Walkability of Large Parking Lots on University Campuses

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Car-dominated university campuses allocate large areas of land for parking lots, which are major hubs for users to start and end their daily walking trips.

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1. Importance of Walking Infrastructure in Developing Sustainable Campuses and Improving Users' Quality of Life

Walking is known to be the most sustainable mode of transportation on university campuses [1]. The continuity and safety of walking paths are considered to be important factors that encourage users to walk on university campuses. Additionally, several factors, such as the quality of pavement, width of walking paths, quality of crossing areas connected to walking paths, availability of shading elements, and installation of pedestrian signs, are perceived as important, as they affect the efficiency of walking on campus [2].

In general, university campuses in cities include several types of urban open spaces, such as squares, plazas, walkways, green areas, and large parking lots. Satisfaction with the quality of these urban spaces positively affects users' quality of life [3]. Campus sustainability is primarily linked to three factors: ease of movement, accessibility, and quality of the public realm. Interestingly, creating high-quality constructed urban open spaces is linked to enhancement of quality of life, social equity, and sense of place for campus communities [4].

Thus, improving the walking infrastructure in campus parking lots is vital for ensuring campus sustainability and enhancing users' quality of life, as parking facilities are among the top pedestrian accident hotspots on university campuses [5]. This is because drivers tend to select parking spaces near their destinations. However, if they cannot find empty spaces, they continue to cruise until they find parking spaces close to their destination, resulting in excess CO_2 emissions and traffic congestion [6]. Thus, it is necessary to improve the walking infrastructure in campus parking lots in order to create a pedestrian-friendly environment that encourages walking.

2. Behaviors of Pedestrians and Drivers in Parking Lots

Non-use of walking paths is affected by pedestrian behavior when parking farther away from the destination. In this situation, pedestrians walk in a diagonal or semi-diagonal path across the parking lot to reach their desired destinations. The same behavior occurs in parking lots that have pedestrian-friendly infrastructure, as pedestrians tend to select the shortest distance to the destination [7]. This is because walking directly to a desired destination by selecting the shortest route is a natural response [8]. However, pedestrians tend to use designated walkways when they are oriented in the direction of their destination in a way that provides the shortest walking distance [7]. The use of campus walkways is conditioned on having proper accessibility and surfaces to walk on while ensuring that walkways are relatively wide and free of obstacles [2].

Designated crossing areas draw drivers' attention and alert them to pedestrians crossing parking aisles, thus, creating safer crossings [9]. On the other hand, unmarked crossing areas are considered ineffective in influencing the behavior of non-compliant drivers [7]. This is because providing crosswalk markings in conjunction with pedestrian crossing signs while implementing other measures can alert drivers that they are approaching a designated pedestrian crossing area [10]. Furthermore, providing curb cuts to connect crossing areas to raised walking paths can ease pedestrian accessibility [11] and enhance safety. Providing sufficient lighting in such areas can also enhance pedestrian use and safety, particularly while walking at night [12]. Additionally, implementing effective traffic calming strategies (TCS) within parking lot areas is important, as most drivers do not obey the stop signs, markers, and speed limits in parking lots [7].

3. Previous Studies Assessing the Walkability of Campus Parking Lots

Currently, there are limited studies assessing the walkability of parking lots, particularly when compared with the number of studies that have evaluated the walkability of residential areas and main streets.

Bezerra et al. [13] presented a feasible and low-budget framework for conducting an infrastructure risk analysis for pedestrians in a university campus parking facility. The study proposed a checklist for the main infrastructure elements that may create a risk for pedestrians in parking lots. These elements were investigated using 23 questions classified into three domains: parking layout, pavement and drainage, and availability of provision for pedestrians. The importance of the study stems from its checklist, which identifies vulnerable points for the assessment of pedestrian infrastructure in parking lots.

In other previous studies, scholars have assessed the walkability of parking lots without providing a comprehensive assessment of the walking infrastructure or its usage. For example, Alhajaj and Daghistani [14] developed a method containing 10 investigation items for assessing the accessibility and safety of university students' walking routes on car-dominated campuses. Their method was based on four physical zones that constituted a typical student's (car user) walking route: off-street parking, the sidewalk on the parking side, crossing areas, and the sidewalk on the destination side. The significance of this study can be attributed to its assessment of walking in the off-street parking zone through two items: an accessibility item (availability of designated walking paths in the parking area) and a safety item (availability of effective TCS, such as speed tables, in the parking area). Both of these items were assessed using field observations and student questionnaires.

Fotino [15] studied the walkability of three inner-city university campuses in Southern Ontario containing pedestrian streets. The study used a previously developed walkability audit tool consisting of 36 investigation items to evaluate the physical design elements of streets that influence walking. Notably, the audit tool incorporated a "Road Attributes" section that investigated two items: (1) the number of entrance and exit points of parking lots and garages that intersect the streets' sidewalks, and (2) the tendency of pedestrians to walk through parking lots to reach most campus buildings.

Wogalter [16] investigated pedestrian trips and falls in parking lots caused by wheel stops. In the study, Wogalter discussed factors related to visual obstruction, attention, salience, and expectancy. He provided an alternative hazard control analysis, along with solutions to limit the risks associated with pedestrian trips and falls in such areas. Although the study did not consider parking lots on university campuses, it focused on a common physical element used in most parking lots in cities and urban spaces, including university campuses. Wheel stops are widely used in parking lots to control vehicle movement, organize parking, and protect designated pedestrian walking areas from encroachment by cars. **Table 1** provides a summary of the aspects of parking lot walkability assessed in previous studies.

Table 1. Previous studies that assessed the walkability of parking lots.

Studied Part of the Parking Lot	Walkability Domain	Method	Study
Connectivity of sidewalks adjacent to a parking lot Walking accessibility to building entrances through parking lots	Continuity Accessibility	Audit tool (completed through field observations)	Fotino [15]
Parking layouts Parking surfaces Stormwater drainage Designated pedestrian areas	Accessibility Safety Parking facilities	Checklist (completed through field observations)	Bezerra et al. [13]
Parking bay surface obstructions (wheel stops)	Safety	Forensic human factors and ergonomics analysis	Wogalter [16]
Availability of walking paths inside parking lots and their linkage to the adjoining sidewalk located at the parking parameters Availability of traffic calming strategies (TCS)	Accessibility Safety	Walking route checklist (completed through field observations) Student perception questionnaire	Alhajaj and Daghistani [14]

However, all of these previous studies have several limitations. First, they did not investigate the appropriateness of parking lot surface quality for walking; this is important because parking spaces are considered the starting area for walking after parking cars. Second, they did not investigate whether appropriate access points were frequently provided along the parking rows to convey parking users to walking paths (located between bumpers) easily and safely after parking their cars. Third, none of these studies examined the continuity of walking paths when they intersect parking drive

aisles. Fourth, they did not investigate whether the parking lot destination edges provided well-defined, controlled, and obvious access areas for pedestrians to exit or enter the parking space, which could prevent potential pedestrian traffic accidents. Finally, these studies did not comprehensively assess the walking infrastructure in parking lots or investigate its appropriateness and effectiveness by assessing pedestrian and driver behaviors. Therefore, the present research addresses these abovementioned limitations in the existing literature and extends current knowledge by developing a method that comprehensively and systematically assesses both the existing walking infrastructure and its usage in campus parking lots, then applies it to assess different large parking lots on a university campus.

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