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Sustainable Status Assessment of the Transit-Oriented Development in Doha's Education City

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Abstract: Doha, the capital of the State of Qatar, has seen rapid growth in recent years, resulting in challenges that can be addressed through sustainable urban design strategies. Such approaches, including Transit-Oriented Development, aim to provide compact urban forms with mixed-use development enabling easy access to the city's transit services. In light of such objectives, and with the 2022 World Cup being hosted in Qatar, the government has invested heavily in its public transportation system and in implementing Transit-Oriented Development. This work presents an analysis of the current status of Transit-Oriented Development in the knowledge hub in Doha known as Education City. A case study methodology was used, which included site observation, photographic documentation, mapping, and statistical analysis based on recent census data. The analysis shows that the use of public transportation throughout the site is relatively low, largely due to the region's hot climate and the local mobility culture, in which there is a general preference for private vehicle use. The culmination of this investigation is a master plan for the study area, which foresees further enhancement of the area while still holding to the aims of Transit-Oriented Development. To this end, key recommendations for modifying the prevailing mobility culture are suggested, such as increasing the availability of multimodal transportation in order to improve public transportation functionality and modifying certain aspects of the public transportation system so that it is convenient and comfortable, even during periods of very hot weather. The findings of this study highlight the potential of urban design to change people's behavior and increase awareness of multimodal transport options.

Keywords: Transit-Oriented Development; Education City; Sustainable Urbanism; urban voids; Qatar

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1. Introduction

The concept of Sustainable Urbanism (SU) has emerged as a response to the climate change crisis. It takes into account environmental and contemporary urban design realities, including population growth, urban sprawl, and overdependence on private vehicles [1]. In many contexts, SU emphasizes the importance of the natural environment. Additionally, it mitigates challenges to economics, community values, and quality of life created by disparities among diverse groups of people. SU encourages people to connect with nature and natural systems, even in densely populated areas [2].

Sustainable urban development can be achieved through careful consideration and by balancing community and economic development, land use planning and design, and appropriate use of technology. It includes fifteen core principles that support a common mission of addressing urban challenges [3]. Sustainable urban development combines land development and nature preservation with principles supporting human development and inhabitants' well-being [4].

Sustainable urban development is characterized by environmental improvements, social equity, and economic growth. For cities to become more sustainable, they need sufficient space to develop and retrofit their structures. Comfort levels in microenvironments can be improved by the design of sustainable cities [5]. However, there are very few studies in Qatar related to Transit-Oriented Development (TOD). One notable such study investigated the area surrounding the Qatar National Museum [6]. The authors found that integrating land use and multi-use transport systems can help create livable communities and improve the urban environment in Doha [6]. Moreover, they proposed a master plan for the urban regeneration of the Qatar National Museum area so that this cultural zone in Doha can also serve as a transit village [6]. This study is significant to urban planning in Qatar because its proposed master plan is envisioned through (A) Green Urbanism, and (B) a TOD design strategy. This approach and its methods can serve to guide other municipal developments in Doha.

These include the densification of districts within the city, which involves retrofitting urban infill. The densification of the urban fabric is made possible through several practices, including: (1) the integration of land use, (2) sustainability through density, (3) compactness of buildings and public spaces aiming for vertical rather than horizontal development, and (4) the availability of an effective transport system and TOD.

The government of Qatar has attempted to address these challenges, in part, by making Smart Growth a priority, including the development of a large-scale public transportation system that will ultimately incorporate interlinked bus, rail, and metro systems. The metro network has been constructed to reduce mobility problems, particularly in anticipation of the 2022 World Cup. However, the local real estate market could not keep up with the overall quick pace of development, which meant that some metro stations were located in undeveloped areas serving a smaller number of people.

Three metro lines are currently in operation, and most metro stations' transit hubs have at least attempted to implement TOD principles, though much of this development is still ongoing. This research investigates the conditions prevailing at and around the Education City (EC) metro station, located in Al Rayyan Municipality, which is the second-largest urban area within Doha. This station serves thousands of students and staff around the EC spatial development zone. EC hosts several international and national academic institutions, student housing, and sports facilities, including the EC stadium and recreation center. Furthermore, a tram system operates alongside the metro to facilitate internal travel within the EC. Moreover, the area, located within a 500 m radius, includes a large parking facility that directly links to the tram.

The selected study area within the EC is a mixed-use educational and research development area. It includes many urban voids, most of which are targeted for future development. Current transportation options in the EC include pedestrian pathways, the tram, and public buses. The phases of data collection include a survey intended to assess public transport users' needs. It also presents an in-depth analysis of the selected site, which describes the EC metro station and the current conditions of the surrounding urban area. Finally, a master plan is proposed with a set of recommendations to improve the functionality of the selected site.

2. Literature Review

Transit-Oriented Development (TOD) is widely recognized as an effective tool for encouraging people to use public transport (PT) and decrease their dependence on private cars. This is achieved by creating compact urban forms with mixed-use development near the transit points. TODs are designed to facilitate environmentally friendly modes of transportation, such as pedestrian and cycling paths, and attractive public spaces placed around key transport facilities such as metro stations, which can then act as local hubs for public activity [7].

From the perspective of new urbanism, TOD refers to the area surrounding a transit station (TS). It is considered an integrated, mixed-use, and pedestrian-friendly development

surrounding a bus or rail station. TOD can be seen as an important approach to city development [8] and can provide an opportunity for economic development by enhancing choices of travel and centers for the development of the economy [9].

As urban systems and metropolitan areas become more complex, an integrated strategic vision is needed. Mobility and accessibility should be addressed in order to improve the urban environment. In recent years, TOD has become a more popular method for urban design [10]. The basic approach of TOD is seen as a mitigation strategy that addresses sustainability concerns through the incorporation of multimodal public transportation (PT), urban density, and mixed land use activities [6]. Greater availability of transit increases its efficiency and reduces the need for private vehicles. Furthermore, improving the efficiency and availability of PT also benefits the local economy and infrastructure [11].

The three elements typifying TOD are: (a) Density, referring to a higher rate of development within a 400 to 600 m radius of the main transport hub; (b) Diversity, referring to mixed land use, with a variety of housing options and commuting modes; and (c) Design, referring to the goal of creating an area which is comfortable, welcoming, livable, accessible, pedestrian-friendly, and connected. The initial "D" letters of these three elements provide the term the "3Ds strategy", which, when successfully implemented, leads to increased PT ridership, improved walkability and cycling, and fewer car trips within a given urban area [6]. Many studies show that the design attributes of TODs can decrease both work and non-work-related car trips. The numerous favorable outcomes of applying TOD strategies, including economic, social, and environmental benefits, can help motivate urban planners and residents to aim for Smart Growth (SG) and sustainable development [12]. The TOD approach to urban development involves encircling transit hubs such as metro stations with a mix of land uses within a well-connected and safe atmosphere. It can be useful to analyze the effect of TOD on mixed-use neighborhoods' livability in order to develop effective urban design frameworks [13].

2.1. Green Transit-Oriented Development and Smart Growth

Green TOD is an allied approach that encourages environmentally friendly design through the optimization of resources and energy efficiency. In addition to the use of green building techniques and sustainable transport systems [14,15], Green TOD also supports biodiversity by paying attention to environmentally protected areas. In addition to benefiting the natural environment and the urban environment [16], urban green spaces are beneficial for the city's social systems [17].

Green TODs are characterized by: (1) high population density, which increases the practicality and usage of PT and decreases per-capita energy consumption; (2) mixed land use, such that residential, commercial, recreational, and other key facilities are made easily available via pedestrian and cycling paths. This also leads to other green neighborhoods; and (3) decreased numbers of onsite parking areas and the replacement of such areas with creating green open spaces in order to mitigate urban heat island effects [18]. In sum, the Green TOD approach can be thought of as an integration of TOD and Green Urbanism principles.

Smart Growth is directly linked to the concepts of walkability and pedestrian connectivity. Its goal is to reduce the dependence on car-based urbanism through several means. These include increasing the density of urban areas and limiting urban sprawl; designing attractive pathways that encourage people to walk and exercise, thus maintaining a healthy lifestyle; and creating efficient alternatives to PT systems [19].

Four propositions define the logic of Smart Growth in relation to urban sprawl. First, urban sprawl is currently the dominant form of urban development, regardless of its driving force. Second, urban sprawl leads to the development of low-density, unplanned, and aesthetically displeasing areas. Third, urban sprawl adversely affects social cohesion, human health, and environmental quality. Finally, the negative effects of urban sprawl can be mitigated by policies supporting compact urban growth and revitalization, as well as the preservation of non-urban areas such as farmland. Smart Growth is desirable because of its many benefits; these include the creation of varied housing opportunities and choices, the

development of walkable neighborhoods, and the preservation of open spaces and natural beauty [20].

Both Smart Growth and New Urbanism are evolving movements that can lead to challenging questions in the research sector about the basic assumptions, current challenges, and appropriate ways to deal with design problems such as urban voids. The most recent approach to Sustainable Urbanism owes much of its theoretical and practical aspirations to these two movements.

2.2. Urban Voids

Urban voids can play a vital role in the process of achieving Sustainable Urbanism if such unused spaces are permitted to evolve through a piece-by-piece urban design. This refers to a procedural type of design involving an incremental area- or neighborhood-based development process. According to [21], piece-by-piece urban design involves setting objectives for an area, then developing policies, design intensives, and controls for achieving those objectives. Lang also adds that the definition of objectives in piece-by-piece urban design is a political act, one based on perceived public interest.

According to [22], a frequently arising challenge for piece-by-piece urbanism is the need to create public–private partnerships to ensure that policies are well implemented, especially in the case of privately owned lands and projects. Another limitation is that the tools available to the urban designer can often be restricted due to requirements related to issues such as zoning, building heights, and setbacks. In such circumstances, urban designers may have to allocate considerable effort to mitigate existing urban challenges, instead of being free to create new schemes from scratch, which can effectively double the work required.

There are three main types of urban voids: reserve spaces, remnant spaces, and defunct spaces. Reserve spaces are those intentionally left undeveloped, remnant spaces are those which are created through deliberate action, and defunct spaces are those which are temporarily undesignated for a specific use [23].

In recent times, the State of Qatar has seen massive population growth and concomitant urban development, particularly in Doha, its capital city and largest population center. Urbanization in Qatar is characterized by rapid growth supported by abundant oil and gas revenue, as well as the construction of mega-projects in and around Doha, which has become a global hub. At the same time, there has been a remarkable shift in Qatar's planning and development approach toward sustainable development, which the government has prioritized in the Qatar National Development Framework (QNDF) [24]. The QNDF outlines how the built environment can serve as a driver of change, focusing on sustainable development and emphasizing the importance of efficient urban planning in providing an improved quality of life for all residents and citizens of Qatar.

Still, the practice of urban planning and design in Qatar faces a number of challenges, a situation familiar to many countries now attempting to shift from car-oriented urban development toward more sustainable planning practices. The Qatari government is making large-scale investments in the development of a number of urban zones, whose goal is to enhance the quality of life for users with minimal impact on the environment and minimal contribution to climate change [25,26].

3. Materials and Methods

3.1. The Research Design

The present research study investigates several opportunities that exist for enhancing the quality of the TOD system in a region with a hot arid climate. It pays careful attention to beneficial features such as connectivity, urban compactness, and multimodal transport under harsh environmental conditions, which can be used as guidelines to urban planners, developers, and policymakers in wide regions of the world. This can, in turn, promote sustainability, thus improving a city's overall quality of life.

3.2. Study Area

Education City (EC), located on the outskirts of Doha (Figure 1), is a community of academic institutions that includes branches of some of the world's leading universities. The site area comprises 1300 hectares and hosts staff and student accommodation, mixed-use buildings, research facilities, hotels, retail areas, and recreational and sports facilities. The latter includes the Education City Stadium, one of the stadiums hosting the 2022 World Cup competitions. The EC campus is a fully integrated environment, facilitating interaction among its existing and future educational and recreational facilities. It is now connected to key transportation networks within Qatar via the newly opened Doha metro and the highway system.

Figure 1. Location map of Education City within Doha (source: Google Earth, edited by the authors).

Various areas of EC are characterized by one or more of three main urban themes: a community (residential area), research facilities (research and development complex), and educational urban development (universities). The built environment around the study area tends to be denser on the South Campus, as this is the location of major transport links, while the North Campus includes many areas left vacant for future development, as shown in Figure 2.

This site is also a good example of TOD implementation in Doha as it contains potential compact urban developments around transit stations. EC hosts three metro stations, called "Education City", "Qatar National Library", and "Al Shaqab". These stations lie on the metro system's Green Line. These stations main serve the site's academic and sports facilities, Al Shaqab Equestrian Club, male housing facilities, and a recreational area called Oxygen Park. The chosen study site around the EC metro station can be accessed through several modes, including the EC tram, a pedestrian path, a tunnel underpass, and by bicycle or car, and with proper development can serve as a good example of a TOD in Doha.

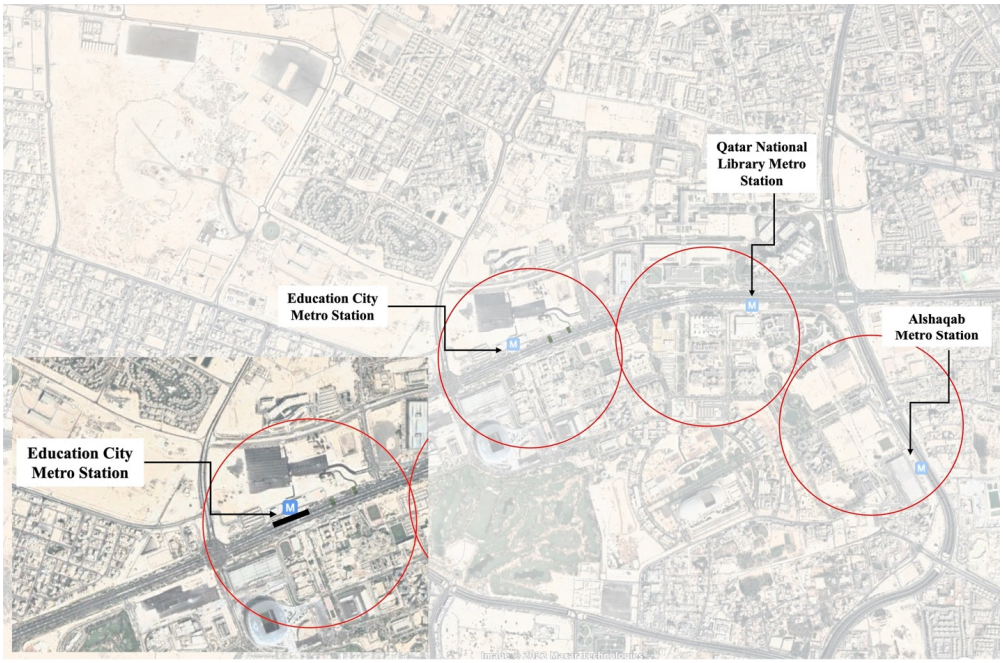

Figure 2. Existing built environment around the Education City station (source: Google Earth, edited by the authors).

Education City is connected to three major roads; the east is bordered by the Gharrafa Highway, and the south is bordered by Al Rayyan Al Jadeed Road. The campus is divided into two zones, one to the north and the other to the south, and comprises twelve precincts, with five located on the South Campus and seven on the North Campus, as shown in Figure 3.

3.3. Methodological Approach

This research employs a case study methodology that seeks to assess the existing quality of urban mobility in EC. The specific site chosen for the study was the area at and around the EC metro station, which is the station closest to the EC Stadium. This is a logical choice for a TOD study location, as it will be of critical importance for the city to assess this area's level of use and capacity, as seen for example in the high number of visitors to the stadium during the 2022 World Cup. It is particularly important to gauge the impact of the region's hot climate, which may affect users' behavior, such as their choices concerning various modes of transportation.

3.4. Data Collection and Analysis

Data collection was undertaken to evaluate the existing built environment around the EC metro station, with a defined 800 m radius study area. This included data concerning land use, buildings, voids, open space areas, and transportation network proximity. The data were collected through site observation, site analysis, photographic documentation, maps, and aerial images.

Several data analysis methods were followed, which included visual mapping, analytical diagrams, simulative images, and census data. Moreover, this study includes a detailed examination of the current state of the selected location in EC, as well as future opportunities.

The functionality of the TOD was assessed by considering a variety of factors such as the built environment, transportation system, voids, volume, functions, and proximity. Each factor plays a major role in the successful implementation of compact urban development. In addition, a survey was conducted on EC metro station users to identify their needs, behavior, and preferred modes of transportation. This survey is intended to obtain information about the variety of urban transportation facilities available in the study area and providing services to schools and universities around the EC metro station. A variety of modes of transportation

exist in EC, such as the tram, shuttle bus, pedestrian pathways, and cars/limousines; hence, the survey questions aim to identify which of these modes of transportation are the easiest and fastest way to reach specific destinations, and which are preferred by users, in addition to understanding the overall quality of these public facilities.

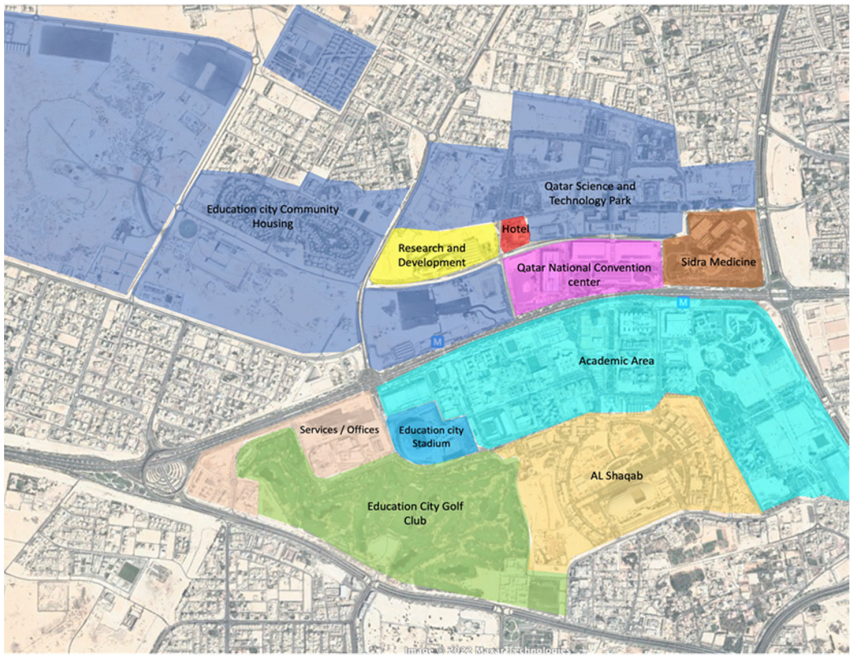

Figure 3. Education City land use (source: Google Earth, edited by the authors).

Moreover, this research incorporates a qualitative analysis aimed at assessing the TOD surrounding the EC metro station. A case study approach was utilized in order to assess the quality of this area's urban mobility development, and the outcome is a schematic design proposal that recommends improvements that can be made, based on TOD principles. The research design of this study is depicted in Figure 4.

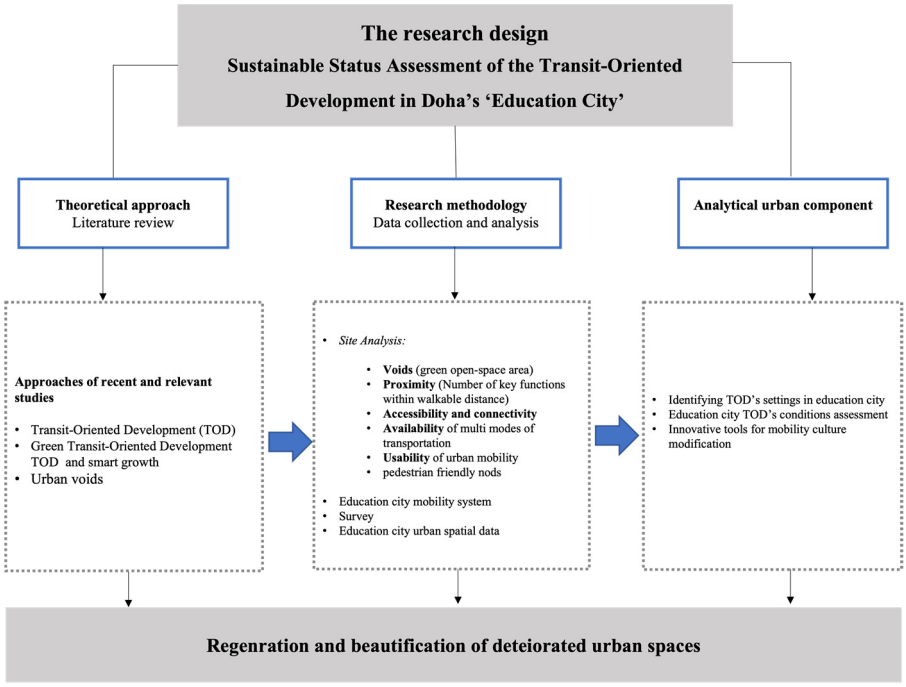

Figure 4. The research outline.

4. Results and Discussion

This section presents the data analysis and the study's findings. It begins with the site analysis, which explores the urban component of EC and its transportation system, including the current road network. It continues with an evaluation of the study area with respect to the elements of Sustainable Urbanism, including urban compactness, mobility, planning and design, and their influence on users' travel behavior.

4.1. Site Analysis

The site investigation of the area around the EC metro station shows that the area is of mixed-use nature, offering residential, commercial, retail, academic, educational, research, recreational, and other community facilities, along with facilities for sports, tourism, and medical services. As shown in Figure 3, the mixed-use educational and sporting facilities are mainly located on the South Campus, whereas the research zone and low-density residential zone are found on the North Campus. The campus hosts a vibrant mix of land uses that serve the EC population and the surrounding Al Rayyan neighborhood, facilitating social interaction between the campus and the wider community.

EC benefits from its internal tram system, which is electronically operated and provides an environmentally friendly way of transporting people around the campus, linking it to the wider PT system. There are 24 EC tram stops serving, with the three metro stations, as nodes of exchange, often acting as social gathering spots. By riding the tram, one can appreciate the EC landscape and enjoy an exciting journey through the campus. The EC tram traverses 12 km. It has 24 stops, of which 17 and 7 are located on the South and North Campuses, respectively. The service runs at intervals of 5–20 min. Figure 5 shows the EC tram route. Only 8% of EC's staff, students, and visitors consider the EC tram to be slow compared to other modes of transportation, perhaps because some tram stops are not yet operational.

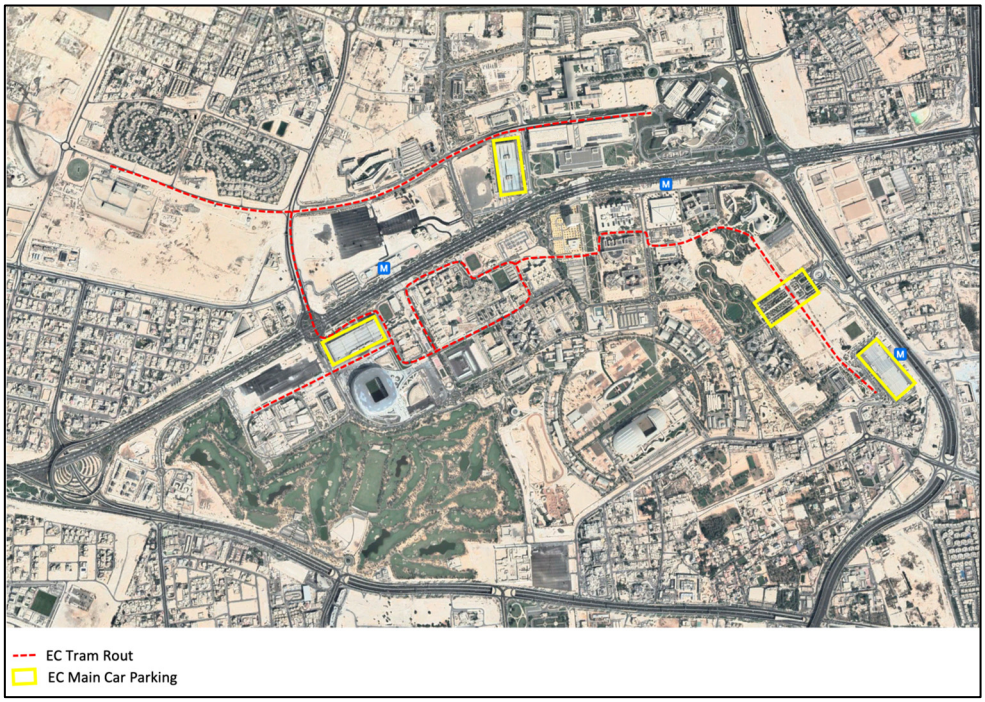

Figure 5. Education City tram route in red, with main car parking sites indicated with yellow rectangles (source: Google Earth, edited by the authors).

The use of the internal road network is restricted, as this is considered a private community with parking spaces allowed only for authorized users. The car parking facilities are situated on the periphery of EC. The internal road network consists of collector and local roads that provide internal circulation and connections to the external arterial

highways. The North Campus is directly accessible from the external highways and includes the Qatar Science and Technology Park (QSTP). The South Campus includes a pedestrian zone, Qatar Foundation (QF) Golf Course, and Al Shaqab Equestrian Club. The pedestrian zone is served by several car parks located at the EC gates. The idea is to reduce internal traffic by allowing visitors to park at entrances, and then use the EC tram and walkways to reach their targeted destinations.

Land use diversity is a major factor affecting non-motorized and public transport, particularly for work and study purposes. Students, staff, and visitors arriving at EC can easily access the campus by car, taxi, bus, or metro. According to the survey, 57% of students, staff, and visitors use their own cars, considering them the easiest and fastest transport means; this may be related to Doha's cultural behavior as well as the generally harsh weather conditions throughout the year.

There are four major car parking facilities located on the periphery of the campus, where the metro's green line provides access to EC through three metro stations, as noted earlier. These can be reached using the EC tram, pedestrian pathways, underpass tunnels, and vehicular roads. Two stations are located along Al Luqta Street, and one is at Huwar Street, providing access to both the North and South Campuses (see Figure 6).

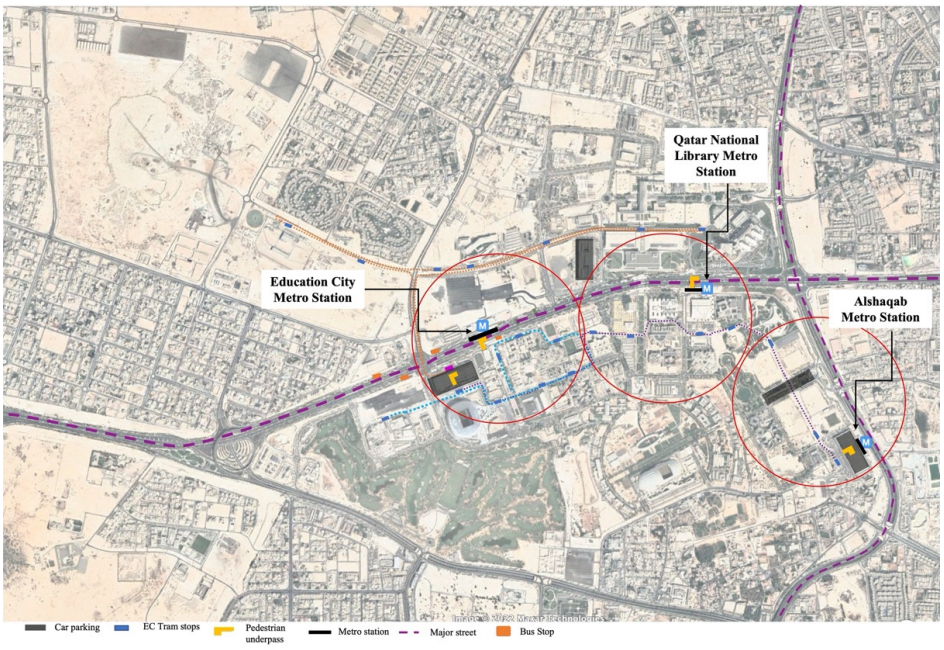

Figure 6. Transportation system within Education City (source: Google Earth, edited by the authors).

The results of the survey indicate that the majority (around 57%) of EC staff, students, and visitors use private cars to commute within EC to reach facilities such as the parks, student center, library, mosque, schools, and universities; see Figure 7. Only 2% of the respondents use the EC metro station to reach EC. Furthermore, within EC, only 17% of the respondents use pedestrian pathways for walking and/or cycling purposes inside EC to connect through the buildings; 15% use the shuttle bus to travel between facilities during break times or for meetings; and 8% consider the EC tram to be slow in comparison with other available modes of transportation within EC. On the other hand, 70% of respondents consider cars to be the fastest way to travel throughout the site. This may be partially due to the fact that some tram stops are currently under construction and thus not in operation. In sum, most respondents consider private cars the most convenient means of transport, followed by the EC tram. This is probably due to the mobility culture in Qatar, as most people use cars to reach most destinations, with other modes of transportation being implemented only recently. Moreover, while 17% of respondents use pedestrian pathways due to their attractive design and the connectivity they provide to various EC buildings, most are unlikely to walk or cycle

due to unshaded parts of the pathway offering no protection in hot weather, a serious issue given the area's hot climate. Most pedestrian pathways are too exposed to the sun, according to 45% of survey respondents, so they avoid using them despite the fact that many paths are at least partially covered with a shading system.

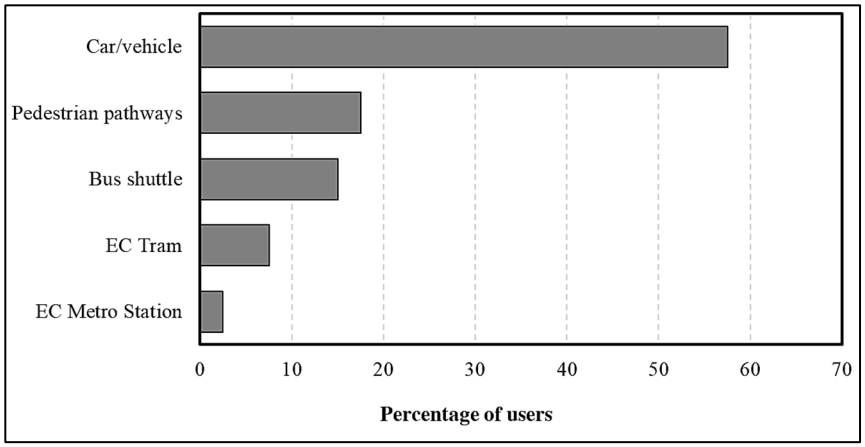

Figure 7. The results of the survey conducted on EC staff, students, and visitors.

4.2. Identifying TOD Settings

The potential to develop TOD within EC is high, due largely to the existing sustainable infrastructure. This can not only serve the community, but also reduce the negative environmental impact of transport emissions and enhance microclimatic conditions.

Infill development at the study site should prove an effective way to maximize density, make better use of infrastructure, and stabilize and enhance existing urban areas. Urban voids can also be utilized to integrate and implement Green Urbanism strategies. As indicated earlier in the Literature Review and according to [27,28], there are three main categories of urban voids: planning voids, functional voids, and geographical voids. Planning voids are created through inefficient planning processes, in the sense that planning has been performed without an understanding of the fabric of the city. Functional voids are the dead vacant spaces in cities that result from the spaces not being used as intended. In most cases, functional voids occupy valuable land while giving an unpleasant appearance to the local environment. Geographical voids are created when natural features of a city, such as a river or a valley, are overlooked by urban planners and designers. Compact urban development can be facilitated by organizing impromptu, short-term activities within the voids. This decreases urban sprawl and encourages walking, biking, and other sustainable alternatives to vehicular travel.

EC has numerous large open spaces reserved for future development but relatively few small open spaces. The West Green Spine is the largest open space within the 800 m radius of the EC metro station defining the study area. This open space, which lies adjacent to three football pitches, is conveniently accessible to students and other school users and is often used for learning and educational purposes outside the classroom. The West Green Spine and other open spaces, as well as urban furniture elements in the area, such as benches, lighting, bike racks, and traffic lights, improve visitors' quality of experience, as illustrated in Figure 8.

The heights of buildings within EC range from 12 to 15 m (see Figure 9). The tallest of these are the EC Stadium and the car parking structure at Qatar Academy. The urban volume is concentrated in the south, and a pedestrian tunnel is provided to connect the metro station to the green spine. The area surrounding the Education City metro station is vacant and needs to be developed in order to encourage the use of available transportation modes so that urban compactness can be successfully implemented.

Figure 8. Education City metro station (**left**). Voids and green open spaces at the study site, including (**A**) West Green Spine, (**B**) football pitch, (**C**) basketball playground, and (**D**) street furniture (source: the authors).

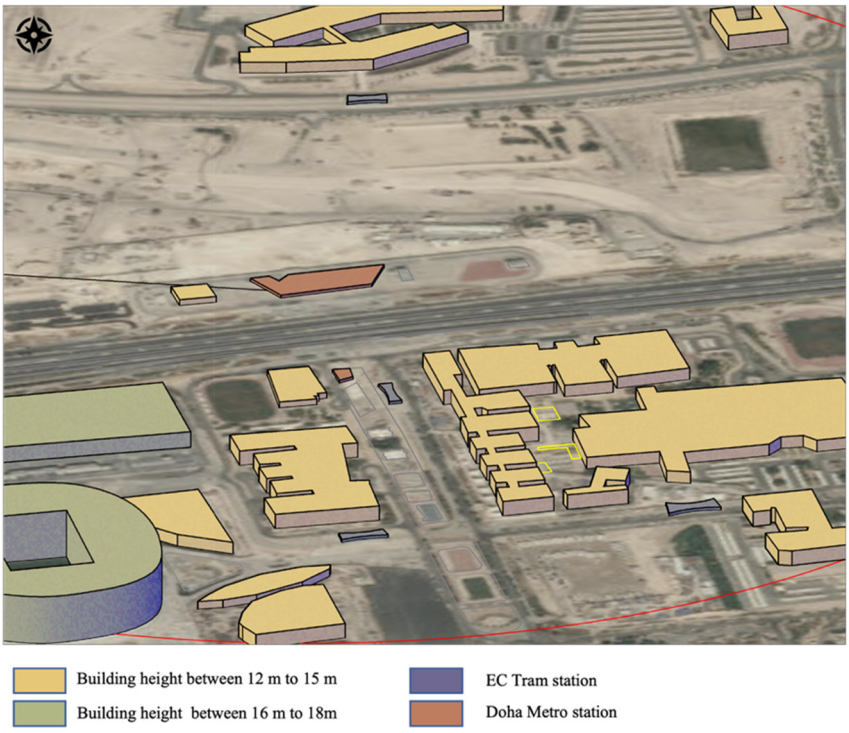

Figure 9. Existing built environment around Education City station (source: Google Earth, edited by the authors).

It is worth noting that, even during the COVID-19 lockdown, construction activities in the metro stations, as well as other major facilities, were on hold. Moving forward, commuting from residential to work areas will require working spaces closer to residents than has previously been typical. Such places are sometimes referred to as "third places," which are not homes or standard workplaces, but instead can be looked at as co-working hubs that are close to home while being comfortable to work from.

There are two types of shading systems in the study area: shading structures and natural shading systems. However, some areas have no shading and thus are very exposed to the sun; the survey found that 45% of users considered that pedestrian pathways are mostly exposed to the sun because of lack of shading in some areas (see Figure 10). In hot weather, shade helps make walking more comfortable and reduces unfavorable microclimate conditions. To reduce direct sunlight exposure, trees should be planted on both sides of streets and pathways. It is worth noting that in the study area, the trees are

currently planted only on one side of the pedestrian pathways [29]. Although pathway furniture was provided along some of the shared pathways, especially if there was a park or kids' playground, the total amount of shaded area in the study area was very low.

Figure 10. Existing shading structures around the study area (source: Google Earth, edited by the authors). (**A**) naturally-shaded pathways, (**B**) existing shaded structures, (**C**) existing shaded pathways, (**D**–**F**) unshaded pathways.

4.3. TOD Condition Assessment

The land use at the study site can be characterized as mainly educational. However, there are also offices, landscapes, and pedestrianized areas. The EC tram corridor, which serves major destinations including Qatar Academy, the main recreation center, Hamad Bin Khalifa University, Awsaj Academy, Awsaj Recreation, and two additional school sites, is still under construction. The transport system and the greater area have generally been designed to encourage people to use public transportation. For example, the car parking sites are located in peripheral areas, so that car owners have better and more convenient access to EC facilities through the use of the EC tram, metro, or pedestrian pathways, as shown in Figure 11.

By establishing a convenient distance between buildings and public transportation, the metro station stops can minimize the reliance on non-sustainable modes of transportation. Many key functions are performed in the South Campus region, all of which are integrated with several primary pedestrian routes connected to the West Green Spine, the metro station, the major car parking facility, and the university campuses. Visitors are expected to park their cars at the major car parking site, and then use the EC tram or pedestrian links to reach their destinations. Visitors coming by metro are likely to exit the metro station by using a pedestrian tunnel to cross Al Luqta Street and then choose between using the pedestrian pathways or the EC tram. Overall, the PT system enables people to reach their destinations faster than travelling by road. However, increasing public awareness of connectivity options can be expected to lead to increased use of this PT system [17,30].

Figure 11. Education City metro station TOD functions (**left**). (**A**) Major car parking, (**B**) metro station, (**C**) bus stop, and (**D**) open parking (source: the authors).

Moreover, our study shows that the waiting time for the EC tram needs to be slightly improved within the functional areas in EC. It is necessary to create information systems to help people find and choose the nearest transport modes. A good example of this technology is software applications in smartphones. In addition, if a cycling culture within the EC is to be promoted, bicycle parking should be more visible and within easy and convenient reach.

Most importantly, since very hot weather prevails for several months in Qatar, shaded pathways must be provided. Most of the existing pathways have a great deal of exposure to the sun and go mostly unused throughout the year, despite the easy access they offer to nearby transport hubs. Moreover, better signage and wayfinding would contribute to a more user-friendly environment and may encourage greater use of PT. Car use should be further discouraged within the site to create a preference for alternative (and more sustainable) transport modes. Bus stops are needed along the main road near the metro station, and these should be integrated with the site's walkways. These ideas are illustrated in Figures 12 and 13.

Figure 12. Wayfinding signage, bus stop, and EC tram stop (source: the authors). (**A**) car parking, (**B**) bus stop, and (**C**) EC tram stop.

Figure 13. Education City metro station TOD proximity (**left**). (**A**) EC tram station, (**B**) metro station linkage (source: the authors).

Moreover, Table 1 Summarizes the Education City TOD conditions and modification tools to improve TOD setting as indicated in this work.

Table 1. Education City TOD conditions and modification tools to improve TOD setting.

TOD Station (Study Area)	A description of TOD Settings in the Study Area	Improvements Needing to Be Made to Current TOD Conditions	Mobile Culture Modification Tools (Behavioral Change)
Education City metro station	At the study site around the metro station, there are • voids (undeveloped areas) • football pitches and basketball courts serving the schools. • green spaces, including West Green Spine.	• Transport culture based less on private motor vehicles • A slight improvement needs to be made to the EC tram's waiting time • Information systems are needed to make it easier for people to locate and select the most convenient transport mode in their area • Promoting a cycling culture should be made a priority at EC • It is necessary to provide shaded pathways • Wayfinding and signage should be improved	• Increasing users' awareness • There is a need to have a direct connection between shared pedestrian paths and facilities. • Place-making for urban open spaces and promoting bicycle and scooter usage • The signage system should be improved, and connectivity should be increased

4.4. Innovative Tools for Mobility Culture Modification

In order to improve the study site's transport system and users' mobility culture, the functionality of the existing transportation plan needs to be reconsidered, such that the use of multimodal transportation is encouraged more strongly. Innovative tools which can be used include a number of mobility solutions that support the existing transportation system while also utilizing shared scooters, bicycles, and e-bikes for transportation, facilitating movement throughout the area for residents, visitors, students, and staff. This can be aided through the implementation of more appealing urban areas and design, with careful consideration of the region's hot climate. Microclimatic conditions at the site also need to be considered. Climate is one of the biggest concerns for people in Qatar, which tends to discourage them from using transport options other than their private cars.

Behavioral change can be achieved through urban design by implementing more inviting places, considering microclimatic conditions, and developing and improving shading systems and green areas. People prefer cars for many reasons, including privacy, weather conditions, culture, and comfort. As public transport usage reduces pollution, improving public awareness of environmental issues arising from automobile use might stimulate the public's use of PT [31,32]. Increasing connectivity and improving the signage system at all existing stops and stations will also be desirable. Furthermore, the transportation infrastructure, including main streets, roads, tram, transit stations, and shared pedestrian pathways, needs to be interconnected with EC facilities. The existing systems need a design intervention in order to better adapt people's behavior to the use of multimodal transportation. Urban voids and open spaces are noticeable in the selected study area near the metro station. With a central focus on the place-making approach for urban open spaces and by promoting other modes of transportation, such as bicycles and scooters, the goals of TOD can be achieved.

The core principles of the conceptual model proposed below are urban compactness and walkability. This conceptual model has two main components: (i) improvements in the site's transportation system, and (ii) innovations intended to encourage a new mobility culture within EC. These involve several changes, which, if properly implemented, can help change the behavior and mobility culture of the site's users. For example, more attention should be given to street orientations at the site to improve shading and thus minimize users' exposure to direct sunlight. Urban voids should be better utilized in order to enhance the area's social infrastructure. There should also be more well-distributed courtyards and public plazas.

Despite the availability of sustainable modes of transport within EC, their level of use is currently very low relative to that of cars. Greater effort should be put into increasing users' awareness of these options through marketing or advertising at local events. In addition, users should be encouraged to use PT as their preferred means of transport, such as by providing smart cards for PT connected to other activities in EC, especially during mega-events.

Currently, private motorized transport is the preferred mode of transport for the site's users due to its easier accessibility and the ability it offers to reach entrances and access points. Although electric car charging spots are available within EC, supporting a shift to a more sustainable transport option, more effort should be made to encourage the use of PT. Reducing the availability of car parking by introducing parking fees, minimizing the walking distance to and from PT stops, increasing PT arrival frequencies, and providing an overall high-quality PT experience will all tend to attract users to PT and alter the prevailing mobility culture. Carpooling can also be facilitated at EC through the provision of an Electrical Vehicle (EV) shuttle bus, transferring users from the car parking facility to desired destinations.

Active mobility (i.e., walking, cycling, and e-scooters) should be supported in order to minimize the need for commuting (see Figure 14). The implementation of compact mixed-use development, especially towards the north, would encourage greater use of the PT system; this can be further supported with better provision of transport connections and a continuation of the West Green Spine into the proposed car-free zone. Pedestrian pathways should be shaded and narrowed in compact areas to utilize building shadows for shading. North–south pathways are better shaded by buildings, increasing their attractiveness for users. The cycling network should be upgraded so that bicycle lanes are visible and clearly separated from both car and pedestrian traffic. Bicycle lanes should be given more shading with the support of trees and building shadows, and bike racks and e-bike stations should be made easily available near the main entrances to metro stations and, when possible, at other PT transit sites.

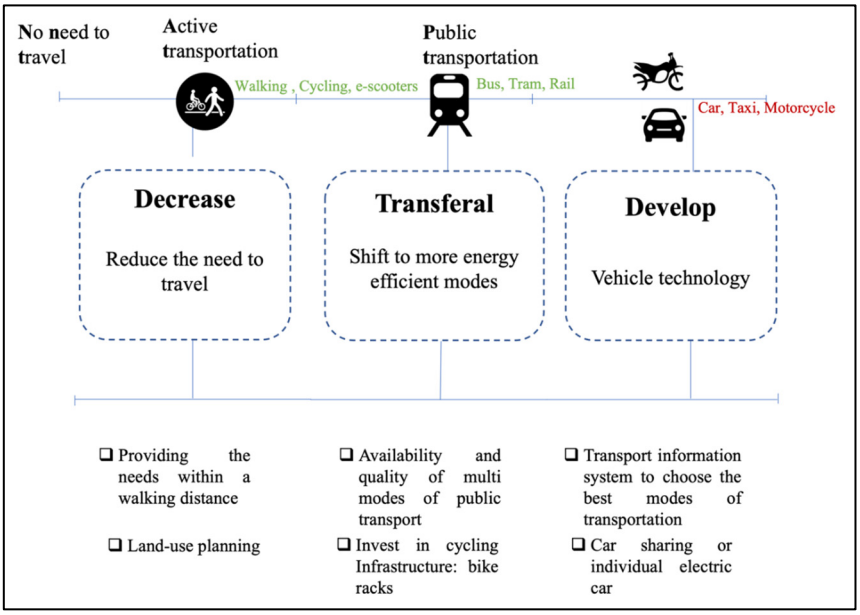

Figure 14. Availability and usability of public transportation (source: the authors).

The current urban planning and design practice in Qatar is reorienting toward the implementation of a more environmentally friendly mobility system. Most Doha metro stations have been designed around the TOD concept by developing a compact urban form with mixed-use areas around the station. This maximizes the use of PT and facilitates the successful implementation of a place-making approach, in turn helping achieve the goals of Sustainable Urbanism. Based on the present analysis, it is evident that the EC has been developed with the same goals in mind, considering multiple modes of transportation to provide connectivity among the main buildings and other facilities. However, the area is also supported by several car parking lots, which increases users' tendency to avoid the PT system.

To promote walkability at the study site, the existing pedestrian pathways need to be improved by: (1) enhancing urban accessibility, (2) providing shading structures, (3) providing aesthetically appealing urban furniture and public art to attract pedestrians and cyclists, (4) providing wayfinding signage to direct users to the nearest walking or cycling paths, (5) improving the connectivity between the North and South Campus, and (6) ensuring easy access and linkages across transportation modes.

The prevailing car-oriented culture can be changed through urban design using Smart Growth principles, creating an environment accessible to pedestrians. Temporary events can also promote denser urban development by showcasing PT systems and thus demonstrating for people how easy and accessible reaching their destinations can be, while also enlivening the urban areas within EC. The build-up of the area surrounding the EC metro station should be based on the principle of urban compactness and act as a mixed-use area. In addition, small-scale urban intervention should be integrated, which can be done by providing shading structures and public art within the urban landscape and by planting more trees. This should enhance the urban space while also improving local microclimatic conditions and attracting positive attention from the community. A car-free zone should be created, with compact and active frontage connected to the metro station. This should be supported with an underground pass connected to the West Green Spine. These improvements will decrease the need to travel by car and increase users' tendency to make use of PT. In addition, the area adjacent to the metro station should be modified so that it acts as both a transit node and as a central gathering and social area within EC. These ideas are illustrated in Figure 15.

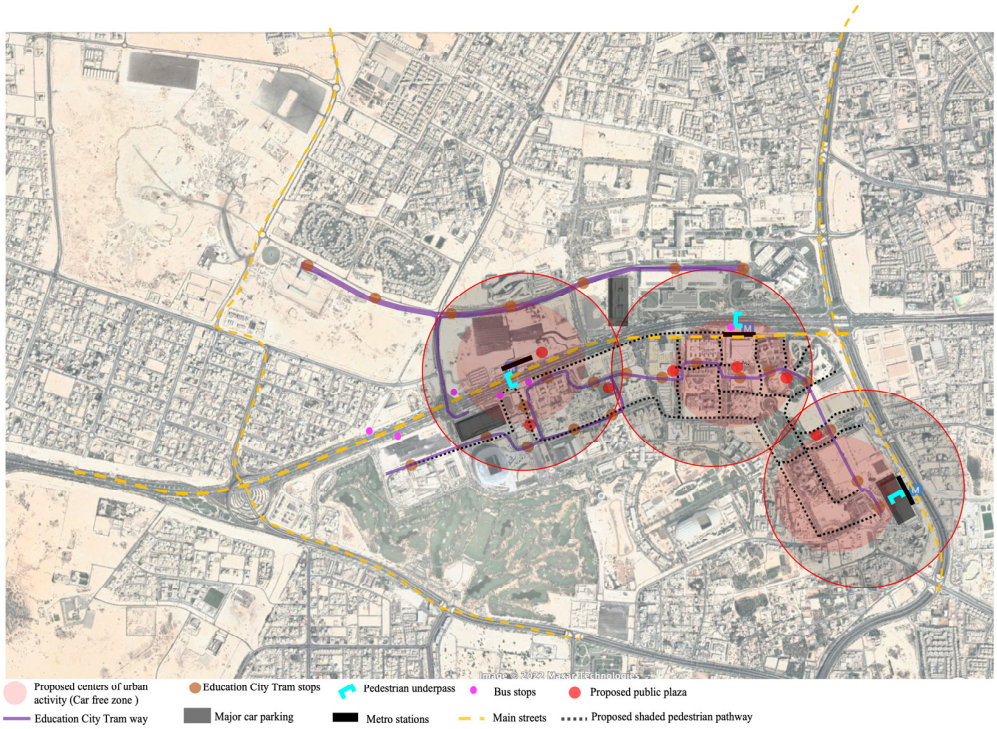

Figure 15. Map of the study area illustrating the proposed scenario (source: Google Earth, edited by the authors).

There are four categories of place-making: (i) standard place-making, aiming to enhance livability in urban areas; (ii) strategic place-making, aiming to improve infrastructure in order to attract economic opportunities; (iii) creative place-making, which seeks to create an identity of place using features such as artwork; and (iv) tactical place-making, which focuses on small-scale development by implementing short-term, impromptu activities. If all of these are implemented at EC, urban livability in the area will be greatly enhanced. Such improvements should include better urban connectivity, active transport pathways shaded by buildings, and the use of trees and/or canopies to enhance the area's microclimatic conditions. Pathways should be made as cool and pleasant as possible and should be safe for all types of users. A holistic visual signage system will also play an important role in the enhancement of these pathways, helping direct users to their desired destinations, and encouraging them toward more frequent use of the pathways.

5. Conclusions

The metro and tram stations in EC can be centers of urban activity in which both economic and social functions are performed. Areas surrounding transit nodes can act as social gathering spots and waiting areas, helping to reduce vehicular traffic, especially during mega-events. The location of tram stations should take into account the design of the surrounding urban areas and pedestrian connections. By increasing the size of commercial and mixed-use zones, the area can be made more livable and act as a genuine TOD. Making greater use of the public plaza concept, thus creating more comfortable public spaces, would also help boost the diversity of active retail frontages and enable the creation of a sidewalk cafe district. Car parking spaces should be reduced in number and be made less visible. All of these changes can enhance urban livability and boost ridership on sustainable modes of transport throughout the study site and beyond.

The present research study thus illustrates some of the opportunities that exist for enhancing the quality of the TOD system in a region with a hot arid climate. Governmental agencies, such as the Qatari Ministry of Transport and Communications, can make use of the recommendations offered here to adopt and enhance areas such as Doha's EC in

line with the best practices of Sustainable Urbanism. With careful attention to beneficial features such as connectivity, urban compactness, and multimodal transport, the mobility culture in EC specifically, and in Doha more generally, can be modified to support greater sustainability, thus improving the city's overall quality of life.

The recommendations presented in this work include suggestions for promoting increased use of the available modes of transport, thus changing the local mobility culture so that there is a stronger preference for PT use and creating a stronger sense of place throughout the study site. Moreover, place-making can be combined with urban design principles to improve the functionality of public spaces so that users' lives are enhanced throughout their work, travel, and recreational activities. For example, to promote walking and bicycle use in the region's hot arid climate, microclimate conditions will need to be improved by planting more trees and providing more water features that can serve as cooling elements, thus providing users with a more comfortable experience. In addition, greater and more significant effort should be devoted to promoting the available sustainable modes of transport within EC, to elevate their usage compared with vehicle use. This can be attained through social media advertising to increase users' awareness of these options.

Some limitations of the present research project are related to the fact that the analysis relates to data from just one site, namely Education City. Moreover, other factors may need to be considered before implementing the recommended modifications. For example, it is preferable that urban planning intervention take place before concrete actions are taken. For instance, proposed artwork may be created after projects have been finalized, but large-scale alteration of areas where infrastructure could, in principle, be improved might not be feasible at later stages. Moreover, there may be limitations in terms of allocating additional space around the study area for planting trees or the extension of parking areas in the vicinity of metro stations.

To generalize these findings further, it is recommended that more sites be analyzed and surveys conducted on users of other metro stations. Moreover, several suggestions proposed in this work apply mainly to hot arid places such as Qatar; however, in areas with modest temperatures and weather conditions, more attention in research might be devoted to other aspects of urban planning and sustainability.

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Abbreviations

EC	Education City
EV	Electric Vehicle
PT	Public Transportations
QF	Qatar Foundation
QNDF	Qatar National Development Framework
QSTP	Qatar Science & Technology Park
SG	Sustainable Growth
SU	Sustainable Urbanism
TOD	Transit-Oriented Development
TS	Transit Station

References

1. Mazzeo, F.; Altavilla, G.; D'elia, F.; Raiola, G. Development of Doping in sports: Overview and analysis. *J. Phys. Educ. Sport* **2018**, *18*, 1669–1677.
2. Oktay, D. Human sustainable urbanism: In pursuit of ecological and social-cultural sustainability. *Procedia Soc. Behav. Sci.* **2012**, *36*, 16–27. [CrossRef]
3. Lehmann, S. *The Principles of Green Urbanism: Transforming the City for Sustainability*; Earthscan: London, UK, 2010.
4. Tang, H.T.; Lee, Y.M. The Making of Sustainable Urban Development: A Synthesis Framework. *Sustainability* **2016**, *8*, 492. [CrossRef]
5. Yang, B.; Xu, T.; Shi, L. Analysis on sustainable urban development levels and trends in China's cities. *J. Clean Prod.* **2017**, *141*, 868–880. [CrossRef]
6. Al-Harami, A.; Furlan, R. Qatar National Museum-Transit oriented development: The master plan for the urban regeneration of a 'green TOD'. *J. Urban Manag.* **2020**, *9*, 115–136. [CrossRef]
7. Furlan, R.; AlMohannadi, M. Light rail transit and land use in Qatar: An integrated planning strategy for Al-Qassar's TOD. *Int. J. Archit. Res.* **2016**. [CrossRef]
8. Khare, R.; Villuri, V.G.K.; Chaurasia, D.; Kumari, S. Measurement of transit-oriented development (TOD) using GIS technique: A case study. *Arab. J. Geosci.* **2021**, *14*, 832. [CrossRef]
9. Ali, L.; Nawaz, A.; Iqbal, S.; Aamir Basheer, M.; Hameed, J.; Albasher, G.; Shah, S.A.R.; Bai, Y. Dynamics of transit oriented development, role of greenhouse gases and urban environment: A study for management and policy. *Sustainability* **2021**, *13*, 2536. [CrossRef]
10. Acampa, G.; Contino, F.; Grasso, M.; Ticali, D. Evaluation of infrastructure: Application of TOD to Catania underground metro station. In *AIP Conference Proceedings*; AIP Publishing LLC: Melville, NY, USA, 2019.
11. Alkhereibi, A.H.; Onat, N.; Furlan, R.; Grosvald, M. Underlying Mechanisms of Transit-Oriented Development: A Conceptual System Dynamics Model in Qatar. *Designs* **2022**, *6*, 71. [CrossRef]
12. Li, C.N.; Lai, T.Y. Sustainable development and transit-oriented development cities in Taiwan. In Proceedings of the 12th Annual International Sustainable Development Research Conference, Hong Kong, China, 6–8 April 2006.
13. Al-Malki, A.; Awwaad, R.; Furlan, R.; Grosvald, M.; Al-Matwi, R. The Effects of Transit Oriented Development on Liveability of Mixed-Use Neighbourhoods in Qatar: A Case Study of Doha's Najma and Al Mansoura Neighbourhoods. *Urban Plan.* **2022**, *7*, 2183–7635.
14. Isaifan, R.J.; Baldauf, R.W. Estimating Economic and Environmental Benefits of Urban Trees in Desert Regions. *Front. Ecol. Evol.* **2020**, *8*, 16. [CrossRef]
15. Al-Thani, H.; Koç, M.; Fountoukis, C.; Isaifan, R.J. Evaluation of particulate matter emissions from non-passenger diesel vehicles in Qatar. *J. Air Waste Manag. Assoc.* **2020**, *70*, 228–242. [CrossRef] [PubMed]
16. Isaifan, R.J.; Al-Thani, H.; Ayoub, M.; Aissa, B.; Koc, M. The economic value of common urban trees in the State of Qatar from an air quality control perspective. *J. Environ. Sci. Pollut. Res.* **2018**, *4*, 285–288. [CrossRef]
17. Furlan, R.; Grosvald, M. A Social-Ecological Perspective for Emerging Cities: The Case of the Corniche Promenade, 'Urban Majlis' of Doha. *J. Infrastruct. Policy Dev.* **2022**, *6*, 1496. [CrossRef]
18. Huang, W.; Wey, W.M. Green Urbanism Embedded in TOD for Urban Built Environment Planning and Design. *Sustainability* **2019**, *11*, 5293. [CrossRef]
19. Artmann, M.; Kohler, M.; Meinel, G.; Gan, J.; Ioja, I.C. How smart growth and green infrastructure can mutually support each other—A conceptual framework for compact and green cities. *Ecol. Indic.* **2019**, *96*, 10–22. [CrossRef]
20. Knaap, G.; Talen, E. New urbanism and smart growth: A few words from the academy. *Int. Reg. Sci. Rev.* **2005**, *28*, 107–118. [CrossRef]
21. Lang, J.T. *Urban Design: A Typology of Procedures and Products*; Elsevier/Architectural Press: Oxford, UK, 2005.
22. Inam, A. Unveiling Vegas: Urbanism at the nexus of private profit and public policy. *J. Urban Int. Res. Placemaking Urban Sustain.* **2016**, *9*, 216–236. [CrossRef]
23. Furlan, R.; AL-Mohannadi, A. An Urban Regeneration Planning Scheme for the Souq Waqif Heritage Site of Doha. *Sustainability* **2020**, *12*, 7927. [CrossRef]

24. GSDP. *Qatar National Vision 2030*; Government Communication Office: Doha, Qatar, 2008.
25. Furlan, R.; Al Saeed, M. Transit-Oriented Development in West Bay, Business District of Doha, State of Qatar: A Strategy for Enhancing Liveability and Sense of Place. *J. Cult. Herit. Manag. Sustain. Dev.* **2019**, *9*, 394–429.
26. Tannous, H.O.; Major, M.D.; Furlan, R. Accessibility of Green Spaces in a Metropolitan Network Using Space Syntax to Objectively Evaluate the Spatial Locations of Parks and Promenades in Doha, State of Qatar. *Urban For. Urban Green.* **2021**, *58*, 126892. [CrossRef]
27. Pluta, A. Urban void as a potential of the contemporary city development. *Bibl. Reg.* **2017**, *17*, 95–103. [CrossRef]
28. AL-Mohannadi, A.; Furlan, R.; Grosvald, M. Women's Spaces in the Vernacular Qatari Courtyard House: How Privacy and Gendered Spatial Segregation Shape Architectural Identity. *Open House Int.* 2022, *ahead-of-print*. [CrossRef]
29. Sanusi, R.; Johnstone, D.; May, P.; Livesley, S. Microclimate benefits that different street tree species provide to sidewalk pedestrians relate to differences in Plant Area Index. *Landsc. Urban Plan.* **2017**, *157*, 502–511. [CrossRef]
30. Chng, S.; White, M.; Abraham, C.; Skippon, S. Commuting and wellbeing in London: The roles of commute mode and local public transport connectivity. *Prev. Med. Rep.* **2016**, *88*, 182–188. [CrossRef]
31. Al-Thawadi, F.E.; Banawi, A.A.A.; Al-Ghamdi, S.G. Social impact assessment towards sustainable urban mobility in Qatar: Understanding behavioral change triggers. *Transp. Res. Interdiscip.* **2021**, *9*, 100295. [CrossRef]
32. Furlan, R.; Al-Mohannadi, A.; Major, M.D.; Paquet, T.N.K. A Planning Method for Transit Villages in Qatar: Souq Waqif Historical District in Doha. *Open House Int.* 2022, *ahead-of-print*. [CrossRef]