Future Cities and Environment

Green Street Design Approach to Realize Green City. Case Study: Medan City

CASE STUDY

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ubiquity press

ABSTRACT

Green cities can solve urban problems without destroying the environment. Green city planning can be implemented through green planning and design. The purpose of this research is to generate planning and design of green streets that can support the realization of green cities. The green city is closely related to urban design principles. The research method used is a qualitative method with observational data collection. The research location is the center of Medan City where the green open space is connected to the city's main road network. Green street planning includes aspects of the street network, pedestrian paths, streetscape, vegetation, bicycle paths, drainage, and parking. Green streets can provide a sense of comfort for their users, drivers, cyclists, and pedestrians. Green streets should be equipped with vegetation for urban heat reduction and drainage to drain rainwater runoff. The green street design approach is expected to support the realization of a green city. Government policies are needed so that green planning and design can be implemented to support the realization of green cities.

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KEYWORDS:
green city; green street; sense of comfort; street design; streetscape; urban design

TO CITE THIS ARTICLE:
Fachrudin, HT, Karolina, R, Fachrudin, KA and Faris, DM. 2023. Green Street Design Approach to Realize Green City. Case Study: Medan City. *Future Cities and Environment*, 9(1): 8, 1–13. DOI: https://doi.org/10.5334/fce.176

INTRODUCTION

Green city planning is not a new concept, but a new approach to solving unsolvable city problems so that urban planning is more sustainable without damaging the urban ecology and environment (Pankaja and Narendra, 2015). Green cities are also referred to as sustainable cities or eco-cities (Brilhante and Klaas, 2018). One of the principles of the Sustainable Development Goals (SDGs) related to this research is the 11th principle, namely sustainable cities, and communities, making cities and human settlements inclusive, safe, resilient, and sustainable (UN, 2021). Green urban planning and design and green communities are some of the attributes of a green city (Kirmanto et al., 2012). Green street have not yet been implemented in several cities in Indonesia, but efforts to provide vegetation on the sides of the street have been made. Green street design is not only by providing vegetation along the road, but also equipped with pedestrian paths and drainage networks. This research focuses on the application of urban design principles related to efforts to realize green cities. The research aim is to provide a green street design approach that can support the realization of a green city with case study in Medan City.

LITERATURE REVIEW

GREEN CITY

Green cities are essential for sustainable development growth, given their status as engines of economic growth, centers of population growth, and resource consumption as well as platforms for culture and innovation (Debrah, 2022). The development of green cities does not escape the individuals who are in these green cities, to improve the greenness of cities requires qualified knowledge, behavioral and psychological improvements, as well as equal inequality. Green cities wisely use renewable energy sources to support the greenness of the city so that it becomes an environmentally friendly city with minimal ecological impact and can improve air quality and health quality in the city (Wątróbski et al., 2016). A green city is a city designed with the environment in which people live, who are dedicated to minimizing waste and pollution output (Saripah Abdul Latif et al., 2013).

According to DeKay (2001), a green city is a city that goes beyond sustainability. A green city should have access to sunlight and wind with a very pattern. Zoning arrangements in cities should consider environmental conditions. Buildings can be arranged according to the direction of the sun. Roads can be oriented to facilitate the movement of wind through the city and there are green spaces between buildings so that the wind flows into each building. In city-scale designs, the microclimate must be considered and the design of parks and plazas in cities that are flowed by the wind. According to Anguelovski, et al. (2018), the green concept is a future city concept whose role is to remove air pollutants to prevent carbon emissions, prevent natural flooding, and mitigate and reduce the temperature in cities. Based on Minister of Public Works No. 5/2008, the standard green belt area is between 20%–30% of road space, and this regulation supports our green concept.

Climate change can be controlled through actions that will adapt and mitigate through the eight attributes of a green city, namely green planning and design, green community, green open space, green water, green waste, green energy, green transportation, and green buildings (KemenPU, 2011; Kirmanto, et al., 2012). Environmental aspects of sustainable urban design consist of water, waste, site and soil, pollution, planning and design, mobility and transportation, and energy. Indicators from urban planning and design aspects are reuse, conservation, land use, city structure, roads, green space (km/road), and percentage of green space (Alexandri, 2007). According to the mandate of Article 3 of Law 26 of 2007, urban development needs to be realized by taking into account the harmony between the natural environment and the built environment (Law no. 26, 2007).

Road and transport networks have a direct impact on the natural components of the environment and especially on the permeability of the soil and oxygen-producing areas. Green city architecture must be able to consider all aspects and materials that can be used to protect the existing environment (Tirla et al., 2014). Achieving sustainability in urban design will provide environmental quality and economic & social benefits. The urban design provides the most important tool in the creation of a sustainable society (Bovill, 2014). Good urban design is sustainable (Carmona, 2009). According to Carmona (2009), one of the fundamental aspects of good city design is the connection between parts of the city. The success of a new city or development depends on how well the connections work. The measure of success is not just functional performance, but how those connections contribute to the quality and character of an urban area: connections, movement options, sense of place, safe routes, good and proper parking, and traffic management.

According to Steinberg, F. and Lindfield, M. (2012), resilient urban design can be seen as an important pathway towards better microclimate management of urban public spaces, thereby reducing the need to manage microclimate through cooling or heating. New Urbanism provides walkable places, which provide many choices for people who live in cities with lifestyles in places that are comfortable and enjoyable. frastructure, and roads, together with the reuse of recycled building materials and components (Moughtin and Shirley, 2005). Proper urban design is the integration between urban design and sustainable concepts. The urban design must have an appropriate urban structure that is in accordance with the pattern or arrangement of development blocks,

roads, buildings, open spaces and landscapes that make up urban areas so as to achieve functional integration and efficiency. The principles of sustainable urban design will prioritize the adaptation and reuse of existing buildings, environmental harmony, sense of place and commercial viability (Carmona, 2009).

GREEN STREET DESIGN

One of the urban design principles is self-sufficiency. According to Clarke (2003) and Jabareen (2006), self-sufficiency encapsulates walkability, integration, and connectivity between pedestrian paths and bicycle paths and communities that can be traversed. In urban areas, urban street design is needed, namely the provision of roads equipped with green lanes and urban green infrastructure networks. Green Street belongs to the urban green infrastructure network system connected with greenways, wetlands, rain parks, forests, and other green infrastructure, forming a material, biological, energy, and communication system according to the concept of ecological urban complex, and recycling of water resources as the core of urban landscape roads (Wang & Yi, 2016). According to Im (2019), green street includes eleven elements of green infrastructure in a city, namely downspout termination, rainwater harvesting, rain gardens, planter boxes, bioswales, permeable sidewalks, green parking, green roofs, urban tree canopies, and land conservation. Green Street is a green infrastructure that is included in three development paradigms, namely sustainable urban development, green infrastructure, and stormwater management.

Green streets differ from conventional roads in that they include rainwater treatment facilities and emphasize benefits such as promotion of pedestrian safety and the aesthetic quality of the environment by combining a larger (permeable) landscape area and narrower roads. The type of rainwater treatment facility varies according to the needs of a particular location and available space. Green streets can be considered as a sustainable development approach, fulfilling various environmental, social and economic objectives so that cities may be more appropriate to implement green streets by reducing attention to excessive resources (Im, 2019). Green streets provide space for green infrastructure with environmental objectives.

Urban roadside greenery in Malang City, Indonesia can affect user perception visually and has six attributes, namely the amount of vegetation, vegetation arrangement, distance between vegetation, vegetation height, type of vegetation and green road median (Ernawati, 2022). The application of green criteria to roads in Indonesia is carried out at the design and construction stages. The Indonesian government is concerned about the concept of sustainability and emission reduction. Green street is concept that can be applied to realize green cities with a focus on watersheds and rivers water management; energy and emission reductions; recycled, reusable and renewable materials; conservation and ecosystem management and social benefits (Djalante S. et al., 2020).

There is a close relationship between urban design and sustainable concepts that influence road construction in cities. Some of the principles of sustainable road design are comfortable, attractive roads for walking, cycling, and transit and integrated with the surrounding functions (El Shimy and Ragheb, 2017). According to PermenPU (2014) from Indonesian Government, the provision of pedestrian paths and green lanes must meet the criteria of accessibility, safety, comfort, beauty, convenience, and interaction. Some of the activities that are allowed on the pedestrian network infrastructure include cycling, social interaction, formal small business activities, cafes, open space exhibition activities, green lanes, road furniture, and utility networks.

Green infrastructure can reduce environmental problems such as noise, rainwater runoff and the heat island effect (Rodriguez-Valencia, 2021). Green Street is in line with the concept of an ecological-urban complex, recycling water resources as the core of the urban landscape street. It also includes urban street flood water control, dust reduction and noise reduction, carbon emission and other functions, which can provide urban residents with unique regional characteristics and humane treatment of streetscape space. According to Wang & Yi (2016), several green street network facilities that can be implemented in a city include storm water management facilities, flow control facilities, detention facilities and arrest facilities. Storm water management facilities can be in the form of urban green belts. Flow control facilities include diversion wells, open channels and grass ditches. The containment facility can be grass. While the catchment facility can be in the form of rainwater culverts. Green Open Space Sub Zone of the Green Line of the road is the left and right sides of the road which are used as the placement of plants between 20%–30% (twenty percent to thirty percent) of the road's space according to the road class (RDTR, 2015). Green streets use the principles of green infrastructure design, green facilities and environmental quality preservation. Green streets can attract people to walk and cycle. Green streets should be equipped with good streetscape and vegetation (Shaneyfelt et al., 2017).

MATERIAL AND METHOD

This research uses qualitative methods. The research location is in Medan City. The study area is the Center of Medan City which is connected to the city's green open space, namely Merdeka Square. The area is also the starting point for the formation of Medan City. The Study area has a diversity of building functions, activities,

and building styles. Data collection was carried out by observation to obtain information about the research location. Data collection by observation is carried out to obtain more accurate and comprehensive information about a place, space, people and phenomenon at a certain time. Observations are carried out within a certain time to get the right results in the entire research area.

The research focuses on road networks, pedestrian paths, streetscape, vegetation, bicycle lane, drainage and parking. In the study area, the road network has three lanes, on-street parking, and pedestrian lanes. Then the data began to be compiled, grouped, and validated to proceed to the analysis stage. Inductive analysis is used in this study, where data is collected to find the suitability of the phenomena in the field and then analyzed and conclusions are drawn according to the theory (Fachrudin, 2022). The green street design is prepared based on the results of the analysis as an appropriate approach to be applied to green cities (Figure 1).

ROAD NETWORKS

The application of a sustainable road network in urban areas can create more livable communities. The criteria for sustainable urban road design include diversity, comfort and streetscape, safety, active roads, environmental quality and economic vitality (El Shimy and Ragheb, 2017). According to Gerike (2021), roads can be planned as ecosystems that synergize with various fields. The road network is equipped with vegetation and rainwater management. Road design can affect the quality of the urban environment, microclimate, noise and air pollution. Shade, street furniture, and greenery are important parts of urban road planning.

PEDESTRIAN PATHS

According to Gerike R. (2021), in the design of pedestrian paths in urban areas, space for pedestrians is treated as leftover space. Walking is the key element of a livable city and contributes to public health and greener travel behavior. The minimum width of the pedestrian path is 1.80 m for two people passing each other and 1.90 m if one pedestrian meets one wheelchair user.

STREETSCAPE

Urban areas require a comfortable streetscape that is complemented by attractive building facade elements, public art, street furniture, lighting and signage. A good and comfortable streetscape can attract people to interact socially (El Shimy and Ragheb, 2017). The determinants of pedestrian movement include urban design and land use; streetscape design; as well as place activities (Gerike R., 2021). Street furniture, window proportions and active use are features of streetscape design. Furniture consists of street lamps, signage, benches, trash cans, bollards and others. The proportion of windows and the active use of building functions has an impact on the streetscape (Ewing and Handy, 2009). According to Gehl (2010), the streetscape quality criteria for pedestrians consist of protection, comfort and delight. Protection is related to safety and security from criminals. Convenience in the streetscape can increase the number of pedestrians. Delight is related to the user and the human scale of the streetscape. Good streetscape design and green structures can increase the number of pedestrians.

VEGETATION

Vegetation has a positive effect on the number of pedestrians crossing the pedestrian paths and the road network (Kim et al., 2019). According to Sarkar et al. (2015), there is an influence between vegetation density and road network connectivity with walking opportunities. The green street network and the trees on the road affect the walking distance traveled by pedestrians. Vegetation on roads can reduce urban pollution, reduce the adverse health impacts of the urban heat island effect and ameliorate adverse environmental exposures. Urban green space is one of the most important components of the built environment in influencing walking, physical activity, health and mortality (Astell-Burt et al., 2014; Sarkar et al., 2015). Vegetation in urban areas can improve air quality, block wind and mitigate rainwater which needed in planning green streets (Shaneyfelt et al., 2017). Green street design must consider vegetation (size, height and type of species) and air quality. The Vegetation Index, Trees on Roads and access to main green spaces serve as measures of greenness (Abelt and McLafferty, 2017).

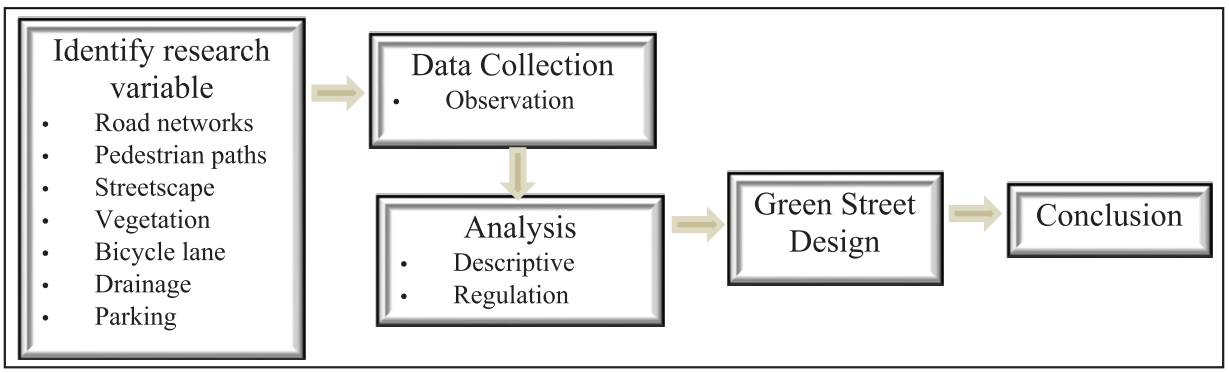


Figure 1 Research Method.

BICYCLE LANE

The bicycle lane should be provided in urban areas to support pollution-free transportation and reduce energy consumption. Cycling activity can increase movement in the city (El Shimy and Ragheb, 2017). One of the activities that can be carried out on the pedestrian network is cycling (PermenPU, 2014). Bicycle lanes can be planned on one traffic lane and require vegetation as a pollutant catcher (Shaneyfelt et al., 2017).

DRAINAGE

According to Tuomi (2016), drainage as handling of rainwater runoff is needed in green street designs, apart from providing sidewalks and vegetation on the roads. Vegetation lower than road level to direct rainwater runoff towards the drainage. According to Wang & Yi (2016) on green streets, open channels and grass ditches can be plan as rainwater flow control facilities.

PARKING

The development of urban land use focuses on roads and parking. The design of highways in urban areas prioritizes the safety of motorists, and pedestrians and the availability of parking (Shaneyfelt et al., 2017).

RESULTS AND DISCUSSION

An analysis of roads was carried out to obtain a green street design approach to support efforts to realize a green city. One of the attributes of a green city is green planning and design. This attribute is related to green street planning. The analysis was carried out on several variables, namely the road network, pedestrian paths, vegetation, streetscape, bicycle lane, drainage and parking.

The research location is in the center of Medan City with a city green open space called Medan Merdeka Square which is directly connected to four roads. On these four roads, there are various functions of buildings with a colonial building style. The research location is the zero point of Medan City which was started to be used in 1880. Figure 2 shows the study area consists of Merdeka Square (A); Balaikota Street (B); Bukit Barisan Street (C); Stasiun Street (D) and Pulau Pinang Street (E).

ROAD NETWORKS

The road network in the study area is divided into four roads, namely Balaikota Street, Bukit Barisan Street, Station Street and Pulau Pinang Street (Figure 3). Each street has 3 lanes and is one way. There are parking facilities (on street parking), pedestrian paths, vegetation and drainage. There are no bicycle paths in this area. The road networks in this area are active streets and should be further improved so that they are sustainable and can create livable communities (El Shimy and Ragheb, 2017; Gerike, 2021).

Figure 2 Study Area.

PEDESTRIAN PATHS

The use of pedestrian paths or sidewalks that function for pedestrians is still not feasible and there are many holes, damaged roads, puddles, there are even uneven paths patched with makeshift tools on the sidewalks. The condition of the sidewalk does not provide comfort to pedestrians when using it. The use of sidewalk is also misused by the presence of motorbikes parked on the sidewalk which will cause inconvenience to pedestrians using the sidewalk (Figure 4).

Along the sidewalk there is a yellow line which is a guide way for the blind that has been installed along the sidewalk but is not feasible and can endanger the blind using the sidewalk. There are many obstacles that will make it difficult for the visually impaired such as potholes, uneven roads and incomplete or broken yellow line information. On the sidewalks there are also additional decorations to beautify the sidewalks and streets, but the placement is not appropriate and reduces the effectiveness of the sidewalks as pedestrian pathways. There is a red ball on the sidewalk that is placed inaccurately, which is on the yellow line which will cut off the yellow line information for the blind. Sidewalks should provide convenience for their users so as to provide environmentally friendly behavior (Fachrudin, 2014; Gerike, 2021).

STREETSCAPE

The building style in the study area has a modern style and partly a Dutch colonial style. The facade of the building gives a characteristic of this area's streetscape. Some of the building facades have ornaments and good proportions of windows. On the pedestrian path, there are street lights, traffic signs, plants, bollards, and electricity and telephone poles. Traffic signs that complement road use are clear

enough and the information presented can be seen clearly by road users. Some signs are not properly cared for and someplace advertisements on traffic sign (Figure 5).

There are electric poles along the pedestrian walkway. It makes the pedestrian walkway dangerous for pedestrians. The placement of electric poles also looks haphazard and stacked with other electric poles and also several electric poles stacked with street lights on the sidewalk. Street lamps that function as street lights also function as power poles, at the top of the street lights are connected electrical cables that are connected along the way. This will be an eyesore for street lights that are designed unconventionally. The cables that are connected along the way are also untidy and chaotic which will reduce the visual quality of the city. A comfortable and safe streetscape will be visually appealing and can increase the number of pedestrians (Ewing and Handy, 2009; Gehl, 2010).

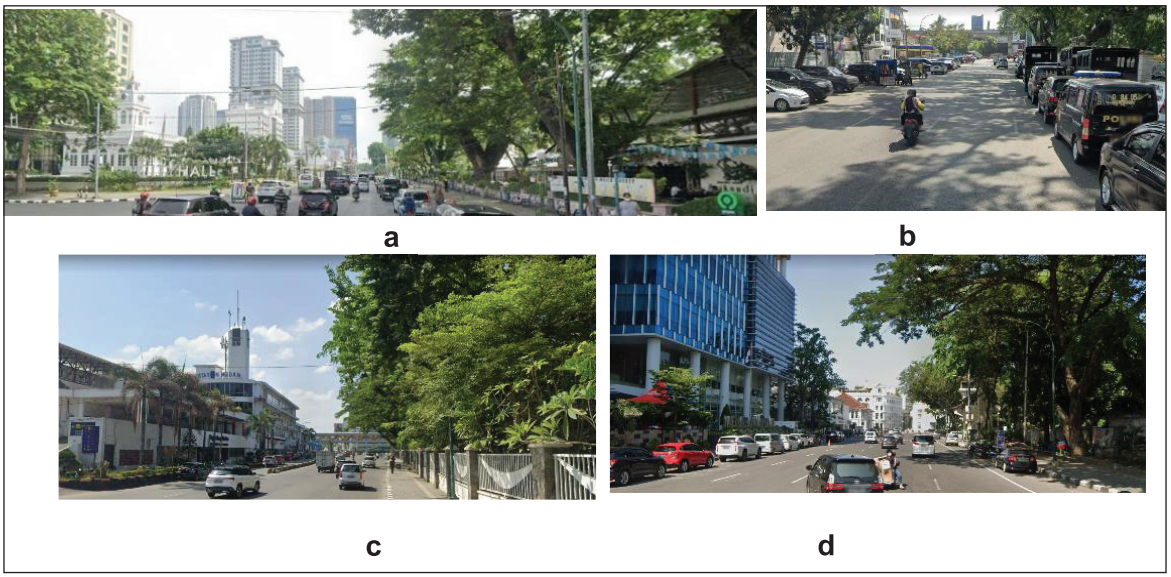


Figure 3 Road Network (**a.** Balaikota Street; **b.** Bukit Barisan Street; **c.** Stasiun Street; **d.** Pulau Pinang Street).

Figure 4 Pedestrian paths.

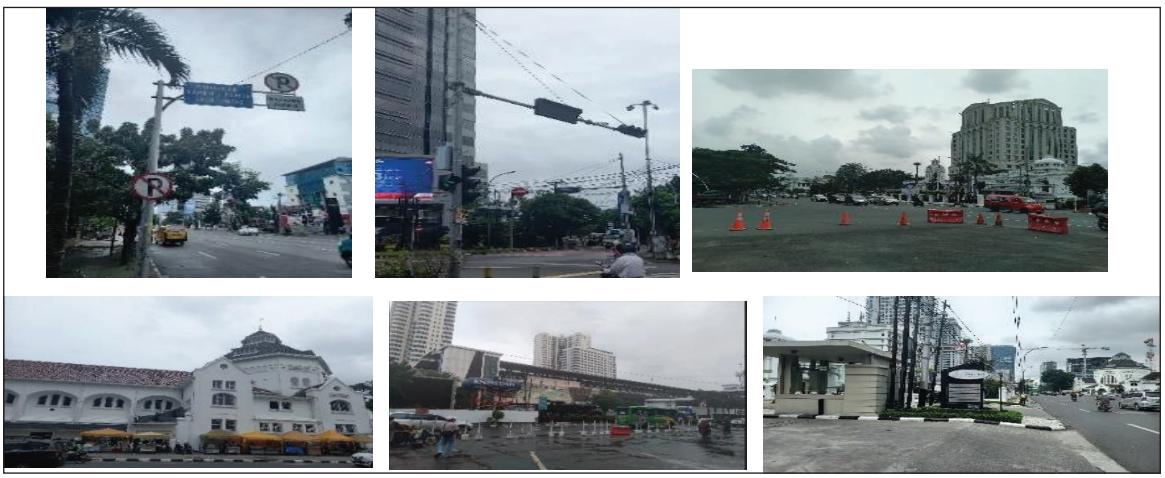


Figure 5 Streetscape.

VEGETATION

There are few trees and vegetation. There are shade vegetation and ornamental vegetation in the form of plants in pots. There are also small plants in pedestrian walkway (Figure 6). The small amount of vegetation in this area results in increased motor vehicle pollution, increased noise pollution, lack of clean air, and lack of shade for surrounding buildings. A green street design approach is needed to improve air quality, block wind and mitigate rainwater (Shaneyfelt et al., 2017; Abelt and McLafferty, 2017).

DRAINAGE

Drainage is on the edge of the sidewalk where rainwater will flow into the ditch under the sidewalk. There are several control tanks on the sidewalk. Providing control tubs at several points can function well to overcome water blockages so that they are easy to overcome. There are several control tubs whose covers have been damaged. But some are still well maintained and colored as additional decorations on the sidewalks (Figure 7). The water flow from the road flows into the gaps on the sidewalk which can function to reduce standing water on the road. Some of the gaps were covered by rocks and some were clogged until finally a pool of water appeared near the gap. There is also a gap that is high above the road which causes the water not to flow completely which causes a pool of water to grow moss in the puddle area. Drainage on green street facilitates the process of draining rainwater on the road (Tuomi, 2016; Wang and Yi, 2016).

In accordance with the opinion of Clarke (2003) and Jabareen (2006), one of the principles of urban design is self-sufficiency which includes walkability, integration and connectivity between pedestrian paths with bicycle paths and communities that can be traversed. This principle can be applied by providing the concept of green streets in urban areas. The green city design approach through green planning and design can be through green street design. Green city architecture must be able to consider all aspects and materials that can be used to protect the existing environment (Tirla et al., 2014).

The application of the green concept at the site can be applied to pedestrian paths, streetscape, arrangement of vegetation and provision of good drainage. Comparison between existing conditions and the green street concept that will be applied shows at Table 1.

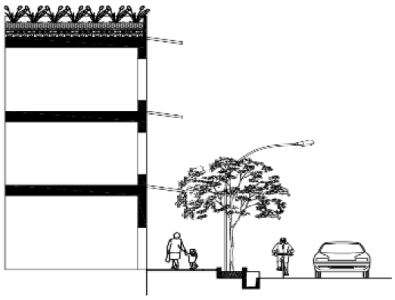
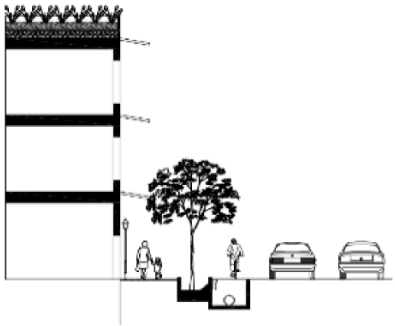
Figure 6 Vegetation.

Figure 7 Drainage.

Table 1 Green Street Design Application.

ITEM	EXISTING	CONCEPT
Pedestrian paths	Some pedestrian paths have shade and some are equipped with special lanes for the disabled  	Pedestrian paths are designed to have shade, special paths for the disabled and bicycle paths. Pedestrian paths are equipped with good street furniture. All of part is integrated to facilitate movement and provide comfort for pedestrians.  
Vegetation	On the side of the street there are shade vegetation and shrubs, but some streets are not equipped with vegetation. Some of the vegetation is above the pedestrian walkway  	On the side of the street placed vegetation as shade and buffer. Pedestrian paths are placed on the edges of buildings and vegetation as a barrier to the street  

(Contd,)

ITEM	EXISTING	CONCEPT
Drainage	Drainage is located under the pedestrian walkway, but in some parts there are open holes that are even higher than the street so that when it rains a puddle of water will appear around the drainage holes.  	Drainage is located directly beside the road and pedestrian walkway to facilitate the drainage of rainwater   At the top of the drainage can be used as a bicycle path or pedestrian walkway 
Parking	Parking is located on the side of the street and part of the pedestrian walkway is used as motorbike parking  	Parking is placed on the side of the street with vegetation as a shade  

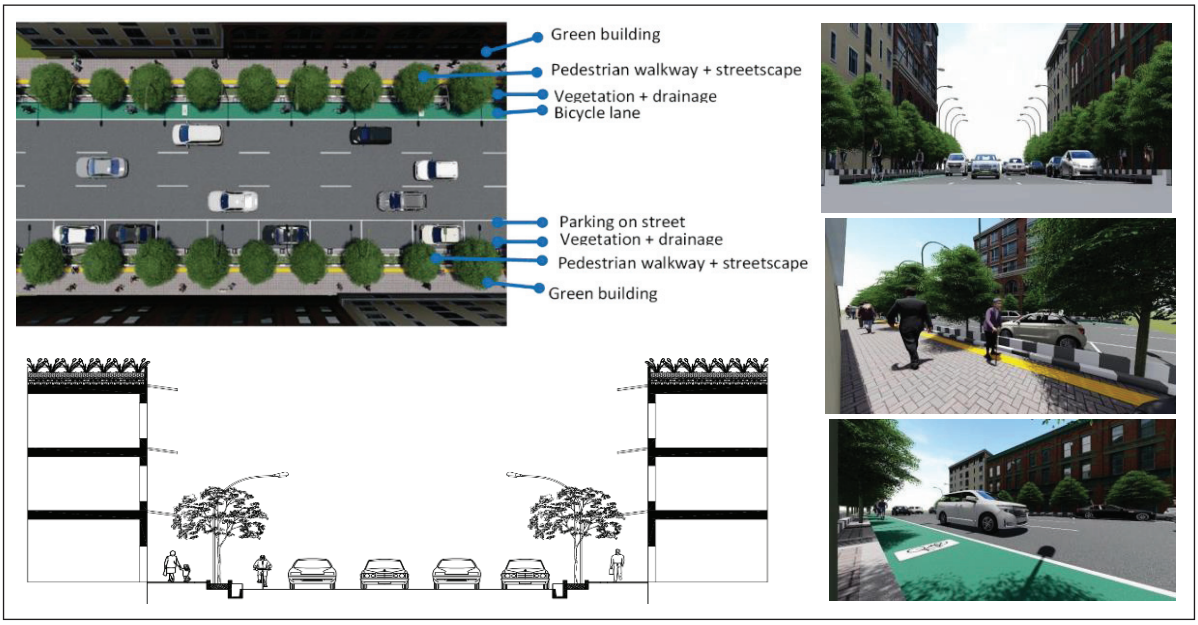


Figure 8 Green Street on one way street.

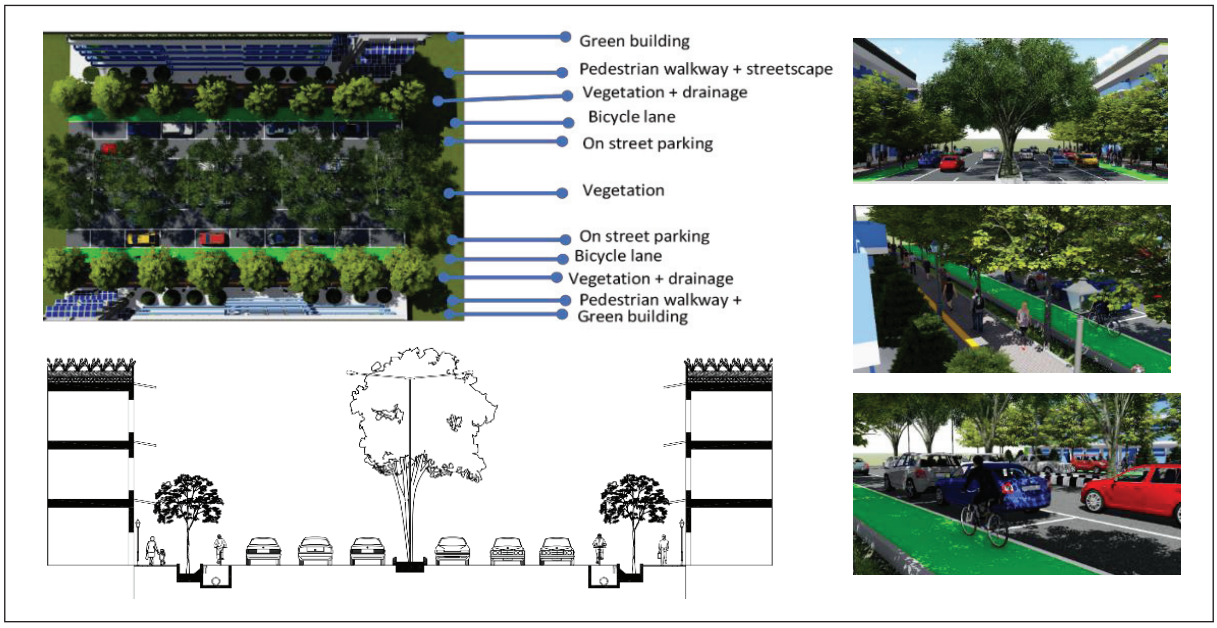


Figure 9 Green Street on two-way street.

Green streets should meet the provision of green infrastructure, green lanes, bicycle lanes, drainage as water catchments and supported by green open spaces from buildings both on land and roofs. There are some alternatives for the provision of green streets (Figures 8 and 9):

- Building area: buildings should adopt green building concepts, for example using green roofs, energy conservation, materials, etc.
- Pedestrian paths equipped with streetscapes such as attractive building facades (including window proportions), park benches, street lights, trash cans, etc.
- Green belts (vegetation) and drainage as urban tree canopies and collect rainwater runoff. Urban green space which includes greening narrow borders on sidewalks and traffic lanes. To overcome the flow of water on the road, drainage is designed to be lower than the road and supported by vegetation which can facilitate water absorption (Tuomi, 2016; Wang & Yi, 2016).
- Bicycle lane, can be planned to be integrated with green lanes on the street (Shaneyfelt et al., 2017).
- Vehicle lanes, roadblocks may or may not be provided.
- On-street parking, can be placed on one side of the street or both sides of the street. However, on narrow roads it is not recommended to have on street parking.

CONCLUSIONS

Green cities support sustainable development goals and as an approach to urban development that takes the environment into account. Urban planners and urban designers play an important role in planning green city concepts. The planning and implementation of the green city concept must be supported by policies from the government. Communities as users become the driving force in implementing the green concept in the city.

The attributes of a green city that related to urban design principles is green planning and design, one of which is self-sufficiency. Part of self-sufficiency is walkability or the ability to walk in cities, integration and connectivity between pedestrian paths and bicycle paths and communities that can be traversed. In urban areas, green streets are needed to support self-sufficiency. Green streets are equipped with pedestrian paths equipped with street furniture, bicycle lanes, drainage, vegetation and road network. Approaches to realizing a green city can be done, among others, by providing planning and physical design of the city. Besides that, green behavior are needed from urban communities as a non-physical aspect. In a green city, green streets should be planned that are integrated with green open spaces and green buildings. Physical planning and policies are required from the city government.

ACKNOWLEDGEMENTS

Thanks to Research Institution, Universitas Sumatera Utara.

FUNDING INFORMATION

This research is funded by Research Institution, Universitas Sumatera Utara, according to the research funding agreement letter of TALENTA Universitas Sumatera Utara in the 2022 budget Year Number: 402/UN5.2.3.1/PPM/KP-TALENTA/2022, 9 August 2022.

COMPETING INTERESTS

The authors have no competing interests to declare.

AUTHOR CONTRIBUTIONS

Hilma Tamiami Fachrudin, ST, M.Sc, Ph.D, GP made the conception and design of work, interpretation of data, analysis, revising it critically for important intellectual content and provided final approval of the version to be published.

Dr. Rahmi Karolina, ST, MT interpretation of data for the work and analysis.

Prof. Dr. Khaira Amalia Fachrudin, SE, MBA revising it critically for important intellectual content and provided final approval of the version to be published.

Dzaki Muzhaffar Faris drafting the design of the work.

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TO CITE THIS ARTICLE:
Fachrudin, HT, Karolina, R, Fachrudin, KA and Faris, DM. 2023. Green Street Design Approach to Realize Green City. Case Study: Medan City. *Future Cities and Environment*, 9(1): 8, 1–13. DOI: https://doi.org/10.5334/fce.176

Submitted: 20 January 2023 **Accepted:** 22 May 2023 **Published:** 03 July 2023