A STUDY ON POTENTIAL APPLICATION AND PEOPLE AWARENESS ON GREEN INFRASTRUCTURE FOR BOULEVARD: A CASE STUDY OF PUTRAJAYA BOULEVARD.

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ABSTRACT

Green infrastructure is a tool in managing the environment towards achieving sustainability by integration of environmental friendly approach into the built environment. The application of green infrastructure assists to cater on the issues such as urban heat island, climate change and greenhouse effects. As the urbanization increases the paved surfaces and decreases vegetated surfaces, it leads to a reduction in evaporative cooling, thus increase the surrounding temperature. The adaptation of green infrastructure allows ecological resources such as green spaces to be maintained in order to mitigate environmental degradation. Therefore, this study focused on the application and people's awareness of green infrastructure for the boulevard in managing energy use and climate change. Suitable green infrastructure is identified based on the characteristics of the site such as the location, function and existing physical elements. The people's awareness and preference on the green infrastructure application were also identified. The methodology used in this study are content analysis on the characteristics of green infrastructure, observation on the existing green infrastructure and its function, a survey of 30 respondents on people's awareness and preference. The interviews with landscape architects, planners, and engineers are conducted to identify the guidelines and principle of green infrastructure applied at the Putrajaya Boulevard. Based on the findings, eleven types of green infrastructure in managing the energy use and climate control can be applied for the boulevard. Referring to the Putrajaya Boulevard, only five types of green infrastructure are applied. Therefore, another six types of green infrastructure are suggested in managing energy use and climate change.

***Keywords** : Green Infrastructure, boulevard, application, awareness.*

INTRODUCTION

Green infrastructure is the provision of a planned network of environmental friendly approach in achieving sustainability in the built environment. It applies innovation through adaptation of ecological approach such as in managing energy use and climate change which provides benefits to the environment (EPA – online, Nilsson et al, 2011). Benedict and McMahon (2006) stated that green infrastructure support conservation and management action in which it guides in land-use decision making by providing a framework in planning and development. This research is focusing on the potential green infrastructure in managing energy use and climate change to be applied at the boulevard, and also on people's awareness of its application. The boulevard is a long and wide street with a formal design and consists of rows of trees. The research is conducted at Putrajaya as it is a relatively new urban area

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thatis moving towards the green city with improvement in sustainability practices. As an urban area, Putrajaya has a lot of paved surfaces and lack of vegetation cover. Thus the cooling effect via shading by trees is quite insignificant which leads to environmental problem such as urban heat island and surface water runoff (Nowak et al.,2006). Therefore, this research seeks to investigate the green infrastructure applied and to identify further appropriate green infrastructure in mitigating the environmental problems with the focus on the boulevard of Putrajaya. A study on people's awareness and perception toward green infrastructure for boulevard in managing energy use and climate change is also conducted.

Green Infrastructure Towards Sustainability in Built Environment

Green infrastructure emphasizes the function of the natural environment through adaptation of multifunctionality to increase the efficiency and sustainability (Benedict and McMahon, 2006). According to Cambridge Advanced Learner's Dictionary, sustainability is defined as *"lasting for a long time*" (CDC – online). It is the ability of something to continue for a long period. According to the Environmental Protection Agency, sustainability provides balance ecosystem between human and nature that create a harmonious lifestyle(EPA – online). It maintains the amount of resources which protect the human well-being and natural environment as illustrated in the following Figure 1.

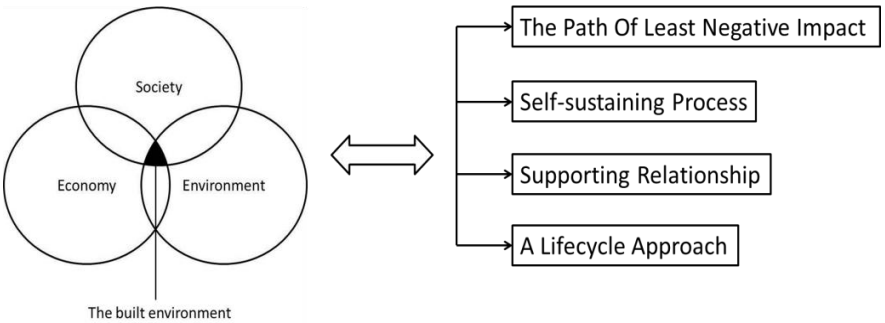


Figure 1: Components (left) and principles (right) towards a sustainable built environment (adapted from Friedman, 2007).

According to Friedman (2007), the three overlapping components (refer Figure 1 – left) which are the environment, society and the economy create a concept towards sustainability. The relationship between all these components gives out the concept of sustainability when the four general principles (refer Figure 1 – right) are followed. The first one is "the path of least negative impact" which means selecting the best way of everything that is projected will giving out minimal bad consequences. For

example by using renewable resources like solar energy. The second one is "self-sustaining process" which means a system or ability to continue by itself without anyone or anything involved.For example energy generated through a designed lighting with photovoltaic panels or solar collectors without avoiding reliance on public utilities. The third principle is "supporting relationship". All the three aspects must be related to each other in achieving sustainability. The fourth principle is "a lifecycle approach". In order to achieve sustainability, a good decision-making for a sustainable system is required to sustain itself throughout its entire lifecycle which is subjected to change. The conception and construction need to ensure that the original attributes of the project will be valued for years to come. The diagram helps in providing a better understanding on how to achieve sustainability. Therefore, green infrastructure is considered one of the approaches to achieve sustainability. According to the EPA (online) and Struck and Lichten (2010), there are five basic components of green infrastructure as shown in Figure 2.

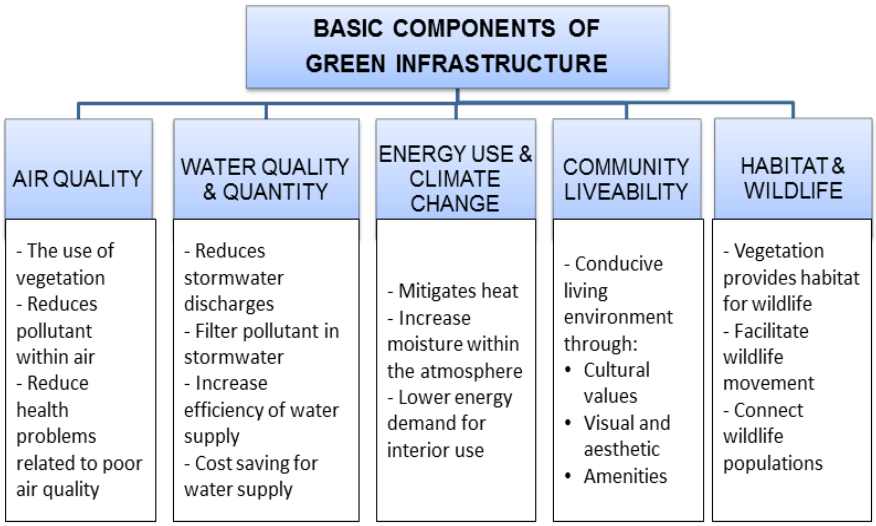


Figure 2: The basic components of green infrastructure

This study focuses on the component of green infrastructure towards managing energy use and climate change. The urbanization has led towards more paved surfaces and less natural land cover that can absorb and retain heat, resulting in the urban heat island phenomenon among others. Therefore, the potential of green infrastructure need to be explored in addressing the environmental problems. Reducing the local temperature helps in lowering the energy demand for the building's cooling and heating (EPA – online, and Forest Research, 2010).

Benefit Of Green Infrastructure Application In Managing Energy Use And Climate Change

As vegetation is one of the elementsof green infrastructure in managing energy use and climate change, it brings several benefits towards the environment, social, and economic (EPA – online, Benedict and McMahon: 2006). The following Figure 3 summarizes its benefits.

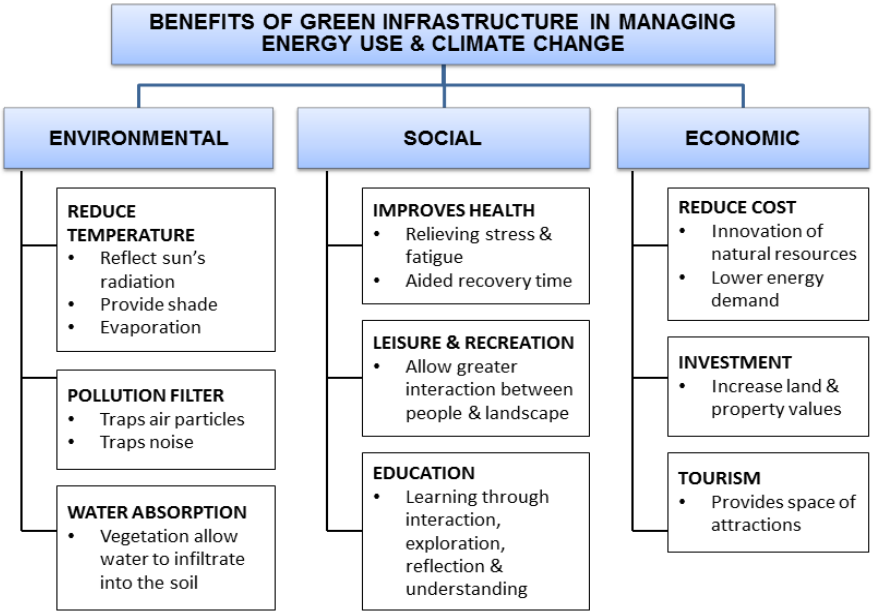


Figure 3: The benefits of green infrastructure in managing energy use and climate change towards the environment, social, and economic (adapted from Mell: 2010).

The Green Infrastructure Research Group from The University of Melbourne stated that, "*Green Infrastructure can provide essential ecosystem services that many people are unaware of…"*. Green infrastructure such as street trees and pocket parks help to moderate the surrounding temperature through evaporation. It minimizes the incidence of heat stress that gives benefits to the health(Melbourne School of Land and Environment – online). Ely and Pitman (2012) stated that the presence of green space within the living environment influences the health towards a better condition. It is useful in relieving stress and fatigue as the green infrastructure acts as platform in providing space for recreation and healthy lifestyle. According to Davies e al. (*see* Mell, 2010), the application of green infrastructure that contributes in managing energy use and climate change offers opportunities for investment in term of physical and economic aspects by increasing its value and regeneration.

The integration of green infrastructure in the built environment reduces the problems related to the environment, social, and economic.

People's Perceptions And Acceptance On Green Infrastructure Towards Managing Energy Use And Climate Change

Perception includesenvironmentaland social issues that have influenced people's behaviour and preferences within the landscape environment(Mell, 2010, Nilsson et al, 2011, and Benedict and McMahon, 2002). The relationship between environmental and social features are presented in Figure 4.

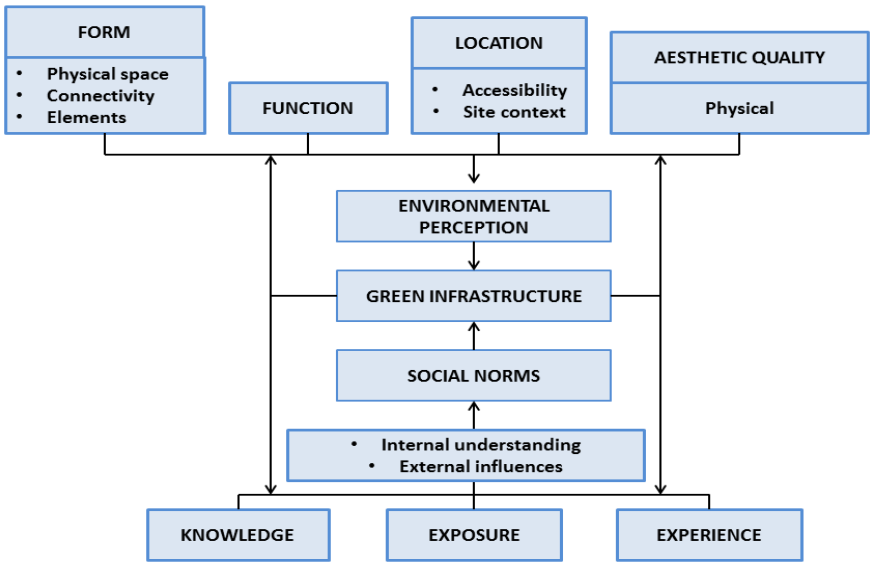


Figure 4: Factors that influence people's perception towards green infrastructure (adapted from Mell 2010:72).

Bowler (*see* Mell, 2010) noted that people are continually engaged with the landscape if they have a deep understanding of the environment surround them. Mell, (2010) stated that the assessment of the way the community value the different landscape elements should be conducted if the planners are to serve that community in the long-term development and management. The study by Mell (2010) shows that the awareness towards sustainable living environment are increasing due to the current environmental issues such as instability in the environment that lead to climate change and global warming has risen their awareness in seeking towards sustainable ways of managing the environment in order to mitigate and minimise those environmental issues. Based on a research, the awareness level of people is low due to little knowledge

about the green infrastructure (Responsive Management, 2005). Harvey (*see* Mell, 2010) stated that perception and acceptance of the landscape setting, including green infrastructure are influenced by the level of understanding of the functions and its composition.

METHODOLOGY

In studying the potential application and people's awareness on green infrastructure towards energy use and climate change at the Putrajaya Boulevard, the methodologies used are as follows:

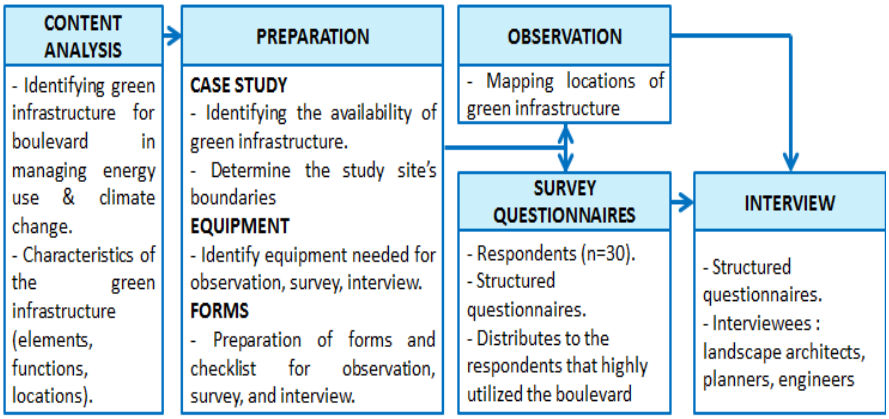


Figure 5: Methodology framework

Figure 5 shows the flow of methodologies used in studying this topic. Several preparations have been done before conducting the field work. The preparation process includes reviewing and extracting significant information on the aspects of the study. The equipments to be used during the fieldworks, targeted respondents, identification on date to conduct the field works and site visit are identified.

First of all, content analysis is done. Based on the literature review, information regarding the green infrastructure that control energy use and climate change are studied to develop further understanding and to assist in conducting the next methods of this research. This method covers the objective on identifying the characteristics of green infrastructure that control energy use and climate change for boulevard. Journals, books, and internet websites are the main sources. The green infrastructure was categorized based on its functions in term of microclimatic control and energy use. It is further analysed based on itscriteria, functions and the location.All the data are recorded in a table form. The checklist is a part of tools to conduct observations.

A visit to Putrajaya is conducted to identify the case study areas and their boundaries. Information regarding green infrastructure had been

identified and recorded. Thus, two sites along the boulevard are chosen. Figure 6shows the layout of the two selected sites along the boulevard:

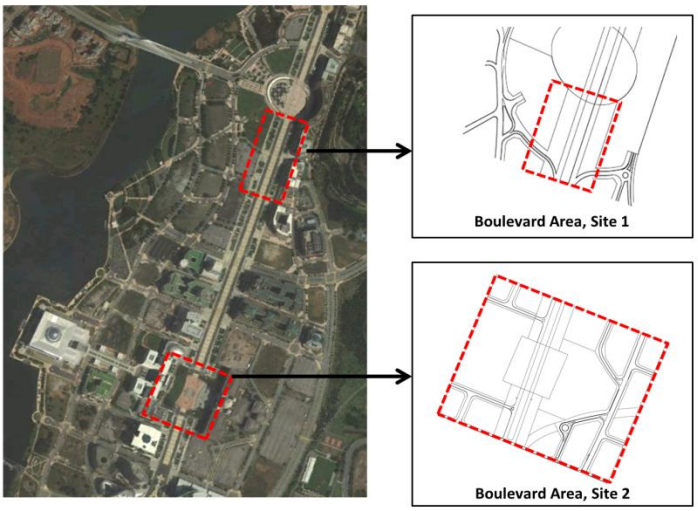


Figure 6: Location of studysites

After conducting a site visit and case studies, observation and surveyis conducted at the same time. The observation is conducted by using a checklist and zoning. The checklist which is made by referring to content analysis is considered as a tool to conduct observations. The checklist components can be seen in figure 7.

G.I.	AVAILABILITY	LOCATION		
		A	B	C
Stormwater bumps out				
Grass verge				
Green Wall				
Solar lighting				
Swale				
Rain garden				
Street trees				
Pocket wetland				
Pocket park				
Permeable pavement				
High mast reflection light				

Figure 7: Checklist For observation

The zoning in figure 8 is based on the function where zone A is green turf, zone B is the vehicular road and zone C is the cascading viewing stage.

Figure 8: Zoning at the boulevard area

At the same time, survey of structured questionnaireis conducted to cover the objective of identifying people's awareness and preference on green infrastructure for boulevard.The respondents (n=30) cover various backgrounds of users that utilized the boulevard as they are the main user, allowing them to give clear and actual answers pertaining the topics. Throughout the survey, therespondents are evaluated based on their familiarity, acknowledgement of the function of green infrastructure available on the site, and their preference towards its application.

Lastly after the observation and survey are done, structured interviews are conducted and the professionals are chosen as the interviewees in order to cover the objectives of studying the potential green infrastructure in sustaining boulevard, and on identifying people's awareness on the application of green infrastructure.The interviewsare basically based on the research aim and objectives which include the guidelines involved in designing Putrajaya Boulevard, the purposes of its applications, future planning of integrating more green infrastructure, and people's acceptance towards its application.

ANALYSIS AND RESULTS

Green Infrastructure For The Boulevard In Managing Energy Use And Climate Change

Based on the literature review, the green infrastructuresthat can be applied for boulevard in managing energy use and climate change have been identified and summarised as follows;

GREEN INFRA.	CRITERIA	FUNCTION	LOCATION
Stormwater bumps out 	-Curb extension -Layers of stones -Topped with soil and vegetation	-The vegetation increases the moisture within the air -Infiltration	-Mid block of street -Intersection of street -At the sidewalk
Grass verge 	-Grass	-Grass increase moisture within the air -Reduce air temperature -Infiltration	-Between footpath &curb -Round-abouts -Roadside
Green wall 	-Vegetation -Vertical structure -Soil/ inorganic materials	-Increase moisture within the air -Reduce air temperature	-Interior & exterior -Outside the building façade, vertical walls
Solar lighting 	-Photovoltaic solar panel -LED lamp -Rechargeable battery	-Converts solar radiation into electricity -Reduce energy use of light on the bulb	-Roadways -Outdoor & garden
High mast reflection lamp 	- Reflection panel	-Reflect direct lighting from bulbs -Reflected light is low in temperature	-Roadways -Outdoor & garden
Swale 	-Vegetation: trees, shrubs, grass -Wide, shallow channel	-Vegetation increase moisture within the air -Reduce air temperature -Infiltration	-Along main roads -Around parking lots

Rain garden 	-Vegetation -Drainage -Turf/ groundcover	-Vegetation return water vapor in atmosphere -Infiltration	-End point of drainage -Near driveway
Street trees 	-Trees with particular canopy -Planters	-Leaves reduce air temperature through evaporation	-Within infiltration planter, swale/ rain garden -Along the sidewalks and roads
Pocket wetland 	-Aquatic plants -Flowpaths of inflow and outflow	-Water increase moisture within the air -Reduce air temperature -Infiltration	-Within open space -Can be linked with swale
Pocket park 	-Trees and greenery -Basic facilities -Lighting	-Regulates microclimate through evaporation	-Onsmall, irregular piece of land -Near street-ends -Alongbike path
Permeable pavement 	- Porous ground surface materials: asphalt, concrete, paving stones, bricks	-Reduce heat retention -Increase soil moisture – reduce surface temperatures	- Sidewalks - Parkings - Roads

Green Infrastructure Application At Putrajaya Boulevard

Based on the observation, literature review, and interview, several green infrastructureshave been identified at Putrajaya Boulevard and their functions have been analysed.

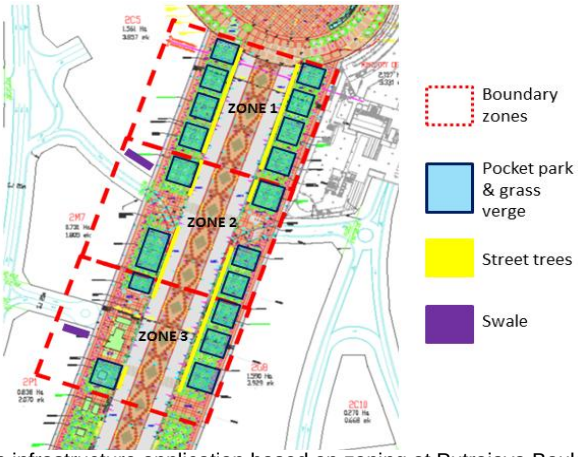


Figure 9: Green infrastructure application based on zoning at Putrajaya Boulevard (site 1).

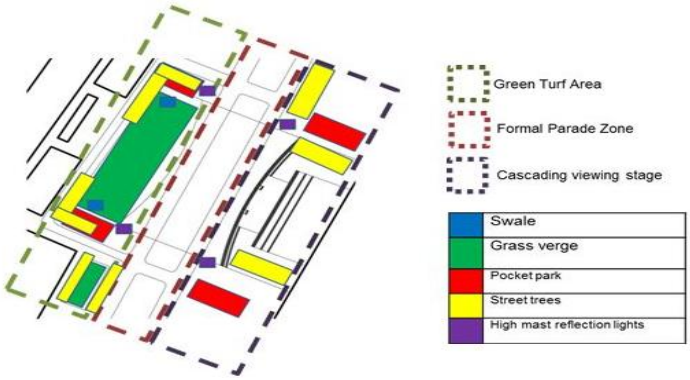


Figure 10: Green infrastructure application based on zoning at Putrajaya Boulevard (site 2).

grass verge | swale | pocket park | street trees | High mast reflection lamps

Green infrastructure	**Functions**
Grass verge	Reduce air temperature, infiltration
Swale	Reduce air temperature, infiltration
Pocket park	Reduce air temperature, infiltration, aesthetic,
Street trees	Reduce air temperature, infiltration, aesthetic,
High mast reflection lamps	Reduce air temperature

Green infrastructure reduces the surrounding temperature by application of greenery and through materials selections. The colours of the materials are from the soft colours that deflect the heat and glare. It is applied for aesthetic purposes as it acts as cosmetic to create unity and harmonious visual with the surrounding façade and landscape. It smoothens the visual effect. In terms of filtration, green infrastructure acts as buffer to filter noise and air pollution towards the adjacent building and spaces.Its application is meant for community socialization by providing space and comfort for the community to participate and utilized the outdoor spaces. It helps people to relax and rest after having a hectic day in the building. Green infrastructure is also applied to management of water as water from the artificial wetland and the sewerage system are being recycled for irrigation to reduce the cost and control the water capacity.

Potential Green Infrastructure To Be Integrated At Putrajaya Boulevard

The potential green infrastructures to be integrated at the boulevard are influenced by the surrounding environment. Through the case study and observation that was conducted at the Putrajaya Boulevard. This site significance in its functions especially during events such as the National Parade, marathon and many more. It is located in the area that applied many green infrastructure.The green infrastructure that have been discovered are grass verge, high mast reflection lighting, street planting, pocket park, swale, street imprint pavement or permeable pavement.

Figure 11: Putrajaya Boulevard

The figure shows the plan of Putrajaya Boulevard which yellow lane is the boulevard. The focused site is the area of Putrajaya Boulevard,located near to the Dataran Putrajaya; a square-shaped formal

plaza within Precinct 3. It is the major focal point along the whole Boulevard. It covers as area of 2.2 hectares and measures 150m by 150m.

Figure 12: Views toward boulevard at Dataran Putrajaya

Figure 12 shows the condition of the site at Putrajaya Boulevard. It is divided into three major zones which are green turf, formal parade zone and cascaded viewing stage. Each of the zone provides a different explanation of the characteristics of the site, current functions, and activities happening there.

Zoning	**A: Green Turf**	**B: Formal Parade Zone**	**C: Cascaded Viewing Stage**
Characteristics	Open green space	Formal boulevard/ vehicular road	Steps to Palace of Justice
Activities	Sport/Leisure	Passing by/ Marching	Sitting/ Watching area

The table shows data collected in each zoning area that has been recorded to support the information in the photographs.

Figure 13: Zoning at Putrajaya Boulevard

Potential Green Infrastructure In Sustaining Boulevard

Based on the structured interviews that have been done, there are numerous of potential green infrastructures that help in sustaining the boulevard. According to the engineer that has been interviewed, type of surface material which are permeable, light in colour and long lasting really help in sustaining the boulevard. As an urban city which practice cycling among the users, Putrajaya has a lot of hard surface material compared to the green area that increase the amount of surface runoff. However, this can be improved by applying green infrastructure.

PeopleAwareness And Preference On Green Infrastructure In Managing Energy Use And Climate Change

In conducting the survey, the respondents chosen are the people who are familiar with the study site. Therefore, only people who live or work at Putrajaya, and utilized the Putrajaya Boulevard are selected to be the respondents. Only green infrastructure that functions for managing air quality and climate control are selected to be evaluated by the respondents.

Based on the interview and survey questionnaire, it shows that the people are well aware of the existence of green infrastructure at the boulevard due to its locations and forms which are clearly visible.

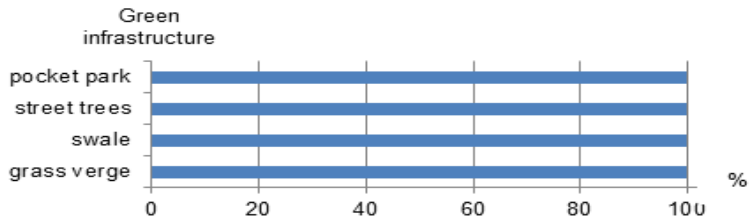


Figure 14: People awareness of the presence of green infrastructure for managing energy use and climate change at Putrajaya Boulevard

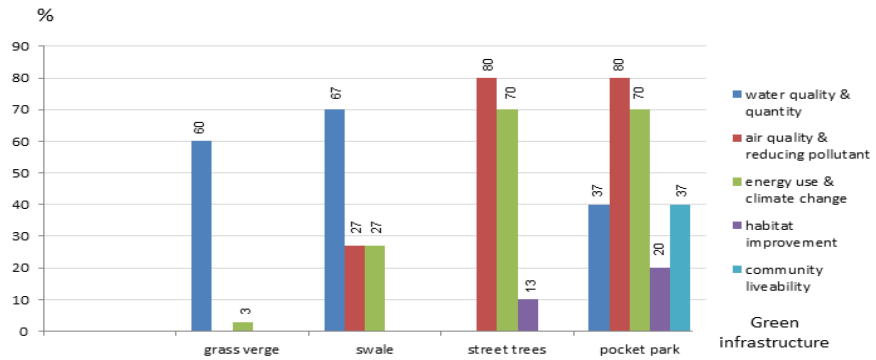


Figure 15: People awareness of the functions of green infrastructure at Putrajaya Boulevard based on five basic components of green infrastructure

The respondents are being asked not only on that function alone as all those five basic components for green infrastructure are also being included. This was conducted to evaluate on the respondent's awareness of the other integrated function of green infrastructure. Based on the survey, it shows that both respondent groups know several functions of the green infrastructure. It shows that the function of the green infrastructure differs from one green infrastructure to another and is multifunctional.As for street trees and pocket park, the more than half of the respondents (70%) knows its function in managing energy use and climate change by reducing air temperature, and for grass verge and swale, only 3%and 27% of the respondents know its function.

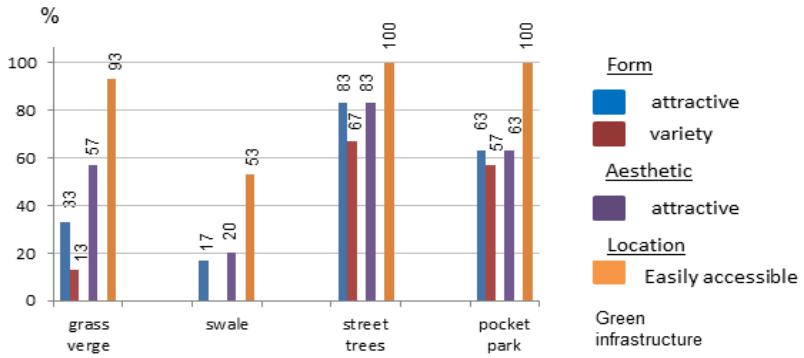


Figure 16: Environmental perception in the form, aesthetic quality, and location of green infrastructure

As for street trees and pocket park, it shows more than 50% of the users agree that other aspects influence their awareness towards the function of green infrastructure. It can be said that, the aesthetic quality and location of the green infrastructure influence the awareness of the function towards green infrastructure. The green infrastructure which is highly rated in aesthetic quality and accessibility shows higher awareness of its function in managing climate change and other four components.

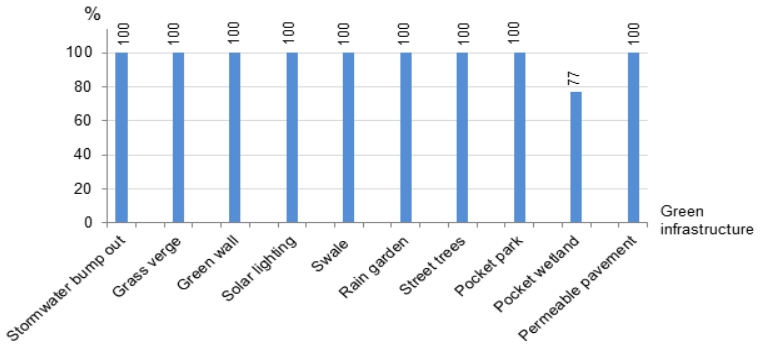


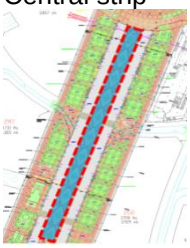
Figure 16: People preference on green infrastructure application at Putrajaya Boulevard

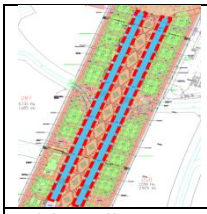
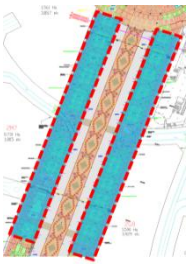
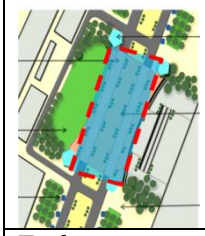
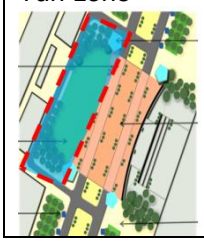
Most of the respondents agree that other green infrastructure should be applied at the boulevard. The majority of the respondents (87%) agree that one of the green infrastructure's functions is in managing climate change. Therefore, green infrastructure with greenery, including grass verge, green wall, swale, rain garden, street trees, and pocket park are highly preferable by the respondents. It shows that people are looking for outdoor space that can provide them with aesthetically pleasure and comfortable as greenery help to reduce the surrounding temperature by increasing moisture within the air. Thus, it provides cooler air to the surrounding environment.

People are very concerned with the aesthetic quality that influences their perception towards the green infrastructure and the environment as people value the environment for its appearance rather than its functions. Aesthetic quality gives good moods, softens the structural effect on the building façade and the environment, and stimulates the sense of welcoming and enthusiastic within that environment.

DESIGN RECOMMENDATIONS

For future development, the design and implementation of green infrastructure at Putrajaya Boulevard should fulfil its functions in term of managing energy use and climate change. The figure below shows the recommendation of green infrastructure application at Putrajaya Boulevard.

Spatial layout of boulevard	**Green Infra.**	**Design guidelines & recommendation**
Central strip 	-Permeable pavement -Grass verge -Portable plants	- More greenery should be introduced at the centre of the boulevard. As the area is meant for ceremonial use, portable planting can be introduced. - More grass as ground surface material should be applied as the process of evaporation will eventually remove heat from the air and increase moisture, thus reducing the surrounding temperature. - The use of light colour and less glare of ground surface materials should be maximized as the area has directly exposed to the sunlight, where it has very minimal of trees to provide shade.
Street	-Permeable pavement	- Permeable ground surface materials should replace the existing tarmac to allow water to be directly infiltrated into the soil.

		-The water that infiltrates into the soil maintains the moisture within the soil, thus reducing the surface temperature.
Sidewalk 	-Permeable pavement -Pocket park -Street trees -Solar lighting -Grass verge -Stormwater bumps out	- Ground surface material for the sidewalk can be replaced with permeable pavement to allow surface water runoff to infiltrate into the soil. - For street lighting, improve the existing street lighting by adding the solar panel which can radiate the solar, thus reducing energy use to light the bulbs. - As for the garden and pedestrian lighting, the use of reflection lighting can reduce the heat produced in the environment. - Reducing of surrounding temperature lead to lower energy demand for cooling purposes inside the adjacent buildings. - The composition of trees and planting should consider for aesthetic quality as it provides a sense of welcoming for people to utilise the outdoor spaces along the boulevard.
Formal parade zone 	-Permeable pavement -Solar lighting -Portable plants	-Permeable and less glare ground surface materials should replace the existing tiles to allow water to be directly infiltrated into the soil and increase soil moisture. - As the area is fully exposed to the sun, solar lighting and less glare ground surface materials should be applied.
Turf zone 	-Street trees -Swale -Grass verge	-Improve the characteristic of the lighting by adding the solar panel which can radiate the solar. -The high mast reflection lighting reflects the light that generated solar energy. -It not only can reduce the heat produced by the light, it can also save the energy used to produce the light.

Cascade viewing platform 	-Permeable pavement -Planting	-Implement permeable surfaces which allow water to infiltrate into he soil, thus increase the moisture within he soil. Therefore, it reduces ground surface temperature.

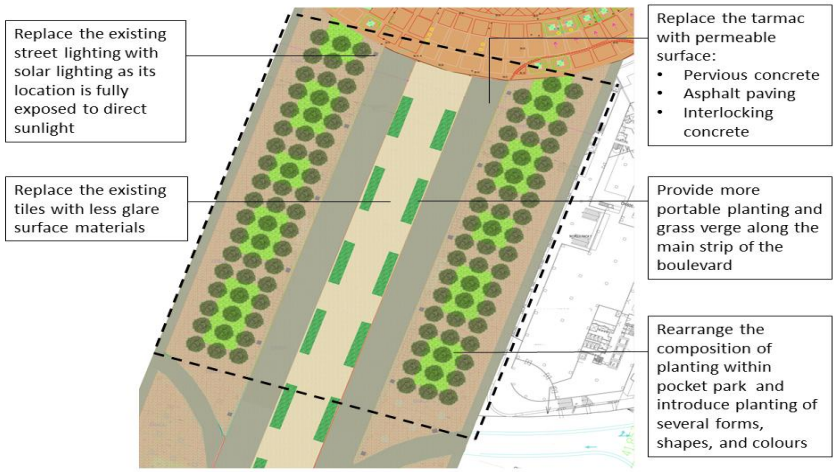


Figure 17: Recommendation on the green infrastructure application in managing energy use and climate change for Putrajaya Boulevard(site 1).

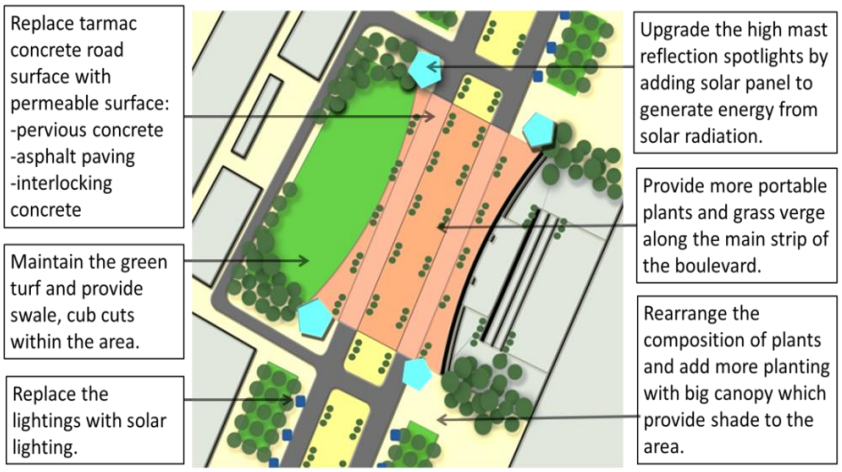


Figure 18: Recommendation on the green infrastructure application in managing energy use and climate change for Putrajaya Boulevard (site 2).

CONCLUSION

In conclusion, there are several potential green infrastructure that can be applied at the boulevard in managing the energy use and climate change. In Malaysia, especially at Putrajaya Boulevard, only several types of green infrastructure for this purpose have been applied. It shows that its application is still low and the local authorities should play their role in implementing green structure at open spaces especially at the boulevard as Putrajaya is moving towards a green city which practice sustainability.

The green infrastructure with the element of vegetation can incorporate street trees, rain garden, grass verge, and green wall. The preference towards the application of more green infrastructure at Putrajaya Boulevard marks the community awareness and support towards achieving Putrajaya as a green city. Based on the findings, it can be concluded that most of the community is aware of the presence of green infrastructure for managing energy use and climate change and prefers more green infrastructure to be applied. Among the perceptions toward green infrastructure, the aesthetic quality plays an important role in increasing people's awareness and preference as it makes the space more welcoming and lively.

As Putrajaya Boulevard is to be of a formal design that are meant for ceremonial activities and street, the aesthetic factor of green infrastructure can be in term of its shapes, forms and colours, and compositions. It is to provide scenic pleasure drives and walking experiences throughout the outdoor spaces. People are also aware of the green infrastructure in moderating the microclimate by reducing the air temperature and glare effect. The form and location of green infrastructure influence the perception of people towards it and offer them with opportunities that promote, attract and engage users.

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