mood or amount of physical activity.

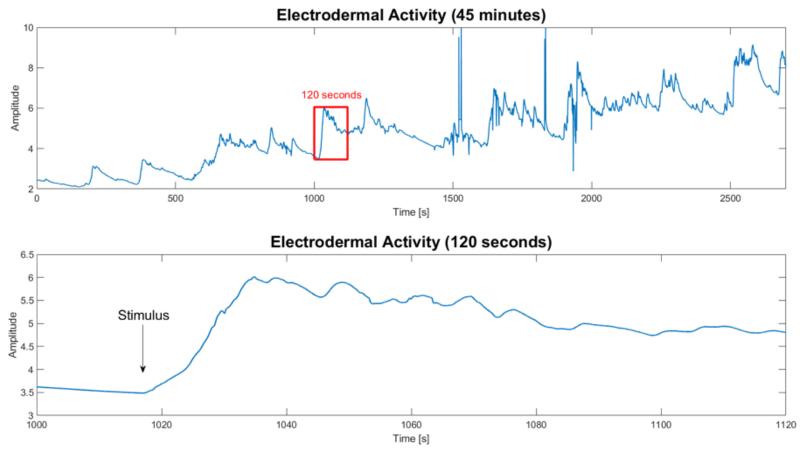


Fig. 118. Plot of Electrodermal Activity (EDA) from Female Participant (upper) and its Zoom-in Segment (lower)

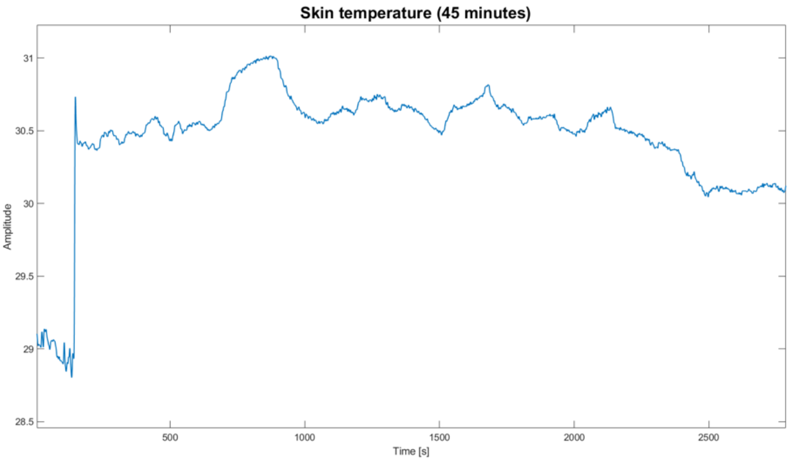


Fig. 119. Skin Temperature Plot from Female Participant

To wrap up this section, we attempted to synchronize biofeedback data by referencing time with five Points of View (PoVs) and activities, as indicated in the chart below. At this stage in the experiment, we were unable to determine whether the activation was brought on by a positive or negative emotion from the data. The Blood Volume Pulse (BVP), which might be related to physical activity, is fairly evident from all the data. The static signal correlates with the subject's action of resting and observing the environment.

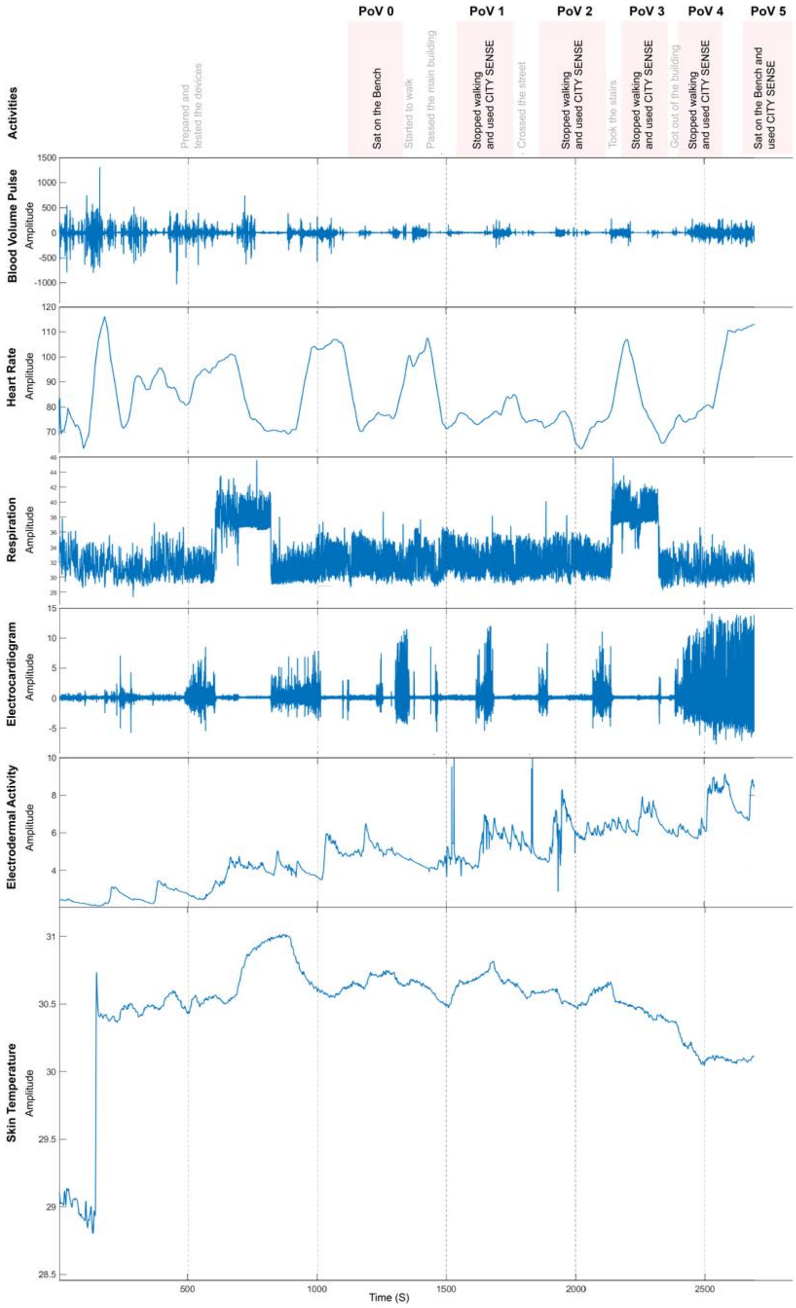


Fig. 120. Overall Biofeedback of Subjects Referencing with the Points of View (PoVs)

However, other statistics are ambiguous and difficult to interpret. An example of this is the mushed Electrodermal Activity (EDA) signal that was present when the person was stopped to snap a picture and answer questions. Additionally, several inaccurate recording values happened when subject was moving. We can now draw the conclusion that a signal's alteration may be influenced by a person's emotional state, a change in their physical activity, or a change in the surroundings.

07 CONCLUSION

7.1 Discussion

Due of resource constraints, time constraints, and certain unanticipated mistakes, a number of restrictions need to be considered. The experiments also featured some methodological flaws. The following list of key areas for improvement is divided into three categories.

Contrains resulting from the differences between conventional and sensory based approaches

The scenarios and variables needed to have been built up and simulated to be the same since our goal was to conduct comparison research between a conventional strategy and sensory based approach. Even still, getting the exact same information from each study proved impractical.

For instance, information such as subjective points of view were hard to obatin using the traditional method, yet it was the primary information from the walking experiment. In addition, the usual study did not take into account the seasons or dates, but our walking trial was carried out in late Autumn, from early to mid-November.

Limitations and errors on the walking experiment

Since the majority of the sensory tools we utilized in this study were new to us and we had no prior experience with them, we were not prepared that it would take each participant as much time to put on, especially the glasses and headset together. We have conducted our walks in the actual environment in late fall, so participants had to wear more clothing than during the warmer months and it was not simple to wear all the devices. Due to these factors, we were only able to conduct the experiment with 4 individuals, which is a small sample size.

Participants required to be highly familiar with the stopping spots in order for the data to be accurate. They also needed to be proficient with the CitySense program since organizers should avoid interfering with the walk, which was not always practical.

Additionally, there were a lot of variables in the actual world that we had no control over, like the weather, the population, and nearby activities. When wearing the gadgets, there may be different impressions than when walking normally because the devices also alter how they moved. In some occasions, the sensory data was not recorded because the participants moved from the proper places throughout the walk or because of poor internet connectivity.

The challenges of synchronizing and processing data
The procedure of synchronizing the data is complicated by the experiment's use of several instruments and the time lag between them. The quality, amount, and reliability of the data were also issues. The data obtained from only one individual was already large and time-consuming to process.

Nevertheless, despite the limitations, we believe that the experiment we carried out might serve as a foundation for future research into the use of the sensory-based approach for urban evaluation.

7.2 Conclusion

The case study of the Leonardo campus presents a tremendous opportunity for performing a comparative study on environmental perception due to the diversity of space characteristics and walkability possibilities. The transdisciplinary walking experiments are also supported by the learning environment at the university. Additionally, the area of focus covers the post-monitoring evaluation of the actual user's perception of the new design campus space.

The presented analytical approaches provide a persuasive explanation of sensory-based evaluation and human-centered design methodology for architecture and urban design students. In addition to challenging earlier urban observation approaches, the outset of a comparative exploratory approach is establishing fresh perspectives for other urban studies and offering a wealth of future opportunities.

Although the case study was conducted with some limitations and with a limited number of participants, the outcomes of the analyses allowed for spatializing the dominant emotions brought on by place experience. Correspondingly, they can be incorporated into the architectural and urban planning process and used to inform urban policies. On this basis, remarks regarding the advantages and disadvantages were discussed and emphasised in the following table.

Features	Conventional Approach	Sensory-Based Approach	
	Conventional Path Analysis	Psychological Data Analysis	Physical Data Analysis
Devices Used	Recording tools – paper, camera, etc. and computer or laptops	Smartphone with City Sense application	Wearable sensors, smartphone and laptop or computer
Data type	Quantitative and qualitative	Quantitative and qualitative	Only quantitative
Participant	Don't need participants	Need large sample size for comparative study	Need large sample size for comparative study
Variables	Subjective opinion	Only uncontrollable factors – weather conditions, activities	Uncontrollable factors – weather conditions, activities and the weight of equipments
Difficulty	Not very complicated	Least difficult – users have to simply answer the questions	Most complicated
Time	Require time to gather the data	Require less time – only to register City Sense for new users	Require a lot of time – to apply and test the devices
Cost	Can be costly – depends on the methodologies	Least Expensive	Most expensive – sensory devices and accompanied software
Scale	Large scale – from neighborhood to urban scale	Small scale – from particular area to neighborhood area	Small scale – from particular area to neighborhood area
Level of details	Low	Medium – need the interpretation	High – Statistical data derived from the sensors
Implementation	Predevelopment phase	During and post monitoring phase	During and post monitoring phase

Advantage, e.g., less complicate, easier, more precise

Disadvantage, e.g., more complicate, harder, less precise

Table. 3. (above) Comparison between two approaches

Physical data analysis offers the best quality and most trustworthy data, despite the fact that it has several disadvantages, including application difficulties, high costs, and time requirements. The psychological and conventional approaches, however, offer greater benefits and require less effort to evaluate. In conclusion, it is difficult to determine whether the strategy is superior to another because its advantages and disadvantages might be applicable in a variety of contexts. the sensory based approaches are suitable for the users experience evaluation during and after the completion of development project that need the detailed data, while the conventional ways are easier to apply , less complicate and can be done within the predesign phase which doesn’t need much detail of data.

Further works

The results of the walking experiment on a sensory-based approach revealed various ‘methodological flaws’ in our investigation. First, the study didn’t pay much attention to potential noise, air pollution, air temperature, and other physical index confounding factors which can potentially influence both the physical and psychological reactions of individuals. In this perspective, all other urban activities can also be seen as significant human perception triggers. It is necessary to conduct additional experiments under control circumstances, such as in simulation environments or smaller spaces, and compare the results to the actual urban environment.

Second, the experiment needs to involve a larger sample size and a more comprehensive range of demographic characteristics, including different nationalities, ages, and academic specialties.

Another crucial concern we have experienced and need to work on is ‘technical drawbacks’. In addition to the complication, the weight, the number of sensors, and the manner in which all of the sensory devices are attached to the observer's body may affect the observer's perception and alter their natural movement pattern, which is contrary to the set targets. The recommendation at this point is to conduct further research on devices and sensors and seek alternative methods of regulating the walking conditions, such as using a recording system rather than a laptop or fewer redundant sensors.

BIBLIOGRAPHY

Abdelfattah, L., Deponte, D., & Fossa, G. (2022). The 15-minute city as a hybrid model for Milan. TeMA - Journal of Land Use, Mobility and Environment, 71-86 Pages. https://doi.org/10.6093/1970-9870/8653

Alhusban, A., Alhusban, S., & Al-Betawi, Y. (2019). The degree of the Hashemite university students' desires, needs, and satisfaction with their campus urban design. Journal of Place Management and Development, 12. https://doi.org/10.1108/JPMD-08-2018-0062

Al-Kodmany, K. (1999). Using visualization techniques for enhancing public participation in planning and design: Process, implementation, and evaluation. Landscape and Urban Planning, 45(1), 37–45. https://doi.org/10.1016/S0169-2046(99)00024-9

Al-Kodmany, K. (2002). Visualization Tools and Methods in Community Planning: From Freehand Sketches to Virtual Reality. Journal of Planning Literature, 17(2), 189–211. https://doi.org/10.1177/088541202762475946

Amoozandeh, K., Winter, S., & Tomko, M. (2022). Space decomposition based on visible objects in an indoor environment. Environment and Planning B: Urban Analytics and City Science, 49(3), 883–897. Scopus. https://doi.org/10.1177/23998083211037347

Andersen, K., & Balbontín, S. (2021). A Walking Methodology as the Participatory Tool for a University Master Plan Design. In B. E. A. Piga, D. Siret, & J.-P. Thibaud (Eds.), Experiential Walks for Urban Design: Revealing, Representing, and Activating the Sensory Environment (pp. 289–301). Springer International Publishing. https://doi.org/10.1007/978-3-030-76694-8_17

Anemogiannis, D., & Theocharis, A. (2021). 'Echoes of Elves and Demons in the Riverbank' the Exploration of History and Folklore in Kythera Through Walking. In B. E. A. Piga, D. Siret, & J.-P. Thibaud (Eds.), Experiential Walks for Urban Design: Revealing, Representing, and Activating the Sensory Environment (pp. 3–23). Springer International Publishing. https://doi.org/10.1007/978-3-030-76694-8_1

Benedikt, M. (1979). To Take Hold of Space: Isovists and Isovist Fields. Environment and Planning B: Planning and Design, 6, 47–65. https://doi.org/10.1068/b060047

Birant, D., & Kut, A. (2007). ST-DBSCAN: An algorithm for clustering spatial–temporal data. Data & Knowledge Engineering, 60(1), 208–221. https://doi.org/10.1016/j.datak.2006.01.013

Bosselmann, P. (1998). Representation of Places: Reality and Realism in City Design. University of California Press.

Buttimer, A., 1976: Grasping the dynamism of lifeworld. Annals of the Association of American Geographers 66, 277-92. (1994). Progress in Human Geography, 18(4), 501–506. https://doi.org/10.1177/030913259401800405

Cafuta, M. R. (2015). Open Space Evaluation Methodology and Three Dimensional Evaluation Model as a Base for Sustainable Development Tracking. Sustainability, 7(10), Article 10. https://doi.org/10.3390/su71013690

Carmona, M., Tiesdell, S., Heath, T., & Oc, T. (2010). Public Places, Urban Spaces: The Dimensions of Urban Design. Routledge.

Carr, S., Francis, M., Rivlin, L. G., & Stone, A. M. (1992). Public space. Cambridge University Press.

Certeau, M. de, & Certeau, M. de. (2002). The practice of everyday life. University of California Press.

Citizen Features | City Sense. (2022, February 10). https://citysense.fr/en/fonctionnalites-citoyen/

Cullen, Gordon. (1971). The Concise Townscape. Routledge.

Dalton, R., & Bafna, S. (2003). The syntactical image of the city: A reciprocal definition of spatial elements and spatial syntaxes. Conroy Dalton, R. and Bafna, S. (2003) The Syntactical Image of the City: A Reciprocal Definition of Spatial Elements and Spatial Syntaxes. In: 4th International Space Syntax Symposium, 17-19 June 2003, London, UK.

Degen, M. M., & Rose, G. (2012). The Sensory Experiencing of Urban Design: The Role of Walking and Perceptual Memory. Urban Studies, 49(15), 3271–3287. https://doi.org/10.1177/0042098012440463

Deleuze, G., & Guattari, F. (1987). A thousand plateaus: Capitalism and schizophrenia. University of Minnesota Press.

Dempsey, N., Bramley, G., Power, S., & Brown, C. (2011). The social dimension of sustainable development: Defining urban social sustainability. Sustainable Development, 19(5), 289–300. https://doi.org/10.1002/sd.417

du Toit, L., Cerin, E., Leslie, E., & Owen, N. (2007). Does Walking in the Neighbourhood Enhance Local Sociability? Urban Studies, 44(9), 1677–1695. https://doi.org/10.1080/00420980701426665

Engen, T. (1991). Odor sensation and memory. Praeger.

Forsyth, A., & Southworth, M. (2008). Cities Afoot—Pedestrians, Walkability and Urban Design. Journal of Urban Design, 13(1), 1–3. https://doi.org/10.1080/13574800701816896

Franck, K. A., & Stevens, Q. (2006). Loose space: Possibility and diversity in urban life. Routledge.

Franz, G., & Wiener, J. (2008). From Space Syntax to Space Semantics: A Behaviorally and Perceptually Oriented Methodology for the Efficient Description of the Geometry and Topology of Environments. Environment and Planning B: Planning and Design, 35, 574–592. https://doi.org/10.1068/b33050

Gehl, J. (1971). Life between buildings: Using public space. Island Press.

Gehl, J. (1987). Life between buildings: Using public space. Van Nostrand Reinhold.

Gehl, J., & Svarre, B. (2013). How to Study Public Life. Island Press.

Gibson, J. J. (1979). The ecological approach to visual perception. L. Erlbaum.

Golonka, S., & Wilson, A. D. (2019). Ecological mechanisms in cognitive science. Theory & Psychology, 29(5), 676–696. https://doi.org/10.1177/0959354319877686

Gregory, R. L. (1997). Eye and brain: The psychology of seeing, 5th ed (pp. ix, 277). Princeton University Press.

Hartig, T. (2008). Green space, psychological restoration, and health inequality. The Lancet, 372(9650), 1614–1615. https://doi.org/10.1016/S0140-6736(08)61669-4

Hartig, T. (2021). Restoration in Nature: Beyond the Conventional Narrative. In A. R. Schutte, J. C. Torquati, & J. R. Stevens (Eds.), Nature and Psychology (Vol. 67, pp. 89–151). Springer International Publishing. https://doi.org/10.1007/978-3-030-69020-5_5

Hartig, T., Kaiser, F. G., & Bowler, P. A. (2001). Psychological Restoration in Nature as a Positive Motivation for Ecological Behavior. Environment and Behavior, 33(4), 590–607. https://doi.org/10.1177/00139160121973142

Hartig, T., Kylin, C., & Johansson, G. (2007). The Telework Tradeoff: Stress Mitigation vs. Constrained Restoration. Applied Psychology, 56(2), 231–253. https://doi.org/10.1111/j.1464-0597.2006.00252.x

Henshaw, V. (2013). Urban Smellscapes: Understanding and Designing City Smell Environments (0 ed.). Routledge. https://doi.org/10.4324/9780203072776

Hinton, A. (2014). Understanding context: Environment, language, and information architecture (First edition). O'Reilly Media, Inc.

Huang, B.-X., Chiou, S.-C., & Li, W.-Y. (2020). Accessibility and Street Network Characteristics of Urban Public Facility Spaces: Equity Research on Parks in Fuzhou City Based on GIS and Space Syntax Model. Sustainability, 12, 3618. https://doi.org/10.3390/su12093618

Ingold, T. (2004). Culture on the Ground: The World Perceived Through the Feet. Journal of Material Culture, 9(3), 315–340. https://doi.org/10.1177/1359183504046896

Insch, A., & Sun, B. (2013). University students' needs and satisfaction with their host city. Journal of Place Management and Development, 6(3), 178–191. https://doi.org/10.1108/JPMD-03-2013-0004

Jacob, Jane. (1961). The Dead and Life of Great American cities.

Jacobs, A. B. (1993). Great streets. MIT Press.

Kaal, H. (2011). A conceptual history of livability. City, 15(5), 532–547. https://doi.org/10.1080/13604813.2011.595094

Kanellopoulou, D. (2017). Walking, feeling, talking: The experience of public space in the historical center of Athens. The Senses and Society, 12(2), 177–192. https://doi.org/10.1080/17458927.2017.1310455

Kaplan, R., & Kaplan, S. (1989). The experience of nature: A psychological perspective. Cambridge University Press.

Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. Journal of Environmental Psychology, 15(3), 169–182. https://doi.org/10.1016/0272-4944(95)90001-2

Kim, J., & Kim, S. (2019). Finding the Optimal D/H Ratio for an Enclosed Urban Square: Testing an Urban Design Principle Using Immersive Virtual Reality Simulation Techniques. International Journal of Environmental Research and Public Health, 16(5), Article 5. https://doi.org/10.3390/ijerph16050865

Krukar, J., Manivannan, C., Bhatt, M., & Schultz, C. (2021). Embodied 3D isovists: A method to model the visual perception of space. Environment and Planning B: Urban Analytics and City Science, 48(8), 2307–2325. Scopus. https://doi.org/10.1177/2399808320974533

Lee, K. M. (2004). Presence, Explicated. Communication Theory, 14(1), 27–50. https://doi.org/10.1111/j.1468-2885.2004.tb00302.x

Lefebvre, H. (2004). Rhythmanalysis: Space, time, and everyday life. Continuum.

Lynch, K. (2008). The image of the city (33. print). M.I.T. Press.

Marrone, P., Orsini, F., Asdrubali, F., & Guattari, C. (2018). Environmental performance of universities: Proposal for implementing campus urban morphology as an evaluation parameter in Green Metric. Sustainable Cities and Society, 42, 226–239. https://doi.org/10.1016/j.scs.2018.07.012

Matos Wunderlich, F. (2008). Walking and Rhythmicity: Sensing Urban Space. Journal of Urban Design, 13(1), 125–139. https://doi.org/10.1080/13574800701803472

Mehta, V. (2014). Evaluating Public Space. Journal of Urban Design, 19(1), 53–88. https://doi.org/10.1080/13574809.2013.854698

Moreno, C. (2020). Droit de cité: De la ville-monde à la ville du quart d’heure. les Éditions de l’Observatoire.

Moreno, C., Allam, Z., Chabaud, D., Gall, C., & Pratlong, F. (2021). Introducing the “15-Minute City”: Sustainability, Resilience and Place Identity in Future Post-Pandemic Cities. Smart Cities, 4(1), 93–111. https://doi.org/10.3390/smartcities4010006

Nevejan, C., Sefkatli, P., & Cunningham, S. W. (2018). City rhythm: Logbook of an exploration (First edition). Delft University of Technology, Multi Actor Systems.

Owen, N., Humpel, N., Leslie, E., Bauman, A., & Sallis, J. F. (2004). Understanding environmental influences on walking. American Journal of Preventive Medicine, 27(1), 67–76. https://doi.org/10.1016/j.amepre.2004.03.006

Payne, S. R. (2010). URBAN PARK SOUNDSCAPES AND THEIR PERCEIVED RESTORATIVENESS.

Perry, C. (1929). The Neighbourhood Unit (Monograph I). In Neighborhood and Community Planning, of the Regional Survey of New York and Its Environs. (Vol. 7).

Piga, B. E. A. (2021). Experiential-Walk: Experiencing and Representing the City for Urban Design Purposes. In B. E. A. Piga, D. Siret, & J.-P. Thibaud (Eds.), Experiential Walks for Urban Design: Revealing, Representing, and Activating the Sensory Environment (pp. 187–206). Springer International Publishing. https://doi.org/10.1007/978-3-030-76694-8_11

Piga, B. E. A., Rainisio, N., & Boffi, M. (2020). The experiential walk diary. Mapping urban experience combining architecture and psychology. URBANISTICA INFORMAZIONI, special issue, 15–18.

Piga, B. E. A., & Salerno, R. (Eds.). (2017). Urban Design and Representation: A Multidisciplinary and Multisensory Approach (1st ed. 2017). Springer International Publishing : Imprint: Springer. https://doi.org/10.1007/978-3-319-51804-6

Piga, B., & Morello, E. (2015). Environmental design studies on perception and simulation: An urban design approach. Ambiances. Environnement Sensible, Architecture et Espace Urbain, 1, Article 1. https://doi.org/10.4000/ambiances.647

Politecnico di Milano: New Architecture campus. (n.d.). Retrieved December 20, 2021, from https://www.polimi.it/en/the-politecnico/university-projects/construction-sites/new-architecture-campus/

ProComp Infiniti System w/ BioGraph Infiniti Software—T7500M. (n.d.). Thought Technology Ltd. Retrieved November 28, 2022, from https://thoughttechnology.com/procomp-infiniti-system-w-biograph-infiniti-software-t7500m/

Rendell, J. (2003). A Place Between, Art, Architecture and Criticism.

Russ, A., & Krasny, M. E. (n.d.). Essays in Urban Environmental Education. 96.

Saegert, S., & Winkel, G. H. (1990). Environmental Psychology. Annual Review of Psychology, 41(1), 441–477. https://doi.org/10.1146/annurev.ps.41.020190.002301

Schimpl, M., Moore, C., Lederer, C., Neuhaus, A., Sambrook, J., Danesh, J., Ouwehand, W., & Daumer, M. (2011). Association between Walking Speed and Age in Healthy, Free-Living Individuals Using Mobile Accelerometry—A Cross-Sectional Study. PLOS ONE, 6(8), e23299. https://doi.org/10.1371/journal.pone.0023299

Schmidt, S., Tinti, C., Levine, L. J., & Testa, S. (2010). Appraisals, emotions and emotion regulation: An integrative approach. Motivation and Emotion, 34(1), 63–72. https://doi.org/10.1007/s11031-010-9155-z

Seamon, D., & Mugerauer, R. (1986). Dwelling, Place and Environment. https://doi.org/10.1007/978-94-010-9251-7

Shatu, F., Yigitcanlar, T., & Bunker, J. (2019). Objective vs. Subjective measures of street environments in pedestrian route choice behaviour: Discrepancy and correlates of nonconcordance. Transportation Research Part A: Policy and Practice, 126, 1–23. https://doi.org/10.1016/j.tra.2019.05.011

Sinclair, I. (1997). Lights out for the territory: 9 excursions in the secret history of London. Granta Books.

Southworth, M. (2005). Designing the Walkable City. Journal of Urban Planning and Development, 131(4), 246–257. https://doi.org/10.1061/(ASCE)0733-9488(2005)131:4(246)

Speck, J. (2012). Walkable city: How downtown can save America, one step at a time (1st ed). Farrar, Straus and Giroux.

Staats, H., & Hartig, T. (2004). Alone or with a friend: A social context for psychological restoration and environmental preferences. Journal of Environmental Psychology, 24(2), 199–211. https://doi.org/10.1016/j.jenvp.2003.12.005

Stancato, G., & Piga, B. (2020). La simulazione parametrica come strumento per informare la rappresentazione | Parametric Simulation as a Tool to Inform Representation. CONNETTERE - UN DISEGNO PER ANNODARE E TESSERE · CONNECTING - DRAWING FOR WEAVING RELATIONSHIPS, DISEGNO, 829-846.

Steg, L., & de Groot, J. I. M. (Eds.). (2018). Environmental psychology: An introduction (Second edition). Wiley-Blackwell.

Tilley, C. Y. (1994). A phenomenology of landscape: Places, paths, and monuments. Berg.

Tuan, Y. F. (1977). Space and Place: The Perspective of Experience. E. Arnold. https://books.google.it/books?id=M9SLfxpkscgC

Tuan, Y.-F. (1975). Place: An Experiential Perspective. Geographical Review, 65(2), 151–165.

Tudorie, C. A.-M., Vallés-Planells, M., Gielen, E., Arroyo, R., & Galiana, F. (2020). Towards a Greener University: Perceptions of Landscape Services in Campus Open Space. Sustainability, 12(15), Article 15. https://doi.org/10.3390/su12156047

Ulrich, R. S. (1983). Aesthetic and Affective Response to Natural Environment. In I. Altman & J. F. Wohlwill (Eds.), Behavior and the Natural Environment (pp. 85–125). Springer US. https://doi.org/10.1007/978-1-4613-3539-9_4

Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., & Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. Journal of Environmental Psychology, 11(3), 201–230. https://doi.org/10.1016/S0272-4944(05)80184-7

US EPA, R. 01. (n.d.). What is Open Space/Green Space? | Urban Environmental Program in New England [Overviews & Factsheets]. Retrieved December 15, 2021, from https://www3.epa.gov/region1/eco/uep/openspace.html

Vasilikou, C. (2016). Sensory Navigation in the City Centre. Perceptual paths, sense walks and interactive atmospheres.

von Lindern, E., Lymeus, F., & Hartig, T. (2017). The Restorative Environment: A Complementary Concept for Salutogenesis Studies. In M. B. Mittelmark, S. Sagy, M. Eriksson, G. F. Bauer, J. M. Pelikan, B. Lindström, & G. A. Espnes (Eds.), The Handbook of Salutogenesis (pp. 181–195). Springer International Publishing. https://doi.org/10.1007/978-3-319-04600-6_19

Waller, D., & Flader, S. (2010). Leopold's Legacy: An ecology of place (pp. 40–62).

Wilson, C. J., & Soranzo, A. (2015). The Use of Virtual Reality in Psychology: A Case Study in Visual Perception. Computational and Mathematical Methods in Medicine, 2015, e151702. https://doi.org/10.1155/2015/151702

Winkler, J. (2010). Space, sound and time: A choice of articles by Justin Winkler in Soundscape Studies and Aesthetics of Environment 1990-2005 [Other]. University_of_Basel. http://edoc.unibas.ch/50524/

Xiang, L., Papastefanou, G., & Ng, E. (2021). Isovist indicators as a means to relieve pedestrian psycho-physiological stress in Hong Kong. Environment and Planning B: Urban Analytics and City Science, 48(4), 964–978. Scopus. https://doi.org/10.1177/2399808320916768

Zhang, Z., Zhuo, K., Wei, W., Li, F., Yin, J., & Xu, L. (2021). Emotional Responses to the Visual Patterns of Urban Streets: Evidence from Physiological and Subjective Indicators. International Journal of Environmental Research and Public Health, 18(18), Article 18. https://doi.org/10.3390/ijerph18189677

Zhisheng, W., Nagai, Y., Zhu, D., Liu, J., & Zou, N. (2019). Based on Creative Thinking to Museum Lighting Design Influences to Visitors Emotional Response Levels Theory Research. IOP Conference Series: Materials Science and Engineering, 573, 012093. https://doi.org/10.1088/1757-899X/573/1/012093