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A greenway for sustainable transportation of the university campus: Diyala University as a case study

Amal Fadhil¹, Raad Waheeb²

¹University of Baghdad, College of Engineering, Architectural Department

²University of Diyala, College of Agriculture, Horticulture and Landscaping Department

Email: amal.fadhil@coeng.uobaghdad.edu.iq

Abstract. Transportation is one of the aspects that enable us to achieve sustainability on a university campus, by taking environmental, social, and economic requirements. Walking is a green mode that can be essential to promoting sustainable transport. This study aims to evaluate the ability of campus physical development planning at Diyala University in creating sustainable transport on campus by determining the problems that exist. The research problem was identified in the absence of a comprehensive view of the importance of greenway network connectivity in the sustainability of the campus and the most important barriers that prevent it from being achieved and the incentives to be activated. The methodology used in this study was the quantitative and qualitative approach, by observing the movement problems on campus and imaging as well as defining thermal hotspots using the GIS program, to active modes of transportation through various strategies. Findings revealed several issues on design solutions that related to three levels for campus's greenways, the relationship of (paths-paths) and (paths-buildings) and (paths-landscape) and the identification of vital foci represented by the areas of intersection, movement, and stopping. Consequently, the framework for a guideline to develop this campus and any campus of similar characteristics. Finally, sustainable design for the University of Diyala has been developed.

Keywords: Greenway, Sustainable transportation, University campus.

1. Introduction

In recent years, there has been a strong trend in sustainability among higher education organizations around the world. Campus greening was the first step for universities to take towards sustainability [1]. Greenways are often considered to be a part of sustainable landscapes and societies, they play a wide range of functions to life, such as cultural, historical, or other community importance, in addition to the quality of environmental assets [2]. Many studies cover greenway subjects and show its dimension related to the environment, society, and physical characteristics. C. Gabr, M, Elkadi, HA shows the network of green paths and their relationship to green outer space, and illustrate that Students perform a set of activities related to outer spaces, they can classify four types of outer space activity, Individual, Social, Academic, and Health [3]. P. H. Gobster and L. M. Westphal presented human dimensions of greenways, that are identified in the studies: cleanliness, naturalness, aesthetics, safety, access, and appropriateness of development[4]. To cover this subject, the study shows the most literature review on the greenway to achieve sustainable transportation, with analyses of the most variables.

1.1 Sustainable transportation



Green Transportation is the subtopic of sustainable development connected to transport, The term implies to move from one location to another by cleaner acts[5][6]. Walking is the best mode of transport because they keep route and schedule independent [7]. The environmental, social, and economic outcomes of Walkability as one of the most successful green modes of transportation closely associated with sustainable development and transport [6]. D. H. Kaplan shows in his study the level of sustainable transportation, mainly walking and bicycling, and Identify the transportation infrastructure impediments that can obstruct non-motorized activity such as the discomfort of weather conditions, the problem of busy streets, safety concerns, and a lack of places to park their bikes [8]. Universities have a strategy to achieve a more sustainable transport service to improve walking ability and to use bikes on campus[9]. Walking can enhance one's health and keep the lifestyle healthier. It also improves social engagement, group sense, and health, and increased people mobility, protection of cultural heritage, civic life, safety, quality of life, and living space, Walking people can reduce energy usage, reduce road and parking capacity, reduce congestion, reduce air emissions, reduce the effects on the climate change and decrease the impact on the atmosphere [10]. Thus walking mode is a vital component to encourage sustainable transport on the university campus.

1.2 Greenway

Greenways can be a component of sustainable design, the greenway design approach is ecological in a very wide context, in particular landscape ecology, which also aims to be systematic, collaborative which process-oriented, Greenway in the campus is a liner outdoor space that essentially functions as a path connector, and social space[2]. It has been designed as a complex environment to welcome and explore rather than just move along[3]. Walking is an important physical activity that has many social and leisure implications. It is researched as a means to promote sustainable development. Many experts suggest cycling to improve physical and mental health. New urbanism spectators suggest that walking be accompanied by good design [11].

The significance of campus greenways is the ability to: connect individuals and places; protect natural resources; promote environmental health; appreciate recreational and enrich outdoor environments with immersive and exciting student activities and interact with local communities[3]. The common problems that are seen on these facilities are narrow streets, the absence of shade, and aesthetic elements, The walkways are facilities which become principal modes of mobility [12]. To create a friendly campus for pedestrians, many principles should be adopted such as walkway continuity, paved high quality and sidewalk safety, security in points of interaction width of walkways, accessibility for disabled users, crossroads, and shading factor efficiency [7]. Walking activities can be promoted by the implementation of the walkability concept by enhancing pedestrian facilities, it becomes important to know how well a street can be pedestrian-friendly and protected through a pedestrian evaluation [5].S. S. Wibowo and D. R. M. Nurhalima presented the PLOS (Pedestrian Level of Service) method that can be divided into two approaches, firstly, that only concerns the pedestrian flow; secondly, the walking environment quality approach, including the interaction of the pedestrian flow and movement of the car [5].

Data used for the PLOS analysis was divided into three categories: vehicles and pedestrians traffic statistics, infrastructure (road design and pedestrian conditions), and land use (related to the status of structures, installations, or spaces along the pedestrian path)[5]. These main classes show the outline characters of the walkway and pedestrian paths when the other studies illustrate the different multivariate. Table 1 reviews the essential levels to study greenways variables by analyzing other literature.

Thus, in this paper, the greenway classification to three levels, that depended on the relation between paths and other components of the university campus, which students used through movement and mobility around campus. Firstly, the intersection between walk paths and other vehicle paths. Secondly, the movement through paths to buildings. Finally, nodes that create from the relation between paths and landscape. So, paths-paths, path-buildings, and path-landscape are the main three levels that underlying this paper.

Table 1. Literature review of green way's variables.

field	variables	reference
Sustainable transportation	Continuity, quality, safety, lighting, signage, a width of paths, disabled-users accessibility, quality of crosswalks, and shading element.	[7]
	Improving the students' bus service from housing to university, create a bus service from the staff residence to the university, add new bicycles, club cars, and electric car schemes.	[9]
	Human dimensions of greenways.	[4]
Walkway Characteristics	The layout of the road network, classification of the road, design of the road crosssection, acceptable length, and width of the road.	[13]
	Connectivity, accessibility, safety, and security, comfort.	[11]
	The pedestrian walkway, destines, safety element, pedestrian facilities, enjoyable.	[10]
	Sidewalk and walkway, crossing, street furniture and amenities, roof and shades.	[14]
	PLOS: user characteristics traffic, safety, and comfort land-use infrastructure.	[5]
	Safety, security, connectivity, proximity, comfort.	[6]

1.2.1. Path - Path: Path to path means the relation between the walkways for pedestrians and other transform paths, to achieve safety, it should study the intersection points and determine the problems. The essence of green transportation would be a walkability strategy plan for pedestrians to move around in a safe and clean environment[6]. Road connections configuration are campus ring route, campus branch path, campus checkerboard path, and campus free-form path[13]. Safety is the danger of pedestrian accidents associated with traffic confrontation, pedestrian structures should be planned according to the idea of possible resolving conflict[5]. The campus checkerboard layout is also evident that the straight-line style is wider, accessibility is bad and it is not simple to divert traffic flow, local traffic-concentrated areas are vulnerable to congestion, and on-campus cars will travel too quickly in a straight line, and it is easy to build a concealed safety hazard[13]. It is also apparent that a long core transit could lead to awkward campus transport; at peak campus traffic, the core of the center road pressure could contribute to congestion, traffic impacts, and the general appearance of a camper[13]. The foregoing shows the relation between path to path demined safeties at the intersection point.

1.2.2. Path - Building: accessibility / comfortable Path to Building means to study the path's characters to engorge walkability. The provision of pedestrian infrastructure would have an impact on the environment along the path, as well as on the psychological views of the pedestrian, a good provision of pedestrian infrastructure is therefore indeed an important factor that affects the number of pedestrians [14]. The campus paths are the reflection of people's linearity operation, the interaction between building and round space, the campus must be connected to all the other elements of the road, the layout of the route has been defined by the spatial configuration of the campus [13]. A. Bolshakov in his study recommended the maximum distance for pedestrian routes on campus should not exceed 800 meters, additional accommodations, teacher residences, and academic buildings should be within pedestrian availability [15].

A pedestrian facility should be able to adapt to existing pedestrian traffic and let pedestrians feel comfortable from the provision of environmental protection or rest areas[5]. Comfort is the major feature in a walking activity that needs to be balanced with a fair degree of accessibility[11]. The importance of trees in shading pavements and streets and achieving the thermal comfort of pedestrians in hot summer periods, albizia lebbek indicated that the best types of afforestation[16]. The cases referred to above explain the relation between the path to a building requires accessibility and comfortable along the walkway.

1.2.3. Path - landscape: attractive / connectivity Path to landscape means to study the connection between paths and green open space to achieve society activation. Greenways offer valuable incentives for continuous connection with nature; intellectual and motivational learning about the biophysical environment and natural systems; and appreciation-building on the role of humans in influencing their environmental climate[2]. Greenway networks are essential components for obtaining a high level of connectivity and continuity and for improving a positive and active learning environment [3]. The best walking experience is when comfort, the aesthetic of the scenery, and other elements come in[11]. Greenways will better serve as a forum for environmental education and environmental art, all of which are important for the relationship between community and nature, as well as offering more immediate awareness and inspiration [2]. Connectivity is essential because it enables customers to switch between spaces. Effectively, Lane's connectivity means more efficient routes and thus a shorter path from a location to a destination [11]. The foregoing presented the relationship between the path to landscapes demined attractive and connectivity in nods points.

2. Material and case study

Diyala University is located 11 km north-east of Baquba city, the center of Diyala, and the university area is 1654774m² so that the university site is a young urban area in al-Nissiya to the city, the location is good for its proximity points to the city, where vehicles can be reached within 15 minutes. Some of these paths active and the other ineffective, the research go to determine constraints that prevent the integration of pedestrian paths and assess occupancy of the university campus. In figure1, a satellite image for Diyala University shows buildings and paths. In figure 2, a site plan shows paths and parking for the university campus. Besides, figure 3 illustrates the thermal hotspots using the GIS program.

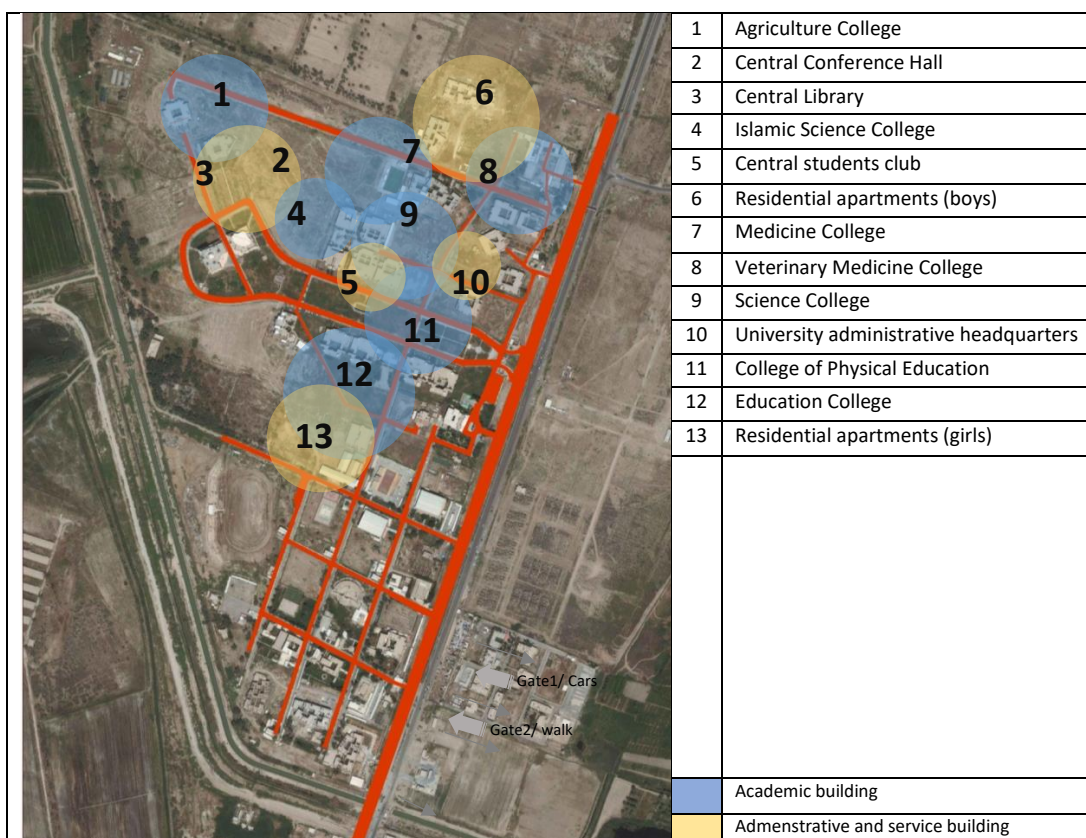


Figure 1. A satellite image for Diyala University shows buildings and paths, ArcGIS 2020, dimensions (1122x 1588) pixels, edited with Ps.

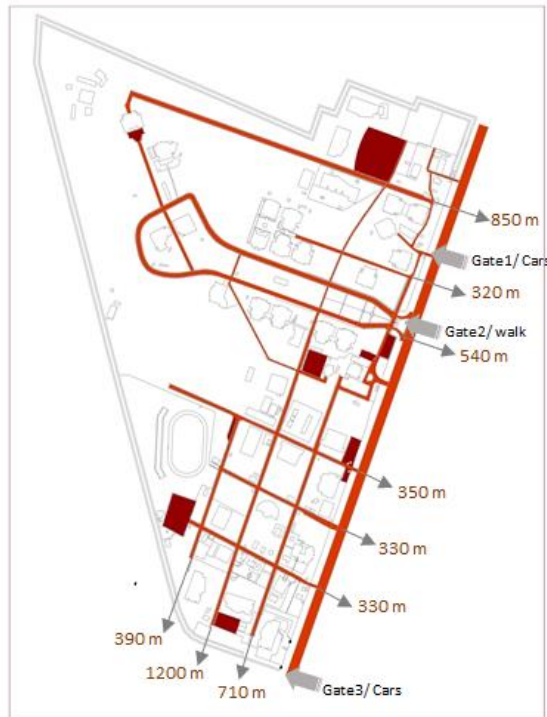


Figure 2. Paths networks and parkings for Diyala university campus, Athour with CAD

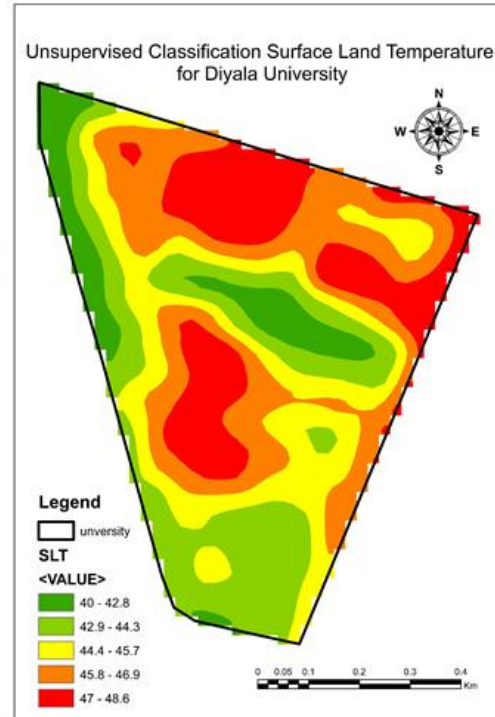


Figure 3. Thermal hotspots using the GIS program, for Diyala university campus.

3. The measurement's method

The quantitative analysis method, a multi-level model, was designed to check the important aspects of the greenway. These aspects are categorized into a series of variables and sub-variables in the theoretical model. They are safety, accessibility, comfort, attractiveness, and connectivity. These variables are derived from the literature review. The suggested model would investigate the most important variables impacting the pedestrian movement of the greenway in terms of green transport. For the aims of the study, the Diyala campus will be divided into three zones, depending on the type of their grouping, their relationship to a district. The first, zone is A that contains medicine college, veterinary medicine college, and the college of agriculture. Zone B includes science collage and Islamic science collage. Zone C covers physical sports college, college of education. These academic buildings connect with administrative, service, and resident facilities by a network of paths. The research goes analyses green way indicate in three levels, path-path, the path to building, path to the node.

The research chose 22 cases of the intersection path of a pedestrian with bath road of vehicles and chose 16 paths to connect with buildings. Then 11 nodes represented the relation of the path with the landscape that uses to gathering students for social activity as shown in Table 2. Figures 4, 5, 6 show the details of intersections, paths, and nods. Table 3 illustrates the checklist to assess greenway variables.

Table 2. Name and number of cases

		Zone A		Zone B		Zone C		All cases
Path-path	crossroad	1c	2c	9c	10c	-	14c	22
		3c	4c	11c	12c	15c	16c	
		5c	6c	13c	-	17c	18c	
		7c	8c			19c	20c	
						21c	22c	
Path-building	pedestrian	1p	2p	-	6p	11p	12p	16
		3p	4p	7p	8p	13p	14p	
		5p	-	9p	10p	15p	16p	
Path-landscape	node	1n	2n	5n	6n	-	8n	11
		3n	4n	7n	-	9n	10n	
						11n	-	

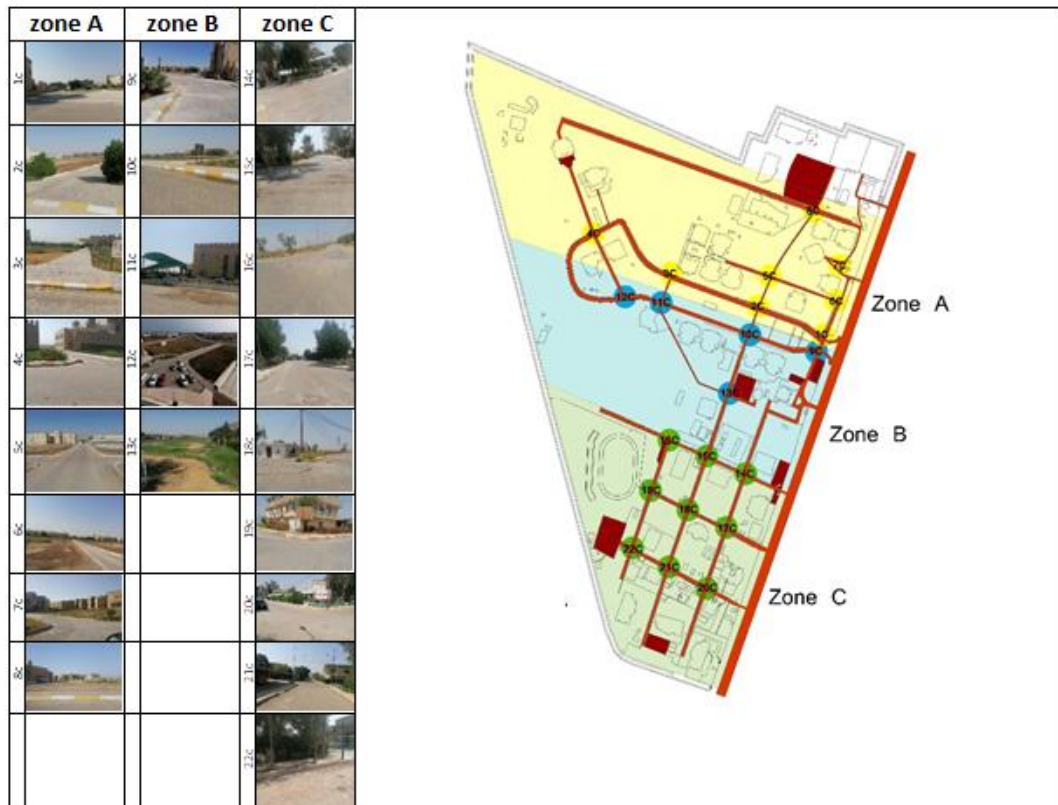


Figure 4. Plan and photos show the intersections (path-path), authors

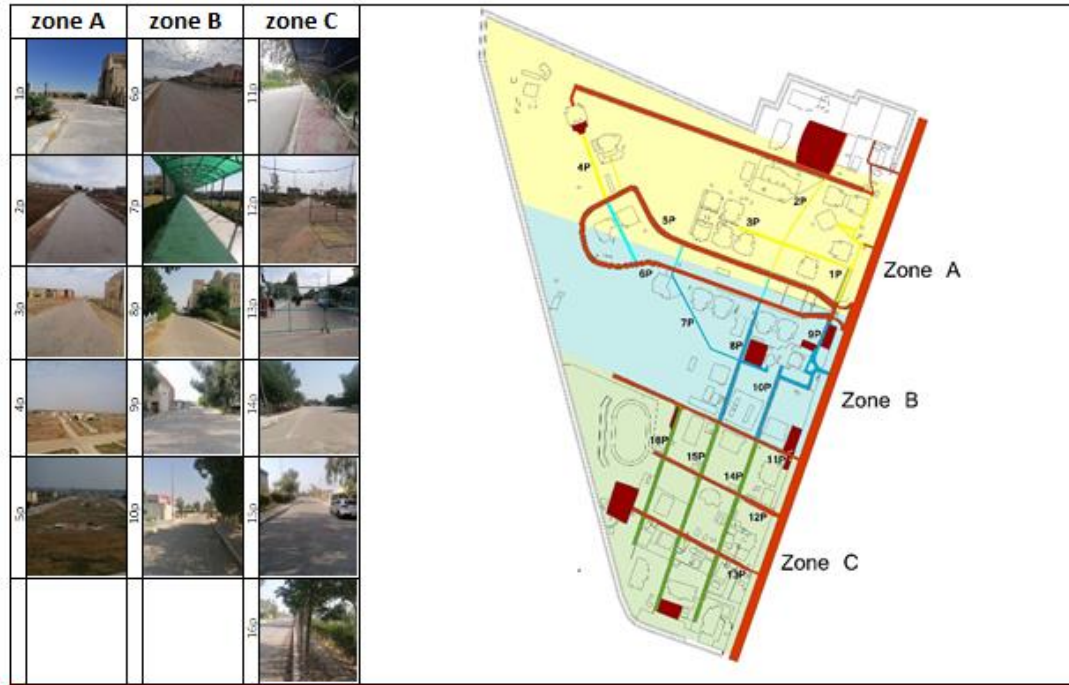


Figure 5. Plan and photos show the paths (path-building), authors

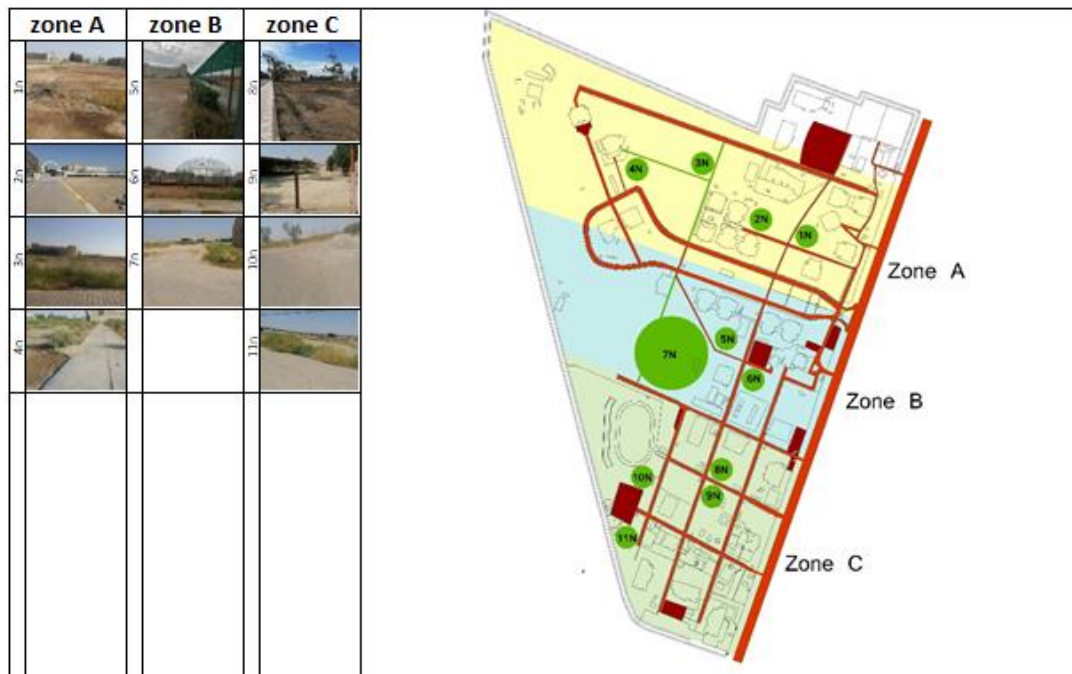


Figure 6. Plan and photos show the nodes (path-landscape), authors

Table 3. Checklist to assess Green Way variables.

levels	relation	Variables	Sub-Variables	Possible values	zone A	zone B	zone C	result	
Path to path	crossway-intersection	safety	Cars	High conflict with pedestrian	18.2	13.6	4.5	36	
				mild conflict	13.6	13.6	40.9	68	
				no conflict	0.0	0.0	22.7	23	
		Parking	blocked pathway	4.5	18.2	4.5	27		
			No blocking	31.8	4.5	36.4	73		
			Barrier from cars	Available	0.0	0.0	13.6	14	
	Not available	36.4		22.7	27.3	86			
	Path to buildings	pedestrian-walkway	Accessibility	Sidewalk - street	one sidewalk	0.0	6.3	0.0	6
					tow sidewalk	12.5	18.8	37.5	69
					no sidewalk - only street	12.5	6.3	0.0	19
				pedestrian width	only pedestrian way	6.3	0.0	0.0	6
					less 1.5 m	0.0	6.3	6.3	13
1.5- 2 m					12.5	18.8	18.8	50	
pavements			3 - 4 m	6.3	6.3	0.0	13		
			concrete	0.0	18.8	0.0	19		
			Brick	12.5	6.3	0.0	19		
			concrete tiles	0.0	0.0	37.5	38		
			marbles	0.0	6.3	0.0	6		
			asphalt	18.8	0.0	0.0	19		
			Disable facility	available ramps/slope	0.0	0.0	0.0	0	
				not available	31.3	31.3	37.5	100	
			Fences	fixed by fences	0.0	6.3	31.3	38	
No fences	31.3	31.3		0.0	63				
Signs	Guidance/Motivational	0.0	18.8	12.5	31				
	not signs	31.3	12.5	25.0	69				
mf	ert	Shading	By trees	0.0	18.8	18.8	38		

Path to landscape	node-stop	attractive	Service	By surrounding buildings	0.0	12.5	0.0	13
				By artificial shed	0.0	6.3	12.5	19
				No shadings	31.3	6.3	18.8	56
				Lighting	0.0	18.8	37.5	56
				Trash cans	0.0	0.0	0.0	0
				no service	31.3	12.5	0.0	44
				Fountain	0	0	0	0
				Statues	0	0	0	0
				not available	36	27	36	100
				Benches(seats)	0	0	0	0
				not available	36	27	36	100
				Soft cape	flow	18	18	0
not flow	9	9	36	55				

4. Result and discussion

4.1. Path to path

The first level of greenway application is represented in the intersection relation between paths to paths. Safety must be achieved in the network planning by three points, related to car movement and parking location and if the barriers available between pedestrians and vehicles. First, cars, which is shown by survey and observation, intersects with the movement of pedestrian students at the main gates and campus entrances, 36% of the elected samples achieved a crosswalk with high conflict, and 68% mild conflict, and only 23% of ways no conflict. That’s mean the campus greenway, not safety. Zone A has a high ratio of conflict when zone C’s way no conflict because 13P closed to be walkway only.

Second, parking, which blocked the walkway and effect on the flow of students, 27% of Parking was located near the intersections, which cause crowded and unsafety movement, and the high ration in Zone B, because a load of cars in this area have parking between building. Third, barriers from cars to make safety to students, 86% of cases haven’t any type of barriers. Only 14% of cases have barriers in zone C, as previously tagged in 13P. In general the crosswalk in the Diyala campus not safe to flow students. Check Figure 7.

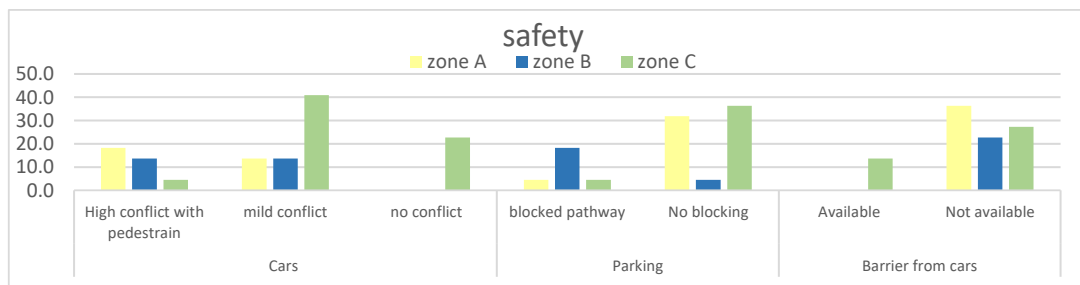


Figure 7. Result of applicable values for safety.

In general, the main impediment in this level is represented in the intersections related to car entrances that can be identified by two gates only because close the rest gates of campus. At the same time the crossways 7c, 1c, 9c are linked to the active entrances of the campus causing the most incompatibility

with pedestrian flow. The pathway between sections 8C and 21C also runs through the campus between residential apartments for boys and girls and public transports stops. The largest percentage of pedestrian students use this route. The pathway also overlaps at 6C and 5C with automobile routes to the College of Medicine buildings. It crosses over with traffic at 2C, 10C heading for the central library, the conference hall, and the Faculty of Agriculture. When moving from zone A to zone B, the intersection is strong at 13C, then moving to zone C, in which the density of the vehicles decreases at the intersection with a lower conflict.

4.2. Path to building

The second level of greenway application is represented in the relation between paths and buildings by pedestrian walking. Accessibility and comfortable are the main variables in this level, each one has sub-variables that are tested in the checklist. The result illustrates in the sidewalks adjust streets, 9% have one sidewalk, 69% of cases have two sidewalks, 19% haven't sidewalk only street, in this zone the student uses the street to walk, it's unsafety and disables reach to the building. 6% only pedestrian way, it encourages students to walk. The second sub-variable is pedestrian width, 13% of the path's width less than 1.5m, it's unsuitable to walk, 50% of cases 1.5-2 m, and it's also not agreeable with the student numbers. and 13% of paths width 3-4m, which promote student walk .the result shows the pavement material of paths between concrete, brick, and tiles in ratio 19%,19%, and 38%, this material suitable, but 6% slippery material in the active walkway, and 19% of paths asphalt which it for cars, not pedestrians. The fourth sub-variable is disabled tools to make the walk more easily, 100% of paths haven't any treatment as ramps or slopes. The fifth sub-variable fences, 38% of paths surrounded by fences that prevent students to contact the landscape during using them. and 63% haven't fenced but no landscape to flow in. the last sub-variable sings, the result shows 69% of paths do not have any signs of Guidance Motivational, and only 31% of cases have signs that motivated the walking. figure 8.

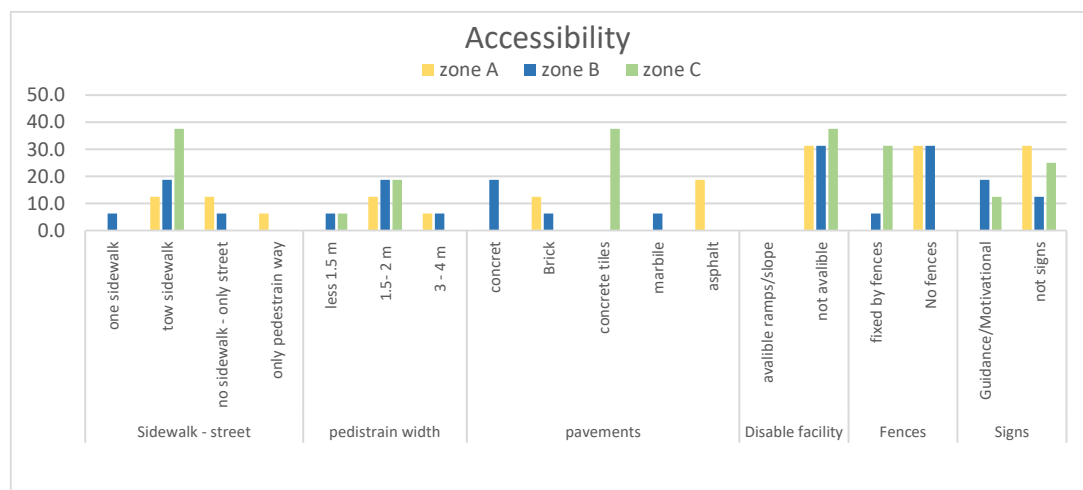


Figure 8. Result of applicable values for the Accessibility.

The other variable in the level path-building is comfortable, that have two sub-variables, shading and provide services. The result illustrates that 38% of paths shading by trees and 13% shading by adjoining building, and 19% shading by the artificial shed, while 56% of paths no shading, these paths are concentrated in zone A. the other sub-variables was service available which help to more comfortable, the result show 56% of paths have lighting, that located in zone B and C, while zone A don't supply with lighting, 44% of cases not have services. figure 9.

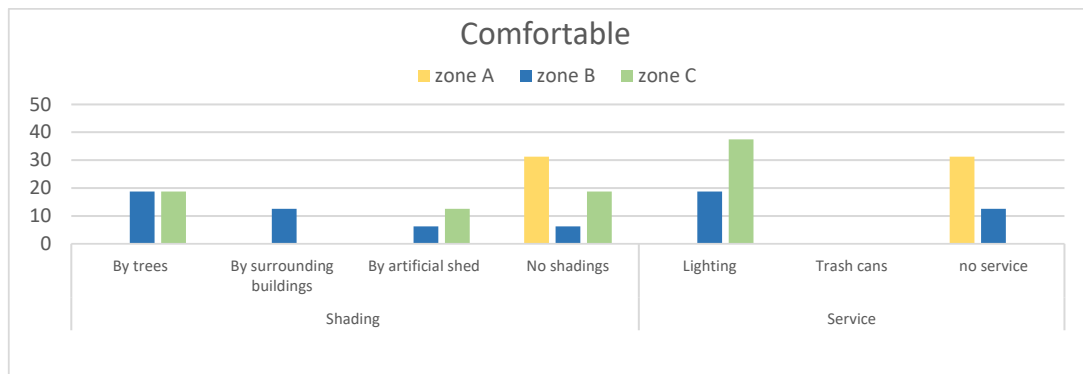


Figure 9. Result of applicable values for the comfortable.

In general, by analyzing the results of this axis, the most important obstacle to the activation of a greenway on the campus of Diyala University is the weak performance of the zone A pathways, which makes Walking in summer periods unacceptable, As well they are not supported by services, lighting, and signs. Zone B has paths 8P .15 P that are dynamic with student movement but narrow sidewalks require students to share streetcars to reach their goal. 13P is the only path for students walking, but it was not designed as a pedestrian path, but rather a car route, so it should be pavement with suitable material. For zone C, all the paths are ineffective for their width less than 1.5m, and the presence of the fence that prevents their integration with the green spaces. But it is a warm-up because of the shading by trees

4.3. Path to landscape

The third level of greenway application is represented in the relation between paths and landscape by nods. Attractive and connectivity are the main variables in this level, each one has many sub-variables that are tested in the checklist. Attractive is one of the variables that result show 100% of cases don't have features as fountain or statue, although a lot of features founded on campus but they ineffective space. and 100% of cases don't have amenities such as seats in landscape nods, despite many seats founded on campus, but they located along the paths that width no more than 1.5 m, whereas preventing students to use the benches with effective, figure 10.

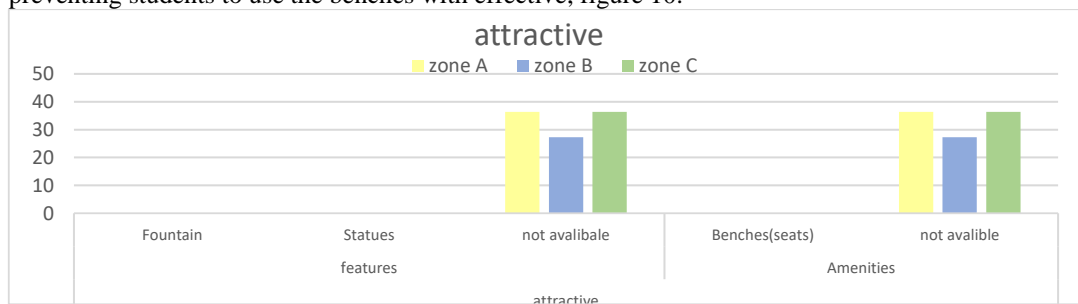


Figure 10. Result of applicable values for the Attractive.

The other variable was connective with the landscape, the result shows that student movement flow easy in zone A and B in a ratio of 36%, but no landscape design to integrate with paths and encourage students to walkability. And 55% of cases not flow, which concentrated in zone C, because surrounded the paths with fences. This level of path-node illustrates the big problem of greenway in the Diyala campus that Inflict obstacles to integrated paths with the landscape, figure 11.

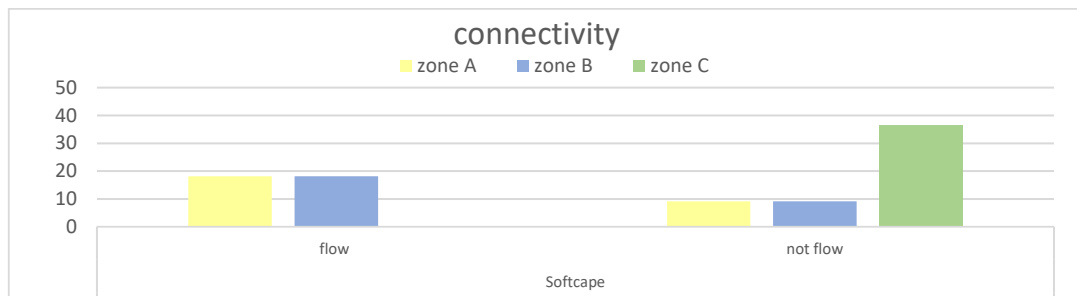


Figure 11. Result of applicable values for the connectivity.

Overall, this level shows the absence of attractive nodes for students during the path of movement. In Zone A, absent the designing nodes, despite direct contact between the path and adjacent green spaces. In Zone C, the specific fencing of the tracks prevented integration with the landscape. This finding is evident in the fact that most of the paths in the Diyala campus are not active greenway. This means that the walking system is loosely connected and discontinuous on its campus.

5. Recommended and improvement

Discussing the previous findings of the checklist shows that the greenway is not in the right orientation that contributes to the sustainability of Diyala's campus. A set of applicable recommendations must therefore be undertaken:

- About other traffic routes from private and public vehicles, the search recommends opening the 11P gate to reduce the momentum of the traffic in the main gate. And use speed tables, crossroad lines as a kind of deceleration from their conflict with pedestrians.
- To increase safety, use barriers between streets and sidewalks to prevent students from getting down the street. These barriers can be green strip or any kind of simple barrier.
- The need to activate the path 2P, 8P, 15P cause being a vital path that links the 3 zones of the campus, and connects the academic, administrative, and residential buildings. It must transform the path from the movement of the car to pedestrian, and the treatment at the intersection of point 8C, 2C, 10C, and 15C. As changes pavement material from asphalt to brick, and fences surrounding the path is lifted, also activated the node on the 1N, 6N, 8N, 9N.
- Rehabilitation of the 13P route to be suitable for pedestrian movement by changing the pavement material, tree-planting, and furnishing.
- For disabled people, they must be considered in the planning and design of the Greenway by providing slopes.
- The need to provide greenway furnishing with seating, waste bins, motivational signs, art pieces, and fountains within the nodes to attract students and provide comfort zones within their walkway.

6. Conclusions

The activation of a greenway on the Diyala University campus contributes to the sustainability of transportation at the university campus. However, the movement of students is being opposed by many of the problems that the research has identified to provide solutions for sustainable transport development. The research has suggested three levels to identify the greenway activation indicators. It was the relationship of paths to other motor paths, and the paths to buildings, and the paths to the landscape. The campus was divided into three zones based on the nature of the gathering of academic and public buildings and how they were linked to the movement network. The results showed that the obstacles were represented by the 2P,8P,15P route, which together represented a vital artery for the student movement on campus and could be activated by adopting the indicators referred to in the recommendations and at the three levels. This research is also the beginning of a series of studies that can cover each of the Greenway on campus.

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