**A Review of Walking and Cycling as a Method of Sustainable Transportation**

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**ABSTRACT**

**Many studies have been conducted focusing on the relationship between climate change and greenhouses related to the transportation and emissions of greenhouse gases. Sustainable transportation is transportation that is capable support the mobility needs of the community in a way that does not harm the environment and does not affect the mobility needs of future generations. This paper systematically reviews seventeen researches on the effectiveness of walking and cycling as one of the sustainable means of transportation. Cycling and walking activities successfully address the problem of dependence on motor vehicles and in turn can reduce carbon dioxide (CO2) emissions and the greenhouse effect that will lead to climate change. More importantly, walking and cycling activities can have a positive impact towards producing an environment of minimal greenhouse gas emissions and a healthy and prosperous community.**

Keywords: Sustainable transportation; walking; active community; comfortable walking distance.

# 1. INTRODUCTION

## 1.1 The Impact of Transportation on Global Climate Change

Many studies have been conducted focusing on the relationship between climate change and greenhouse-related transportation and gas emissions. Caprì et al. (2016) noted that research towards addressing climate change problems, especially those related to reducing greenhouse gas emissions and impacts, has become a major focus among world scientists.

Sustainable transportation is transportation that is capable of supporting the mobility needs of society in a way that does not damage the environment and does not affect the mobility needs of future generations (Rodrigue, 2020). Walking and cycling are among the simplest and most effective examples of sustainable transportation and have proven their effectiveness in many developed countries (Wang et al., 2016). When compared to driving, walking is a manual effort/force, with lower speeds and tends to travel shorter distances. Many researchers consider walking to be an active and sustainable transportation. This may be due to the positive effects of walking on human health and its environment (Balsas, 2003; Loo et al., 2017; Millward et al., 2013).

The first objective of this study was to identify comfortable walking and cycling distances. The second objective, aims to identify the physical building environment in an area whether urban, residential or institutional campuses that encourage walking and cycling activities. Finally, this study also aims to examine other factors that also influence the level of walking and cycling activities in an area. The scope of the study is limited to non-motorized transportations, namely walking and cycling.

# 2. LITERATURE REVIEW

According to Cubukcu (2013), walking plays an important role in the continuity of a place. Places are easily accessible on foot and when people walk, they get to know their neighbours and they can identify strangers in the neighbourhood easily. In other words walking helps increase social supervision. Generally, residential areas are places where people not only relax, but also spend time with family, entertain friends or simply to unwind. Among the most effective development strategies to encourage walking and cycling activities is to identify the location of a focal point; the distance to transit stops and stations within walking distance. According Scheiner (2010b), distance is an important factor in deciding whether one is to walk to any destination. For example, distance to the nearest facility turned out to be an important impact factor influencing the frequency of shopping trips on foot. Furthermore, a study by Ye et al. (2005) (refer to Table 1) emphasizes that pedestrianization and cycling approaches can encourage the use of public transit. It also promote a transport linkage loop integration system as a key element of smart development policy.

Table 1: Key Elements in Smart Growth Policy, Ye et al. (2005)

|  |  |  |
| --- | --- | --- |
| Planning |  Transportation | Economic Development |
| * Public facilities planning
* Comprehensive planning
* Mixed land use
* Density increases
* Road connectivity
* Alternative/innovative water
* Infrastructure and systems
* Public facilities planning
 | * Pedestrian
* Facilities for cycling
* Promotion of public transit
* Integration of systems and node networks
 | * Neighbourhood businesses
* Revitalization of the city center
* Infill development
* Use existing infrastructure
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Findings by Kaplan (2015), revealed that the situation of high social implications for cycling and walking can improve the social and health environment among students and staff on a university campus. Thus, an in-depth study of the characteristics of the campus environment is needed to enhance these sustainable activities. Increased walking and cycling activities can lead to a more engaging community environment functioning in helping to improve the health of individuals and communities. A sustainable community environment such as landscaping and appropriate infrastructure along walking and cycling routes to important destinations such as grocery stores and public transport stops can also help reduce carbon dioxide (CO2) emissions into the the environment. The findings of the studies in Table 2 describe the study environment and sustainable transportation activities in terms of effective distance, physical building environment and other factors that also influence the level of walking and cycling activities.

Table 2: Study on the effectiveness of walking/ cycling

as one of the means of sustainable transportation.

|  |  |  |  |
| --- | --- | --- | --- |
| No. | Articles | Study environment | Relevance of the study to walking and cycling activities |
| 1 | (Australian & Sustainable, 2004). | Western Australia | A distance of 400 meters is considered a good practical walking/cycling distance in planning a pedestrian -friendly community. |
| 2 | (Zahran, Brody, Maghelal, Prelog, & Lacy, 2008) | Data is from the United States Census Bureau. | This study analyse the spatial distribution of healthy modes of transportation (cycling and walking) on a district scale. |
| 3 | (Scheiner, 2010a) | All over Germany. This study reports findings from a longitudinal analysis of a German-wide travel survey for the period 1976-2002 | The results show that even in the same distance category, car consumption has increased. This is due to the convenience in owning a private car and using public transport in Germany. |
| 4 | (Scheiner, 2010b) | City of Cologne, Germany | The distance to the nearest facility turns out to be an important factor influencing the frequency of shopping trips on foot or by bike. |
| 5 | (Gunn et al., 2017) | Melbourne Central Business District | Introducing Donut-buffers as a method of calculating the purpose of walking trips between distances of 401m-800 m and 801m-1200 m compared with standard network buffers at distances of 400 m, 800 m and 1200 m respectively. |
| 6 | (Kasim, Shahidan, & Yusof, 2018) | Campus environment in Malaysia | 5 types of Pedestrian Landscape Environmental Settings (LESP) were introduced. |
| 7 | (Kasim, Shahidan, Ujang, & Dahlan, 2019) | Campus environment in Selangor, Malaysia | Pedestrian thermal comfort encourages pedestrians to walk further. The results show the importance of shading materials and man -made pavements for pedestrian comfort. Shading can reduce pavement temperature even from low albedo materials such as dark gray asphate. |
| 8 | (Kasim et al., 2020) | Campus environment in Selangor, Malaysia | Studies prove that with a good Pedestrian Landscape Environment (LESP) design can improve the thermal comfort of pedestrians in tropical environments up to 1.0 km. |
| 9 | (Benson, Bruner, & Mayer, 2020) | Quebec Province, Canada | Individual experiences and factors related to the implementation of the walking school bus in Northeastern Ontario were explored using semi -structured interviews (parents) and focus groups (students and conductors). |
| 10 | (Wang, Wang, & Yang, 2020) | China | Motivating individuals to choose green transportation is becoming increasingly important. Based on a push-pull-mooring framework, this study aims to explore how such factors foster an individual’s willingness to switch to green transportation. |
| 11 | (Gao, Kamphuis, Helbich, & Ettema, 2020) | Residential areas in the Netherlands. (Dutch National Travel Survey) 2010–2014. | The residential environment is associated with the walking activity behavior of residents. The results of the study found that walking for transportation had no relationship with the residential environment. Shorter distances to public transportation and to daily amenities are positively associated with walking for transportation. |
| 12 | (Wang, Ettema, & Helbich, 2021) | Residential areas in the Netherlands. (Dutch National Travel Survey) 2015–2017. | Walking backgrounds are a good and simple way to increase an individual’s energy, but there is limited evidence stating whether neighborhood environments differ from recreational and travel trails. |
| 13 | (Ki & Lee, 2021) | A study of the relationship between urban greenery and walking activities in Seoul, Korea. | The results of the study found that there is a relationship between urban greenery and walking activities in Seoul, Korea. Also, this study found that low-income residents typically live in areas of low greenery, yet walking time is more sensitive to greenery. |
| 14 | (Eugenia, Manuel, & Alonso, 2021) | To promote more travel on foot, this study analyzes the factors influencing the choice of walking route, in addition to distance. | The main factors for choosing a walking route are those related to attractions (e.g., green areas, amenities, tourist attractions etc.) and accessibility. |
| 15 | (Chen & Wang, 2020) | Apply the framework to Fresno, California, and Cincinnati, Ohio USA. | The results show that the efficiency of transportation transit services needs to be improved to achieve the same level of cycling, while they help with accessibility. |
| 16 | (Khalil, 2010)  | Principle *Neighbourhood Unit Concept dan New Urbanism* | The results show that it should be pedestrian -friendly as well as a design that encourages the use of bicycles, rollerblades, scooters, and walking as daily transportation. Walking distance should be within 10 minutes walk from home and work as well as pedestrian -friendly street/path design and free from motor vehicles. |
| 17 | (Hasan, Ahmad, & Hadiuzzaman, 2014) | Neo-traditional Design Principles and Smart Growth  | The main factors of integration (principal integration) of the new city are pedestrian and main transport transit facilities (mass transit). Increased walking activities can reduce the rate of car driving (reduce release of CO2) by increasing access and infrastructure facilities for walking activities. |

These studies clearly support sustainable transportation options walking and cycling are the best steps toward reducing excessive reliance on fossil-based fuels and in turn reducing the effects of global warming.

## 3. METHODOLOGY

This paper systematically reviews seventeen (17) research papers on the effectiveness of walking or cycling as one of the sustainable means of transportation. As mentioned in the introduction, sustainable transportation is focused on walking or cycling. This study reports the results of research to identify walking distances. These are i) distances between the house to major amenities such as grocery stores and suitable public utility stations, ii) physical built environment in an area whether urban, residential or campus, and iii) other factors that can help improve the level of walking and cycling activity.

# 4. RESULT AND DISCUSSION

The discussion will focus on three (3) parts. The first part of this study was to identify the effective walking and cycling distances. The second part, is to identify the physical environment ( urban, residential or campus) that can help improve the level of walking and cycling activities. And finally, it examine other factors that also influence walking and cycling activity in an area.

## 4.1 Comfortable Walking Distance

Distance is an important factor in deciding whether to walk, bike or drive to a destination. For example, distance to the nearest facility turns out to be an important factor influencing the frequency of shopping trips by walking or cycling (Scheiner, 2010a). Scheiner (2010a) also made a longterm study from 1976 to 2002 in Germany on the factors that cause the trend in population behavior from walking or cycling to car use. The results of the study found that the convenience of owning a car and the increase in distance caused the trend to change to the use of private cars as the main mode of transportation.

Studies by Khalil (2010) and Hasan et al., (2014) helped explained the development theory of the Neighbourhood Unit Concept, *New Urbanism*, *Neo-traditional Development*, *Smart Growth* in the context of walking activities in urban environments. The concept of a Neighborhood Unit by Clarence Perry in 1920 where an organized neighborhood is based on a distance of ¼ miles (400 m) or equal to a five minutes walk as the distance between home and school. Meanwhile, in the early 1990s, New Urbanism recommended a ten minute walking distance, where most amenities were within that distance.

In Western Australia, for example, a distance of 400 meters is considered a good practical approach in planning a pedestrian -friendly community (Australian & Sustainable, 2004). Therefore, location of important places, shops and other services are within a 5-minute walk of the residence. In the meantime, Gunn et al., (2017) stated that “there is evidence supporting the optimal walking distance” and they added that “there is evidence that people walk more than 400 m to get to a destination”. They then made an analysis in identifying the distances that support the purpose of the walking trip in the surrounding area located within 20 km of the Melbourne Central Business District. They introduced Donut-buffers as a method of calculating the purpose of walking trips between distances of 401m-800 m and 801m-1200 m compared to standard network buffers at distances of 400 meters, 800 meters and 1200 meters respectively. The results showed that local food outlets including supermarkets, cafes / food shops, and small food shops, located within a distance of 401m-800m and 801m-1200m are suitable for transportation stops. This suggests that the purpose of the trip to the destination will encourage walking.

These studies clearly support that suitable and comfortable walking or cycling travel distances range from 400m to 1000m i.e. within 5 to 10 minutes of travel.

## 4.2 Relationship of Physical Environment with Walking or Cycling Activities

Many environmental features act as catalysts to walking and cycling activities. In one study, Kasim et al. (2018) introduced what is termed as Landscape Environmental Settings for Pedestrian (LESP). LESP is the landscape elements that can be seen in the pedestrian’s walkway surrounding within 3 m radius that affect the thermal comfort of the pedestrians at the particular type of situation. Of the five types of LESP, it was found that LESP Type 5, which is a landscape environment that has two rows of trees on the left and right of the walkway has the most comfortable thermal comfort rate (Kasim et al. 2019).

Based on survey data of a questionnaire on walking behavior among a total of 2350 residents, Ki and Lee (2021) found that a significant relationship between urban greenery and walking activities in Seoul, Korea. Residents choose areas with abundant levels of greenery for walking and cycling as the manin mode of moving around. Path features that improve walking habits are green areas or ease of access, which are less noisy and unpolluted (Eugenia et al., 2021). Kasim et al. (2020) revealed that in a tropical environment, a conducive pedestrian landscape environment encouraged pedestrians to walk within a distance of one (1) kilometer comfortably.

## 4.3 Other Factors Affecting Walking or Cycling Activities

Motivating individuals to choose a sustainable means of transportation is important. Based on the push-pull-mooring framework Wang et al. (2020), examined how push, pull and mooring factors foster individual readiness to transition to sustainable transportation. The results showed that push factors such as perceived discomfort, drove individuals modes to choose private cars, while pull factors, including system benefits and green transportation campaigns have attracted individual mode shifts to sustainable transportation.

Next, studies that have been conducted in Fresno, California, Cincinnati and Ohio USA, show that the efficiency of transit services needs to be improved to reach population levels for walking and biking (Chen & Wang, 2020). The results of accessibility to multi -purpose roads indicate the need for more efficient green/sustainable transportation facilities for low -income neighborhoods.

Zahran et al. (2008) made an analysis based on a census conducted in the United States related to the space distribution of sustainable types of transportation namely cycling and walking. The results showed that the rate of increase in the amount of cycling and walking as a means of transportation increased with the increase in population density and the concern of the local community. Similarly in the Netherlands, having neighborhood environmental factors that support transportation by cycling and walking methods results in high percentage rates of this type (Wang et al., 2021).

The excellent understanding of the population to promote the implementation of sustainable transportation has resulted in a method called the walking school bus among children to school in Quebec, Canada (Benson et al., 2020). The campaign involves the distance between home and school is within 2.0 km and below. They argued that increases in physical activity, socialization and community participation, and being outdoors could benefit mental health, knowledge of road safety and perceptions of environmental influences were expressed as positive outcomes. Thus, the factors of infrastructure and landscape facilities during the course of these sustainable activities can improve the quality of leisure activities and can achieve the goal of carbon-free sustainable transportation.

# 5. CONCLUSION

Rising urban air temperatures and increased risk of heat wave events are serious public health problems associated with the current main transportation system. Promotion and investment in sustainable transportation can reduce the use of motor vehicles and thus high air pollution while still meeting the needs of a wide range of individual travel options. This will ultimately alleviates traffic congestion and improves quality of life. The large number of private vehicles and the rapidly growing car journey also cause environmental problems such as acid rain, air pollution, and noise pollution in the city.

This paper summarizes and reviews studies on the effectiveness of walking and cycling as a mode of sustainable transportation. The first part comments on the importance of planning a distance between 400m to 1000m within 5 to 10 minutes of travel to a transport facility/transit in a residential area can support walking and cycling activities as a means of sustainable transportation.

The second part of this study shows evidence that green areas on pedestrian and cycling paths such as trees on trails and city parks can cool the environment and encourage these activities. However, a comprehensive understanding of the possible consequences of each planning for the thermal comfort of pedestrians and cyclists is required in the early stages of planning practice.

The third part of the survey shows clear evidence that cycling and walking activities successfully address the problem of dependence on motor vehicles and in turn can reduce carbon dioxide emissions that affect climate change. Among the most important findings is that walking and cycling activities can have a positive impact towards producing a healthy and prosperous environment and community.

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