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Scenario-based Application of Neighborhood Greening Methods towards Mitigating Urban Heat Environment in a World Heritage Site - Malacca, Malaysia

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Malacca city, located on the west coast of the central part of the Malaysian Peninsula, has been designated as a UNESCO World Heritage Site. At present, it is feared that the urban heat environmental condition will gradually worsen in the future. Employing a new design approach that modifies the surrounding heat environment by creating organically linked neighborhood green spaces, which encourage pedestrian walkability, will assist in efforts to conserve and improve the town as a sustainable heritage site. Through this research, firstly, future greening potential area were extracted based on the field survey and the results of the overlaid site appraisals which encompass microclimatic factor, visibility to the historical landscape elements and theoretical pedestrian movements by implementing computer simulation techniques. Based on the identified potential greening area, the three neighborhood greening scenarios were set: 1) based on the existing condition, 2) type of following existing conservation design guideline, and 3) type of maximized greening area with new pedestirian pathways. Then, the microclimate simulation was carried out for respective scenarios and the comparative study was made specifically from the viewpoint of where and how much each scenario could contribute to the urban heat environment mitigation through the investigation of changes of micrclimate conditions such as ambient temperature and surface temperature. From the results, we confirmed that the neighborhood greening approaches proposed through this study has been effectively functioned as a streetscape conservation-oriented urban heat environment improvement methods for historical town in a tropical region.

Keywords: Heritage Site, Neighborhood Greening, Urban Heat Mitigation, Walkability, Microclimate

1.0 Introduction

Malacca city, located on the west coast of the central part of the Malaysian peninsula, has been designated as a UNESCO World Heritage Site. The city retains a large number of historical buildings and streetscapes in its center. In recent years, the town has become one of the country's most popular tourist destinations, attracting more than 10 million visitors annually from both inside and outside the country. However, from the viewpoint of the environment surrounding the designated area, green spaces (vegetation and open spaces) are very limited in number and size, and most are separated from each other. In addition, chronic traffic congestion is caused by the continuous traffic through the narrow streets that have shaped the form of the town. Consequently, it is feared that urban heat environmental conditions will gradually worsen in future. Because of the year-round hot and humid weather as well as the multiple issues of anthropogenic heat and shortage of green spaces, it cannot be said that a pleasant walking environment has been provided for pedestrians strolling around the historical area. For the purpose of sustainable conservation and improvement of the town as a heritage site sustainably in the future, it is expected that a new analysis and design approach will create organically linked neighborhood green spaces that will encourage people to walk around the area more actively through a modification of the surrounding heat environment. With this being the current situation, the aim of this study is accumulating scientific knowledge in contributing to the improvement of walkability through a quantitative analysis of microclimatic condition, in particular, focusing on the aspect of mitigating urban heat environment by applying several scenario-based neighborhood greening approaches.

2.0 Methodology

This research is applied case study based on the previous paper (Saito, 2014b), which demonstrates future potential greening areas within the same study area through the analytical determining approaches by combining the result of several important aspects: urban microclimate and urban design qualities (accessibility, connectivity and visibility) and existing conservation design guideline. Initially, to set the three different scenarios including existing condition by referring to the result of that previous paper. In this step, the following two scenarios are proposed: 1. Greening in accordance with the existing conservation plan and design guideline in the study area, and 2. Greening maximally with street planting along the proposed pedestrian walkway by considering existing condition. Then, to make greening implemented digital urban models based on those three scenarios by using CAD and Geographic Information System (GIS) as a main spatial data management and editing tools. Subsequently, carrying out the computer simulation with microclimate models (ENVI-met). As a result, urban microclimatic conditions in particular indices such as ambient air temperature and surface temperature are derived as an important environmental indicator. Based on the results, to analyze detail microclimatic conditions depend on the each scenario, especially by focusing on the changes of temperature distribution patterns and sectional profile on the representative streets. After synthesizing the results from these steps mentioned above, the findings about future neighborhood greening and its potential contribution to improving walkability along with the urban heat environment mitigation is discussed. The flow of main contents is summarized in the Figure 1.

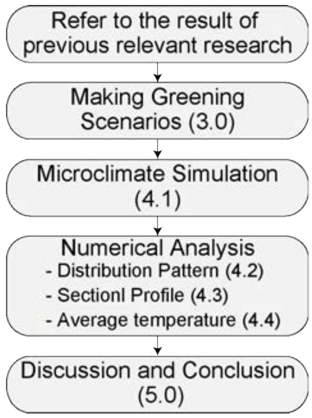


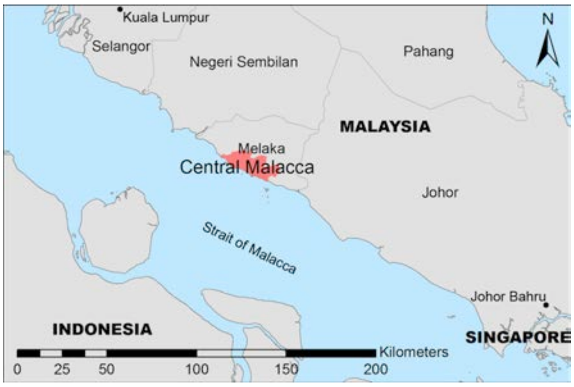
Figure 1: Key aspects related to analysis and those flow

2.1 Relationship with relevant previous works

To achieve the purpose mentioned in the previous section, this research combines and applies spatial data, analytical tools, and procedures that were used in previous studies done by authors. Saito (2013b) developed the fundamental research base including a spatial database, relevant planning documents in Malaysia, and analytical tools and procedures for microclimatic simulation by applying computer simulations and visibility studies using Space Syntax theory. In particular, with regard to microclimatic analysis in a tropical region, aspects of the outdoor physical environment such as air temperature, wind speed, and relative humidity were investigated by applying computer simulation models in a newly developed housing area with several blocks scale (Saito, 2011 and 2013a). From the aspects of a data acquisition and analysis tools, the merits and demerits of approaches that apply digital technologies, such as development and management of spatial databases, and data integration as a contribution to understanding the urban physical environment, were discussed by Saito (2014a). By combining the developed spatial database and analytical techniques which are mentioned above, the future potential greening area which could be expected to improve neighborhood walkability are identified through analytical approaches which combined three different perspectives: the urban heat environment, urban design/configuration, and existing development plans/directions. On the basis of those previous related works, this study attempts to apply and implement the results and findings as a contribution to obtaining new greening design methods for improving walkability in a world heritage site in a tropical region through a quantitative analysis based on the neighborhood greening scenarios.

2.2 Selection of case study area

The study was conducted in the central area of Malacca, Malaysia. The town of Malacca is located on the west coast of the Malaysian Peninsula and faces the Strait of Malacca (Figure 2(a)). The town is rich in remnants of tangible and intangible diverse cultures from ancient times through the present day as a result of its long history as a colonial city, occupied by different western counties—Portugal, the Netherlands, and Britain. Inherited historical buildings and streetscapes that reflect diverse cultures are present in the central area of the town, which was registered as a UNESCO World Heritage Site in 2008. The designated heritage site encompasses two zones: the core zone (0.37 km^2) and a buffer zone (1.69 km^2) surrounding the core zone. This study narrows the study area to an area measuring 480 m × 320 m, including the Malacca River that flows through the town center (Figure 2(b)), for further micro-scale consideration.



(a) Location of Malacca

(b) The UNESCO-designated historical area

Figure 2: Malacca, Malaysia

2.3 Spatial database and system framework

The major data sources used, which include digital and non-digital spatial data and officially observed climatic data, are listed in Table 1. The most significant basement data for this study were developed by the local authority, and several necessary data for analysis were prepared by the author.

Table 1: Stored Spatial Database

Category	Type	Source from
2D Vector (Polygon)	Cadstral Data (Lot)	Local Authority
	Block	Original (Based on Cadstral Data)
	Building Footprint	Original (Based on Cadstral Data + Field Survey)
	Building Height	Original (Based on Field Survey + Panoramic Photos of Building Facade)
	Current Landuse	Local Authority
2D Vector (Line)	Road	Local Authority
	River	Local Authority
2D Vector (Point)	Planting	Field Survey + Aerial Photos
Image data	Aerial Photos	Local Authority + Aerial Photos
Paper-based Map	Topographic Map	Department Survey and Mapping Malaysia
Observatory data (Meteorological data)	24 Hour Mean Temperature and Humidity	Malaysian Meteorological Department
	Prevailing wind (Wind Rose)	Malaysian Meteorological Department

3.0 Neighborhood Greening Models

By applying the previous paper mentioned in the section 2.1, the neighborhood greening models are set based on the future potential greening area by considering several analytic viewpoints. In this step, to come up with the several scenarios from the different approaches, then each scenario is used as a subjective of comparison study with the effects of urban heat environment mitigation using microclimate simulation in the next chapter.

3.1 Greening Scenarios Setting

Initially, to make the scenarios towards neighborhood greenings models for the next step. In here, the three different scenarios including existing conditions are described. The Case 1 is the existing condition and regarded as a baseline model for the comparative analysis. Next, the Case 2 is the minimum greening implemented models by following the landscape plans and design guidelines of the existing conservation and management plan (Melaka Town and Country Planning Department, 2008b and 2008c). Finally the Case 3 is the maximum greening implemented models including a covered pedestrian walkway by planted trees and new connection pathways with back lane covered by permeable surface materials, designed in accordance with the urban configurational aspect such as built form, street width and layout, and open spaces distribution. As a key basic concept, both of the Case 2 and Case 3 are planned to enhance a future walkability within the study area through a neighborhood greening. Especially in the Case 3, putting a priority on a quantitative measurement of an extent of urban heat environment mitigation through the greening and implementing new pathway, rather than a feasibility of the scenario contents in the future. The details of the each proposed planned scenario are described in Table 2. And Table 3 shows the breakdown of the study area's Green Coverage Ratio (GCR) as a basis for knowing and measuring of the green space distribution on the each scenario. This shows the GCR is only 1.0%, 2.9% and significantly increased 12.6% on the Case 1, Case 2 and Case 3 respectively.

Table 2: Greening Scenarios

	Basic ideas / directions	Detail Plan / Actions
Case 1:	Existing condition	-
Case 2:	Following the existing conservation plan and detailed guideline (Melaka Town and Country Planning Department, 2008b and 2008c)	1. Replacing existing on-street parking zone with Green Walkway (covered by permeable surface using grasscrete paver) 2. Potted plant (Not included in the microclimate simulation)
Case 3:	Proposing newly vegetation, open walkway and neighborhood pathway	1. Open Walkway (Covered by Terracotta Tiles) with 1.5 m in width along the shop houses especially on 9 m width road 2. Trees (Cratoxylon Formosum) and Car park with 2.4 m in width along the Open Walkway. The tree pairs are proposed in alignment with the party walls of the shophouses (5 - 6 m varies) so that the building façade could be opened to the open walkway and road (Refer to Figure 6). 3. Three new neighborhood pathway for connecting a major street with an inner-street (back lane). Refer to Saito, 2014b 4. Replacing existing unutilized back lane with Green Walkway (covered by grasscrete paver)

Table 3: Calculation of GCR (Green Coverage Ratio)

	Existing Setting		Proposed Neighborhood Greening Area				Total Green Coverage Area (m^2)	Total Study Area (480 x 320 m) (m^2)	GCR (%)
	Trees Coverage Area (m^2)	Green Spaces (m^2)	Trees Coverage Area (m^2)	Green Walkway (m^2)	Inner Walkway (m^2)	Green Spaces (m^2)			
	(A)		(B)				(C) = (A) + (B)	(D)	(C) / (D) * 100
Case 1	1,099.6	373.5	0.0	0.0	0.0	0.0	1,473.1	153,600.0	1.0
Case 2	1,099.6	373.5	0.0	3,015.3	0.0	0.0	4,488.4	153,600.0	2.9
Case 3	1,099.6	373.5	10,666.3	0.0	5,835.1	1,417.3	19,391.8	153,600.0	12.6

Through these scenarios above, the following things are expected to make a positive impact to the area.

- Improvement of walkability by organically connecting pedestrian walkway.
- Reducing urban heat environment especially from the aspect of air temperature and surface temperature by providing shaded area by planted trees. Total 220 trees are newly proposed (currently 53 trees within the study area)
- Reducing number of on-street car parking by providing trees planting (Reducing the number of parked car to less than half of the current condition.)

3.2 Implementing Green Spaces Based on the Scenarios

Secondly, implementing and making digital models of green spaces and pedestrian walkways to the study area by following scenarios that came up with in the previous subsection. In here, the potential area for future greening is applied as a basis, which is objectively calculated based on the different perspectives considered several important aspects (Urban Microclimate, Urban Configuration, and Existing Conservation Plan) in the previous paper. As the Figure 4 shows, the areas that are implemented the neighborhood greening plan by following scenario-based guideline described in

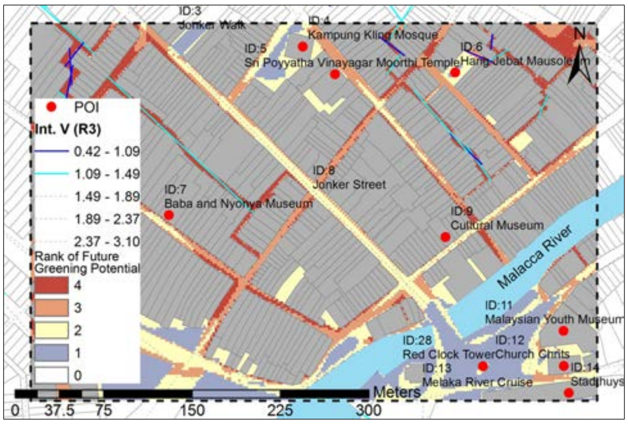


Figure 3: Potential Area for Future Neighborhood Greening (Saito 2014b)

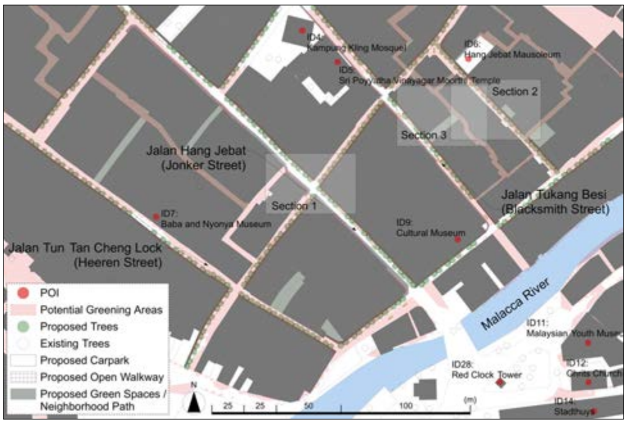


Figure 4: Neighborhood Greening Scenario based on the Higher Potential Area
(By coambining Rank 3 and 4 on Figure 3)

Table 2 are proposed. Those areas are basically on the pink color zone in Figure 4, which are derived from combined two top potential areas for future greening shown in the Figure 3. Additionally, in the Case 3, the three neighborhood pathways exclusive for pedestrian are proposed. These are intended to connect major streets and narrow back lane, and are supported by an improvement of the Integration Value based on the Space Syntax Theory and combined with existing buildings conditions along the streets. And the open walkways, which have 1.5 m in width along major streets, are proposed (Refer to the Figure 5(b)). Those open walkways are provided both sides (for the 9 m width streets) and one side (for the 6 m width streets) in accordance to the width of existing major streets. In addition to that, proposing street planting on the created vacant spaces after reducing the number of existing on-street car parking that are uninterruptedly seen on site to less than half. As for the street planting, the trees are (total 220 trees) implemented to one side of the streets due to the space limitation regardless width of streets. The detailed information about design components and dimensions are described in Table 2, Figure 5 and 6. The digital models after implemented all greening based on the each scenario are converted to the GIS format and stored in spatial database with other layers accordingly.

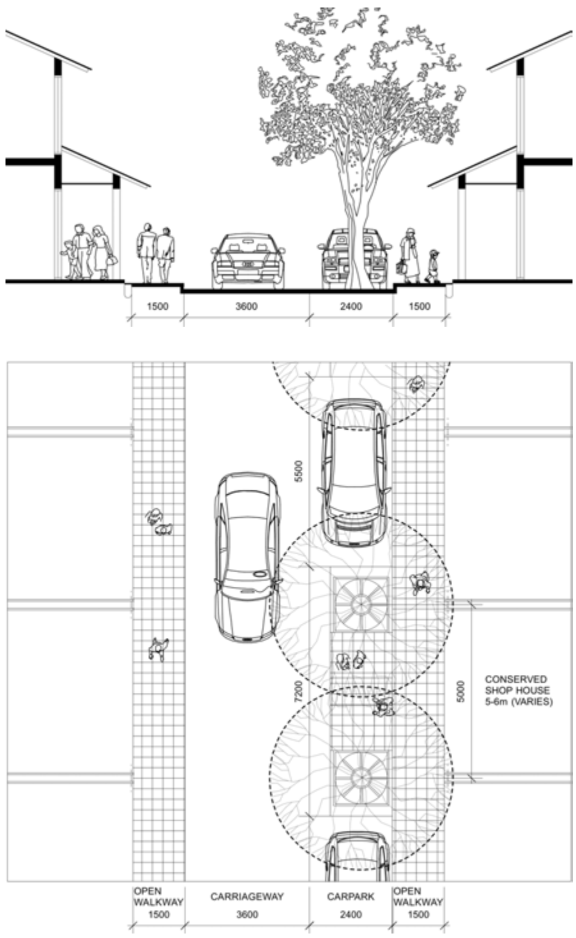


Figure 5: (a) Section and (b) Plan of a typical 9 m width road (Adapted from Melaka Town and Country Planning Department, 2008c and URA Singapore, 1997)

4.0 Effects of Each Greening Scenario on Surrounding Microclimate Conditions

In this chapter, the microclimate simulation is carried out using the digital modeling data by implementing scenario-based neighborhood greening in the section 3.2. With regard to the numerical results derived from the simulation, the comparative analysis are made especially focusing on ambient air temperature as well as surface temperature, which has a significant influence over an urban heat

Figure 6: Image of Street Planting based on the Case 3

environment. As the previous paper (Saito, 2014b) confirmed and pointed out, an index of the wind velocity is excluded form the analysis because of no significant changes due to the low prevailing wind all year round in this region (Refer to the initial setting for microclimate simulation in Table 4).

4.1 Simulation of Neighborhood outdoor environment

A microclimatic simulation within the 480 m × 320 m area in the Malacca heritage site is conducted. This simulation model mainly considers the aspects of building height, tree height, and existing land-cover conditions in three-dimensional space using an ENVI-met [1] simulation model. Table 2 lists the initial settings [2] used in the simulation. The grid size (2 m × 2 m × 2.5 m) and the number of grids (240 × 160 × 20; x, y, z) are fixed. The types of land cover are categorized into three types: soil [3], concrete [3], and asphalt [3]. The buildings [4], grass [5], and trees that include height information are located on these land covers.

Table 4: Initial Parameter Settings

Date	June 21, 2012*
Duration	24 hours (6 pm June 20 to 6 pm June 21)
Wind Velocity	1.8 m/s** at 10 m above the ground
Wind Direction	45 degrees** (from North-East)
Temperature	301.3 K*** (28.1 °C)
Relative Humidity	80.5%***

*The day of Summer Solstice in 2012, Malacca
**Yearly Prevailing Wind and Direction in 2012, Malacca
***Monthly Mean Value in June 2012, Malacca

4.2 Distribution of Air Temperature and Surface Temperature

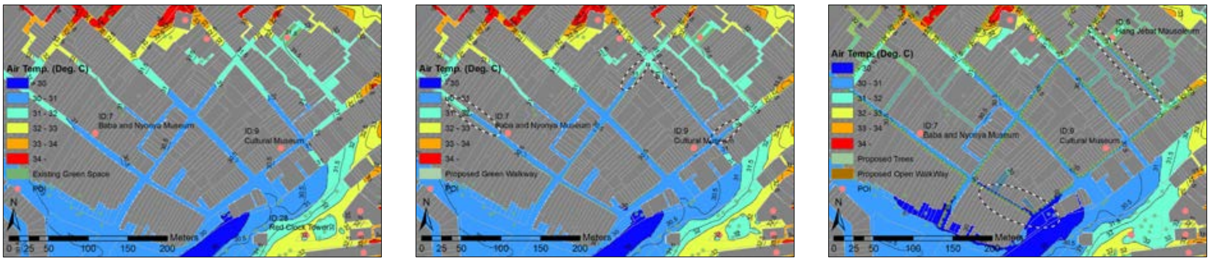
Figure 5 and 6 shows the results of ambient air temperature and surface temperature distribution respectively based on each scenario at 2 pm and 1.5 m above the ground.

4.2.1 Air Temperature

From the overall perspective, the extent of changes of air temperature distribution pattern based on each scenario is not so obvious, in particular no observable changes between Case 1 and Case 2. However, a closer look at the result by considering streets width shows that the distribution patterns of lower temperature are extended until surrounding junctions on the relatively narrow width within the dotted circles in Case 2 (Figure 7(b)) compared with Case 1 (Figure 7(a)). And it is observed that the

[1] ENVI-met is a three-dimensional microclimate model designed to simulate the surface-plant-air interactions in urban environment with a typical resolution of 0.5 to 10 m in space and 10 sec in time. Further detailed information: http://www.model.envi-met.com/ (Last access: 31 May, 2015)
[2] All initial input data are referred to the official observation data in 2012 at the nearest weather station from the study area by the Malaysian Meteorological Department.
[3] Albedo: Soil (0), Concrete (0.4), Asphalt (0.2)
[4] Albedo: Wall (0.25), Roof (0.3)
[5] Grass height: 0.10 m

low temperature distributions are seen on the back lane and are relatively narrow streets, then those areas are spreading towards the surrounding in the Case 3.

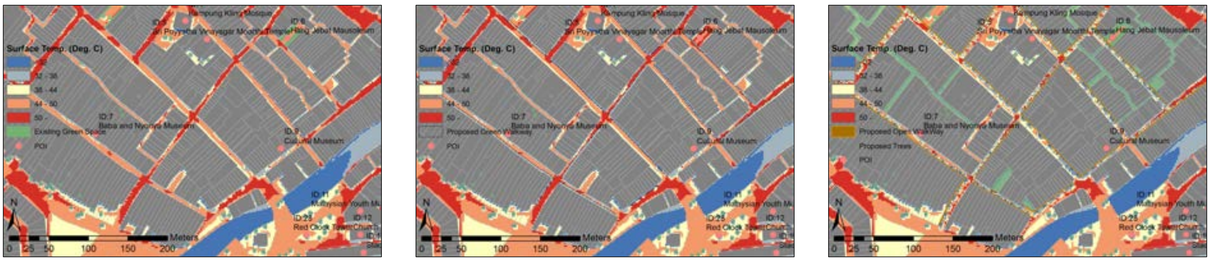


(a) Case 1 (b) Case 2 (c) Case 3

Figure 7: Air Temperature at 2 pm above the ground

4.2.2 Surface Temperature

Next, the distribution patterns of surface temperature are focused on from the same viewpoint as section 4.2.1. The result of the Case 2 (Figure 8(b)) shows that noticeable surface temperature reductions are seen on the green walkway covered by permeable materials using grasscrete paver. In the Case 3 (Figure 8(c)) shows that surface temperature reduction area are seen under the trees crown on the open walkway due to the solar radiation sheltering effect by trees. It is observed that those effects are spreading around the area just below the tree crown compared with the Case 2, which the areas of surface temperature reduced are limited only on the green walkway. The viewpoint of a relationship between temperature changes and location on the streets surface will be elaborated in detail in the later section 4.4.



(a) Case 1 (b) Case 2 (c) Case 3

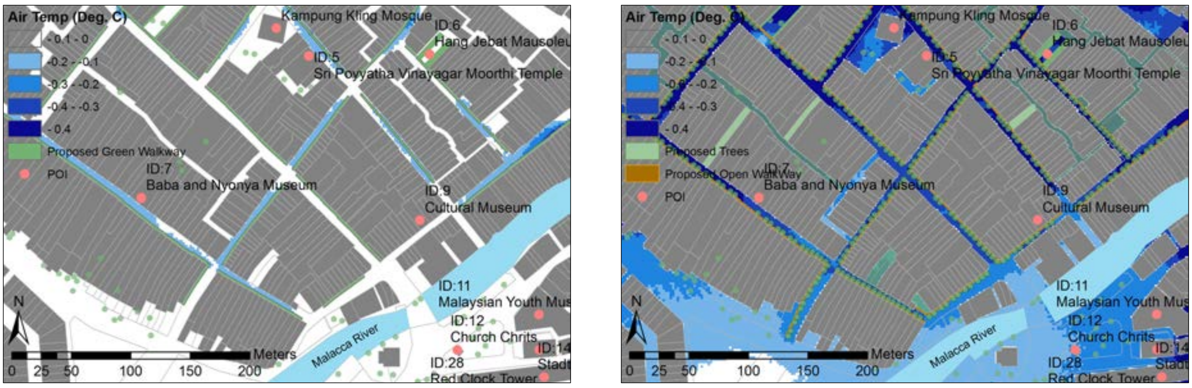
Figure 8: Surface Temperature at 2 pm on the ground

4.3 Distribution of Subtraction Based on the Result of Each Scenario

Figure 9 and 10 shows the subtraction of the distribution pattern of ambient air temperature and surface temperature based on each scenario at 2 pm and 1.5 m above the ground using the result of Case 1 as a basis.

4.3.1 Subtraction of Air Temperature

In here, more detail of the distribution patterns within the study area is discussed by calculating subtraction between each scenario for each environmental indicator. Firstly, the changes of the air temperature between Case 2 and Case 1 are focused on shown in Figure 9(a). As described in the section 4.2.1, the changes of distribution patterns of approximately 0.1 - 0.3 C° in air temperature are seen on the relatively narrow width streets which have about 6 - 9 m in width. These confirmed effects are due to green walkway covered by permeable surface using grasscrete, and those effects are limited in location and couldn't be seen around junctions. Whereas, the effects through the Case 3 (Figure 9(b)) are seen in the not merely under the trees but also could be extended to the surrounding junctions and open spaces along the streets. The approximately 0.5 C° differences also could be seen in some locations around junctions. From those results above, it was confirmed that the degree and extent of the effects are large and widely spread, and contributed towards air temperature reduction within the whole study area through the neighborhood greening in Case 3.

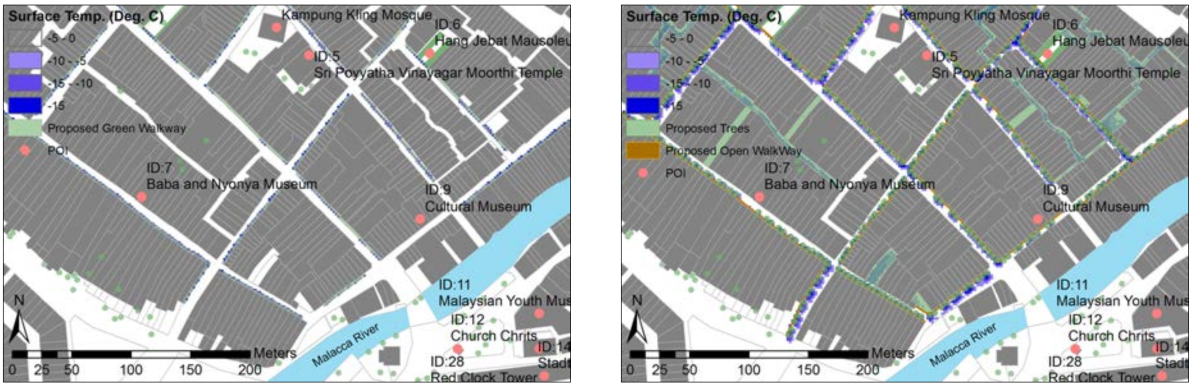


(a) Case 2 – Case 1 (b) Case 3 – Case 1

Figure 9: Difference between the scenario (Air Temperature Distribution)

4.3.2 Subtraction of Surface Temperature

Next, the subtraction of surface temperature distribution is focused on here. As described in the 4.2.2, the reduction of surface temperature are seen only on the green walkways finished by grasscrete shown in Figure 10(a) in Case 2. Whereas, in Case 3 (Figure 10(b)), the effects of surface temperature reduction approximately 10 - 15 C° could be seen on the area about 5 m around tree crown cover on the ground due to the position of the sun at 2 pm.



(a) Case 2 – Case 1 (b) Case 3 – Case 1

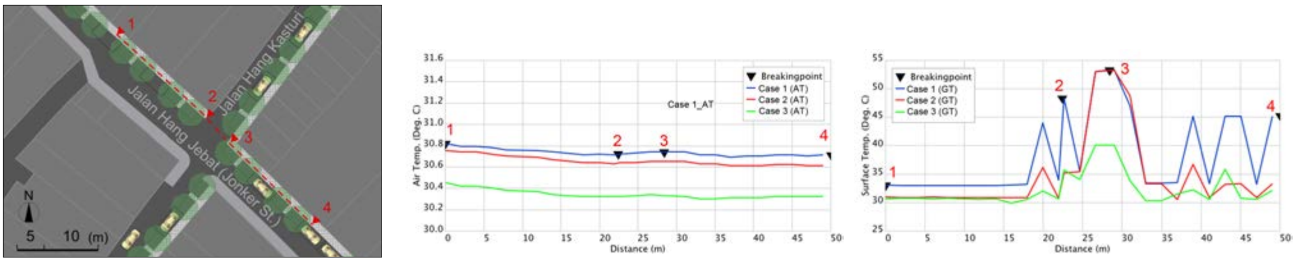
Figure 10: Difference between the scenario (Surface Temperature Distribution)

4.4 Profile of Air and Surface Temperature Changes on the Pedestrian Walkway

Addition to the distribution pattern analysis stated in the previous section, the extent of contribution to the reduction of air temperature and surface temperature on the streets in accordance with the street width are analyzed in detail through this section. The following three streets are chosen to observe the detail temperature changes on the street in cross section.

- On 9 m width street implemented pedestrian walkway to the both side (Section 1 in Figure 4)
- On 6 m width street implemented pedestrian walkway to one side (Section 2 in Figure 4)
- Back lane covered by permeable surface using grasscrete paver (Section 3 in Figure 4)

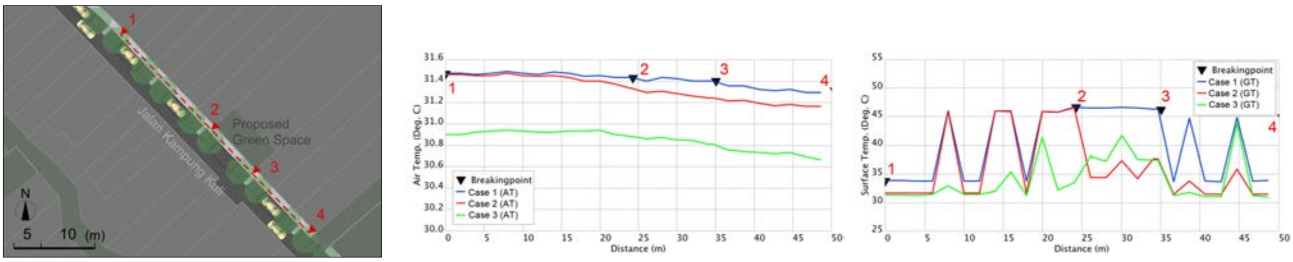
Firstly, the analysis in the section including the 4 breaking points over the junction on the 9 m width street shown in Figure 11(a) is made. The result of air temperature shown in Figure 11(b) describes the effects of air temperature reduction of Case 2 even though the difference between Case 1 and Case 2 is moderate. As for the comparison to the result of Case 3, the average temperature reduction is approximately 0.4 - 0.5 C°. There is the junction between breaking point 2 and 3, but no significant changes are seen. Whereas, as for the changes of the surface temperature shown in Figure 11(c) describes that approximately 15 C° higher especially on the asphalt between breaking point 2 and 3 are seen rather than other surfaces.



(a) Surrounding setting (b) Air Temperature (c) Surface Temperature

Figure 11: Profile of Section 1 (about 9 m in width)

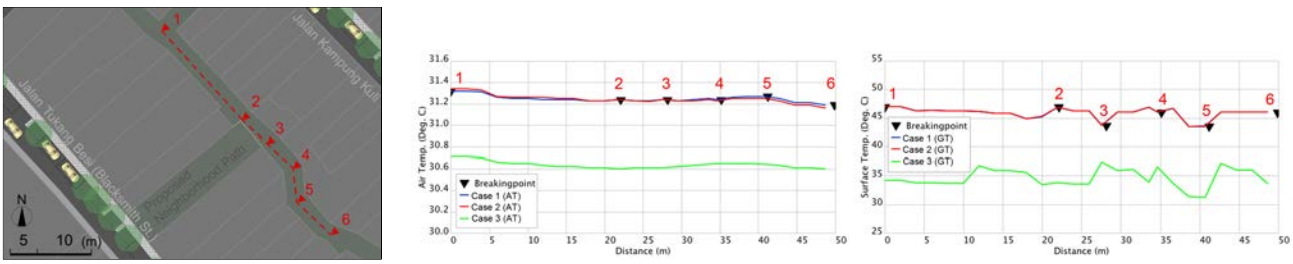
Next, the cross-sectional profile on the 6 m width street shown in Figure 12(a) is focused. The result of air temperature shown in Figure 12(b) describes the effects of air temperature reduction of Case 2 even though the difference between Case 1 and Case 2 is moderate as in the case with the condition on the 9 m width street. As for the comparison to the result of Case 3, the average air temperature reduction is approximately 0.4 - 0.5 C°. As a whole, the air temperature on this 6 m width street is approximately 0.5 C° higher compared with the result on the 9 m width street (Section 1). However, it was confirmed that the temperature reduction effect itself due to greening is slightly higher than on 9 m width because the degree of differences between before and after greening. And there is the proposed pocket park between breaking point 2 and 3 in Case 3, but no significant changes are seen in terms of air temperature reduction. Whereas, as for the changes of the surface temperature shown in Figure 12(c) describes that the localized effect to reduce surface temperature is seen especially on the location between breaking point 1 and 2 due to the presence or absence of street planting.



(a) Surrounding setting (b) Air Temperature (c) Surface Temperature

Figure 12: Profile of Section 2 (about 6 m in width)

Finally, the cross-sectional profile on the back lane and proposed neighborhood pathway covered by grasscrete paver is focused. The result of air temperature shown in Figure 13(b) describes the moderate effect of reduction due to the permeable surface about 0.6 C° is seen on the back lane. There is the proposed neighborhood pedestrian pathway between breaking point 2 and 3 in Case 3, but no significant changes are seen in terms of air temperature reduction. As for the surface temperature shown in Figure 13(c), about 15 C° temperature reduction could be seen due to the differences of finished surface, but no noticeable effects are seen due to the proposed pedestrian pathway.



(a) Surrounding setting (b) Air Temperature (c) Surface Temperature

Figure 13: Profile of Section 3 (on a back lane: about 4 m in width)

4.5 Average Air temperature and Surface Temperature on the Pedestrian Walkway

In here, the average air temperature and surface temperature on pedestrian walkway is highlighted in order to examine the degree of contribution to the temperature reduction in the whole study area by neighborhood greening through Case 1 (existing condition) and Case 2, 3 (proposing condition). As a result, Table 5 shows that average 0.5 C° and 0.8 C° reduction in air temperature on Case 2 and Case 3 respectively through comparison to the result of Case 1. Similarly, average 4.3 C° and 7.0 C° reduction in surface temperature on Case 2 and Case 3 respectively are confirmed.

Table 5: Air and Surface Temperature changes on the pedestrian walkway within the study area

	Pedestrian Walkway	Total Length within Study Area (m)	Average Air Temperature (C°) *	Average Surface Temperature (c°)
Case 1	Terracotta Tiles	1,597.7	31.9	39.6
Case 2	Permeable Surface (Grasscrete paver)	3,091.2	31.4 (-0.5)	35.3 (-4.3)
Case 3	Terracotta Tiles under the Trees	3,527.6	31.1 (-0.8)	32.6 (-7.0)

* 1.5m above the ground

5.0 Conclusion

Through this study, the objective comparative analysis focusing on the degree and extent of contribution to urban heat environment amelioration based on the scenario-based neighborhood greening and proposing pedestrian walkways are carried out. For that purpose, several objective analyses from the viewpoint of distribution pattern of air and surface temperature (section 4.2) and subtraction based on each scenario (section 4.3), and cross-sectional profile of both of air and surface temperature on different street width (section 4.4) have been made. As a result, obtained important findings are follows:

From section 4.2 and 4.3:

- Through the proposing pedestrian walkways covered by permeable materials, the effects to the air and surface temperature reduction could be seen but those degree of contribution is not so significant and those extent is also limited just on the particular walkways (from Case 2).
- Whereas, through the proposing pedestrian walkways with street planting, it shows significant contribution to reduce the surface temperature on the street under and around tree crown cover area. As a result, the proposed greenings have a significantly positive effect to reduce ambient air temperature and those effects could be widely spread towards surrounding area. It is expected that urban heat environment would be ameliorate within a whole study area not merely on the pedestrian walkway (from Case 3)

From section 4.4 and 4.5:

- It is cleared that the average air temperature on 6 m width streets is slightly higher than 9 m width streets. It is considered that air temperature around relatively narrow streets get influenced by heat from surrounding building walls and surface of asphalt. However, a slightly higher degree of effects to the air temperature reduction is observed on the 6 m width streets. Hence, it is expected that there are higher potential through more active greening especially onto the narrow width streets.
- Regarding the relationship between the extent of greening in the study area (GCR) and contribution to the amelioration of urban heat environment, by increasing the GCR to 2.9% (+1.9%) bring the area to drop average 0.5 C° in air temperature and 4.3 C° in surface temperature on the 1.5 m above the walkway and the ground covered by the permeable materials respectively (From Case 2). And, by increasing the GCR to 12.6% (+11.6%), it contributes to drop average 0.8 C° in air temperature and 7.0 C° in surface temperature by providing street planting along the proposed pedestrian open walkway (From Case 3).

As a conclusion, from proposing scenario-based neighborhood greening approaches which are aiming at enhancing future walkability with conserving historical buildings and streetscape, it is confirmed that the average 0.8 C° and 7.0 C° reduction in air temperature and surface temperature respectively by overlaid shadow cast through the street planting which are total 272 (+220) trees in number along the newly proposed pedestrian walkway. These significant positive effects supported by scientific data show the expectation of enhancing the volume and flow of pedestrians by organically connecting each Point-Of-Interest such as an important historical building with walkway in the future. And in particular, the reducing the surface temperature through the street planting along the streets has considerable impact to ameliorate urban heat environment not only on the streets but also the whole study area. Additionally, this greening ways using street planting implemented has considered safeguarding a visibility to the historical buildings and streetscape carefully from the urban design perspective not only from the aspect of the physical environment. As a consequence, the neighborhood greening approaches proposed in this study has been effectively functioned as a streetscape conservation-oriented urban heat environment improvement methods for historical town in a tropical region. Furthermore, to continue an analytical study on reduction in traffic volume will be required to achieve the overarching goal of enriching the town through enhancing walkability in the Malacca World Heritage Site as a future study.

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