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RESEARCH ARTICLE

Rethinking the campus transportation network in the scope of ecological design principles: case study of Izmir Katip Çelebi University Çiğli Campus

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Abstract

The concept of sustainability, which has become increasingly important in every aspect of life, has become a topic that is often emphasized for university campuses, which can be considered a small urban model. Many universities in Turkey and abroad are working on sustainable campuses. They set many environmental, social, and economic targets such as reducing the carbon footprint, using green technologies, designing by human and environment oriented principles, using green transportation systems, reducing costs, and eliminating social injustice. In this study, the transportation network of İzmir Katip Çelebi University, Çiğli Campus, which was established on an area of 70 ha in 2010, was examined within the scope of sustainability and ecological design criteria, and a transportation network focused on pedestrian and bicycle was also suggested. This study consists of two stages. In the first stage, the current situation analysis of the campus transportation was presented, and in the second stage, recommendations were made for a sustainable transportation system within the campus, taking into account the ecological design criteria.

Keywords Ecological design principles · Sustainable campus · Sustainable transportation

Introduction

Universities have always had an important role in social, economic, and political life changes. These important national and global positions make universities one of the key organizations toward achieving sustainable development at different scales and in all dimensions. This increases environmental and social responsibilities on and off campus. Education and training is the most important tool in fulfilling these comprehensive responsibilities. Sustainable development through education, research, and information transfer from universities is expected to be innovation centers. In this context, sustainable university campuses are gaining importance. It is not possible to have a sustainable world in a place where universities

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support unsustainable conditions, and it is possible to say that the universities could act as a catalyst to create a sustainable world (UNEP 2013). One of the most important initiatives in this regard is the Declaration of Tallories, which defined the ten steps to be taken for sustainability as a result of the conference held in Tallories in 1990. This declaration has been one of the most important foundations for sustainable universities. Today, more than 400 universities from over fifty countries have signed this declaration (UNEP 2013; Osmond 2013; McMillin and Dyball 2009; Mendoza et al. 2019; Amrina and Imansuri 2015; Toor and Havlick 2004; Villegas-Ch et al. 2019; Sesana et al. 2016). The Declaration of Tallories, along with many initiatives for sustainable universities, has also led to many later reports and declarations on the issue. In this context, in 1990, the National Natural Life Association of America "Campus Ecology Program" was established and played an important role in the development of sustainability in universities. The United Nations declared the 2005–2014 decade as the Education Decade for Sustainable Development and represented the goals globally. In 2010, the International Sustainable Campus Network (ISCN) and the ISCN-GULF Sustainable Campus Declaration were established. In 2011, under the umbrella of the Global Universities Partnership for Environment and Sustainability (GUPES), a guide to the design of sustainable university campuses was prepared by the Greening Universities Initiative, which was established under the leadership of the United Nations Environment Program (UNEP) and the Environmental Education and Training Unit (EETU). These declarations and agreements require high commitment, such as vision and mission, for signer universities, but they are a general guide to a sustainable future. Universities should use these guides to create their own sustainability visions and policies (UNEP 2013; Osmond 2013; McMillin and Dyball 2009; Mendoza et al. 2019; Amrina and Imansuri 2015; Toor and Havlick 2004; Villegas-Ch et al. 2019; Sesana et al. 2016).

Evaluation of the work of universities on environmental issues is a very new issue; "Green League," "Environmental and Social Responsibility Index," "Sustainability Tracking and Assessment System-STARS," and "Green Metric" are several examples. Among them, Green Metric is the first global metering system and stands out (Grindsted 2011; Suwartha and Sari 2013]. However, there are guides that are not intended for evaluation purposes but can be useful nonetheless. The most important of these is the "Greening Universities Toolkit" by UNEP.

In this study, "Sustainable Transportation," one of the components of the sustainable campus, was emphasized, and a campus transportation network model based on ecological design criteria was produced in order to increase the sustainability of the transportation system in Katip Çelebi University Çiğli Campus. In this context, the transportation targets and ecological design criteria of the guides and studies developed for Sustainable Campuses in the literature are discussed in detail.

Transportation-oriented evaluation of criteria systems developed for sustainable campuses

According to the "Greening Universities Toolkit V2.0: Transforming Universities into Green and Sustainable Campuses" guide by UNEP, actions to ensure sustainable transportation are seen in Table 1 (UNEP 2014).

According to the Green Metric, which is an evaluation system, the sustainability of a campus is measured by statistical evaluation of structure and infrastructure (15%), energy and climate change (21%), waste (18%), water (10%), transportation (18%), education (18%) criteria, and the indicators of each criterion. The indicators for measuring the sustainability of the transportation system, which is effective at 18% in scoring, are seen in Table 2 (GreenMetric 2013).

In the Sustainability Tracking and Assessment System-STARS V2.2., transportation is described as "Transportation is a major source of greenhouse gas emissions and other pollutants that contribute to health problems such as heart and respiratory diseases and cancer." In addition, the extraction, production, and global distribution of fuels for transportation can damage environmentally and/or culturally significant ecosystems and may financially benefit hostile and/or oppressive governments. At the same time, institutions can reap benefits from modeling sustainable transportation systems. Biking and walking provide health benefits and mitigate the need for large areas of paved surface, which can help campuses to better manage storm water. Institutions may realize cost savings and help support local economies by reducing their dependence on petroleum-based fuels for transportation. (AASHE 2019). Sustainability Tracking and Assessment System-STARS V2.2's criteria for transportation and scoring system are seen in Table 3.

Markowitz and Estrella (1998) stated that the following practices should be carried out in order to ensure sustainable transportation in the campuses (Balsas 2003).

- Car sharing system
- Parking spaces
- Promoting public transport
- Internet system for transportation information
- Promoting bicycle transportation
- Promoting pedestrian transportation

Ecological design for sustainable transportation on campus

Ecological design; it is a post-modern paradigm that reveals the limits of functionalist design and emphasizes that the human structure should be a product of the ecosystem, not only as a result of personal, social, and cultural differences of the environment, the city, the housing, and the landscape.

Table 1 Greening Universities Toolkit V2.0 Transport Action Plan (UNEP 2014)

Category	Action
General	Employment of transport manager
	Development of university transport policy
Commuter transport	Student housing and services on or close to campus
	Awareness and promotion of alternatives to private transport—posters, stickers, events and competitions, websites, awards and incentives
	Regular liaison with public transport providers to optimize services to the campus
	Incentives for staff to forego use of private commuter transport
	Secure, undercover bike racks, and shower and facilities, lockers and bike repair workshop for cyclists
	Car-pooling programs
	Reduction of car parking spaces and provision of dedicated spaces for car pool vehicles and electric vehicles (and also charging points)
	Establishment of shuttle bus service where the university has multiple campuses
	Acknowledgment that for reasons of social equity, disability, etc., some staff and students will still need to use private vehicles to access the campus
	Pedestrian-friendly campus to minimize internal motor vehicle trips
Travel on university business	Acquisition and promotion of video conferencing technology to staff and students
	University managed revegetation program to offset emissions for air travel, and/or commitment to 'third party' carbon credit/carbon offset program
	Purchase of fuel efficient vehicles for university fleet
	Regular maintenance to optimize motor vehicle fuel efficiency

Ecological design is a whole design process with social and psychological factors, highlighting cultural preferences, emphasizing locality and symbolism, and understanding the internal dynamics of natural data and harmoniously with it (Jim and Chen 2006; Farr 2011; Berke and Conroy 2000; Deng et al. 2012; Lee and Chan 2008; Moos et al. 2006; Moughtin et al. 2003; Camagni et al. 2002; Mapes and Wolch 2011

Ecological design according to Yeang and Woo (2010) is to develop the design by being aware that everything in the ecosystem on Earth is chained and that intervention within that chain affects the ecosystem, both locally and globally. Ecological design is there to ensure that the human-made environment or design systems are most compatible and well-compliant with the natural environment (Yeang and Woo 2010; Robinson 2011; Monteiro et al. 2019; Oktay 2004; Baran et al. 2011; Van der Ryn and Cowan 2013; Dayaratne 2018; Birkeland 2002).

Sustainability is the main element of ecological design. Designs created by ecological approach strike a balance between what they receive and give from the environment (Rapoport 2016; Batty et al. 1979; Gauthier and Gilliland 2006; Raman 2010).

In a study on campus transportation network, Kalaycı Önaç and Birişçi (2017) suggest taking into consideration the following when designing the master plans (Kalaycı Önaç and Birişçi 2017):

- Day and night usage of campuses actively and safely with the energy efficient lighting systems preventing light pollution and energy waste

Table 2 Green Metric Sustainable Transportation Criteria (GreenMetric 2013)

	Criteria	%
Transportation	Per capita vehicle Services	%18
	Zero emission vehicle policy in the campus	
	Zero emission vehicles per capita	
	Ratio of parking spaces to total campus area	
	Transportation program designed to limit or reduce parking Spaces in the campus for the last 3 years	

Table 3 Sustainability Tracking and Assessment System-STARS V2.2., Transportation Criteria (AASHE 2019)

Credit	Application to:	Points available
OP 15: Campus Fleet	Institutions that own or lease motorized vehicles	1
OP 16: Commute Modal Split	All institutions	5
OP 17: Support for Sustainable Transportation	All institutions	1
Total points available (if all credits are applicable)→		7

- The rainwater management systems with effective drainage solutions
- Accessibility for all kind of disabilities for universal design
- Floor covering materials
- Ground floor parking lots to prevent car parking on road sides which impedes the bicycle and pedestrian pavements
- Constructed shading elements or planting of parking lots, walking and bicycle roads to provide shadings
- Planting with design principles, e.g., roadside and refuge shading planting and covering plants to provide bio-comfort especially in summer
- Continuous bicycle lanes through campus separated from vehicle and pedestrian roads, as well as appropriate number of bike racks to encourage the use of non-motorized vehicle use
- Raising the standard and comfort of pedestrian transportation by benches, fountains, and garbage cans as well as aesthetical value.

Ecological design for the transportation network supports environmental sustainability and bio-comfort. Planted and constructed shading elements by pedestrian ways, bicycle lanes, and constructed large open surfaces provide biocomfort for users in summers. Impermeable and permeable large ground surfaces should be planted, and if it is not possible, reflective materials should be used for covering to reduce the absorption of heat and heat island effect (Alpay et al. 2013).

Existence of biking roads and facilities supports the sustainable living regarding health and ecological impacts to environment. Convenient connection of the bicycle networks and availability of bike facilities for parking close to the destinations contribute the preference of bicycle usage.

A research conducted by Buehler (2012) shows the direct correlation between more bike commuting and the existence of bike parking and cyclist showers at work. The research results also illustrate that free car parking relates to less bike commuting (Buehler 2012).

The development of charging stations to utilize solar energy to charge electric vehicles also provides a sustainable transportation system. Figure 1 shows a charging station with modes of AC, DC, and wireless charging in Delft University of Technology (Chandra Mouli et al. 2020). The smart bike systems supported by IoT (Internet of Things) Technologies also make it possible for people to check out the data on web application about the availability of parking spot and users behaviors in cities and campuses (Fig. 2) (Angulo-Esguerra et al. 2017).

According to Bach et al. (2006), the following are the features that should be considered in the design of the bike routes:

- Directness: directness and shortness of the lanes
- Consistency: comprehensible and connected lanes
- Attractiveness: infrastructure with legible signage, adequate lighting, and limited waiting times at intersections
- Convenience: fluent and comfortable traffic flow, flat and drift-resistant pavement, apart from walls and main roads, and reduced slopes
- Safety: divided lanes, even pavement surface, decent lighting, and minimizing the hazardous crossings

The drainage system is an important component along road networks that causes roads to be flooded if not planned correctly. In this case, green infrastructure systems improve the water quality, infiltration, and drainage, protect the ground water, and prevent the floods (Saygin and Ulusoy 2011; Ryan 2018; Flynn and Traver 2013; Traver and Ebrahimian 2017; Copeland 2016).

The correct design of the drainage systems helps trees to flourish in the urban environment, while improving air quality, storm water managements, habitat for all lives, mitigating heat island effect, and many more. The structured manmade ground surfaces cause the compact and less porous urban soil and effect the nutrition characters for trees to survive and subsurface water retention. Growing interest of multifunctional designed suspended pavement systems is seen as one of the solutions in limited green areas in intensely constructed urban areas. These subsurface bioretention techniques transmit the surface nutrition and water to the compacted subbase and porous soil rich of oxygen, water, and nutrition. Study of Tirpak et al. (2019) in Knoxville, Tennessee, USA, which was observed over 27 months, showed the viability of suspended pavement systems to manage urban storm runoff with pollutant removal

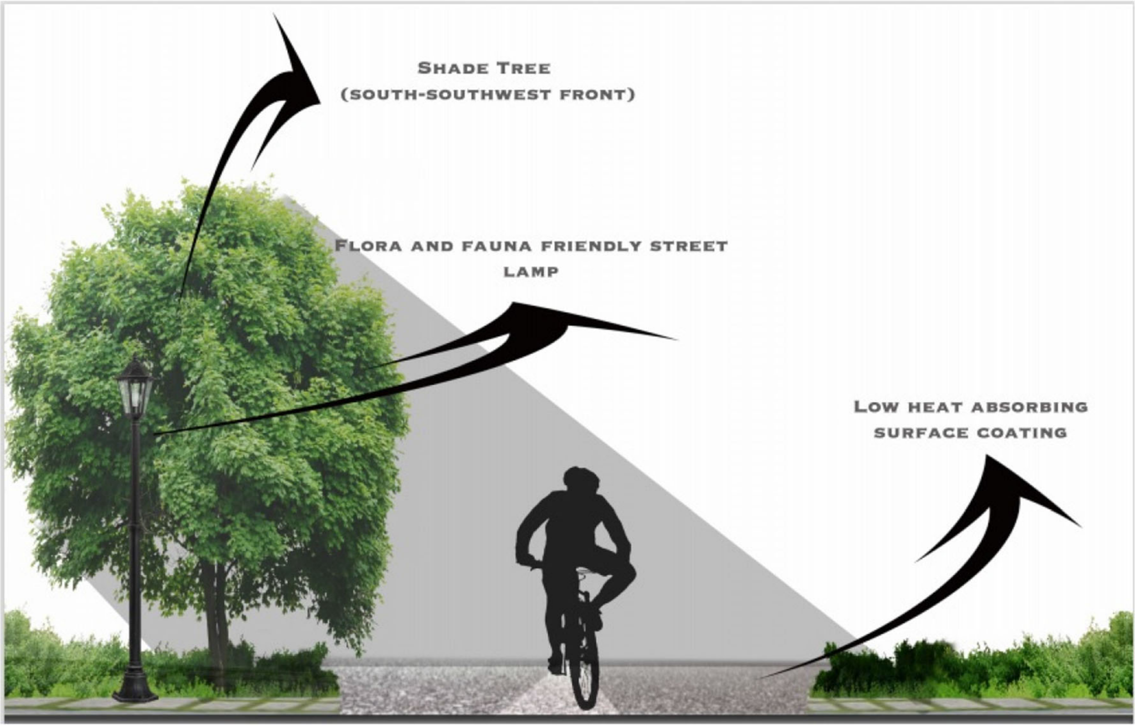

Fig. 1 Projected bicycle lane section (Alpay et al. 2013)

capabilities in addition to hydrologic effectiveness (Tirpak et al. 2019) (Fig. 3).

Lighting is a component that affects the comfort of transportation on campus. Night light pollution affects ecosystems increasingly by prevalent effects on nocturnal and diurnal species (Pawson and Bader 2014). The spectral composition changes, areal pattern, and duration of lighting have also ecological impact in the nighttime environment (Gaston et al. 2012) (Fig. 4).

Study conducted by Shahzad et al. (2018) shows that the consumed energy during the usage of LED and HPS luminaires has the 87–96% of ecological impacts of lighting. Fossil fuel consuming energy systems have higher environmental impacts than renewable-based energy technologies. This environmental impact highly decreases by a shift from fossil-based energy systems to renewable energy systems (Longcore and Rich 2016; Smart Lighting Solutions with LED technology is more ecologically beneficial than traditional lighting solutions based on the key factors stated by Castro et al. (2013):

- Efficiency: Smart Lighting Solutions helps saving more energy and reducts rate of carbon by 50 and 70% compared to traditional technologies.
- Improved management: it's attainable to manage the color of the light, the intensity, and direction of the

Fig. 2 Front and back view of solar e-bike charging station. Retrieved from (Chandra Mouli et al. 2020)

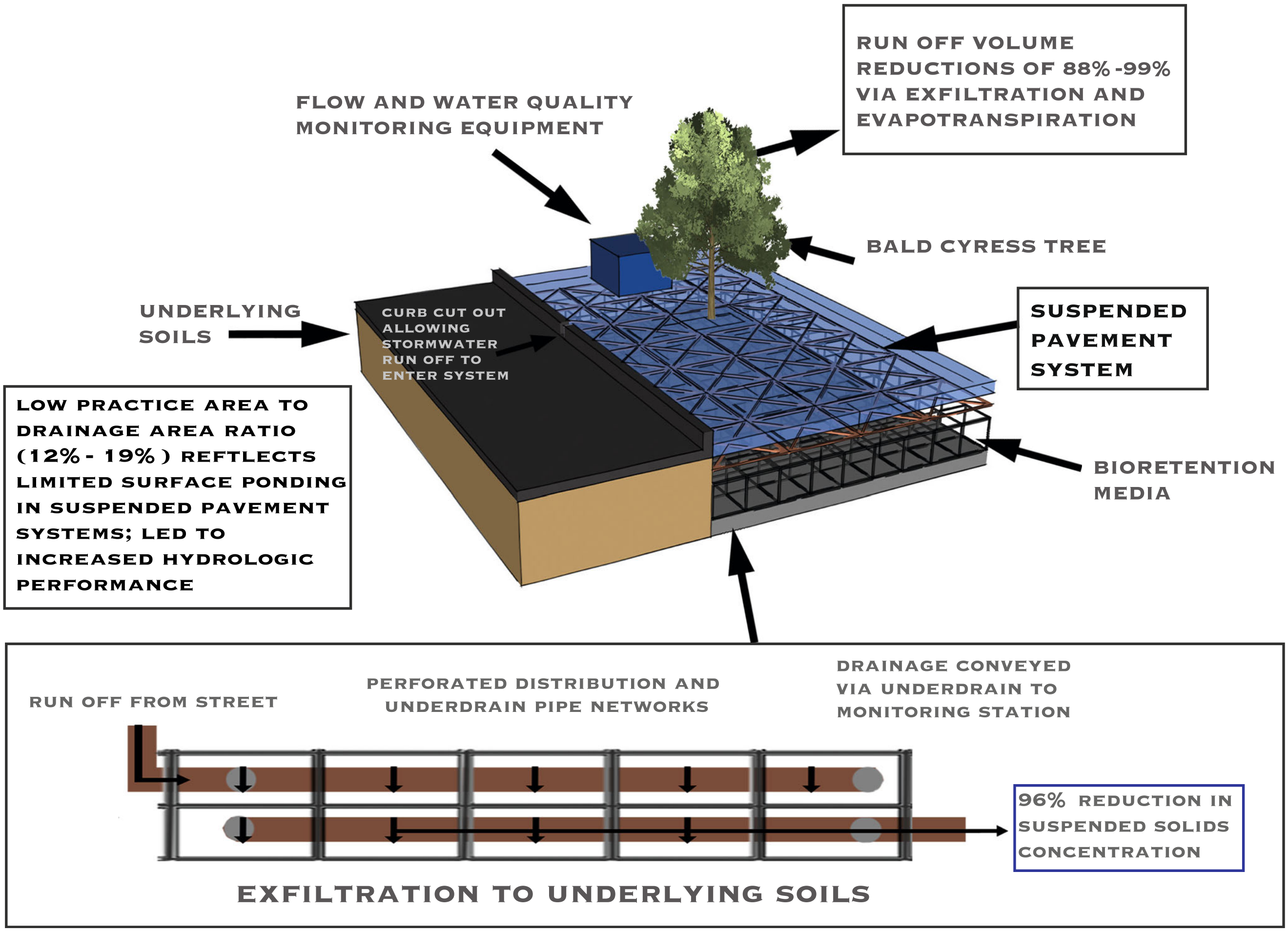

Fig. 3 Suspended pavement system, green infrastructure (Tirpak et al. 2019)

light beam, through design of new lighting systems incorporated in electronic and communication systems which will provide a good vary of useful factors. Smart control permits to modify level of

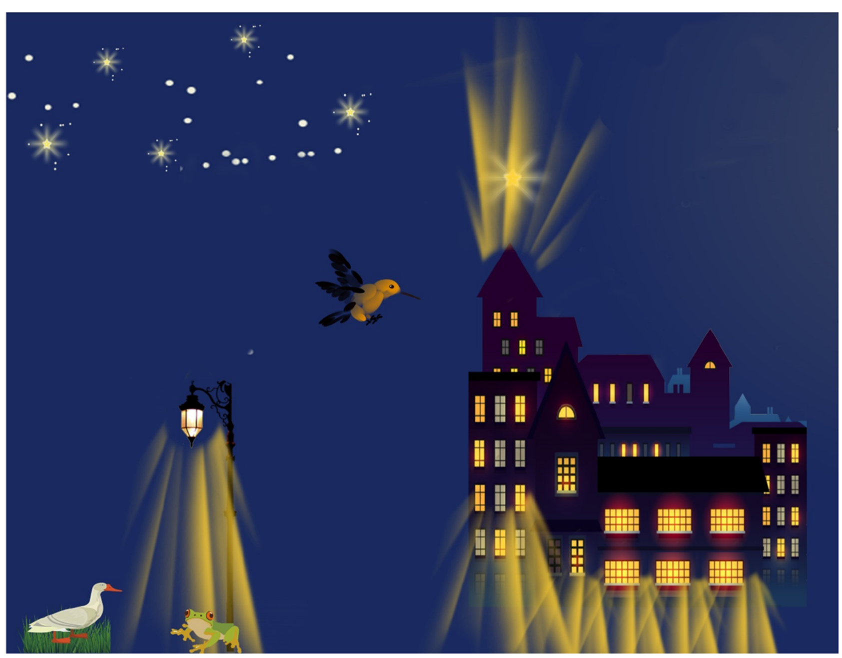

Fig. 4 Ecological and astronomical light pollution (Gaston et al. 2012)

Fig. 5 Location of İzmir Katip Çelebi University Çiğli Campus

lighting according to external conditions and may help to consumption of energy up to 80%.
- Durability: LED lighting systems' life expectancy range between 50.000 and 100.000 h. It is possible to extend durability with the help of smart control systems.

Falchi et al. (2011) proposes a set of rules to control light pollution to protect environmental and ecological quality:

- Do not enable luminaires to send light directly at and higher than the horizontal.
- Limit the downward light flux only in the space to be lit.
- Abstain over lighting.
- Turn off the light when not in need of use.
- Seek for zero growth of the amount of build in flux.
- Firmly discourage the short wavelength blue light.

When the above definitions are examined, it seems inevitable that ecological criteria will be taken into account in the designs to improve the sustainability of transportation on university campuses.

Materials and methods

Research area

İzmir Katip Çelebi University Çiğli Campus (38° 30′ 55.2204″ N latitude, 27° 1′ 52.4532″ E longitude), as shown in Fig. 5, it is located in the north of Izmir, within the boundaries of the Balatçık District of Çiğli District. To the west of Katip Çelebi University Çiğli Campus is the Izmir-Canakkale highway, Izmir-Canakkale highway to the east, 35m wide highway and highway link road to the north, and industrial and residential areas to the south. The total area of the campus is 70 ha. When examining the implementation zoning plan in Fig. 6, on-campus roads are not shown. On-campus roads, structures and parking lots can be seen via satellite photo in Fig. 7.

Other materials

The literature described in the introduction section was used to determine ecological design criteria for sustainable transportation at İzmir Katip Çelebi University Çiğli Campus.

However, ArcMap 10.4 and Lumion software were used for digitization and visualization. Also, DEM data downloaded via the USGS website has been used for drainage analysis with ArcGIS software.

In addition, data obtained from photographs taken in the field study carried out on campus (road covering type, plant presence, pavement width, etc.) data.

Methods

In order to reveal the current situation analysis in the study, which started with literature review, on-campus land use status (road network and structures) was drawn via satellite photo using ArcMap 10 software. Later, the following data were collected through the photos of the campus.

- Paving types of roads
- Vehicle/pedestrian status
- Plants on the side of the road
- Bike path
- Parking lots
- Quality of road lighting
- Drainage system

After the current situation analysis is completed; ecological design criteria for sustainable transportation in the literature were evaluated, and recommendations have been developed according to photos taken from the campus. But for the drainage problem, an analysis with GIS was also used along with the photos.

ArcGIS 10.4.1 software "Hydrology" module was used to solve the drainage problem in the campus area. First of all, by using the "fill" command through the DEM data of the workspace, the gaps and errors were eliminated. Then the water flow direction is calculated with the command "Flow Direction."

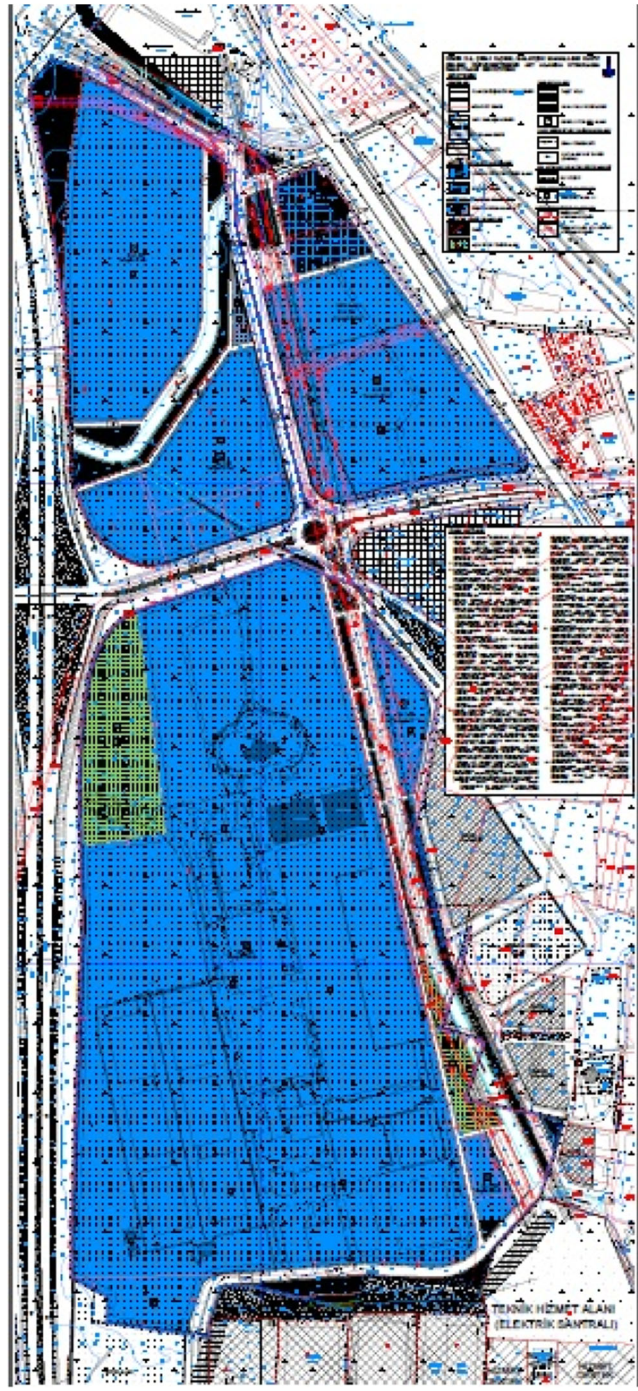

Fig. 6 Zooning Plan of İzmir Katip Çelebi University Çiğli Campus (IKCU 2019)

Flow accumulation is performed after the above operation is complete. It is important to determine the threshold correctly for the emergence of stream areas. As a result of these procedures, water catchment areas have been identified (Soydan and Benliay (2018).

Fig. 7 2019 Satellite Image of İzmir Katip Çelebi University Çiğli Campus (Google Earth 2019)

According to these findings, a sustainable transportation scheme has been prepared to be dealt with ecological design criteria at İzmir Katip Çelebi University Çiğli Campus.

Results

Current situation analysis

After checking in through the main gate of the campus, it is worth noting that all roads except the one shown in yellow are the vehicle path and there are 8 parking spaces (Fig. 8). Paving types vary on vehicle roads. However, two materials, mainly parquet stones or concrete roads, were used (Fig. 9). Some of these road ways do not have pavements, while others have different pavement widths. Coating materials used on pavements also vary (Fig. 10). As seen in Fig. 11, the pedestrian path is moving in the direction of the rectory building starting from the right of the campus entrance gate. However, it does not have continuity. Different materials have been selected as coating material on pedestrian roads as shown in Fig. 11. Although there is no bicycle path in the campus, there are 2 bicycle parking lots as seen in Fig. 12. Plant presence is continuous along the roads throughout the campus. However, there are not enough plants in most of the gathering areas and along the pedestrian paths. Therefore, pedestrian paths and gathering places are exposed to the sun, and it causes a problem in Izmir climate (Fig. 13). As seen in Fig. 14, there are eight parking spaces on campus. Only the top of the car park to the right of the entrance door is covered with solar panels. In this way, solar energy is obtained and shadow space is created for vehicles. In other parking areas, the floor covering varies as concrete or hardstone, but there is no shading element or planting. Throughout the campus, the drainage system is formed along roads and at tree bottoms (Fig. 15). There are different sizes of lighting elements used on pedestrian and vehicle roads, but these do not have environmentally friendly technology (Fig. 16).

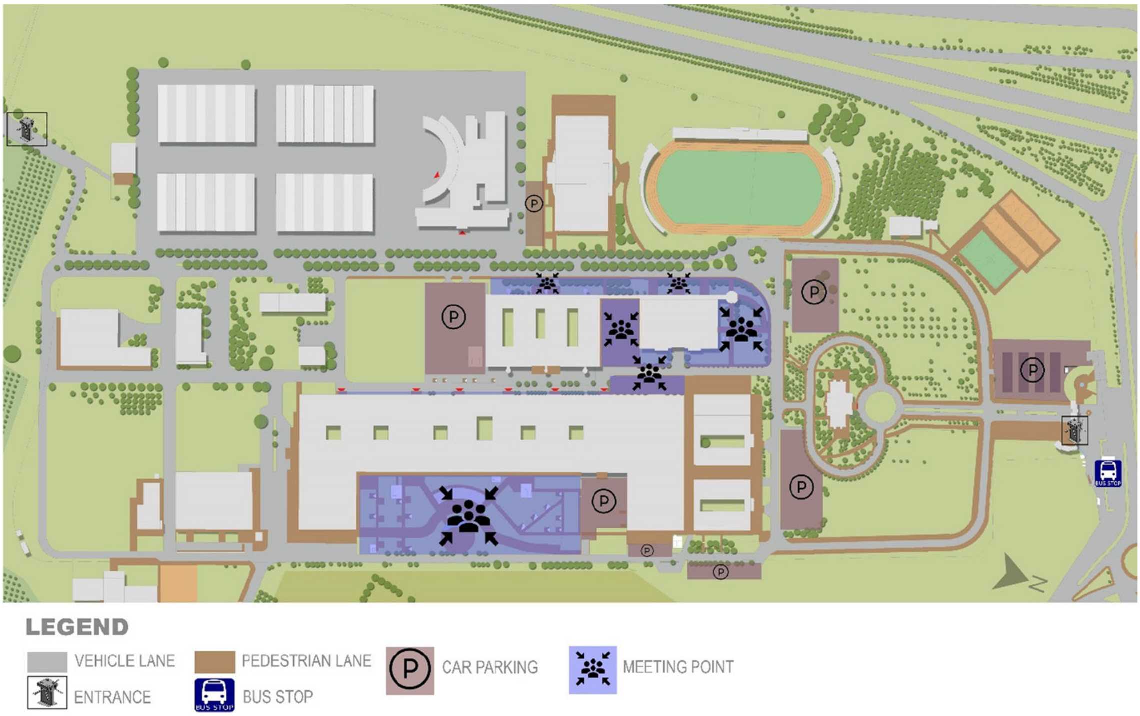

Fig. 8 General transportation scheme of IKCU Çiğli Campus

As detailed in the above photos, Katip Çelebi University Çiğli Campus has developed eclectically. In different periods, with different design decisions, more as a result of the applications made to solve the need of that day, today's campus emerged in the 10-year period. Ecological criteria such as the use of ecological materials, green energy, and re-evaluation of natural resources were not considered in any equipment that is part of on-campus transportation.

Discussions and evaluation

In the light of the information obtained from the examination of the current situation of the campus and the literature review, ecological design approaches for sustainable transportation within the campus are grouped under five headings.

Roads

The transportation roads in the campus directed to interior ring around the campus. Many vehicle transportation roads were suggested to be converted to pedestrian ways with the goal of minimizing number of vehicles and air pollution in the campus. These roads were designed to be covered with the semi-permeable road surface materials which have the features of low capacity of heat absorption and retention. Trees with visual value and large canopies were used through the roads for bio-comfort and aesthetical quality (Fig. 17).

Fig. 9 Vehicle path paving materials

Fig. 10 Pavement paving materials

Biking roads

To promote biking and healthy life in the campus, the comfortable and secure bike lanes for bikers were proposed on the plan. Taking into consideration capacity, quality, and distance to the building of the bike racks, and the flow and unceasing connectivity of the bike lanes, a sustainable transportation way was provided (Fig. 18).

Pedestrian lanes

A central axis was developed through the campus in the hearth as a pedestrian road, which was a semi-pedestrian in the previous. It is attempted to provide safety and active usage of the pedestrians. In this way, the vehicle traffic and the flow were directed to the peripheral axes in the campus connected as a ring. The universal design criteria for accessibility were applied by the unceasing pedestrian lanes and sidewalks, supported by shading plants to provide comfortable access to the campus buildings. To promote walking and healthy life habits for pedestrians besides of sidewalks, a lot of pathways in the groves were designed in the campus area (Fig. 19).

Lightings

A lighting system was developed to ensure 24/7 safe and sustainable transportation throughout the campus considering mode of energy savings and preventing night light pollution. The lightings on the vehicle roads and pedestrian lanes were placed with a distance regarding minimum energy usage for efficient lighting. The mode of solar energy and LED was suggested to be utilized (Fig. 20).

Parking areas (bike and vehicle)

New designated parking lot locations were planned considering the appropriate proximity to the buildings. The capacity and quality of parking area were improved by shading trees and PV solar panels in the proposal plan to prevent road side car parking under trees (Fig. 21).

Fig. 11 Pedestrian road paving materials

Fig. 12 Bicycle parking lots

Planting

Plants were chosen according to their substantial features to create flourished ecological habitat in the campus. Attractive plant species with color, smell, and fruits for people and animals such as birds, butterflies, and many more were distributed around the campus. A visual buffer zone with special plants designated around the campus to impede toxic air, carbon dioxide, and noise pollution especially from the highway at the northwest and west boundaries of the campus. The parking lots, refuges, sidewalks, and bicycle lanes were shaded with the trees having large canopy. The land surface all the way through the campus is covered with ground cover plants to prevent heat island and provide bio-comfort (Fig. 22).

Drainage

The current drainage system and the surface slope to direct rainwater was a malpractice on the application. Thus, the water collects on the vehicle roads and pedestrian ways in rainy days especially in winter times. Instead of impermeable concrete and asphalt surfaces in current use of vehicle roads, pedestrian ways, and parking lots, permeable surface covering materials for rain water infiltration should be utilized through the campus. To prevent atmospheric heating and heat island, the low SRI (Solar Reflective Index) value surface materials also should be preferred for ground cover. However, the correct selection of the locations of Rogers and grids is also very important for the establishment of a sustainable drainage system. To solve the issue of rain water flows and accumulations, the grids and Roger points were offered via the analyses which are performed with ArcGIS 10.4.1 software "Hydrology" module (Fig. 23). The appropriate solution for the sustainable drainage system has been produced by addressing the photos taken on drainage problems throughout the campus together with the above analysis.

New ecological design proposal

In line with the above-mentioned approaches, a sustainable campus transportation network based on ecological design principles was planned as in Fig. 24. The main element of ecological design is sustainability. Designs created with an ecological approach establish a balance between what they

Fig. 13 Plant existence

Fig. 14 Car parks

get from the environment and what they give. In an ecological design, the following rules should be taken into account: All types of structuring areas should be seen within an urban ecosystem. Construction areas should be associated with the critical problems of the city at every scale. A structuring area should take responsibility for the problems and opportunities that will arise. In other words, these opportunities will be the problems and possibilities the building will give to its immediate surroundings. Ecological design should conserve energy and reduce waste in and around the building. The structured area should be able to reflect the diversity of the biological, hydrological, geological, and microcharacter of its environment. Most importantly, it should use and benefit from the ecosystem and environmental design that exist within the traditional urban fabric. Landscape ecology key ideas related to green urban infrastructure for ecological landscape designs, emphasizing process relationships and physical and functional commitment, include a multi-scale approach with clearly defining the texture. The multiscale approach is based on hierarchy theory, which addresses the structure and behavior of functional systems at multiple scales simultaneously. For example, hierarchy theory is used in common transportation planning. To understand dynamics and local traffic capacity, it is necessary to understand the connection of local roads with the major highway system (Ahern 2007). At the same time, hierarchical systems are also valid for landscapes with the same applications. While defining the landscape, heterogeneous areas of the land, as well as large heterogeneous areas of land, they are also "intertwined within the land in larger areas to limit or control ecological processes"—by definition, especially those associated with species movement or hydrological processes. Addressing shift patterns and ecological processes in applied horizontal ecology are the norm that is accepted as a multiscale approach (Leitao and Ahern 2002; Ndubisi 2002).

With an understanding of ecological processes, the pattern, the importance of the process, dynamics, and connectivity, spatial configuration is the integration point. In applied landscape ecology, it is considered almost universal to describe the mosaic pattern and to understand the landscape spatial configuration. It uses three basic landscape elements to describe the landscape structure model: patches, corridors, and matrix. It differs from a patch circumference; it is a nonlinear and relatively homogeneous area. The patches function as multiple wildlife habitats, aquifer recharging areas or sources, and provide space for species or food. A corridor is a specific land cover type linear space that differs in content and physical structure in its context (Forman 1995). In the corridors serve many functions, including landscape habitats for wildlife, roads or canals for plants, animals, food and wind or barriers

Fig. 15 Drainage system

Fig. 16 Lighting elements

to act such as movement. The matrix area is the dominant land type in terms of degree of control over connectivity and continuity and landscape dynamics (Forman 1995; Forman and Godron 1986).

Landscape areas are in a complex structure with character and structure defined and based on biophysical processes. In order to understand this complexity and develop different approaches for ecological design, the complexity of a landscape is tried to be understood by the method of integrating and overlapping the elements that make up the landscape. It is aimed to understand ecosystem health and biodiversity at the scale of the area and landscape. Our environment is surrounded by various systems consisting of hydrological, active transportation, recycling - energy use and plant choices. The smooth operation of these systems enables the landscape to work in a sustainable structure. Systems consist of 3 parts. System elements are their relations and properties with each other. Studies are carried out on in-campus transportation systems, mainly bicycle and pedestrian use. It is aimed to improve pedestrian paths and paths for pedestrian use. Bicycle use is one of the practices that are tried to be popularized in university campuses. For this reason, bike sharing and improving the infrastructure and roads of bicycle use are at the forefront. In order to reduce the entrance of private vehicles into the campus, studies such as reducing the number of parking lots or making them paid. By creating a pool of vehicles close to the campus, people coming to the campus are encouraged to reach the campus by car sharing or public transportation. Universities such as Melbourne and UCL aim to reduce the carbon emissions they create by creating an environmentally friendly vehicle fleet.

Handicapped transportation is considered in many campuses and is indicated on interactive maps of university campuses. While it was aimed to increase the use of bicycles, it was found that the bicycle path was generally fallen with the pedestrian path. It is aimed to increase the usage by increasing the infrastructure services such as bicycle parking area. The overall goal of university campuses is to reduce vehicle access to the campus. For this reason, in many campuses, transportation cannot be made to every point. Vehicle roads are generally covered with asphalt, which is not a permeable material. Open car parks integrated with vehicle roads have been identified in the campuses. Generally, there are large, collective parking areas, and in some campuses, vehicles can get closer to the buildings with pocket parking lots nearby.

Conclusion

The sustainability of a campus consists of many different components. According to the Green Metric; sustainable transportation has 18% share in all these systems. When previous studies and standards established on the subject are examined, issues such as increasing the use of bicycles, reducing the number of private vehicles, using shuttle buses for employees and students, and promoting public transportation come to mind. These are important environmentalist approaches that reduce carbon emissions, but alongside these basic approaches, the less voiced ecological design also significantly increases sustainability. Ecological design is to develop the design by being aware that everything in the ecosystem on Earth is chained and that intervention within that chain affects the ecosystem, both locally and globally. This

Fig. 17 Roads

Fig. 18 Biking roads

research has also local and global impacts if it is implemented on the study area. It does not only reduce environmental malpractices and hazardous effects on the ecological habitats of the area, but also develops healthy habits and behavioral change to a more sustainable world by users who will be designers of the future from disciplines grown from this campus. The biggest problem of the transportation network of the campus is the excess surface flow at the door, and when the drainage system is not good, it causes too much water to accumulate. In some places, it is not possible to walk or drive. For example, there is water everywhere until you enter the building where you parked the car. Doing materials are wrong, they need to use semi-permeable materials in such a place, the road slopes are not correct, and also roads not suitable for walking.

With the use of permeable material, it is aimed to reuse rainwater. Roof gardens, which are one of these design solutions, allow rainwater to be collected slowly, create a microclimatic effect, and increase the amount of green. With pedestrian-oriented transportation, it is aimed to reduce the amount of carbon dioxide generated by the use of vehicles and a healthy life. While reducing the use of private vehicles, it reduces the carbon footprint, while contributing to the increase of permeable surfaces by reducing parking areas or planning underground. By using local plants, it is aimed to reduce maintenance costs and adapt the plants to the environment without experiencing any adaptation process and without losses. By reducing the amount of grass areas, instead of designing rainwater gardens and structural seating areas as aesthetic value, which ensures the flow of rainwater from the soil, maintenance and irrigation costs of the lawn areas are reduced.

When starting the analysis, it is necessary to reveal the natural and structural components of the study area. Accordingly, designs should be made in accordance with the current climate and geography, without playing with land plastic too much. Flat lands offer more alternatives for university establishment and circulation. Practices that require less landscape maintenance and irrigation should be implemented with the use of local plants suitable for the geography and climate of the campus. Renovation of the existing buildings in the campus according to the energy-saving building characteristics and the construction of new buildings in line with the criteria of energy-saving buildings will provide significant energy savings. It is important to use water-saving equipment when it is anticipated that water consumption is higher than day and night use throughout the campus. Rain water management should be done to avoid using city water supply for

Fig. 19 Pedestrian lines

Fig. 20 Height and low outdoor solar lightings

irrigation of landscape areas. Rain water should be collected by various methods and used in landscape areas. Areas created for rainwater collection can also have aesthetic value and recreational features in terms of landscape. Unnecessary irrigation should be avoided with moisture sensor irrigation systems in areas with high rainfall and humidity. Vehicle entry into the campus should be restricted. Considering that it will be easier for the city to reach the campus by public transportation, the need for private vehicles is expected to decrease. For this reason, it can be a deterrent to vehicle entry to the campus by making the parking lots for a limited period and for a fee.

Waste management is indispensable in university campuses where consumption is high. First of all, solid wastes should be separated with various boxes. Campus users should be regularly informed about this issue. Organic wastes from food and landscape waste should be converted into compost and the amount of organic waste should be reduced. By using it as a fertilizer in landscape areas, the use of chemical fertilizers is also reduced. Pests that may occur in campus landscapes should be fought with integrated pest management. Thus, chemical substances are prevented from mixing into groundwater. Studies should be carried out to increase biodiversity as vegetative in units such as herbarium, arboretum, and botanical garden in university campuses. Meeting-rest areas should be established within the campus. If grass texture is desired to be obtained in the gathering areas consisting of green areas, the species that are easy to maintain and require less water should be preferred. Pedestrian circulation should be easier for the campus. For this reason, pedestrian-friendly walkways should be designed, away from vehicle pressure. Walking paths should be made healthier by planting. Access by bicycle on campus is an ecological transportation alternative. Bicycle paths should be designed appropriately so that in-campus bicycle circulation is easy. In addition to the bicycle path, other infrastructure works that support bicycle use should be designed together with functions such as parking spaces and shower areas.

For transportation to the campus, care should be taken to be suitable for use on pedestrian and bicycle paths outside the campus. Necessary arrangements should be made to ensure safe access to the campus on foot and by bicycle. Closed garages should be created to increase the amount of green

Fig. 21 Bike and vehicle parking areas

Fig. 22 Plantings

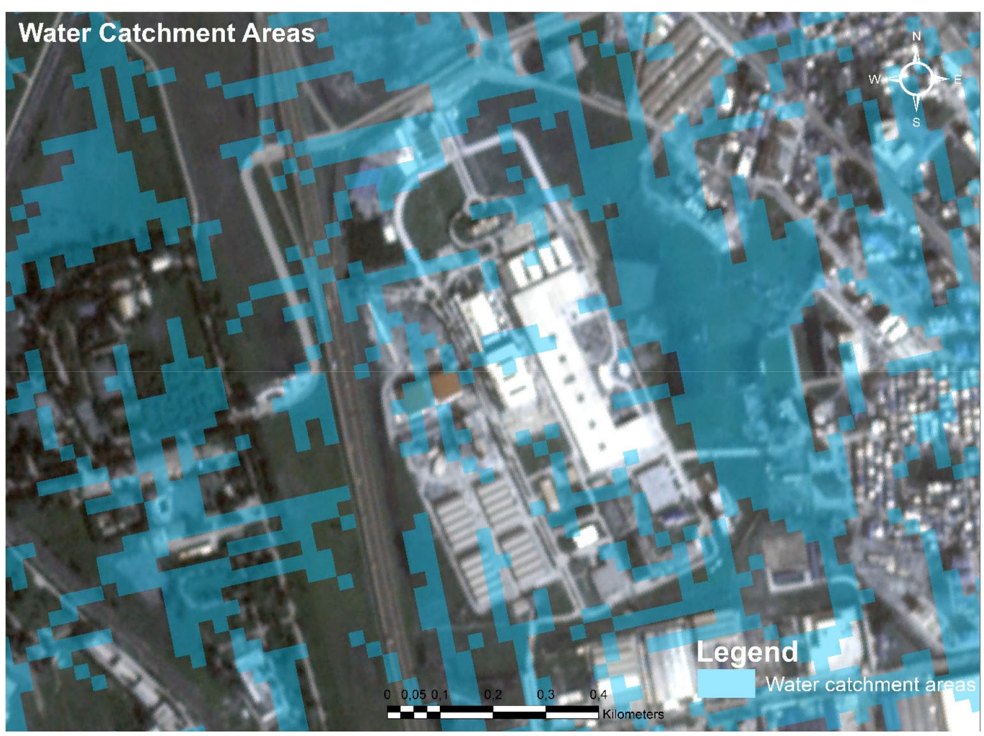

Fig. 23 Water catchment areas

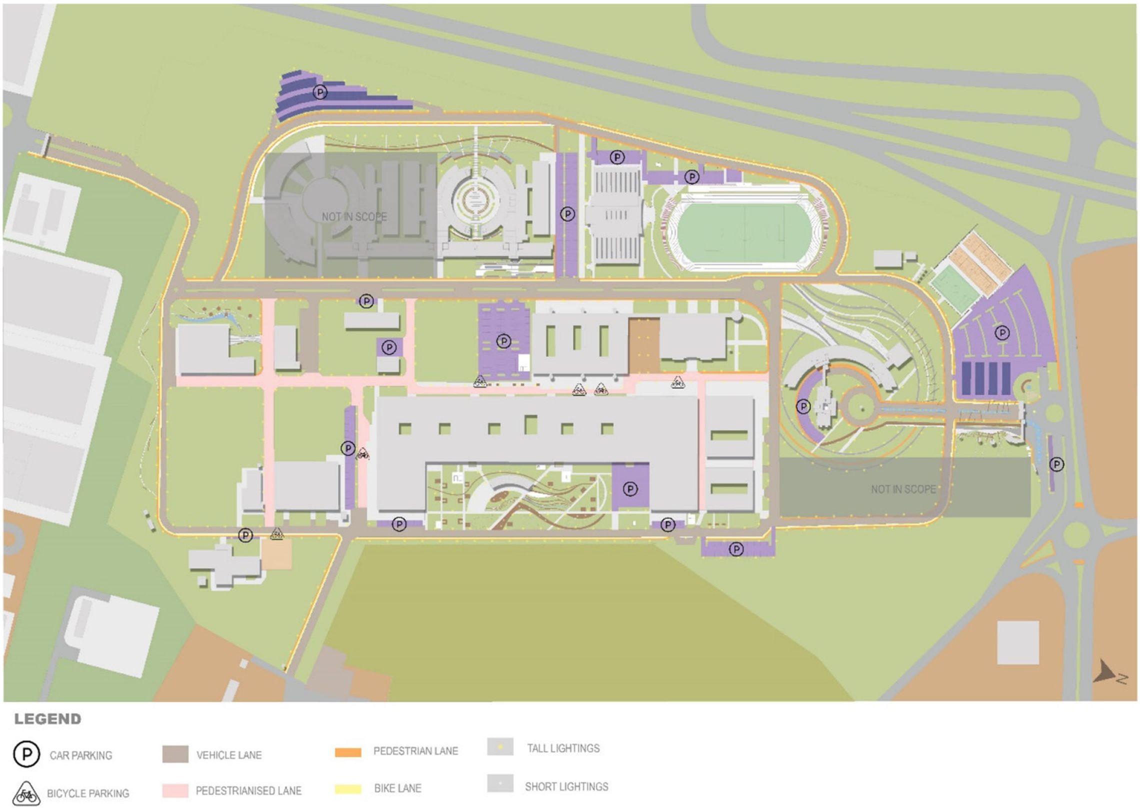

Fig. 24 Sustainable campus transportation network based on ecological design principles

space. If outdoor parking areas are laid with permeable material, they should allow water to drain. At the same time, it should be aimed to reduce the number of users by making these parking lots for a certain period of time. Although urban universities do not have a problem with accessibility, transportation by private vehicle is high. It both creates the need for more parking lots and increases the CO2 emitted to the city. For this reason, for the users coming from distant points to the campus with the vehicle pool system, vehicle pools should be created in places close to public transportation, and they should be encouraged to leave their vehicles at these points and reach the campus by public transportation. Special discounts should be provided to encourage the use of public transport. Especially in university campuses with high electricity and heat energy consumption, studies should be carried out to obtain energy from renewable alternative energy sources. Since university campus areas often have large green spaces, they are expected to serve as patches or corridors from the urban landscape matrix. It is predicted that a university campus plan and design in line with the determined principles will provide great benefits to the city where it is located ecologically. In order to reduce the infrastructural burden created by the campuses, these principles can be easily applied on existing campuses.

In this study, transportation scheme of Katip Çelebi University Çiğli Campus has been discussed with the ecological design approach. As a result of the study, a transportation plan was developed that will increase the bio-comfort level of the campus residents with the use of ecological materials and a design approach that increases the individual's harmony with the environment. More research and practices for sustainable campuses should be increased to inspire and motivate communities. Behavioral changes take long time, to be able to establish a more consolidated environmentally protective and sustainable life habits it would be right place to start from universities.

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