

Smart pedestrian network is an approach for promoting walkability: A case of Riyadh city

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ABSTRACT

SPN is an important aspect of smart and sustainable mobility in cities that promote walkability (SPN) walking is becoming an important component of transportation and urban policies to achieve more sustainable development. Riyadh's rapid urban expansion and population growth have increased pedestrian accidents and damaged people's daily walking conditions during the last four decades. As a result, implementing the Smart Pedestrian Network has the potential to significantly increase walkability and create more sustainable urban spaces. The research technique is deductive, with modern technology playing a significant part in introducing new ways to pedestrian path planning and design, ultimately improving this form of transportation in Riyadh. The current paper concluded with proposed guidelines for strategic implementation using the Smart Pedestrian Network system and a conceptual framework for smart pedestrian networks, both of which could add value to exploring the pedestrian network in more advanced ways in Riyadh. The application of a smart network for pedestrians resulted in increased walkability and satisfaction with walking in Riyadh city, according to the findings

Keywords: Walkability, Smart mobility, Information and Communication Technology, Smart Pedestrian Network, Saudi Arabia, Riyadh City.

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1. Introduction

Cities will host more than 56% of the global population by 2030, indicating that the global urban population is continually increasing [1]. This pattern shows that residents in these areas are experiencing difficulties with their living conditions [2]. The use of urban streets as an element of urban life is jeopardized today, particularly in rising nations such as Saudi Arabia, due to the rapid rise in automobile ownership, population expansion, ineffective transit systems, poor quality urban architecture, and other challenges [3]. Cities have been built for decades to accommodate automobile traffic, ignoring basic human requirements for physical movement and the detrimental environmental repercussions of motorized traffic. For example, Riyadh has an average of 274 autos per 1000 residents and undertakes approximately 7.4 million car journeys each day, thus relying on walking for transportation has never been an issue [4]. The perception of Riyadh's streets being automobile thoroughfares has exacerbated the situation. The main reason people do not walk is that most streets do not have adequate sidewalks and crosswalks [5].

There are various potential to efficiently drive urban growth toward sustainability in an era of digitalization, artificial intelligence, the Internet of Things, and Big Data. Big Data solutions lay the framework for new organizational linkages, enabling for the creation of a varied range of creative products and services that suit people's demands while also considering the environment [6]. A smart city's goal is to foster people-centered and long-term development. Technology is critical to the transition of modern society. Smart cities are rapidly evolving to meet the needs of civilians by utilizing various intelligent technologies [7]. ICTs (information and communication technologies) are a driving force in smart cities, speeding up social progress toward digital urbanism [8]. ICT-enabled applications are being developed to improve the efficiency with which various urban

services are delivered [9]. Smarter cities can be built in existing or newly constructed cities thanks to advances in information and communication technology [10].

The goal of the Smart Pedestrian Network is to encourage long-term mobility. Its goal is to reach out to a variety of market segments by giving information on appropriate walking routes that will meet the needs of potential users as well as the demands of various stakeholders.[6]. To ensure the successful development of innovative products, the Smart Pedestrian Network (SPN) System must be implemented using a variety of data sources [11].

The term "walkability" refers to how people perceive the street as a place to walk [12]. One of the major factors influencing the decline of walking is the transformation of cities'-built environments. The spread of cities causes increased urban sprawl, which leads to increased vehicle use, which increases car travel and vehicle transportation [13]. Walking is an important mode of active transportation for a healthy and livable community. Walking, on the other hand, is a healthful type of physical activity as well as an environmentally beneficial way of transportation [14]. When individuals feel in control of the streets they walk on, walkability grows enormously. When no one appears to be in charge of the streets, however, they fail [15]. Francis (1987), The importance of street vibrancy and walkability in influencing urban life on and around the street cannot be overstated. It aids in identifying the most active places in a town, and residents want to dwell near major public thoroughfares [16].

Walkability is becoming increasingly valuable for a variety of reasons. In addition to reducing pedestrian accidents and pollution caused by automobiles, pedestrian transportation has social and recreational benefits [17]. The most obvious benefit of walkability in a neighborhood is the health benefits of exercise for people. A walkable neighborhood can provide a safe environment. The most significant safety benefit of walkability is that it increases the number of pedestrians, causing cars to be more aware of pedestrians than they were previously (sidewalks and crosswalks). It makes the environment safer for adults, especially children, by reducing the number of pedestrian injuries caused by slow-moving automobile [18].

Context-based design solutions that assist the creation of more livable areas or are compatible with attaining sustainable development goals are increasingly being charged with urban designers and planners.[19] Diversity, path context, comfort, interest, architectural and urban design, the feeling of place, scale, protection, and other design ideals have all been prioritized by urban designers and planners [13].

A solid understanding of how to apply the context-based approach to the construction of entire streets in a specific area is required for the creation of a practical, functional street. Once the context of a region is understood, the role of each street can be established, and design parameters selected to achieve a balance between land use and street design [19]. The relationship between land use and street design affects the character of the street. The overall dimensions and design treatments of the buildings, as well as the roadway, display character not only in the driving lanes, but also in the overall proportions and design treatments [20]. In the area between a building's edge, a street tree, or a parked automobile, a character can be found. The position and quality of street components have an impact on this aspect of the character. In addition, the surface qualities of the character can be used to characterize it (Ibid).

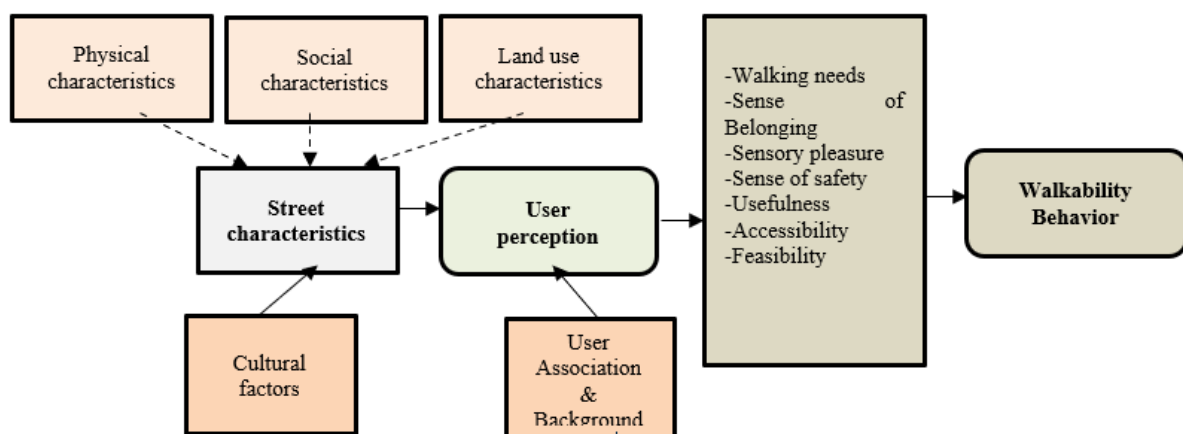


Figure 1. Conceptual framework of walking needs on the main street [12]

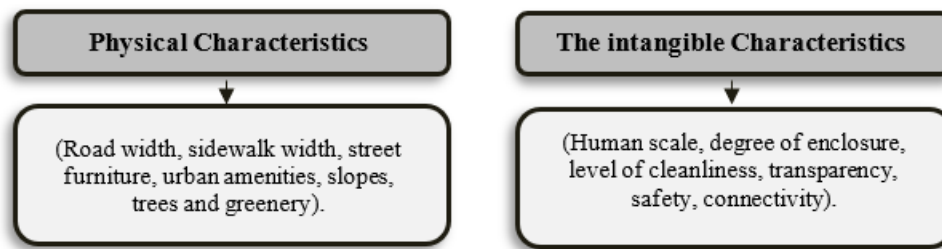


Figure 2. The qualities of urban design for pedestrian network (Author, 2022)

A walkable city will have a well-developed pedestrian network, easy access to public transportation, building connections, pedestrian priority, and a human-scale focus. In recent years, some academics have focused on the topic of increased walking and walkability in urban settings.

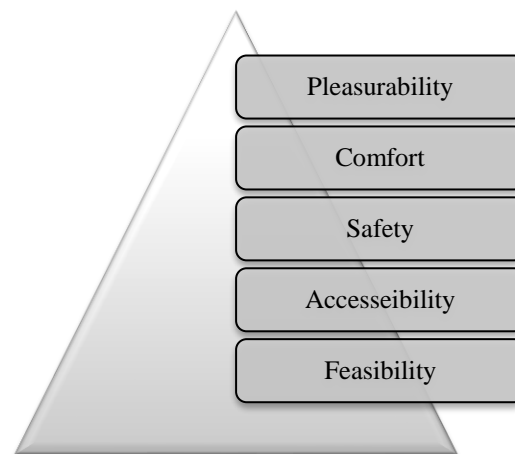


Figure 3. The concept of a hierarchy of walking needs [21]

Over the last decade, the term "smart mobility" has become somewhat of a buzzword in the planning and transportation fields. After a passionate initial phase in which information technology and digital data were seen as the solution to improving mobility efficiency, appeal, and trip quality, a new phase has emerged.[22] To effectively improve urban sustainability, new technologies must be integrated into citizens' habits. Such considerations are especially important in the context of smart mobility, where social dynamics have a significant impact on how ICTs used in transportation are used. ITS (Intelligent Transportation Systems) reduce pollution and congestion, increase safety, and improve demand management and public transportation promotion. Improved walkability is one of these new goals in smart mobility development [10]. As previously stated, the majority of Intelligent Transportation Systems (ITS) applications encourage motorized traffic flow, so pedestrian mobility is largely ignored. A research thread is dedicated to gathering data on pedestrian mobility [6].

2. Information and Communication Technology (ICT) for a walkable city

Currently, available technologies are advancing at breakneck speed. Electronic sensor systems are abundant in urban environments; these technologies can be used to create efficient smart pedestrian mobility systems that encourage walking, reduce GHG emissions, and improve citizens' quality of life [23]. As technology advances, citizens have become more involved, and cities have become more responsive in recognizing demands and providing solutions and services. Despite the importance of technology in smart cities, not all services are technologically based [24] ICT-enhanced solutions have the potential to improve city operations. However, it includes a debate originating in (human) geography that, while investigating exclusionary spaces in urban environments [9], ICT can encourage and empower people to walk by removing immaterial barriers like a lack of knowledge or boring public transportation, as well as by providing data to decision-makers to better understand how and where people travel. Combining these two elements into a revolutionary technique has the potential to significantly improve urban accessibility, attractiveness, safety, comfort, and security [23].

2.1. Smart pedestrian network applications & functions

The Smart Pedestrian Network has enormous potential for increasing walkability and, as a result, for creating more sustainable and livable urban environments [25]. Using the User Interface functions, the Smart Pedestrian Network applications system collects pedestrian preferences [26]. Following the potential user's submission of information, the SPN applications will respond based on the user's profile. Pedestrians can download, save, and track their local routes using the SPN system. Following that, the user's location is identified, and the best routes, as well as media data including metrics, statistics, images, video, and recommendations, are provided [6].



Figure 4. Pedestrian network model in an urban area [27]

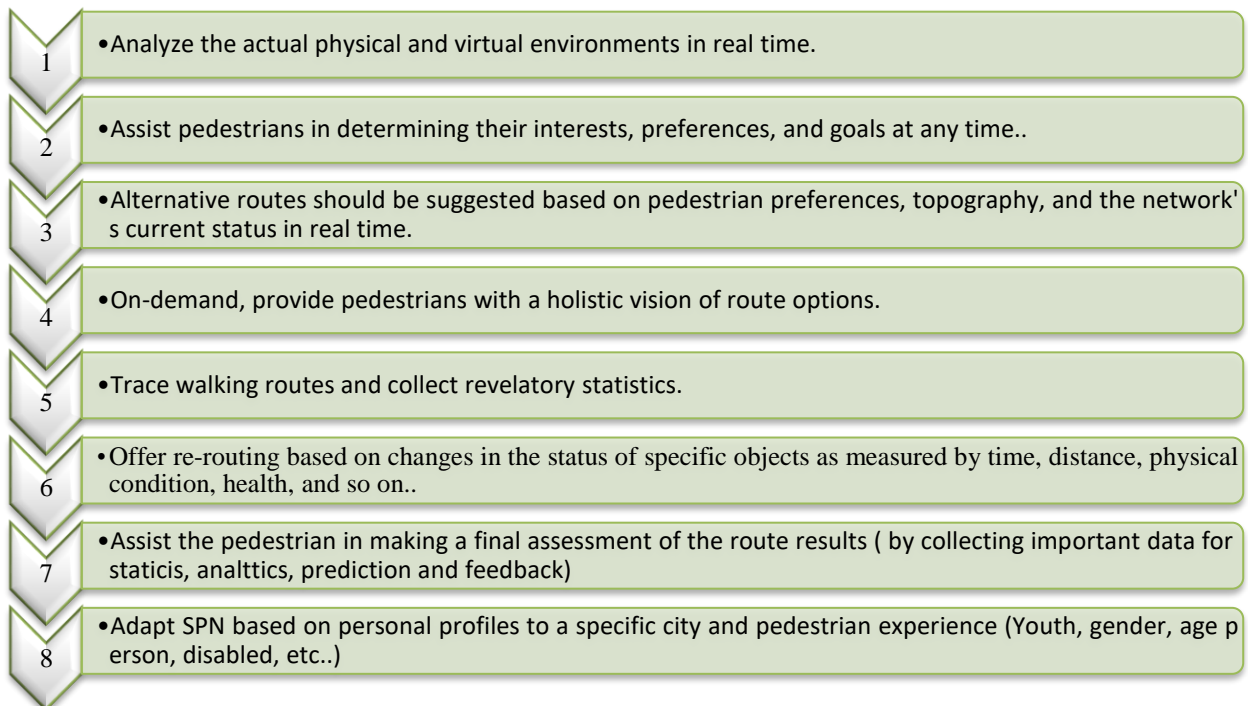


Figure 5. Main objectives of the SPN Application System [28]

2.2. Smart pedestrian network conceptual model for improving walkability

The section that follows provides an overview of the most important currently available technologies to consider when creating an innovative pedestrian network.

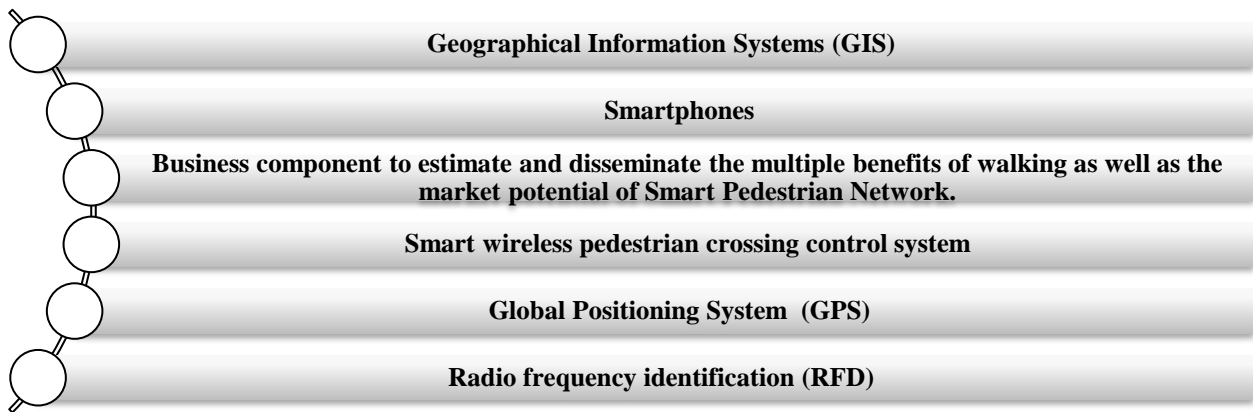


Figure 6. Smart pedestrian network: An integrated conceptual model for improving walkability, source: (Author, 2022).

2.3. Urban planning component supported in a Geographical Information Systems (GIS)

The use of Geographical Information Systems is required for the development of any smart pedestrian mobility system (GIS). GIS data can be obtained from a variety of sources, including commercial, free, private, and public [23]. Crowdsourcing can also be used to collect GIS data, allowing pedestrians to actively highlight issue areas in a transportation network. Furthermore, employing big data machine learning, social media can be a rich source of information that can be transformed into useful data. The GIS engine can incorporate OpenStreetMap and other publically available resources [29].

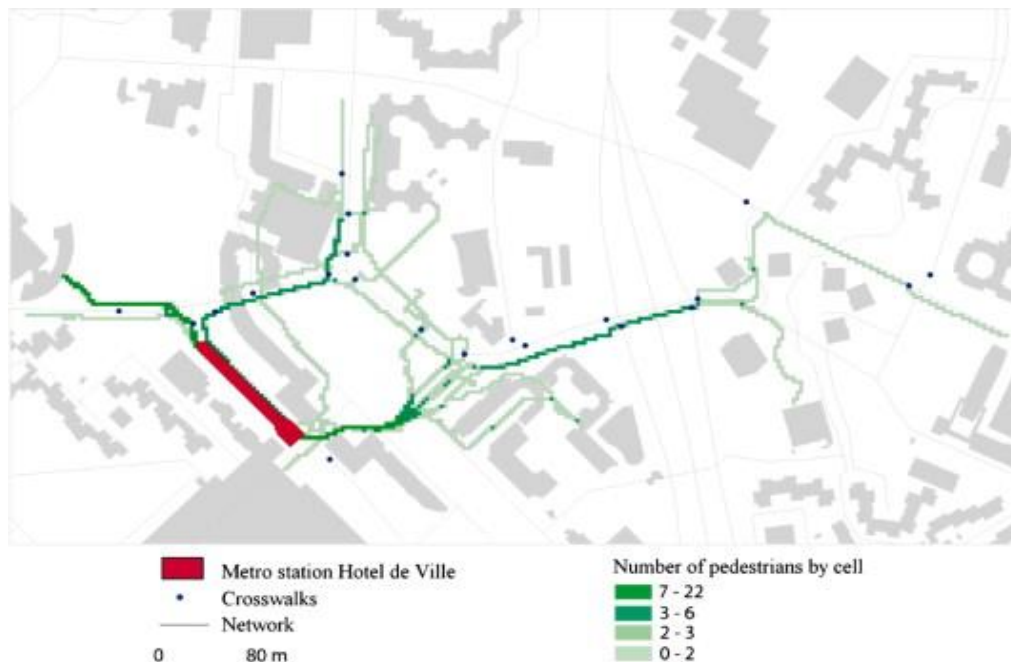


Figure 7. A GIS-based methodology for identifying pedestrians' crossing patterns, source: (<https://www.sciencedirect.com/science/article/pii/S0198971511001281>)

In the urban planning component, a GIS-based multi-criteria model is used to analyze pedestrian conditions and promote the adoption of planning strategies. Urban planning provides a Roadmap for a Smart Pedestrian Network. The goal of SPN in urban planning is to provide a tool for assessing pedestrian conditions, identifying regions that are more or less walkable, and, as a result, providing urban and transportation guidelines for improving walkability and sustainable mobility. The suggested tool is based on a multi-criteria GIS-based model that incorporates supply and demand-based walking basics.[30] (Figure (8) below shows the structure of the GIS model.

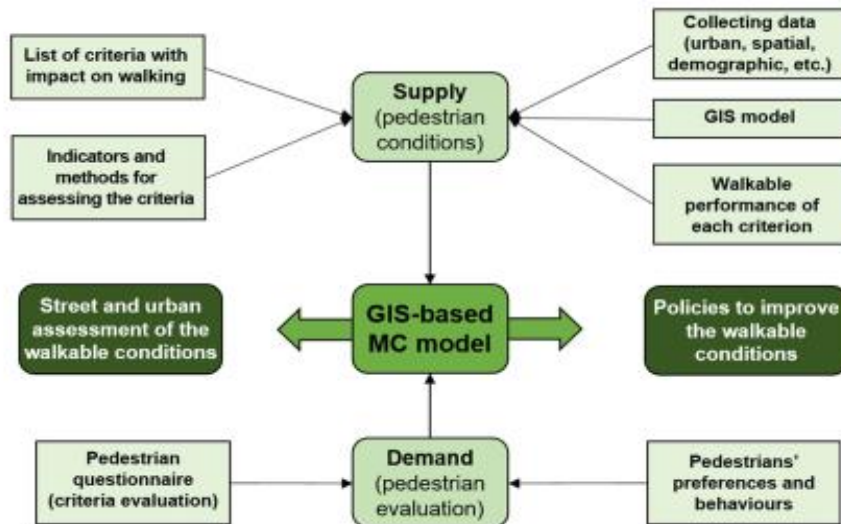


Figure 8. Structure of the GIS-based multicriteria model [30]

The pedestrian navigation smartphone app displays alternative routes based on the pedestrian's preferences and needs. A smartphone application is also being used to inform residents about appropriate walking routes and to provide feedback to municipal authorities via crowd-sourcing [6].

A business component to estimate and disseminate the numerous advantages of walking as well as the market potential of SPN. The business component evaluates and disseminates the numerous benefits of walking, as well as the market potential of SPN. SPN has the potential to improve walkability and, as a result, generate more sustainable and livable urban settings by fostering an innovative linkage of these three components [30].

2.4. Smart wireless pedestrian crossing control system

- *A passive method based on the Wi-Fi network.* A passive method based on the Wi-Fi network is used to estimate the number of pedestrians in a traffic scenario posed by signal intersections in urban areas, as well as the exact location where the stationary pedestrians are waiting to cross, by distinguishing between pedestrians who wait at the pedestrian crossing and pedestrians who walk. The pedestrian operator can then be linked into intelligent control management systems that optimize traffic in real time [31].

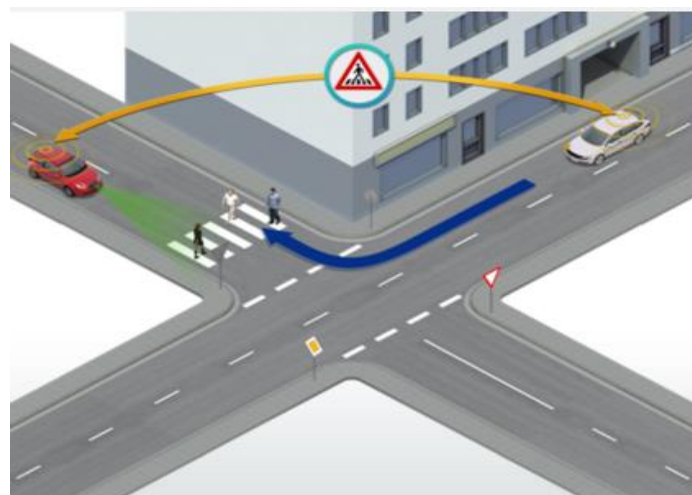


Figure 9. Using SPN Wi-fi network in Urban space, source: (<https://www.car-2-car.org/about-c-its/>)

- *Mobile Mapping System (MMS).* The technique's four key processing units are accessibility to the crossing location, the presence of traffic signs and lights, and visibility of motorists and pedestrians near the pedestrian crossing. The research findings are transferred to a Geographic Information System

(GIS), where they are theorized and handled in the context of city administration. However, each unit creates a significant number of parameters that may be exported to GIS for visualization, and the weighting of these parameters has been done according to traffic authority norms, allowing the computation of a pedestrian crossing safety index [31].

- *PLS (pedestrian lighting system)* and its ideal size for pedestrian crossing the suggested system uses energy-saving LED lights and directs the luminous flux towards the pedestrian crossing area in the driver's direction of travel to alert him of the presence of a dangerous region, as well as changing the movement speed to prevent any risk. The suggested system consists of creating and implementing a multi-signal Smart Traffic Signal Control (STSC) system for Smart City applications based on the controller of the roadside unit to improve public transit efficiency and reduce traffic congestion (RSU) [31]

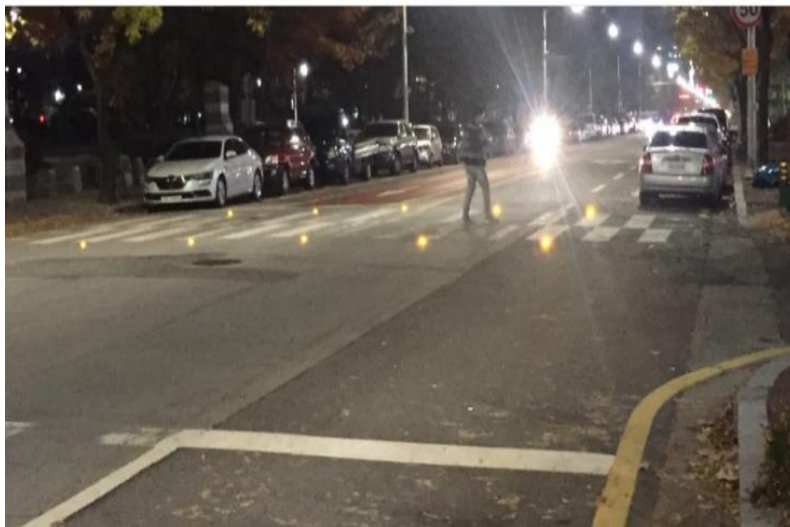


Figure 10. The crosswalk features warning LEDs embedded in the road, source: (<https://newatlas.com/crosswalk-warning-system/58667/>)

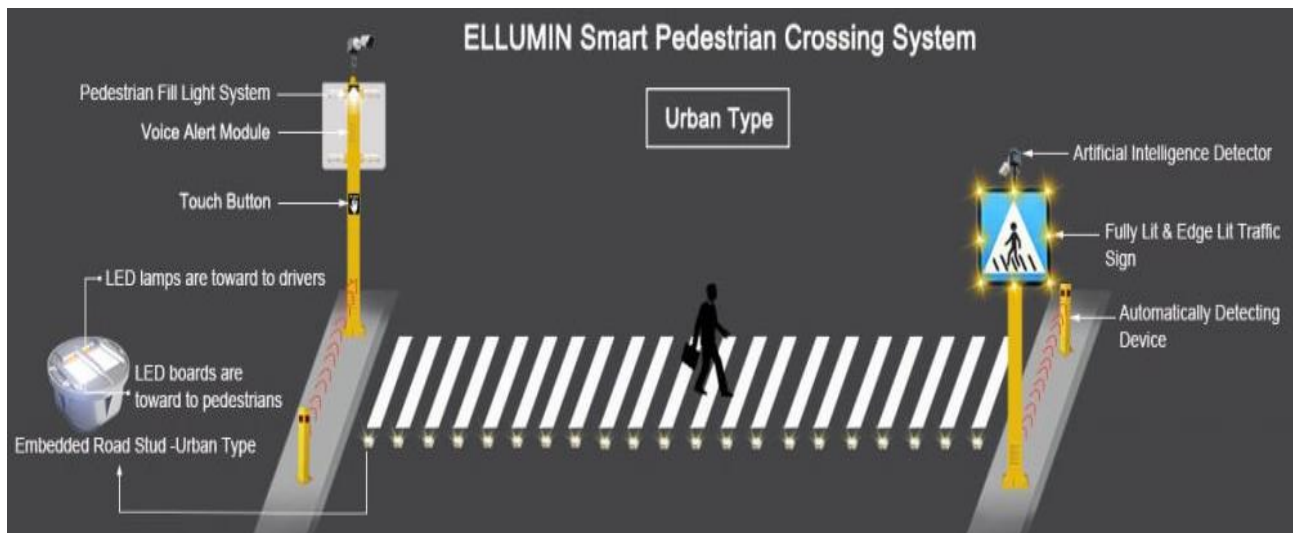


Figure 11. Illumine smart pedestrian crossing cross, source: (<https://www.ellumin.com/project/non-light-control-area-intelligent-pedestrian-system%EF%BC%88urban-type%EF%BC%89/>)

2.5. Global positioning system (GPS)

Pedestrians can be given information on traffic signs obtained from the Internet. RFID tags can be used to track pedestrian flows, density, mobility, and speed. Before RFID adoption, any privacy concerns should be addressed. (Ibid) [23].

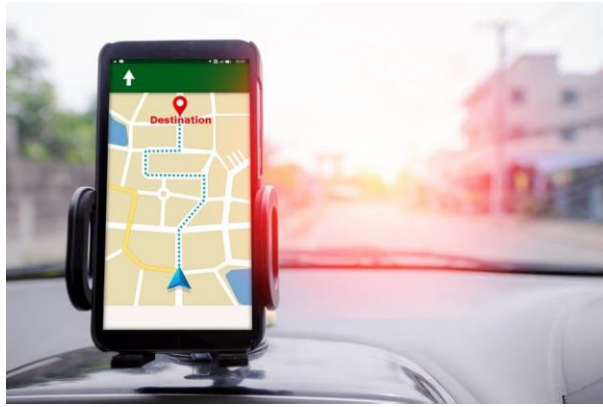


Figure 12. GPS Navigation, source: (<https://thexplorion.com/gps/>).

2.6. Radiofrequency identification (RFID)

Identification by radiofrequency RFID (radio frequency identification) is an intriguing communication technology that can help with navigation (RFID). RFID technology has the potential to provide infrastructure for pedestrian communication [23]. Information on traffic signs can be accessed from the Internet and given to pedestrians. Pedestrian flows, density, mobility, and speed can all be monitored using RFID tags. Any privacy problems should be resolved before RFID adoption. (Ibid).

3. Saudi Arabia as a case study

With a population of over 31 million people and a land area of more than 2.15 million km², the Kingdom of Saudi Arabia is the largest country in the Arabian Peninsula [32]. Saudi Arabia is a major Islamic country. The presence of holy places draws the majority of visitors to Saudi Arabia. People in Saudi Arabia engage in activities such as shopping, education, jogging, business, and so on. There is an increase in the pedestrian environment at this time. The risk of pedestrian accidents has increased significantly as the pedestrian environment has grown [33].

Cities in Saudi Arabia have risen greatly in size and population since the early 1970s, owing to rising economic growth and wealth [34]. Air and water pollution, frequent flooding, rising land surface temperatures, a shortage of affordable housing, and increased energy demand are all environmental, social, and economic consequences of such metropolitan growth [35]. It also increases the total number of vehicles in each city, which has an impact on transportation systems and road networks by increasing pedestrian accidents, resulting in more frequent accidental injuries and deaths, increasing average trip times, and reducing available parking spaces in commercial and residential areas [36].

Riyadh is the capital city of Saudi Arabia. In the last 50 years, Riyadh City has grown from a walled hamlet to a metropolis of approximately six million people [37]. Because Riyadh has never had a successful public transportation system, the Master Plan prioritized the private automobile as the city's principal source of transit [38].

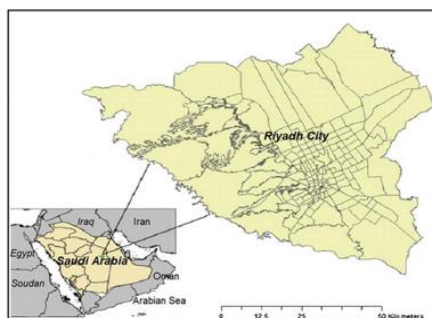


Figure 13. Riyadh city, Saudi Arabia, source: (<https://www.tandfonline.com/doi/full/10.1080/21650020.2018.1463867>)

Although walking is a significant means of transportation and necessary human activity, Riyadh politicians appear to have overlooked it. The problem of walkability in Riyadh goes beyond the built environment [4]. They perceived it as more of a roadblock for automobiles. Rather than developing a pedestrian-friendly environment by improving the city's walkability, municipal planners showed a total bias in favor of the city's motorized mode of transit [5]. They saw it as more of a hindrance to car movement. Rather than creating a pedestrian-friendly environment by improving city walkability, city planners demonstrated a complete bias toward a city-motorized mode of transportation [4]. Many non-physical obstacles prevent people from walking [5].

3.1. Proposed guidelines strategic implementation by using SPN system in Riyadh city

The following Figure shows the Future implementation of Smart mobility guidelines in Riyadh City to improve the situation of the pedestrian network in Riyadh city.

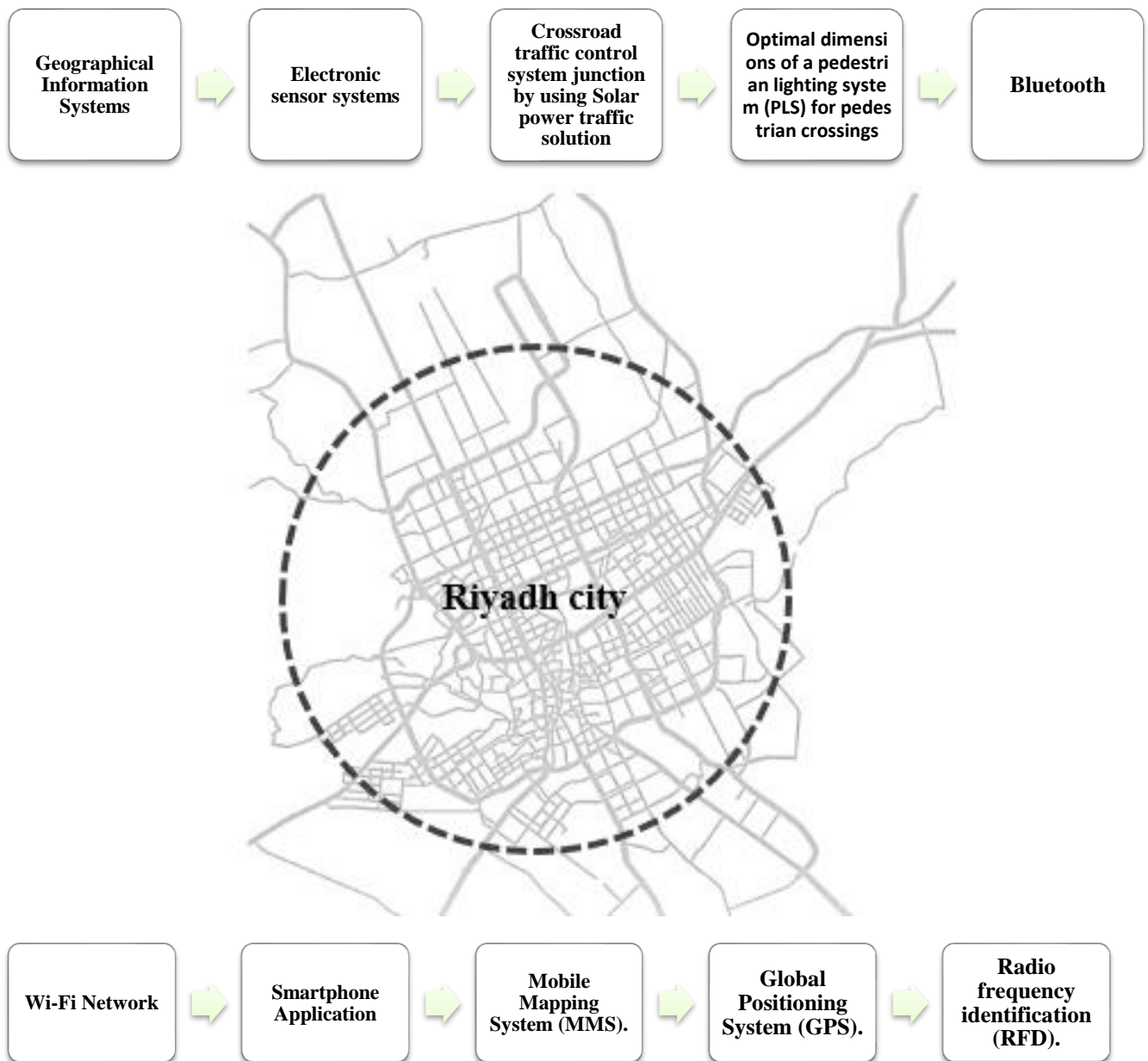


Figure 14. Proposed guidelines strategic implementation by using SPN system in Riyadh city, source: (Author, 2022)

Table 1. Proposed guidelines strategic implementation by using SPN system in Riyadh city

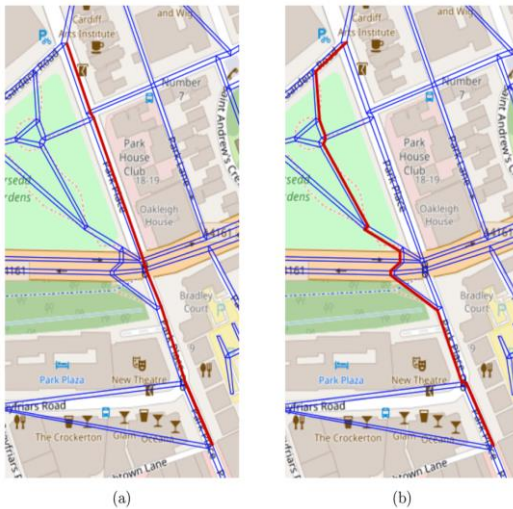
Strategy Of SPN system	Method	Example
Geographical Information Systems (GIS)	<p>GIS-enabled pedestrian audit tools can be a quick and efficient way to collect and analyze pedestrian infrastructure characteristics, allowing planners, practitioners, policymakers, and community members to make better walkability decisions. Pedestrian mobility data can be incorporated into a centralized GIS database and utilized to build complex maps for the system. Users of the app may see this rating system and predict how many traffic fatalities are probable in a specific place. These algorithms consider a wide range of traffic factors, including crossings, speed limits, and street</p>	

Figure 15. Roadmap by using GIS, source:(

<https://www.gislounge.com/mapping-best-route-pedestrian-safety/>)

**Electronic
sensor
systems**

Networks of electronic sensors Electronic sensor systems, which are widely used in today's cities, are another important technology. Sensors can be used to monitor the state of the pedestrian network in real time. A variety of technologies, such as traffic flow inductive loop sensors, air pollution sensors, traffic cameras, and so on, can be used to collect data.

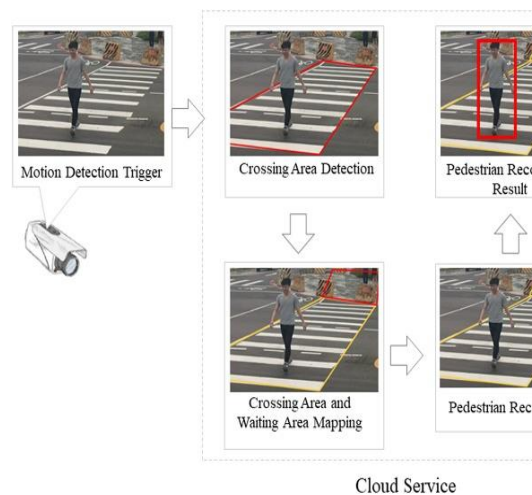


Figure 16. Using Cameras and big data are available via an internet connection, source:

(<https://onlinelibrary.wiley.com/doi/abs/10.1002/spe.2742>)

Crossroad traffic control system junction

By using a Solar power traffic solution

To realize the pedestrian mode, you must control the traffic flow in both directions and the pedestrian in both directions. You can use the cycle mode or install the pedestrian crossing bottom.

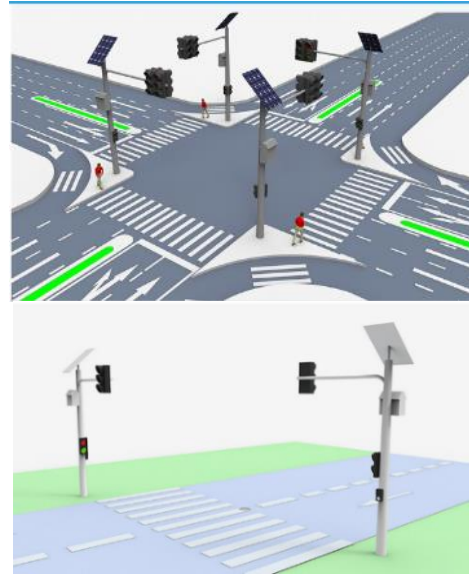


Figure 17. Using solar power traffic solution, source: (<https://www.nobleled.com/solutions/solar-power-traffic-solution/>)

Optimal dimensions of a pedestrian lighting system (PLS) for pedestrian crossings

Consider the pedestrian lighting system (PLS) and its ideal dimensions when constructing pedestrian crossing infrastructure. For example, a method for detecting crosswalk markings in intelligent vehicle systems and pedestrian security using laser-based applications.



Figure 18. Improving Community Connections with Smart Traffic Signal Control (STSC) system Mid-block, multi-lane crosswalks in Key Largo, FL, source: (<https://carmanah.com/resources/rrfb-community-walkability-powerpoint/>)



Figure 19. Using pedestrian lighting system, source: (<https://www.ellumin.com/project/non-light-control-area-intelligent-pedestrian-system%EF%BC%88urban-type%EF%BC%89/>)

Bluetooth Without the need for an internet connection, pedestrians can obtain critical local information via Bluetooth. By collecting smartphone addresses, it may also be used to track pedestrian mobility and create origin-destination matrices. Bluetooth can also be used to link a variety of other devices or sensors, such as fitness trackers and health monitors.

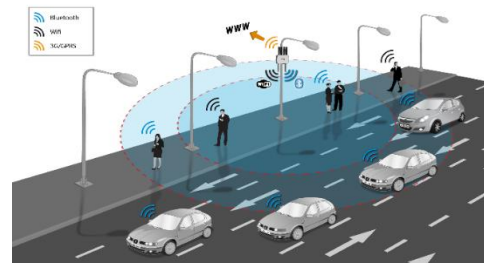


Figure 20. Using SPN -Bluetooth in street design, source: (<https://www.manxtechgroup.com/people-counting-using-wifi-and-bluetooth/>)

Wi-Fi Network Pedestrians can utilize Wi-Fi to communicate information and provide location-based services because it is a duplex communication technology that supports TCP/IP. Furthermore, the primary technologies for internet connection are the various mobile communication generations -2G, 3G, 4G, and the upcoming 5G. As a result, pedestrians now have access to a wealth of data that can be delivered to them in real time.



Figure 21. Using SPN Wi-Fi Network, source: (<https://www.extremetech.com/extreme/133708-gm-leverages-wifi-direct-to-give-pedestrians-a-better-chance-of-jumping-out-of-the-way-of-cars>)

Because internet connectivity is required for any smart pedestrian mobility system, Wi-Fi networks can be a significant source of internet access.



Figure 22. Using SPN Wi-Fi Network, source: [31]

Smartphone application Through a smartphone navigation application system, users may be able to provide crowd-sourced feedback to municipal authorities on issues related to pedestrian network conditions.



Figure 23. Smartphone app for pedestrian navigation, source: (<https://www.cnet.com/news/google-begins-testing-ar-walking-navigation-for-maps/>)

Mobile Mapping System (MMS).

The following are the results of the current study's method:

- Ease of access to the crossing area.
- road signs.
- Visibility is close to the pedestrian crossing between the car and the pedestrians.

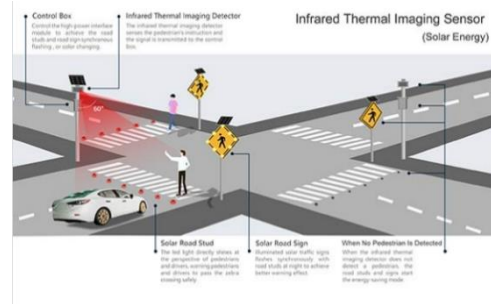


Figure 24. Using Mobile Mapping System,source: (<https://www.nk-roadstud.com/intelligent-transportation/pedestrian-crossing-monitoring-system.html>)

Global Positioning System (GPS)

(GPS) may be used to rebuild 3D models, allowing a map of the built environment to be created.



Figure 25. Using GPS data combined with photos,source: [27]

Radio Frequency Identification (RFD)

One such opportunity is radiofrequency identification (RFID) technology, which is a good example of how we can influence the adoption of new technology. RFID's success, like that of other technologies that have progressed from specialized to mainstream use (such as video recorders, computers, and global positioning systems), will be determined by user experience as well as technical factors.



Figure 26. Using RFD runway in an urban area, source: (<http://rfdrunways.blogspot.com/p/phase-1-construction-work-areas.html#!/p/phase-1-construction-work-areas.html>).

Source: (Author, 2022).

Figure 27 shows conceptual framework for a smart pedestrian network application in Riyadh City.

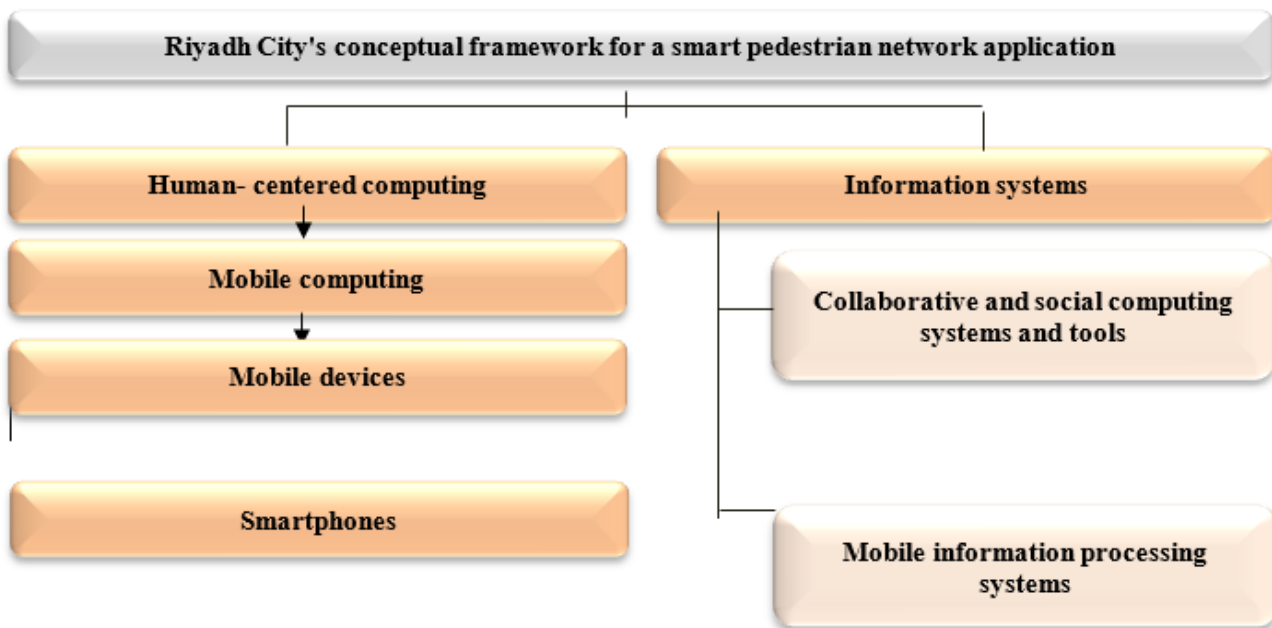


Figure 27. Conceptual Framework for a smart pedestrian network application in Riyadh City, source: (Author, 2022).

4. Conclusion

This study presents a variety of strategies and models proposed by researchers for the implementation of a Smart Pedestrian Network. As a result, there is a need to implement smart pedestrian mobility in cities due to its importance, which is especially important in Riyadh. Smart Pedestrian Networks can encourage and empower people to walk by removing immaterial barriers such as a lack of information or a repetitive journey, as well as by providing data to decision-makers to better understand how and where people travel. Walking is an environmentally friendly and democratic mode of urban transportation that benefits both pedestrians and the urban environment. Walking has numerous health, financial, social, and environmental advantages. Smart Pedestrian Network technology and applications can help to create smart walkable cities by enhancing and positively supporting all variables related to the perception and qualities of the built environment, as shown below:

- GIS, Bluetooth, and mobile communications can aid in improving connectedness.
- Increased safety by crowdsourcing and image processing from traffic cameras.
- Smart sensor technologies and GIS mapping help with path selection in the pedestrian network; (navigation systems may encourage interactions between pedestrian behavior and the urban environment).
- A decision-making strategy makes cities more walkable by modeling physical and perceptual characteristics that have the greatest impact on people's mobility patterns.

Further research directions for the Smart Pedestrian Network should include the development of a pedestrian network in each city, particularly Riyadh, as well as the provision of financial resources for smart pedestrian network solutions. Further research could look into the Smart Pedestrian Network's role in improving safety and lowering pedestrian accidents in Riyadh.

Declaration of competing interest

The authors declare that they have no any known financial or non-financial competing interests in any material discussed in this paper.

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