MAPPING THE WALKABILITY OF MAIN CAMPUS, UNIVERSITI SAINS MALAYSIA USING GEOGRAPHIC INFORMATION SYSTEM (GIS)

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By

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I hereby declare that all corrections and comments made by the supervisor(s)and examiner have been taken into consideration and rectified accordingly.

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ABSTRAK

Dalam komuniti USM, kebolehjalan kaki telah berkembang menjadi penting untuk menyepadukan kemampanan di semua peringkat. Peningkatan pelajar yang memandu kenderaan bermotor di kampus semakin membimbangkan kerana menyumbang kepada pencemaran kampus. Masalah ini bertentangan dengan Agenda Matlamat Pembangunan Mampan (Sustainable Development Goals), untuk mencapai keharmonian sosial, kemakmuran ekonomi, dan perlindungan alam sekitar. Bagi menangani masalah ini, matlamat awal kajian ini adalah untuk menilai setiap segmen laluan yang boleh diakses di Kampus Induk USM untuk menentukan prestasinya kebolehjalanan kaki di seluruh kawasan kampus, yang dibahagikan kepada 8 zon. Aspek seperti ketersambungan, kecerunan pejalan kaki, kebolehcapaian kerusi roda, keadaan permukaan, perabot jalan, tempat teduh, tempat perlindungan, halangan, ruang hijau, dan kewujudan kedudukan kiri dan kanan untuk laluan pejalan kaki dipertimbangkan semasa menilai setiap segmen laluan. Peringkat seterusnya adalah untuk menentukan prestasi kebolehjalan kaki setiap zon berdasarkan keputusan penilaian. Keupayaan perisian QGIS untuk membezakan prestasi setiap zon membolehkan visualisasi data mengenai kebolehjalan kaki setiap zon dengan menghasilkan peta. Keputusan peta QGIS memberikan maklumat penting tentang zon dengan prestasi kebolehjalan kaki yang tertinggi dan terendah, menjadikannya lebih mudah untuk memutuskan langkah yang perlu diambil untuk meningkatkan kebolehjalan kaki di zon tersebut dan seluruh kawasan kampus. Mengikut kajian ini, Zon 1 dan Zon 2 mempunyai prestasi kebolehjalan kaki yang tertinggi dan terendah dengan skor 61% dan 43% masing-masing. Oleh itu, langkah mesti diambil untuk meningkatkan kebolehjalan kaki dalam kalangan warga kampus dan memaksimumkan peluang bahawa transformasi yang amat sukar ini ke arah kampus yang lebih mudah diakses, mampan dan sihat akan berjaya.

ABSTRACT

In the USM community, walkability has grown to be essential for integrating sustainability at all levels. Students' growing willingness to drive motorized vehicles on campus, in particular, has become a source for concern because doing so, contributes to campus pollution. This problem goes against the Sustainable Development Goals (SDG) Agenda, which aims to achieve social harmony, economic prosperity, and environmental protection. In order to address this problem, the initial goal of this study is to evaluate every accessible route segment in the USM Main Campus to determine how well it performs in terms of walkability for the entire area of the campus, which has been separated into 8 zones. Indicators including connectivity, sidewalk slope, wheelchair accessibility, surface degradation, street furniture, shades, shelters, obstructions, green spaces, and the existence of left and right positions for pedestrian pathways are considered while evaluating each segment of the route. The next stage was to determine each zone's walkability performance based on the evaluation results. The capability of QGIS software to differentiate the performance of each zone allows for the visualisation of data regarding each zone's walkability by producing a map. The QGIS map's results provide crucial information about which zones have the highest and lowest walkability performance, making it easier to decide what measures should be taken to improve walkability both in that zone and throughout the campus area as a whole. According to this study, Zone 1 had the highest walkability performance with a score of 61%, while Zone 2 had the lowest walkability performance with a score of 43%. Therefore, steps must be taken to enhance walkability among campus residents and maximise the chance that these incredibly difficult transformations toward a more accessible, sustainable, and healthy campus will succeed.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Universities must deal with the mobility of the campus users as part of their sustainable campus plans as institutions throughout the world pledge to providing advantageous living and learning environments for their students and employees.

Since 2000, Universiti Sains Malaysia (USM) has embraced Education for Sustainable Development (ESD) and the "University as a Living Lab" approach through the concepts of Kampus Sejahtera (Healthy Campus) and University in a Garden. In 2015, it has continued its sustainability journey by embedding 17 Sustainable Development Goals (SDG) within its ecosphere. USM seeks to promote sustainability in the community both on and off campus through education and research. In order to achieve the APEX goal, USM has established The Centre for Global Sustainability Studies (CGSS) that will assist the university in mainstreaming sustainability at all levels.

Sustainable Development Goals number 11 is targeting sustainable cities and communities. One way to achieve the target for sustainable cities and communities is to encourage walking. Walkability of the space is important for walking activity because it has connection between the built environment and physical activity. A walkable environment able to encourage people to walk. Safe sidewalks and walkways that lead to a prominent area, such as a playground, school, or retailers, are frequent walkability element in a walking-friendly neighborhood. Previous study suggest that the features has to be within walking distance of each other (Qureshi et al, 2011).

In a university, the community require access to networks of connected, direct, and convenient paths that connect the hostel, faculties, greenways, public transportation stops, as well as other facilities to improve their campus environment, which is based on safety, performance characteristics, pleasure, and learning, campus walkability is an essential element of campus mobility (Makki et al., 2012). Therefore, the major purpose of assessing walkability on a university campus is to encourage healthy living, lower emissions, and increase long-term mobility (Angelidis et al., 2014). Finally, in order to improve walkability for the campus population, pedestrian pathway must able to fulfill the purpose of its services.

1.2 Problem Statement

The rising desire to drive among young people has grown. Students are more inclined to drive rather than walk to their intended location on campus. As a result, in the transition to more sustainable urban futures, reducing private-car ownership, energy consumption, and the transportation sector's overall negative effects on the environment and society is crucial (Baptista et al., 2014).

Following that, numbers of car and motorcycle that registered on the main campus have shown a significant increase. According to Borrego (2018), motorized vehicles contribute to air pollution. Having a large number of cars on campus is not a positive factor. Car ownership is frequently associated with increased mobility, traffic congestion, additional time spent stuck in traffic, enhanced levels of pollution, high transportation costs, reduced mobility and accessibility, as well as significantly reduced campus quality of living (Luke, 2018).

The Sustainable Development Goals (SDGs) are a set of targets for achieving social peace, economic prosperity, and environmental protection. Universities, via education, research, and innovation, play a key role in achieving the goals of sustainable development. As a result, the rising pollution rates on campus as a result of the increased usage of motorized vehicles shows that it does not complement the SDG Agenda for campus. Because the community on campus chooses to travel by car or motorcycle, it is also crucial to measure the feasibility of active modes such as walking. Through its educational and research initiatives, USM hopes to encourage sustainability among both the campus community and the surrounding area. However, there is still less study on the walkability performance in the main campus of USM. Hence, this research is to identify and mapping the walkability performance based on route segments in USM Main Campus.

1.3 Objectives of Study

1. To evaluate the pedestrian pathway in USM Main Campus based on several indicators.
2. To measure the walkability performance in the USM Main Campus.
3. To map the walkability performance in the USM Main Campus according to specific zones.

1.4 Scope of Work

The primary routes of the USM Main Campus are the subject of this study, which encompasses all major roadways without considering the shortest path for walking. These main roads are important because they serve as the main routes for all pedestrians in the campus to travel to academic buildings and facilities. In this study, the pedestrian pathway must only be observed and evaluated during regular weather conditions. This research could not be conducted on rainy days because the evaluation includes shade as one of the main criteria for walkable performance.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

In this chapter, this research is divided into several components for literature review while the findings and results generated by previous researches related to the components are discussed. Besides, some example of case study also being discussed and related to evaluating the walkability performance and mapping method. Components that being discussed in this chapter are walking as sustainable mode, indicators for walkability index, mapping walkability index and active mode in sustainable campus.

2.2 Walking as Sustainable Active Mode

The earliest and most basic method of human transportation is walking. Everybody is a pedestrian, and travelling by foot is frequently the first and last form of transportation. The cheapest, greenest, and most convenient form of transportation is frequently regarded to be walking (Lin and Yang, 2019). Walking also lessens the harmful effects of motorised traffic on the environment in terms of CO2, air pollutants, and noise, according to Taleai and Amiri (2017). Therefore, reducing short trips by car and increasing the number of walking trips is crucial to improving the sustainability of our cities (Pinna and Murrau, 2018). Kamboj and Krishna (2017), added that walking is the most accessible form of exercise and an active means of transportation that aids in the prevention of numerous physical and mental conditions linked to sedentary lives, including obesity, diabetes, and depression. The World Health Organization (WHO) suggests engaging in regular bouts of physical activity lasting around 10 minutes to improve health (WHO, 2010). Therefore, daily walking to regular places can assist in achieving this goal set by the WHO.

Walking is the most significant method of urban transportation, and it creates various benefits in a community, as worries about urban sustainability grow in the future. Walking is also a free activity, and its benefits at the neighborhood level are linked not just to community fairness and increased social capital, but also to personal well-being and the long-term maintenance of excellent mental and physical health (Barton et al., 2015). They also stated that pedestrian access to services and equipment is an important component of urban sustainability, in which the built environment's quality and morphological components play a key role.

Proponents of walking or cycling as active forms of transportation frequently point to health and environmental benefits. While any amount of walking or bicycling is good for your health, the environmental benefits, such as reduced pollution and greenhouse gas emissions, are mostly dependent on how much Active Transport (AT) replaces car trips. (Piatkowski et al., 2015).

According to Blečić et al. (2015), walkability is the capability of the built environment to inspire people to walk. The authors claim that walkability is a composite excellence of urban space generated by the combined effect from several spatial factors related to an organization and performance characteristics of cities, physical configuration of the urban fabric with its block structure and pathway connectivity, existence and range of options intended as possible origin and destinations of trips and the quality of pedestrian accessibility, which is dependent on the level of comfort. The majority of walkability assessment methodologies are based on these built-environment characteristics.

These methods, in fact, pinpoint how and to what extent the urban environment wants to encourage walking and makes urban prospects accessible and usable. The information gathered can be used to inform urban policies and projects aimed at encouraging active living and improving people's well-being. A person's decision to walk is influenced by a variety of spatial and non-spatial elements (Carlson et al. 2015). A walkable environment contributes to people's well-being by makes it much easier to access and use daily urban services, activities, and public space, it encourages people to be self-sufficient, interact, and lead physically active lifestyles. As a result, we view walkability to be an enabling urban state that may effectively support people in expressing their human qualities (Blečić et al., 2020).

From another perspective, according to Cubukcu (2013), a place's long-term viability is determined by a variety of criteria, including safety and accessibility. Walking, as a result, is critical to a place's long-term viability. Walkable places are accessible, and when people stroll, they get to know their neighbors and can quickly spot outsiders in the area. To put it another way, walking aids social surveillance. Walkable neighborhoods, according to the Sustainable Cities Institute, help to reduce greenhouse gas and other emissions by requiring less driving, improve residents' health by providing more opportunities for exercise, reduce crime by facilitating social interaction among residents, and support the local economy by encouraging residents to shop in nearby areas.

Built environments that promote active modes of transportation, such as walking or cycling and public transportation use according to a previous study by Koohsari et al. (2013), are associated with a range of short- and long-term benefits, including increased capacity and reduced congestion in the general transportation network, reduced environmental impacts by lowering greenhouse gas emissions, and improved public health and community wellbeing.

Promoting walking and cycling for transportation is a viable technique for not just addressing urban traffic congestion and pollution, but also for providing significant health advantages associated with increased physical activity (Mueller et al., 2017). According to Babalik-Sutcliffe (2013), this is further backed by the advice to focus urban transportation policy on minimizing automobile journeys and increasing alternate means of transportation such as public transportation, walking, and cycling. Furthermore, because of their good effects on human health, walkability and cycling are recommended (Dyck et al., 2011).

A healthy lifestyle includes physical activities such as walking, jogging, cycling, and swimming. Promoting walking and cycling is vital in cities where people rely on private motor vehicles to get around (Song et al., 2017). Poor air quality, rising temperatures, and climate change are all caused by motorized vehicles (Borrego et al., 2018). Walking and cycling, as well as other forms of sustainable transportation, can help to alleviate these issues (Lee et al., 2016). Walking, according to Cubukcu (2013), is critical to a place's long-term viability and provides substantial advantages to the campus community.

Walking has been linked to a number of other advantages, including improved air quality, reduced traffic congestion, and the reduction of obesity. It also promotes neighborly interactions as well as a healthier and more comfortable style of life in the city. There are numerous arguments for the link between the built environment and walking (Handy et al., 2006). Walkability is the most important component of a sustainable alternative mode of transportation, since it provides societal benefits and contributes to public well-being, environmental prosperity, and climate preservation. A pedestrian-friendly landscape can reduce the usage of automobiles and encourage people to walk (Keat et al., 2016).

According to Williams and Thompson (2013), the findings suggest that encouraging people to walk should be a key strategy to promote sustainable and healthier urban life. Walking is not only a healthy and environmentally friendly means of transportation, but it also enhances mental and physical health. According to Pooley et al. (2013), the difficulty is that many individuals are unaware of the benefits of walking, either as they've never heard of them or because they have never experienced them. Even if individuals realize that walking is healthier for them and the environment, it is insufficient to motivate them to walk.

Walking, being an active means of transportation, is also significant as a sustainable mode of transportation. Walking is influenced by a range of elements, including socioeconomic considerations, the built environment, and others, according to the ecological model (Sallis et al., 2006). Walking is one of the most affordable and convenient forms of transportation. Due to the broad availability of sustainable mobility in metropolitan settings, there is a growing interest in walkability. In metropolitan regions, walking has become an essential mode of transportation for short excursions. As a result, a thorough examination is required to assess the quality of walking environments (Barros et al., 2015).

Walking is the most environmentally friendly mode of transportation. It is the most socially egalitarian, economically viable, and environmentally friendly means of public transit (Ariffin et al., 2021). According to Rafiemanzelat et al. (2017), walkability is the foundation of a sustainable city and a key idea in sustainable urban planning. It's a metric for how walkable a location is.

Furthermore, walkability encourages the key characteristics that make a city more sustainable and livable, as well as a healthy society (Zhoua et al., 2019). Meanwhile, according to Wang and Yang (2019), the streets are linked to low-impact transportation, such as walking, cycling, transit, and green automobiles, contributing to an ecologically friendly, affordable, rapid, and convenient mode of transportation that saves time. Increased pedestrian accessibility and sustainable mobility are critical in tying economic, social, and environmental advantages together for long-term development (Nakamura, 2016).

Walking, which is a form of active transportation, contributes to a more sustainable transportation plan by lowering greenhouse gas emissions. To encourage people to walk, a good walking environment must be created, which is mostly determined by street network and connectivity. Cleaner and greener travel modes, such as public transportation, cycling, and walking, are frequently pushed as a means of minimizing auto dependency and boost the transportation system's sustainability in order to reduce greenhouse gas emissions in the transportation sector (Rifaat et al., 2019).

The degree of accessibility to more sustainable mobility options such as walking and cycling has been found to be reduced in auto-oriented suburban regions (Bertolini et al., 2005). Walking and cycling, according to Tight et al. (2011), can contribute significantly to sustainable transportation goals, with accessibility being the most crucial component. Active transportation, which includes walking and cycling, refers to human-powered modes of transportation (Cole et al., 2010). Active travel is one of the most effective strategies to incorporate physical exercise into everyday routines, which not only promotes public health but also helps to mitigate climate change. Although it is well accepted that walking and cycling are beneficial to one's health, Mccartney et al. (2012) mention that there is a paucity of research on how to encourage active transport.

Constructing a walkable and cyclable city, according to the NSW Government (2004), is an important aspect of creating a sustainable city that is egalitarian, livable, cost-effective, healthy, environmentally sound, and safe. Active transportation, such as walking or cycling, has been highlighted as a high priority project to reduce physical inactivity by the National Public Health Partnership (NPHP and SIGPAH, 2001). To mitigate the negative environmental impact of an increasing trend in private car use, transportation planners have long urged for an increase in the use of sustainable modes of transportation such as walking (Corpuz et al., 2005). Walking is also a cost- effective and environmentally sustainable mode of transportation and exercise. It has a high level of acceptance, especially among sedentary people (Bauman et al., 2002).

According to Choi and Kim (2021), planners, policymakers, and researchers are increasingly interested in promoting public participation with active transportation, particularly walking and cycling, because of its good effects on human and environmental health. Walking and biking are a big aspect of sustainable mobility and an important part of the tourism and leisure experience (Hall and Ram, 2019). The value and attitude of active transportation users have a significant impact on their walking and riding habits (Arroyo et al., 2020). Understanding values and attitudes toward active transportation provides a foundation for promoting walking and biking for personal advantages as well as broader contributions to place-making and sustainability, according to a prior study by Audrey et al. (2015). Importantly, research on active transportation in Asia, such as Bangkok and Manila (Bakker et al., 2018) and smart cities in India, have underlined the importance of encouraging more walking and cycling and reducing automobile dependence for sustainability (Koley, 2020).

Schäfer et al. (2010), on the other hand, have steadily emphasized the need of encouraging people to adopt active transportation options such as cycling and walking. People like to walk for a variety of reasons, including travel-related issues as well as mental, social, and environmental health.

Walking provides numerous advantages over other modes of transportation, including freedom from motorized traffic congestion, the absence of the requirement for parking, the absence of air and noise pollution, low/no monetary cost, and improved mood and stress relief. Local governments are also attempting to boost the share of active transportation modes in order to promote physical activity, improve air quality, reduce accident rates, lift spirits and mood, and reduce the inevitable fatalities (Abbasi et al., 2022). To expand walking and thereby benefit from its potential benefits, it is necessary to identify factors affecting sustainable transportation options. This would lead to more effective planning and policymaking in order to reach the aims and views of encouraging people to walk (Blecic et al., 2020).

2.3 Indicators for Walkability Index

2.3.1 Connectivity

The significance of pedestrian connectivity and accessibility cannot be emphasized (Rotmeyer, 2006). According to Kumar (2014), connectedness refers to the ease with which people can travel from one site to another, and it is an important consideration when planning pedestrian routes. Connectivity is a need for pedestrian activity since it is a measure of the built environment's relatedness (Peponis et al., 2008). It suggests that a more connected constructed environment is more conducive to walking, regardless of other neighborhood characteristics (Berrigan et al., 2010). Networked connectedness, according to Rotmeyer (2006), acts as a public space that links the built environment while simultaneously protecting people from automobile pollution and dispersing ground layer density.

The ability to form and monitor links between two location in the spatial structure is one of the most essential aspects of complex networks (Bafna, 2003). Street connectivity, according to Jabbari et al. (2021) is defined as the directness and accessibility of alternate paths linking locations that can attract or dissuade pedestrian traffic. Streets connectedness seems to be one of the most important planning processes that affects the economy, environment, and culture of a city (Gorsevski et al., 2012). Because it investigates how a city's street placements are connected, street connectedness was chosen (Azmi and Ahmad, 2015). The number of intersecting streets per land-area unit is characterized as street connectedness, which is defined as the directness and availability of other routes (Talavera-Garcia and Soria-Lara, 2015). There are more viable walking routes when there are more traffic intersections (Azmi and Ahmad, 2015). Denser connectedness, according to Jabbari et al. (2021) provides more walking options and has a positive impact on walking, and streets with more links obtained higher rankings than those with fewer connections.

People were encouraged to walk since it was tied to street connectivity (Koohsari et al., 2017). A society's walkability is boosted by the existence of walkways and pedestrian crossings connecting them, in addition to having a diversity of walking destinations. It's also important to be able to go somewhere quickly and efficiently. This characteristic is referred to as connectivity. Good connection is obtained when many crossings and shorter block lengths combine to create an accessible and navigable neighborhood (Southworth, 2005). Two methods for assessing connectivity are the number of intersections per square mile and the ratio of the direct route between two sites to the actual distance traversed (Handy et al, 2002).

2.3.2 Sidewalk Slope

In stated or revealed preference surveys, a number of researchers have sought to link objectively assessed physical environment features to participants' claimed inclination to walk (Rodriguez et al., 2014). The latter found a substantial negative association between increased walking time and the likelihood of walking or cycling due to the slope of the local terrain. The number of climbed steps and road crossings, according to Olszewski and Wibowo (2005), were the most relevant characteristics contributing to an equivalent walking distance that was proposed to characterize the access to metro stations in Singapore. Slopes were measured in terms of the equal number of climbed steps in their research.

Sun et al. (2015) discovered a considerable disparity between pedestrians' perceptions of the existence and steepness of slopes on the one hand, and objective slope measurements on the other, using a different approach. Finally, according to Broach and

Dill (2015), severe upslopes of 10% are seen as twice as expensive as travel with less steep territory. Depending on the individual, walking on a level surface may be more pleasant than walking down a negative slope, despite the latter's theoretical energy benefit. Furthermore, travelling downhill ceases to be energetically favorable beyond a certain point, because increasing one's speed would result in an instable stride (Hunter et al., 2010). The attractiveness of walking is significantly reduced by steep slopes (Meeder et al., 2017).

According to Rakha and Reinhart (2012), the workflow's present design rationale will support any scheme used to evaluate the walkability of created neighborhoods. Because the subdivisions are focused on minimum slope, the streets formed will have the lowest slopes, resulting in less effort when walking. In this context, it is discovered that the steepness of sidewalks is the only factor that influences transportation walking (Bahrainy et al., 2015).

2.3.3 Suitability for Wheelchairs

Those who use wheelchairs commonly go across paths with obstructions such like bumps or curb descents or terrain that is exceedingly rough. Surface features such as roughness could have an impact on comfort and variables associated with bodily harm. Considering these relationships can assist guarantee that all public and private pathways are safe and comfortable to use. The walking zone, according to Boodlal (2003), should not be less than 1.2m wide, which is the minimum width required for disabled persons, those using a guide dog, crutches, walkers, and wheelchair users, who require around 1.5m to turn about and 1.8m to pass other wheelchairs. However, vegetation causes fractures in the sidewalk and changes in level, making it difficult for those with disabilities to elevate their feet, crutches, or wheelchairs. Furthermore, wheelchair users find it difficult to roll over substantial elevation changes.

Low-hanging branches are also a safety issue, particularly for pedestrians with vision problems who may not notice them and others with mobility disabilities who may have difficulty bending under them. The installation of manholes for maintenance purposes is a common characteristic of sidewalks built atop drainage. If and when walkers drop their keys and hand phones over the grating into the manholes, these manholes become a problem in and of themselves, while manholes that are not adequately covered or maintained constitute a threat to pedestrians with walking assistance or in wheelchairs. Sidewalk pavements constructed of concrete, tarmac, or other materials should be slip-resistant and aesthetically contrasted. People who use wheelchairs or walking assistance find it particularly challenging to navigate surfaces that are not slip resistant (Keat et al., 2016).

2.3.4 Surface Degradation

Any walkway, sidewalk, or way set aside and utilized exclusively by pedestrians is referred to as a pedestrian path. Grinding, crack filling, and patching of sidewalk slabs or route segments are among the infrastructure maintenance demands. In many circumstances, replacing sidewalks or resurfacing paths is the only option. Maintenance is required when surface conditions deteriorate to the extent where tripping risks exist or when worsening running or cross slope conditions make routes unavailable.

According to a study by Zumelzu et al. (2020), pedestrian accessibility declines in regions with increased housing density, particularly in blocks in the Monteverde neighborhood’s interior streets, which have a low presence of green areas, poor sidewalk quality, street fronts, and no entrance garden. According to the People According to research, individuals prefer to shop in safer areas, which are connected with spaces of higher spatial quality.

They claim that walkability is a composite excellence of urban space generated by the conjunction with several feature related to an organization and features of cities, physical configuration of the urban fabric with its block structure and pathway connectivity, existence and range of activities intended as possible origin and destinations of trips, and the efficiency of pedestrian ease of access, which is dependent on the level of comfort. The majority of walkability assessment methodologies are based on these built-environment characteristics (Blecic et al., 2015). According to Forsyth (2015), the existence and width of sidewalks, as well as the distance to travel, influence people's willingness to walk. It also matters if a pathway is pleasant and attractive to walk, if it is comfortable, and if it is viewed as safe and inclusive.

Vegetation, on the other hand, causes sidewalk fractures and changes in level, making it difficult for those with disabilities to raise their feet or crutches (Keat et al., 2016). In their study, Alemgena et al. (2018) noted that sidewalks are important in transportation since they provide a safe route for people to walk alongside that is segregated from motorized traffic. It's a representation of the path's surface quality. Among the identified safety factors, the pedestrian walkways surroundings, crossing opportunity, support facility, personal protection, obstacles, surface quality, and sidewalk width are the most affecting factors that need to be considered for improvements to make each segment of the city a more pedestrian-friendlier environment. Because the reason for not preferring the sidewalk implies that street vendors, sidewalk irregularity, and surface quality are compromising pedestrian safety.

Surfaces having numerous cracks, bumps, holes, or plants growing in the surface or between the cracks perform poorly. Bicyclists, in-line skaters, and wheelchair users would find it difficult or impossible to move along the portion if the path or trail surface was in bad condition. If the surface is uneven and there are numerous or severe holes and irregularities in the surface, grade the surface condition as extremely poor for dirt or gravel segments. Surfaces with few or no bumps, cracks, holes, or plants growing in the surface or between the cracks are thought to perform better. A brand-new surface would be considered exceptional. If the surface is dirt or gravel, it must be uniform and compact, with no imperfections or holes, in order to be rated as excellent (Christian et al., 2010).

2.3.5 Street Furnitures

The phrase street furniture refers to a variety of objects and pieces of equipment that are placed along streets and highways for a variety of functions. Benches, traffic barriers, bollards, post boxes, phone boxes, streetlamps, traffic signals, traffic signs, bus stops, tram stops, taxi stands, public bathrooms, fountains, watering troughs, memorials, public sculptures, and waste receptacles are among the items included. Aesthetics, visual identity, function, pedestrian mobility, and road safety should all be considered while designing and placing furniture. Walkability has been linked to people's behavior patterns, and street furniture provides convenience in residential everyday life.

According to Azmi et al. (2013), street lighting, street crossing signals, safety during night walks, traffic volume and speeds along nearby streets, presence of trees and awnings, attractiveness of environment/building articulation, cleanness, and street furniture for resting are all factors that positively influence walking from the perspectives of safety, convenience, and attractiveness.

The proportion of windows on the street and active street frontage, and the quantity of pieces of street furniture are all important streetscape aspects. All types of signage, benches, parking meters, trash cans, newspaper boxes, bollards, streetlights, and other items that fall into this category are considered street furniture (Ewing et al., 2016). In a comprehensive review, Cauwenberg et al. (2018) found that leisure time walking is associated with walkability and visually pleasant landscape. Greenery and street furniture are two aspects that can add to aesthetically pleasant surroundings.

Walking facilities, such as the availability of sidewalks, sidewalk condition, and benches, were also often indicated as a factor related with walking, according to Yun (2019). Visual interest, visibility of landmarks along the pathways, vistas of public gardens, street design, transparency of fronting structures, apparent activity, street trees, and illumination were all shown to be connected to path context. (Southworth, 2005).

2.3.6 Shades

Shades are crucial because they protect pedestrians from direct sunshine, allowing them to walk more comfortably. Walking in the shade is more pleasant, especially on hot and humid days (Kasim et al., 2018). The availability of shade and visual aesthetics offered by vegetation such as trees and bushes, which can also act as an aural buffer separating pedestrians and traffic, can also improve the pedestrian walking experience (Keat et al., 2016). Shade as a comfort component of walking, according to Vasilikou and Nikolopoulou (2020), validates the findings of previous studies on the importance of climatic and thermal comfort in regard to pedestrian mobility in an urban setting. This conclusion is supported by the city's hot climate, which emphasizes the need of thermal and climatic comfort in public spaces.

2.3.7 Shelters

A shelter is a tiny structure or covered area designed to protect people from the elements or danger. Although the primary aim of a bus shelter is to protect passengers from the elements such as wind and rain, extra effort such as better designs and beautiful colors can improve the entire experience of passengers waiting for the bus. Intramodality and sustainable mobility can be aided by bus stop shelters (Galanis and Eliou, 2011).

2.3.8 Obstruction

Obstructions are anything that stops a road, passage, entry, or other path so that nothing may travel through it, as well as the act of blocking something in this way. Block, hamper, and impede are some popular synonyms for obstruct. All of these words refer to interfering with someone's activity or progress. Obstruction refers to intentionally or unintentionally placing hurdles in the way of something in motion or progress.

Pedestrian mobility is hampered by obstructions, which lower the effective walkway width. As a result, determining the access available to pedestrians requires assessing barriers. Parking lots and unlawful building materials in a residential area pose a threat to pedestrians on a sidewalk, and neighboring authorities should consider maintaining and taking legal action to ensure user safety (Alemgena et al., 2018). According to a previous study by Saelens et al. (2003), expanding walking as an active form of transportation requires street connectivity, path continuity, low impediments for walking movement, and no need to cross major roadways.

2.3.9 Green Spaces

Green space is land that is covered in grass, trees, shrubs, or other plants to some extent. Parks, community gardens, and cemeteries are examples of green space. Open areas where grass, trees, water sources, bushes, or other types of vegetation are partially or totally covered with grass, trees, water sources, shrubs, or other sorts of vegetation are known as public and green spaces. Green spaces in cities help to lessen the effects of pollution and the urban heat island effect, which refers to heat trapped in densely populated areas. As a result of human activity, the urban heat island effect arises in towns and cities.

According to Matsuoka (2010), students require a restorative and stress- relieving environment on their campuses, which can be provided by greening and natural components. According to current research, a campus environment rich in trees and nature can help to integrate the campus community and, as a result, boost students' academic performance. A high-quality green environment can help encourage students to stroll more on campus.

Greenery and street furniture are two aspects that can add to aesthetically pleasant surroundings. Green spaces are connected to higher walkability scores, according to a study by Jabbari et al. (2018). They also indicated that green areas provide more appealing walking settings and have a good impact on pedestrian microclimatic conditions. Kenworthy and Newman (1999) went on to say that the amount of energy a city uses, the air quality, urban sprawl, and green open space could all be important markers of a city's sustainability.

2.3.10 Existence of Left and Right Position of Pedestrian Pathway

A well-planned road network, according to Southworth (2005), has roadways that are well connected to other modes of transportation. The streets also provide a diverse range of facilities and spaces, as well as a proper quality of paths, adequate walking distance, and clear signage.

Walking as an active mode of transportation benefits from a transportation system that includes features such as efficiency of pedestrian crosswalk, availability of sidewalk, sidewalk width, sidewalk continuity, well-connected street network, street density, and topography (Kamruzzaman et al., 2014). Increased number of alternate routes and a well-connected street network both contribute to closer proximity of destinations and more efficient travel patterns (Oakes et al., 2007). Ford (2013) emphasized that, in addition to having many destinations, a walkable community requires instant access to those places. Sidewalks, or pedestrian roadways, direct people where to go and make it easier to get from one place to another.

2.4 Mapping Walkability Index

The Geographic Information System (GIS) has been widely utilized to analyze pedestrian surroundings and record the levels of walkability of route segments. Leslie et al. (2007) stated that GIS can be utilized to construct a walkability index and that certain walkability variables can be easily calculated in a GIS context. Shumi et al. (2015) used GPS-enabled devices to conduct walking interviews and create a geo-referenced scoring system to measure the perceived walkability of various routes by female pedestrians in Dhaka, Bangladesh. GIS software was used to map the objective levels of walkability, and the scores were divided into three categories: high, medium, and poor walkability.

The method was developed utilizing a GIS environment to produce thematic maps that are simply understandable and have an instant impact, based on a prior study by D'Orso and Migliore (2020). This strategy has the advantage of assisting policymakers in identifying places where walkability has to be addressed as well as identifying the most significant situations that impede pedestrian accessibility. Furthermore, it is feasible to predict how the quality index will evolve if possible interventions in a pedestrian network are implemented. In fact, the database can be updated each time a quality-improvement or -decreasing intervention is carried out.

The participant mapping exercise used in this study is part of a long line of research that has used cognitive maps to investigate residents' conceptions of the built environment (Vertesi, 2008), how conceptions differ among individuals and groups (Claudia et al., 2012), and how conceptions change over time (Vertesi, 2008). Place-based qualities, particularly perceived walkability, are more important to this inquiry than how people choose to depict space. As a result, participants were given a labelled base map to offer spatial orientation and assure a greater level of consistency than would have been predicted from freeform hand-drawn maps (Vajjhala, 2005). This method has the advantage of gathering and transmitting inhabitants' impressions of walkability in a fashion that can be easily aggregated and analyzed with the help of a GIS.

The spatially referenced and attribute data were joined and analyzed using ArcGIS 10.4 (ESRI 2016). A preliminary visual examination of walkability was carried out by mapping Walk Score and perceptions of walkability separately, then together. The point density function within ArcGIS was used to highlight the most walkable locations within Omaha according to survey respondents. Finally, maps were developed as appropriate to highlight differences in the perceptions of walkability among different cohorts of respondents. A simple point density analysis was performed to identify clusters of walkability points. Clusters of high walkability were defined as those locations with five or more walkability points per km^2.

The goal of spatial MCDA is to map citizens' values in space. It is an experimental phase that combines the walkability evaluation CAWS approach (Blecic et al., 2015), GIS tools, and the results of citizens' value analysis to synthesize citizens' values in space. This phase creates a series of choice maps that depict distinct groups of citizens' freedoms to choose whether to walk in the city. Finally, in a spatial decision problem, MCDA and GIS services are employed to create decision maps that depict the driving values of citizens walking through the city (Fancello et al., 2020). In terms of operation, the

CAWS model considers three elements of the built environment: the number and variety of destinations, the distance between destinations, and the quality of pedestrian accessibility, all of which are combined to produce a final walkability score (WS) for each point in space. The WS that results express a person's ability to walk to a set of important urban destinations for daily life from a specific point in space, and the elaborated walkability maps provide an analytic representation of the spatial distribution of the population's pedestrian mobility capital, providing valuable information for policy interventions and spatial improvements (Fancello et al., 2020).

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As a result, a series of decision maps highlighting the walkability of the 11 citizen clusters were created. The decision maps for clusters 3 and 9 are shown in Figure 2.1. Three maps were created for each cluster, one for retail and commerce, one for services, and one for green and recreational areas (Fancello et al., 2020).