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DEPARTMENT OF GEOGRAPHY, TOURISM AND HOTEL MANAGEMENT

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Contents

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The Relationship of Home Renovation and Gender at Suburban Housing of Semarang City in Indonesia

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Abstract

The purpose of this study was to explore gender influence on home renovation based on family life cycle in suburban housing of Bukit Kencana Jaya Semarang, Indonesia. Sixty households were interviewed and the resulting data were analyzed using the mix method. This attempt is important to determine the gender roles and relations influencing housing demand policies. The result showed most renovation activities were conducted on families with children, in addition to formulating two deductions. First, in single and new couples, gender productive roles tend to support house function in terms of economic existence and societal perception. Second, in families with children and elderly, these utilities serve as a habitat for income sources and welfare support.

Keywords: family life cycle; gender; home renovation

Introduction

The definition of gender covers the social interpretation applied to differentiate men and women during family and community interactions (Wieringa, 1998; Sullivan, 2004). This concept appears naturally flexible and is location based depending on religion, culture, public structure and educational status influencing individual mindset as well as community response. Under these circumstances, the development of persons is an important factor in observing the performance of gender relations roles. Gender relations play siginificant functions in participation and decision making for family subsistence (Soeharso & Kusumowidagdo, 2016; Rotman, 2005). A common instance involves the determination of the specific area to revamp and is possibly influenced by the family head, regardless of mutual relationship or power difference. One party appears more dominant, compared to the others. The outcome forms one of the identities representing gender relations. Moreover, gender refers to a regular activity (Tjørring, 2016), although is also about decision making in this paper. Therefore, households are viewed as individuals responsible for the decisions in the renovation. Furthermore, gender also relates to age, sex, family structures and power relations within the home.

The negligence of space requirements during house acquisition is mainly responsible for the potential adjustments. Based on Agusniansyah & Widiastuti (2016), the average Indonesian residence has experienced certain alterations in physical conditions, due to space demands. These circumstances are caused by the increasing family size, changing in marital status, and household structure (Clark & Onaka, 1983). A positive response involves initial design modification to accommodate the space diversification.

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Home renovation is closely related to the influence of family life cycle to utilize space. The life cycle includes the developmental stages comprimising single, new, and household with children and elderly persons. This concept determines the extent of adjustment. For instance, in single setting, the bedroom assumes the most important segment to maintain the functional quality and performance, as well as typically serves as a favourite space to relax. Meanwhile, families with children exhibit various habits and patterns. Also, the characteristic of space utilization is related to health care concerns (Davey, 2006; Fischer & Khorunzhina, 2014). For instance, the major renovation is performed in the kitchen. Moreover, the common pattern involves creating an additional room or converting the space from the terrace to a living room. This adjustment is due to additional activities in an effort to improve family life quality, e.g. children education events (Tupenaite et al., 2010). This description clarifies the relationship between gender and home development in terms of how to improve the quality of family life. However, recent researches have not comprehended the correlation between gender and home renovation, but on the decision influencing factors, including economic and environmental considerations. Meanwhile, gender determinants on reconstruction focused extensively on the performance of gender role and relations. For example, older persons tend to maintain the original house design, compare to relocating to a smaller shelter. The gender role in a domestic space is connected to the decision maker, as regards the renovation and also implementation (Knodel et al., 2005). This position covers the expected behaviours, values and attitudes appropriate for male and female. Three varying gender roles are assigned within a family, termed productive, reproductive and community (Munro & Smith, 1989; Kaufman, 2000). Productive roles are associated to the income of family members, specifically, the household head, and are also conducted inside and outside the environment. Meanwhile, the reproductive aspects represent parental upbringing, child bearing and domestic chores. These situations are also in terms of nurturing and generally describe the feminine positions. Lastly, community roles depict the associations between family members and the surroundings, in addition, to the external communication patterns, or network creation for family sustenance.

Moreover, gender relations consider the home personality of the rooms requiring renovation (Hasell & Peatross, 1990). These measures refer to individual interactions with others, and are observed from the interpretation of assigned functions, including decision making and welfare. In a family context, gender relations are also connected to power interactions, as well as the strong desire for control in people and family assets (Kandiyoti, 1988). However, in Indonesian culture, the relationship is geared towards patriarchy and extended families. This paper is aimed at exploring the influence of gender roles and relations on the home renovation decisions in Bukit Kencana Jaya housing complex. This location is occurs in a low and middle housing facility in Tembalang district, Semarang city. The diversification of house types and the length of the occupancy are the primary reasons for the present research. Furthermore, the sample area comprises 110 hectares, and 6 sub-complexes. Based on the master plan for Semarang, between 2010-2030, the research location has become one of the developing areas at suburban districts with the main function of a sub-city settlements with low - medium density.

Data and Methods

The gender determinants were identified as influencing factors in the decision to conduct home renovation, including the gender roles and relations of family members. Gender roles and relations also include the individual conditions related to the level of education, sex, job type, income and assets ownership (Rotman, 2005; Safran-Norton, 2010). In addition, gender influence is also visible in the analysis of family perceptions towards house function as a means to enhance life quality (Munro & Smith, 1989; Shrestha, 2000), and is adjusted to fit the family life cycle.

This paper employed a mixed method, described as a combination of quantitative and qualitatitive analysis. Initially, quantitative approach was employed to determine the sample quota and location, followed by the qualitative process involving interviews and field observations. Based on preliminary survey in March 2020, the location of Bukit Kencana Jaya Housing complex comprises six clusters, including Bukit Mutiara Jaya 1, Bukit Mutiara Jaya 2, Bukit Mutiara Jaya 3, Bukit New Mutiara, Bukit Saphire Jaya and Bukit Permata Jaya. Also, a convenient sample technique was derived to yield sixty respondents. The survey was performed during the coronavirus pandemic, where physical and social distancing were enacted. Furthermore, sixty participants were considered to have represented the total population, as the proportion of the number was in accordance with the size of the sample house types.

Interview questions were composed of three aspects, including profile identification related to gender

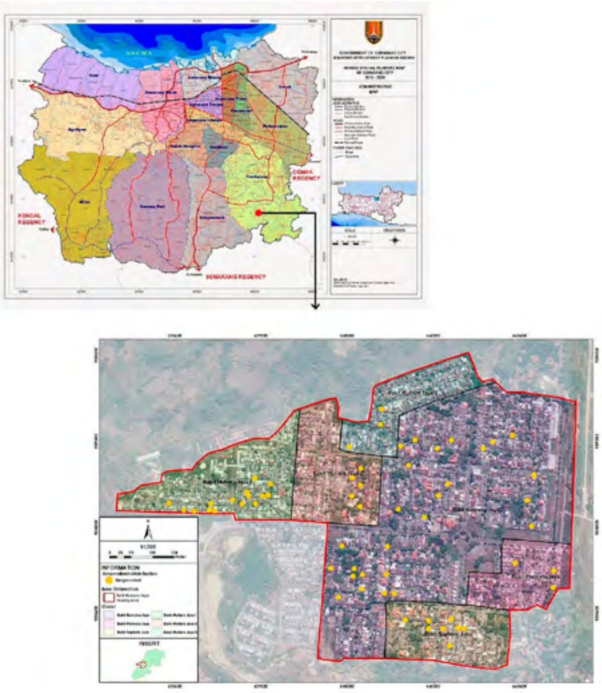

Figure 1. Location of the study area and sample distribution [click on figure to zoom]

attributes, detail information on renovation and considering factors in the first home purchase. The detailed outline of the interview questions are as follows.

This paper included three analysis stages, using descriptive and explanatory technique. The first involved the evaluation of home renovation typology for each family life cycle, while the second and last were based on the influence of gender roles and relations to home renovations, respectively. Therefore, in terms of the four types of family life cycle, it is necessary to observe an operational definition termed, single as

Table 1. Interview Guidelines

Part	Questions
A	
Profile Identifications	Sex, age, educational background, income, family member size
	Home ownership status
	Land status
	Length of occupation
	Buying mechanism (cash/credit)
B	
Home Renovation Activities	Land plot area
	Housing type
	The number of bedrooms
	The number of bathrooms
	Part of house to be renovated
	Renovation motivation
C	
Consideration Variables In Buying First Home	The number of bedrooms and bathroom to meet the family needs
	Yard availability
	Business space accessibility
	Amenities
	Access
	Environment conditions

the unmarried house owner, new family as a recently married couple without any children, families with children as household in the medium family developmental stage, mostly with 2-5 offspring, while elderly as family members of over 65 years old living alone or with spouses, but the children reside separately and independently.

Results and Discussions

Analyis of Home Renovation Typology

Family composition tends to influence the housing demands, and is strongly based on the degree of economic conditions (Karsten, 2007). Clark and Onaka (1983) complemented the report of marital status and family composition as greatly impacting housing demands. Furthermore, field observations showed significant variations in home renovation activities based on the family life cycle.

The first group refers to singles, where the most important aspects in determining home ownership include marital status, house costs, and work experiences. Also, the activities of these individuals involved excess time consumption outside the home, in terms of long working hours, hangouts, and other outdoor fun engagements (Wu, 2010) Therefore, single groups do not oblige to effect home renovations,e.g creating additional bedrooms or upgrading house floors, as interviews data showed a significant satisfactory level.

The second type describes the new families, where changes in marital status are a very influential decisive factor in house ownership and reconstruction (Wu, 2010). Field observation data emphasized the major facelifts to include the transformation of a garden into a terrace as a business startup workspace. However, the variety of business involved the opening of food shops, laundries, and water refill services. Furthermore, the economic motive appears as a very strong determinant in shaping the behavior of new family groups. This is consistent with the interview data, where majority of responses showed the income level as the most important factor in home ownership.

Figure 2. Example of types of physical adaptation according to family life cycle
A - For single – original design preservation
B - For new family – terrace is used for home based business

The third is a family with children commonly residing in smaller shelters, with an area of 21-22 m² in the research location. This condition is due to high income allocation to consumption needs, in terms of feeding, school fees, and future savings costs (Tan, 2012). Therefore, the group does not have sufficient funds to acquire larger houses. In line with the family structure growth, it is necessary for home renovation to accommodate the increasing space requirements. The survey data clearly showed over 91% of respondents from families with children performed renovations, while the remaining were in rented houses. Furthermore, the variety of changes encompassed additional bedrooms, bathrooms, building floors and kitchen expansion.

Lastly, elderly families are less probable to effect home renovations. Apart from the declining house size, the renovation have probably been initiated during the family with children stage. This category generally uses part of the home as a place for self-actualization and field observations showed the active role in assisting neighbors with child care and other nurturing activities. As an evidence, elderly families are known to open child care and shuttle services for school children. These efforts foster a sense of self-confidence in the ability to demonstrate a productive role in economic terms. In addition, the renovations commonly involved turning the yard into a garden. This is proven to be positive for health maintenance and food sustainability (Hwang et al., 2011).

Analysis of Gender Role Correlation to Home Renovations

The gender determinants describe the urgency to accommodate family members requirements in a fair and proportional manner, depending on the roles and relations (Shrestha, 2000). Housing demands reflect family size, individual background, financial abilities and preferences. This search has become very personal as the types and conditions of each household vary in terms of family life cycle. In the single group, the entire respondents resided in a 21 m² shelter. Also, previous research viewed single and young families to involve smaller accommodation, compared to families with children (Wu, 2010). Based on interview results of single group, house preferences were more influenced by workplace distance. This finding is in accordance with (Andersen, 2011), where single people tend to select houses with higher non-financial considerations, e.g. as related to ease of maintenance and access to places often visited. The discovery also supports the performance of gender role in a productive aspect. Furthermore, housing location is a very important concern for job opportunities and income generation activities (Munro & Smith, 1989).

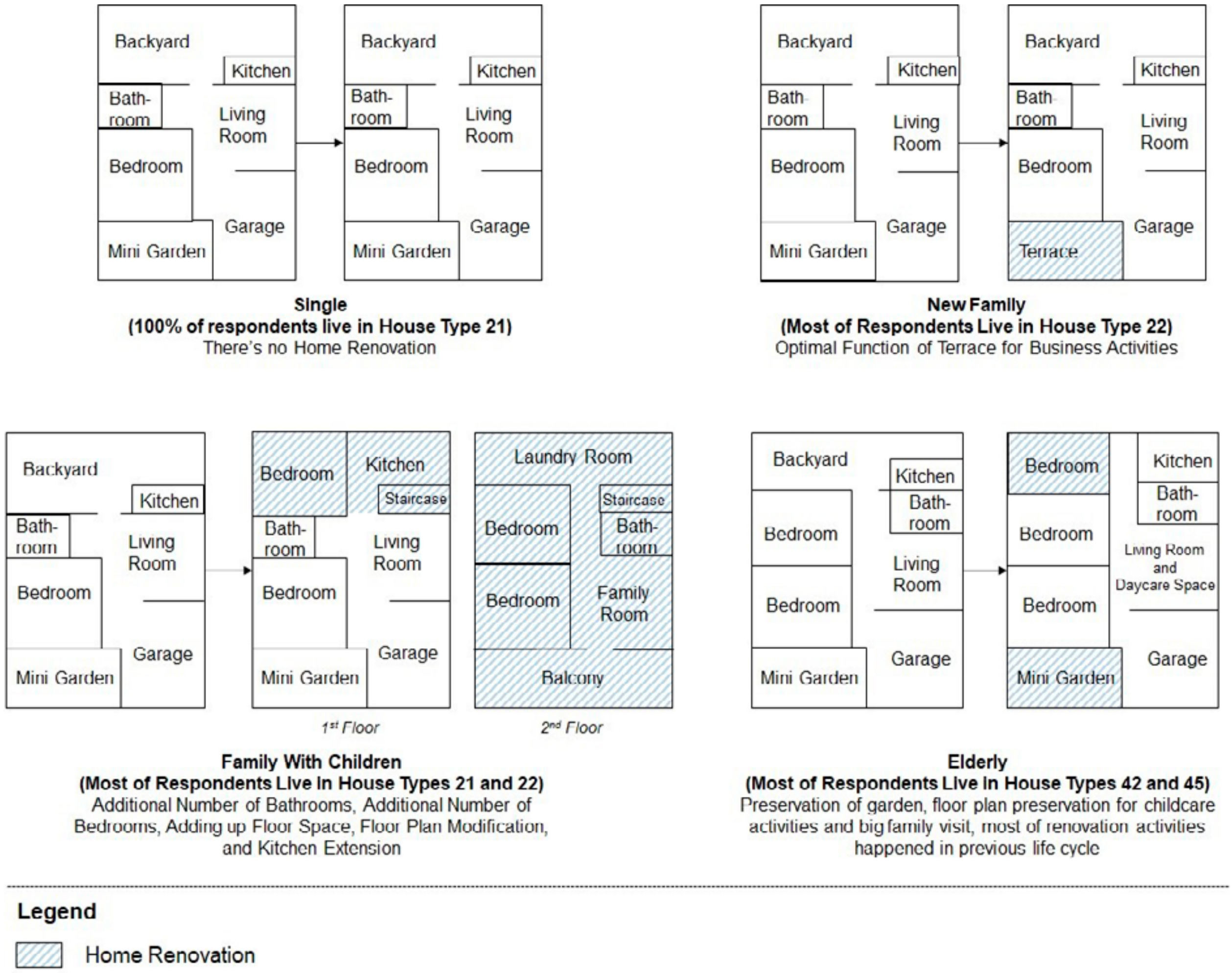

Figure 3. Home Renovation Pattern For Each Family Life Cycle

The overall respondents in the new family group have lived separately from parents. In addition, the need to be independent encourages the plan to acquire a house more suitable with family development. This shows marital status occurs in a close relationship with home ownership as stated by (Fischer & Khorunzhina, 2014). The renovations possibly involve widening of kitchen space and the need for a terrace/front yard for socialization purposes. As a consequence, recognition forms a representation of identity and position within the community. A presence of a terrace also serves as a place for home business activity to support family income. Field findings showed 33 and 67% of respondents reside in a 21 and 22 m^2 apartment, respectively, and were classified as small types. Also, the results revealed similiar pattern with the single group, where gender productive role was more profound than community involvement. The renovation of terrace supports the reason for income earning activities. However, the primary residential selection factor in the new family category was the distance to school. This clarifies the acknowledgement of future needs, depending on additional family members. Furthermore, the prospective gender reproductive role has been carefully considered.

Families with children mostly dwell in small shelters of 21 and 22 m^2, contrary to the need for a bigger house unlike the single and new families (Wu, 2010). Tan (2012) reportedly agreed to the previous research and further stressed the relationship of home ownership to household size, but the possibility is actually eroded by feeding and family health needs. Additional children in a family reduces the possibility of buying a house. Interview results showed families with children in smaller accommodations as there are surplus needs to fulfil, including the excess home purchase loans. Therefore, to anticipate the change in household size, renovations were initiated. As proven, 91% of the respondents in families with children performed embarked on the reconstruction. Meanwhile, the rest were unable to afford the opportunity, due to occupying rented houses, and are in limited financial conditions. Families with children experiencing divorce showed a tendency to change accommodations, using the rental system. Moreover, interview results supported (Clapham, 2009), where divorce is believed to influence family financial conditions, as home ownership appears very significant (Fischer & Khorunzhina, 2014). Therefore, the possibility of divorce is also a high stake in house purchase, as well as uncertainty in revenues, house prices and financial assets. The impact of this situation caused the inability to acquire a house by loan or cash. In addition, divorced and non-divorced conditions are examples of gender role influence, as it determines house preference, as well as the renovation. Furthermore, the pattern of the revamp motive in family with children denotes a gender reproductive role. Therefore, family livelihood, child rearing and income stability significantly contribute to home reconstruction.

Based on the acquired data, 87.5% of elderly families occupied personal houses and the remaining 12.5% were in rentals. The house sizes varied between 21, 42, and 45 m². This proves the existence of elderly families in massive houses. Painter & Lee, (2009), however, argued the changes in health status and age instigated the reduction in home ownership maintenance, and were also responsible for the transition to smaller housing units. Elderly families in 42 and 45 m² tend to preserve existing design, despite being separated from the children. The primary reason was to maintain the rooms for the visitation of the children and grandchildren. These particular groups regard a comfortable environment and yard availability as very significant.

Based on interview results, the availability of kindergartens and primary schools are main considerations for house preference among elderly families. The dependency on the two facilities is important in the opening of child care centers and shuttle services for school children. These activities are predominantly conducted by elderly families in personal residences. Another positive impact from the use of existing space is the ability to socialize and build relationships with neighbors (Martin-Matthews, 2007). For instance, the outdoor space possibly serves for social functions, including recitation, reading corner, knitting lessons and other handicraft activities. The observations also showed a more dynamic housing development in the elderly family group (Hwang et al., 2011). Under this circumstance, the house serves as a place for reciprocal connection with the environment, in terms of a mutual social relations with neighbors and the use of yard for community events. In general, community role appears more dominant, compared to reproductive and productive positions for elderly persons.

Analysis of Gender Relation To Home Renovations

Gender relation is determined by the household structure, including nuclear or extended. In addition, the concept is also influenced by the number of family members and patriarchal cultural factors. According to Sakina (2017) and Kandiyoti (1988), a patriarchal culture continues to develop within the framework of Indonesian society. This philosophy appears in various spheres, termed, economics, education, politics and also law. In the scope of home renovation, patriarchal culture is perceived from household decision making. However, in practice, the majority of conclusions are achieved by men as the family head (Holmes & Jones, 2010). This is very pronounce in situations where the only income source originates from the husband. Therefore, women tend to increasingly lack the courage to partake in household decision making.

This phenomenon existed during decision making on house segments to renovate. Moreover, men are commonly known to decide without discussion and agreement with the women/wives or other family members. This is culturally accepted as there is a general mindset where decision making powers reside in husbands. However, the situation has resulted in increased limitations of women participation in similar processes, including the determination of the home area to renovate.

The difference in power relations between husband and wife instigates imbalanced preferences. Conversely, the women are expected to prioritize the kitchen as a high value space (Shrestha, 2000). This reason is due to longer duration spent in the kitchen, as the unit determines cleanliness, health and resilience. As a consequence, poor women involvement in decision making is constantly neglected. Interview results concluded the control over decision making was influenced by access to gender productive roles. Moreover, a solid relationship exists between access to decision making and income level of individual family member (Munro & Smith, 1989). Higher earnings correspond to an extensive power in this context. Figure 3 shows the results of field observations and interviews, and obviously supports the decision making within the household, as determined by the amount of savings. In addition, the priority of achieving renovation is greatly influenced by effective funding. Concurrent and fast reconstruction is possible with relatively large resource availability.

In a continuing basis, women tend to become insecure about self-actualization at the family and community levels. This is probably resolved by holding family discussions. However, for families with secondary education and above (high school and tertiary graduates), a culture of interaction is manifested in the use of shared space (Knodel et al., 2005). For instance, in families with children, everyone mutually agrees on the room to renovate. Figure 3 denotes the process of home renovations as collectively decided by family members.

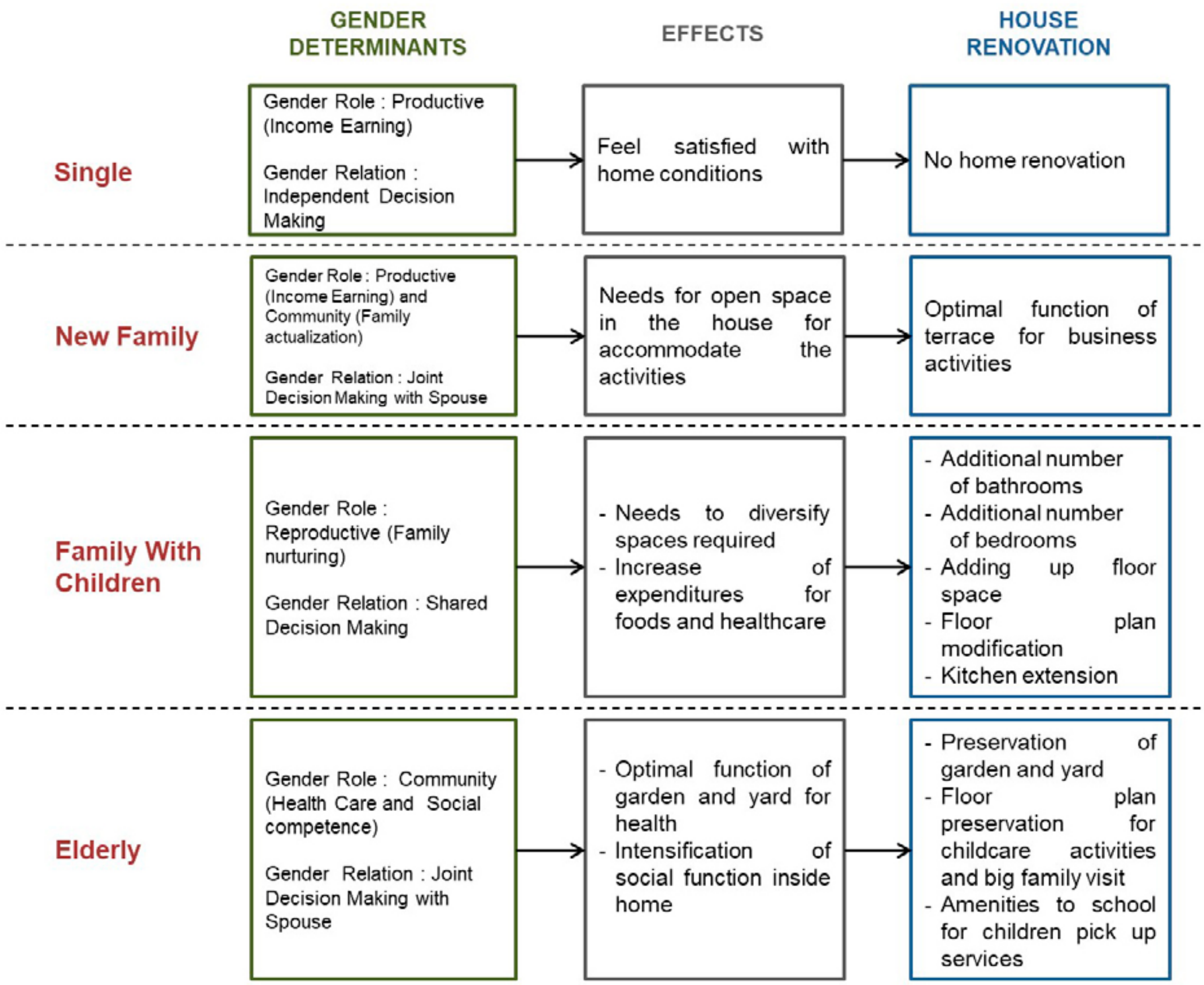

Figure 4. The correlation of gender role and gender relation, family life cycle, and home renovation

The need for various space types in families with children is also determined by environmental and cultural indicators (Hasell & Peatross, 1990). In extended families, the living room serves as a semi-public space. Therefore, the renovation pattern is to preserve the space in a living room, but the usage increases. There are additional purposes to jointly applied in a living room, including a place for receiving guests and also for family benefit.

Conclusion

Based on interview results and discussions, changes in housing conditions were dependent on family development dynamics. This was indicated by the characteristic variations in the four family life cycle stages. However, households without any renovation plans due to financial constraints, marital status and ownership issues, were also prevalent.

The gender determinants, including the roles and relations, showed the houses were expected to serve as an identification of family social status, as well as individual capacity enhancement and community development. In addition, gender roles are related to the extent of responsibility demonstrated by extended members and also the optimal contribution to the success of the family structure. Meanwhile, gender relations determines the conditions, discussions, participation and cooperation required to achieve an improved life quality. Therefore, the relationship of gender determinants and house renovations were divided into two characteristics in Bukit Kencana Jaya complex. First, in singles and new families, the gender influence was based on the residential function in terms of maintaining social status, economic existence and family position.As a consequence, gender roles serve as productive and community functions. Second, in families with children and elderly persons, the focus was with respect to protection and welfare maintenance needed to support the fulfillment of basic requirements and mental or spiritual health. Furthermore, a consolidation exists in the reproductive and community roles of a house as a significant instrument in supporting livelihoods and fostering harmonious interactions with neighbors.

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Active and Passive Adaptation of Floating Houses (Rumah Lanting) to the Tides of the Melawi River in West Kalimantan, Indonesia

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Abstract

Floating houses or Rumah Lanting are one of the settlement cultures found in most river streams in Kalimantan and are observed to be different from several other houses in the area. They are mitigation-proof houses designed to respond to the risk of disasters usually experienced in the traditional settlements of West Kalimantan. Their structures have the ability to adapt to environmental conditions including natural disasters such as the river tides routinely experienced as a flood during the rainy season and as ebb in the dry season.

This study aimed to identify the human-adaptation process existing in these floating houses through direct observation for two years during the dry and rainy seasons as well as in-depth interviews conducted with occupants of these buildings. The adaptation processes identified include the active and passive adaptation of the dwellers. The active aspect was observed from the behavior of occupants in accommodating the occurrence of disaster in the surrounding environment while the passive was identified as the physical changes implemented in the building to mitigate the disaster. The focus of this research was on some dwellings on the river banks settlement in the Melawi River near Sintang Regency of West Kalimantan Province and a qualitative approach with a case study was implemented. The samples were determined through a non-probability approach in the form of a purposive sampling method based on certain selected criteria which included the previous experience of ebb and flow of river water in the Rumah Lanting.

The results showed the existence of active and passive adaptations for the dwellers of the floating houses in West Kalimantan. The active aspect observed involves the behavior of the occupants in adapting to natural disasters with the focus on the changes in the activity patterns, territory, and privacy. Meanwhile, the passive aspect showed some modifications in the architectural elements of the building such as the position, orientation, access, and function.

Keywords: Floating House; Active Adaptation; Passive Adaptation

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Introduction

Indonesia is a country with cultural diversity spreading throughout the Archipelago as observed with each region having different culture according to its characteristics. One of the manifestations of this is the settlement practice which involves living on the ground and water towards adapting to environmental conditions. This is necessary because nature is always changing and people need to adapt to climate change. Moreover, the settlements in some areas are developed due to the influence of natural reserves, geography, and the supporting capacity of environmental ecology (Clark, 2009). This is associated with the concept of settlement formation which is defined as a process involving ecological elements such as climate, water sources, sunlight, and soil (Marpaung & Senders, 2020). The culture of the locals in a settlement is also usually influenced by the economic, social, and cultural factors of the inhabitants. Furthermore, the spatial characteristics of settlements have been described in a previous study as the relation of the environment with the community's socio-economic conditions (Reinmann et al., 2016).

The settlement culture of Kalimantan is closely related to the natural environment and socio-economic conditions of the local community. The geographical condition with extensive forests and large rivers also influences the settlement cultures of the people with some living in the forest while others chose to live on the large rivers. Historically, the people living on the river are migrants aiming to conduct some economic activities such as trading, storage of goods, etc at the past arrival-time. These riverside settlements are, however, one of the factors initiating regional development in several regions of the city.

The development of these riverbanks as settlements is a consequence of the interaction between migrants and indigenous people as well as the high intensity of their activities. This gradual interaction led to the participation of these migrants in the improvement of the economic conditions of local communities which are geographically located in the interior areas without accessibility and infrastructure. These problems change the orientation of the settlements towards the river (Mentayani, 2016).

A floating house structure is one of the settlement cultures in Kalimantan and it involves the residence of local people by the side of a river. These houses are usually constructed with local materials and are still available in several major rivers in West Kalimantan. They exist as dwellings in the Melawi River which is one of the major rivers in the area. It is important to note that riverside settlement is a culture with a system of values, rules, and norms. Moreover, the local wisdom and culture of the people living in the established settlements of a particular area are usually the character of the surviving cultural identity on the riverside (Wicaksono, 2018). Individual efforts to preserve local wisdom also usually affect the sustainability of a community's cultural identity (Pesurnay, 2018).

The scholars in some publications identified the two main reasons people live in a floating house to include history and life necessities. Historically, the floating house is a general dwelling structure for people from outside villages to temporarily stay till the completion of their interaction and economic activities with the indigenous community. In terms of life necessities, the occupants are people without property rights on the mainland that build structures on the river as a place to live (Mustansyir, 2013).

The main problem for the floating house occupants is the limitation of space for activities. This affects their movements and also requires effective utilization of particular existent rooms. The traditional design of the structure also has particular spaces for different activities and the absence of insufficient space to accommodate these activities has the ability to cause conflicts among the dwellers. There is, therefore, the need for adaptations and changes in the living pattern of the house with respect to the environmental conditions. This is important because an efficient arrangement and multi-purpose functionalization of limited space can affect productivity and minimize conflicts (Guo, 2002). This adjustment is usually continuous and has become the habit of the occupants such that they eventually become comfortable while conducting their activities in the building. Moreover, space is continuously provided in line with the daily activities of the owner in order to mitigate the limitations of the floating house (Estaji, 2017).

The process of adaptation by the occupants occurs internally with the focus on the space and activities and externally which involves a creative interaction between the occupants and the environment (Priemus, 1986). The external adaptation process is a measure of the occupants' ability to adapt to the building's conditions and the environment. In several areas of Kalimantan, the floating house is an example of a structure designed to respond to changes in the environmental conditions due to disaster such as a flood during the rainy season and aridity in the dry season. These conditions also occur in the Melawi River with the water level usually rising and reducing significantly due to climate change. The river water level normally rises during the rainy season, thereby, causing the flood to reach settlements on the land with a height of 1-2 meters while the riverbed is usually visible by leaving 2-5 meters of water surface to river stream width during the dry season. This, therefore, requires some level of adaptation from the occupants of the floating house. This has been the norm for a very long time and has become a habit for the occupants to achieve a comfortable living while performing their daily activities.

This study, therefore, aimed to identify the occupants' adaptation process and activities within a floating house. This involved the observation of the activities of the occupants inside the floating houses during the river's particular disaster in the form of flood and ebb for 2 years using Melawi River in the Sintang Regency of West Kalimantan as the case study.

The purpose of this study was to recognize the adjustment process autonomously implemented by the occupants towards river tides disasters and the physical changes usually made in the floating houses. This is necessary because, according to Riyandari (2018), the direction of the disaster management process in the riverbank settlements has always been focused on prevention through the involvement of the local governments. It is, therefore, possible for stakeholders to prevent flooding in riverbank settlements by issuing appropriate policies on disaster prevention efforts such as the construction of early warning systems or the development of a natural disaster mitigation layout for dwellings in these settlements.

Melawi River Characteristics

Melawi River is a tributary of the Kapuas River in West Kalimantan. It stretches from Sintang Regency to Ambalau Sub-District which is located at its upstream. The length of this river is approximately 600 km with a depth of approximately 12-16 meters to the riverbed. It currently functions as the economic and transportation lifeblood of the interior communities in West Kalimantan, especially the upstream areas. The Melawi River has experienced regular extreme tides such that it becomes shallow in the dry season, thereby, making it difficult for water transportation routes. Meanwhile, it overflows in the rainy sea-

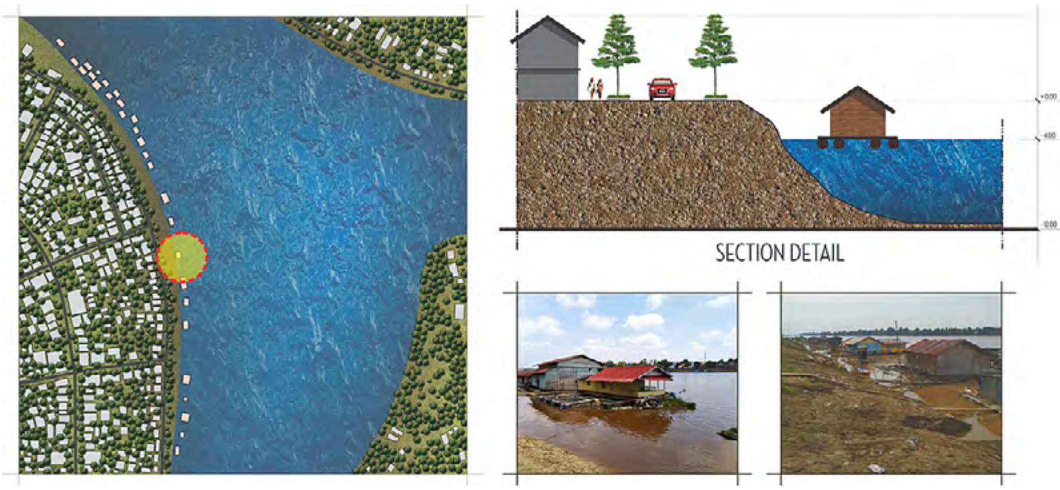

Figure 1. Normal condition of Melawi River

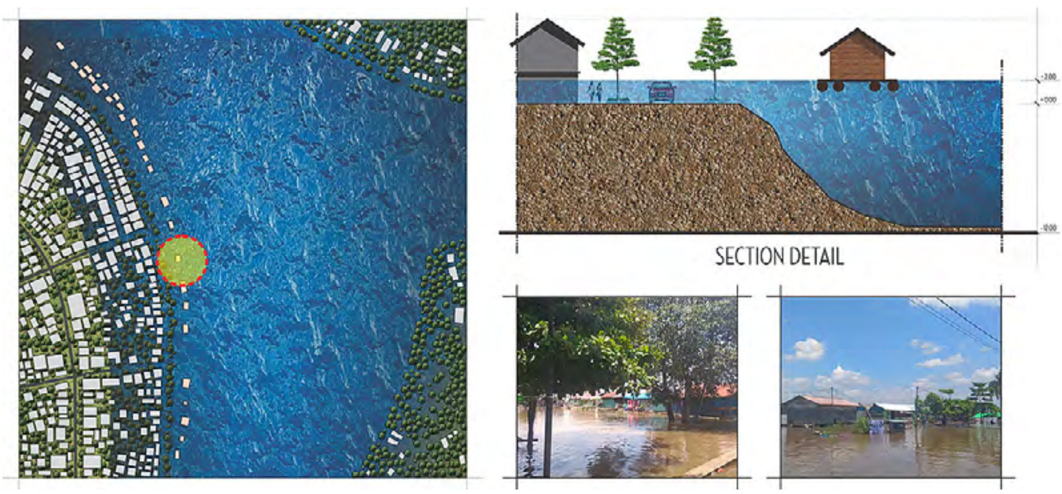

Figure 2. Flood condition of Melawi River

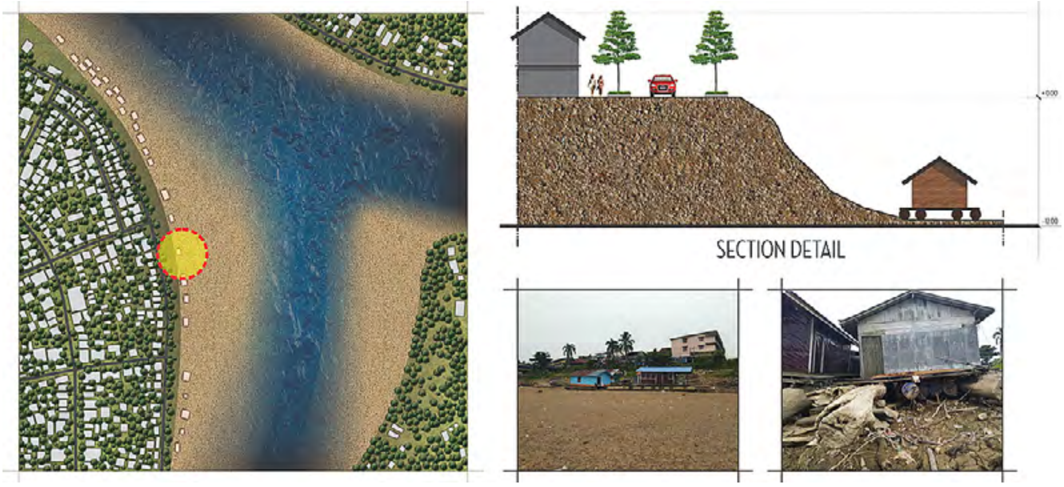

Figure 3. Ebb condition of Melawi River

son and this causes flooding with a height of up to 2 meters in the inland settlement.

Several floating houses on its riverbank are regularly affected by these tides starting from the time the occupants began the settlement. It has, therefore, become a traditional practice for them to respond to this environmental condition.

Literature Review

Floating House

The floating house is a unique phenomenon usually found in riverside areas. Its uniqueness lies not only in its shape but also in the daily life patterns of the occupants. It is usually made of wood such as Meranti, Bengkirai, or Belian (Mustansyir, 2013) and a built-construction on the water. The design of this house is a flexible structure due to its ability to adjust its level to the changes in the river's tides (Afdholy, 2017). It is considered a cultural asset for the riverside community and has been reported to be advantageous by being an erosion barrier and river fluctuation controller (Daryanto, 2004).

Rumah Lanting is generally a house made of wood and serves as local wisdom for riverside communities. It is responsive to the environment due to climate change, disasters, and other internal and external factors. The floating houses in West Kalimantan are spread along major rivers such as the Kapuas, Melawi, and other rivers where they experience tides which makes them follow the water level.

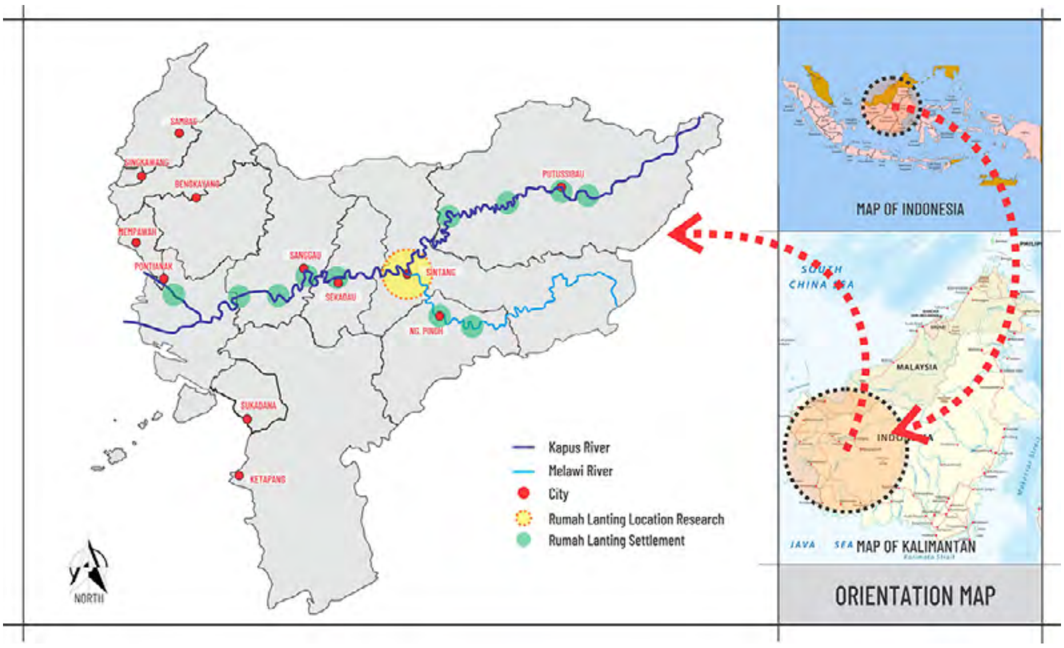

Figure 4. Map of distribution of Rumah Lanting on the Kapuas and Melawi Rivers in West Kalimantan

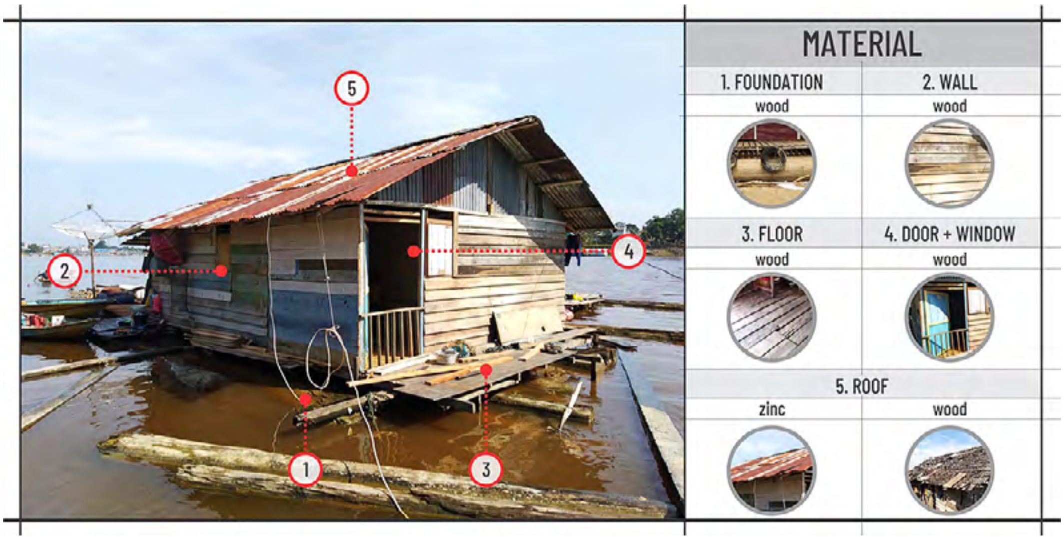

Figure 5. Materials of Rumah Lanting

Adaptation

Adaptation is an individual's ability to adapt to a certain environment through a behavioral process established on psychological factors in anticipation of future issues (Gifford, 2012). It is also defined as people's effort to adapt to the past and unpredictable disasters. The concept is also described as the ability of individuals to adapt to their environment which usually has physiological, morphological, and cultural effects. The process, however, involves the application of technology and social institutions (Soemarwoto, 1991) in adapting to climate change phenomena causing natural disasters in the surrounding environment (Hilmanto, 2010).

Adaptation is an indicator of an individual's capacity and ability to withstand hazards including those caused by changes in natural conditions. Humans with adequate competence and capability in disaster management survive while those with moderate levels are vulnerable to be victims of disasters. Some of the external factors influencing the individual level of vulnerability to disasters emerge in the form of pressure and shocks from outside while the internal ones involve using resources to cope with disasters (Chambers, 2006). This means individuals adapt to environmental conditions through the employment of all survival aspects in all their activities. There are, however, two types of the adaptation process and they include passive and active processes. The passive process involves changing an individual's particular activities according to environmental conditions while the active aspect means changing the environment's physical elements according to an individual's desires (Gerungan, 1991).

Method

This research was conducted using the qualitative method and this involves understanding certain phenomena in research subjects by considering their behavior, perceptions, motivation, actions, and other activities as an integrated behavior. Moreover, some of the descriptions were made using words or language (Moleong, 2005) and the procedures for the implementation of this method are flexible according to needs and based on field situations and conditions (Danim & Darwis, 2003). A case study approach was employed in this study and this is an in-depth analysis of a system which is the same across different cases. This means all the cases are integrated and interconnected as part of the research process (Merriam & Tisdell, 2016).

The floating houses selected as the object of research were those that have experienced ebb and river water flow. It is important to note that these buildings are designed to withstand disasters (Sihombing, 2019) or respond to natural disasters without changing or adding any physical element to the building. The condition of the floating structures is different from others built on the riverbank which requires adding some properties to bear the occurrence of disasters (Gultom, 2018).

Several floating houses positioned alongside the Melawi River in Sintang Regency of West Kalimantan Province were used in this research with the samples selected using a non-probability approach through purposive sampling based on certain predetermined criteria. This technique was applied due to its ability to determine research samples with specific attention to obtaining more representative data (Sugiyono,

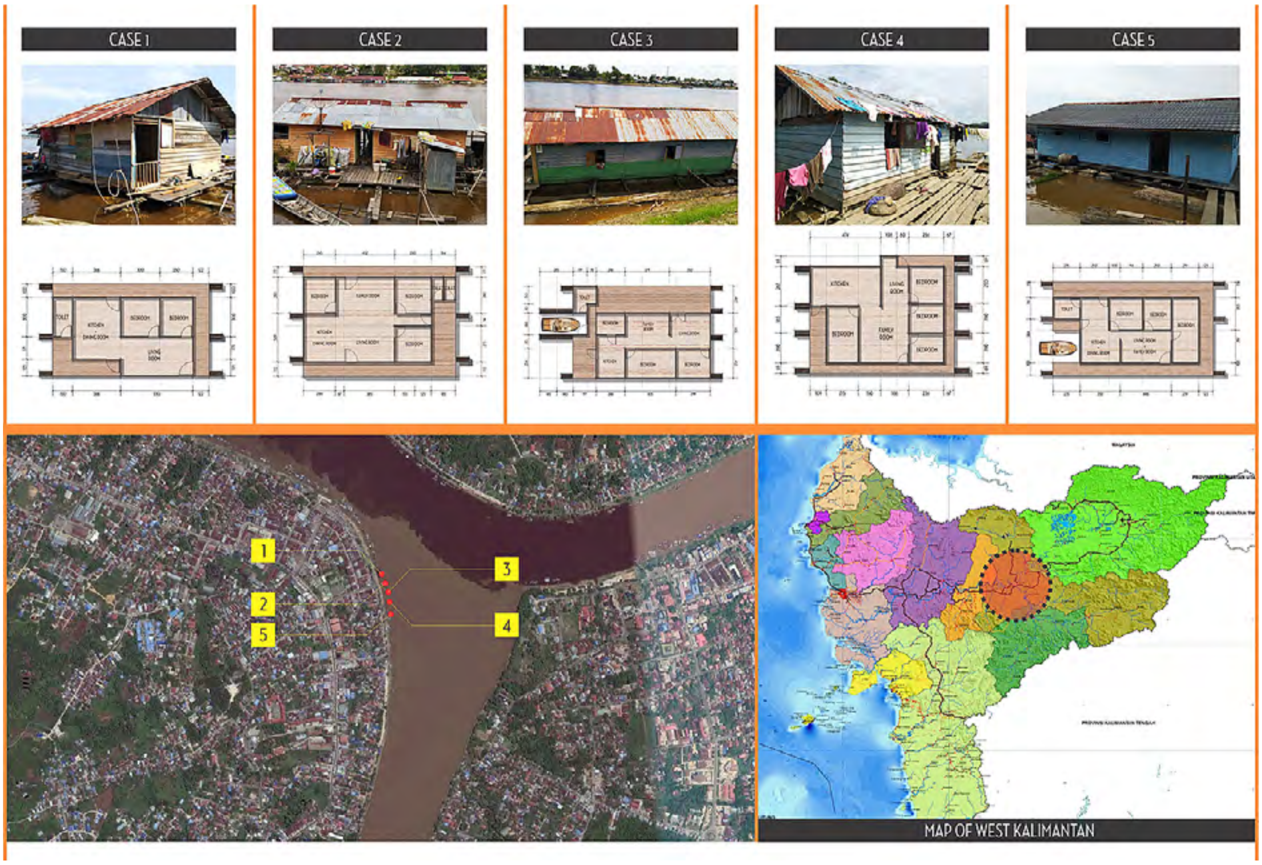

Figure 6. Location and research objects

2012). The selection criteria include the floating houses which is a unit with physical elements adapted to the river's environmental conditions due to climate change and those with certain elements changed as a response towards adapting to environmental conditions such as flood and ebb.

This study aimed to identify the adaptations routinely experienced in the floating houses due to changes in environmental conditions such as a flood during the rainy season and ebb in the dry season. The variables used were active and passive adaptations with the active aspect analyzed by focusing on the changes in the occupants' behavior in response to the changes in the environmental conditions at the time of disaster while the passive involved determining the changes in the physical aspect of the floating house due to changes in the environmental conditions.

Findings and Discussion

Occupant Characteristics

The occupants were discovered to have lived in a floating house for at least 5 years, 12 years on average, and the longest was 20 years. Most of the occupants are second consecutive generation while the rest are new people that bought the structure from previous owners. Moreover, the physical condition of the floating houses has not changed significantly since they first occupied it with the only modifications focused on repairs due to damaged elements such as roofs, floors, and walls. It was discovered that the length of time they have lived in the structure affects their ability to adapt to the changes in the environmental conditions. The adaptation process currently experienced in the area was reported not to be new but a process of transposition and change which occurred through adaptation and deliverance (Hutcheon, 2006).

The analysis of several floating houses in the research location also showed the adaptation process to achieve comfort occurred in the early days of occupying the structure. This was observed from new occupants which were considered to be comfortable with the house in less than a year of residence. This is observed from their ability to adapt to the limited area in the floating house after enjoying wider space in the in-land houses which makes them conduct their activities with ease. It is important to note that the level of comfortability was assessed based on the ease with which the occupants conduct their activities in the floating house area.

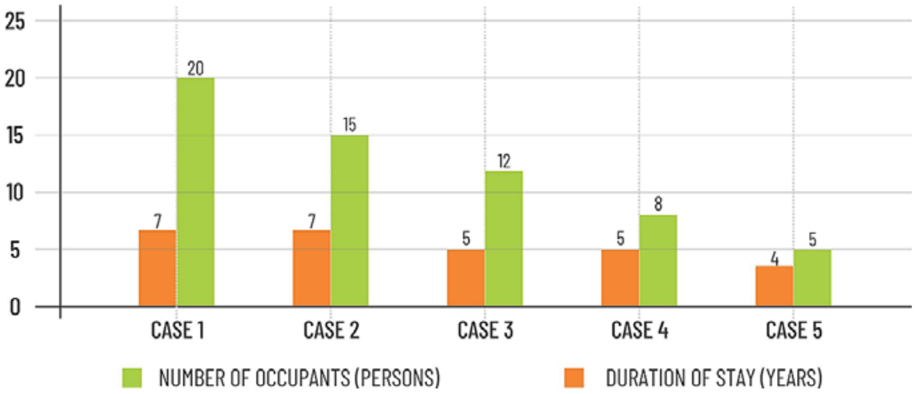

Figure 7. Number of occupants and duration of stay in Rumah Lanting

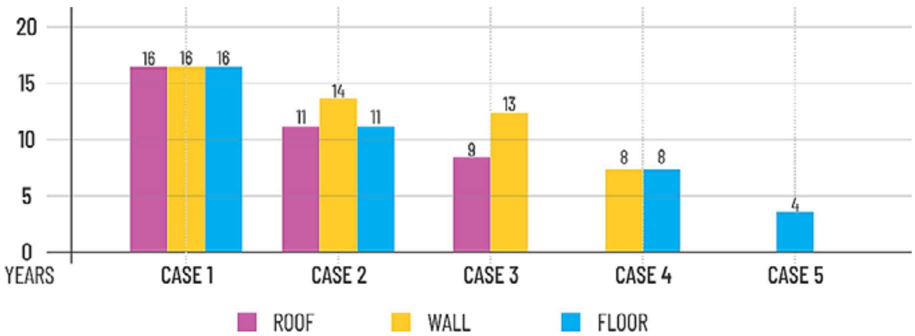

Figure 8. Part of Rumah Lanting renovation time

Floating House Characteristics

The characteristics of the floating houses were determined by analyzing the inner and outer spatial layout patterns. These patterns were created based on the behavior of occupants in arranging the spaces in line with their activities and intimate relationships as well as in relation to the physical environment. This is in line with the description of behavior patterns as a unit of the relationship between behavior and the environment (Laurens, 2004). Moreover, the occupants' experience and habits also influence the arrangement of spaces towards achieving comfort. It is also important to note that the ability of an individual to adapt to the environment differs according to their response (Rapoport, 1998).

The spatial layout in the floating house is arranged using a centralized approach and this pattern does not usually change due to the difficulties associated with maximizing the limited area. The living room is usually the center area for most activities due to its status as the only public area. It is used as a multifunctional space due to the need to perform several activities in the limited space. It is, however, important to note that the same activities conducted in normal houses on the mainland are also in the floating houses such as bathing, eating, sleeping, working, playing, and several others.

The outdoor layout is also closely related to the inner space and the surrounding environment. Behavioral settings are interactions between an activity and a specific place which occur consistently according to time and situation (Haryadi & Setiawan, 2010). Most of the floating houses are oriented towards both the land and the river and they also have a circulation route for entrance in both directions. There is also a terrace which serves as an intermediate area between the outer and inner spaces and surrounds the building to serve as an open space for the occupants.

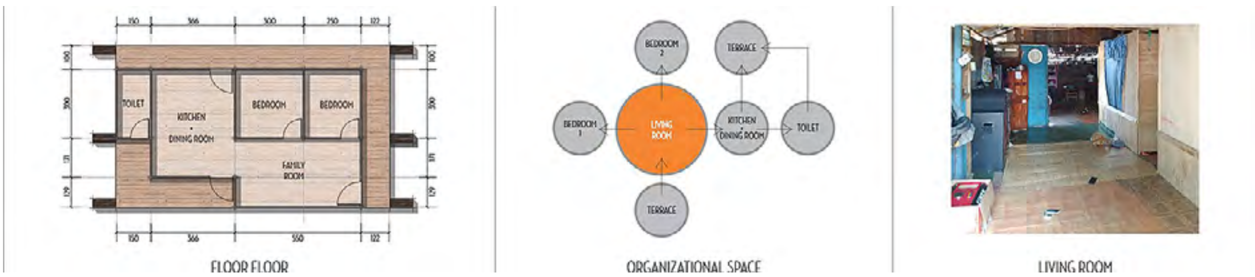

Figure 9. (a) Floor plan case 1; (b) Organizational space case 1; (c) Living room case 1

Figure 10. (a) Floor plan case 2; (b) Organizational space case 2; (c) Living room case 2

Figure 11. (a) Floor plan case 3; (b) Organizational space case 3; (c) Living room case 3

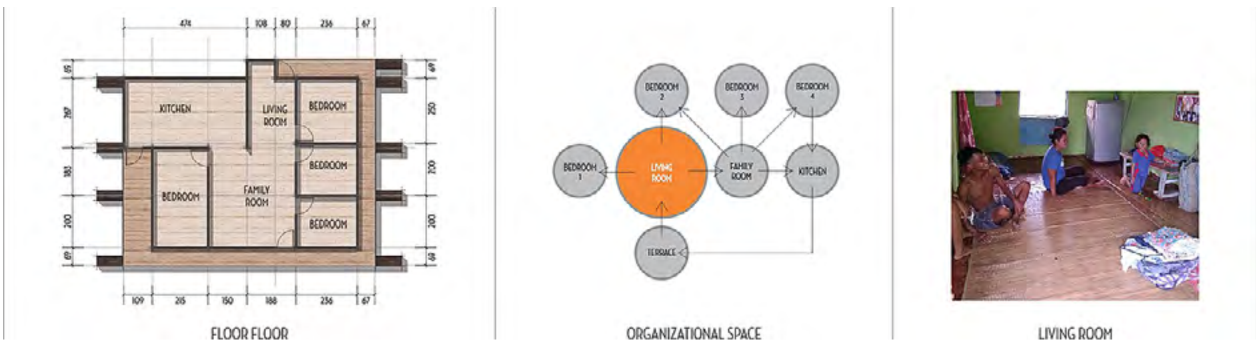

Figure 12. (a) Floor plan case 4; (b) Organizational space case 4; (c) Living room case 4

Figure 13. (a) Floor plan case 5; (b) Organizational space case 5; (c) Living room case 5

Adaptation Process

The occupants of the floating house usually experience a drastic change in environmental conditions when the water level rises or drops and this indirectly forces the people to adapt. This means each of them can modify the building according to the climatic conditions in order to achieve comfort and safety (Roaf et al., 2009). This involves understanding the nature of the natural phenomena usually experienced (Lang, 1987) in order to individually adapt to deal with the environmental pressures. The adaptation is required to survive and ensure comfortability and it is mostly achieved through several engineering actions, improvements, or changes in different aspects of life. This process, however, occurred both actively and passively.

Active Adaptation Process

One of the adaptation processes in the floating house is active adaptation. This involves the participation of the occupants in making adaptive actions and also emphasizes the important role of individuals in influencing the environment (Kartasapoetra, 1987). This adaptation can be allopathic and regarded as an individual active strategy in dealing with environmental changes (Gerungan, 1991). It is important to note that the environmental conditions in the study area change due to the rise and fall of water level in the Melawi river and the occupants are required to respond through a behavior that there is enough space to conduct activities both within and around the house.

The privacy of the floating house is also adjusted in the time of disaster such that the access to the buildings is controlled by occupants in normal conditions but this is limited due to the environmental conditions during floods. Meanwhile, the access can be easily visible to guests during periods of low tides, and this is known as the open limitation access type of privacy.

The activity patterns of the occupants in the Rumah Lanting also change during the period of natural disasters. These activities are standard during normal conditions but the movement in space becomes more

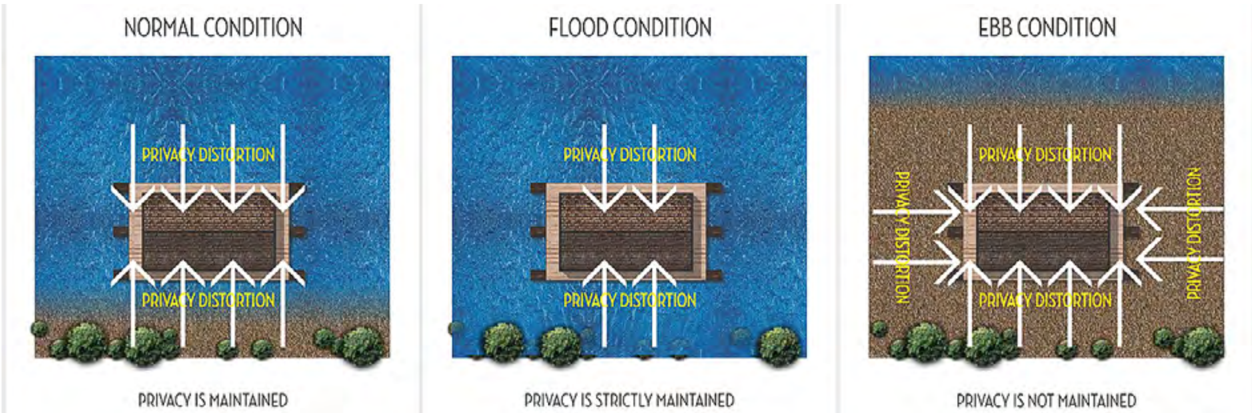

Figure 14. Territory modification in floating house

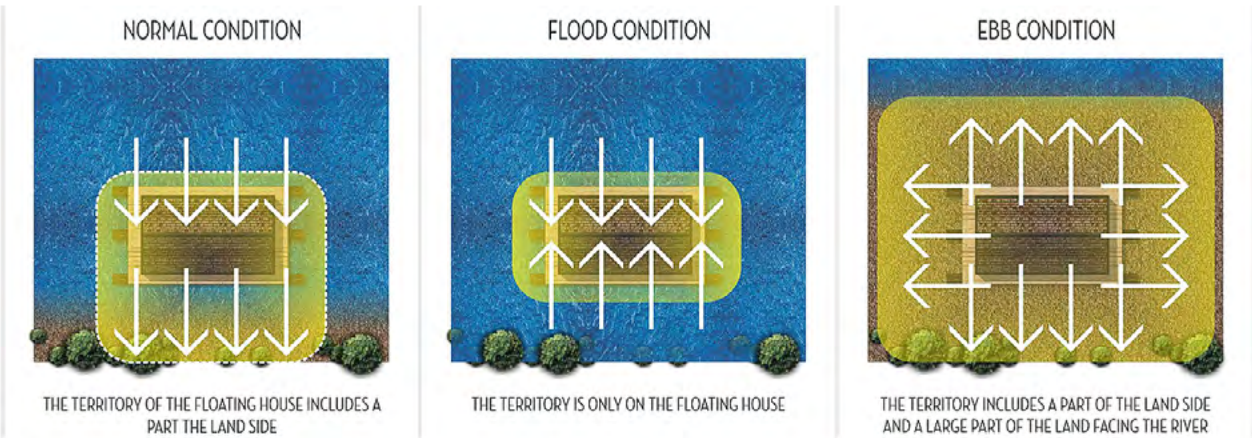

Figure 15. Privacy modification in floating house

change. Some of the activities inside the house such as bathing, playing, and interacting with neighbors are moved outside in order to adapt to the environment and this further affects territory, privacy, and activity restrictions.

The territory of the floating house is usually changed during a disaster. It is land-oriented in normal conditions but the activities towards the land are reduced during flooding and this makes the territory narrower, thereby, leading into the building. During low tide, the territory becomes wider due to the fact conservative and tends to be focused more on the inside during floods while the activity space is more expansive with the use of outdoor space during the time of low tides. These activities are similar to those usually conducted by residents living in mainland houses. Meanwhile, Rumah Lanting is a house which can be adjusted based on the activity patterns and the wishes of the occupants as well as the changes caused by natural disasters. This is observed from its elevation which is always designed to be above the surface of water and land.

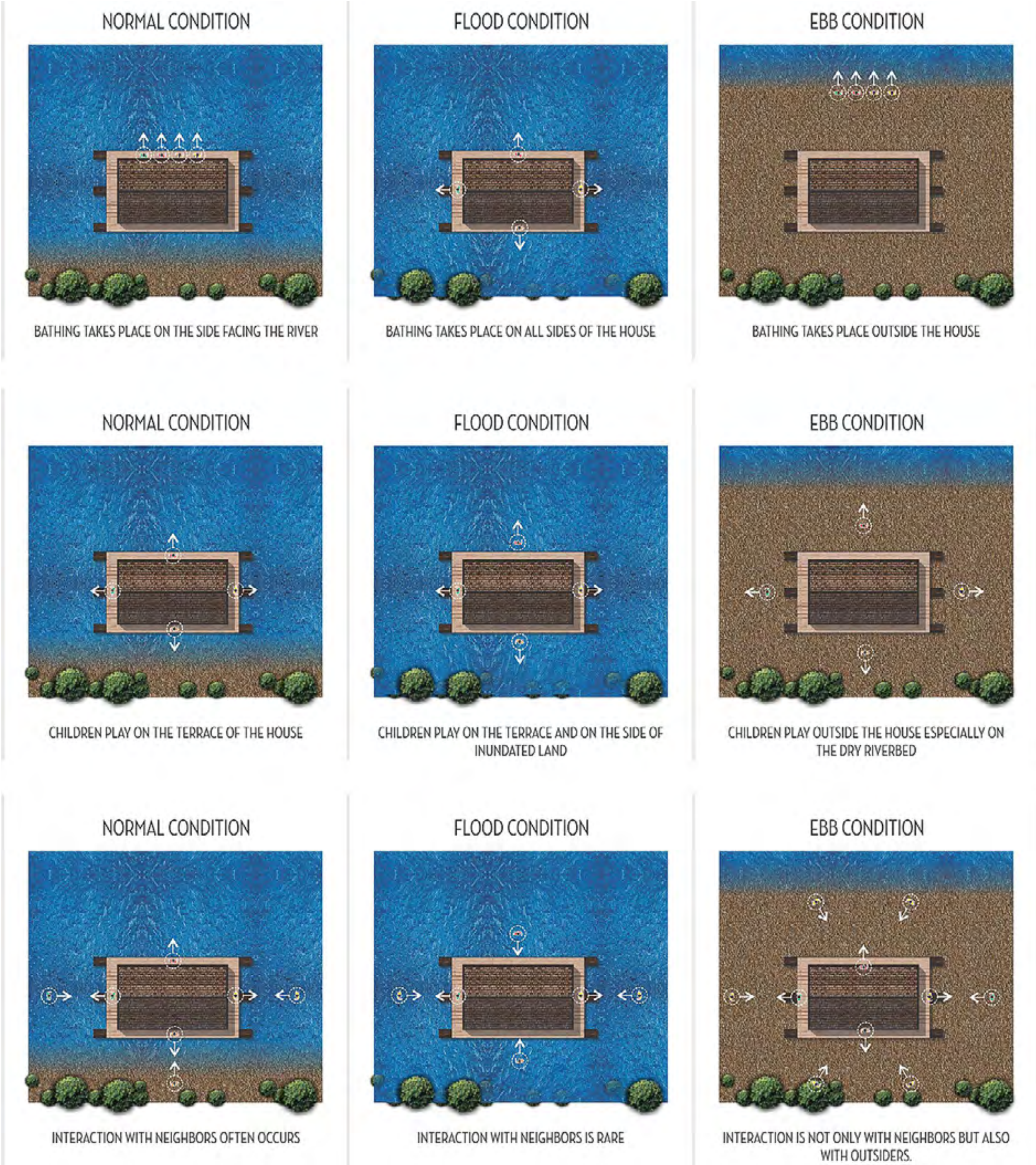

Figure 16. Activity pattern modification in floating house

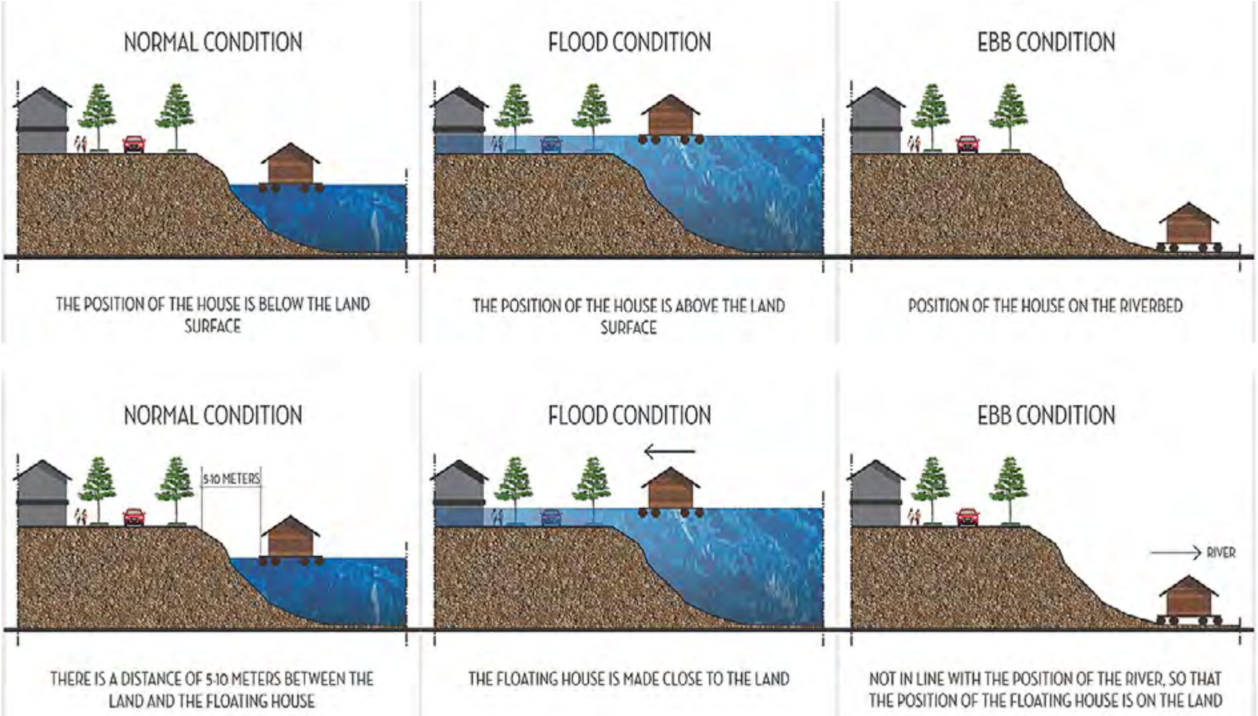

Figure 17. Position modification in floating house

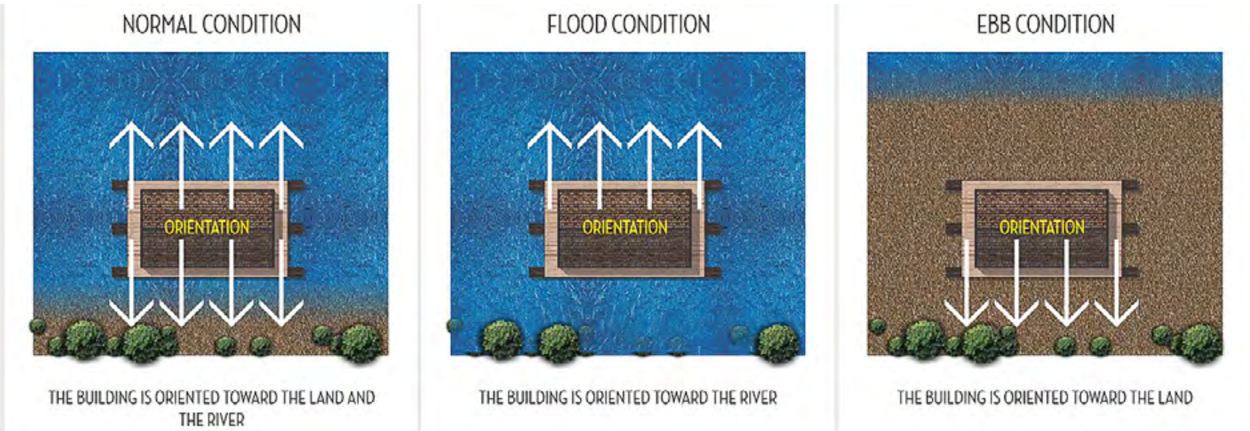

Figure 18. Orientation modification in floating house

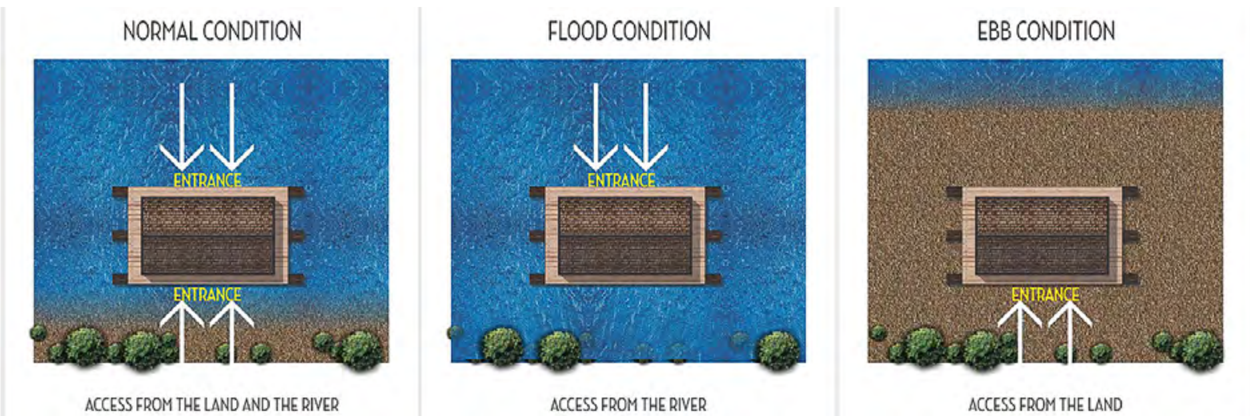

Figure 19. Access modification in floating house

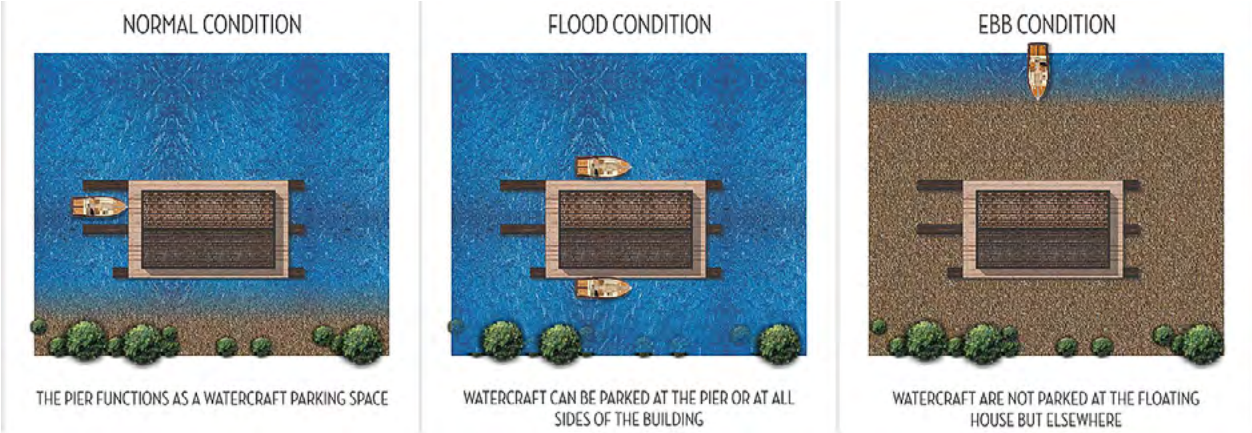

Figure 20. Function modification in floating house

Conclusions

The data and analysis obtained were used to draw the following conclusions:

1. The adaptation of the occupants was observed to be related to their period of stay in the floating house. Their focus is usually to ensure comfortability inside the house despite the changes in environmental conditions.
2. The floating house has a multi-functional space which accommodates different activities. The adjustments made to these activities do not prevent the adaptation process and the changes implemented inside the house do not significantly affect the building's physical appearance.
3. There are two main actors in the adaptations of a floating house and these include the occupants and the house. The occupants are significant to the active adaptation process while the house is the main object of the passive adaptation process.
4. Active adaptations involve the responses of the occupants towards adapting to the changes in environmental conditions with the focus on activity patterns, territory, and privacy.
5. Passive Adaptations are made by making adjustments and changes to the floating house with the focus on the position, orientation, access, and function in order to achieve comfortability.

Acknowledgement

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Investigating Outdoor Thermal Comfort of Educational Building Complex in Urban Area: A Case Study in Universitas Kebangsaan, Bandung City

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Abstract

Campus building was a place to accommodate various educational activities, which were both carried out indoors and outdoors. The environment, including the building and its exterior, provided thermal comfort that was influenced by the context, such as the mass of the facility, vegetation, and constructing envelope materials. The microclimate also influenced the environment, such as temperature, wind speed, and humidity. This study aimed to investigate the outdoor thermal comfort of campus building in urban area during summer, while also identifying the influential factors. This research referred to a case study, examining the thermal quality of the educational building environment using ENVI-met software, based on the Predicted Mean Vote (PMV) index as an indicator of outdoor thermal comfort, in Universitas Kebangsaan (UK). The results showed that the outdoor environment had low thermal comfort conditions during the day, as it also had different thermal satisfactory situations, due to differences in physical characteristics in each zone. This characteristics included, (1) The SVF determinant as indicators of the shading factor should be supported by the presence of vegetation and the use of pavement material, (2) Although the wind speed factor does not really affect the thermal comfort in the outdoor space, the interconnection between open gaps is likely to make breeze distribution in the area better. This study offered direction for campus planning, in order to maintain the optimal capacity of the natural environment, such as (1) Strategizing to create a better shadowing factor in the outer space, which was supported by controlling the use of pavement materials, (2) Directing the density of buildings by making open spaces more permeable, in order for better wind distribution in the area. From this study, the campus current conditions and future design development potential was also observed.

Keywords: Outdoor thermal comfort; Educational building; Urban area; Micro climate; PMV

Introduction

Outdoor thermal conditions in the campus area, significantly impact students' comfort in carrying out their activities (Huang et al., 2019). Student academic activities are carried out both indoors and outdoors, especially for individual or group study. Moreover, campus as an educational facility should provide a good outdoor environment, in order to support the students' activities.

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The outdoor thermal comfort is influenced by regional climate and urban conditions. These factors produce four variables affecting the thermal comfort of the human body, including air and mean radiant temperatures, humidity, and wind velocity (Zomorodianet al., 2016). The outdoor environment also contains circulations, open spaces, and other physical elements, as the opened gap is usually designed as a green park or sports facility. In many universities, campus buildings with an outdoor environment, such as a green park and sports facility, are often observed.

Also, thermal comfort was separated from climate factors. Designing buildings and outdoor environments by considering climatic factors not only provide comfortable thermal conditions, it also increase satisfaction and improve human health (Ghaffarianhoseini et al., 2019). Apart from external factors, internal indicators also affect thermal comfort. These factors are in the form of clothes used and activities carried out (Fanger, 1970). Besides these two factors, design elements also affected, such as artificial surface materials, paving, concrete, asphalt, with buildings and vegetation (Jeong et al., 2015).

Campus buildings are usually located in urban areas, which causes discomfort vulnerability, due to the microclimate. In the parametric studies carried out by Bajsanski et al. (2019), the urban microclimate was improved and more comfortable, through different street orientations, vegetation, and building geometries. Mitigation of thermal overheating in an urban context, including campus building, is very important in obtaining better conditions for human well-being. Therefore, several studies have also been conducted to see the potential for urban environment mitigation.

Thermal comfort research in the campus area had started to be carried out, for example, the study of outdoor conditions on campuses, in summer and winter climates (Huang et al., 2019). Also, previous studies had been conducted in subtropical urban areas, which focused on the influence of various design element types (Xi et al., 2012). Furthermore, wind environment as an essential aspect of urban micro-climate was also studied in two schools in Nanjing, which focused on schoolyard wind environments, from the standpoint of children and teenagers (Liu et al., 2019). Various micro-climatic factors, such as seasons, various types of design elements, wind, vegetation, and more, are needed to be considered in the case of educational buildings, within an urban context. Recent research in Kuala Lumpur, also tried to study the thermal characteristics in a university campus, in the tropical climate. This study used the ENVI-met simulation, and discovered that there were significant impacts of shading and vegetation, on increased thermal comfort (Ghaffarianhoseini et al., 2019). ENVI-met simulations had also been used to devise solutions, in order to reduce heat stress, and create student thermal comfort in open spaces, between education buildings. This study used PMV as a parameter to assess its thermal comfort (Abdallah et al., 2020).

ENVI-met is one of the most commonly used software tools, which aids in understanding the impact of architectural and urban designs, on outdoor thermal comfort (Salata et al., 2016). This software simulates the interactions between the urban design and the microclimate, in order to calculate human comfort. It also generates output containing the thermal comfort parameters, including external and internal input terms (Taleghani et al., 2015). Also, this software is often used in analyzing thermal comfort in educational building cases.

Moreover, Universitas Kebangsaan is one of the educational building complexes in Bandung, Indonesia. This campus is located in the urban area of Bandung, as it preserves the original campus design from 1992. After being established for a long time, Universitas Kebangsaan has plans to physically develop its campus. There are increasing demands from the number of students that needs to be accommodated, as the limited site ownership makes this campus optimize the existing land. This future campus development should be able to create a better quality outdoor environment, in order to accommodate student activities.

This study aims to explore the thermal characteristics of various outdoor areas of the campus building, which is located in an urban environment. Also, this research tries to identify the important parameters, which affects outdoor thermal comfort. Additionally, this study should also suggest some future design considerations, based on the parameters observed. The research is conducted using the ENVI-met simulation, as the benefits of this study should provide input for future campus developments. Broadly, this study also contributes to the development of knowledge, which is related to the outdoor thermal comfort conditions in types of educational building complexes, especially in tropical climates, such as Bandung City.

Data and Methods

Based on phenomena occurrences, this research used a quantitative descriptive-comparative approach, which explained data in the form of numbers. This study also referred to a case study, by examining the thermal quality of the educational building environment using ENVI-met software, based on the Predicted Mean Vote (PMV) index. PMV was used as a parameter of thermal comfort in this study. Based on ISO 7730, PMV is an index that predicted the average value of human groups against 7 thermal sensation scales, based on the heat balance of the body (International Organization for Standardization, 2005). The seven thermal sensation scales consisted of +3 hot, +2 warm, +1 slightly warm, 0 neutral, -1 slightly cool, -2 cool, and -3 cold. Generally, neutral was a condition of comfort that needs to be achieved in the thermal comfort of an environment, for humans (Olesen & Parsons, 2002). This research used the seven thermal sensation scales, which were accumulated from the climatic conditions at the research area. JMP software analysis was also carried out, in order to compare the simulation results.

This research had the following stages :

1. A literature review was carried out, in order to build a repertoire of knowledge related to climate, thermal comfort and its standards, educational buildings, and recent research;
2. Modelling case studies from primary data obtained;
3. Inserting climate conditions data in Envi-Met software, and carrying out the simulation;
4. Analyzing and interpreting the simulation results descriptively and comparatively;
5. Carrying out a more in-depth investigation, based on the different characteristics of the outdoor area in the case studies;
6. Drawing conclusions.

Data and Sources

The data used were both primary and secondary. Primary data were directly related to case studies, such as measurements of size, orientation, vegetation, building materials, and the environment. This type of data collection was carried out by direct observation of the case study area. Secondary data used were also in the form of macroclimate information, which were obtained from the meteoblue web and literature. These two main data were both used to obtain thermal comfort, with both external and internal factor data.

External factor data

The external factor data were related to climate, and obtained from the meteoblue web. This site provided global climate data, which were collected from a span of 30 years, with hourly weather information. Meteoblue weather models were based on the NMM (Nonhydrostatic Meso-Scale Modeling) technology, which specifically described the weather in an area, such as temperature, wind speed, and clouds (Meteoblue, 2020). The drawback of this data was the fact that it was unable to reproduce details of local weather effects, such as hot islands, cold air currents, thunderstorms, or tornadoes. Even at that, this data was sufficiently a representative of the climatic conditions in the case study locations studied. The climate data as an external factor, was very useful in predicting the level of thermal comfort (Sujatmiko et al., 2019).

The main reason for using this data was the long collection period, as it represented the climate of an area. The research had also compared the climate data with those held by the official weather station, which belonged to the Meteorology, Climatology, and Geophysics Agency (BMKG), Bandung. The results of the comparison further showed a close suitability, as the meteoblue web data was still used in this study. Specific climate sample data were also obtained in the case area, in order to ensure accuracy.

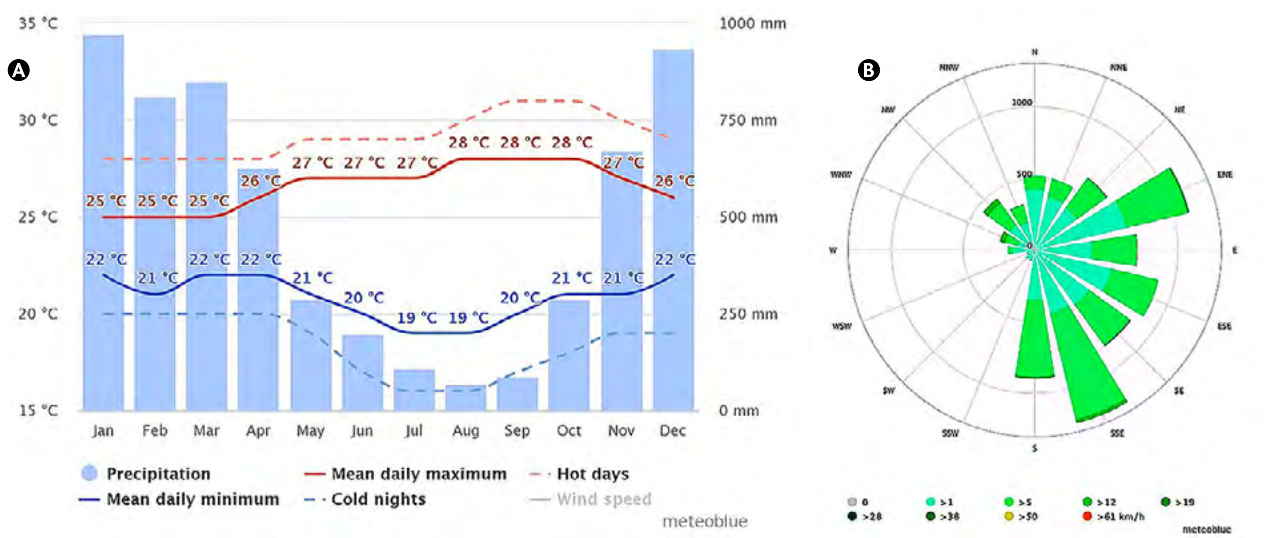


Figure 1. (A) Temperature and precipitation; (B) Wind rose

Source : meteoblue.com (Meteoblue, 2020)

Climatic data were obtained at a specific area, at 6.93°S & 107.63°E. External data were also collected on extreme climatic conditions, within a year. The extreme conditions were considered to provide a picture of the thermal conditions, which needed more concern, with the selected month being September. There were also extreme high and low temperature limits at 31 °C and 17 °C, within the month (confirmed in BMKG data), respectively (see Figure 1a) (Badan Meteorologi Klimatologi Geologi, 2020). Therefore, this temperature range was used as input. Regarding the wind, it was obtained from the Southeast, with a speed and altitude of 2.2 m/s and 10 m, respectively (see Figure 1b).

The extreme conditions in September were also observed in the sun path diagram. The position of the sun was directly above the equator (Equinox), causing the air temperature to rise (see Figure 2.a). This phenomenonalso caused radiation emission received at the area, which was the highest in a year. The duration of exposure due to the angle of the sun, also reached the maximum level(see Figure 2.b).

Meteorological data obtained was on September 14, 2020. Based on the meteoblue data, the information collection day had the highest peak temperature with humidity, which seemed to vary.The most dominant wind came in from 104-137° direction, as the South-

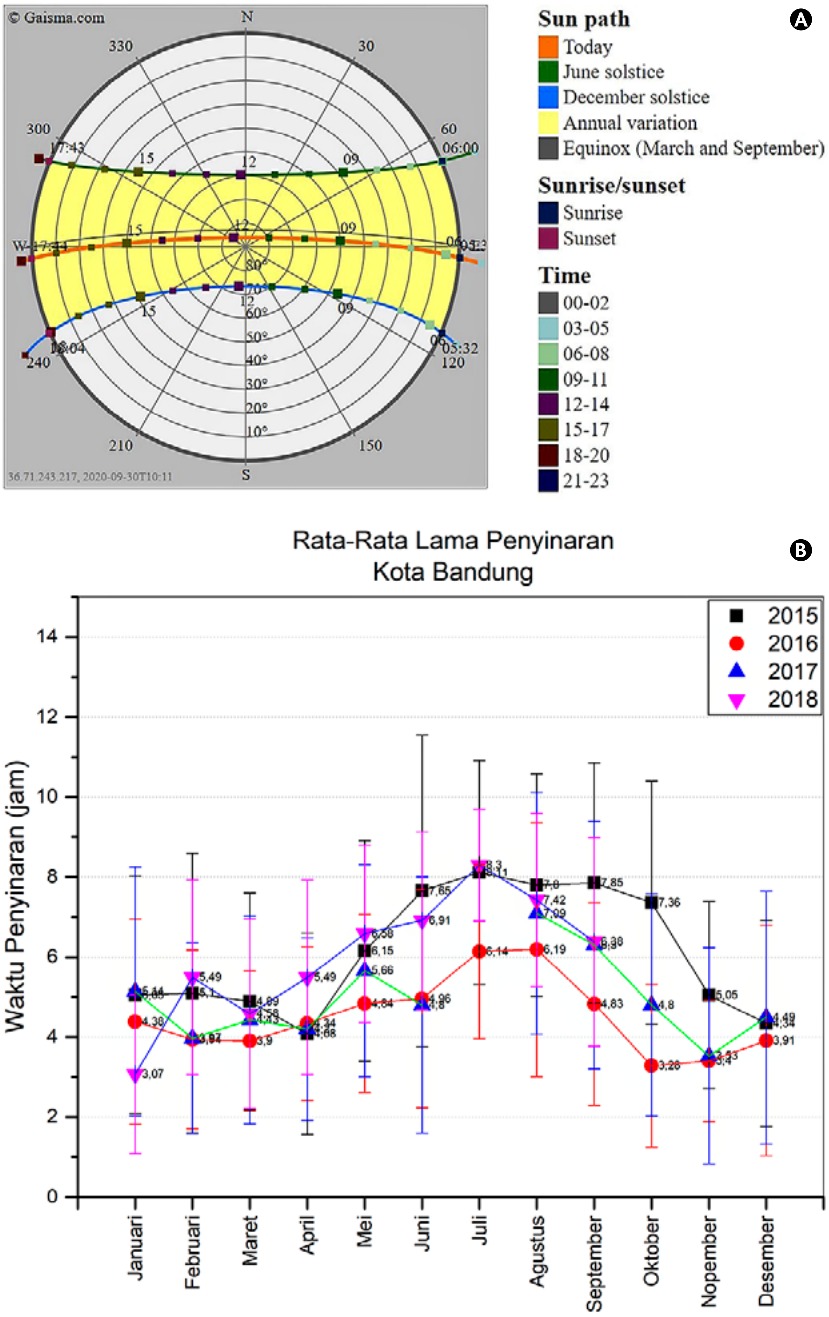


Figure 2. (a) Sun path diagram and (b) sunshine of Bandung

Source : (a) Gaisma (2020) and (b) Kusyanto et al. (2019)

east direction was obtained as the simulation input (see Table 1). This information had also been confirmed by using Meteorological, Climatological, and Geophysical Agency (BMKG) data. The difference in the mean temperature data was only 0.1 °C lower, compared to the BMKG data.

Table 1. Meteorological data

Time	T (°C)	Rh (%)	V (m/s)	Wind Direction (°)
12:00 AM	19.24	71	2.27	131.42
1:00 AM	18.74	72	2.44	124.99
2:00 AM	18.01	74	2.61	122.47
3:00 AM	17.64	75	2.69	121.33
4:00 AM	18.04	74	3.26	117.35
5:00 AM	17.92	74	3.42	110.56
6:00 AM	16.79	78	3.01	111.45
7:00 AM	16.51	80	2.88	110.32
8:00 AM	18.56	75	2.97	109.65
9:00 AM	21.08	70	2.62	107.74
10:00 AM	23.45	63	1.65	104.04
11:00 AM	25.28	58	0.51	78.69
12:00 PM	27.00	52	0.54	338.20
1:00 PM	28.57	48	0.85	69.44
2:00 PM	29.53	44	0.30	360.00
3:00 PM	30.00	42	0.42	315.00
4:00 PM	30.07	42	0.36	326.31
5:00 PM	29.84	43	0.00	180.00
6:00 PM	29.20	46	0.58	120.96
7:00 PM	28.44	47	1.25	118.61
8:00 PM	27.49	52	2.08	125.22
9:00 PM	25.35	61	2.26	135.00
10:00 PM	24.11	64	1.77	137.29
11:00 PM	23.13	68	1.63	137.49

Reference: meteoblue.com (Meteoblue, 2020)

Internal factor data

This study also used data from internal factors, such as the personal characteristics of students' parameters, which became the subject of the research. The characteristics that needed to be included in the BIO-met software on ENVI-met, were age, sex, height, weight, clothing level, and metabolic rate (see Table 2). As the subject of this research, the characteristics selection were also obtained from the reference of students, including,

Table 2. Internal factor input

Data Input	
Age	21 years old
Sex	Male
Height	164.3 cm
Weight	58.8 kg
Occupation	Student
Clothing	0.75 clo
Activity / Metabolic Rate	Standing 69.84 W.m^{-2} (1.2 met level)

1. **Age:** The age parameter used in this study was 21 years. This choice was due to the average age of students within the range of 18-25 years (Hulukati & Djibran, 2018).
2. **Sex:** The sex parameter also used in this study was the male gender. The actual thermal response tended to vary by gender, with this difference tending to decrease under the conditions of increased ambient temperature, and clothing insulation (Yin et al., 2020). Under certain conditions, the thermal sensation of women was lower, compared to men, resulting in this study usingmaleparameters (Wang et al., 2019).
3. **Height and weight:** The parameters of height and body weight obtained were 164.2 cm and 58.8 kg, respectively. They were selected based on the average weight and height, according to the age and sex groups (Muljati et al., 2016).
4. **Clothing insulation level:** The clothing level parameteralso used was 0.75 clo. This value was obtained, based on the assumption of clothes commonly used by students in Indonesia. The values were a combination of men's briefs (0.04), t-shirt (0.08), shoes (0.02), calf-length socks (0.03), long-sleeve flannel wear (0.34), and straight trousers-thick (0.24) (Parkinson & de Dear, 2017).
5. **Metabolic rate:** Also, the metabolic rate parameter used was 69.84 W.m^{-2} (1.2 met level). This value represented standing activity (Gonzalez, 1995), which was used as the minimum basic event. The assumption that there were other student activities, such as sports or other events, were interpreted to be higher than the minimum score.

Case Study

The research location was at the Universitas Kebangsaan in Bandung. The university is a development college from the Institut Teknologi Adityawarman (ITA), which was established on August 15, 1985. It had its own campus in the academic year 1992-1993, which is located at Terusan Halimun Street 37 (Pelajar Pejuang 45) Bandung, West Java, Indonesia (see Figure 3). Also, the campus building was located in the downtown area of Bandung, as it had been 28 years since its establishment.

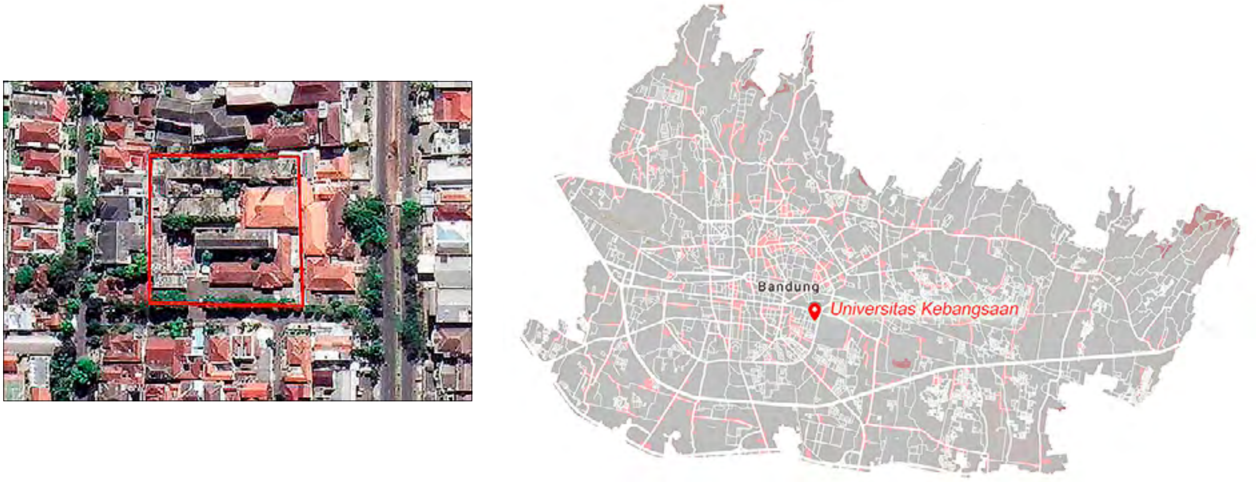


Figure 3. Location of case study in urban context of Bandung

One of the important premises of 2018-2028 their strategic plan, was to achieve academic excellence and distribution at every level of the structure, by integration through physical campus development. Campus development was also directed to become a "city campus", which had facilities and infrastructures in national and international competitions that were likely to still uphold the environment, religion, technology, socio-culture, and sustainability in the future. With this developmental plan, it was very important to evaluate the existing condition of the building, as input for future development.

Outdoor zone division

Due to the different characteristics of the outdoor area on this campus, the division of the external zone was necessary. This zoning was needed, in order to observe the specificity of the thermal comfort quality, from different areas. This division also facilitated the presentation and explanation of the data. Additionally, this division was also considered, based on differences in functions or specific characters in Table 3.

The outdoor zone was further divided into six, namely corridor 1, 2, 3 (COR1, COR2, COR3), canteen (CAN), court (COU), and parking (PAR) areas. The six

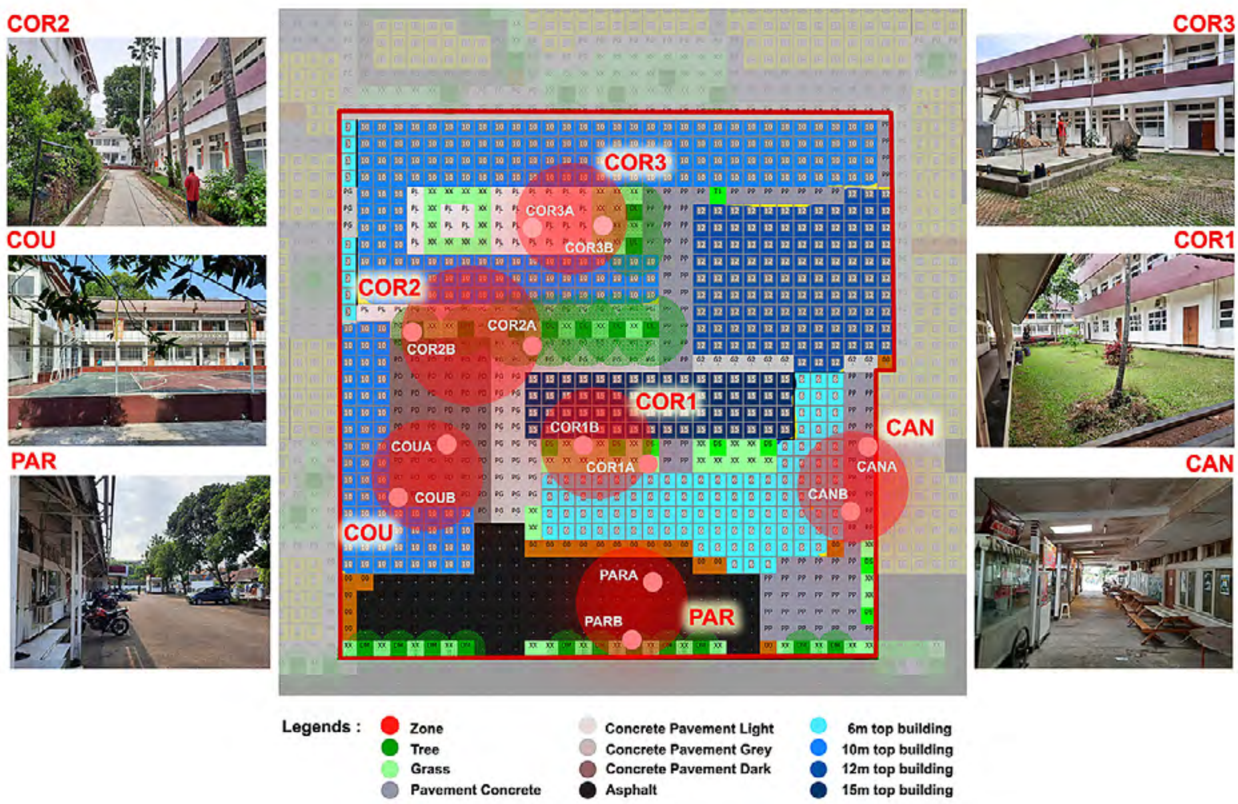


Figure 4. The outdoor zone division in the case study

sub-zones were divided, based on differences in physical characteristics, including location within the area, building orientation, vegetation ratio, surface material, and construction geometry adjacent to the outdoor zone (Figure 4 and Table 3). In Figure 4, these characteristics were shown in details, as the difference in building height, surface material, and vegetation area representing the division of the zones, were observed.

Furthermore, the six zones were further divided into 12 points. The division of the 12 sub-zones was carried out, due to each zone still having differences (Figure 4 and Table 3). This zonal divisions were expected to provide an in-depth description of each different character, in the campus outdoor environment. Further in the study, discussion and analysis were referred to this zoning.

The average thermal condition in the six different zonal division, provided an initial description of this study. In Table 4, it was observed that the average air and radiant temperatures, humidity, wind velocity,

Table 3. The outdoor zone division is based on different characteristics.

Zone	Sub Zone	Description	Building Orientation	Direct Radiation (time)	SVF	GnPR (%)	PLC (%)	PLCM	Spesific Characteristic
COR1	COR 1A	Corridor 1A	North - South	10-16	0.2	37%	5%	Grass and pavement	Corridor
	COR 1B	Corridor 1B	North - South	13-16	0.3	35%	0%	Grass	Corridor
COR2	COR 2A	Corridor 2A	North - South	08-13	0.3	27%	21%	Grass- Concrete Pavement	Under the tree and between building
	COR 2B	Corridor 2B	North - South	None	0.1	45%	23%	Concrete Pavement Light	Under the tree and near from building
COR3	COR 3A	Corridor 3A	North - South	09-16	0.3	0%	25%	Concrete Pavement Light	In the middle of court and between building
	COR 3B	Corridor 3B	North - South	13-16	0.2	29%	6%	Grass and Concrete Pavement Light	Between building and under the tree
CAN	CAN A	Canteen A	East - West	11-14	0.30	0%	25%	Concrete Pavement	Between building (In the middle of canteen)
	CAN B	Canteen B	East - West	10-12	0.20	1%	24%	Concrete Pavement	Circulation in between building
COU	COUA	Court A	East - West	09 - 15	0.5	0%	25%	Concrete	In the middle of basketball court
	COUB	Court B	East – West	08 – 12	0.2	0%	25%	Concrete	Near building
PAR	PARA	Parking A	East - West	08-16	0.5	0%	25%	Asphalt	In the middle of parking area
	PARB	Parking B	East - West	None	0.3	25%	13%	Asphalt	Under the Tree
SVF		Sky View Factor							
GnPR		Green Plot Ratio							
PLC		Pavement Land Cover							
PLCM		Pavement Land Cover Material							

Reference: author's own work

Table 4. The average thermal condition in different zone division

Zone	Sub Zone	The average of thermal conditions (6 am - 5 pm)				
		Air Temperature (°C)	Humidity (%)	Wind Velocity (m/s)	Mean Radiant Temperature (°C)	PMV
COR1	COR 1A	24°C	59%	0,9 m/s	41°C	1,2
	COR 1B	24°C	60%	1,1 m/s	36°C	0,8
COR2	COR 2A	24°C	58%	0,37 m/s	39°C	1,2
	COR 2B	25°C	58%	0,41 m/s	30°C	0,8
COR3	COR 3A	24°C	59%	0,58 m/s	44°C	1,4
	COR 3B	24°C	59%	0,73 m/s	41°C	1,2
CAN	CAN A	25°C	56%	1 m/s	35°C	1
	CAN B	25°C	57%	0,1 m/s	33°C	1
COU	COUA	25°C	57%	0,7 m/s	42°C	1,4
	COUB	25°C	56%	0 m/s	38°C	1,3
PAR	PARA	26°C	54%	1 m/s	48°C	2
	PARB	24°C	58%	1 m/s	31°C	0,7

and PMV were at 24-26°C & 31-48°C, 54-60%, 0-1.1 m/s, and 0.7-2 (neutral-warm), respectively. This data derivative were also to be discussed in more depth, within this study.

Results and Discussion

This chapter discussed the results of the research, which were related to the data interpretation, obtained from the simulation outcomes. This data was analyzed using ANOVA and regression approaches, in order to see the significance of the problem. PMV maps from the case studies were also presented, in order to help interpret the results of the data.

The ANOVA and line diagram (Figure 5 and Figure 6) showed the linear change in thermal comfort at 08:00 am – 04:00 pm. Therefore, the discussion of PMV maps focused on the phenomena that occurred per two hour unit time.

The average PMV value at the Universitas Kebangsaan building complex was on the thermal sensation index, from slightly cool until hot. Changes in the average PMV value were linear with changes in air temperature and humidity, with wind speeds having quite different data trends. When the wind speed increases, the PMV value and the temperature also increased, during the day. Also, the average wind speed at the research area was 0.68 m/s. This value was in the slightly calm and low category, for the outdoor space scale (Stewart, 2004). Moreover, the wind speed does not have a significant effect on PMV in the area (Figure 6). The PMV value in the study area was also more influenced by air temperature and relative humidity (Figure 6). These results further indicated that, in order to establish outdoor thermal comfort in the Universitas Kebangsaan area, the various aspects that controls the air temperature and

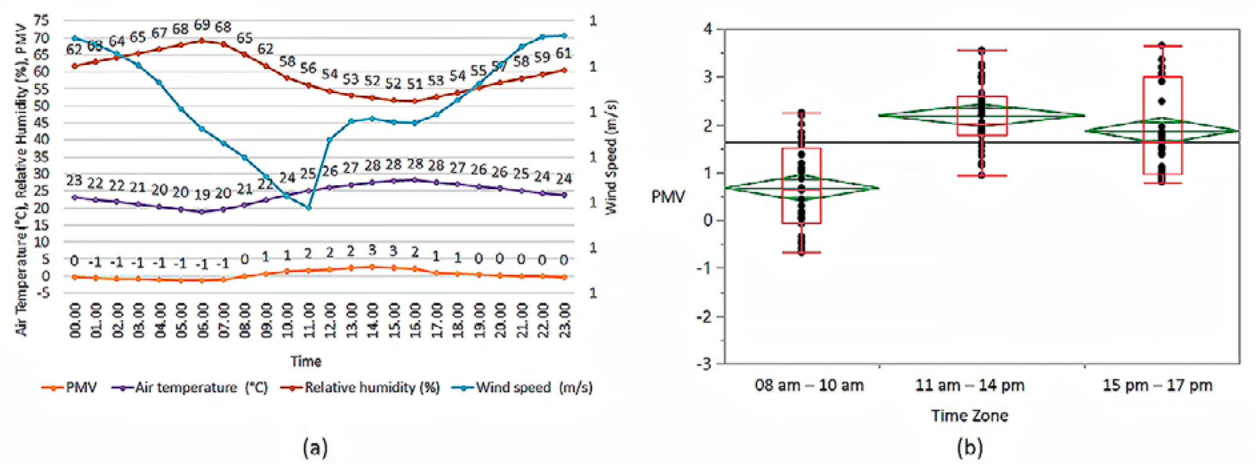
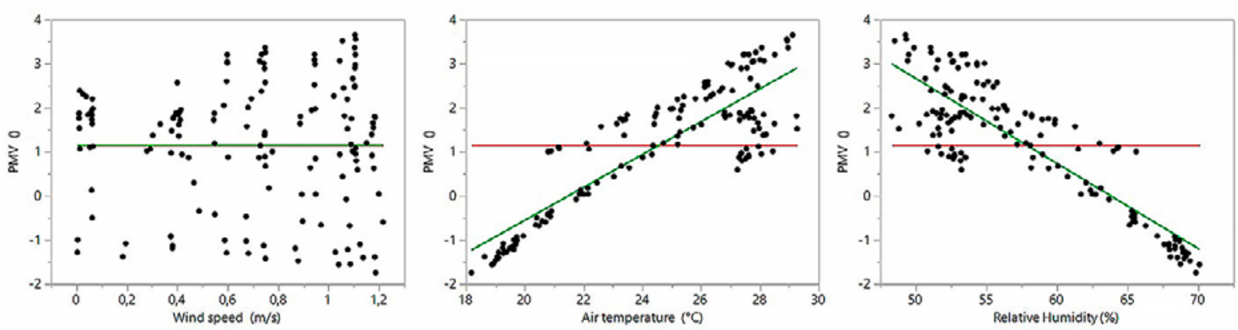


Figure 5. (a) average thermal condition data in 24 hours; (b) average thermal conditions in 3 time zones



Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	1,1460349	0,245926	4,66	<,0001*
Wind speed (m/s)	0,0072677	0,312428	0,02	0,9815
Air Temperature (°C)	0,3725089	0,018676	19,95	**<,0001***
Relative Humidity (%)	-0,192881	0,008935	-21,59	**<,0001***

Figure 6. Regression value between PMV and other thermal factors

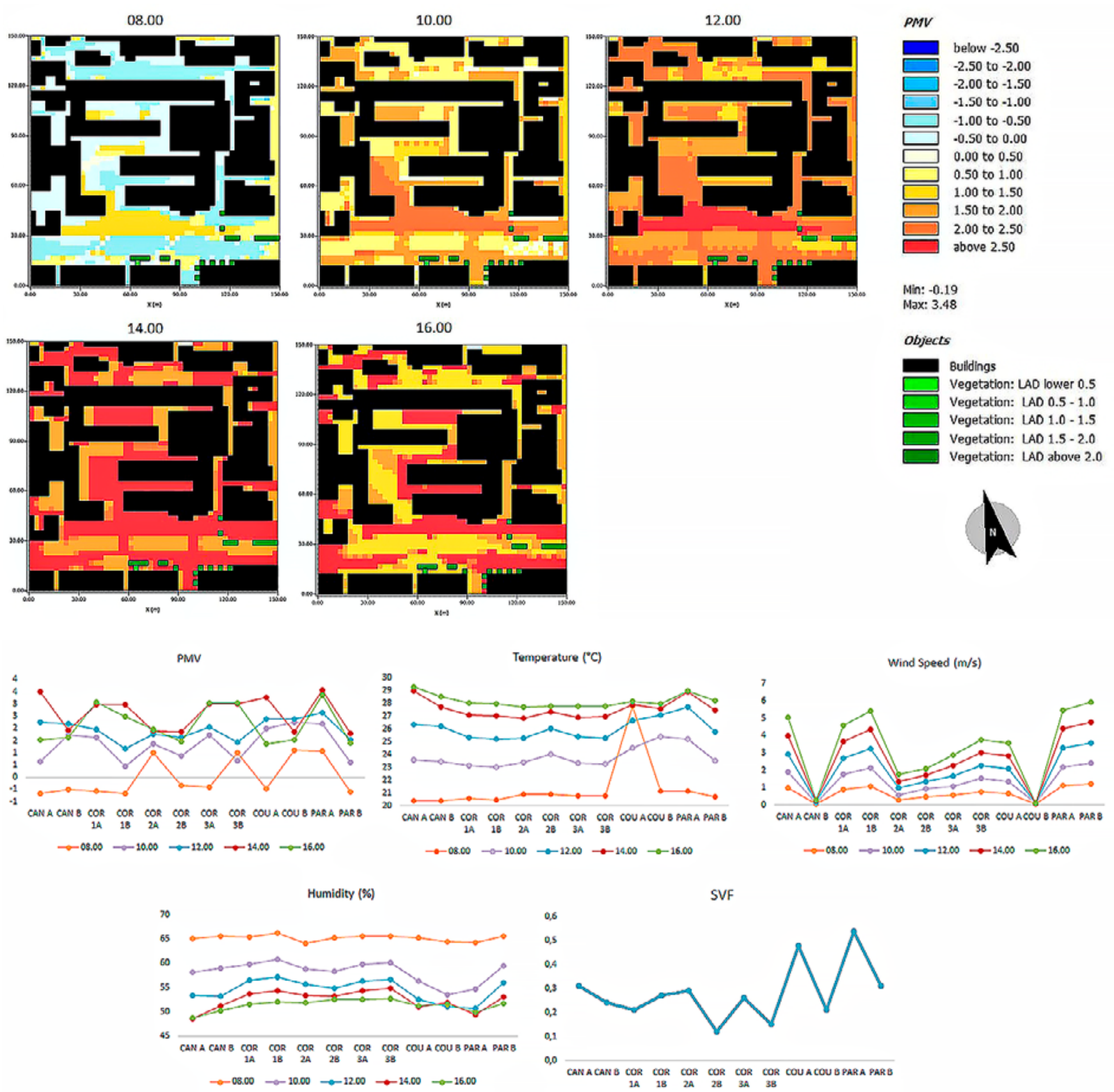


Figure 7 . Simulation result for 5 different time (08.00,10.00,12.00,14.00,16.00)

relative humidity of the campus environment, were considered.

The PMV maps in the morning showed almost the entire area in a comfortable condition, which was indicated by a light blue colouration (Figure 7). The Anova analysis (Figure 5) also showed the range of PMV values in the morning at -0.68–2.24, with a slightly cool–warm thermal sensation. This condition was due to the position of the sun irradiation in the morning, which was not right above the building. These conditions made a lot of outdoor space shaded, by the surrounding buildings. However, areas with less shadow exposed to direct sunlight, had a higher PMV value. The higher PMV value was further shown with yellow colour, or at PAR A, COU B, and COR 2A areas. Generally, areas with less of shadow had large open space.

Towards the time of day at 10:00 am, the outdoor conditions were getting more uncomfortable, which was indicated by light–dark yellow, with a value of 0.5–2.5 (Figure 7). This condition reduced the activities in the outdoor space. The Anova analysis also showed a thermal sensation that was slightly cool–hot during the day, with the PMV value ranging from 0.93–3.55 (Figure 5). This condition was due to the changing position of the sun, as it also reduced the shadow area. In the middle of the day, when the sun's position was at 90° or right on the top of the building, the shadow of the outdoor area became less. These conditions allowed the outdoor area become more uncomfortable, as the higher PMV value ranged from 1.50–2.50, with a slightly warm–hot thermal sensation. The most uncomfortable conditions were at 02:00 pm–03:00 pm, with a PMV index value of 3, which was also linear with the increasing air temperature, at 28°C.

The thermal maps in the afternoon further showed a lower PMV value, than during the day (Figure 7). The outdoor area having lower PMV was close to buildings and trees. These conditions made the outdoor area become more shading, although there was still a PMV value above 2.5 in some areas. The thermal sensation felt in the afternoon was slightly cool–hot, with the PMV value ranging from 0.79–3.64. The cause of this condition was due to the fact that the average temperature in the afternoon was still high, similarly as during the day. The higher air temperature was also caused by the building density and the type of pavement material in the campus area. Those conditions made solar radiation to be absorbed more by the material, as much rays were distributed in the area. The use of surface materials should also consider its sustainability in terms of circulation, water infiltration, maintenance, and also thermal comfort (Ramadhan et al., 2018). The use of surface materials that do not respond to heat was very important to the achievement of outdoor thermal comfort. This also had an impact on the active social interactions at the area, which was the case of students' relationships.

In addition to surface materials, the low wind distribution in the area also made radiation to be released slowly. According to Syafrina, building density blocked the wind flow, and caused heat to be trapped longer in an area (Syafrina et al., 2020). Therefore, it was necessary to consider building density and preparation of open space planning, in order to make a better wind distribution in the campus area.

The most comfortable sub zone was at PAR B, with the average PMV value of 0.65. This sub zone had a higher shadow intensity throughout the day, which resulted in the lower radiation received in this area.

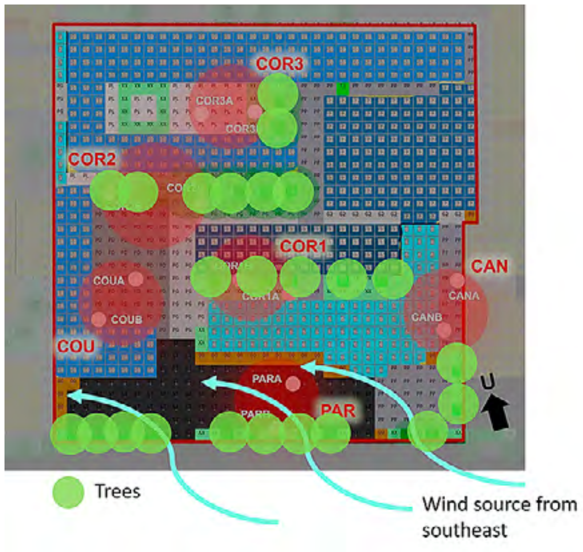


Figure 8. wind direction illustration

The shadow in this sub zone resulted from wide canopy plantations, as the previous research stated that trees and vegetation cooled the air by shade, and reduced the amount of sunlight hitting the ground (EPA, 2020). The area having large open space at the front of the campus, made this zone connected directly to the wind, which occurred from the Southeast. Those conditions were observed to have affected the decreased air temperature (Figure 8). According to a study conducted by Bajsanski et al. (2019), the mitigation overheatingof horizontal and vertical surfaces reduced up to 7%, through the disposition of different trees.

The most uncomfortable sub zone was at PAR A, with the average PMV value at 1.74. This area became the least of shadowing, throughout the day. The asphalt pavement characteristics in this area had relatively high heat capacity, automatically affecting the thermal environment, as an effective heat absorbent and producer (Halliday et al., 2007). Also, Figure 9

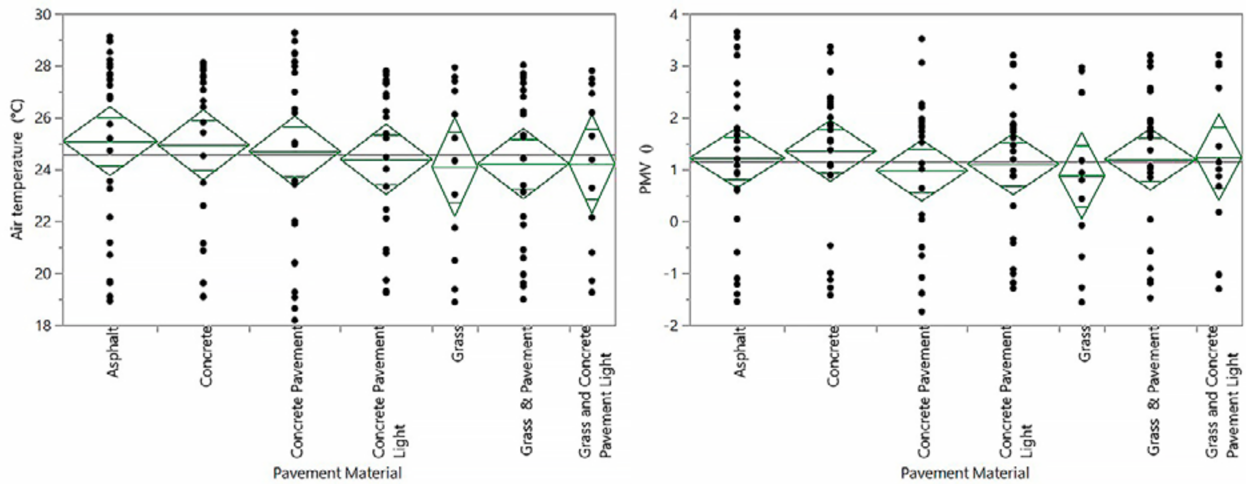


Figure 9. (a) Anova diagram of pavement material due to air temperature and (b)PMV

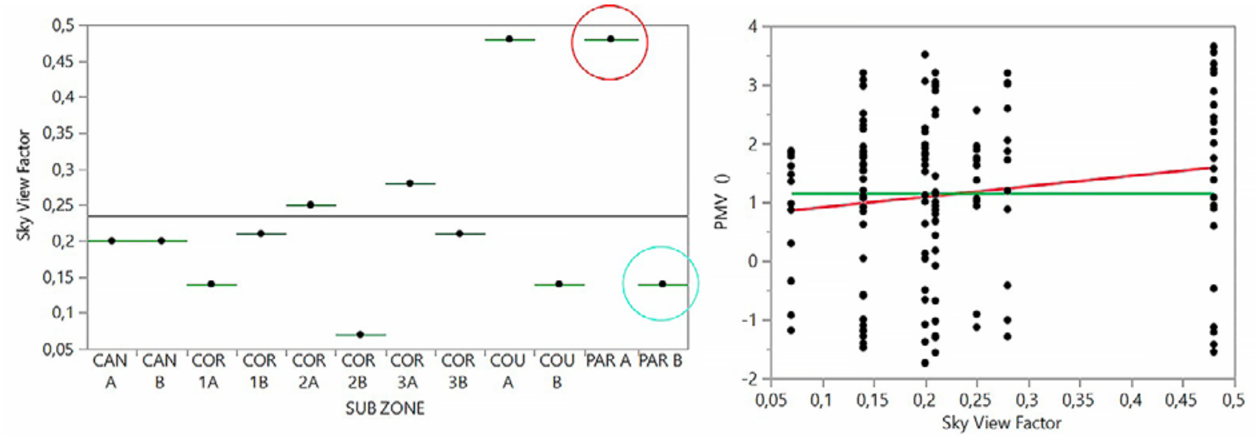


Figure 10. (a) Average of Sky View Factor in Sub Zone; (b) regression value between Sky View Factor and PMV

showed that the differences in character of the land cover material, had different effects on thermal condition.

The Anova diagram in Figure 9 showed that the areas using asphalt and concrete as land cover, had higher temperature than others. However, the lower temperature area used grass material as land cover. The temperature difference also affected PMV, the higher conditions caused greater Predicted Mean Vote.

The two sub zones located in the same area showed that differences in physical characteristics affected thermal conditions, in that zone. The shading factor in the outdoor space further showed that higher SVF value resulted in greater PMV parameter, while also allowing the area become more uncomfortable, due to the fact that it received large solar radiation. Also, the higher SVF value closer to 1 indicated the wider open space, which enabled the greater solar radiation received in the area (Figure 10).

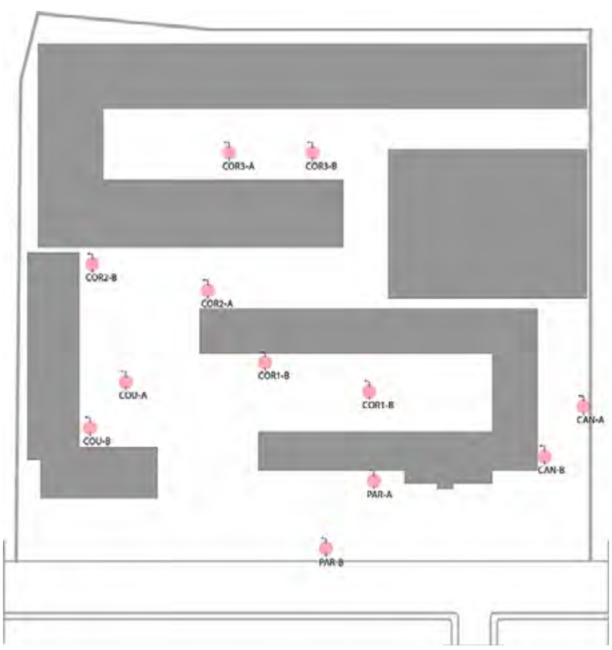


Figure 11. Twelve points location in case study (six zones)

Further discussion was developed in more depth, in order to observe the characteristics and differences that affected thermal comfort. The following was a discussion of the 6 zones (12 points), based on Figure 11. Based on the range of PMV conditions from 6 zones (12 points), results were observed to vary between 08.00-16.00. This difference further showed that each zone had a different thermal response.

Corridor 1 Zone (COR1)

Zone 1 was divided into two corridors (COR1-A and COR1-B), with a park between the two buildings. Each of these corridors was bounded by buildings and parks, with different orientations. COR1-A had the north and south bordering the garden and class buildings, respectively. However, the COR1-B borders the park and buildings to the south and north (Figure 11 and 12), respectively. This zone further extended from the East-West direction, with the east and west being bordered by a closed corridor and open space, respectively.

The corridors in this zone had a high occupancy rate, with classrooms and libraries around them. Also, along this corridor, some seats caused students to gather, discuss, or carry out assignments. This corridor had an area smaller than the width of the others, and was the greenest, due to havingquite a lot of vegetation and grass.

In the simulation, COR1-B and COR1-A received direct radiation from sunlight for 6 and 3 hrs, from 10:00–16:00 & 13.00–16.00 durations, respectively. Also, the highest heat events at COR1-A & COR1-B occurred at 15.00 & 14.00, with PMV values of +3 and, +2.5, respectively. Judging from the characteristics of these two corridors, COR1-B had a longer duration of sun exposure than COR1-A.

The difference in radiation reception was because COR1-A had a smaller SVF than COR1-B, with a value of 0.2. Previous research further stated that a higher SVF value indicated the reduced shade density of

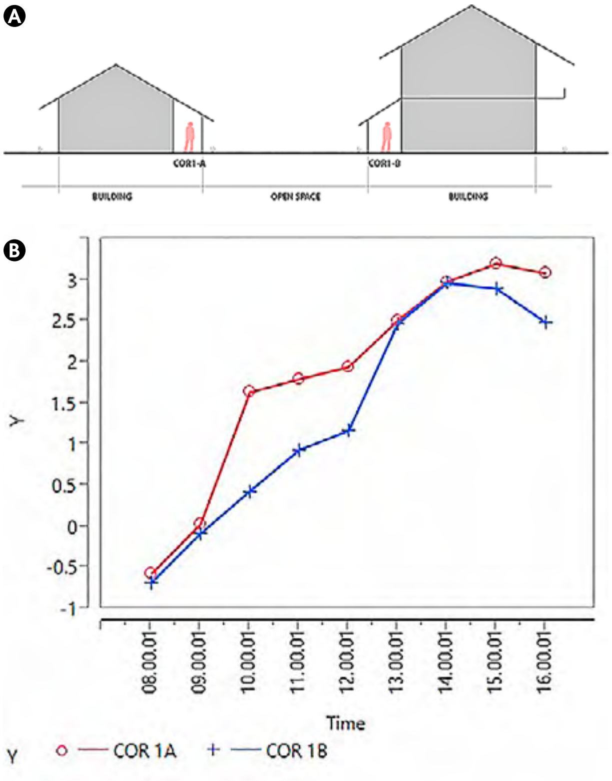


Figure 12. (a) Section of COR1A and COR1B (b) Comparison of PMV at 2 points location in the COR1 zone

an area, as radiation reception was high, therefore providing a higher heat effect (Dirksen et al., 2019). However, the Predicted Mean Vote difference graph showed that COR1-A had a higher PMV value than COR1-B.

These results indicated that the shading character shown by the SVF was also influenced by other physical character factors, such as the height of the surrounding buildings, presence of vegetation, and the type of land cover used. COR1-A had grass and paved surfaces, with the height of the surrounding buildings consisting of 1 floor (± 3 m). However, the land cover type of COR1-B consisted of grass, with the height of the surrounding buildings having 2 floors (± 6 m).

The taller the building with sufficient vegetation, the lower the temperature around the area (Paramita & Fukuda, 2013). Lower temperatures also increasingly affected the thermal comfort of an area, with the type of land cover similarly influencing radiation absorption. Pavement cover also absorbed more radiation than those of the non-pavement. The radiation that was absorbed more on a surface, emitted a higher temperature (Olgyay et al., 2015).

The higher radiation absorption was observed from the Mean Radiant Temperature (MRT) value. The MRT is the radiation from the surface of a place or the human body, as it is also an essential factor in thermal comfort (Olgyay et al., 2015). COR1-A & COR1-B had a higher MRT value of 41 & 36˚C, respectively. The difference in the MRT value from the simulation results also reinforced that differences in physical characteristics, such as building height and land cover caused distinguished thermal comfort in an area.

Corridor 2 zone (COR2)

COR2 was double corridors (COR2-A and COR2-B) between two buildings and the field. This corridor extended in an East-West direction, where the areas to the east and west were bordered by opened and closed corridors with buildings, respectively. COR2-A was located in a circulation path with concrete pavement, between two buildings. However, COR2-B was located close to trees, between buildings, and open fields, which had large pavement covers (Figure 11 and 13). The corridors in this zone were circulation areas and campus sports fields, which were often used for student activities.

In the simulation, these two corridors received direct radiation from the sun for 4 hrs, from 10:00–14:00. The highest heat events at COR2-A & COR2-B further occurred at 15.00 and 13.00, with a PMV value of approximately +1.5 & +2.5, respectively.

The difference in PMV also showed that COR2-A had a higher PMV value than COR2-B (Figure 12). The difference in PMV was due to the fact that COR2-A had a higher SVF value than COR2-B, at 0.3. The characteristics of COR2-B, which were the closeness and highness in the percentage of vegetation and trees,

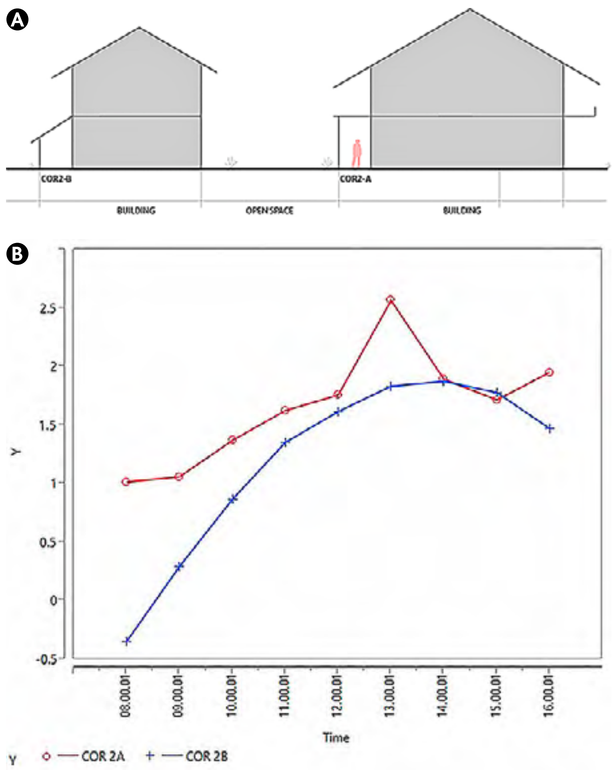


Figure 13. (a) Section of COR2A and COR2B (b) Comparison of PMV at 2 points location in the COR2 zone

made this area possess a lower PMV than COR2-A. As explained in previous research, the character of land cover and vegetation influenced the radiation received in an area (Olgyay et al., 2015). Besides that, the area of COR2-B bordering the open field, made the wind received higher by 0.41 m/s. The movement of the wind functioned in the transfer of heat from an area or material to another (Gunawardena et al., 2017; Wonorahardjo, 2012). For this reason, the openness of an area was observed to flow smoothly (Syafrina, 2020).

Corridor 3 zone (COR3)

Zone 3 was two corridors (COR3-A and COR3-B) located in the northern area of the campus site. COR3-A was observed to border open spaces to the north, and buildings to the south. However, COR3-B bordered buildings to the north, and parks to the south. The east and west sides of these two corridors were bordered by open spaces (Figure 11 and 14). Also, COR3-A was surrounded by a 2-story building, while COR3-B was located under a tree.

COR3-A and COR3-B received sunlight radiation for 7 and 3 hrs, from 9.00–16.00 & 13.00–16.00, respectively. The duration of this exposure was almost the same as zone 1, where the corridor bordering the garden in the south obtained less exposure time. For SVF, COR3-A & COR3-B had values of 0.3 and 0.2, respectively.

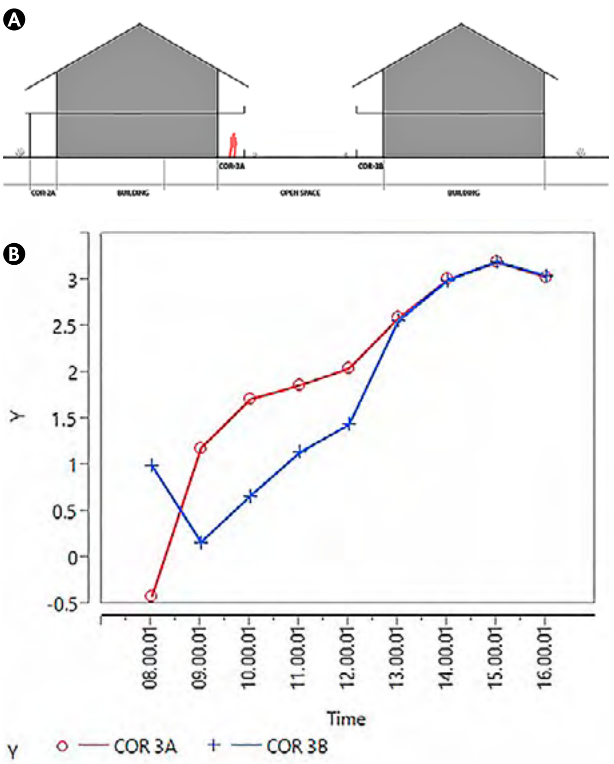


Figure 14. (a) Section of COR3A and COR3B (b) Comparison of PMV at 2 points location in the COR3 zone

The simulation results further showed that when the simulating process started at 8:00 AM, COR3-A and COR3-B had PMV values of +0.5 and +1, respectively. Afterwards, COR3-B experienced a decrease in PMV at 9.00, which then increased simultaneously with the value of COR3-A till 13.00, with the second Predicting Mean Vote parameter reaching +2.5. After 11.00 PM, the PMV value then started increasing for both corridors, until it reached the hot peak (PMV +3) at 15.00. The simulation results showed that COR3-B had the same PMV value as COR3-A, when both received sunlight at 13.00 to 16.00. Also, SVF had a significant role in the PMV value, as this condition was the opposite of the simulation results in zone 1. However, it also had similarities in terms of other physical characteristics, such as land cover. More extensive pavement cover and less vegetation resulted in the lower thermal comfort of an area.

Canteen zone (CAN)

The canteen zone was located to the east of the site. Within this zone, two points were simulated (CAN-A and CAN-B), as shown in Figure 15.

The simulation point for CAN-A was in the middle area of the canteen zone, while CAN-B was located in the circulation between the buildings. The length of irradiations that occurred on CAN-A and CAN-B

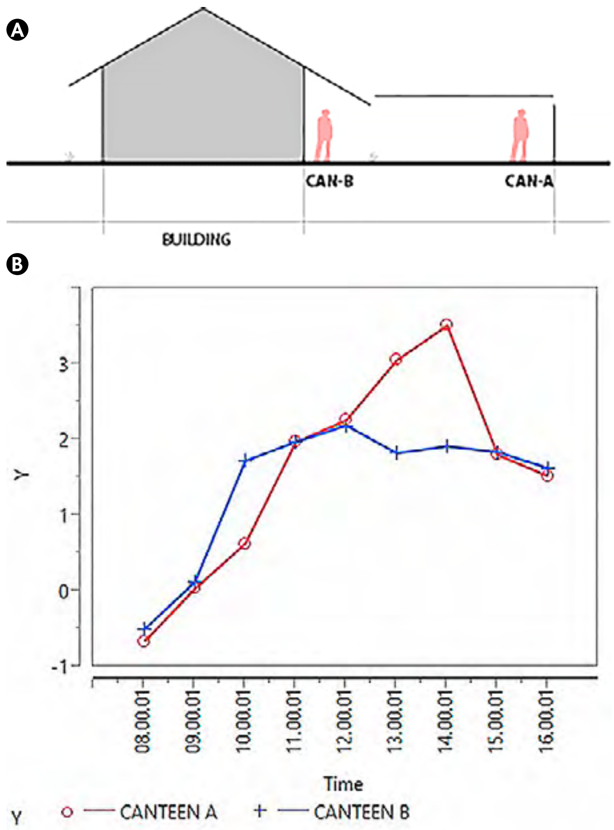


Figure 15. Section of CAN-A and CAN-B (b) Comparison of PMV at 2 points location in the CAN zone

was 3 and 2 hrs, starting from 11.00–14.00 & 10.00–12.00, respectively. Also, the surfaces of the two corridors were concrete pavement, as both further had SVF values of 20%.

The simulation results then showed that CAN-A had a very high PMV value during the day, than CAN-B. This condition occurred at 14.00, where CAN-A received solar radiation for 3 hrs. When compared with CAN-B, the PMV value at 14.00 was approximately +1.7. The highest PMV value for CAN-B further occurred at 12.30, with a value of +2. The graph of the difference in PMV values also showed that CAN B had a higher PMV in the morning than CAN A, which was around 08.00-10.00 hrs. This condition was due to the duration of exposure experienced by an area. The position of CAN-B was directly exposed to solar radiation, while CAN-A received a shadow from the building, to the east. During the day to evening, the CAN-B area became lower than CAN-A, due to the fact that the sun's position had changed. This resulted in the CAN-B area obtaining more shadow from the building next to it (Figure 15). CAN-A was located at the intersection of 2 corridors, and was quite far from the building, with the area having a higher wind speed. However, wind speed had no significant effect in this area, as the same average PMV value on both corridors at 1, was observed.

Court zone (COU)

The field zone was an open area used for sports fields, as there were two points of simulation carried out in this zone, namely COU-A and COU-B. COU-A and COU-B were located in the middle area of the field, and between the building with the open space, respectively (Figure 11 and 16).

Both simulation points had a concrete base surface, and do not have vegetation. This surface influenced the temperature conditions in the surrounding environment, as it increased the PMV value. The durations of radiation that occurred in COU-A and COU-B were 6 & 4 hrs, starting at 9.00–15.00 & 08.00–12.00, respectively. Also, the SVF values for both COU-A and COU-B were 0.5 & 0.2, respectively.

From the simulation results, COU-A and COU-B had the highest PMV values at 15.00 & 12.00, with more than +3 and +2.5, respectively. When viewed from the irradiation time, each simulation point reached the highest peak of PMV at the end of the simulating process. The SVF also had a significant effect on the PMV value, with COU-A at 0.5, making it a hot simulation point. Also, a considerable SVF made the Mean Radiant Temperature (MRT) value higher. A higher MRT also caused the PMV value to be greater, especially during the day at COU-A point. In the

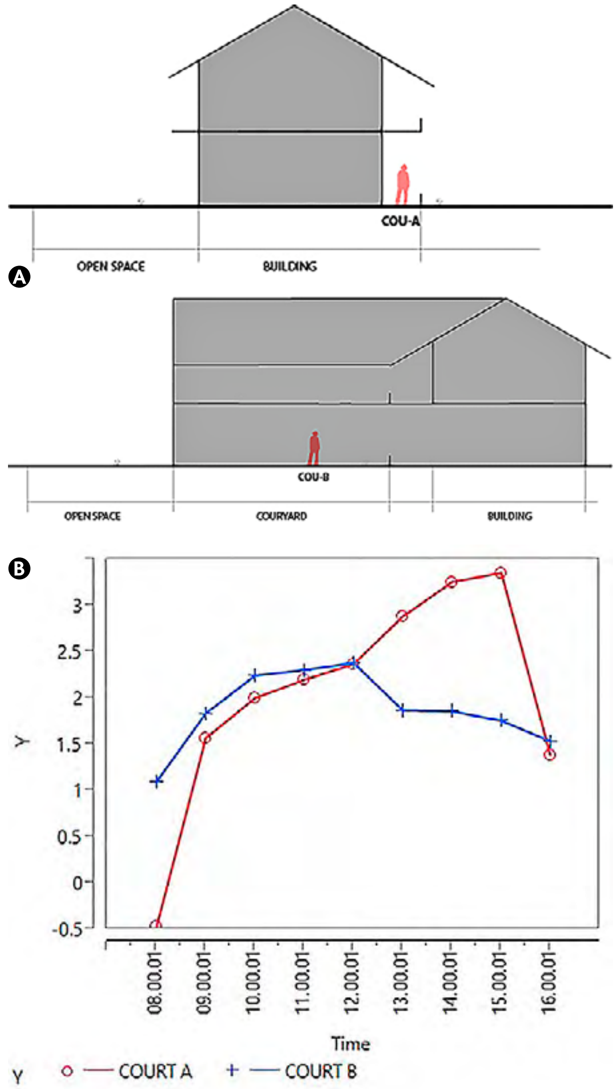


Figure 16. (a) Section of COU-A and COU-B (b) Comparison of PMV at 2 points location in the COU zone

morning, COU-A was still lower than COU B, due to the fact that the area (COU-A) received shadows on a 3-storey building. This was also due to the fact that solar radiation had not been received much (Figure 8). Besides that, the COU-A was located in the opened field, making this area receive higher winds than COU-B, which was located very close to the building, and obstructed from the direction of the wind movement, flowing from the Southeast. This condition was the same as the previous five zones, which showed that the density of an area influenced wind movement. Although in some zones, the wind speed has no significant effect. This condition also indicated that wind was not very effective in increasing thermal comfort, due to its small velocity value. Therefore, even though improvements need to be made to build a better wind environment as mentioned by Liu et al. (2019), it was useless when the initial velocity occurred to be too small.

Parking zone (PAR)

The parking zone was located at the south of the site, which was the entrance area used for assembling vehicles. This zone consisted of two simulation points, namely PAR-A and PAR-B. The PAR-A zone was located in the middle of the parking area. However, PAR-B was located in the parking area and under a tree.

PAR-A was located in the middle of the parking area without any roof covering it, as the SVF value obtained was 0.5, while PAR-B was at 0.3. PAR-A also has extended irradiation of 8 hrs from 8.00–16.00, while PAR-B does not get sunlight in one day. Also, PAR-A and PAR-B consisted of asphalt, for surface materials.

The simulation parameters differed quite a lot between PAR-A and PAR-B, resulting in the PMV values being different between the two. PAR-A was also observed to have a higher PMV value than PAR-B. The highest PMV values that occurred at PAR-A and PAR-B wete more than +3 and +1.5, at 15.00 and 13.00, respectively. Judging from the existing parameters, the size of the SVF and the length of exposure, had a significant influence on the value of PMV in PAR-A. Also, it was the same with some of the zones previously discussed, which stated that the presence of vegetation had a significant effect on differences, in thermal comfort. Trees produced a significant increase in human thermal comfort, due to the fact that they reduced and absorbed solar radiations, which were used to reap water on the leaves (Oke, 1987; Zheng et al., 2018). As observed in Table 4, PMV at the two points had a very significant difference, due to the radiation received also being different.

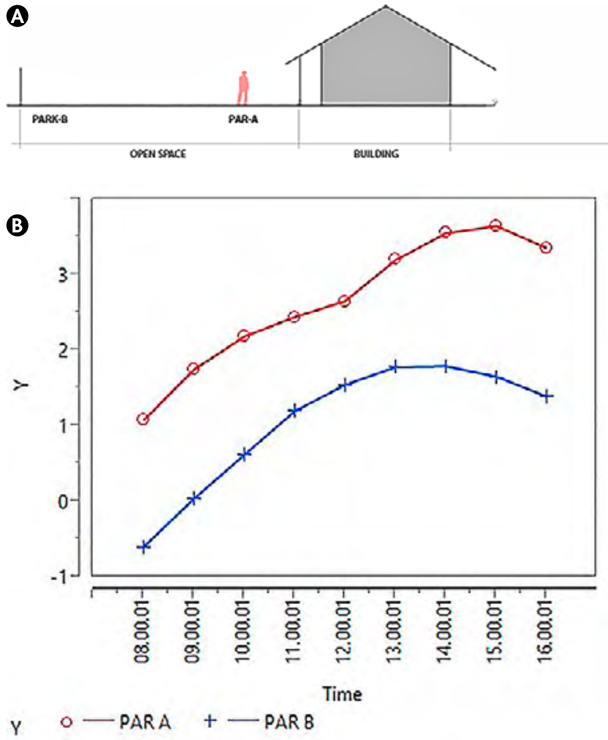


Figure 17. Section of PAR-A and PAR-B (b) Comparison of PMV at 2 points location in the PAR zone

Conclusion

Due to the thermal comfort analysis in this study, future current conditions and design potentials were identified. This evaluation study showed that the outdoor zone in the Universitas Kebangsaan, which was located in Bandung urban area, had low thermal comfort value, due to several factors. It also had different thermal comfort conditions, due to differences in physical characteristics in each zone. Some of these factors were:

1. The SVF as indicators of the shading factor should be supported by the presence of vegetation, and the use of pavement material.
2. Although the wind speed factor does not really affect the thermal comfort in the outdoor space, the interconnection between open spaces should make breeze distribution in the area better.

This study also offered direction for campus planning, in order to maintain the optimal capacity of the natural environment, such as:

1. Strategizing to create a better shadowing factor in the outer space, supported by controlling the use of pavement materials.
2. Controlling the density of campus buildings, by making open spaces more permeable for better wind distribution in the area.

The outdoor thermal considerations in this study were also expected to create a more comfortable environment, especially for educational buildings in urban areas, as it is supposed to be fully utilized, while reducing the influence of heat into the building.

Acknowledgments

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Measuring Neighbourhood Hardships and Neighbourhood Change between 2010-2015 in Suburban Neighbourhoods of Buffalo Metropolitan Area, New York

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Abstract

Neighbourhoods in urban and suburban areas experienced changes in terms of physical, social, economic, and demographics. Neighbourhood Hardship Index (NHI) had been used to measure neighbourhood socio-economic condition, using various census variables. Suburban neighbourhoods which underwent a change lead to stratification into striving outer suburbs and declining inner suburbs. The context of this study was suburban neighbourhoods in Buffalo Metropolitan Area (BMA), New York. This paper aimed at highlighting spatial variability of neighbourhood change in inner- and outer-suburban neighbourhoods of BMA between 2010-2015. This study examined factors that significantly contribute to neighbourhood change. Also, this study examined whether there a difference in the change of neighbourhood hardship index between inner- and outer-suburban neighbourhoods. Composite NHI was developed from economic, demographic, and housing variables. Neighbourhood change was measured by comparing the composite NHI 2010 with that of 2015. The findings depicted a variation of change in hardships index across suburban neighbourhoods. Neighbourhoods with higher hardship index were primarily located in inner suburbs. Policy implications call for concerted efforts to tackle the decline in the economy, education, demography to promote equity across neighbourhoods in suburban areas.

Keywords: suburban neighbourhood; neighbourhood change; suburban stratification; Neighbourhood Hardship Index

Introduction

Suburban Neighbourhoods Transformation

In the traditional metropolitan model, metropolitan areas consisted of an urban core and suburban ring. Distinctive socio-economic characteristics of neighbourhoods in urban and suburban areas lead to a dichotomy of urban and suburban neighbourhoods. Urban core or inner cities in the United States metropolitan areas are known for having distinctive differences with its suburbs in terms of physical, social, economic, and demographics aspects. Urban and suburban neighbourhoods experienced changes in terms of physical, social, economic, and demographics. As neighbourhoods changed, there was spatial variability of changes that occurs in urban and its surrounding suburban areas.

In recent discussions about the contemporary metropolitan model, the dichotomy of urban and suburban was criticized (Hanlon, 2006), suburban neighbourhood have diversified and became more heterogeneous (Hanlon et al., 2010). Suburban neigh-

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bourhoods were also becoming heterogeneous and stratified due to the recent growth and decline of suburban neighbourhoods (Hanlon & Vicino, 2019). Thus, the dichotomy of urban and suburban no longer holds true. Recent metropolitan development is beyond the urban-suburban dichotomy (Tzaninis & Boterman, 2018). Suburban areas in the U.S. metropolitan areas are no longer monolith (Orfield, 2002). The growth and decline of suburban neighbourhoods create different trajectories among suburban neighbourhoods. Some suburban neighbourhoods thrive, especially the affluent outer-suburban neighbourhoods, while some other suburban neighbourhoods decline, mostly the older inner-suburban neighbourhoods. Suburban neighbourhoods underwent a change, which leads to stratification into declining inner suburbs and striving outer suburbs.

With the transformation and stratification of suburban neighbourhoods, another issue pertinent to suburban neighbourhood change in The United States is the discussion about suburban decline. Since America is a suburban nation with a majority of the population lives in the suburbs, the suburban decline is the next American urban crisis following the inner-city crisis. The fact is since 2000, approximately 80% of Americans living in metropolitan areas, and 40% of suburban neighbourhoods are classified as "at-risk" (Orfield, 2002). Thus, this issue of suburban decline will have an impact on approximately 32% of the population in the nation, which is a very large population. The suburban decline is an imminent crisis face by American metropolitan areas after the inner city urban crisis (Lucy & Phillips, 2000b). This suburban decline phenomenon had been investigated by urban scholars since early 2000 and gain more attention since then.

The trend of suburban decline is marked by its total population decline, out-migration from declining suburban neighbourhoods, and increasing poverty in suburban neighbourhoods. Inner-suburban population declines partly because their affluent inhabitants have left to outer-suburban or exurban neighbourhoods. Their motivation to move is related to their pursuance of a better job, housing, opportunities, public services, and neighbourhood conditions in the outer suburban neighbourhoods. There is an increasing poverty level in inner-suburban areas due to the out-migration of the middle-income class pursuing more opportunities in outer-suburbs and in-migration of the low-income population to inner-suburbs from the inner-city. This causes a dwindling tax base and an increasing poverty level. This pattern is prominent, especially in inner-ring suburban areas which share a border with the inner city.

Inner suburban neighbourhoods' decline is signaled by an increasing percentage of the population living in poverty. The suburbanization of low-income people from the inner city to suburban areas also increases poverty in suburban neighborhoods; this is recorded in the period of 1990-2000 (Berube et al., 2005). Suburban poverty is a centrifugal spin outward of poverty from the inner city to suburban neighbourhoods, especially inner suburban neighbourhoods. This triggers the decline of the inner-ring suburbs (Hanlon, 2010). The trend of growing suburban poverty also occurs in many metropolitan suburbs in the U.S. (Lucy & Phillips, 2000a, 2000b, 2006).

Some suburban neighbourhoods experience a decline in relative income and dwindling tax-base to finance infrastructures and public services. The income distribution across U.S. metropolitan areas has shifted. The suburban areas, which were originally heralded as thriving, currently experience a decline in relative income. There is a trend of inter-suburban income disparities. From the sample of more than 2,500 suburban neighbourhoods in 35 metropolitan areas, half of the suburban areas had income below that of metropolitan level during the period of 1990-2000 (Lucy & Phillips, 2006). Suburban municipalities are often facing a downward spiral for not being able to sustain a sufficient level of public services due to a lack of a tax base (Hanlon, 2010).

In addition to the suburban neighbourhood decline issue, there is a racial composition shift that accompanied the process of inner-suburban decline. The out-migration from the inner-suburban to outer-suburban neighbourhoods is sometimes racially inclined. White-flight to more affluent suburban neighbourhoods. There is an influx of immigrants and racial minority groups in the inner suburbs. Racial and ethnic diversity is growing in suburban neighbourhoods. The influx of migration of immigrant and racial minority groups in suburban neighbourhoods creates racial and ethnic heterogeneity in suburban areas. The trend is showing an increasing percentage of Black, Hispanic/Latino, and Asian populations (ethnic minorities). Another way of framing the neighbourhood hardships, neighbourhoods change, and their variability was by using the lens of social inequity. Saleh (2020) relates neighbourhood change to the spatial inequity to access quality education in various suburban neighbourhoods. Neighbourhood change leads to spatial inequity of access to quality basic education between inner suburban neighbourhoods and outer suburban neighbourhoods. This study, alongside the paper on spatial inequity in accessing quality education in Buffalo Metropolitan Area, was part of a dissertation conducted by Saleh (2019).

Measuring Suburban Neighbourhoods Socio-economic Change and Its Hardship Level

To measure the change in neighbourhood socio-economic conditions, scholars can compare the hardship experienced by that particular neighbourhood. The hardship can be measured using a standardized index so that it can be compared. Changes in neighbourhood socio-economic conditions over a certain period of time can be measured by comparing the changes in the neighbourhood hardship index between the two years of measurements. Neighbourhood socio-economic condition assessment, in some cases, is measured using a standardized measure, called Neighbourhood Hardships Index (NHI) or Neighborhood Deprivation Index (NDI) (Messer et al., 2006). Neighbourhood socio-economic conditions are widely assessed using various variables in census data. This study attempted to measure the changes of socio-economic aspects of neighbourhoods over the period of 2010-2015 and compare the changes between the two neighbourhood location categories in the inner-suburban and outer-suburban neighbourhood context.

Suburban Neighbourhoods of Buffalo Metropolitan Area

The context of this study was suburban neighbourhoods in Buffalo Metropolitan Area (BMA), New York, United States. There was a dichotomy between urban and suburban neighbourhoods of metropolitan Buffalo, followed by stratification of suburban neighbourhoods of the BMA. Thus, the suburban neighbourhood change is of particular interest in this study, particularly the stratification between inner- and outer suburban neighbourhoods. The declining inner-suburban neighbourhoods and the disparity they have with the peer outer-suburban neighbourhoods is a focus of this study. The case study area to analyze suburban neighbourhood change in the declining metropolitan area was suburban neighbourhoods in Buffalo Metropolitan Area (BMA), New York, United States.

This paper aimed at highlighting spatial variability of neighborhood change in inner- and outer-suburban neighborhoods of the Buffalo Metropolitan Area between 2010-2015 by measuring the changes of values of standardized Neighbourhood Hardships Index between 2010 and 2015. Furthermore, this study compared the changes in NHI value experienced by inner-suburban neighbourhoods and outer-suburban neighbourhoods. This study argued that there is a significant difference between inner- and outer-suburban neighbourhoods in terms of their suburban hardships index change. This discrepancy causes spatial inequity between the two suburban neighbourhood categories.

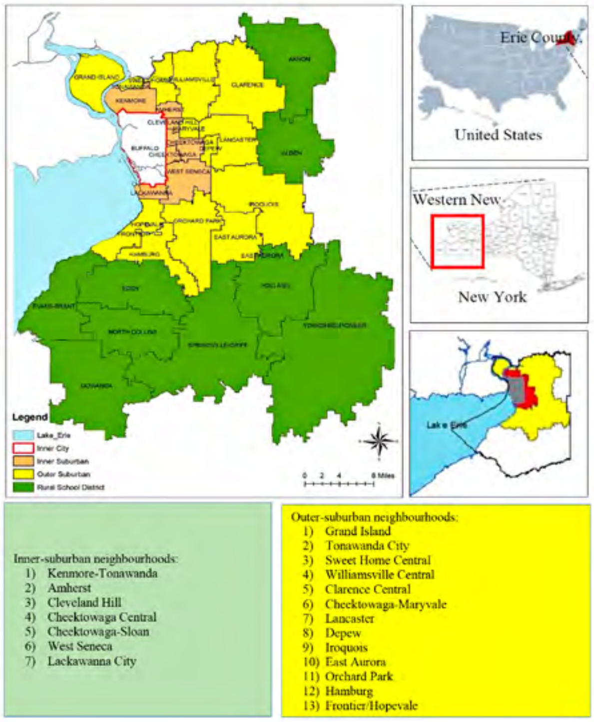

Figure 1. Study area: Buffalo Metropolitan Area, New York
[click on figure to zoom]

This study was important to be conducted because there is a lack of understanding of the suburban neighborhood change phenomenon in the context of the declining metropolitan area, like the Buffalo Metropolitan Area. Previous literature on suburban neighbourhood change mostly sampled 1639 suburban neighborhoods of 13 metropolitans of big cities in the U.S. (Hanlon et al., 2006), which did not include declining metropolitan areas. Hanlon et al. (2006) suggested the need for subtler frameworks to analyze suburban neighbourhoods to understand the structure of contemporary metropolitan areas.

There is a need to study suburban neighborhood change in the context of a declining city in the U.S., such as Buffalo. Therefore, this study is significant to be conducted for several reasons, among those are: 1) the growing percentage of suburban poverty and suburban decline will be the next urban crisis and will affect a very large number of population in the nation if left unaddressed, 2) the current suburban change (socio-economic shift coupled with school socio-economic shift) affects current school performance and future neighborhood's likelihood to grow. 3) the spatial inequity of suburban neighborhood quality, educational opportunities, and educational outcomes between suburban neighborhoods, if left unaddressed, can lead to more debilitating impacts and social costs in the future.

Data and Methods

Review of Methods to Measure Neighbourhood Change

The change of suburban neighbourhood changes (growth/decline) can be measured by calculating absolute change and relative change. The results of measurement of suburban decline using both methods should be complementary to each other. The utilization of absolute change to measure suburban decline was conducted by several studies (Lucy & Phillips, 1997, 2001). Both studies incorporate variables from sociodemographic of the suburban area, e.q. population, population density, housing, employment; but use relative income measurement. The utilization of relative change and construction of index to measure suburban decline was introduced in the study of Orfield (1997) and Hanlon (2008). Both studies incorporate variables from sociodemographic of the suburban area and use ratio or relative income measurement.

Variables to construct an index of suburban decline in Orfield (1997) include the percentage of female-headed households, the percentage of children less than five years old in poverty, relative median household income, and household tax. In Hanlon (2008), the variables to construct an index of suburban decline were changes in population size, changes in relative median household income, and changes in poverty. However, the difference lies in the denominator of the relative income variable in those two studies. In Orfield (2007), the relative income of a suburban neighbourhood was measured in ratio to the overall metropolitan area, while in Hanlon (2008), the relative income of a suburban neighbourhood was compared to overall suburban areas. Mikelbank (2006) also investigated the change of suburban within the metropolitan context by using the relative measure.

However, different from Orfield and Hanlon, who used the index to measure decline, Mikelbank only used population change as an example. He used the location quotient (L.Q.) to measure the change of population in suburban areas. A relative measure of the population in 2000 was measured by making the ratio between a certain suburban population in 2000 with the overall metropolitan population in 2000. A relative measure of the population in 1990 was measured by making the ratio between a certain suburban population in 1990 with the overall metropolitan population in 1990. Furthermore, L.Q. of a certain suburban neighbourhood is the ratio between the relative population in 2000 and relative population in 1990.

Based on this review of methods to measure neighbourhood change, this study measured neighbourhood change between 2010-2015 by utilizing absolute change and incorporating variables from sociodemographic of the suburban areas. This study constructed an index to measure suburban neighbourhood change and suburban decline between the two measurement years.

Data and Analysis

The data source was derived from American census data, called the American Community Survey (ACS) in the year 2010 (ACS, 2010) and the year 2015 (ACS, 2015). Census data was retrieved at the block-group level for suburban neighbourhoods in the BMA. Block-groups are categorized based on their location, whether they are located in inner-suburban neighborhoods or outer-suburban neighbourhoods.

This study hypothesized that there is a significant difference in neighborhood hardships between inner- and outer-suburban neighborhoods. To prove that hypothesis, the following analysis steps were undertaken. The analysis comprises of the descriptive analysis of suburban neighborhoods and suburban neighborhood change. The descriptive part depicted the variables that shape suburban neighborhoods, which are grouped in population, economic, social, and housing aspects. The suburban change section was elaborated by the following structure: 1) measurement of neighborhood deprivation index in 2010 and 2015, 2) measurement of the suburban neighborhood change that occurred between 2010-2015, and 3) identification of the differences in the trajectory of neighborhood change between inner-suburban neighborhoods and outer-suburban neighborhoods.

Neighborhood change was calculated by measuring the change of Neighborhood Hardship Index (NHI) between two measurement years, which are 2010 and 2015. Neighborhood hardship index in 2010 and 2015 need to be calculated prior to calculating the neighborhood change between the two periods of measurements. The neighbourhood hardship index for each year of measurement is calculated by incorporating a set of 12 census variables, namely population number, the percentage of White, the percentage of African-American (Black), the percentage of Hispanic, the percentage of female-headed household with children, the percentage of people with education attainment more than high school graduates, the percentage of the population in poverty, the household income, the unemployment rate, the percentage of owner-occupied housing, the percentage of vacant housing, and the median housing value of owner-occupied housing. Those census variables used were reflecting the five urban social domains, namely: (1) income, (2) labor force, (3) housing, (4) demographic, and (5) education. Those contributing variables were undergone a Principal Component Analysis (PCA) to determine which factors most contribute to the change and identified as components that contributed to suburban neighbourhood change.

Results

First of all, this study examined factors contributing to the Neighbourhood Hardship Index of suburban neighbourhoods in 2010 and 2015. Secondly, this study measured suburban neighbourhood change between 2010-2015 experienced by two categories of suburban neighbourhoods, namely inner-suburban and outer-suburban neighbourhoods. Thirdly, this study conducts analysis to support the argument that there is a significant difference between the change in Neighbourhood Hardship Index in the period of 2010-2015 between inner suburban neighbourhoods and outer suburban neighbourhoods. The findings of the study are described in the following.

The Contributing Factors of Neighbourhood Hardship Index

The Principal Component Analysis (PCA) was performed in this study to examine which variable has a higher impact on the hardship index. PCA accounted for the inter-correlation among sociodemographic variables. PCA eliminates the issue of multicollinearity among various variables used to identify neighbourhood hardships change. Prior calculation of standardized score of Neighbourhoods Hardship Index (NHI) treated each variable as equal without giving different weight for several variables that are considered more important affecting NHI. Descriptive analysis and standardizing scores also did not consider the inter-correlation or multicollinearity among variables. PCA was performed to address this issue. PCA was also beneficial in reducing the number of variables and grouped them into several groups that possess similar characteristics, further called a component. PCA used the Varimax rotation method. PCA produced five (5) components representing 61% of the total variance. The component loadings are presented in Table 1. The components, the Eigen-values, and the total variance explained are shown as well.

PCA was successful in elaborating components (a group of factors) affecting neighbourhood change in BMA. Table 1 informs that overall, five (5) components extracted from PCA could explain 61.15% of the total variance in neighbourhood change. Based on the percentage of variance explained by each component, neighbourhood change was contributed by the change in racial composition (15.13%), poverty and family structure (14.28%), housing ownership and value (11.23%), income and belonging (10.51%), and education and employment (10.00%).

Table 1. The components and their explanatory power

Components	Component Name	Variables loaded to component	Eigen-value	% Total Variance	Cumulative %
Component 1	Racial composition change	The change in the percentage of White, change the percentage of Black	1.816	15.130	15.130
Component 2	Poverty and family structure change	The change in the percentage of Hispanic, changes in the percentage of female-headed household, and change in the percentage of the population in poverty	1.714	14.279	29.409
Component 3	Housing ownership and vacancy change	Change in percentage of owner-occupied housing and change in the percentage of vacant housing	1.348	11.232	40.641
Component 4	Income and belonging	Change in household income and change in median housing value of owner-occupied housing	1.262	10.513	51.154
Component 5	Education and employment	Change in percentage of education attainment (less than H.S.) and change in the unemployment rate	1.200	10.001	61.155

Discussion

Components Contributing to Suburban Neighbourhoods Change in Buffalo Metropolitan

The GIS maps illustrated the variables that contribute to neighbourhood change to delve into details of factors contributing to the neighbourhood change elaborated in Table 1. The distribution of neighbourhood undergone changes was presented consecutively in Figure 2, Figure 3, and Figure 4. The top three components that contribute to neighbourhood change are: (1) the change in racial composition, (2) poverty and family structure, (3) housing ownership and vacancy. The suburban neighbourhood delineation between inner-suburban and outer-suburban neighbourhood was also drawn in the map to better observe the different trajectories of change between the two suburban neighbourhood categories.

Based on the distribution of neighbourhoods undergone a decline in the percentage of the White population, it is observed that inner-suburban neighbourhoods experience more decline in the White population. The white population tends to leave inner suburban neighbourhoods to more affluent outer-suburban neighbourhoods or newer suburbs. From Figure 2, it is also observed that the suburban neighbourhoods located in the northeastern part of Buffalo Metropolitan Area were experiencing a declining percentage of the White population, who moved outward from outer-suburban neighbourhoods that are bordering inner-suburban neighbourhoods.

Figure 3 depicts that inner-suburban neighbourhoods experience more change in poverty level. Inner-suburban neighbourhoods bordering inner-city Buffalo are experiencing an increase in the percentage of the population in poverty. The high percentage of the population living in poverty in the city of Buffalo spills over to its neighbouring inner suburbs.

Figure 4 illustrated that more neighbourhoods in inner-suburban neighbourhoods also experienced an increase in the percentage of vacant housing. An increase in the percentage of vacant housings in the neighbourhood is a signal of declining neighbourhoods. More vacant housings in the neighbourhoods indicate that people are leaving the neighbourhoods, and furthermore, the vacant houses in the neighbourhood are left unmaintained.

Geographic Pattern of Suburban Neighbourhoods Change in Buffalo Metropolitan Area

Figure 5 corresponded to the overall calculation of suburban neighbourhoods change between 2010-2015 in Buffalo Metropolitan Area. If the hardships index in 2015 is higher than the hardship index in 2010 (changes in index value between 5-25), that neighbourhood is considered as declining. If the hardships index in 2015

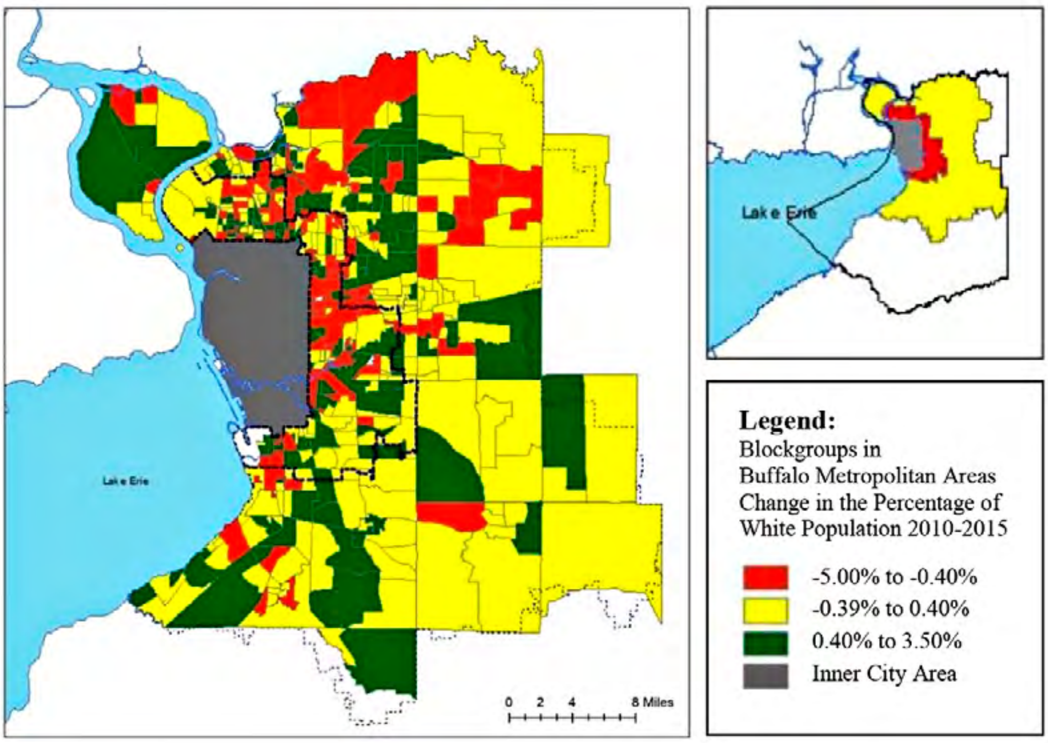

Figure 2. The first component contributing to Neighbourhood Change between 2010-2015 (The change in racial composition: White population)

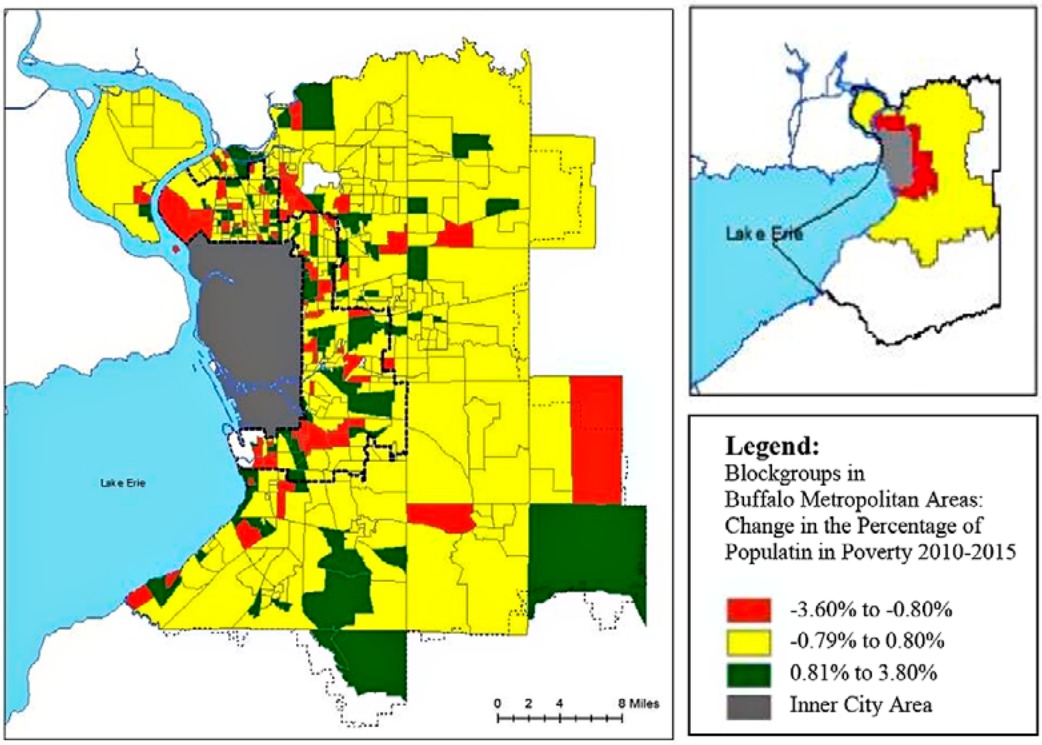

Figure 3. The second component contributing to Neighbourhood Change between 2010-2015 (The Percentage of Population in Poverty)

is approximately the same as the hardship index in 2010 (changes in index value between 0-5), that neighbourhood is considered stable. However, if the hardships index in 2015 is lower than the hardship index in 2010 (changes in index value between 0 to -20), that neighbourhood is considered as improving. The spatial distribution of block-groups that experienced a decline, remain stable, and improved was depicted in that figure.

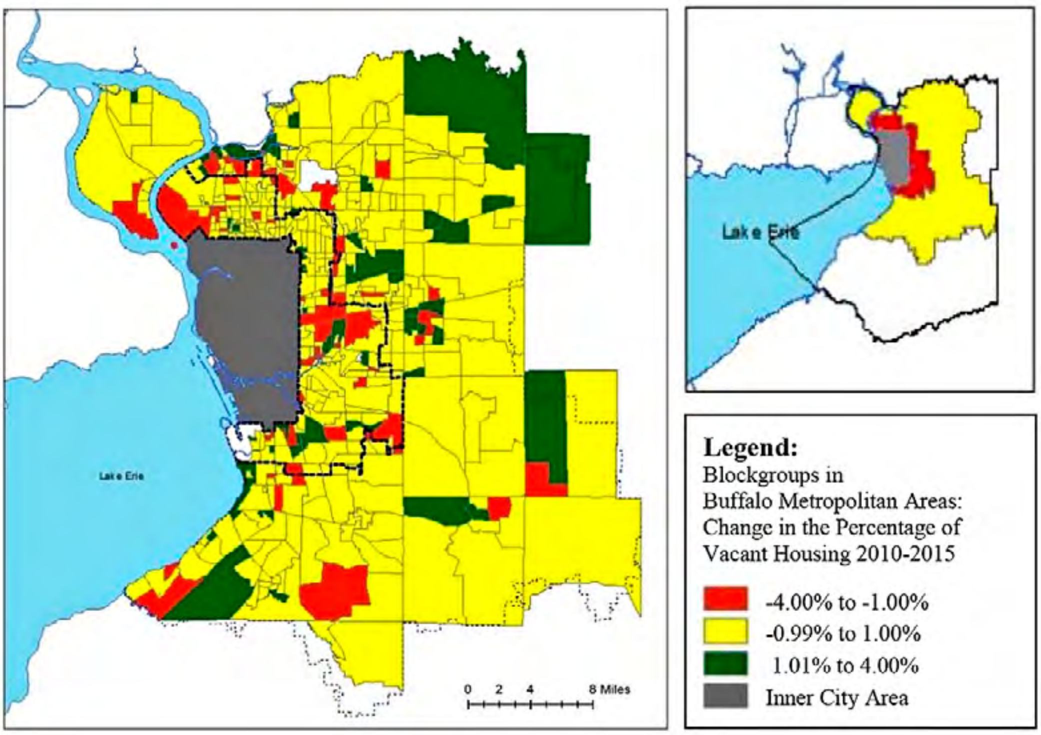

Figure 4. The third component contributing to Neighbourhood Change between 2010-2015 (The Percentage of Vacant Housing)

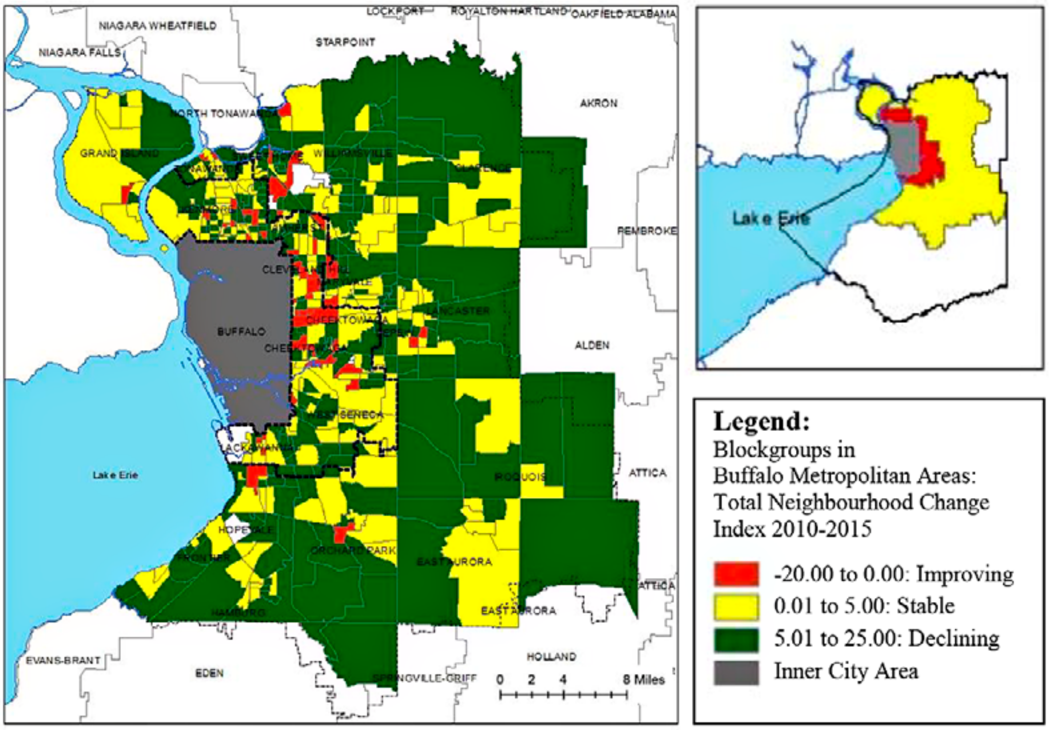

Figure 5. Overall Neighbourhood Change Index between 2010-2015

Declining block-groups (illustrated by red colour in the map in Figure 5) were mostly located in inner-suburban neighbourhoods. Those inner-suburban block groups were located in Kenmore, Cleveland Hill, Cheektowaga, and Lackawanna. Most block-groups in outer-suburban experienced improvement and stability, except for some small number of block-groups in Sweet Home near University at Buffalo North Campus, Depew, Orchard Park, and Frontier neighbouring Lackawanna. Figure 5 also highlights low socio-economic-status neighbourhoods in inner-suburban that experienced a decline. Those block groups were located in Cheektowaga neighbourhoods. Suburban neighbourhoods that experience improvement (illustrated by green colour in the map) between 2010-2015 were mostly located in outer-suburban neighbourhoods. This illustration shows that there is a pattern of suburban neighbourhood change in the Buffalo metropolitan. Furthermore, this GIS map also supports the hypothesis that there is a difference in the trajectory of neighbourhood change between inner-suburban neighbourhoods and outer-suburban neighbourhoods.

In addition to that, a statistical analysis (T-test analysis) was also conducted to support the hypothesis that there is a statistically significant difference in Neighbourhood Hardship Index between inner-suburban neighbourhoods and outer-suburban neighbourhoods. The result of statistical T-test analysis shows that there is a significant Neighborhood Hardship Index (NHI) difference between inner and outer suburban in 2010. However, the T-test analysis for the year 2015 shows that there is not a significant difference in NHI in 2015. This means that outer-suburban neighbourhoods started to have similar values of hardship index with the inner-suburban neighbourhoods.

Conclusion

Based on the findings and discussions, it was identified that suburban neighbourhoods decline occurred in older suburbs of inner-ring suburban Buffalo Metropolitan Area. This study also showed a pattern of decline in inner-suburban neighborhoods of BMA, just as mentioned in previous studies of the decline of older suburbs or inner-ring suburbs in metropolitan America (Hanlon, 2008, 2010; Hanlon & Vicino, 2007; Short et al., 2007). This also followed the patterns of suburban growth and decline (Lucy & Phillips, 1997, 2001). However, this study also found the pattern of suburban neighbourhoods which experience improvement. Outer suburban neighbourhoods experienced ascent in their socio-economic condition and descent in their neighbourhood hardship index. This phenomenon also occurred in other metropolitan areas in the U.S. Different trajectories of neighbourhoods change is a source of inequality, and neighbourhood

Table 2. The highlight of the difference between inner and outer suburban neighborhoods

Aspect	Inner-suburban	Outer-suburban
Neighborhood change		
Neighborhood demographics	More diversity. More racial minority groups in Lackawanna (South), Cheektowaga Central (West), Cleveland Hill (West).	There is less diversity in most outer suburban neighbourhoods, especially in southern outer suburban neighbourhoods. Diversity in outer-suburban neighbourhoods occurred in the northeastern part of suburban BMA (Sweet Home, Williamsville).
Neighborhood hardships	The higher mean of neighbourhoods hardship index in inner suburban means inner suburban block-groups are experiencing more adversities.	Outer suburbs have a lower mean of neighbourhoods hardship index. Fewer hardships are experienced by most outer suburban block groups.
	Based on statistical analysis (T-test analysis), there is a significant Neighborhood Hardship Index (NHI) difference between inner and outer suburban in 2010, but not a significant difference of NHI in 2015. This means that outer-suburban neighbourhoods started to have similar values of hardship index with the inner-suburban neighbourhoods.	
Change of neighborhood hardships	Most declining block groups are located in inner suburban neighbourhoods. The block groups clustered in Cheektowaga, West Seneca, Kenmore-Tonawanda.	There are enclaves of block-groups experiencing a decline in outer suburban neighbourhoods of Sweet Home scattered near University. A small enclave of declining block-groups in Grand Island, Depew, Orchard Park, and Frontier.
	Both suburban neighbourhood categories experience change (grow, stable, and decline). However, declining block groups are more prevalent in inner-suburban neighbourhoods, while socio-economically ascending block-groups are more prevalent in outer-suburban neighbourhoods.	

change may lead to changing opportunities for residents (Owens, 2012). This study also depicts suburban neighbourhoods of BMA are becoming more heterogeneous in terms of socio-economic condition.

The highlight of the difference between inner and outer suburban neighbourhoods in the Buffalo Metropolitan Area is depicted in Table 2.

This study adds to a prior study of the suburban neighbourhood change in the Buffalo Metropolitan Area. Previously, Buffalo suburban neighbourhood change was studied only as part of nationwide metropolitan areas research between 1990-2000 (Lucy & Phillips, 2001, 2003). In those two prior studies, two observations were made: 1) Buffalo metropolitan area lost population during the 1990s (-1.6%), and 2) Buffalo metropolitan had a high percentage of suburban neighbourhood's decline (71.4%). The study findings also add to that information about Buffalo Metropolitan Area suburban change timeline between 2010-2015. First, during the study timeframe of 2010-2015, overall BMA showed stable population growth, with some suburban neighbourhoods experienced a decline in population while other suburban neighbourhoods experienced a gain in total population. Most inner-suburban neighbourhoods lost their population (mean of change of total population = -1.15%), but most outer-suburban neighborhoods gain population (+2.84% change of total population). Second, during the period of 2010-2015, Buffalo suburban neighbourhoods had a lower percentage of suburban neighbourhood decline as opposed to Lucy and Phillips' findings in the timeframe 1990-2000.

Our findings of this study also elaborate in more detail about the characteristics of suburban decline in Buffalo suburbs. Early work by Lucy and Philips (2001, 2003) stated that the suburban decline in BMA was very high, with 71.4% of suburban neighbourhoods being studied undergone decline. However, Lucy and Phillips (2001, 2003) did not dichotomize suburban neighbourhoods into two categories of inner-ring and outer-ring Buffalo suburban neighbourhoods. The findings of this study add to that knowledge by describing that the decline has occurred mostly in inner suburban neighbourhoods. In addition to that, the percentage of suburban neighbourhoods decline was lower during 2010-2015. The result of the study also in line with the current debate on suburban dynamics, that there is strong evidence of variation within the suburbs themselves. There is great variation along the urban/suburban spectrum, and the socio-economic characteristics of inner suburbs are more like urban areas than they are like outer suburbs (Airgood-Obrycki, Hanlon, & Rieger, 2020).

With the utilization of Geographic Information System (GIS), this study also illustrated the spatial distribution of suburban neighborhoods which are declining, stable, or growing. In addition to that, the utilization of GIS visualization in the study also had pinpointed the spatial distribution of inner-suburban neighbourhoods that experienced a decline. That adds to the knowledge to understand the structure of contemporary declining metropolitan areas, especially in the case of Buffalo Metropolitan Areas. The result of this study suggests that suburban neighbourhoods change happening in Buffalo Metropolitan Areas, and this suggests more studies to examine whether this has wider significance and this phenomenon is also happening in other declining metropolitan areas in the United States.

This study recommends further analysis of suburban neighbourhood changes in metropolitan areas which experience a decline in the past decades, such as metropolitan areas located in Rust Belt areas in the northeastern region of the United States. This will add to our understanding of the structure of contemporary declining metropolitan areas in the northeastern region of the United States.

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Promoting Urban Water Bodies as a Potential Strategy to Improve Urban Thermal Environment

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Abstract

Cities are found warmer than in nearby surrounding rural areas due to change in surface properties and lack of evaporation, indicated as urban heat island (UHI). On the other hand, bodies of water have been known to generate a positive impact on the urban microclimate by maintaining a cooler thermal environment. Although researchers have been conducted many experiments and measurements to illustrate its potential benefits, most of them are studied in terms of its capacity to ameliorate the air temperature. In this paper, the benefits of urban water bodies are evaluated regarding their radiation properties. With the main objectives to find a novel approach to take advantage of urban water bodies' abilities to improve the urban thermal environment, a series of field measurements have been conducted inside an urban scale model. Generally, the measured long-wave and short-wave radiation within the urban canyon shows that bodies of water tend to absorb and store more heat, which in turn generate lower surface temperature as compared to those flat concrete surface.

Keywords: urban microclimate; water bodies; field measurement; outdoor scale model; radiation

Introduction

Cities tend to experience a warmer thermal environment than their surrounding areas due to their urban surface properties, creating well-known Urban Heat Island phenomena (UHI). Among many factors contributing to its formation, UHI is mainly caused by a large variety of land use, such as urban geometry and urban fabric. These factors create distinctive thermal characteristics that differ from those found in rural areas (Landsberg, 1981; Paramitha & Fukuda, 2014; Paramita & Matzarakis, 2019; Akbari & Kolokotsa, 2016). The lack of evapotranspiration and dominance of hard surface affect the storage and transfer of radiative heat that alters the radiation balance. Which in turn, increased absorption of radiation and sensible heat released by urban structures result in a warmer air temperature in cities (Harman & Belcher, 2006). UHI is also known to contribute to various urban problems such as high energy consumption, thermal discomfort, deterioration of health and wellbeing (Chao et al., 2020; Varquez & Kanda, 2018; Tzavali et al., 2015). While these artificial surfaces tend to negatively affect the microclimate (i.e., surface temperature and air temperature), urban greens and urban blues have favourable impacts by ameliorating the UHI effect through creating cooler spots and comfortable spaces (Gunawardena et al., 2017; Amani-Beni et al., 2018; Völker et al., 2013; Li & Yu., 2013).

Especially of bodies of water located in towns and cities, many researchers have found that its ability to ameliorate the air temperature is prominent, especially during the day (Jacobs et al., 2020; Syafii et al., 2017; Jin et al., 2017; Gross., 2017). Correspondingly, its surface temperature is also lower than those found in the surrounding urban fabric, primarily due to evaporation cooling (Lin et al., 2020). In particular, evaporative cooling from bodies of water is considered a com-

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mon form of passive cooling. The thermal environment around and above the body of water is somewhat distinctive from that of the concrete ground due to changes in the way the water cools and heats. Bodies of water are considered great absorbers, but they also show little thermal response due to their distinctive characteristics (Oke, 1987; Pearlmutter et al., 2009). Body of water allows the transmission of radiation wave to enough depths while the existence of convection permits the heat gain to diffuse through large volume. Body of water also has unlimited moisture for evaporation, which provides an efficient latent heat sink. Lastly, water bodies have a relatively exceptional large thermal capacity as compared to the concrete surface (Gunawardena, 2017). Regarding surface energy balance, where bodies of water within the urbanized area are usually found to swallow, the radiation exchange is expected to dominate the energy budget during low wind speed conditions (Van Hove et al., 2015). These features are likely to make the surface temperature of bodies of water colder than those found on the ground, resulting in a cooler air temperature above the bodies of water. These reductions of temperature are most likely to illustrate the act of bodies of water as a thermal buffer due to its relatively larger thermal inertia (Ampatzidis & Kershaw, 2020). Due to cooling by evaporation, the process raises the latent heat portion of the surface energy balance and impacts the other energy portion (i.e. sensible heat and stored energy). These continuous processes increase the latent heat, reduce the stored energy's magnitude, and eventually lower its immediate surrounding air temperature.

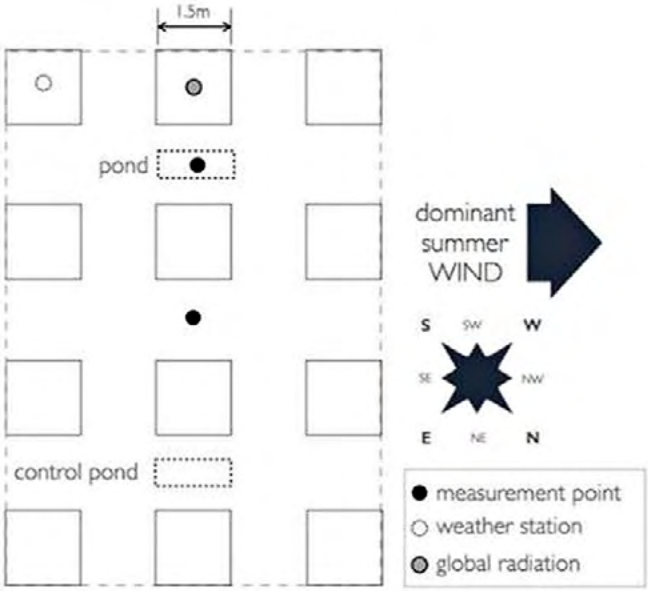
Thus, the present study aims to evaluate these cooling benefits in regards to their radiation properties. A series of field measurements were conducted inside an outdoor scale model, namely COSMO (Comprehensive Outdoor Scale Model), to make an apparent extent of the bodies of water cooling effect. The COSMO generic form provides an effective evaluation tool for microclimate study within a relatively uniform area. Compared with more complex real-world conditions, the scale model field measurements yields results that are easier to interpret and suitable for assessing urban microclimate. (Kanda, 2006; Kanda et al., 2007; Kawai & Kanda, 2010a; Kawai & Kanda, 2010b; Park et al., 2012).

Study area and methodology

With the main objectives of finding a novel approach to take advantage of urban water bodies' abilities to improve the urban thermal environment, a series of radiation exchange measurements was performed within the outdoor scale model canyon. The field measurement was conducted during the summer season of 2016 alongside the other thermal assessment and evaluation (Syafii et al., 2017). COSMO (Figure 1) is a 1:5 scaled-down simplified residential district in Japan that consists of a cubical array of 512 concrete cubes situated in Saitama Prefecture, Japan (Kanda, 2006; Kanda et al., 2007). The concrete cubes are 1.5 m × 1.5 m × 1.5 m each, painted dark grey and hollow. They are arranged in a lattice-type square with intervals of 1.5 m, creating urban canyon-like formations. The outdoor scale model's ability to recreate thermal patterns similar to actual urban conditions shows a promising way to study under actual climate conditions comprehensively.

The three-dimensional (3D) short-wave and long-wave radiation within the outdoor scale model canyon were measured with a net radiometer to achieve

Figure 1. COSMO (Comprehensive Outdoor Scale Model), Saitama, Japan
Source: https://www.google.com/earth/ (left image)



case	total pond	pond size	configuration
pond	1	1.5 m x 0.5 m	paralel
control pond	1	1.5 m x 0.5 m	paralel

Figure 2. Experimental studies arrangement on the radiation exchange

the study's objectives, utilizing a simplified integral radiation measurement process. The radiation properties of a canyon with bodies of water is compared to a non-water condition. The body of water is in the shape of a 1.5 m × 0.5 m water pond. Figure 2 illustrates the experimental setting for the radiation exchange measurements. The Net Radiometer (Eko MR-60) monitored four different radiation components (incoming and outgoing radiation fluxes, both long-wave and short-wave) and placed on a tripod (40 cm above the ground). The data was collected once every 10 sec for two days on a typical hot summer day.

Concurrently, the experimental study also monitors both (water and concrete) surface temperature alongside the integral calculation of radiation. A thermal camera unit (infRec R500 pro) was used to capture both surface temperature. During the monitoring process, the thermal camera unit was shielded with a custom build polyurethane box to restrict the effect of other surface-related radiation (Figure 3). These supplementary measurements were utilized to determine the correlation between the integral radiation measurement result and the difference in the surface temperature value, which might illustrate the indirect cooling effect of bodies of water.

Figure 3. Surface temperature monitoring equipment and setting

Results and discussion

The experimental study objective is to better understand the general effect of bodies of water toward urban microclimate in regards to its radiation properties. The following discussion reports the monitored radiation exchange and surface temperature above two different surfaces modification, namely water pond and concrete ground, during the summer season in Japan. The hourly average of the measured incident radiation (long-wave, *Lw*, and short-wave, Sw, radiation) above the concrete ground and the pond is shown in Figure 4, respectively. The "down" represents the direction where the incoming radiation comes from the concrete floor or water surface, whereas "up" means the incoming radiation from the sky. On the other hand, the incoming radiation from the short axis and the long axis, relative to the COSMO canyon will be denoted as SW–NE (South West – North East direction) and SE – NW (South East – North West direction) as shown on Figure 1. Additionally, the radiation properties are following the spatial variation of radiation balance on high latitudes of Japan, where they might be experiencing deficit net radiation (Dingman, 2014). Regardless, this paper focuses more on the distinctive profile of radiation exchange between two different surface conditions, water and concrete, inside an urban canyon. The result hopefully shows the potential benefits of having bodies of water in cities.

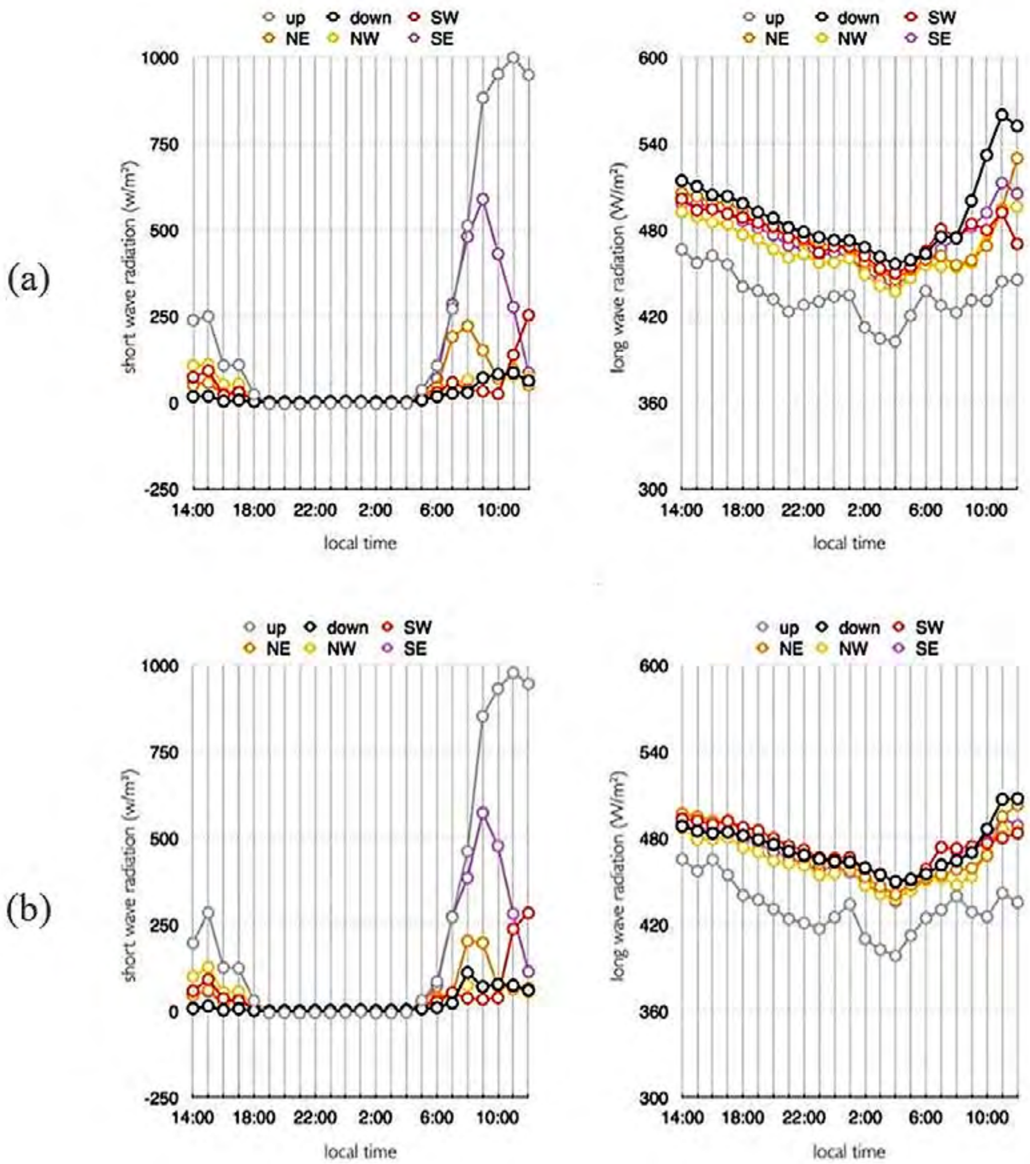


Figure 4. The above-the-concrete-surface (a) and above-the-water-pond (b) measured Short-wave - *Sw* and Long-wave - *Lw* radiation (hourly averaged)

For the most part, similar diurnal trends exist on both radiation profile. The incoming short-wave radiation (*Sw*) from the up direction (the sky) and the long-axis of COSMO was prominent during the day. The *Sw*, which is mainly composed of the direct component of the incoming radiation, seems to be associated with the degree of openness relative to the sky. These incoming radiations show higher value than those incoming radiation from the immediate wall or the short-axis (i.e., SW and NE direction). On the other hand, the incoming long-wave radiation (*Lw*) from below (i.e., the ground surface) was found to be stronger than the other portion of recorded *Lw* radiation. These findings suggest that the ground surface tends to release more heat as a consequence to have more exposure relative to the sky. The *Lw*, which mainly shows the conduction and convection portion of the re-radiation from the stored heat, tends to release exceptional heat if the surface or the urban element absorbed more heat. These tendencies are comparable to the *Sw* profile, where the monitored radiation coming from the long axis has shown stronger intensities than the radiation coming from the COSMO wall. These patterns further emphasized that the radiation exchange within the urban canyon was primarily generated by the sky and the ground part rather than by the vertical canyon surfaces. That further highlights the vital role of ground surface alteration in towns and cities for a better thermal environment. These thermal characteristics are also observed with those obtained from the numerical model, where the local sky view primarily influences the outgoing *Lw* (Harman & Belcher, 2006).

While both surfaces have similar daily patterns, the intensity of the measured radiation is of different significance. Figure 5 illustrates the difference between the recorded radiation component from above the concrete surface relative to the pond to further understand the phenomena. The radiation portion from the sky was omitted from the analysis, assuming that the values are the same. In the graph, the positive value implies that the radiation component coming from the concrete surface is relatively stronger, and the negative value illustrates the opposite. Overall, the chart shows a fluctuating short wave differential (ΔSw) value yet more constant in the long-wave differential (ΔLw) value. The ΔSw profile indicates that under all conditions, with or without a water pond, the Sw radiation portion tends to have the same state during the night when there was no sunshine. In the daytime, it was relatively fluctuating, with most of the Sw coming from the long canyon axis when there was no water pond, especially during the morning time. However, when the pond was present, the *Sw* was primarily recorded coming from the water at the end of the daytime period. The findings suggest that the pond tends to reflect the *Sw* radiation component, especially when the angle of the incident light was relatively high, creating fluctuating radiation properties.

Furthermore, the calculated ΔLw profile suggests a stronger radiation intensity above the concrete surface during the day, especially the radiant portion coming from below. The concrete ground appears to release greater radiation in comparison to those coming from the pond. Also, the rise in the calculated ΔLw value tends to be associated with direct radiation from the sun. The recorded high value of long-wave radiation difference in the daytime period might indicate the capacity of the pond to store and retain notable heat. In contrast, the concrete surface tends to release the radiation back to the atmosphere immediately. Due to water availability, *Lw* above the water ponds also

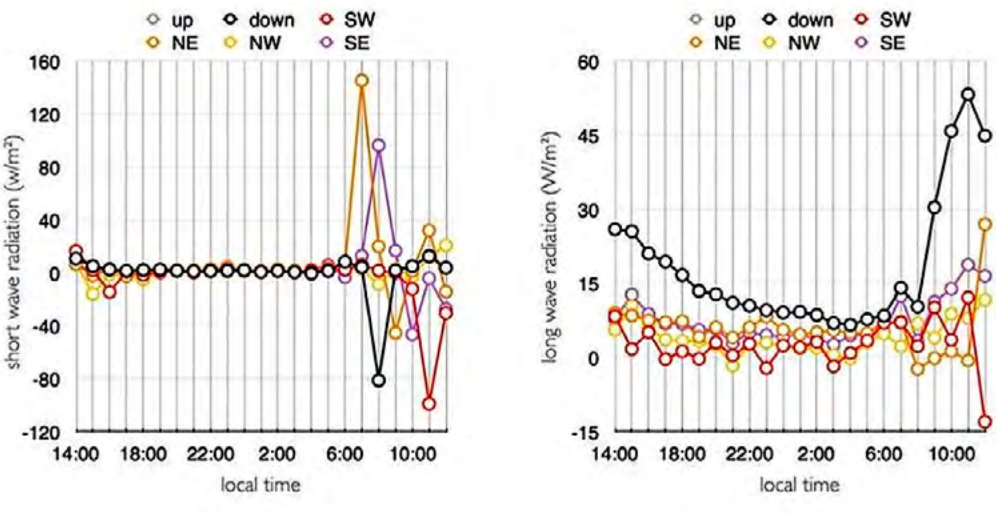


Figure 5. The difference of measured short-wave (ΔSw) and long-wave (ΔLw) radiation above the concrete ground relative to the pond

comes in the form of latent heat flux from the evaporation process, which considers beneficial to the urban thermal environment (de la Flor & Domínguez, 2004; Robitu et al., 2006; Dingman, 2014).

Meanwhile, as the heat begins to re-radiate from the surfaces in the nighttime period, the monitored ΔLw indicates a declining trend towards sunrise. Even though the concrete surface has a relatively high radiation value, the pattern suggests that the heat intensity generated by the pond appears comparatively stronger, which compensates for the high Lw radiation recorded coming from the ground concrete surfaces. There is a possible warming effect due to the water pond's presence, as found by (Steeneveld et al., 2014; Theeuwes et al., 2013). Still, the radiation profile shows that the water pond seems to perform better than the concrete surface regarding the undesirable excess of heat. These tendencies lead to lower re-radiation and trapping of heat inside the urban canyon.

This radiation profile, which was produced from different surface conditions, was naturally converted into different surface temperatures (*Ts*). Lower heat release from the water surface would result in cooler surface temperatures (Robitu et al., 2006). As seen on the monitored *Ts* (Figure 6), the recorded water *Ts* can be up to 14 °C cooler than the concrete surface in the daytime period. Under this ideal condition, the lower *Ts* could also mean reducing the availability of latent heat flux, which might reduce the cooling effect (Gunawardena, 2017). However, the diminishing pattern of *Ts* during the nighttime period tends to match

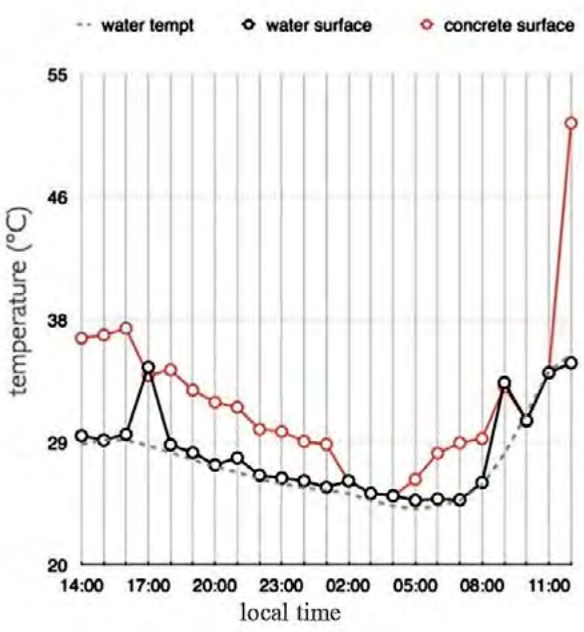


Figure 6. The comparison of measured surface temperature (*Ts*) of water and concrete (hourly average) taken from the thermal camera

the diminishing trend of *Lw*, which most likely indicates that the most crucial element in the fluctuation of surface temperature within an urban canyon is the long-wave radiation component. These findings further suggest that the ability of the pond to regulate the radiation exchange could ameliorate the surface temperature, which in turn benefits its surrounding microclimate by creating a cooler air temperature.

Conclusion

The mitigation capacity of bodies of water shows potential benefits in improving the thermal environment in towns and cities. Generally, water not only aesthetically pleasing but could increase the thermal quality of urban microclimate. Primarily through evaporation, bodies of water ameliorate the warm urban air temperature. The evaporation process alters the radiation exchange and surface energy balance by cools its surface temperature, thus creating a beneficial thermal environment.

With a focus on the quantitative analysis, the monitored long-wave (*Lw*) and short-wave (*Sw*) radiation within the urban canyon illustrate a phenomenon where water bodies tend to absorb and store more heat than flat concrete surfaces. The experimental study result confirms the degree of the pond impact on the radiation properties within the urban canyon, creating notable cooler surface temperatures. These findings provide a future possibility of altering urban water bodies' ability to modify their radiation properties by changing their heat capacity (i.e., maintaining lower water temperature, increasing water mass, etc.). These physical parameters, which can be controlled by preserving positive responsiveness to heat, should be taken into consideration when bodies of waters are built to mitigate the severe impact of UHI. Such results also indicate that bodies of water should be integrated into future planning and design in towns and cities to enhance the quality of the thermal environment.

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The Concept Design for Adaptation of Climate Change Through Integrated and Sustainable Flood Infrastructure in the Coastal Area of Pekalongan, Indonesia

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Abstract

The coastal area of Pekalongan, especially the estuary area of the Banger River, Loji River, and Gabus River, are often experiencing to tidal floods. Tidal Floods that occur pose a great risk due to the sedimentation of river mouths and floods from the watershed to the coastal area of Pekalongan. This study aims to assess the impact of climate change on flood frequency patterns and the contribution of each sub-watershed to the total discharge that occurs, as well as to analyze the effect of increasing sea level that occurs in the coastal area of Pekalongan. The method used in this research hydro-meteorological, hydraulic, and hydrodynamics two-dimensional analysis. The results showed that the climate change that occurred in the coastal area of Pekalongan was indicated by an increase in the average temperature of about 1° Celsius and the trend towards maximum yearly precipitationthat occurred during a period of twenty years had increased (2000-2019 period). An Increasing temperature that occurs has a significant risk to sea-level rise and increasing uncertainty hydrometeorological hazard (tidal flooding). Recommendations from this study are structuring the drainage system based on an integrated landscape arrangement concept to improve the economy, tourism, social, and environment to achieve sustainable coastal infrastructure.

Keywords: TidalFloods; Sea Water Rise, Pekalongan

Introduction

Pekalongan is a city that grows and develops in the north coast of Central Java. Pekalongan has been potential to be impacted by the sea level rise and flooding at the mouth of the Banger River, Loji River, Gabus River. According to the results of a study conducted by (River Basin Organization Pemali Jauna, 2020) the area of the flood inundation that occurred in the northern coast of Pekalongan, namely 458.3 ha which inundated residential areas, agricultural land and road and bridge infrastructure which are the main logistics route in the northern region of Central Java. The tidal flood that occurred caused economic losses and disrupted community activities on the coast of Pekalongan. Handling of tidal flood that has occurred has been carried out with a pump system in areas that are experiencing inundation, but it is still not effective in solving the rob flood problem that occurs. Approach that can be taken to solve the tidal flooding on the north coast of Pekalongan is the arrangement of the coastal area of Pekalongan using the concept of sustainable development.

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Figure 1. Flood Conditions on the Coast of Pekalongan Coast
Source: jatengtribunnews.com (26 February 2020)

The old development principles need to be changed so that infrastructure development can refer to the new environmental management principles that are more environmentally friendly. On the other hand, every infrastructure development must look at social factors related to society as well as other impacts caused by infrastructure development, so that it will add to the economic value resulting from the arrangement of the coastal area Pekalongan.

Based on these facts, this study aims to determine the impact of tidal flood in the coastal area of Pekalongan and provide adaptive efforts to handle tidal flood through regional structuring and sustainable coastal infrastructure development. Sustainable zoning and development of coastal infrastructure are integrated with various existing sectors such as tourism and agriculture to improve the economy.

Methodology

Study Locations

The city of Pekalongan is located 6º50'42"–6º55'44" South Latitude and 109º37'55"–109º42'19" East Longitude on the northern coast of Java. The entire area of Pekalongan City is included in the integrated watershed, covering the Sengkarang watershed, the Kupang watershed, and the Susukan watershed. Based on data from the Minister of Public Works and Housing Regulation No. 04 of 2015, it is known that the location of the Pekalongan tidal flood inundation is in the Pemali Comal river area. The research location is in the Kupang Watershed, which has an area of 234,048 km² with a length of the main river that is 53.23 km. The upstream of the Kupang water-

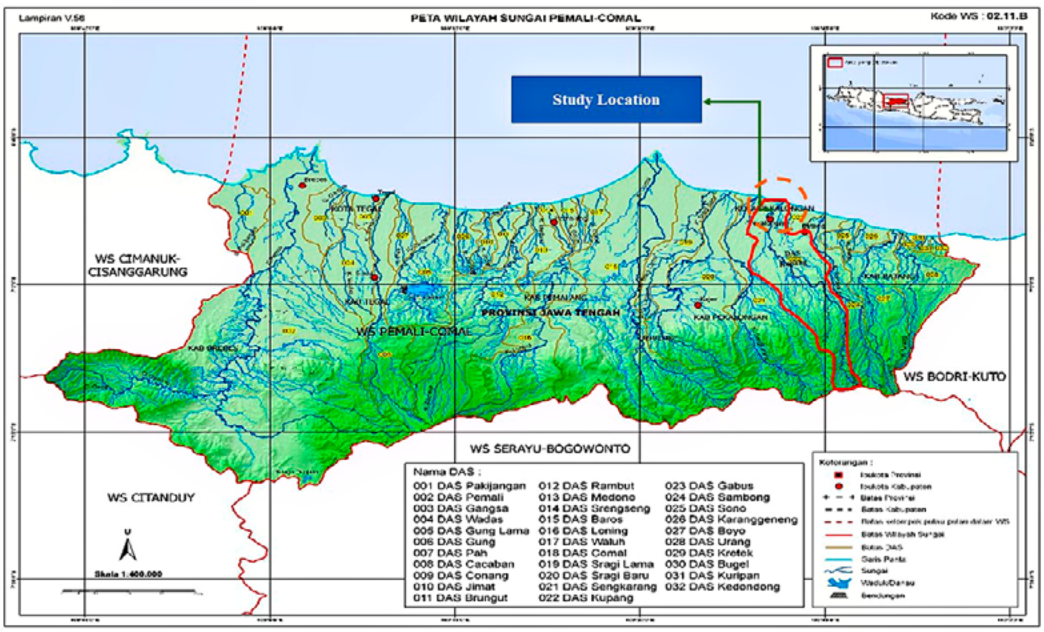


Figure 2. Map of Study Location for the Kupang Watershed in the Pemali Comal River Basin

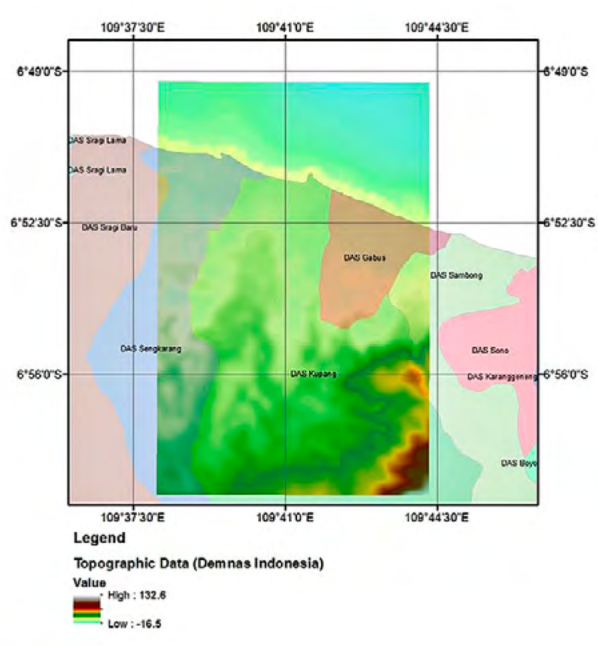


Figure 3. Topographic data Location Area

shed is in Pekalongan Regency and the downstream in Pekalongan City.

Based on the results of the inventory of tidal flood inundation data that occurred in Pekalongan (River Basin Organization Pemali Juana, 2019), there were four affected villages with a total inundation area of 458.3 hectares with a variation flood inundation height varying from 20 cm to 1 meter. The locations affected by the flood in Pekalongan are:

- Kendang Panjang 26 hectares
- Panjang Wetan 69,3 hectares
- Krepyak Lor 163 hectares
- Degayu 227 hectares

Based on existing topographic data, the depth of the waters' study location ranges from -16.5 meters and the maximum land height is 132.6 meters. This topographic data is very significant to be used, especially for interpreting data and studying floods on the coast of Pekalongan.

Methodology

This research begins by collecting secondary data from several agencies such as Meteorological, Climatological, and Geophysical Agency in Indonesia, River Basin Organization Pemali Juana Pemali Juana. The data analysis carried out was climate change analysis using data for the last 20 years (2000-2019), hydrological analysis, and flood modeling, coastal analysis and modeling. In performing analysis and handling design using ArcGIS, HEC-RAS, Delft 3D, AutoCAD applications. The research flow in this study is shown in Figure 2. Meanwhile, the concept of beach modeling using the hydrodynamic Delft 3D model is shown in Figure 5.

In this study quantitative research method was used are secondary data. The analyzes included: i) hydrological-meteorological analysis, ii) two-dimensional hydraulic analysis, iii) two-dimensional hydrodynamic analysis of the Pekalongan coastline, iv), and a map of the inundation depth distribution map due to climate change. Modeling was carried out in 2 scenarios, namely the existing condition scenario in 2020 and the scenario in the future condition, namely in 2070.

The first thing to do is to change the National Demnas data in the form of terrain into a GeoTIFF. After that, a meshing is made with the involvement of 20 m x 20 m, and the boundary conditions are made

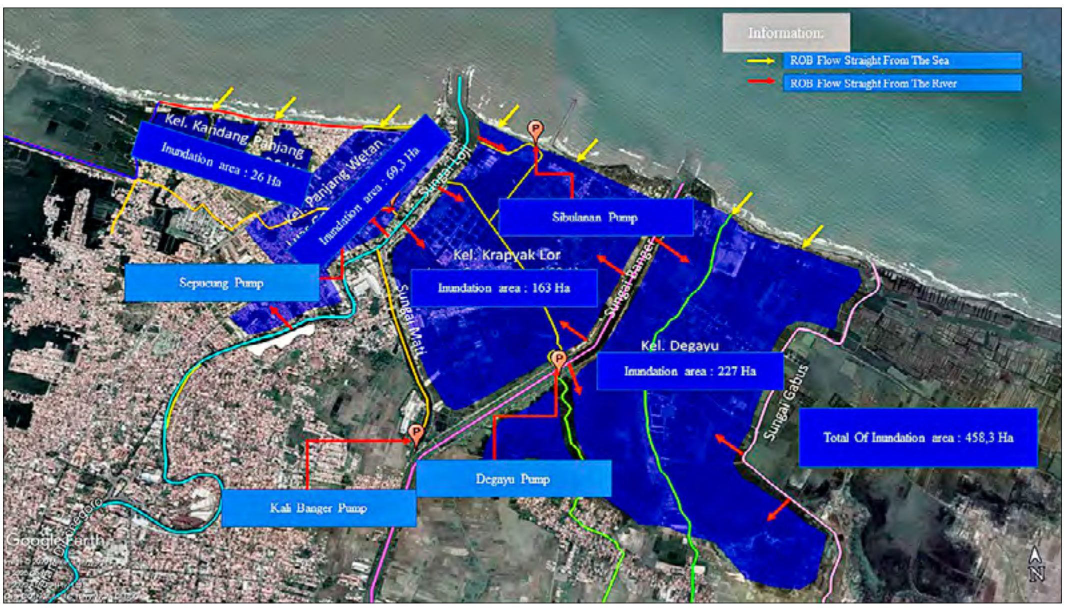


Figure 4. Inundation Area and Existing Pump System for Tidal Floods

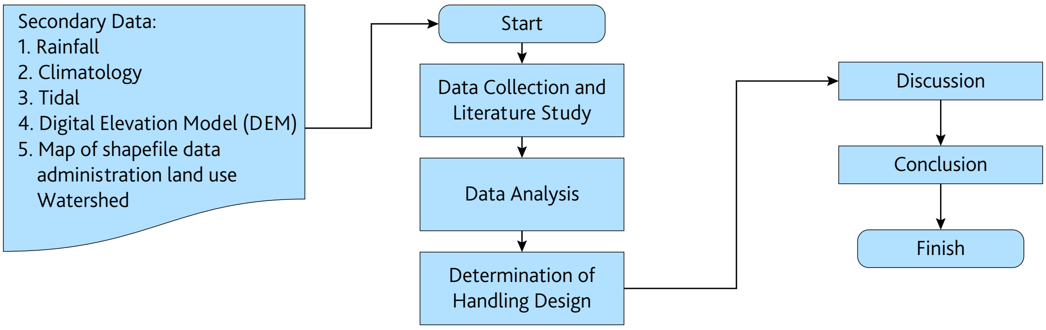


Figure 5. Research Flow

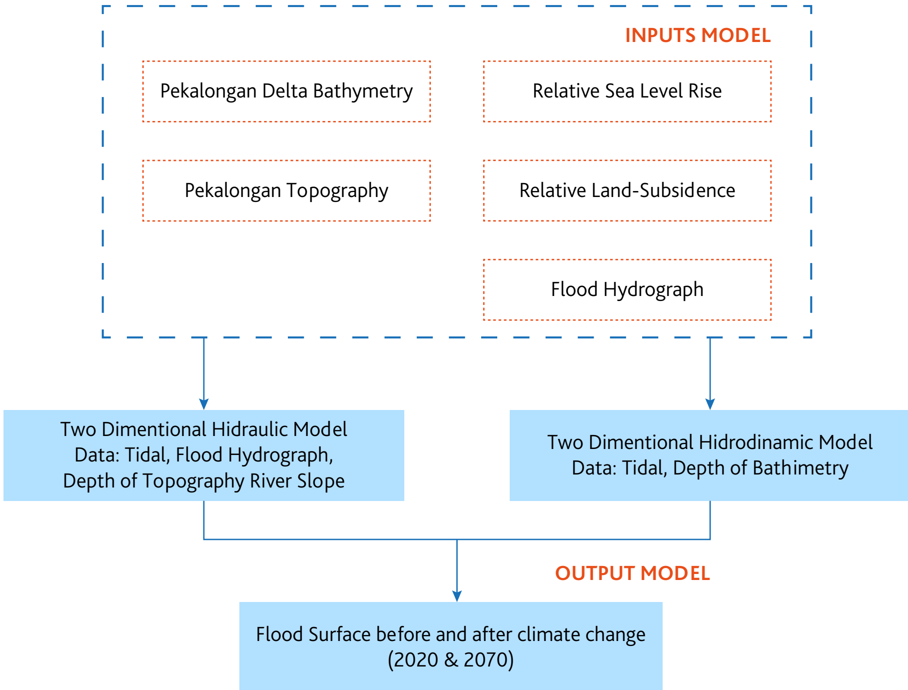


Figure 6. The methodology of two-dimensional hydraulic and hydrodynamic modeling

from upstream and downstream. After that, the modeling was run and flood inundation was obtained. The flood inundation modeling is limited to the downstream of the river around the Pekalongan coast. The timestep used in modeling is about 5 seconds. The timestep selection is crucial in the success of modeling. In this study, the modeling carried out was not specific to field safeguards but only to assess the potential for existing flooding. Further study of floods will require more data, especially data on the distribution of floods that occur based on observations made by related agencies,

The Parameter of modeling as following:

- Manning Roghness value: 0.025 (clean, straight, full stage, no rifts or deep channel;)
- The boundary condition is divided into Upstream boundary and downstream boundary. Upstream boundary using flow hydrograph and Downstream boundary using maximum tidal elevation.

Flood Discharge Calculation

To estimate the amount of peak runoff (QP), a synthetic unit hydrograph (HSS) is used which is based on the physical characteristics of the watershed, this is because there is no river discharge observation data that can be used to make a unit hydrograph. In making the hydrograph of the synthetic unit previously calculated the rain plan that will be used incalculating the flood discharge. The HSS used is the Nakayasu method (Irawan, 2020) to determine the peak discharge that occurs at the research location. So that the peak discharge magnitude can be used in modeling the flood in the study area. The equations used are as follows:

Interval Time (T_g) and Peak Time (T_p)

$$T_g = 0.5279 + 0.058 \text{ L to L} > 15 \text{ km} \quad (1)$$

$$T_g = 0.21\, L^{0.7} \text{ to L} < 15 \text{ km} \quad (2)$$

$$T_p = T_g + 0.8\ T_r \tag{3}$$

Where:

- T_g = delay time (hours)
- T_r = unit of time of rainfall (hours)
- T_p = peak time (hours)
- L = length of river

Peak discharge for effective rain is 1 mm in an area of A km²

$$Q_p = \frac{AR_e}{3.6T_p + T_{0.3}} \tag{4}$$

Where:

- Q_p = peak flood discharge (m³/s)
- R_e = effective rain unit (1 mm)
- T_p = time from the beginning of rain to the peak of the flood (hours)
- A = the area of the watershed oto the outlet
- $T_{0.3}$ = time of discharge reduction, from peak to 30%
- α = hydrograph parameter

Where:

- α = 2.0 in the usual drainage area
- α = 1.5 on the ascending part the hydrograph is slow and fast descending
- α = 3.0 on the ascending part of the hydrograph fast and slow descending

The equation for the basic form of hydrograph for the hydrograph for the Nakayasu unit consists of four curve segments which are expressed by the following equation:

When the curve rises: 0 < t <

$$Q_{(t)} = \left(\frac{t}{T_p}\right)^{2.4} \tag{5}$$

Where:

- $Q_{(t)}$ = runoff before seeking peak discharge (m³/s)
- t = time (hour)

When the curve declines:

Value hose: t ≤ $(T_p + T_{0.3})$

$$Q_{(t)} = Q_p 0.3^{\left(\frac{tT_p}{T_{0.3}}\right)} \tag{6}$$

Value hose: $(T_p + T_{0.3}) \le t \le (T_p + T_{0.3} + 1.5T_{0.3})$

$$Q_{(t)} = Q_p 0.3^{\left(\frac{tT_p + 0.5T_{0.3}}{1.5T_{0.3}}\right)} \tag{7}$$

Value hose: $t \ge (T_p + T_{0.3} + 1.5T_{0.3})$

$$Q_{(t)} = Q_p 0.3^{\left(\frac{tT_p + 0.5T_{0.3}}{2T_{0.3}}\right)} \tag{8}$$

Coastal Hydrodynamic Analysis

a) Governing Equation of Hydraulic Model

The software used for two-dimensional flow modeling is HEC-RAS (River Analysis System). The regulatory equations used for 2D HEC-RAS modeling are the conservation equation and the continuity equation. Assuming an incompressible flow, the mass conservation equation (continuity) in the form of unsteady flow is as follows:

$$\frac{\partial H}{\partial t} + \frac{\partial (hu)}{\partial x} + \frac{\partial (hv)}{\partial y} + q = 0 \tag{9}$$

Where t is time, u and v are the velocity components in the x direction and in the y and q direction are the source / link flux forms (HEC-RAS Manual Reference, 2018). Two-dimensional flow modeling also applies the Navier-Stoke momentun equation for shallow flows. The momentum equation that applies is as follows:

$$\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} = -g\frac{\partial H}{\partial x} + vi\left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2}\right) - c_f u + fv \tag{10}$$

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = -g\frac{\partial H}{\partial x} + vi\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2}\right) - c_f u + fv \tag{11}$$

$$c_f = \frac{n^2 g|V|}{R^{\frac{4}{3}}} \tag{12}$$

$$f = 2\omega \sin\phi \tag{13}$$

Where u and v are velocities in the Cartesian direction (m/s), g is the acceleration due to gravity (m²/s), vi is the horizontal efficiency of eddy viscosity, cf is the friction coefficient, R is the hydraulic radius and f is the Coriolis parameter (HEC-RAS Reference Manual, 2018). The momentum equation in the form of a simple and differential diffusion wave is as follows:

$$\frac{\partial H}{\partial t} - \nabla \cdot \beta \nabla H + q = 0 \tag{14}$$

$$\beta = \frac{(R(H))^{\frac{5}{3}}}{n|\nabla H|^{\frac{1}{2}}} \tag{15}$$

$$\frac{n^2|V|V}{(R(H))^{\frac{4}{3}}}=\nabla H \quad (16)$$

$$V=\frac{(R(H))^{\frac{2}{3}}}{n}\frac{\nabla H}{|\nabla H|^{\frac{1}{2}}} \quad (17)$$

Where V is the velocity vector (m/s), R is the hydraulic radius, and ∇H is the slope of the surface elevation and n is the empirical value of the Manning coefficient (HEC-RAS Manual Reference, 2018).

b) Governing Equation of Hydrodynamic Model

Delft3D-FLOW solves the Navier Stokes equation for incompressible fluids, under shallow water and the Boussinesq assumption. In the vertical momentum equation, the acceleration is negligible, which leads to the hydrostatic pressure equation. In the 3D model, the vertical velocity is calculated from the continuity equation (Deltt-3d, 2014).

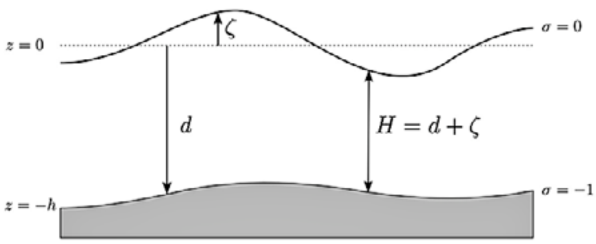


Figure 7. Definition of water level (, depth (h) and total depth (H) (Delft-3d, 2014)

c) Depth-averaged continuity equation

The depth-averaged continuity equation is given by:

$$\frac{\partial \zeta}{\partial t}+\frac{1}{\sqrt{G_{\xi\xi}}\sqrt{G_{\eta\eta}}}\frac{\partial(d+\zeta)U\sqrt{G_{\eta\eta}}}{\partial \xi}+\frac{\partial(d+\zeta)V\sqrt{G_{\eta\eta}}}{\partial \eta}=0 \quad (18)$$

Where U and V indicate the depth-average velocities on orthogonal curvilinear grid.

Momentun equations in horizontal direction

The momentum euqations in ξ and η direction area given by:

$$\frac{\partial U}{\partial t}+\frac{U}{\sqrt{G_{\xi\xi}}}\frac{\partial U}{\partial \xi}+\frac{V}{\sqrt{G_{\eta\eta}}}\frac{\partial U}{\partial \eta}+\frac{UV}{\sqrt{G_{\xi\xi}}\sqrt{G_{\eta\eta}}}\frac{\partial\sqrt{G_{\xi\xi}}}{\partial \eta}-\frac{V^2}{\sqrt{G_{\xi\xi}}\sqrt{G_{\eta\eta}}}\frac{\partial\sqrt{G_{\eta\eta}}}{\partial \xi}-fV$$

1

$$=\frac{1}{\rho_0\sqrt{G_{\xi\xi}}}P_\xi-\frac{GU\sqrt{U^2+V^2}}{C_{2D}^2(d+\varsigma)}+F_\xi+F_{s\xi}+M_\xi \quad (19)$$

The fourth termon the right-hand side represents the effect of secondary flow on the depth average velocities (shear stress by depth-averaging the non-linear acceleration terms).

d) Boundary Condition

In some timesteps, boundary conditions must be given to all domains (HEC-RAS Manual Reference, 2018), namely:

1. Water level: the value of the water level H = Hb is given one side of the boundary condition.
2. Water level gradient: the slope of the water surface Sb in the normal direction along the boundary. This condition is expressed as follows:

$$\nabla H \cdot n = S_b \quad (20)$$

Discharge: A Qb debit that is crossed in boundary conditions must be available.

3. The boundary requirement for coastal hydrodynamic modeling is to use the results of tide analysis.

Discussion

Climate Change Analysis

Intergovernmental Panel on Climate Change (IPPC) stated that global climate change has resulted in an increase in the average temperature in Indonesia from 0.004 to 0.04oC per year. An increase in temperature of 1.5oC results in the risk of sea- level rise, an increase in heavy rainfall which of course will have implications for flooding in coastal areas or downstream of rivers. There are three features of climate change aspects, namely temperature, rainfall, sea level rise. Climate change studies use climatological data around Pekalongan sourced from the Meteorological, Climatology and Geophysics Agency. The analysis was tcarried out to study the factors that influence climate change at the location, namely temperature and rainfall over a period of 20 years (2000-2019).

Results graph annual average temperature on the north coast of Pekalongan for twenty years (2000-2019) showed an increase in average temperatures

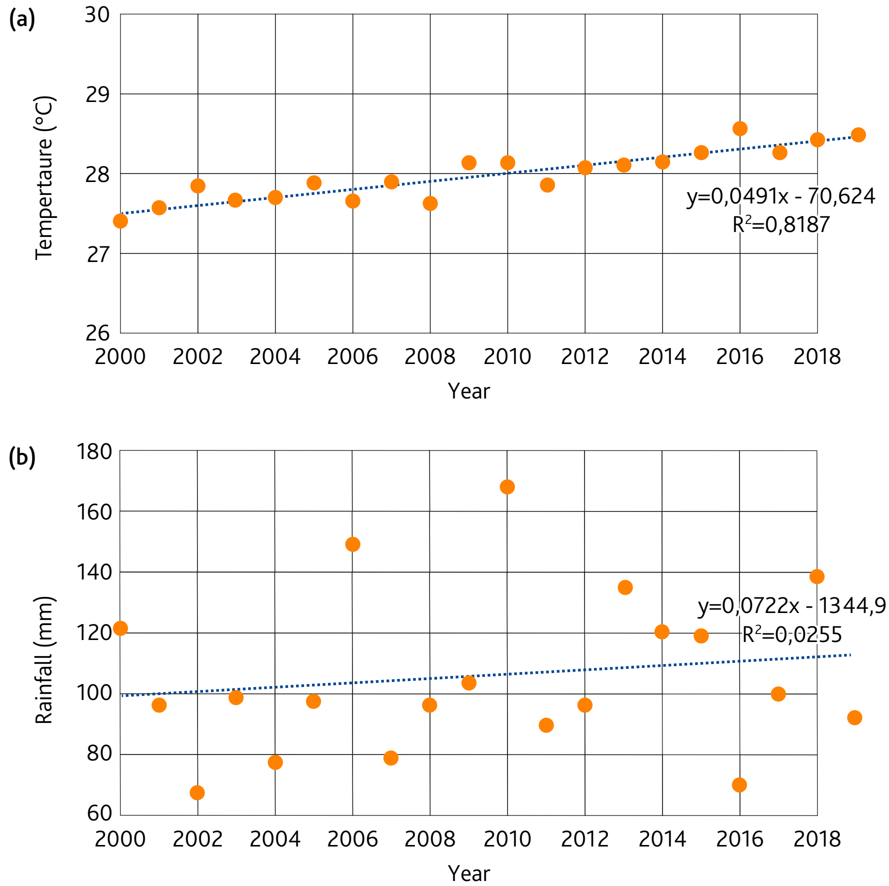


Figure 8. Trend of temperature rise (a) and maximum annual rainfall (b) in the Pekalongan area

around 1° Celsius and a trend towards maximum rainfall occurring during the period of twenty years has increased (Figure 8).

Climate change also causes changes in rainfall patterns, the total annual rainfall in Pekalongan City for twenty years tends to decline although not significantly (Figure 9), this is in accordance with the results of predictions have been in the Java Island region (Figure 10), where in the location of the City of Pekalongan experiences a trend of changes in rainfall decreasing lightly in the years 2032-2040 (Meteorological, Climatological, and Geophysical Agency, 2020). Meanwhile, the duration of rain will last for a short time with a tendency for rainfall intensity to be higher than normal rainfall, which causes flood disasters (Meiviana, et al., 2015).

The results of studies that have been conducted (Perdana, 2015) show that the north coast of Cen-

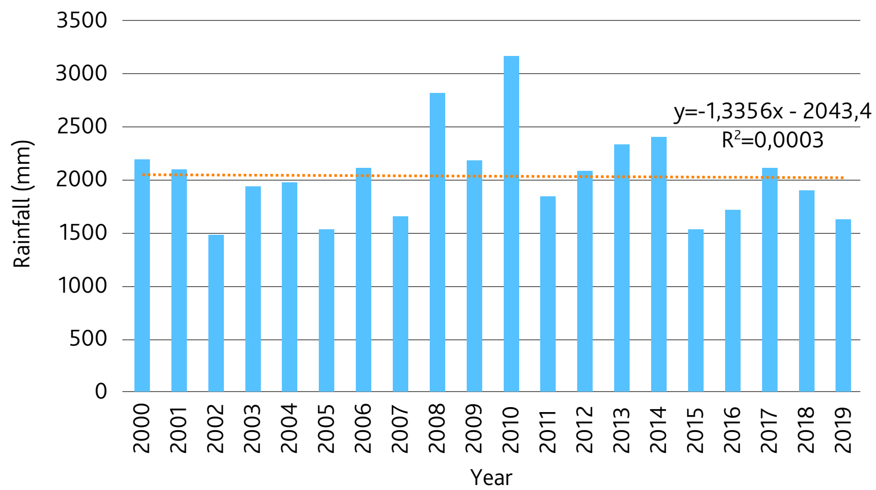


Figure 9. Trend of Total Annual Rainfall in Pekalongan Region (2000-2019 Period)

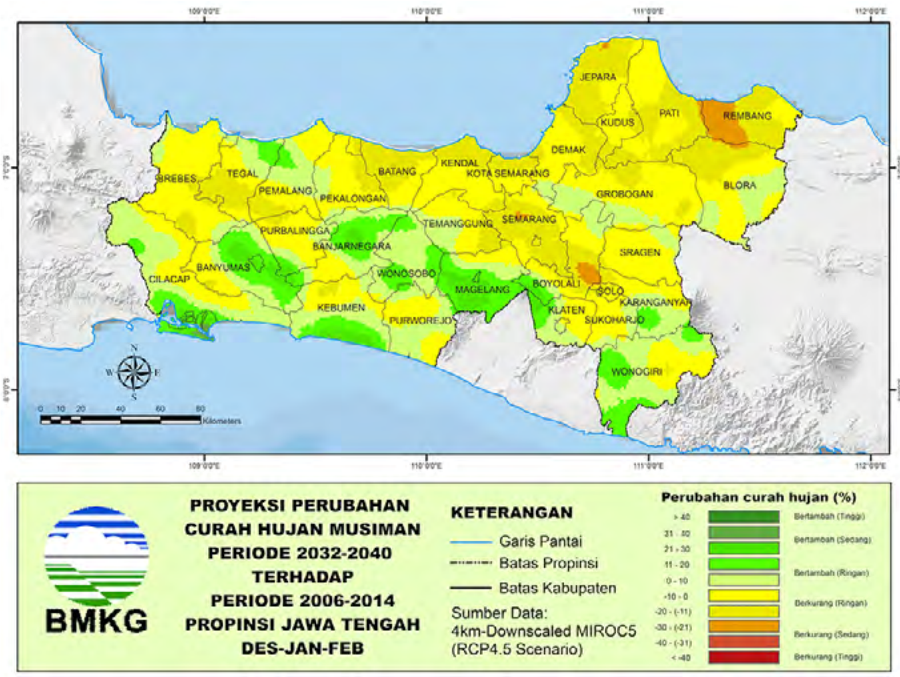


Figure 10. Projected Changes in Rainfall for the Period of 2032 - 2040 (Source BMKG)

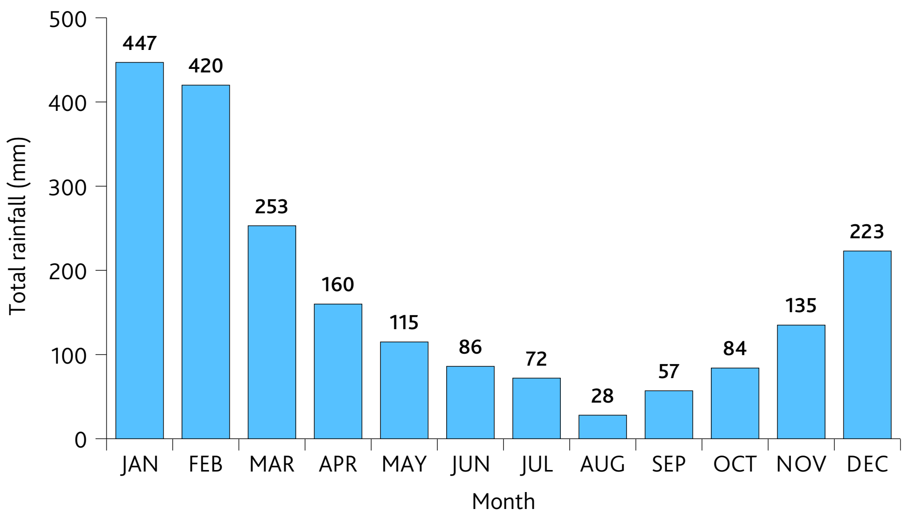


Figure 11. Rezim of Monthly Average Rainfall in Pekalongan Region (2000-2019 Period)

tral Java has a monsoonal climate. In the monsoonal rainfall pattern, the region has a clear difference between the rainy season and the dry season. In general, the dry season lasts from April to September and the rainy season from October to March.

Tidal flooding is expected to continue to increase both in frequency and in height in the future, in line with the tidal floods are expected to continue to increase only because of the likely climate change trend to be ongoing or so. Changes in rainfall patterns will affect the occurrence of flooding in the downstream area of the Kupang watershed (Pekalongan coast). This is due to an increase in the maximum rainfall intensity which tends to be higher and the ability of the soil to infiltrate is very low.

Flood Discharge Analysis

Hourly rain distribution (rain distribution) is determined by direct observation of the hourly rainfall recording data at stations that have the most influence on the watershed. If available, it can mimic the behavior of hourly rain which is similar to the local area at the same latitude and altitude. This distribution is obtained by grouping the rain heights into ranges with certain heights intensity duration frequency (IDF). From the data that has been compiled in the range of rain heights, a design rainfall distribution is selected based on the analysis of the highest frequency and frequency of appearance in the distribution of rain at certain times. The results of the rain distribution in the intensity duration frequency (IDF) in Pekalongan. IDF describes

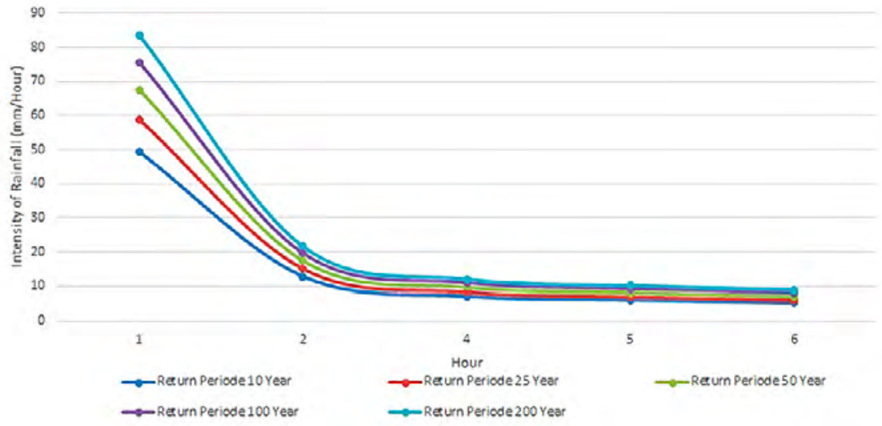


Figure 12. Intensity Duration Frequency in Pekalongan

the value of the number of rain as a function of duration for a certain return period and is very important for the design of hydraulic structures (Overeem, et.al., 2008). The IDF has many drawbacks in hydrology and surface water engineering including in the design of urban drainage infrastructure. IDF graph form can be seen in the following table and figure 12.

Analysis of the planned flood discharge using the Nakayasu Synthetic Unit Hydrograph (HSS) method, this is in accordance with the explanation provided in the methodology. The rain input used is the calculated rain from the Gumbel probability distribution with various return periods as previously analyzed with the focus of the analysis, namely the Kupang watershed with the main river, the Banger River. The results of the calculated flood discharge analysis with various return periods can be seen in the following figure.

Based on the graph above, a 50-year return period was used in modeling the floods in the Kupang watershed, where the Pekalongan River is the main river with a control point at the study location with a planned discharge of 557.23 m^3/s. Based on the analysis of the discharge that enters the Banger river network system, which is about 70% of the total discharge in the Kupang watershed, so the amount of discharge to be used in the flood modeling is 390.06 m^3/s.

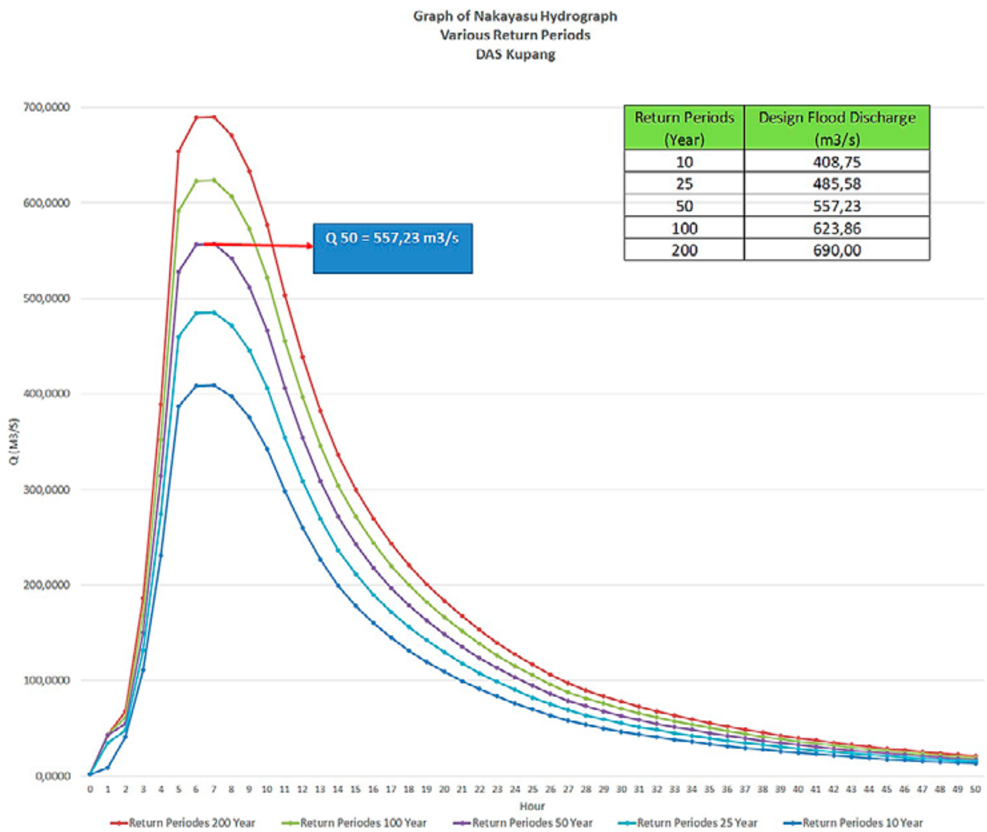


Figure 13. Flood Discharge Graph Planned Various Return Periods

Hydraulic Flood Two Dimensional Model

The distributed model is generally used to investigate the effects of land cover change on flood discharge due to urbanization. The model must have sufficient spatial data parameters to resemble actual conditions and to achieve good accuracy (Fardi et.al., 2011). Unfortunately, most developing countries have limited and inadequate datasets. Circumstances can be a problem in distributed flood model simulations. The number of scenarios that must be developed and analyzed is so complex that a simple numerical method is used to calculate the flood area in each scenario.

One of the efforts made is to study the effect of the distribution of flood hydrographs and flood inundation. For the model of flood hazard, it is necessary to do 2D flood flow modeling. Mapping a 2-dimensional flood model is very useful to identify areas that are potentially affected by flooding (Formanek et al., 2013) The input hydraulic model is very important for hydraulic flood modeling. Hydrograph analysis for rivers where there is no or very little flood hydrograph observation, it is necessary to look for the characteristics or parameters of the drainage area first, for example, the time to reach the top of the hydrograph (time to peak magnitude), bottom width, area, slope, the longest channel length (length of the longest channel), runoff coefficient and so on (Siregar, 2016). The resulting solutions represent flood characteristics such as inundation area, inundation depth, and flow velocity Two-dimensional hydraulic analysis using hec-ras software where this modeling is basic modeling to determine the area of inundation that occurs based on hydrological data input in the form of a flood hydrograph. The Result of the analysis is given in the figure below.

The rivers that were carried out by flood discharge modeling were the Pekalongan River and the Banger River. From the results of the flood modeling, inundation or runoff occurred from the Pekalongan and Banger rivers. The locations affected include Jalan Kusuma Bangsa, Jalan Wr. Supratman, Jl. Panjang Wetan, Jalan Sampangan, Jl. Jranpang, Jl. Trimbing and Jl. Krapyak. To overcome the flood problems above, structural and non-structural efforts are needed. Structural efforts include building infrastructure to deal with floods, such as retention ponds, long-storage, polders, reservoirs. Non-structural efforts made include improving disaster mitigation and outreach to the community around the Pekalongan Coastal Coast. The thing of concern in handling floods around the coast is the presence of tidal conditions that cause back-water around the coast, which impedes the flow to the sea and raises the water level in the upstream. In order for the flood problem to be addressed properly, it is necessary to carry out an integrated solution so that it can be resolved comprehensively.

Coastal Hydrodynamic Model

Two-dimensional hydrodynamic modeling using Delft-3d software. The boundary conditions used in the modeling are the tides of sea water with the addition of sea level rise and land subsidence in the next 50 years. From the analysis, the increase in water level due to global warming is estimated to be 230 mm and decrease of land subsidence is 240 cm. This data is used to perform hydrodynamic modeling. Changes in tidal fluctuations can be seen in the table below.

The modeling process is carried out by using the flow module where in this modeling the boundary conditions used are astronomical boundary require-

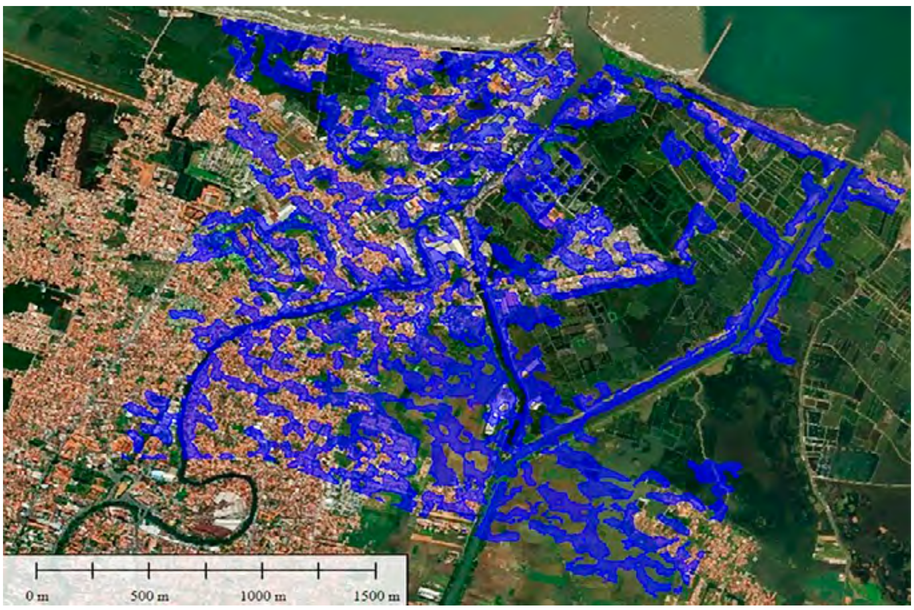


Figure 14. The Result of hydraulic flood two dimentional modelling in Pekalongan Coastal

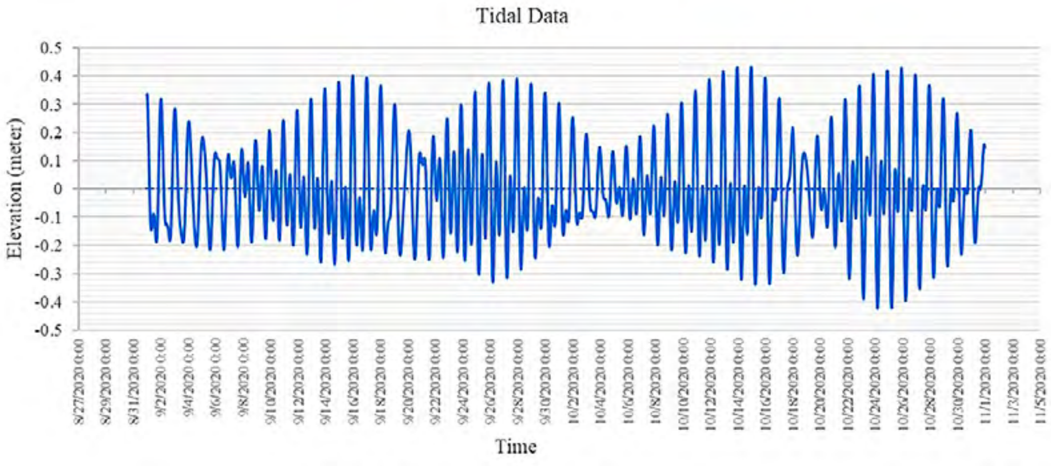
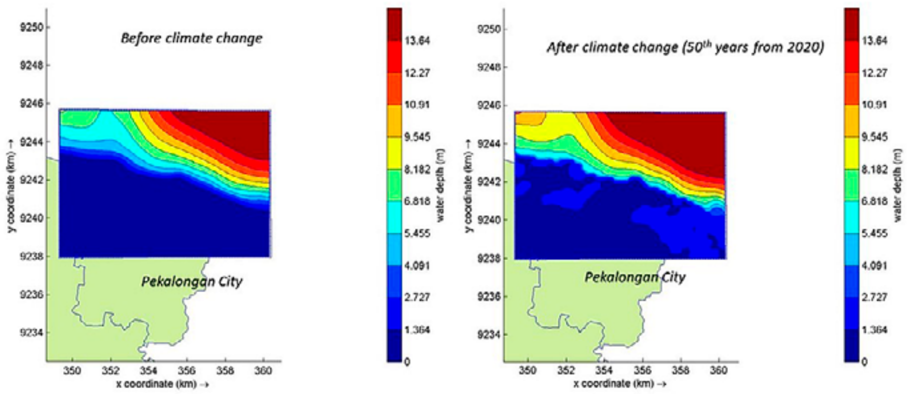


Figure 15. Tidal Data Used

ments which describe the fluxutation of sea level at high tide and low tide. From the results of the analysis carried out, it can be seen in the image below that at the moment the coastal area of Pekalongan is still safe against sea water, for the next 50 years based on sea

Environment, the existing infrastructure arrangement in Pekalongan which refers to eco green infrastructure will certainly have an impact on the environment which includes conservation, prevention of water pollution, preserving biota and preserving the



The Simulation is using hydrodynamic model DELFT-3D :
(a) Before Climate Change and Land-Subsidence ; (b) After Climate Change and Land-Subsidence (50th years from 2020)

Figure 16. Result of Hydronynamic model before and After Climate Change and Land Subsidence

level rise and land subsidence, several coastal areas of Pekalongan are inundated by tides. From the modeling results, the coastal area of Pekalongan is very vulnerable to sea level rise in the future. In addition, with flooding due to higher flood discharge due to changes in land use, the flood inundation in the coastal area has become wider not only in the coastal area but to the upstream coastal area around Pekalongan City. This condition is the basis for how structural efforts are made to solve these problems.

Coastal Hydrodynamic Model

The concept of sustainable development in the arrangement of the Pekalongan coastal area through the development of integrated tidal flood control infrastructure, can be explained as follows:

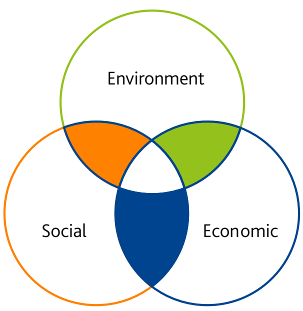


Figure 17. Three aspects of sustainable development

environment, preventing destruction. water which has an impact on the environment, reduces air pollution or increases in CO_2 and so on.

Economic, structuring existing infrastructure in Pekalongan from an economic perspective, to increase revenue from the Pekalongan Regional Budget, namely through the use of embankments / embankments as an outer ring road that can contribute to economic recovery, the use of polders as conservative reservoirs that can be used as tourist attractions, greenbelt areas or Green areas that can be used as agricultural or plantation land which are useful for increasing production yields so as to restore the economy, development of resorts and cafes around the coast also supports economic improvement.

Social perspective, the existing infrastructure arrangement in Pekalongan will establish coordination between the local government and the community towards the environment. One example is the formation of a Green Community which is mutually beneficial to the local government. In addition, there is empowerment of human resources that occurs in the surrounding community, namely by involving the surrounding community in the management of tourism, fisheries and other related fields.

The involvement of all relevant stakeholders is also needed in the handling of the Pekalongan coastal tidal flood. Holistic coordination also means that all problems of damage and environmental management of the coastal areas of Pekalongan must be the responsibility of all parties (government, NGOs, communities, and individuals) and all regions (whether local, regional, national). The responsibility of the regional head moves all stakeholders to realize the vision and mission of the region through the Pekalongan coastal area arrangement policies, strategies and programs, both short and long term. So that the problem of tidal flooding on Pekalongan Beach can be resolved with holistic policies both structurally and non-structurally.

Design Concept

Alternative 1

The concept of alternative flood management 1 in the Pekalongan area that will be carried out is a physical treatment that aims to limit the tidal inflow towards the mainland, create temporary storage of water from the land that should be wasted downstream, periodically pump the stored water downstream and increase the river storage capacity by making embankments. The concept of alternative flood management 1 can be seen in the following figure 18.

Physical development that requires handling include:

- Making a dike separating land and sea areas
- Making longstorage / carrying channel parallel to the tidal floods separation dike
- Utilization of pumps requires a larger and optimal capacity so that the tidal flood inundation area can be immediately pumped into long storage and retention ponds as water storage and will be pumped when the river water level has receded.
- Making river embankments and / or raising sungi parapets which are still not high enough
- Perform river normalization, especially in the river estuary area
- Making drain collectors at several locations which are at a lower elevation than the tide level. A pumping system is needed in this area so that stagnant water can be channeled into rivers / sea.

Alternative 2

The tidal flood handling concept in alternative 2 adopts a waterfront city concept that is integrated with regional development planning to support economic improvement on the coast of Pekalongan through integrated area development such as tourism, raw water storage, industrial, sports, business areas and residential areas. The objective of this alternative design is to protect the coastal area of Pekalongan from the threat of tidal flooding and environmental degradation. Through this design concept, it is hoped that several main issues related to problems in the coastal area of Pekalongan, such as the threat of tidal flooding, land subsidence, limited raw water, and

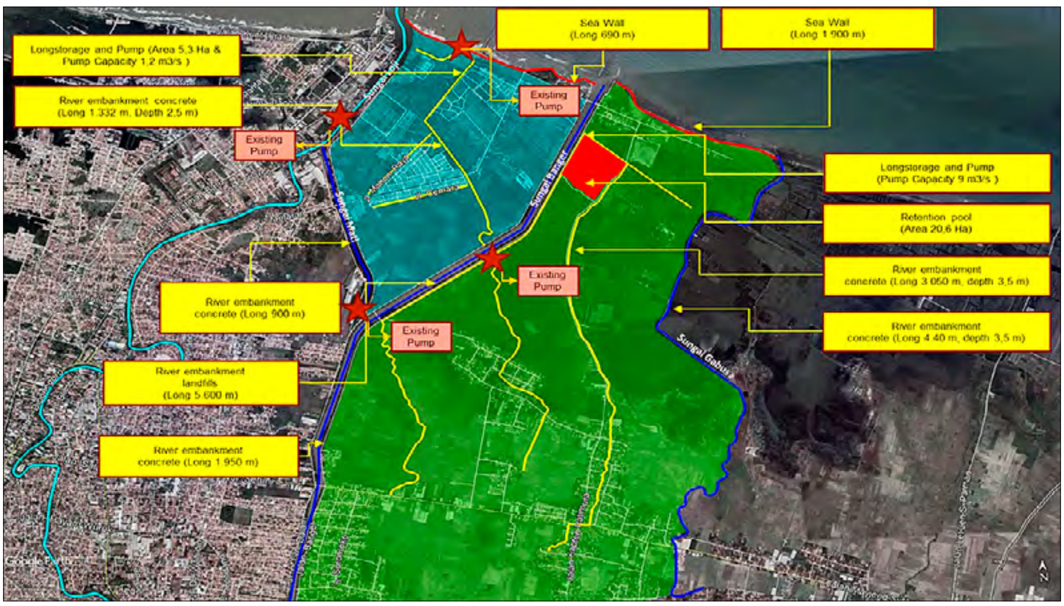


Figure 18. Design Concept (Alternative 1)

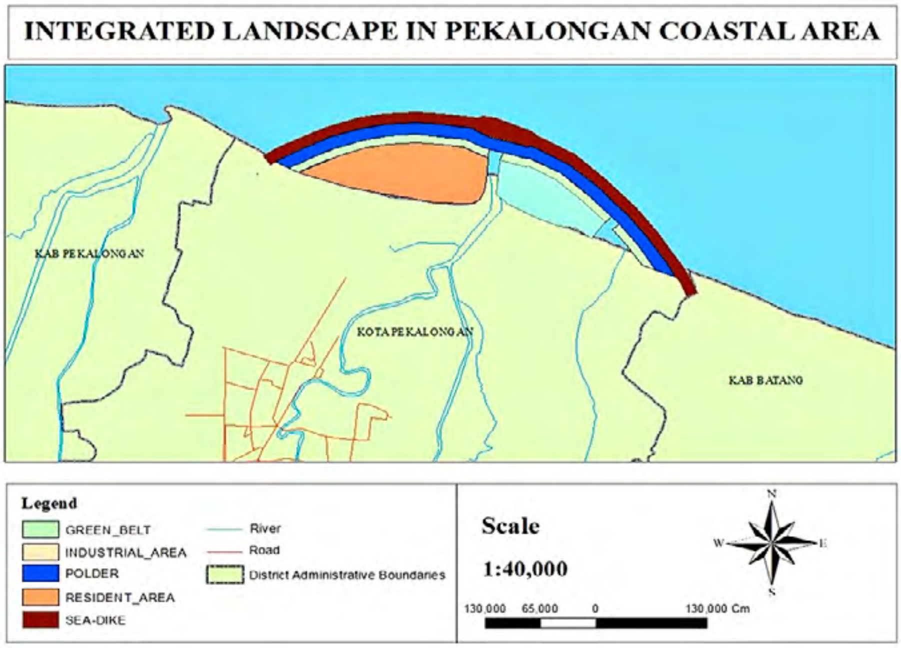


Figure 19. Layout Map of Pekalongan Tidal Floods Management Concept Design (Alternative 2)

the arrangement of the transportation and settlement system can be resolved. Based on the concept previously described, there are several stages in realizing a waterfront city on the coast of Pekalongan, namely:

1. Construction of sea embankments and river estuaries
2. Construction of sea reservoirs, floodgates and construction of pumping stations
3. Reclamation of coastal areas that can be utilized as an integrated residential area or business area
4. Development of supporting infrastructure, roads and bridges connecting areas, residential areas and business areas located on reclaimed land.

The real condition design concept for alternative 2 can be seen as shown below.

Explanation related to the Pekalongan flood handling design concept Alternative 2:

1. The arch is the outermost part of the arc of sea dikes or levees sea which can be used as an outer ring road or road travel with a primary function as a sea dike protecting sea water runoff, overtopping or may overcome the tidal flood
2. The polder can be used as a reservoir for raw water originating from the Banger River and the Loji River and separated by a water gate on the middle side

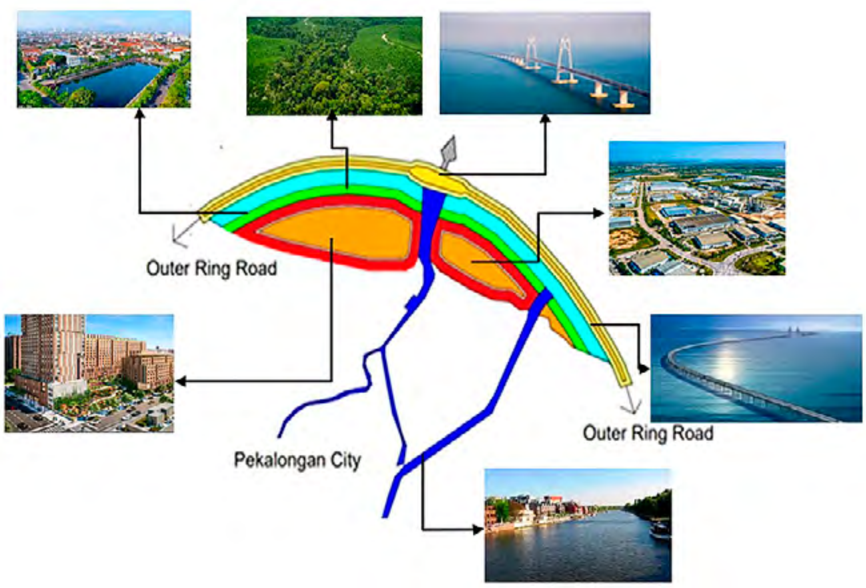


Figure 20. Design Concept for Tidal Floods Pekalongan Flood Management (Alternative 2)

which is a canal that functions as a channel for fishermen to enter and exit.
3. Green belt area or green area that is used for protection of the environment, conservation of water, fisheries and is useful as a tourist spot, namely a mangrove tourism park.
4. Residential areas that use green roofs and green walls which aim to create buildings that are environmentally friendly as well as Industrial, Sport and Business Areas such as those aimed at improving the economy of the Pekalongan community.

Alternative Design Concept Philosophy 2:

The concept of structuring forms an arc which has a philosophy, which is to symbolize the stability realized through sustainable development that is able to improve the economy and symbolizes conformity to targets which can be seen from the existence of regional arrangement designs and infrastructure development in accordance with existing quality standards. The Handling Design Concept can be seen as shown below.

Conclusion

During the last 20 years there has been an increase in temperature around the north coast of Pekalongan by one degree Celsius. This will certainly have an impact on increasing sea level on the coast of Pekalongan. The increase in maximum daily rainfall during the last twenty years has also occurred in the Kupang watershed, which is the chatcment area of the Pekalongan River. Both of these can increase the incidence of flooding in the downstream watershed or the coast of Pekalongan. The total area of the tidal flood inundation that occurred was 458.3 ha, with inundation heights varying from twenty centimeters to one meter.

The results of the flood modeling show that there are flooded areas, especially in areas around river flow, particularly in areas affected by tides. One thing of concern in handling floods around the coast is the presence of tidal conditions that cause back water around the coast, thus obstructing the flow to the sea and raising the water level in the upstream. In order for the flood problem to be resolved, an integrated solution is needed so that it can be resolved comprehensively.

Regarding the two design alternatives that we present, there are several considerations in choosing the right alternative in solving the tidal flood problem on Pekalongan beach. In choosing alternative 1, it is necessary to pay attention to operations related to operation and maintenance of flood pumps. If the flood pump experiences problems or does not function optimally, then the flood management in the coastal area of Pekalongan cannot be handled optimally. So it requires human resources as operators who are able to operate and maintain flood pumps properly, as well as public concern to protect the environment from waste problems. If using alternative design 2 to solve the problem of tidal flooding in Pekalongan, it does not require much operation and maintenance. but the consequences are large costs at the beginning of development.

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The Perception of Pathumthani Residents toward its Environmental Quality, Suburban Area of Thailand

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Abstract

The urbanization process is often concentrated mostly in urban areas, resulting into urban development sprawl. This has effects on the lifestyles and activities of urban people, which in turn significantly affects the health of the city. The quality of the urban environment plays an important role in public health with respect to urban issues ranging from quality of utilities and services to quality of life. This study aims to study the perception of Pathumthani residents toward its environmental quality through spatial cluster analysis. A total of 1,000 sets of data collected from the interview survey among residents or commuters traveling through Pathumthani province was used for this study. The residents' response towards environmental factors was examined through the classification of their different opinions among built environment and health aspects. The statistical analysis which was performed in this study was cluster analysis to demonstrate its relationship. With the level of satisfaction on environment aspect and health status in indicating number of congenital diseases, the result of this study found that condition of living environment (through Likert scale) affects the urban health with statistical significance of ($P < 0.05$). Therefore, provincial health policy should focus more on developing a healthy city in consistence with economic and social development while putting adequate mechanisms for environmental surveillance monitoring at the community level. The result of study can confirm the usefulness of this unconventional approach by asking residents or commuters about their satisfaction on built environment which can represent as an evidence-based planning approach by linking local people attitudes and translating them into creating liveable and better urban environmental quality. To have a good understanding of local people preferences, the recommendation to be given to the capacity of communities can be focused for improving people's quality of life by providing better accessibility, high quality of infrastructures and services. Finally, a set of features of satisfied built environment can help to support the continued growth of the city in term of basic need and sufficiency provision of facility and utility system.

Keywords: built environmental; health; satisfaction; quality of life; urbanization

Introduction

The urbanization process in the developing world has been occurring in a rapid pace with high growth concentration mostly in urban areas (World urbanization prospects, 2018). The quality of the urban environment has become an essential element to be considered in public health discourse like issues ranging from solid waste disposal, safe water and sanitation as well as safety and injury prevention. Health is de-

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fined as a state of complete physical and mental which represent not just a lack of disease or weakness, but also includes a social well-being. To reach the highest standards of health is an ultimate goal in achieving and exemplifying one of the fundamental rights of all human beings irrespective of race, religion, political beliefs, economy or society (WHO, 1946). For Thailand, the direction of health movement has changed over time, originally focusing on AIDS prevention and control, development and improvement of occupational health work, environmental health work, expansion of quality of public service, consumer protection, child health development, agricultural development, and traffic pollution problems solution (Development Plan No. 1-7: 1961-1996). This led to a development strategy that focuses on the development of the "people" as a whole and effective management to restore the economy. It is imperative to note that health is a well-being that consists of complete and balanced physical, mental, social and spiritual well-being a person. The development of public health is carried out in relation to various economic, social, cultural, values, behavior and environmental factors. The health policy is planned to comprehend the problems more holistically (Development Plan No. 8-9: 1997-2006) and immediately after the 10th National Development Plan, balancing and sustainability became the center of emphasis. Balancing the developmental strategy of the country is achieved by linking all dimensions of integrated and holistic development including the "human, social, economic, environmental and political dimensions". Consequently, it can be seen that the issues to be considered in an urban health is not just the health factor, but other influencing factors should also be included.

However, in this current age of chronic diseases, association between population health and the built environment still remained. It can be seen that physical spaces can directly expose people to urban pollutants and influence on people lifestyles (Perdue et al., 2003). The consideration of the built environment includes all the human-made physical spaces which corresponds to the spaces for living, recreation and working. The physical structures like urban components were engineered and designed by people which became the places for our everyday life of working, living, playing and socialization. Also, urban physical is affecting to the enhancement of social capital in either positive or negative perspectives (Iamtrakul et al., 2018). These urban elements include our buildings, furnishings, public open spaces, roads, utilities, and other infrastructures which affects our health condition through both direct and indirect pollutions and externalities (Collaborative on health and the environment, 2016). The built environmental factors can generate both positive and negative impact on the urban health depending on an appropriateness of the planning and development. Its positive effect to the cities can be viewed from composition of green spaces, sidewalks and bicycle lanes that promotes physical exercise and mental health, improved markers of cardiovascular and metabolic health (Centers for Disease Control and Prevention, 2011; Office of the Surgeon General, 2015). In terms of the negatives, it contains built environment factors associated with more motor vehicle-pedestrian incidents. These increasing exposures consists of harmful contaminants in urban ambience which can reduce life expectancy and worsen the ill effects of some respiratory conditions (Teo et al., 2015; Grant et al., 2009). Therefore, the level of carbon consumption in our environments must be reduced since carbon has been proven to be impactful on human conditions and behaviors in a variety of ways (Ebmeier, 2012). The built environment also includes housing component and several housing factors are associated with mental and physical health impacts, e.g., air quality, infestation, noise, lighting, housing tenure and design (Macdonald, and Thompson, 2003). In the case of Thailand, one of the countries that has experienced significant changes in various areas of urban growth showed the main reason for rapid expansion of the urban areas due to peoples' migration to bigger cities. It is projected that in near future, more than 73 percent of the Thai population will become urban (Office of knowledge management and development, 2015). Although the greatest growth of population has occurred in Bangkok and vicinity (5 province namely; Nakhon Pathom, Pathumthani, Nonthaburi, Samut Prakan, Samut Sakhon), the unfortunate situation is that it has also created environmental problems such as dispersion of environmental pollution caused by emissions of pollutants from vehicles, industrial suburbs and houses, as well as pressures in demand for utilities. These challenges also include lack adequate of drinking water, waste and hazardous waste from homes, hospitals and industries, congested traffic caused by the rapid increase in number of vehicles etc. (Bureau of technical advisors, 2020).

In terms of social and economic problems, these are obviously seen in the outskirt are of Bangkok due to various activities concentrated disproportionately within this zone. A complex mix of activities around the industrial spaces, living neighborhoods, and commercial areas has resulted in the diversity of the population within the area. Considering the urban sprawling phenomena, the suburban areas also induce a large concentration of commercial activities, educational institutions as well as industrial estates and the regional market that attracts visitors from neighboring provinces and represented as regional attraction nodes. A wide range of activities and social diversity can reflect the demand on city's infrastructure both availability and quality of services which are at the core of many of the challenges faced by rapidly urbanization.

According to the Pathumthani Provincial Health Office (2020), there are 6 major public health problem areas in hierarchical order of importance which consist of: 1) non-communicable diseases (NCDs), disease group include mental health/ drugs/traffic accidents, 2) communicable diseases, spread by insects, 3) environment related illnesses such as exposure to general waste/solid waste/waste water/unhygienic food/ pesticide residues, 4) dependency (i.e., home addiction) bedridden/falls/dementia, 5) mother and child health and 6) elderly health. Therefore, urban development should be seen as an essential part of driving force for an urban growth capable of creating a wide range of urban utilization activities. However, in situation where activity within the city is overly developed, it could lead to problem dimensions that can be impactful on the health of the citizens of the city; leading to deteriorating state or the risk within the city. Therefore, this study focused on the study of the relationship of the built environmental and urban health based on residents' perspectives in order to provide guidance in urban health development as regards development issues in the urban environment. This study is expected to generate a positive influence and a fundamental human need in order to live with complete happiness under urban development.

Data and methods

Literature review

When we look at the components of the built environment, it is expected it involves several material determinants of health including housing, neighborhood conditions and transport routes because they have an effect on the social, economic and environmental conditions (Barton et al., 2006). Good health impact is directly or indirectly dependent on the built environment in terms of health condition and wellbeing; including those traditionally associated with infrastructure planning and environmental health. These externalities include air quality (indoor and outdoor), climate, water quantity and quality, noise, traffic-related injuries, etc. (Borasi, et al., 2012; Frumkin et al., 2004; Sustainable development commission, 2008). The quality of space utilization is obviously depending on living and working physical condition which includes buildings, streets, and built environment components. Consequently, the health of individuals and populations is affected by the surrounding environment that is planned and managed by urban development. This process is an essential part that controls and drives urban growth through which a wide range of urban activities are created. However, there are series of activities that can cause physical and environmental degradation in service areas capable of affecting the society and causing economy disorder. It has become obvious that all these impacts on the urban health ranging from the deteriorating conditions to the risks within the city has caused a shift in conceptualizations of health and disease prevention. The paradigm shift is from the treatment of illness in individuals to disease prevention and health promotion in populations, with more focus on the impact of the environment on collective well-being (McLeroy et al., 1988; Stokols, 1996).

The built environment results in the differences between the objective environment and subjective perception of the environment through residents' view. Perceptions of different people may influence the understanding of these cognitive representations, and perceptions of the environment which may not correspond to objective reality (Ewing & Handy 2009). Perceptions of the built environment reflect an individual's interaction with the actual environment, involving an awareness and perception through their primary receptive senses (Sherrington, 1961). Consequently, respondents' direct experiences with specific residential location can be captured and reflect through their perspective which plays an important role in disease dynamics and in determining the health of individuals, particularly from the built environment (Pinter-Wollman et al., 2018). The current understanding of health combines absence of disease and a state of complete physical, mental and social well-being which emphasize the approach of prevention as important as cure to be explored for long-term solutions (Tsekleved & Cooper, 2017).

Therefore, the definition of health to be considered in the built environment design should cover a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity (WHO, 1946). However, there is relationship between health outcomes and risk factors associated with the built environment like physical activity, dietary intake, blood pressure, obesity, cardiovascular disease, diabetes mellitus, cardiometabolic syndrome, and mental health (Nathan et al., 2018; Durand et al., 2016; Christian et al., 2011; Sundquist et al., 2015). On a final note, the built environment has been increasingly recognized as being associated with health outcomes which has been regarded as part of the problem, though it differed among diverse groups, ranging in different socio-economic characteristics. However, all concerns factor that are based on individual level associated with built environment must be included as a part of the solution (Villanueva et al., 2013). Different residents to perceive the same physical space through different lens can be evidence supporting the importance of environmental variables in health and perception in environmental quality which is a key decision-point for planners to understand prior to any design, planning and policy intervention.

Study area and data collection

Data for this study was collected from a data sample using the method for calculation of population size of Taro Yamane's calculation formula (Taro, 1967). It was considered with the acceptable size error of 95% from the population of 1.129 million people (2017). For a wider coverage and a larger data sample size, a total of 1,000 data sets were collected from people living within the area or traveling through Pathumthani Province which is the representative of suburban area of Thailand (Figure 1).

The study area consists of 7 districts which are; 1) Nong Suea District, 2) Thanyaburi District, 3) Lam Luk Ka District, 4) Khlong Luang District, 5) Lat Lum Kaeo District, 6) Sam Khok District, and 7) Mueang Pathumthani District. The number of questionnaires which were distributed in the study area were determined from the population size of each district to demonstrate the appropriate representation of the population in each area. All districts were achieved through the number of distributions of questionnaires to cover the number of samples in spatial areas of all grids.

Procedure and analysis

This study focused on the relationship of built environment and urban health by perform the evaluation through cluster analysis as depicted in Figure 2. A total set of 1,000 data from residents living within the area or traveling through Pathumthani province was input into the step of analysis which consisted of 2 group of variables as follows:

1. *Built environment factors:* comprises of water, air quality, dust pollution, noise, industrial area, housing, infrastructure, transportation. These factors were assessed by using Likert scale to demonstrate level of problem about built environment factor. The level of assessment can be classified by Likert scale ranging from 1 [the lowest satisfaction of environment aspect] to 5 [the highest satisfaction of environment aspect] in all attributes of built environment factors.
2. *Health status factors:* comprises of congenital disease and it was explained by variable of health status in indicating number of chronic diseases. The data of congenital disease were collected from questionnaires by asking whether there is an underlying disease or not. The level of health was classified in 5 level which 1 score represents the lowest level of

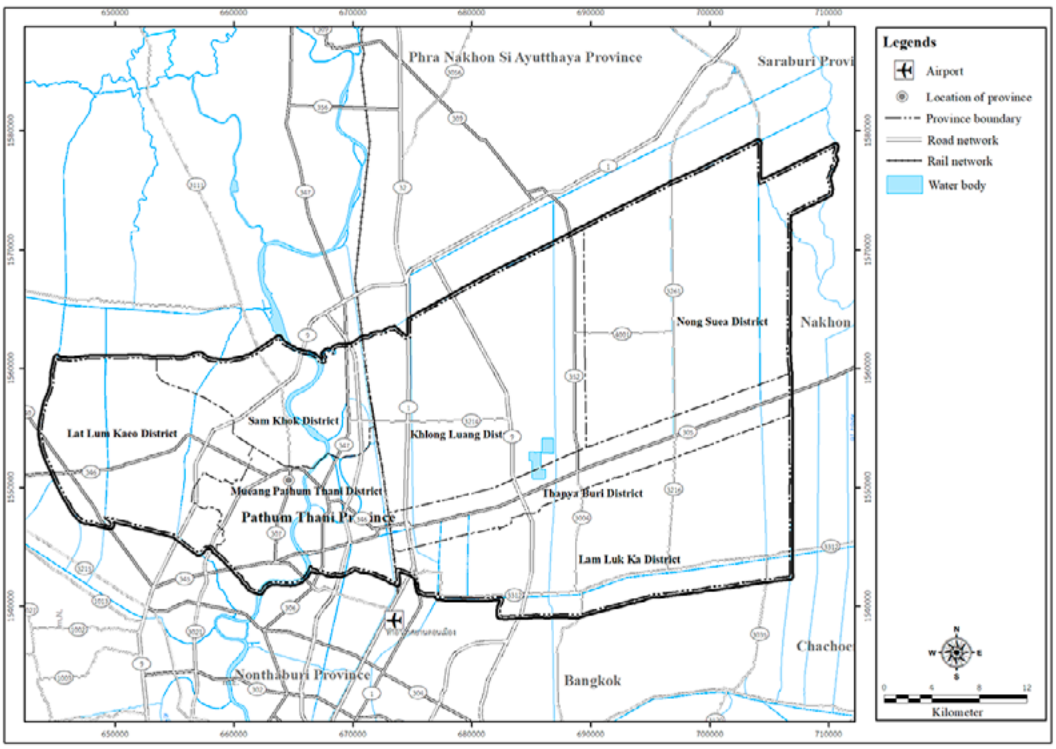


Figure 1. Study area: Pathumthani province

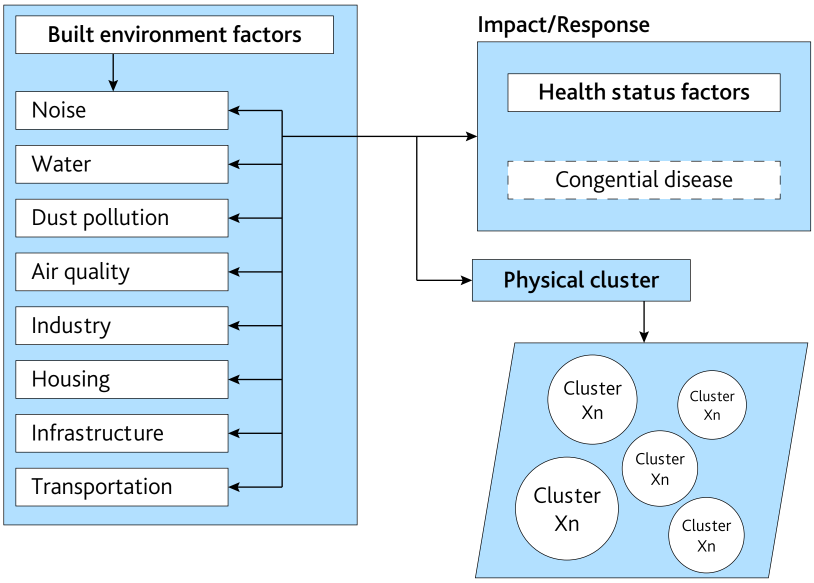


Figure 2. Framework of study

health status (respondents with more than 4 diseases) and 5 score demonstrates good health condition (respondent without any congenital disease).

A cluster analysis was performed to classify different built environment factors in the study area and its relationship with health condition of residents. To evaluate all aspect of the built environment factors that affects the health status of samples from residents in the study area, the level of significance for the analyses was set at $p < .05$. Thus, the imported variables to be input in the clustering analysis consist of the set of data from built environment factors and health status factors which was explained in the previous details.

Results

This study was conducted to determine the relationship between the factors affecting the development of healthy cities. The result of analysis was considered through a spatial visualization by using geographic information system (GIS) to classify different 'the built environment' factors in the study area. The relationship of built environment that affects the health condition by using a cluster analysis. The details of the study results are as follows:

Built environment

The factors that are considered for environmental quality assessment by residents' perspective in built environments includes water, air quality, dust pollution, noise, industrial area, housing, infrastructure and transportation. These factors were assessed by using Likert scale range from 1 to 5 score in all built environment factors. The result of analysis by using average statistics were visually demonstrated in Figure 3 and Figure 4.

Most problems in the built environment were found in infrastructures ($\bar{x}$=2.63), dust pollution ($\bar{x}$=2.67), housing ($\bar{x}$=2.68), air quality ($\bar{x}$=2.73), transportation ($\bar{x}$=2.84), noise pollution($\bar{x}$=2.85), water quality ($\bar{x}$=2.97) and industrial area ($\bar{x}$=3.06), respectively. In overall, it was discovered that the direction of opinions and attitudes of the respondents reflect the current situation of urban development and health characteristics. By considering air quality and noise level, it was found that the main sources are from an industrial area which has been influenced by rapid growing of capital city, Bangkok. The installation of air quality monitoring station around the study area provides an information of pollution source which are mainly from factories and traffic congestions. Moreover, recent development trend of suburban area has induced urban activities through urbanization, industrialization, which also increase in dust pollution problems. Additionally, it was found that majority of citizens lived in residential areas with air pollution exceeds the safe level reported by the Pollution Control Department. A non-negligible driver of rapid growth of suburbanization resulting in huge demand of water supply due to economic expansion and more coverage of transport network. Moreover, housing projects and industrial employment area has been constantly evolving which created impact on increasingly serious water environment problems of approximately 60 percent of the agricultural area of the province.

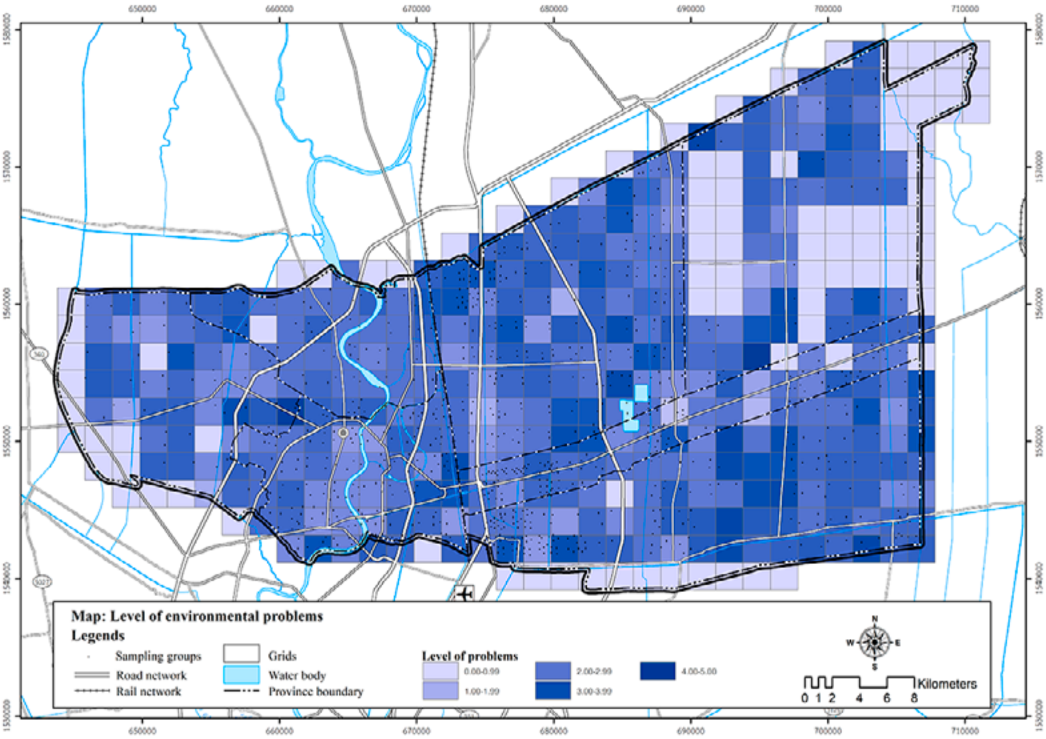
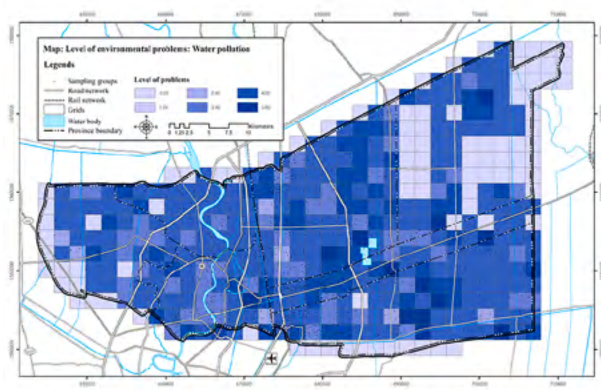
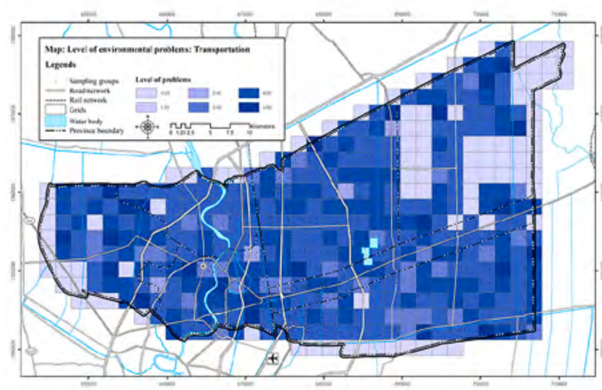


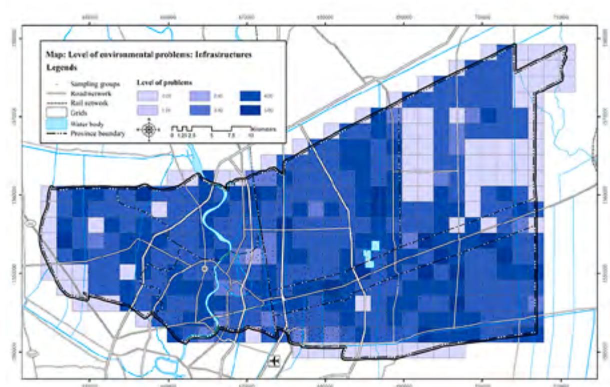
Figure 3. Summary of average score of overall built environment classified by grids



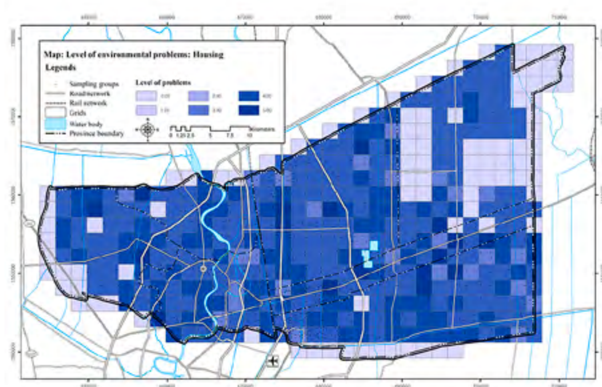
A. Water pollution



B. Transportation

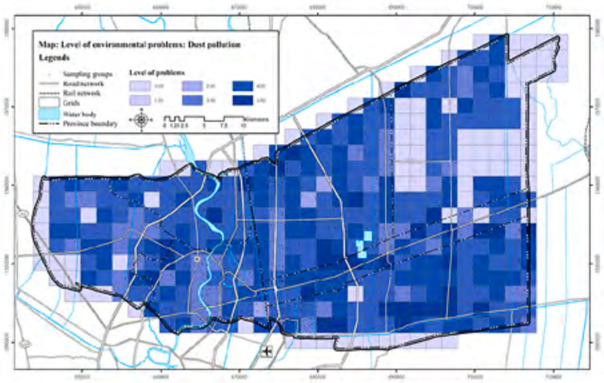


C. Infrastructures

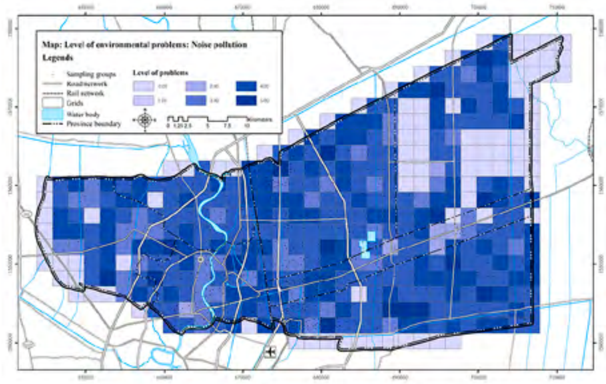


D. Housing

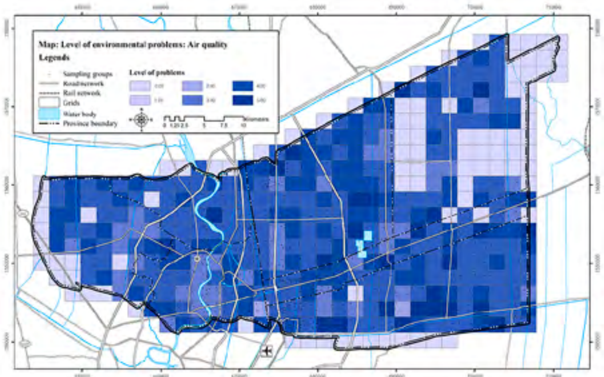
Figure 4. Average score of different built environment factor *(continued on next page)*



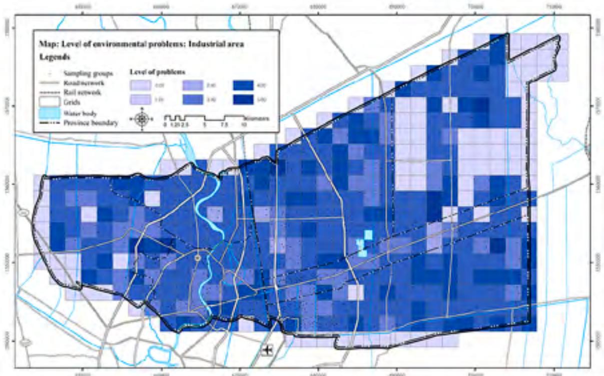
E. Dust pollution



F. Noise pollution



G. Air quality



H. Industrial area

Figure 4. Average score of different built environment factor *(continued from the previous page)*

In terms of residents' perspective on physical aspects, the variables relating to the living conditions of the neighbourhoods and the community would be selected to represent the satisfaction of the neighbourhood environment. The more liveable condition will present the tend to be satisfied with the current environment. However, in terms of the environment, the reflection of respondents showed a negative direction with lower scores, especially, on issues of dust and air pollution that is being faced by other areas aside Pathumthani province. This problem is already at the macro level and it is facing everyone which necessitates collective search for solution to ameliorate the situations. However, in terms of policy, it can be seen that there is no effective measurement in place to tackle this current problem. The score value for this factor could obviously be seen to be the lowest when compared to other factors.

Health outcomes

Considering, health status that the number of congenital disease data were collected from questionnaires, asked whether there is an underlying disease or not. It was found that the most common diseases found in the study area were hypertension, allergy, diabetes, heart disease, dyslipidemia, pneumonia, obesity, cancer, and neuropathy. Therefore, environmental quality assessment based on the interviewers provide the direction with self-reported indicators both health condition and perceived neighborhood quality. Health outcomes was considered in term of the diseases. The analysis was performed by using explanatory variable of health status representing on the basis of number of chronic diseases (Figure 5).

The classifications of relationship between built environment and health effects

The impact of cities on health is both direct and indirect, and most of urban health problems are caused by interrelated factors. In the dimension of urban development, the influencing factors should cover multidimension of urban aspects. However, it must consider all urban element in term of the physical, social and economic environment of urban areas which comprise of the way of living and behaviour of people. Analysis of the composition of perception on built environment factors produced from data collection based on in depth interview and factor scores provide a quantification tool to summarize health information based on an influencing from a number of variables in a manageable and meaningful form of association of urban components. On classifying different built environment factors in our case study, the result of clustering on the relationship of built environment

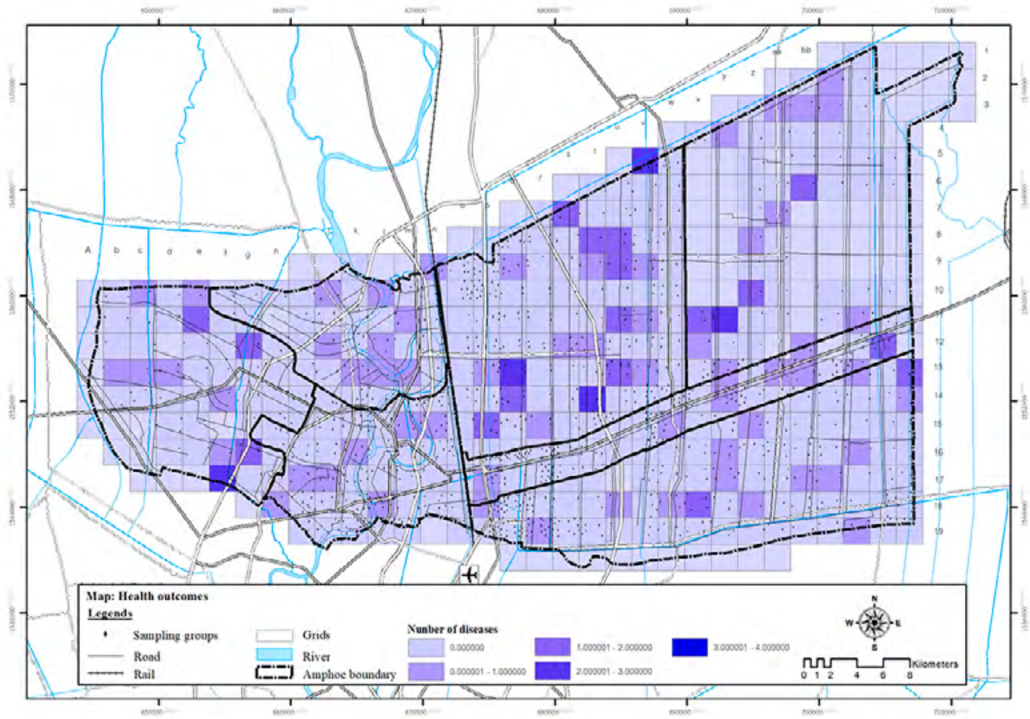


Figure 5. Clustering of Health outcomes

that affects the residents' health condition are shown in Table 1 and Table 2. The cumulative percentage (cumulative %) presents that the factors obtained after the analysis among all 3 group of factors were able to explain the total variability of the variables 65.122 percent. The spatial visualization of different clusters in the study area can be demonstrated in Figure 6.

mental quality score which reflected by their attitude. Furthermore, it was found that most of the residents demonstrate their moderate satisfaction on neighbourhood environment which might be positively influenced by the liveability of physical features of transportation, housing, industrial areas, and infrastructure systems.

Table 1. Eigenvalues from successive extractions of principal components from built environment factors

Factors	Clusters		
	1	2	3
Dust pollution	0.806	-0.104	-0.211
Air Quality	0.760	-0.148	-0.369
Noise	0.717	0.261	0.345
Water Quality	0.667	0.010	-0.168
Housing	-0.060	0.813	-0.045
Infrastructures	-0.098	0.781	-0.048
Transportation	0.094	-0.447	0.673
Industrial Areas	0.443	0.381	0.551

Group 1: The main concern of residents in this group are in relation with environment pollution which comprises of water quality, noise pollution, air quality and dust pollution. The level of the health condition of most of the residents demonstrates the good level which can be the best characterized their satisfaction on households' local environment. This is due to the value of moderate to high level of the environ-

Group 2: The characteristic of this group is characterized as a moderate level of satisfaction on their environmental quality based on the attitude of the people who live in the area. In terms of the satisfaction of the urban infrastructure (transportation, utility and facility) and urban environment (water quality, noise pollution, air quality and dust pollution), most of household and community focus heavily on

Table 2. Classification of different the built environmental factors and health impacts

Factors	Clusters						
	1		2		3		P-value
Transportation	2.95	Medium	2.73	Medium	2.74	Medium	0.000*
Water quality	3.28	Medium	2.57	Medium	2.72	Medium	0.000*
Noise pollution	3.33	Medium	2.81	Medium	2.16	Medium	0.000*
Housing	2.76	Medium	2.02	Medium	2.89	Medium	0.000*
Industrial areas	3.28	Medium	3.41	High	2.54	Medium	0.000*
Infrastructures	2.73	Medium	1.94	Medium	2.83	Medium	0.000*
Air Quality	3.16	Medium	1.80	Medium	2.58	Medium	0.000*
Dust pollution	3.27	Medium	1.73	Medium	2.27	Medium	0.000*
Health condition	3.71	High	3.65	High	3.63	High	0.063

**Note: statistics significance at 0.050 with 1,000 data sets. The highlight on different built environment aspects represents the explanatory factor of the specific cluster.*

Remark: Built environment and health aspect are classified into 3 ranges which consist of: High level (3.34-5.00 score), Medium level (1.67-3.33 score) and Low level (0.00-1.66 score).

community-level aspects of infrastructure, particularly on improvement in local accessibility and access to local services. Although, inadequate information to capture the variation in environmental quality that is present across settlement type in the study area, this cluster presents the high satisfaction score on industrial area which might be due to the residential allocation of this cluster is located within the development of a green environmental protection industry. In terms of health in consideration to congenital disease dimension, the health means was at a moderate level. As for the health condition, it is found that average score of the satisfaction on their own physical health of this group are at the high level.

Group 3: This group is classified by the satisfaction level of transportation and industrial areas factor. The influence of man-made structures on environmental preference also leads to the environmental problem which related to congestion problem with proportion and scale of imbalance space utilization together with degradation of urban environment quality. Although, the perception on quality of urban environmental, particularly around industrial area presents the moderate level, the scoring shows clear pattern of

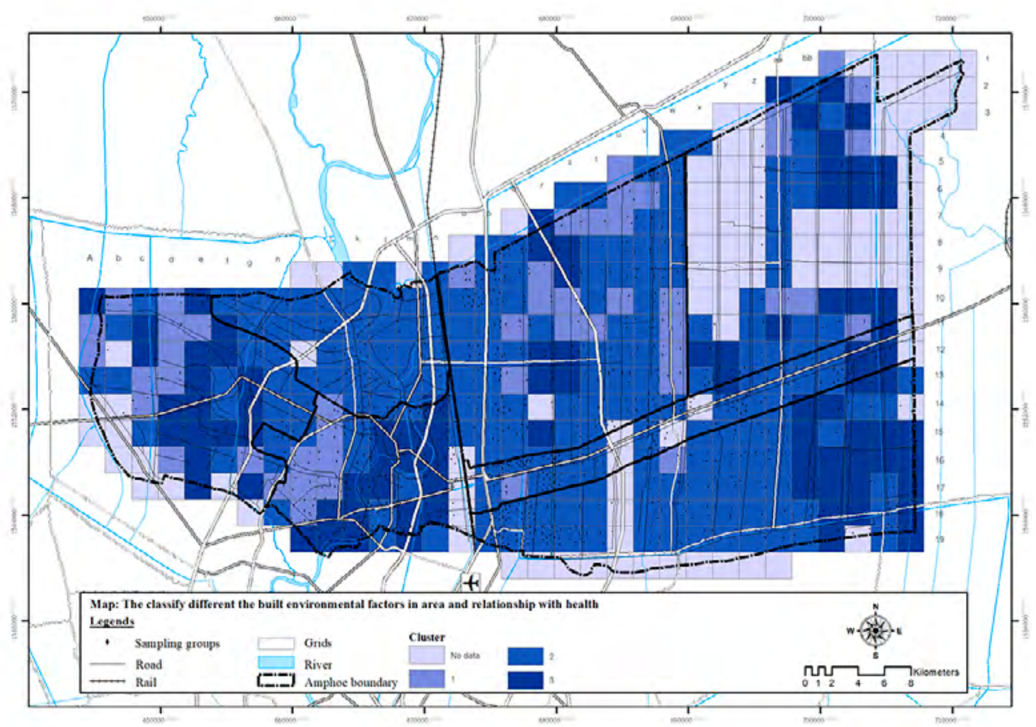


Figure 6. Clustering of different built environmental factors in the study area

environmental impact (water quality, noise and dust pollution) around their neighbourhoods that resulted to low quality living conditions. On another hand, there may be a diverse range of housing choice that is affordable around this cluster's community with well-linked to public transport, walking and cycling infrastructure (moderate level of satisfaction). For health factor, average health score is found to be good, however the overall perspective of environmental quality still not led them to high quality of life.

Discussion

It is interesting to derive residents' opinion of their satisfaction on built environment nearby neighbourhoods (noise pollution, water pollution, dust pollution, air quality, industrial area, housing, infrastructures and transportation) together with their health condition (number of congenital diseases). The satisfaction assessment based on Likert scale was input for clustering their spatial classification. The three group of built environments that affects the residents' health condition can be categorized into three major domains as described in the following detail (Table 2).

Group 1: Perception of Pathumthani residents toward urban environment

The first group of residents demonstrated their high level of preferences in all built environment factors and their health status compared to others. However, the water quality (3.28), noise pollution (3.33), air quality (3.16) and dust pollution (3.27) are the key concerned for this group and represented as major environmental stressors in urban areas. The preferences among local people are always overlooked in the local plan to reflect the status quo of urban environment condition. Furthermore, it was found that most of the environmental problems in Pathumthani province are due to the impacts of rapid development with the sprawling of suburban. This is consistent with the study of Frank and Engelke (2005) stated that urban density is the main feature of built environment and relates to the level of air quality. Additionally, with the rapidly expanding across several communities with hundreds of housing projects in Pathumthani province as well as industries are the major source of wastewater. Some of the water pollution arising from those sources has been treated to the effluent quality standards, while some have not been treated before draining into the sewer system. In addition, air quality and noise problems in Pathumthani province have been discovered to be as a result of the presence of industrial city and continuous expansion of Bangkok; resulting into a large number of establishments. This also leads to the problem of noise pollution in Pathumthani province which can be classified into 2 categories according to the source of the pollution; industrial areas and traffic congestion. The current urban planning and management is necessary to cope with the environmental degradation, particularly on carbon footprint from urban development by prioritising climate-friendly measurement.

Group 2: Perception of Pathumthani residents toward urban facilities and services

The opinion of the second group shows their concerns related to social aspects of city life, in particular to level of satisfaction, experiences, and perception of their everyday environment on living (2.02) and utilizing urban infrastructures (1.94). The reflection of residents (as main users) in term of quality of living and community well-being can provide an valuable information to address these complex urban challenges, and particularly for improving plan for 'area-based' interventions. It was found that housing quality is one of the main factors associated with everyday life at individual level. Therefore, improvements in housing quality is highly recommended since it is associated with positive general health, mental health, asthma, and mortality outcomes (Frank & Engelke, 2005). It is a fact that housing factors are related with mental and physical health impacts, e.g., air quality, infestation, noise, lighting, housing tenure and design (Macdonald & Thompson, 2003). This assertion is in consistent with the study results from Gibsona et al. (2011) and Sandel et al. (2018), which was found strong evidence on characterizing housing's relationship to health. The characteristics of the living environment that has different conditions according to the socioeconomic context (Iamtrakul & Chayphong, 2021). Thus, the enhancement on housing stability, quality, safety, and affordability will definitely address their effects on health outcomes (physical and social characteristics of neighborhoods).

Group 3: Perception of Pathumthani residents toward urban accessibility and attractions

It is important to note that the transportation problems (2.74) and industrial areas (2.54) influence on this group of residents' preferences. The perception of residents concerning their health and well-being due to node of intensive industrial activities and its density relates to the level of traffic. The suburban development of Pathumthani showed significant associations and the urban atmosphere around industrial that has tendency to exacerbate exposure to harmful emission, especially heavy vehicles mixed and traffic congestion. Concentration of industrial activities, notably those of large-scale petrochemical, power generation and heavy industrialization creates environmental pressures. Combined with all of the economic activities within that area has potential adverse effects on the health of local communities through their occupational and residential roles (World Health Organization, 2004). This is due to the possibility of direct exposure to PM2.5 and NOX from industries and these are associated with decrease lung function (Bergstra, 2018). The environmental problem and other situations in the province were related to several sites of industrial activities with low efficient network of transportations. Thus, the integrated of friendly transportation system such as rail-based transport must be recommended to be consistent with allocation of urban attractions while increasing the accessibility and connectedness of non-motorization modes.

Conclusion

The aim of this study is to identify the relationship between built environment and urban health through perspective of residents. Data collection was sampling from Pathumthani province to understand people's preferences for built environment characteristic. The number of questionnaires was input into each grid in order to cover the sample in spatial area. We then analyzed the association on the basis of satisfaction of built environment factors (transportation, water quality, noise pollution, housing, industrial areas, infrastructures, air quality, dust pollution) which is consistent with health condition of residents in the study area. By applying the cluster analysis, the results of the classification were made into 3 clusters. On considering the perception of Pathumthani residents toward its environmental quality through spatial cluster analysis, it was found that the factors relating to or affecting the health issues emanated from the condition of the built environment. There are several dimensions of environmental factors that are related to health issues reflected from preferences of residents. This study classified three group of perception of Pathumthani residents which comprises of urban environment, urban facilities and services and urban accessibility & attractions. The results of assessment can represent as a promising tool to integrate local perception by asking their response towards different built environment aspects which is essential step of participatory planning approach. The evidence based on level of perception among residents in the target area could demonstrate how people perceive the quality of local government plan and services through their planning and management. It can be seen that built environment plays a key role in support of systematic environmental management, eco-industrial cities development and promotion, and development of friendly transportation network and logistics system. Thus, the quantification of individual level contextual differences based on perception of residents concerning health and well-being can provide useful information for improving built environments and measurement to improve community health behaviors as well. This is due to significant findings of association between health-related quality of life and urban context. Finally, consideration should be given to the people and communities for the capacity to access high quality of service and infrastructure to support the continuous growth of their city in term of basic infrastructure, sufficient utility system, and effectively provision.

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