# Towards Green Roads in Malaysia: Review of Road Characteristics Effects on Road Surrounding Microclimate with Respect to Roadside Trees

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**Abstract**

Due to the rapid Malaysian metropolitan development, some amount of forests and vegetation have been replaced by impervious and artificial urban road surfaces, lead to increasing ambient temperature of many Malaysian urban areas. Urban greenery including roadside trees planting is believed to be a useful mitigation strategy of road surface temperature and thus the local ambient temperature. Malaysian cities appear to have different roadside roads conditions which help cooling the air and providing shade. Many researchers have suggested various environmentally methods to alleviate ambient air temperature by planting the vegetation in urban areas which are closely connected to the roads of a city. However, there is a lack of studies to concern influence factors of roadside trees and road characteristics on each other in the face of surface and air temperature reduction surrounding the road. This study first identifies a pattern on the effects of road characteristics, including road orientation and road width with an overview on the capabilities of roadside tree planting and road design to mitigate road surrounding microclimate. It then provides guidelines for urban development towards green roads in a tropical city.

*Keywords:* Road orientation; Road width; Roadside trees; Road surface temperature; Ambient air temperature

## 1.0 Introduction

Rapid world urbanization in metropolises has been remarkably increased owing to the socio-economic factors of modernization to achieve human-scale development (Huang, 2008). However, massive urban areas occupied manufactured materials and fabricated surfaces have imposed significant undesirable changes in the landscape and natural ecosystem. Consequently, human-made urbanized developments have altered the climatic characteristics of urban areas. Such environmental changes have direct and indirect effects on the local climate of urban areas, specifically, resulting in worldwide temperature alteration which is referred Urban Heat Island or UHI (Landsberg, 1981; Emmanuel, 2005; Gartland, 2008). The effect of urban heat island has been explored extensively over the world (Oke, 1978, 1988; Streutker, 2003; Gartland, 2008). Different scales can be formed from the heat islands such as around a single structure, a vegetative canopy, or a throughout the city. The main cause of this phenomenon is from the urban surface changes in which vegetation is replaced by paved surfaces such as surfaced roads which effectively store short-wave radiation (Jin et al., 2005; Stathopoulou & Cartalis, 2009). Indeed, reduced vegetation and increased impervious urban surface materials led to a reduction in the amount of shaded areas over urban spaces; therefore, intercepted solar radiation areas would be reduced. Due to this additional solar radiation multiple absorption, such phenomena occur in relationship to an increase in the surface temperature and then ambient temperature (Oke, 1978; Gartland, 2008; Reed, 2010; Shahmohamadi et al., 2011). Since paved road surfaces are one of the factors affecting urban heat island, numerous studies have been carried out on the thermal behavior of fabric surfaces to the urban environment (Anak Guntor et al., 2013). As road can be the intersection between structural and urban scales, it affects inside and outside microclimates by discharging heat transfer through the material surfaces to the surrounding area which is elevated the outdoor and indoor temperatures (Carnielo & Zinzi, 2013). In tropical cities, the fundamental issue to design roads is not only to protect it from tropical climate conditions in general, but also from high levels of solar radiation intensity in the long period of the day (Ali-Toudert, 2006). Accordingly, road climatology is essentially concerned with investigating the variables that impact the air and road surface temperature along a road (Postgård & Lindqvist, 2001). On the other hand, to mitigate UHI, trees contribute to the urban microclimate amelioration with reducing air temperature by evaporative and shading cooling (Santamouris, 2007; Givoni, 1994). As road surfaces absorb high levels of solar radiation, roadside trees can provide shade and avoid direct sunlight (Chow & Roth, 2006). As Malaysia is a part of the tropical climate regions affected by high air temperature, reduction of green areas for urban development led to increasing impacts of urban heat island.

The current study focuses on the combined effects of both geometric roads characteristic and roadside trees on road surface temperature and air temperature and thus improvement of road surrounding microclimate. The research seeks to provide some preliminary results concerning road characteristic and roadside trees in reducing road surface temperatures in urban roads and, using simplified assumptions, to discuss some implications for potential road surface temperature mitigation resulting better their surrounding urban environment.

## 2.0 Methodology

This study first presents the effects of road characteristics, including road width and road orientation by using a secondary data to reveal the existing literature on the relationship between road and roadside trees characteristic and road surrounding environment. It also identifies the strategies required to explore future plans to address road microclimate modification by using the finding of former studies. It provides guidelines for urban development towards green roads in Malaysia.

## 3.0 Findings and Discussion

### 3.1. Urbanization and Urban Heat Island

Growing urbanization is directly related to the urban heat island due to human activities, changing ground surfaces and reducing vegetation and green areas. Further details will be discussed in this section

#### i. Urbanization

Up to 61% of the global population is expected to live in metropolitan areas by 2030 especially in Asian cities (Rajagopalan et al., 2014). Although urbanization development make better lives and comfort, the immoderate and unexpected growth of urbanization led to unpleasant side effects worldwide such as global warming and air pollution (Mirzaei, 2010). Without reasonable planning of the urbanization process will subsume to continue environmental issues which are causing the urban environment to deteriorate (Priyadarsini et al, 2008). Besides, urbanization growth has changed the urban landscape with more artificial urban surfaces and less greenery with a consequent increase in urban heat island (Oke, 1982). Increasing of urban paved surfaces is related to urbanization and population growth (Stankowski, 1972). As metropolises continued to increase demographically and physically, the temperature difference between urban and rural areas will be increased. Since rapid urbanization has caused a faster rate of change to be continued, it is needed to improve a methodology and strategy which recognize the impacts of urban development. Malaysia has experienced urban space transformations since 1970 up to present. Not only numbers of cities have been increased, but also urban centers capacities have improved outward to the suburbs boundaries. Totally, the current population of Malaysia has reached to 30,267,367, increasing slightly from 2013. The Malaysian population was 28,334,135 according to the 2010 census. This made Malaysia the 42nd most populated countries worldwide (DeSA, U. N., 2013).

Therefore, Malaysia despite of urbanization and industrial development can be confronted with the consequences of environmental problems progress due to human activities.

#### ii. Urban Heat Island

An urban heat island (UHI) is a metropolitan region or city which is remarkably hotter than its surrounding countryside or rural areas due to human activities (Hinkel et al., 2003). UHI is one of the most recognized forms of microclimate change systems referred to as a dome of increased air temperatures in the urbanized areas (Christensen, 2005; Park, 2007). It occurs noticeably during the winter and summer and the temperature difference normally is higher at night than during the day. As a population center gets larger, it leads to development its area and increase its average air temperature. The UHI intensity depends on population, city size, and industrial development together with physical design, geographical climate and meteorological weather conditions (Oke et al., 1991). This phenomenon was authenticated firstly over 150 years by Howard (1833) in London, although he was not who named this phenomenon. Since heat islands have been investigated in many of the mega cities worldwide, it has been documented in most of these major cities around the world (Voogt 2004). Urban heat islands intensity has obtained increasingly concern due to the rapid procedure changes from natural green surfaces to artificial paved surfaces with a high percentage of heat absorption by buildings and urban structures (Oke, 1987). The first study on urban climate in Malaysia was carried out by Sham (1972, 1973) in 1972, Sham figured out markedly the higher temperatures in Kuala Lumpur by contrast to rural areas using temperature traverse methods. Later, in 1973, he found increasing air temperature from 6 $^{o}$C to 7 $^{o}$C for Kuala Lumpur and Petaling Jaya. Sani in l990/9l found 4 °C to 5 °C UHII on clear days; however, 2 °C on cloudy days in Kuala Lumpur. Besides, in 1992 and 2007, Ahmad studied the influence of urban parks on air temperature and soil moisture content on land surface temperature in Kuala Lumpur respectively. In 1992, he investigated the maximum of UHI intensities under clear skies from 3 °C to 5 °C and minimum about l °C in raining days. He also found soil moisture content reduces the land surface temperature, which can affect urban heat island intensity by 2007 in Kuala Lumpur. Elsayed (2007) stated that due to reducing the amount of trees in Kuala Lumpur, the ambient temperature has been increased. He examined nocturnal heat island intensity in different locations in Kuala Lumpur by 2006. He found that the intensity of the UHI has increased to 1.5 °C since 1985. Another study has been done by Sin and Chan (2004) in Penang Island using 65 weather stations. He found the major UHI intensity in Georgetown, Air Itarn, Bandar Bayan Baru and Bayan Lepas varied from 2 °C to 6 °C depending on the size of urban areas. In order to investigate the intensity of the heat island in Muar, one of the rapid growing cities in the south of Malaysia, in 2011 Rajagopalan et al. (2014) found 4 °C temperature changes during the day and 3.2 °C at night caused a changing air temperature pattern in this city.

Table 1: Urban Heat Island Intensity (UHII) studies in Malaysia

| **Authors** | **Location** | **UHI Intensity** |
|---|---|---|
| Sham (1973) | Kuala Lumpur | 6-7 °C |
| Ahmad (1992) | Kuala Lumpur | 3-5 °C |
| Sani (l990/9l) | Kuala Lumpur | 2-5 °C |
| Elsayed (2006) | Kuala Lumpur | 1-5 °C |
| Sin & Chan (2004) | Urban centers in Penang | 2-6 °C |
| Rajagopalan (2011) | Muar | 3-4 °C |

Consequently, the intention of UHI studies in Malaysia is more focused on air temperature UHI in Kuala Lumpur. However, none of the studies is focused on the effects of road characteristic on road surface temperature with respect to roadside tree characteristics.

### 3.2. Urban Roads and Urban Road Surrounding Environment

The road as part of urban planning is an important concern in bioclimatic urban design methodology (Oke, 1988). The road can be seen as the intersection between structural and urban scales, as it is made up of the shared surfaces among the buildings and the open urban canopy. Thus, the road influences both outside and inside microclimates and subsequently impacts the warmth felt by individuals and additionally the energy utilization in urban structures. The fundamental problem confronting engineers who build roads is designing a road that can withstand a tropical climate and that has the necessary safeguards to protect it from not only the tropical climate in general, but also from the high levels of sunlight and subsequent radiation received throughout the characteristically long periods of intense sunshine during the day (Ali-Toudert, 2006). As incoming sun-oriented short-wave radiation is absorbed during the day, it brings about immediate warming of the surface, and the radiation is also taken in great quantities by the road deeper layers. The urban road surrounding microclimate is influenced by several parameters including the road geometry (orientation and width), the vegetation and trees and the properties of surfaces. According to absorption of solar energy by road surfaces, these parameters cause to increase surface temperature and thus air temperature. The extent and trend of the impact of urban roads on urban environment and thereby on road surface temperature and air temperature is discussed in this section.

In summary, despite of road infrastructure development, environmental issues related to the roads such as increasing road surface temperature have grown significantly and further efforts should be made to address road surrounding microclimate

#### i: Relationship between Road Orientation and Road Microclimate

Road orientation as a geometric features affect urban microclimate, increasing the road surface temperature as well as air temperature directly above it (Oke, 1981, 1988; Voogt, 2002). One study shows that the road orientations with respect to the solar radiation were discovered to have a considerable impact on urban road surfaces (Nunez & Oke, 1977). A large-scale numerical study displayed decisive role of road orientation with respect to sunlight on the urban surfaces (Arnfield, 1990). Other studies investigated that thermal comfort outdoor is extremely depend on solar radiation and road orientation due to long time sun exposure (Mayer, 1987, 1993). Specifically, Ali- Toudert and Mayer (2004) investigated road thermal comfort in different road orientation in arid regions in Ghardaia, Algeria (32.4833° N, 3.6667° E). They found out E-W oriented roads had less shade rather than N-S oriented ones to protect from solar radiation in summer days. Indeed, N-S oriented road canyon can provide enough shadow to make more pleasant microclimate. They concluded that to create more roads thermal comfort could be by rotating the roads to intermediate orientation such as NE-SW or NW-SE. In 2006, another study was done by Ali-Toudert and Mayer in Ghardaia, Algeria (32.401° N, 3.801° E.) for a typical summer day which is located in a hot and dry climate. They studied the effects of road orientation, including E–W, N–S, NE–SW and NW–SE oriented roads on outdoor thermal comfort. In E–W roads, the air temperatures were moderately warmer than N–S roads. In E–W road, the maximum air temperature was at 4 pm and for N–S road, the maximum value was at early afternoon, following the solar exposure time. Van Esch et al. (2012) discussed the influences of road design parameters such as road orientation on solar access affecting road microclimate. They studied two orientation; E-W and N-S of roads in The Netherlands (52.3167° N, 5.5500° E) in summer and winter (June, March, December). They found that in E-W oriented roads are exposed large percentages of direct solar radiation during the day compared to N-S oriented roads in summer. The provided guidelines for urban designers that in north side of east–west oriented roads may be placed some trees to provide shadow to the road surfaces. Besides, for the north–south running roads, small trees can be placed on the east side of the road, making shade to the west-facing facades.

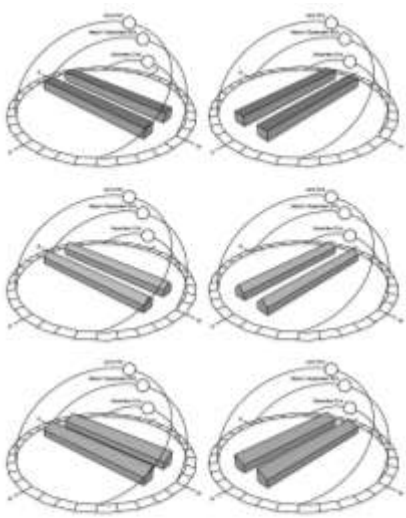

Figure1: Solar path and relative to the road directions, Image Copyright Van Esch et al. (2012)

As a result, both surface and air temperatures have shown that the road orientation influences on urban road thermal performance. To be improved roads thermal comfort, the roads can be rotated to intermediate orientation such as NE-SW or NW-SE. Another the solution can be planting trees in the appropriate direction of trees with respect to the road orientation.

**ii: Relationship between Road Width and Road Urban Environment**

Another influential factor of road geometry on road surrounding microclimate to be studied is road width (Eliasson, 1996; Ali-Toudert & Mayer, 2006; Pearlmutter et al, 2007; Bourbia, & Boucheriba, 2010; Van Esch et al, 2012). In 1996, Eliasson studied the seasonal and monthly air temperature in the wide road (45 m) and narrow about 13 m for a three year period in the city of Goteborg, Sweden (57.7000° N, 11.9667° E). He investigated temperature distribution in relation to differences in road geometry and land use. He argued that due to small air temperature variation during 3 years of case studies, road geometry has a small influence on the air thermal pattern, at least in the city Centre. In contrast, in the Constantine City (Algeria) located at (36.3500° N, 6.6000° E) was conducted by Bourbia, & Boucheriba (2010) which is characterized by a semi-arid climate with hot and dry in the summer. It was evaluated air and surface temperatures within different widths of the urban roads during the month of July 2007 in a two weeks period. The result shown that narrow roads had lower temperature either air or surface. And wide urban roads increase daytime air temperature. Adding vegetation into the road environment and planting trees could be a strategy to mitigate surface and air temperature. Ali-Toudert & Mayer in 2006 found that road thermal environment can be depending on road geometry such as road width. He studied air temperature and solar collection during a typical summer day on the 1st of August from 7 am to 20 pm in Ghardaia, Algeria (32.401N, 3.801E). He claimed that in wide road, the thermal environment is extremely stressful and approximately independent of the road orientation (road oriented E-W is a little more stressful). To mitigate the thermal microclimate in wide roads, planting of proper trees to create shade was suggested. Along with these studies, Van Esch et al. (2012) investigated the effects of urban road design parameters such as width of roads on solar access affecting on road thermal performance. The widths of roads were 10, 15, 20 and 25 m in the Netherlands (52◦06_N and 5◦11_E) in summer and winter during three months of June, March, and December.

The results have shown that with the increasing road width, the amount of solar collection of area increases significantly. He suggested some planting strategies to reduce this amount of solar collection in the summer, contributing to urban sustainable microclimate.

Therefore, although there are few researches that they do not evaluate the high rate of impact of road width on urban road microclimate, some studies show that wide roads chapter more solar energy which increase ambient temperature surrounding road environment. They acknowledge that in these situations, planting trees can be the best strategy to reduce temperature and better thermal comfort.

**4.0 Malaysian Green Road: Required strategies to address roads problems environmentally**

Solutions to address the environmental problems of Malaysian roads should lead to the implementation of green road standards, despite the fact that these issues are still infancy in the road construction sector by Malaysian government (Shariet al, 2008). Green roads, as a system of reducing the environmental impacts of road infrastructure, introduces sustainable practices, including materials management, energy reduction, stormwater management and road lifetime span. Based on the literature review (Bryce, 2006; Elsayed, 2012). Two overall strategies are theorized with regards to the implementation of green roads in Malaysia involving sustainable technical strategies and sustainable non-technical strategies as shown in figure 2.

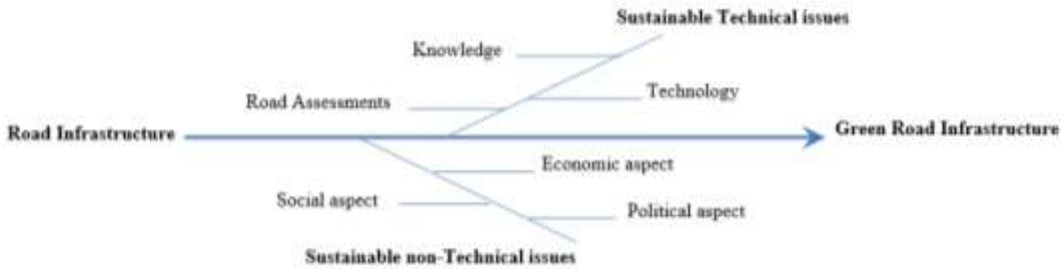


Figure 2: Required strategies to achieve Malaysian green road

**4.1. Sustainable road technical strategies: Assessments/ Technology/ Knowledge**

Although a Green Building Index has been established in Malaysia, as a sustainable building assessment method, green road assessments are still new in the Malaysian road construction industry while sustainability has become important in road infrastructure worldwide to improving the green roads (Darus et al, 2009, ). In summary, it seems that in order to establish green road assessments in Malaysia based on previous studies; first it needs to have a road database that allows users to get the required information to create and maintain the system environmentally friendly. It should be noted that green road methods and standards should be created as well. Green road programs, tools, indicators and design codes should be applied within the system. Figure 3 illustrates the implementation requirements to achieve a Malaysian green roads assessment.


Figure 3: Implementation requirements of Malaysian green roads

Furthermore, technology is another important aspect as sustainable technical solutions to replace a problematical road with an environmental friendly road. In order to achieve this goal, many technologies exist to reduce the environmental impact on roads. The use of advanced planning, intelligent construction, and efficient maintenance techniques need to be incorporated into every modern highway design (Bryce, 2006). It is notable that knowledge, in general, regarding sustainability affects the rest of the strategies that will be acquired with good levels of knowledge in sustainable design and construction in Malaysia. Knowledge adequacy, knowledge acceptability and knowledge appropriateness are major themes for this aspect (Elsayed, 2012).

**4.2. Sustainable road non-technical strategies: Economic/ Social/ Political Aspects**

Economic, social and political factors are known as the non-technical issues which affect the technical ones as factors required to achieve the green roads. Economic issues are inextricably tied to the knowledge which can introduce the economic benefits of sustainable approaches as well as technology which are the major concerns among the Malaysian road construction industry. Meanwhile, there are social issues in terms of readiness and acceptance of sustainable road methods among the Malaysian construction industry that would make easier access to the green road target. Potential support from the government is political issue in terms of providing incentives as well as enforcing green roads as a regulatory mechanism affects the rest of the strategies created to address the Malaysian road problems environmentally and thus changing them to green roads

**5.0 Conclusion**

Malaysian urban development has created a series of environmental changes such urban heat island due to greener reduction, land surface changes and human activities. Paved urban roads lead to urban microclimate modification with the consequences of increasing ambient temperature. The effects of road characteristic on the road surface temperature should be noted as well as the role of roadside trees to reduce road surrounding microclimate. Road orientation and width are two factors that can affect surface and thus air temperatures. Intermediate orientation such as NE-SW or NW-SE can create better roads thermal comfort. In addition, planting trees in the appropriate direction of trees with respect to the road orientation can prevent sun exposure to the road surfaces. As road width is another factor affecting road surface temperature, wide roads chapter high rate of solar radiation and thus the surface temperate are increased. Planting trees can be a solution to reduce surface and air temperature in the road surrounding environment. These solutions and strategies should lead to the implementation of green road standards, despite the fact that these problems are still unsolved in the roads infrastructure in spite of years of effort by the Malaysian government.

**6.0 Acknowledgment:**

This research was supported in part by the Graduate Assistant Scheme of Universiti Sains Malaysia. Also, Authors would like to acknowledge research funded by the Malaysian government and University Science Malaysia through the Fundamental Research Grant Scheme with number of 203/PPBGN/6711298.

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