Turkish Journal of Remote Sensing and GIS
Türk Uzaktan Algılama ve CBS Dergisi

2020 Turkish Journal of Remote Sensing and GIS

Turk J Remote Sens GIS, September 2025, 6(2): 131–143
Journal homepage: http://www.dergipark.org.tr/en/pub/rsgis

Geographic Information Systems-Based Bicycle Parking Accessibility in Sustainable Campus Planning: Erciyes University Campus

Sürdürülebilir Kampüs Perspektifinde Bisiklet Parklarına Erişilebilirliğin Coğrafi Bilgi Sistemleri Tabanlı Analizi: Erciyes Üniversitesi Kampüsü

Ömer Buğra Karakoç[1], Barış Ergen[2]*

[1]*Erciyes University, Institute of Natural and Applied Sciences, Department of City and Regional Planning, Kayseri/Türkiye.*
[2]*Erciyes University, Faculty of Architecture, Department of City and Regional Planning, Kayseri/Türkiye.*

ORIGINAL PAPER

***Corresponding author:**
Barış Ergen
ergen@erciyes.edu.tr

doi: 10.48123/rsgis.1604590

Article history
Received: 20.12.2024
Accepted: 19.05.2025
Published: 27.09.2025

Abstract

Campus areas follow the model of a city, with a unique population, transportation system, and urban and environmental services. They also serve important functions within cities, offering various beneficial services. Consequently, the sustainability of university campuses contributes to the overall urban sustainability. Furthermore, the consideration of campus sustainability involves multiple factors, and transportation is one of the most important. This study examined the areas served by the bicycle parking points located on the Erciyes University campus, particularly the areas within a walking distance of 500 m. The study used geographic information systems (GIS) and network analysis and found that some buildings within the campus were not located within 500 m of the bicycle parking points by walking. Notably, it is not sufficient to determine the service areas by simply considering a circle with a diameter of 500 m centered on the bicycle parking point. This study underscores the influence of bicycle parking locations on campus sustainability and the benefit of using GIS in the planning of transportation infrastructure.

Keywords: *Bicycle parks, GIS, Network analysis, Sustainable transportation, Erciyes University campus*

Özet

Kampüs alanları nüfus, kentsel hizmetler, ulaşım, çevresel hizmetleri ile küçük kent modeli oluşturmaktadır. Kampüs alanları sunduğu hizmetler ile kentlerin önemli parçalarıdır. Üniversite kampüslerinde sürdürülebilirlik kentsel sürdürülebilirliğe de önemli katkılar sunmaktadır. Sürdürebilir kampüs çok yönlü bir yaklaşımı içermektedir. Ulaşım ise sürdürülebilir kampüsün en önemli başlıklarından birisidir. Bu çalışmada Erciyes Üniversitesi Kampüs Alanı içinde yer alan bisiklet park noktalarının 500 metre yürüme mesafesi içinde hizmet ettiği alanlar araştırılmıştır. Çalışmada coğrafi bilgi sistemleri (CBS) ve network analizi metodu kullanılmıştır. Çalışmada Erciyes Üniversitesi içinde yer alan bazı binaların bisiklet park noktalarından 500 metre yürüme mesafesi içinde yer almadığı tespit edilmiştir. Çalışmada 500 metre yarıçap ya da çap ile hizmet alanı belirlemenin doğru sonuç vermediği varılan diğer önemli bulgudur. Kampüs alanlarının sürdürülebilirliği açısından bisiklet ulaşımının önemli oluğu ve ulaşım altyapı alanlarının belirlenmesinde GIS önem arz ettiği çalışmanın sonuçları arasındadır.

Anahtar kelimeler: *Bisiklet parkları, CBS, Network analizi, Sürdürülebilir ulaşım, Erciyes Üniversitesi kampüsü*

1. Introduction: Transportation and Sustainability

The transportation sector is one of the sectors that contributes most to air pollution and greenhouse gas emissions (Yedla, 2015). It affects every component of the natural environment, such as water, vegetation, geomorphology, soil, animal life, and atmosphere, potentially contributing to problems such as urban air quality, ozone depletion, acid rain, and global warming (Black, 1997). Cycling represents an environmentally friendly and healthy alternative to motorized transport in urban areas (Li et al., 2020). In addition, it supports positive environmental impacts by reducing greenhouse gas emissions, minimizing noise pollution, and increasing social interaction (Mora et al., 2021). Integrating cycling and public transportation by providing bicycle parking areas is beneficial to the economy, the environment, and public health (Arbis et al., 2016).

Sustainability is an integrated concept encompassing relationships between human and natural systems (Cabezas et al., 2004), comprising three major dimensions: economic, ecological (environmental), and social (Purvis et al., 2019). Another approach claims that there are four intrinsic aspects of sustainability: economic, ecological, social, and political (Holling, 2001). Sustainable transportation, defined as "meeting current transportation and mobility needs without compromising the ability of future generations to meet those needs" (Black, 1996), has recently become an important goal in transportation planning and related studies (Rybarczyk & Wu, 2010). To develop a sustainable transportation system that provides economic, ecological, and social benefits, the transition from personal vehicles to bicycles and public transportation has gained significant attention (Arbis et al., 2016). Moreover, Capodici et al. (2021) emphasized that geographic information systems (GIS) can be a valuable tool for supporting policy-makers in the development of transportation sustainability and policies.

Walking, followed by cycling, has been recognized as the most sustainable mode of transportation within university campuses (Alhajaj, 2023). Studies have shown that reducing journey times, which includes more sustainable forms of transport than the car, such as bicycles, will ensure sustainable mobility (Dell'Olio et al., 2019). Universities often decide on land use by infrastructure and facilities that can encourage walking or cycling (Kaplan, 2015).

Sustainable transportation planning on the campus can be ensured by promoting sustainable modes of transportation for university campuses (Dehghanmongabadi & Hoşkara, 2018), such as walking, cycling, using public transportation, car sharing, discouraging single-occupancy cars (Dell'Olio et al., 2019; Balsas, 2003) using together with higher parking charges (Dell'Olio et al., 2019), thus, university campuses can provide a laboratory for testing and implementing various alternative transportation strategies, reducing infrastructure costs and minimizing their impact on surrounding areas (Balsas, 2003). There are many immediate, social, and economic benefits to promoting sustainable modes of transportation for university campuses. Besides, universities provide an educational milieu for sustainability (Dehghanmongabadi & Hoşkara, 2018).

Accessibility involves the distribution of destinations and access points surrounding a given location, the ease of arriving at them using various means, and the amount and features available for various needs and activities (Handy, 2020). In another approach, accessibility is a fundamental concept for transportation planning that includes the ease and comfort of people reaching a desired destination and generally refers to physical access to services or an intended destination (Öztaşkın & Levend, 2023). Accessibility using bicycles has recently gained attention (Li et al., 2020); however, it varies according to the purpose of the journey (Miller, 2018). A review indicated that the majority of the studies on bicycle accessibility focus on specific issues (Iacono et al., 2010; Saghapour et al., 2017), and most studies adopt a survey-based approach (Li et al., 2020). However, it is also necessary to evaluate accessibility using quantifiable measures (Murphy & Owen, 2019). While many factors are thought to positively influence the levels of bicycling in urban areas, high-quality, well-connected bicycle infrastructure is widely considered a precondition (Pritchard et al., 2019).

1.1 Transportation and Bicycles

The presence of bicycle parking at destinations increases the convenience of using bicycles as a means of transportation (Mora et al., 2021; Hunt & Abraham, 2007) and the opportunities to use them for business travel (Mora et al., 2021; Noland & Kunreuther, 1995). The availability and quality of cycling facilities have a significant impact, especially on increasing network connectivity (Cohen et al., 2008; Koohsari et al., 2014; Lowry & Loh, 2017). As a healthy and low-carbon form of non-motorized mobility, cycling plays an essential role in supporting the sustainable development of urban transport (Zhuang et al., 2025).

Various metrics are involved, particularly the proximity of facilities or infrastructure to a specific area or a person's location, and the walking distance covering a certain area is often considered in urban planning (Mora et al., 2021). Lee et al. (2020) examined walkability using GIS. Clarence Perry proposed an ideal neighborhood unit based on a walking distance of 0.25 miles in 1929 (approximately 400 m) (McNeil, 2011). Moudon et al. (2006) stated that walking distance had a positive correlation with the environmental qualities of housing and daily shopping (McNeil, 2011). The observations indicate that access to bicycle parking within walking distance is an important factor for sustainable transportation. Studies appear to suggest relatively similar distances, for example, 250–500 m (Eskind, 2024), 300–500 m (Daniella & Wangsa, 2019), and 500 m (Wang et al., 2018; Cinkiş & Erdin, 2022), and Hosford and Winters (2018) accepted a distance of 500 m for bike share points in their study. Therefore, 500 m is generally accepted for the service area of bicycle parking, and accordingly, we used 500 m in the present study.

1.2 Bicycles and GIS

GIS has emerged as an important tool in recent years, which is based on imaging technologies (Ahmed et al., 2017). GIS is used to display, analyze, and manage spatial data and is increasingly used in transportation (Miller, 1999; Nyerges, 1995). GIS service area analysis is often conducted to calculate coverage distances around bus stops or train stations (Gutiérrez & García-Palomares, 2008). The service area used in network analysis is the region that covers all accessible streets (Balasubramani et al., 2016).

GIS analyses help us better comprehend where cycling infrastructure should be located and how it should be given priority (McNally et al., 2023). Veillette et al. (2018) reported that GIS-based approaches could be used for the selection of bicycle parking site locations. However, the determination of bicycle parking locations has received relatively less attention (Veillette et al. 2018). Öztaşkın and Levend (2023) examined access to bicycle parking points with the help of GIS. Overall, GIS-based spatial analysis and indicators provide important inputs for the location of bicycle stations (Bahadori et al., 2021). New bicycle parking locations can be determined by GIS, and it can help find suitable bike paths where decisions are consistent (Guler & Yomralioglu, 2021). Davidson (2023) noted the use of GIS in cycling infrastructure, especially in visualization. Güldü et al. (2024) indicate that there are many methods for bicycle facility planning, and GIS is important in determining bicycle infrastructure and routes. Bicycle planning is an important part of local transportation, and GIS offers a variety of tasks, including advanced analyses, mapping locations, and understanding the connectivity of bicycle networks (McNally et al., 2023). University campuses could be considered as small cities (Nagowah et al., 2019). Therefore, sustainable transportation and integration of different transportation modes are becoming increasingly important. In the literature, there are studies on the integration of different transportation modes in campus areas using Transportation Demand Management (TDM) (Dehghanmongabadi & Hoşkara, 2018; Balsas, 2003), investigating pedestrian behavior (Kaplan, 2015; Alhajaj, 2023), using observational Parking Walking Infrastructure Checklist (PWIC) and Pedestrian and Driver Behaviors Record (PDBR) methods (Alhajaj, 2023), using the Revealed Preferences (RP) and Stated Preferences (SP) surveys approach and qualitative and quantitative research methods (Dell'Olio et al., 2019). In this study, unlike other approaches, bicycle parking area location selections were evaluated for the integration of bicycle parking areas with other transportation modes using GIS and network analysis/convex hull.

GIS and network analysis have been used for a long time and continue to be used, especially in transportation. This study aims to contribute to the existing literature in terms of integrating the data obtained by network analysis with different transportation modes, as well as to investigate the adequacy of bicycle parks located in campus areas within walking distance. In this study, the accessibility of bicycle parking stations at Erciyes University in terms of walking distance was investigated and convex hull method is the originality of the study. The study aimed to identify the service areas of the bicycle parks, the buildings within Erciyes University, and, if any, the areas without service. Are the service areas of the bicycle parks in Erciyes University sufficient for pedestrian walking distance? It constitutes the problem subject of the study. The other problem of the study is whether different modes of transportation can be integrated with bicycle parks. The study hypothesizes that bicycle parks do not adequately serve all buildings on campus in terms of 500 meters of walking distance.

2. Material

This study investigated pedestrian access to the bicycle parking areas on the Erciyes University campus. The study aimed to identify the service areas of the bicycle parks, the buildings within Erciyes University, and if any, the areas without service. Given that measurements determined by radius or diameter are misleading and do not accurately indicate pedestrian movement, 500 m traveled on foot was accepted as the metric. Bicycle parking areas were determined by identifying the parking areas in the CitySurf-KayBis application. Then, the roads obtained from the Geofabrik website (Geofabrik, 2024), which is compatible with the OpenStreetMap app, were updated. In addition to the Geofabrik data (Geofabrik, 2024), the available pedestrian roads within the campus were identified, and the map was updated. The dirt roads that were not designated for pedestrian access were excluded from the calculation. The base map with a satellite image was obtained by adding the Google Earth map from the XYZ Tiles command in the QGIS software.

3. Method

A QGIS network analysis was performed in this study. Network analysis is used in many fields (Büke & Erturaç, 2016), and in GIS applications, it is related to the mathematical subdisciplines of graph theory and topology (Curtin, 2007). Ultimately, network analysis is used to calculate distances between points or nodes on a network, such as roads, paths, and so forth (Comber et al., 2008).

Zhang et al. (2019) created bicycle islands in Shanghai City by network analysis and determined the serviced area by convex hull method. Convex hull has also been used in different studies for bicycle networks (Liu et al., 2024; Putta & Furth, 2019).

Unlike studies that include GIS and network analysis approaches for bicycle parking areas, the use of buildings served by convex hulls in especially campus areas constitutes the original aspect of the study.

Herein, the center points of the bicycle parking stations were identified and marked as centroids. Then, the roads and services within a walking distance of 500 m of the center points were determined using the service area method in the network analysis. The network service area can be defined as the area that covers all accessible streets (Balasubramani et al., 2016), involving the calculation of coverage distances and thresholds on a straight line (Gutiérrez & García-Palomares, 2008). The areas covered by the roads in the service area were then determined using the Convex Hull tool in QGIS. Finally, the service area and buildings located within 500 m of the bicycle parking points were highlighted.

4. Results

First, bicycle parking points were determined based on their geographical center (centroid). In determining the centroids, the Centroids option was selected under the Geometry Tool tab in the Vector menu in the QGIS program interface. The interface to the program is shown in Figure 1.

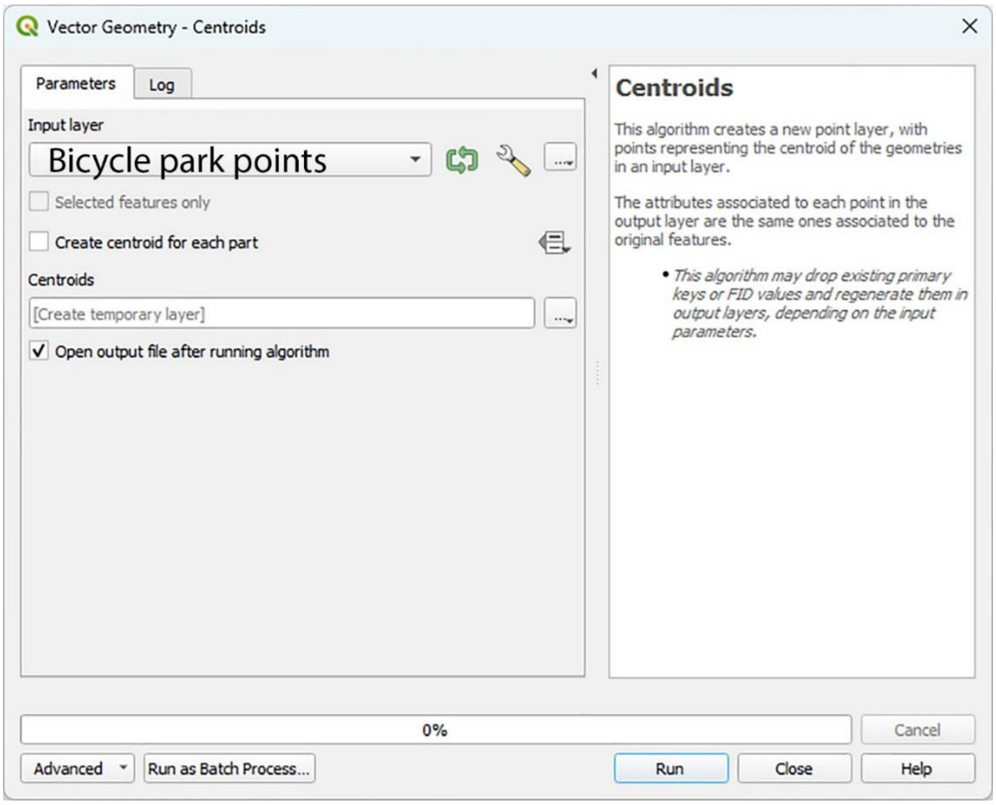

Figure 1. Determining the centroids

When bicycle parking points were selected as centroids in the program interface, four parking areas and centroids appeared. Figure 2 shows the bicycle parking points on the Erciyes University campus, represented as centroids.

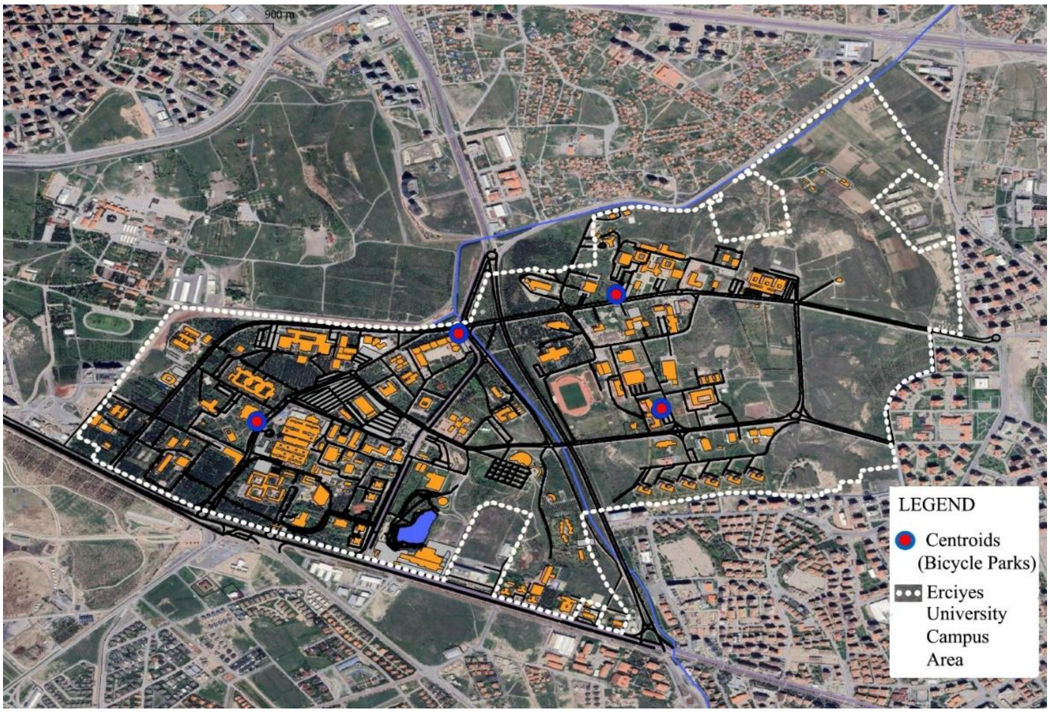

Figure 2. Bicycle parking points (centroids)

Network analysis was used to determine the areas that the bicycle parking points serve. The “service area” command was used in the Network Analysis menu of the QGIS program. After selecting the roads in the service area (from layer), we chose to calculate the shortest path, and the centroids with bicycle parks were selected in the vector layer as the starting points. Then, 500 m was selected as the travel cost because it was considered the maximum convenient walking distance after parking the bicycle. The program interface is shown in Figure 3.

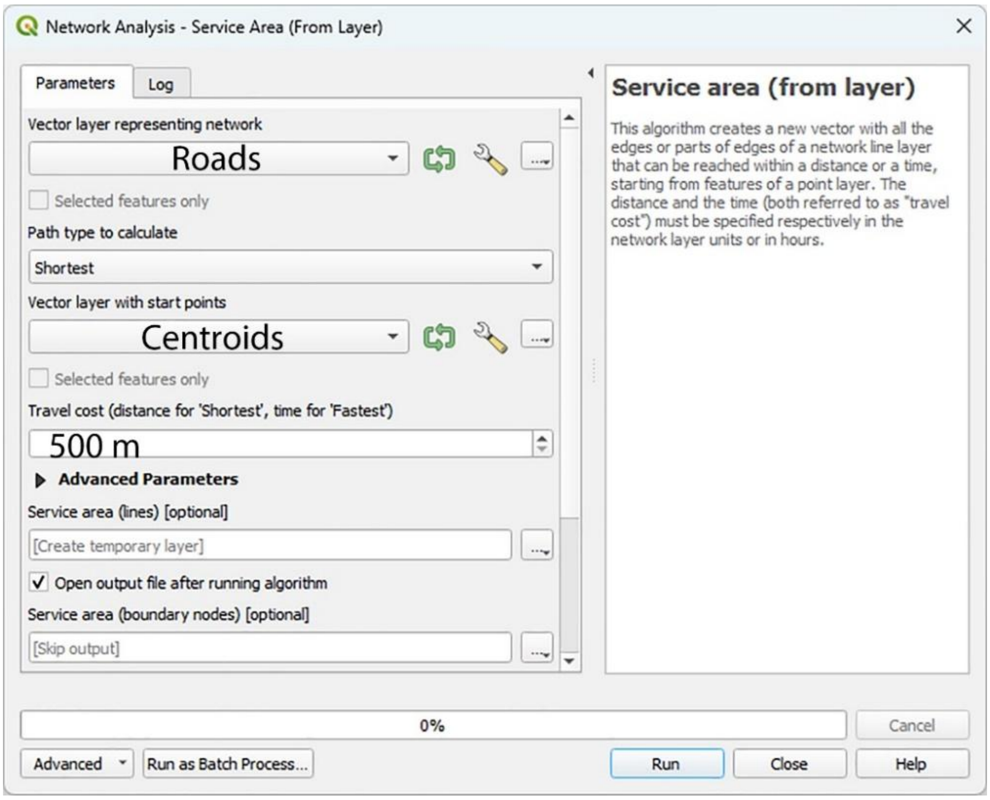

Figure 3. Service areas (from layer)

The results of the network analysis based on the data above are shown in Figure 4. Using the bicycle parks as centroids, the roads they serve within 500 m of walking are shown in red. The roads shown in black are the roads that are not within 500 m of walking from the bicycle parking points, indicating areas where bicycle parking does not serve.

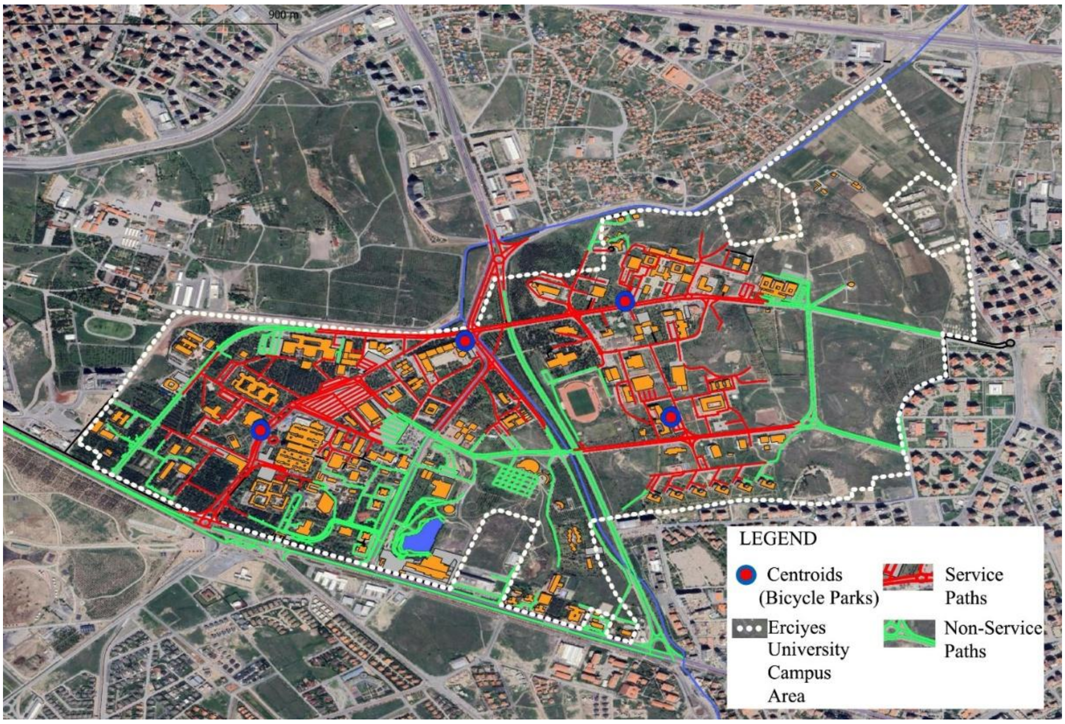

Figure 4. Roads that bicycle parking points serve (within 500 m)

The Convex Hull tool was used in the geoprocessing tools in the vector menu to show the service areas covered by the bicycle parking, as shown in Figure 5. Notably, some areas are not located within a walking distance of 500 m when bicycle parks are considered as the center.

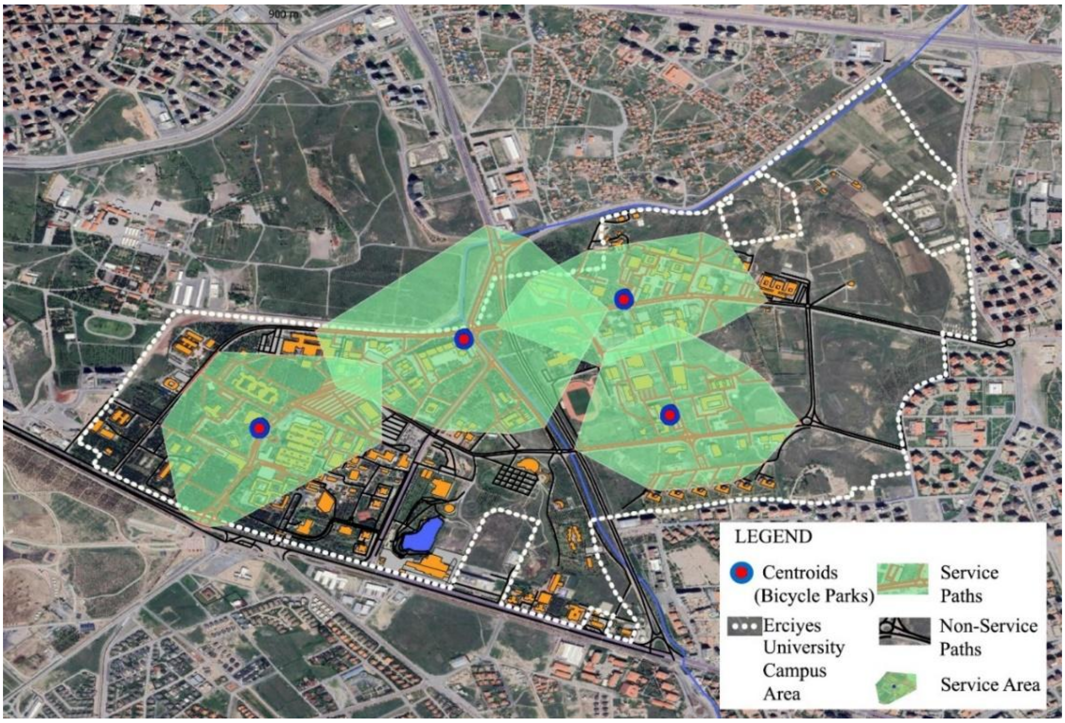

Figure 5. Service areas of the bicycle parking

The “select by attribute” command was used to select the buildings located within the 500 m of walking to bicycle parks. Figure 6 shows the steps required to select the buildings using the Convex Hull tool.

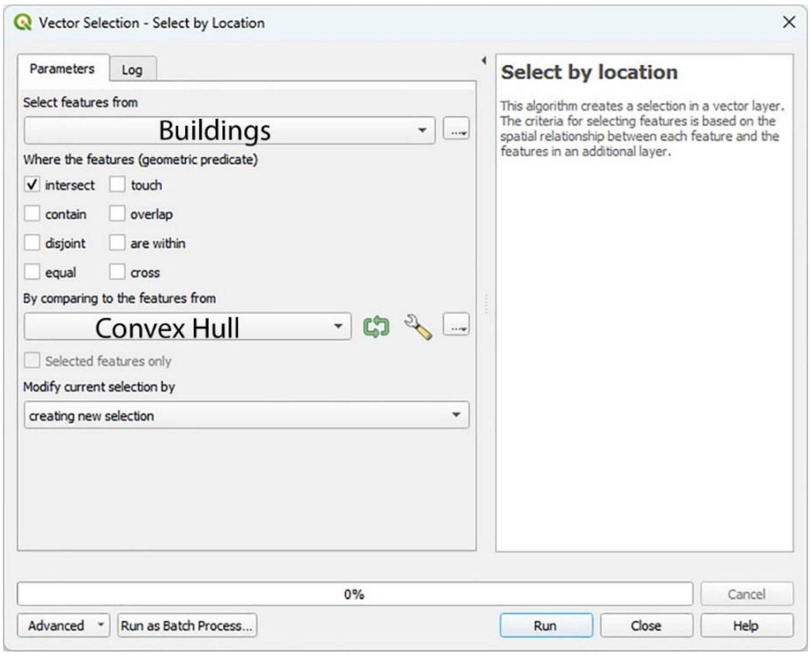

Figure 6. Selecting buildings in the campus area based on location

In the “select by attributes” command interface, in the “select features from” section, all structures on the campus were selected. In the next step, intersection points were selected as geometric predicates. In the “by comparing the features from the section”, the areas obtained using the Convex Hull tool were selected. Thus, the intersection areas of the structures and the service areas were determined. In Figure 7, the buildings located within 500 m of walking to the bicycle parks are shown in yellow. The buildings shown in orange are not accessible within 500 m of the bicycle parking areas.

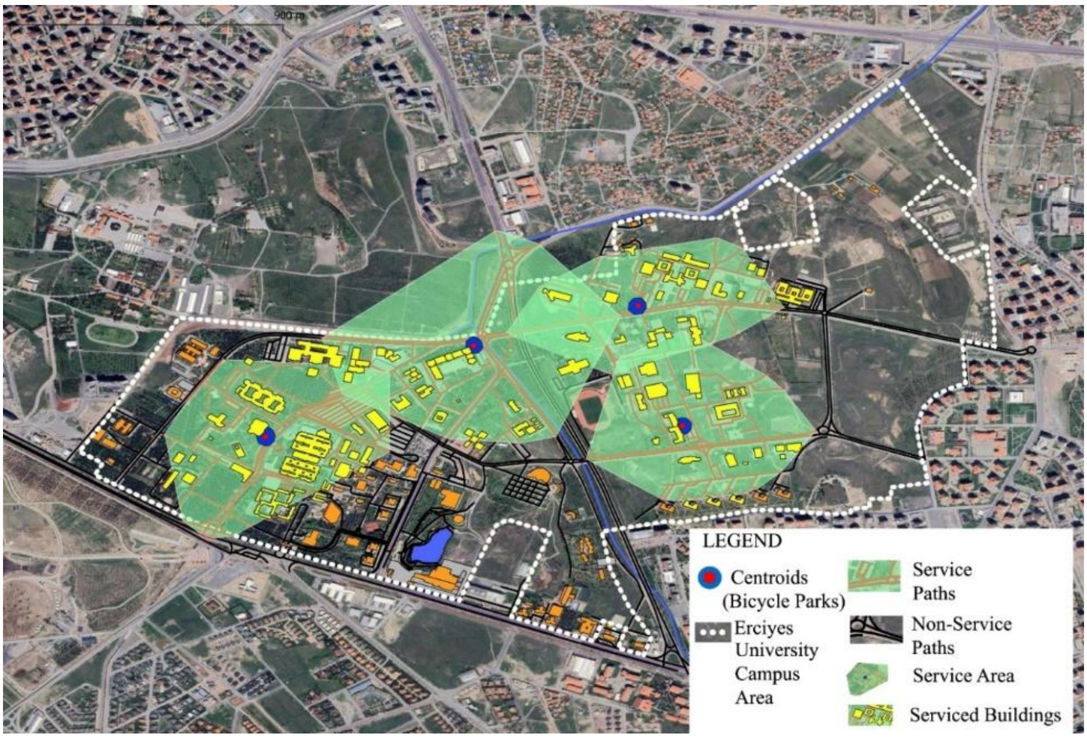

Figure 7. Service areas of the bicycle parking and the included buildings

The walkability study showed that there was no bicycle parking within 500 m of walking to the Faculty of Space and Aviation Sciences, Department of Information Technologies, Sabancı Cultural Center, Faculty of Medicine Classrooms, Old Lodgings, Erciyes University Congress and Cultural Center, Erciyes University Children's Hospital, Hasçelik Training and Research Center, swimming pool, the à la carte restaurant, and Erciyes University Hızıroğlu Training Hotel in the campus area.

5. Discussion and Conclusion

Previous studies have predominantly measured access and walking distance to bicycle parks by radius. In the case of Erciyes University campus, considering the access distance based on the radius or diameter does not accurately reflect the pedestrian movement, including buildings that are not actually accessible.

Figure 8 shows the service areas that can be obtained by determining the accessibility of bicycle parking points based on the radius. If the service areas are determined using the radius, all buildings on the campus may be considered accessible by bicycle parking, except for the Congress and Culture Center, the swimming pool, the à la carte restaurant, Erciyes University Hızıroğlu Training Hotel. However, we found that several more buildings within the campus cannot be accessed within a walking distance of 500 m from the bicycle parking points, as shown in Figure 7.

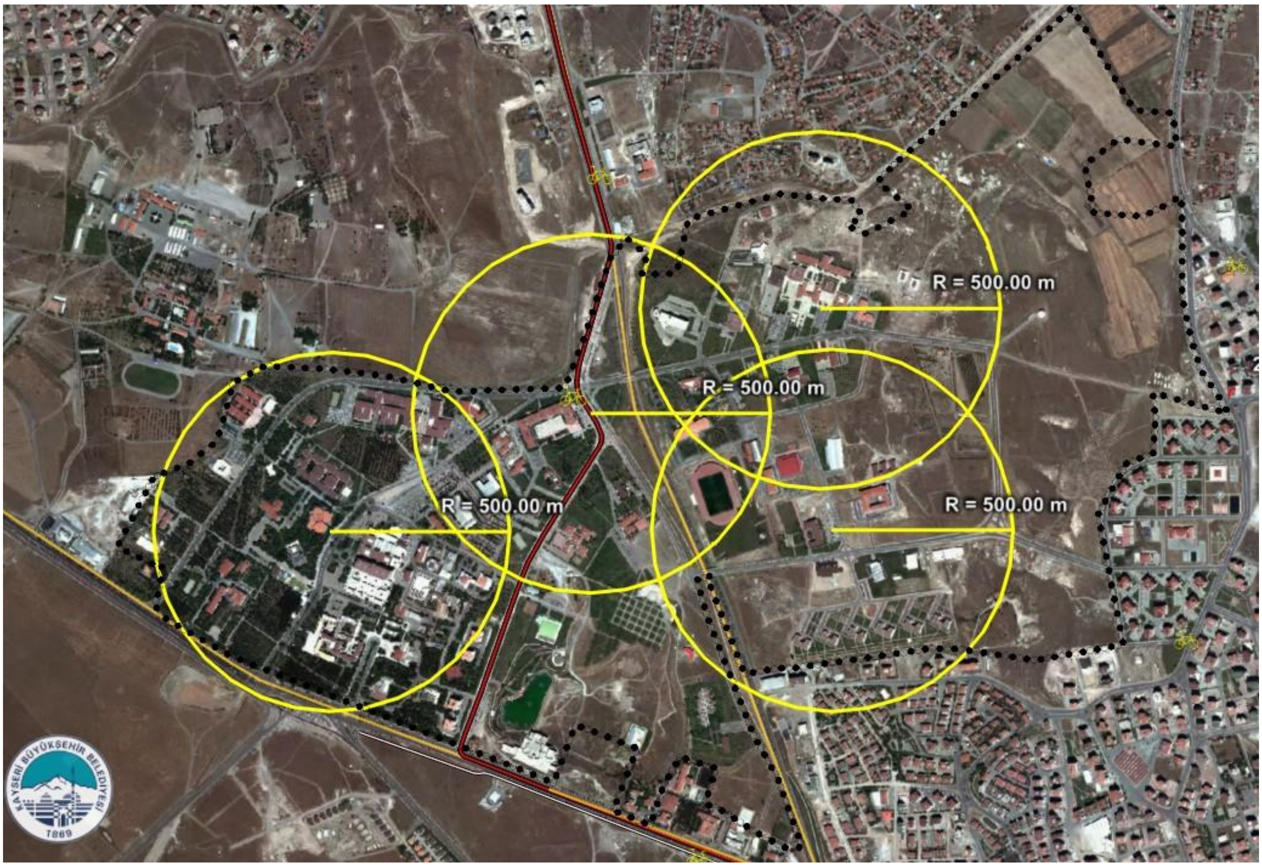

Figure 8. Determination of service areas by radius (Source: Prepared using the Kayseri Metropolitan Municipality CitySurf application)

The comparison of Figures 7 and 8 shows that network analysis provides more accurate results regarding the actual distances that pedestrians will be expected to travel from the bicycle parking.

Based on the results, one of the existing bicycle stations has been suggested to move to a different location, and three additional bicycle parks were proposed to cover the areas that do not receive service. Figure 9 shows the proposed bicycle parking points, the first of which is located at the Faculty of Aviation (west), and the second is integrated with the Erciyes University Hospitals tram stop (in the middle). The third is located near the Erciyes University Hızıroğlu Training Hotel and student dormitory (east).

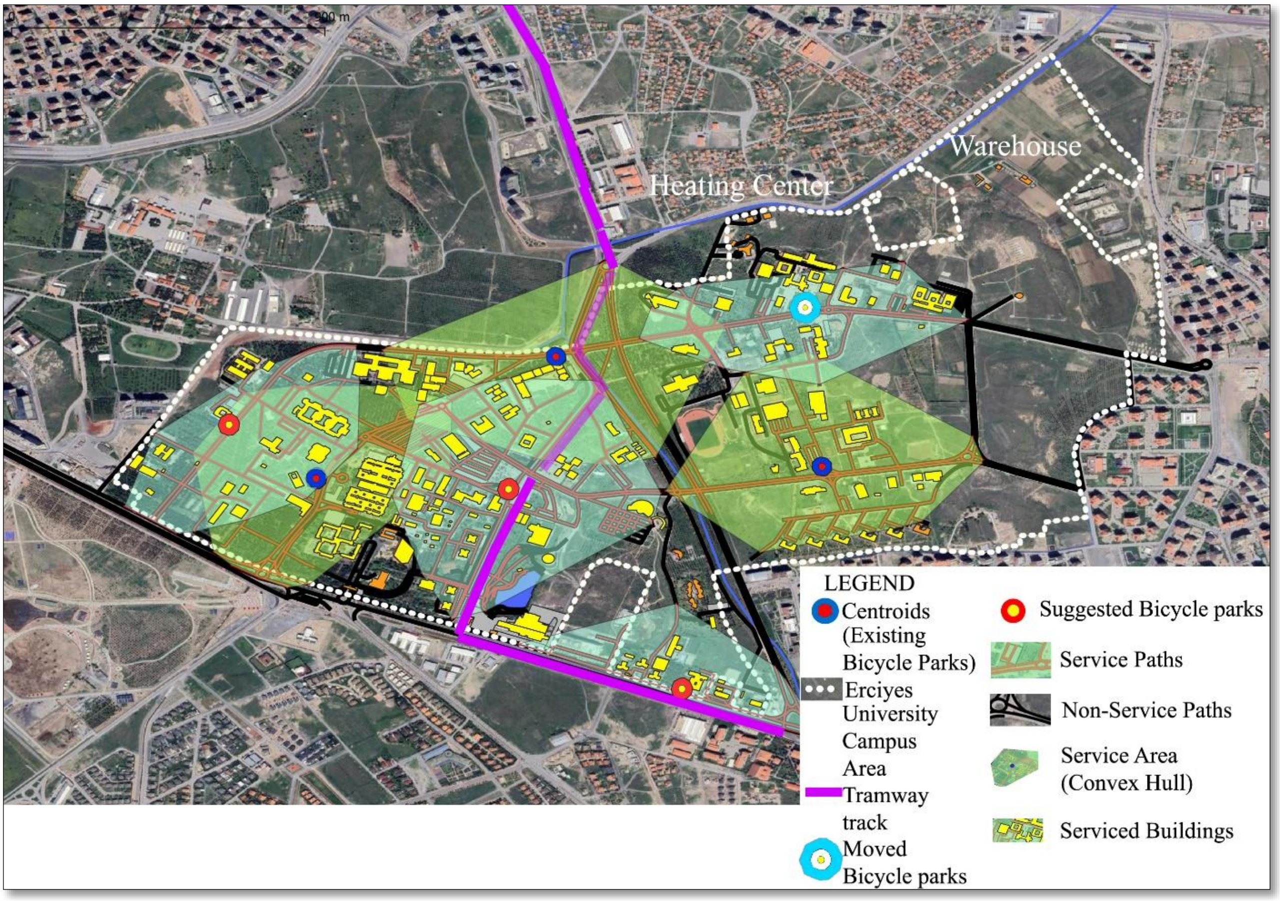

Figure 9. Proposed bicycle parking points and their service area

Figure 9 shows that the proposed bicycle parking points provide access to the entire campus within 500 meters of walking distance. These service areas are represented by the convex hull. Network analysis enables the determination of pedestrian access to encompass all the buildings on the campus, and it is seen that it provides more accurate results in pedestrian access than the radius shown in Figure 8.

The hypothesis that the accessibility of bicycle parks to all buildings is not sufficient is confirmed by this study. The bicycle parks, which constitute the research problem, were tested for providing sufficient access within walking distance of 500 meters, and it was concluded that they do not provide sufficient service to the entire campus within a pedestrian walking distance of 500 meters.

Arbis et al. (2016) have emphasized the importance of integrating bicycle parking points with different types of transportation points and public services in sustainable transportation planning. Ensuring sustainable campus space and greater flexibility among travelers is aimed especially by combining public transportation and bicycle parking station with the proposed bicycle park at the Erciyes University Hospitals tram stop. A bicycle park was proposed on the east side providing better access to the hotel visitors, and considering that the study is ultimately based on the campus area as a whole.

These proposed bicycle parking points aim to integrate bicycle parking with the main bus stops, tramway stops, and parking areas within the campus. Thus, people coming to the campus by different modes of transportation will be able to access the buildings within the campus by bicycle, and people coming to the campus by bicycle from outside the campus will have access facility to different modes of transportation. With the newly proposed bicycle parks, a more environmentally friendly campus environment will be offered as bicycle use will increase on campus, and increased bicycle use will also lead to a decrease in vehicle emissions. In addition, the increased use of bicycles will provide a campus area where people will interact socially compared to individual car use. Figure 10 shows the integration of existing and proposed bicycle parks with different modes of transportation. When Figure 10 is compared to Figure 4, it can be seen that the newly proposed bicycle parks provide access to all campus buildings except the warehouse and heating center within a 500-meter pedestrian walking distance.

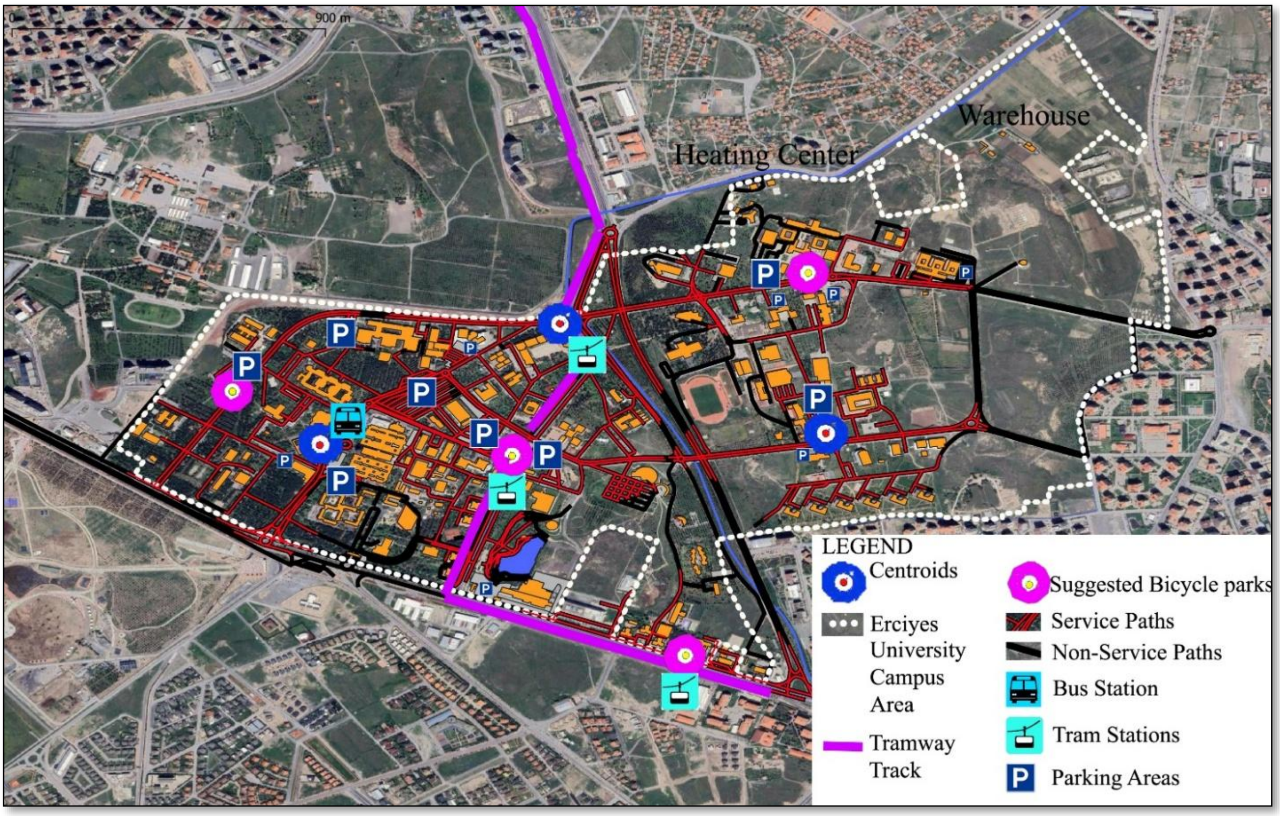

Figure 10. Roads that bicycle parking points serve and relations between the other transportation modes

Furthermore, bicycle parking that integrates with different modes of transportation may positively affect people's decision to choose cycling over the alternatives, considering the convenience and safety of local parking. In addition, if bicycle parking areas serve all buildings on the campus, this may increase bicycle use, which is one of the important points for a sustainable campus. Non-motorized access, specifically pedestrian and bicycle access, not only brings environmental benefits such as less greenhouse gas emission production and reduced acid rain but also less fossil fuel consumption and economic benefits. Moreover, bicycle use may promote more social interaction than individual car use. Ultimately, besides contributing to a sustainable campus, enhanced bicycle use may significantly contribute to the overall urban sustainability.

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