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# The implication of street network design for walkability: A review

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**Abstract.** A street network-friendly design allows walkability among people and is proven beneficial to the environment, community health, and economy of the city. Walkability in a street network increases potential trips by pedestrians through sidewalks and linked streets to create shorter travel distances. Street designs for pedestrian walkways are commonly ignored, with more focus on vehicular access, consequently leading to a lack of effort in improving the street network designs linked to various destinations. Accordingly, this paper reviews the street network designs affecting walkability from the perspective of the urban community. A systematic literature review method was employed to identify and analyse the articles published in the Scencedirect.com database between 2004 and 2020 using two keywords: street network design and walkable city. The main finding suggested that street networks were associated with proper street designs. Therefore, a walkable city developed from a thriving street network design improved local physical activities and healthy communities.

## 1. Introduction

Walkability in a constructed environment pertains to pedestrian-friendly streets designed to provide established facilities and more convenient and safer spaces for urban pedestrians [1]-[2]. Besides, walkability promotes the fundamental elements comprising a sustainable and livelier city and a healthy community [3]-[4]. Meanwhile, the streets are linked to sustainable transportation, known as low-impact transportation (walking, cycling, transits, and green vehicles), hence contributing to an environmentally friendly, affordable, fast, and convenient means of travel that saved time [5]-[6]. For example, increased pedestrian accessibility and sustainable transportation are essential in closely linking sustainable development through economic, social, and environmental benefits [7]-[8].

On another note, the interdependence between walkability and city streetscapes promoted the experience of active physical activities, such as leisure, exercise, or recreation [3]-[9]. A study on cities by Wang and Yang (2019) indicated that walkability measurements, the built environment, health, and walkability applications were the three major perspectives concerning walkability in a community [5]. Therefore, walkability could be described as a pedestrian-friendly street design for



short-distance travelling highly associated with built environment attributes, thus leading to environmental and health benefits in community life.

Travellers using various transportation modes usually end the journey with an element of walking [2]-[10]. In other words, having no pedestrians was equivalent to having no walkability. Hence, street network designs have become an important element in creating a pedestrian-friendly environment. For example, the design elements must include suitable softscape and hardscape elements and high-quality environments, facilities, and amenities. The design elements required measuring to produce pedestrian-friendly streets and efficient street networks in a sustainable city [7]-[11]-[12].

A study in transportation by Ferrer and Ruiz (2017) reported that the main factors influencing people's walkability rate were feelings of insecurity involving crime rates, a high density of traffic lights, and having to walk along the main road [13]. Additionally, Sdoukopoulos et al. (2016) suggested that people were discouraged to walk due to the poor infrastructural and environmental conditions provided [2]. Therefore, street network designs were crucial in encouraging people to walk and increase the urban walkability rate. Further comprehension of street network designs and urban walkability should be specifically assessed to produce sustainable and effective street network designs for the community.

However, the requirements of street network design elements varied depending on the context of street location and function. Besides, the space design for pedestrian walkways was commonly ignored, with more focus on vehicle accessibility, such as proposing sidewalks with minimum provision for pedestrian access [8]-[14]. However, a few studies in the relevant literature investigated the relationship between street network designs and walkability. Moreover, research of street network design conducted on a site study such as New York City [15] or Seoul, Korea [12] describes the influences of the street design implies only for the local context. Accordingly, a review with various site studies provides a broad view in context of street network design studies for a research consideration. Further studies are required to provide an in-depth understanding to produce sustainable and effective street network designs for the community. Therefore, this paper reviews the street network design affecting walkability from the communal perspective in a built environment and discusses the issue of street network designs and walkability in the built environment field, including the environmental sustainability disciplines relevant to public health.

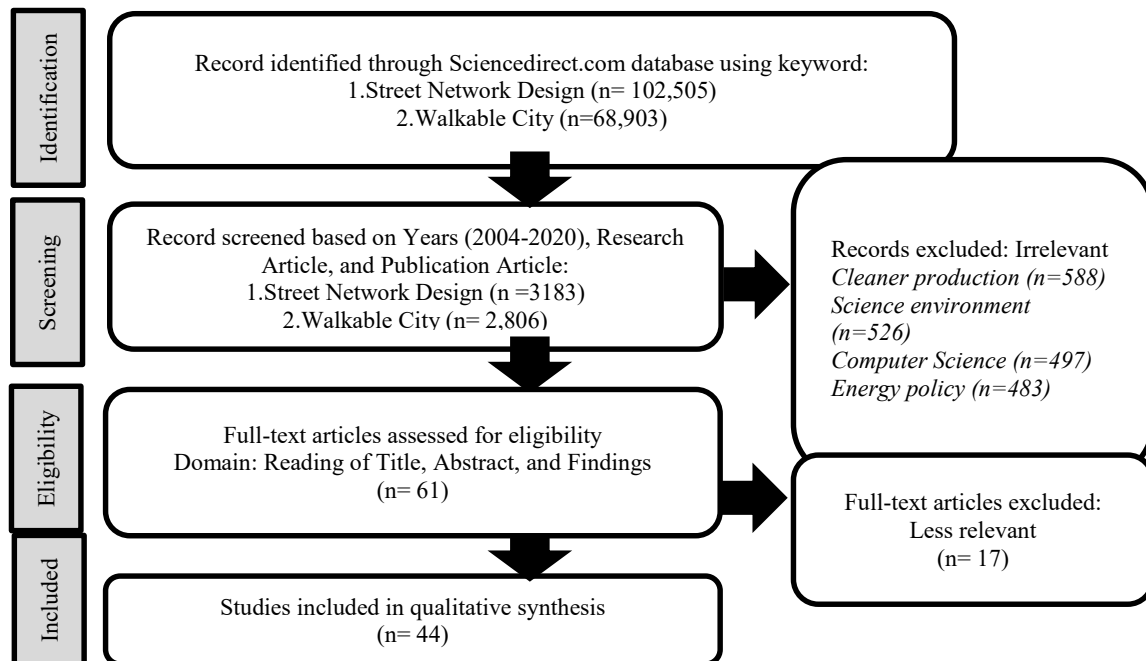
## 2. Methodology

The systematic literature review method employed in this study focused on identifying and analysing the data reported in the relevant literature. Scencedirect.com data sets were used to gather the articles based on two keywords: street network design and walkable city. Scencedirect.com provides reliable research publication more than 1.4 million articles available online. This open access research database covers six indicators related to street network design and walkability which are (i) accident prevention and security, (ii) city and built environment, (iii) health and place, (iv) landscape and urban planning, (v) social and community, and (vi) transportation and traffic safety. The groundwork for this study began with reading the title, abstract, and findings in the article reported in relevant Scencedirect.com publications from 2004 to 2020. The data was then analysed to measure the street network design factors affecting urban walkability.

The keywords (i) street network design and (ii) walkable city were searched in Scencedirect.com, with 102,505 results found using the keyword 'street network design' and 68,903 results found using the keyword 'walkable city'. All the results found were screened through selected terms and the removal of less relevant articles. The screening process was selected based on the research article type and relevant publication title from 2004 to 2020. Following the assessment and identification of eligible full-text articles, duplicate and less related articles were removed based on the title, abstract, and findings. The remaining articles were then read and choose.

Following the appropriate reading of articles through selected terms and the removal of irrelevant ones, 44 publications were identified as utilising walkability in street network designs. Several

principles were identified based on the six relevant journal indicators selected for this study. The principles of sustainability approach involved the environment, community, health, and economy in creating a walkable city. For example, Sdoukopoulos et al. (2017) highlighted walking as one of the contributing factors to sustainability principles [2]. As such, all the reviewed papers are described in Table 1.



**Figure 1:** Flow chart of the study selection process.

### 3. Results and discussion

All the selected papers summarised in Table 1 and Figure 2 outlined the study findings on the implication of street network designs for walkability. The results included six indicators: (i) accident prevention and security, (ii) city and built environment, (iii) health and place, (iv) landscape and urban planning, (v) social and community, and (vi) transportation and traffic safety.

**Table 1.** Summary of findings from selected articles.

Indicators	Authors (Year)	Findings
Accident Prevention and Security	Kang (2019)[15]; Ferrer and Ruiz (2018) [13]; Rifaat, Tay, and Barros (2011) [16]	<ul style="list-style-type: none"> <li>Street design elements could reduce pedestrian collisions,</li> <li>Built environment factors influenced decisions to walk for short trips</li> <li>Loop and lollipop street patterns increased the risk of injuries but lowered the risk of death and property damage during accidents</li> </ul>
City and Built Environment	Cambra and Moura (2020) [17]; Dean <i>et al.</i> (2020) [18]; Sun, Wallace, and Webster (2020)	<ul style="list-style-type: none"> <li>Street improvements led to an increase in pedestrian volume and influenced walking experiences</li> <li>Walking decisions were influenced by built environment designs</li> <li>Network links or connections and the shortest path led to the increasing number of metro users</li> </ul>

	[19]; Kang (2017) [12]; Rafiemanzelat, Emadi, and Kamali (2017) [4]; Jensen <i>et al.</i> (2017) [20]; Sdoukopoulos <i>et al.</i> (2017) [2]; Koohsari <i>et al.</i> (2017) [21]; Singh (2016) [22]; Lamiquiz and Lopez-Dominguez (2015) [23]; Bhattacharyya and Mitra (2013) [7]	<ul style="list-style-type: none"> <li>• Short-distance destinations and areas with a high frequency of passers-by were associated with higher walking volume</li> <li>• Walkability and built environment strongly related to creating a sustainable space</li> <li>• Walkability and a new complete street renovation were related to gender proportions and attracted people's interests</li> <li>• Enhancement of current infrastructure for pedestrians and the provision of access for all pedestrian types to encourage walking</li> <li>• Street connectivity was associated with travel behaviour and encouraged walking</li> <li>• Walkability related to buildings presented on both sides of a street determining the street's liveliness</li> <li>• Built environment attributes could influence pedestrians to walk on one-way trips</li> <li>• Transportation planning and engineering, health, tourism, social inclusion, crime prevention, and urban designs are factors to achieve sustainability in the walkability development</li> </ul>
Health and Place	Wang and Yang (2019) [5]	<ul style="list-style-type: none"> <li>• Community walkability and health were highly related to build environment attributes</li> </ul>
Landscape and Urban Planning	Zuniga-Teran <i>et al.</i> (2019) [24]; Lua, Sarkar and Xiao (2018) [25]	<ul style="list-style-type: none"> <li>• The use of green spaces influenced by walkability elements allowed for social interaction</li> <li>• Street greenery and the number of parks were associated with higher walking probabilities and health benefits</li> </ul>
Social and Community	Su <i>et al.</i> (2019) [26]; Jun and Hur (2015) [27]; Shamsuddin <i>et al.</i> (2012) [28]	<ul style="list-style-type: none"> <li>• The development of a socio-economic community affected walkability</li> <li>• Walkability enhanced a community social environment</li> <li>• Lack of walkable elements and awareness among citizens affected citizens' walking behaviour</li> </ul>
Transportation and Traffic Safety	Gonzalez-Urango <i>et al.</i> (2020) [29]; AlKheder and AlRukaibi (2020) [30]; Ruiz-Padillo <i>et al.</i> (2018) [1]; Yoshii (2016) [31]; Thielman <i>et al.</i> (2015) [32]; Koohsari <i>et al.</i> (2016) [33]	<ul style="list-style-type: none"> <li>• Street walkability improvements ensured that people walked safely and leisurely in the city centre</li> <li>• Creation of wide green areas with shaded pathways, underground parking, and bicycle lanes to encourage walkability</li> <li>• Good living standards and environmental attributes influenced people's walkability</li> <li>• Walkability with improvement of pedestrian facilities resulted in safer pedestrian routes and improved neighbourhood quality</li> <li>• Walkability was associated with transport walking involving all age groups but irrelevant to physical leisure activities among young adults</li> <li>• Street network measures and well-connected street network were associated with walking frequency as a transportation</li> </ul>

Figure 2 demonstrates that the city and built environment indicator led to the highest result in the number of articles used among previous studies on street network designs and walkability, followed by the second result (transportation and traffic safety indicator), the third result (accident prevention and security indicator), the fourth result (landscape and urban planning indicator), the fifth result (social and community indicator), and the sixth result (health and place indicator). The indicators reflected that well-connected and well-designed street networks associated with walkability benefited the environment, economy, society, and community health. Besides, street networks with good connections and designs promoted physical activities that encouraged people's walkability rate in the community and led to a sustainable environment.

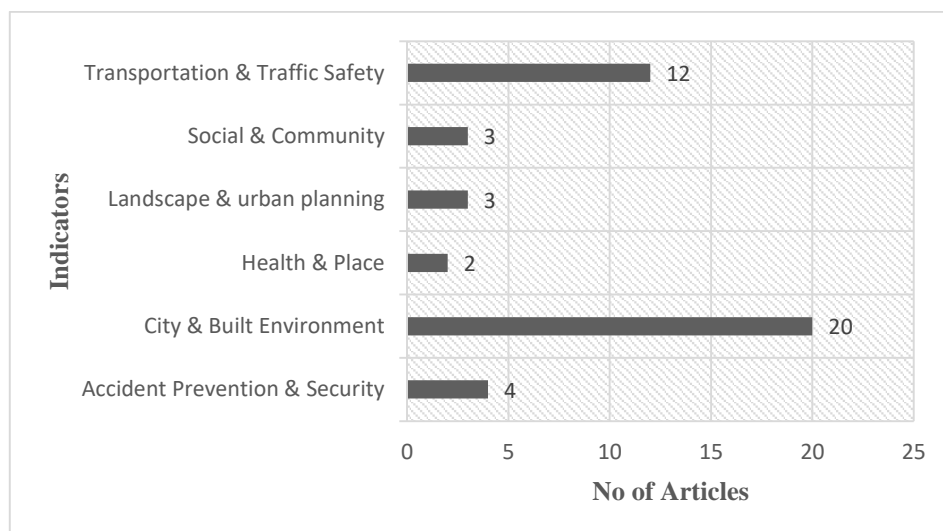


Figure 2: Studies on indicators in street network design and walkability.

The city and built environment indicator presented the highest result of 20 articles, which suggested that built environment attributes influenced urban development. Accordingly, the street network designs considered in built environment attributes paralleled community needs in developing a successful city. Specifically, streets networks were designed to attract all travel modes and provided opportunities for commercial activities in livening the place. Livelier forms of the environment in a walkable street produced more physical communal activities.

Pedestrian-friendly streets indicated importance in the widespread use amongst cyclists, the physically handicapped, transit users, and pedestrians of all ages. Additional designs and pedestrian infrastructure required for other groups (children, the elderly, and people with disabilities) ensured a positive pedestrian experience in the environment. Thus, specific street facilities were required, such as bicycle parking areas, specific bicycle lanes, and pathways for the blind. Other pedestrian categories with mobility issues (people with small children, older people, and people carrying heavy items) needed consideration in planning street network designs.

The transportation and traffic safety indicator were rated the second highest with 12 articles, thus suggesting that a good street network design and walkability rate relied on urban transportation planning. Improving street designs by linking a point to other points increased walkability by influencing pedestrians to walk. Nevertheless, improvements towards linked streets remain scarce in town developments compared to city centres [8]. Hence, good street networks implied well-connected streets in providing multiple route choices to reach a destination.

Studies on the city and built environment indicator suggested that pedestrian flow improved when the streets provided linkage to multiple attractions. Besides, the linkage to the aesthetic attributions of street corridors or street greenery, such as parks, showed high possibilities of people's walkability and

affected walking behaviours. Street networks involving walking, cycling, or using other active transportation modes that connected to sidewalks, pedestrian pathways, bicycle lanes, and streets shortened the distance between destinations with high street network connectivity.

Furthermore, the results revealed that the accident prevention and security, landscape and urban planning, and social and community indicators had an almost similar number of articles (three) excluding the accident prevention and security indicator by one article. The accident prevention and security indicator specifically presented more compact and connected street networks in encouraging people to walk and cycle to reduce vehicle and transport usage, simultaneously increasing traffic safety in the community. Good street networks needed to be attractive and convenient to pedestrians and provide comfortable conditions for people who travelled by foot, bicycle, or transit. Additionally, safe places to walk, cycle, and drive should be publicly provided.

Moreover, public road safety improved communal safety and reduced injuries. Pedestrians were discouraged to walk if a street was unsafe and posed a high risk of severe injuries from accidents. Besides safety, security factors also influenced people's walkability, including street conditions which led to criminal activities. Different locations and communal environments had different security concerns. Age and gender were also one of the factors relating to security concerns due to different abilities and thinking. Optimising the usage of street lighting in dark areas or after dark was one of the solutions in encouraging people to walk and reduce the opportunities for crime or fear. The presence of more people on the street made the street liveable and enabled pedestrians to feel safe.

However, studies revealed that the distance to destinations was the main factor affecting people's walkability apart from other factors, such as the weather, physical difficulty, safety, or fear of crime [13]. Furthermore, both the landscape and urban planning indicator and social and community indicator had the same ranking. Strategic locations and attractive street environments in retail areas that provided suitable facilities, excellent streetscape designs, and good qualities could encourage people to walk and improve the economy. Social and community indicators found that areas with low socio-economic activities would result in lower neighbourhood walkability in the surrounding area. Also, softscape elements in street designs such as tree-planting created an interesting environment that gave a pleasant scenery and shade to pedestrians, thus encouraging people's walkability.

Figure 2 demonstrates that the lowest indicator, health and place, reported two articles, as most of the other studies examining the health and place indicator in other study fields were less relevant to the implication of street network designs for walkability. Hence, the selected article was chosen to investigate the relationship between the health and place indicator and street network designs for walkability. Successful walkable streets resulted in continuous and active community life, a user-friendly facility, a pleasant place to reside and perform daily activities, and pedestrians' comfort and safety. The development of the design and physical features of a built environment in a specific area influenced human activities, behaviours, lifestyles, and affected the community emotionally [34].

The health and place indicator detected the relationship between the health and built environment, whereas studies in transportation and health suggested similarities whereby more compacted and connected street networks reduced disease rates in the community. Meanwhile, the landscape and urban planning indicator revealed that urban greenspaces positively influenced human health and encouraged people to walk. Nonetheless, limited studies in the health and place indicator implied the lack of awareness concerning greenspace for street designs in the community. Therefore, additional greenspaces in street designs were required in emphasising walkability by proposing street network designs.

#### **4. Conclusions**

This paper reviewed the street network design affecting walkability from the perspective of urban communities and detailed the implications of street network designs for urban walkability to produce efficient street network designs for a sustainable community. As such, the finding suggested that well-connected and well-designed street networks were associated with walkability that benefited the

environment, economy, society, and community health. Additionally, efficient street networks promoted physical activities that encouraged people to walk, consequently leading to a sustainable community and environment.

Also, the finding suggested that the street network designs for pedestrians required connections and links from one destination to another and contributed to the growth of walkability in towns compared to city centres. The development of a walkable city was derived from a thriving street network design that improved local physical activities leading to healthy communities and neighbourhoods. Thus, this paper focused on the built environment field that included environmental sustainability disciplines relating to public health and implied walkability in a street network as an essential concept for a sustainable urban design. Regardless, the studies in current literature investigating the relationship between street network designs and walkability to understand and produce efficient street network designs remain scarce. Therefore, a sound knowledge of street network designs enabled the development of a walkable and healthier city.

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