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Research Paper

Evaluation of Grid Pattern City in Tropical Zone Considering Urban Morphology Viewing from Shading Aspect

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ABSTRACT

The impact on urban microclimate is basically governed by city morphology, materialization and landscaping of neighborhood. The modification of these parameters, such as city pattern, building facets design, tree pattern and tree species, can help to be healthy urbanism. This paper discusses about the evaluation of grid pattern city in tropical zone, which is aging, but still using as business area considering urban morphology with respect to shading since shading has supreme influence on thermal comfort. The purpose of this research is to investigate shading condition of existing city pattern to know whether the city is still reasonable to live or not by analyzing morphological elements using geographic information system (GIS), 3D modelling program (sketch up), shading analysis tool, quantitative method and statistical analysis. The scheme of this research is divided into two main parts: evaluation by the effect of type of colonial style building facet and evaluation by the effect of tree pattern and different tree species. The result provides hypothesis of urban morphology and appropriate design recommendation for Grid pattern city to maintain old urban area in conformity with tropical zone without vanishing original image of the city.

1. Introduction

1.1 Background and objective

As the world population is rapidly increased, urban area becomes more crowded and green area is replaced by new buildings due to high demand for building construction (Broere et al., 2016; Salman et al., 2018; Gago et al., 2013). It has been decades many researchers have studied impacts of high building density and they are trying to find treatment method of urban city in terms of urban elements (Anisha et al, 2010; Roth, 2003) (Elshater, 2012). In tropical zone, shade and air movement are principal measures used to improve thermal comfort, in both outdoor and indoor areas (Schiller et al.,2004; Nastaran et al., 2012).

Yangon Central Business District (CBD) is an old colonial grid pattern urban area in tropical zone in lowland area which was built and implemented by British planner (Myint, 2015; wikipedia, 2016; YCDC, 2014). Because of the tropical zone, the area should have proper shading for users. There are many street venders along the street platform and so there are always the customers. Moreover, as the city is old, streets are quite narrow and most of the streets are only one way. Therefore, people who are using public transportation must walk to their destination. The area should have continuous shading for the pedestrians, also for the people who are waiting for the bus. In this case, we need to evaluate whether the city has continuity or not. The urban form of Yangon CBD is a proper area where we can evaluate the colonial grid pattern city which is in tropical zone.

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1.2 Research review

1.2.1 Grid pattern city planning

One of the basic characteristics of Grid planning, is the design of the town, following a plan consisting of rectilinear blocks and straight streets usually with a square created by leaving a block or part of a block unbuilt (S del Campo, et al., 2010; Quora, 2014). Most of the planned cities from the classic age until the nineteenth century follow this pattern. Greek colonies spread this model through southern Europe, the Roman Empire brought it beyond (Ellie, 2007).

1.2.2 Thermal comfort

Thermal Comfort is vital in providing healthy indoor and outdoor living, quality of life in urban environment and reducing energy consumption (Hanan et al., 2014; Anderson, et al., 2015). Thermal comfort is a condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation (ASHARAE Standard 2010; Jamaludin, N., et al 2014). (Al-Homoud, 2008; Ibrahim et al., 2014) agreed that thermal considerations are vital in most buildings involving people occupancy. The outdoor thermal environment should be designed to increase human productivity and performance (Nazhatulzalkis, J., et al 2014; Tzu-Ping, 2011).

1.2.3 Urban morphology

Urban morphology is the study of the physical form of a city, which consists of street patterns, building sizes and shapes, architecture, population density and patterns of residential, commercial, industrial and other uses, among other things (Lau, 2011; Srinurak et al., 2016; Justin CK Ho et al., 2015). Analysis of physical form focuses on street pattern, lot pattern and building pattern, sometimes referred to collectively as urban grain (Hashim, 2017). (Dickinson, 1950) said that morphology of towns reflects its functions and idea of planning and building at each phase of its development.

1.2.4 Urban shading element

Proper air movement and well shading of urban area is a major concern, especially in tropical climate which has high temperature and relative humidity (Shishegar et al., 2013, Givoni, 1994; Nield et al., 2016). The sunshine can affect the people's feeling which is not only psychologically but also physically (Wiebke et al., 2014). Environmental factors include the height-width ratio of the street canyon, ground paving materials, street orientation, and facades of buildings on canyon sides (Zhao et al., 2008; Andreou et al., 2014; Belakehal et al., 1996). According to (Emmanuel 2007), better air temperature may not necessarily lead to better thermal comfort. In this case, facet design is one of the major concerns with the shading of the urban area. Urban street trees can decrease local air temperatures and urban heat island effect (Rizwan et al., 2008) and make the comfortable environment for urban residents, particularly pedestrians, in summer (Sanusi et al., 2016; EPA, 2016; Prianto, et al., 2000; Rabitual, 2015). So, landscape design of the area should also be considered to cover the area with shading.

2. Methodology

Methodology of this research aims to evaluate the value of ancient grid pattern city in tropical zone with respect to shading of the study area.

To be fulfil the objectives of this study, the first approach was reviewing the past researches regarding with the development of urban city planning pattern and history of grid pattern city, climatology which is absolutely affecting the urban environment, urban morphology which are the essential elements of a city and, the characteristic of urban shading which makes the city comfort.

The scheme of this research is divided into two parts to evaluate the study area; the evaluation of colonial grid pattern city by the effect of type of colonial style building facet and the evaluation of the area by the effect of tree pattern and different types of tree species.

We used previous research morphological data which are building height, type of building facet, type of trees, location of street vendors and bus stops which are essential for evaluating shading. Type of building facet and tree species are categorized according to its shading magnitude in the previous study. For calculating shading magnitude, the hottest time interval for pedestrian and vendors, 12:00pm to 3:00pm is chosen, and three-dimensional program is used. The quantitative data of type of Building and type of tree species are analyzed by using statistical method to know the relationship between urban morphological elements.

From the past research, we could know types of building facets and tree species of study area and its shading. Therefore, in this research, we established the shading map for this area evaluated by the urban morphology of grid pattern city by using geographic information system (GIS).

From this research, we hope this study can be supportive data and can be provided appropriate design suggestions for future development to maintain the old urban city not to vanish the historical facts and heritage. Moreover, we expect this method can contribute to other similar areas' research.

2.1 Site study

The study area is part of Kyouktada township, the center of CBD. There are seven grid pattern cities in CBD of Yangon and Kyouktada township is one of the unique areas in CBD as it has many colonial era buildings, including 39 landmark buildings and structures protected by the city (Khaing Myint Mo et al., 2016), (Khaing Myint Mo et al., 2018). The city is in tropical zone and thus, the area should have proper shading especially on the street platform where many pedestrians and vendors are always using.

2.2 Building height and type

According to the previous study analysis, there are six types of colonial building facets as shown in **Fig.1**. Buildings with big canopy are almost government office buildings and others are mix-use (residential and commercial) buildings. Most buildings in this era are four-story buildings with brick pillar.

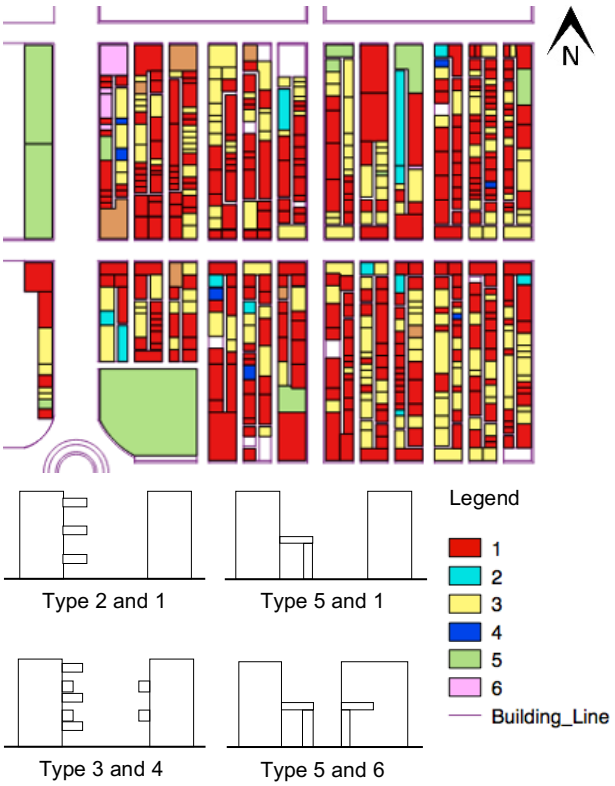


Fig.1 Building type

2.3 Tree pattern and type

As shown in **Fig.2**, eleven tree species in study area are generally found out in the previous research. Trees are found only in main road because narrow streets can get proper shading from buildings. Furthermore, east to west direction has bigger shaded trees than north to south. Therefore, we can deduce that tree planning system in study area is designed by considering the sun path.

Fig.2 Type of tree species

2.4 Parametric shading analysis

2.4.1 Type of building

Shading magnitude was examined by choosing six facet types along North to South and East to west street direction from the study area and prepared 3D model. 3D modelling program was used to know the facet area and shading area affected by facet design. Then, Shading magnitude ratio was calculated by using equation [1] city (Khaing Myint Mo et al., 2016). In this case, Time was limited as 3:00pm in April since it is the highest temperature of the day for tropical zone and all the street vendors are also allowed to open at that time.

$$Shading\ magnitude\ ratio = \frac{F.A}{S.E.F.D} \quad [1]$$

Where, F.A = facet area

S.E.F.D = Shading Area Effected by Facet Design

After the calculation of shading magnitude ratio, types of building facet and shading magnitude ratio are put as the GIS data to point out the location of the different building facet types and which types of building types are

much more in the area and to be easy to analyze statistically. In this case we used anova statistical analysis to prove that shading of the urban area is much more depending on the type of building facets rather than the building height.

2.4.2 Type of tree and tree pattern

In this study, we used overlay method and buffer method to analyze the tree pattern and planning system. Different type of tree species shading area were created by three-dimensional program and compared each types of tree species and tree pattern along South to North direction and East to West by using statistical analysis. Finally, we can know how the colonial grid pattern city is planning the trees and tree species of the area.

3. Result and discussion

3.1 Shading effected by facet design

According to the result of the ratio of the shading, shading magnitude ratio is listed hierarchically as shown in **Table 1**. The result showed that shading magnitude of six types of building facet of the N-S and E-W are same though the sun path is different. It can be strongly proved that hierarchical order of the effect of the facet types on shading are correct. Therefore, it can be the supportive data and it can help for determining the appropriate facet design for tropical zone.

Table 1. Hierarchical order of building type

Building Type	SMR (n-s)	SMR in order	SMR (e-w)	SMR in Order
1	0.93	5th	0.14	5th
2	0.95	3rd	0.19	3rd
3	0.97	2nd	0.23	2nd
4	0.94	4th	0.18	4th
5	0.93	5th	0.16	6th
6	1.30	1st	0.24	1st

Table 2. Perspective statistic of building type and its shading magnitude ratio

N=554

Building Type	Count	Sum	Average	Variance
1	332	283.48	0.85	0.05
2	12	9.88	0.82	0.09
3	186	169.32	0.91	0.04
4	7	6.58	0.94	0.00
5	13	8.24	0.63	0.15
6	4	5.20	1.30	0.00

In the result of anova single factor in **Table 2**, building type 1 are a lot in the study area. Furthermore, we can check the average value of building type and building type six is the highest and so that overall shading magnitude of type 6 is higher than others.

Table 3. Statistical analysis of building facet

Building Facet	Ms	F	P-value	F critical
Between groups	0.383	7.387	1.02e-06	1.464
Within building type	0.052			
Total				

H0: Type 1=Type 2=Type 3=Type 4=Type 5=Type 6

H1: At least two types are different

Moreover, according to the result of the anova statistical analysis, F normal is higher than F critical and, also P-value is lower enough as shown in **Table 3**. It means the study area has differences in achieving shadow highly depending on the type of building facets.

The result of scatter chat in **Fig.3** shows that there is no relationship between building height and shading magnitude. Therefore, the height of the building is not highly influencing on the shading magnitude of grid pattern city in tropical zone and it is highly relying on the type of building facets.

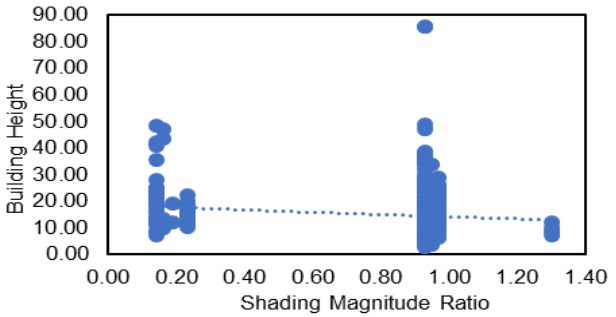


Fig.3 Relationship between building height and shading

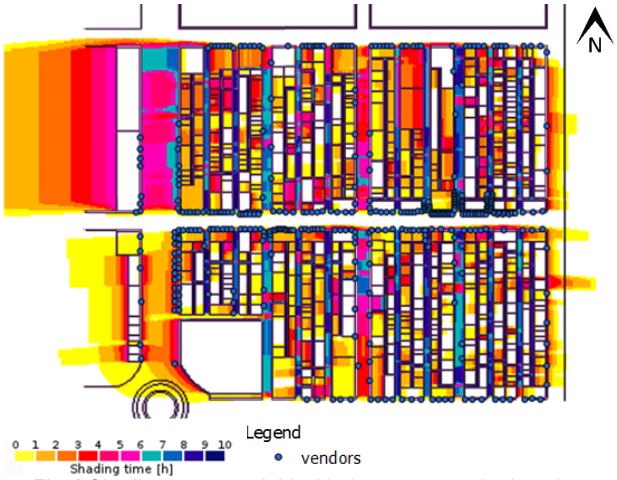


Fig.4 Shading map overlaid with the street vendor location

The overlaid result of the shading analysis with the vendor location shows that most of the vendors who are facing to the East, West and North direction receive the shading influenced by the front building because of the sun path as shown in **Fig.4**.

However, vendors who are facing to the South cannot get the shading at 3:00 o'clock since the street exists in the E-W direction. So, although other areas have suitable shading depending on the sun path and facet design, buildings which are facing to the South direction needs to be considered carefully in designing the facet design. Moreover, street elements such as trees and shading devices are also compulsory to consider for promoting the shading.

3.2 Shading effected by trees

From the result of the calculation, the shaded area of each tree species was compared.

The hierarchical order of the shaded area of different kind of tree species was resulted in **Table 3** and we can check from there which species give more shading. We found that big tree which has a big crown area can give more shading.

Table 4. Characteristic of tree species

Tree Species		Ht	C.A	S.A (sq.m)	Quantity	
No.	Type	(m)	(sq.m)		E-W	N-S
I	Manila Palm	6	7.27	4.033	26	26
II	Neem	8	18.62	19.983	125	143
III	Gold Mohur	12	18.68	21.26	2	4
IV	Almond	10	29.23	31.912	9	2
V	Laburnum	11	29.2	33.106	12	10
VI	Star Flower	9	65.66	37.049	10	8
VII	Mahogany	10	42.05	37.939	3	0
VIII	Mango	9	49.36	40.239	10	10
IX	Padauk	10	65.75	48.24	27	10
X	Rain Tree	12	94.65	56.84	0	4
XI	Banyan Tree	15	94.57	105.297	2	2

Ht=Height C.A= Crown Area S.A= Shaded Area

The investigation of relationship between shaded area and tree height and crown size had done in the previous study as shown in **Table 4**. According to the result of past analysis, the magnitude of shaded area by tree species is depending on tree height. Tree shaded area magnitude is also depending on crown area of tree species. So, the bigger the crown size, trees will provide the better shading.

When we overlay the shading of the trees as shown in **Fig. 5**, vendors and bus stand, most of vendors makes their shops under the tress and near to the bus stands and some vendors have to open their shops in common public area though those areas cannot get enough shading.

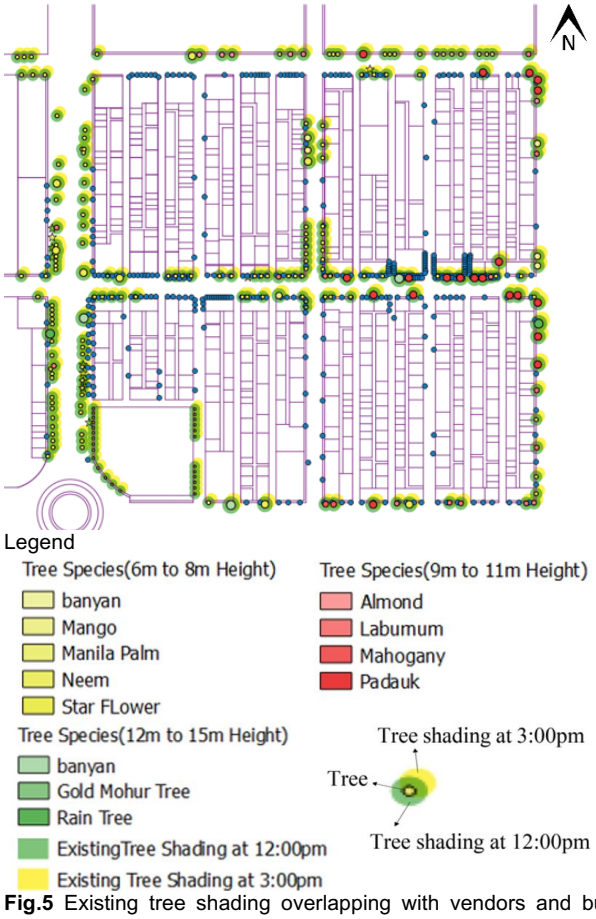


Fig.5 Existing tree shading overlapping with vendors and bus stand (Khaing Myint Mo, et al., 2018)

4. Design suggestion

4.1 Building facet design

For North to South direction, there are only narrow street and most of them are residential mix-use building type. Therefore, among the residential building type1,2,3 and 4, type 2,3 and 4 as shown in **Fig.6** are preferable as their shading magnitude are higher than type 1.

Fig.6 Building Type 2,3 and 4

For East to West direction, building facets types like building 5 and 6 as shown in **Fig.7** which has big canopy

should be considered because having the big canopy in the building facet can help to get the urban comfort in city.

Fig.7 Building with Big canopy along main road

4.2 Tree pattern and species

For giving the design suggestion, pros and cons of tree species for urban area in tropical zone are considered as shown in **Table 5**. From there, we could explore the suitableness of tree species for each street orientation and we could suggest suitable tree species. **Fig. 8** shows recommended tree species in suitable area respectively and its shading analysis by using buffer.

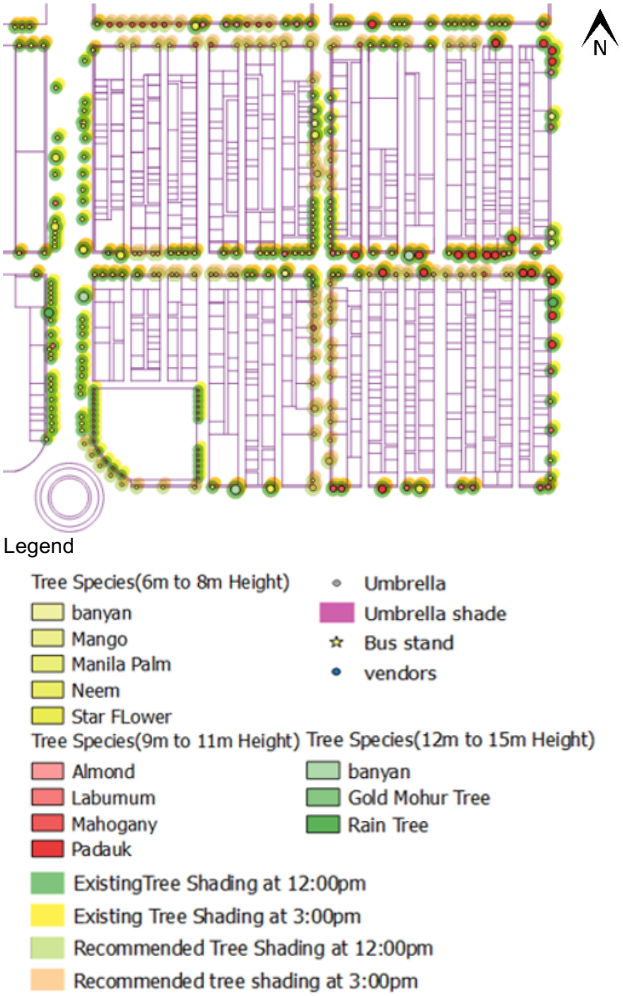


Fig.8 Buffer analysis of recommended tree shading

Table 5. Pros and Cons of tree species for old urban city

Tree species	Pros and Cons for grid pattern city
I	It has less shading as the crown size is small. It is good for aesthetical purpose.
II	It is not so high and have enough shading for pedestrians and vendors. A lot in N-S direction as it is good for aesthetics and suitable to plant on wide platform.
III	It is a little bit high and but not so big crown, can have enough shading for pedestrians and suitable for both directions.
IV	It is medium high and crown size, furthermore, leaves are big, can receive well shading. It is suitable for both directions. There is more almond tree in E-W direction.
V	It is medium high and crown size, can receive well shading. It is suitable for both directions.
VI	It is medium high and well for shading. As the crown size is bigger than its shaded area, it is not so much suitable for shading compared to other species.
VII	It is medium high, but big crown size. It can be found only in E-W direction and can have enough shading.
VIII	It is medium high, but big crown size. It can give well shading. However, it has plenty of fruits in its season and difficult for maintenance. It is not suitable for downtown street.
IX	It is medium high, but big crown size. It can be found more in E-W direction and can get enough shading. It is one of the remarkable tree species of Myanmar as it blooms yellow flower in Myanmar New Year. It is suitable for both directions.
X	It's quite high and crown size are too much. It can give large shaded area. It is suitable for wide streets. It exists only in N-S direction. Because of extreme big crown size, it can disturb the street platform and building aesthetics. So, it is not suitable for urban area.
XI	It's quite high and big crown size. It can give largest shaded area. However, it can cover the building aesthetics because of big crown size. It is not suitable for downtown streets.

4.3 Urban shading elements

Here, for narrow street which cannot design big canopy and tree, the author gives example of umbrella roof as a street shading element as shown in **Fig.9**. By adding those kind of street elements, people will get more desire on walking and the area will be more active and livable. The umbrella roof was recommended along

Table 6. Suitableness of type of facet and tree species

Street type & Examples of shading	Street width	Pavement width	direction	Facilities	Problem with current conditions	Suitable facet Type	Suitable tree type
A	30m	2.5m	E-W	One way	As it is wide street and platform, some of the area cannot receive enough shading.	3,5,6	I, II, III, IV, V, IX
B	25m	2.5m	N-S	Two ways	Commercial area has no proper shading along the pavement. The street can get shading in the morning and evening, but not in noon.	2,3,4	II, IV
C & D	15m	1m	N-S	One way	It has narrow street where cannot build building with big canopy and plant the tree. It can have shading in the morning and evening, but not in noon. Platform is narrow and occupied by the ground floor, thus pedestrian has to work on the street.	2,3,4	Urban shading element like street roofing should be designed
E	30m	2.5m	E-W	One way	Pedestrian area has no shading. Platform is wide enough to create shading for pedestrian	3,5,6	I, II, III, IV, V, IX

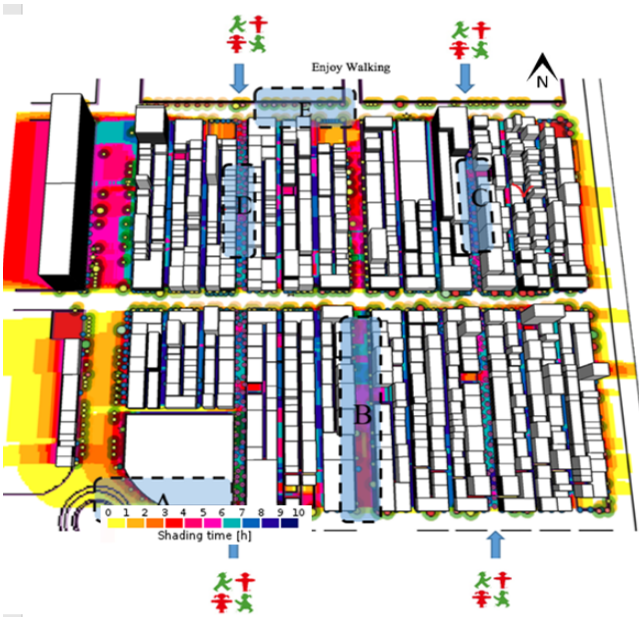
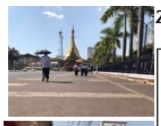


Fig.9 Overall shading map with design proposal

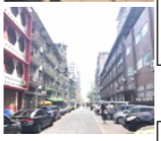


ZONE A (Main Road E-W)

Centre of downtown. Though it has some aesthetical trees, the area is not getting proper shading as the tree is high and have small crown.

ZONE B (Main Road N-S)

One of the main road existing along N-S direction of downtown and the commercial area has no proper shading along the pavement. It should have either big canopy or tree shading



ZONE C & D (Secondary Streets N-S)

Secondary roads which has lots of commercial and residential mixed use buildings. It has narrow street where cannot build building with big canopy and plant the tree.

ZONE E (Main Road E-W)

One of the main road of downtown along E-W direction and the commercial area has no proper shading along the pavement.

the two secondary roads which are the commercial area where has many users.

For integrating the research's results, there are two main focuses of implementation which are building facet design recommendation along the N-S and E-W direction and tree species and tree pattern design along the N-S and E-W direction respectively. Suitableness of facet design and tree species are explored in **Table 6** for proposing design.

Fig.9 describes the overall shading map of the study area by suggested design with examples considering urban morphology viewing from shading aspect for tropical zone. The city is getting continuity of shading with appropriate design suggestion focusing on colonial style building facet and original tree pattern and species. If we can follow the design suggestion of this study, the evaluation value of the study area will also be high. We hope this study will be the supportive data for Yangon grid pattern city and other grid pattern city which has same condition with the study area.

5. Conclusion

The results of the study have already revealed the condition of Yangon grid pattern city and the supportive data to be able to evaluate the value of the city considering urban morphology viewing from shading throughout the following steps. The investigation of shading condition of Yangon Colonial city which is in Tropical Zone is carried out in this study considering urban morphology viewing from shading aspect in order to evaluate the ancient grid pattern city of tropical zone.

Our findings present types of building's facet which are existing in the colonial grid pattern city and trees pattern and types which are essential for one township not only for aesthetics but also for the human comfort. From there, we can be beneficial to know the preferable types of building facets to attain more shading. The result showed that shading magnitude of six types of building facet of the N-S and E-W are same though the sun path is different, and it can be strongly proved that the hierarchical order of the effect of the facet types on shading are correct. Therefore, that hierarchical order can be the supportive data and it can help for determining the appropriate facet design for tropical zone.

Furthermore, the result shows the average value of building types and building type 6 is the highest and the overall shading magnitude is higher than others. There is no relationship between the building height and shading magnitude. So that the height of the building is not highly influencing on the shading magnitude of the grid pattern city in tropical zone and it is highly relying on the type of building facets. Therefore, facet design is very important for the tropical city which has strong sunshine.

Moreover, street elements such as trees and shading devices not only for the street vendors, also for the pedestrians are also compulsory to consider for promoting the shading. Therefore, we continuously investigated the tree pattern and different shading of tree species of the Yangon grid pattern city.

From the result of the calculation, the shaded area of each tree species was compared. The hierarchical order of the shaded area of different kind of tree species was resulted and we can check from there which species give more shading. We found that big tree which has a big crown area can give more shading. Banyan tree is the highest tree and crown area and its leaves are also big so that its shaded area is wider than other trees. But it should be noted that those kind of big trees takes lots of land area and it can obstruct the aesthetic of the building facet.

In addition to these, the present study could reveal the original image of the tree pattern of Yangon grid pattern city. In this case, tree shadings are very useful for helping to cool the street platform and it is the most cost effective. Therefore, we need to give better design guideline to achieve the enough shading in the area.

The investigation of evaluating the Yangon grid pattern city is executed through preparing the overall shading map. From the map, it can be said that the Yangon grid pattern city has continuity of shading in the narrow street along North to South direction as the shading can get alternatively depending on the building. So, the pedestrians can get the shading in one side in the morning and another side in the evening. However, at noon, the area which has big canopy and shaded tree can only get the shading. Along East to West direction, the middle main street has enough shading from trees, and it has large tree as well. Most of the platform of main street has the continuous tree shading and the secondary and tertiary streets do not have the tree and so they are not getting the shading by tree as it is too narrow to have the trees. So, the pedestrians and the people who are using those roads cannot get the shading at noon. In addition, the type of the facet of the building which exists in the secondary and tertiary narrow street is receiving less shading magnitude because most of the building types along that street is building type 1 and 3 as most of them are mix used building which are combined residential and commercial rooms. As the streets are quite narrow to plant the trees and to give a big canopy design on facet, another efficient urban shading design element should be considered for those narrow streets.

Therefore, this study provides the suitable design guideline to inhabitants and local government in the study area for future development. These guidelines are offered to be supportive data for designing the buildings of ancient grid pattern city which is in tropical zone to get comfort in the old urban area. According to the result, finding and discussion of the previous studies, we have already known the good and bad points of the existing condition of Yangon grid pattern city. So, the contribution

of the study deems the design guideline for the area when we design the building which types of building facet design would be preferable. In addition, the proposed approach here seeks a better way not only to maintain the ancient grid pattern city to keep the history but also to make the area to be relevant with modern facilities. Therefore, this study conducts the formulation of urban design guidelines not only for the study area but also for the similar area.

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