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AN ANALYSIS ON SPATIAL PERMEABILITY AND FLUID DYNAMICS OF WIND AND THERMAL IN TROPICAL RIVERSIDE RESIDENTIAL AREAS OF BANJARMASIN CITY, INDONESIA

(Analisis Permibilitas Keruangan dan Dinamika Fluida Angin dan Suhu Kawasan Permukiman Tropis Sungai di Banjarmasin, Indonesia)

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Abstract

Riverside settlements in Banjarmasin that were initially based on their river culture and nature are currently experiencing degradation of life quality and nature. This is caused by fires, floods, and a high risk of urban heat island. In terms of spatial configuration there are no interrelation and integration between regional architecture and infrastructure, which are based on land and water. Problems occurring in these areas are density, less interconnectivity, poor accessibility, and very low intelligibility. In addition, the areas' thermal comfort is very low – poor wind circulation, high humidity, and uncomfortable temperatures. In the study the researcher conducted an experiment based on permeability approach to solve the challenges and problems related to spatial and thermal comfort by using a spatial analysis method, space syntax, and a thermal comfort analysis method, Envimet. This study compared the existing condition with a model architecture of a city block kampung settlement, which was based on local vernacular architecture of Banjarmasin river banks. The research concluded that the intelligibility performance of spatial permeability approach could be improved. This approach resulted in a symbiosis between spatial configuration of land and water and the regional architecture. However, in terms of thermal comfort no significant improvement of performance occurred because the morphology of the area was relatively flat and the proportion of the average height of buildings was low. Consequently, wind path as ventilation was not formed and area thermal comfort was not created.

Keywords: space permeability, space intelligibility, fluid dynamic, vernacular kampung city block, riverine setlement

Abstrak

Permukiman tepian sungai di Banjarmasin secara alami merupakan permukiman berbasis pada alam dan budaya huni sungai, saat ini mengalami degradasi kualitas kehidupan dan alamnya. Hal ini diakibatkan oleh bencana kebakaran, banjir dan tinggi resiko terjadinya urban heat island. Secara konfigurasi keruangan tidak terjadi hubungan dan keterpaduan antara ruang arsitektur dan infrastruktur kawasan yang berbasis daratan dan perairan. Fenomena yang terjadi adalah kepadatan, hubungan kawasan darat dan sungai yang lemah serta degradasi kualitas lingkungan. Selain itu kenyamanan termal kawasan pun sangat rendah, yaitu: aliran angin yang tidak lancar, kelembaban cukup tinggi dan suhu yang tidak nyaman. Penelitian ini mencoba melakukan eksperimen melalui pendekatan simulasi permibilitas ruang dan kenyamanan termal dengan menggunakan metode analisis ruang dengan program Space Syntax dan metode analisis kenyamanan termal dengan program Envimet. Penelitian ini membandingkan kondisi eksisiting dan usulan model arsitektur permukiman kampung beringkat yang berbasis arsitektur permukiman vernakular tepi sungai Banjarmasin. Kesimpulan dari penelitian ini adalah melalui pendekatan permibilitas keruangan yang mensimbiosiskan konfigurasi antara ruang darat dan air serta arsitektur kawasan dapat ditingkatkan kinerja kejelasan keruangannya tetapi secara kenyamanan termal tidak menunjukkan peningkatan kinerja secara signifikan karena morfologi kawasan

yang relatif datar dan dengan proporsi ketinggian rata-rata bangunan yang rendah sehingga tidak terbentuk jalur pergerakan angin sebagai sarana ventilasi dan kenyamanan termal kawasan.

Kata kunci: permibilitas ruang, kejelasan ruang, dinamika fluida, permukiman vernakular bertingkat, permukiman tepi sungai

INTRODUCTION

Population growth, limited land, and climate change become the issue in urban areas. Tropical climatic condition in general has the properties of high solar radiation and high humidity. Spatial pattern in a settlement becomes a reference in creating a sustainable and successful settlement in its development. Kampung Riverfront Cityblock is a concept of upward residential development in small areas to manage dense settlements. Kampung riverfront cityblock is developed by considering the spatial localities of a residential area: integration of space, space connectivity, visibility, and value of spatial permeability. Today vertical housing development tends to be seen to have mixed use – fully capable of providing the basic daily needs of residents, work, spiritual, education, and other functions spatially integrated with each other.

According to Spreiregen 1965 that the development of water-based cities basically occurs in coastal areas which is in turn connected by networks of land or water. Banjarmasin City is a city with a lot of river networks that connect one another. Rivers become links connecting different regions so that they have configurations that affect further development of the city.

The development of road networks has begun to change the people's way of thinking, especially in residential orientation that regards rivers as the rear zone of houses and this zone tends to be a waste zone. The condition of rivers in Banjarmasin is slowly degrading because of people's activities and the sporadic settlements development on them. Another result of this is that several small rivers that were connected to each other have begun to break up and some even have already become dead. Based on the data obtained in 2000, there were nine streams that become dead due to residential activities and domestic waste.

In the last few years, responses to the world's environmental problems generally start from environment awareness to energy awareness. In relation to the water areas of 216 river cities in Indonesia, about 60% of the problems are water and waste-related. The waste disposed in the waters includes industrial waste, solid waste, and harmful substances.

Banjarmasin is one of the cities in Indonesia crisscrossed by many rivers and small streams. Environmental problems present in this city include the lack of aquatic environment control due to wide spans of the upstream and downstream, waste resulting from mining activities, and household waste directly disposed to the river. In addition, the city has a spatial problem which is the root of these environmental problems. This problem is related to settlement on riverbanks, developed with vernacular architecture. The development of this settlement is overlapping, sporadic, and tends to be detached urban setting. As a result, this settlement is prone to fires, high floods/inundations, and squalor. Seventy five percents of the problems of spatial settlement in Banjarmasin are found in banks of big and medium rivers. Densely populated settlements result in a low spatial permeability and tend to be inaccessible. As for small rivers, they have disappeared due overpopulation which occupy the rivers' area so that they become dead rivers and eventually dry land.

The government of Banjarmasin is planning to build a kampung riverfront cityblock located on the banks of the rivers as prevention against the strong current of land-based development that indirectly degrades waterfront areas. This cityblock is designed to be responsive to environmental conditions, climate, and the trend with a very strong

current of change occurring once every several years. This settlement is a generic form derived from vernacular settlement characteristics so that the people's spatial adaptation level will not change completely. In addition, in this development spatial pattern is plotted according to the local culture.

Kuin is an old region in the city of Banjarmasin. It was Banjar Kingdom's territory and the embryo of Banjarmasin. Based on historical records, residential areas at the mouth of the Kuin River and the Barito River's banks were the first settlements in Banjarmasin before Banjar Kingdom was established in these areas (Prayitno, 2012). Kuin region is now densely populated and its residential area is positioned alongside the river. Kuin's residential area has unique characteristics in terms of its architecture and planning in which there is a network of riverine alleys that connects houses. These alleys are called 'titian' or walkways by local residents. The river and land in Kuin area correlate significantly despite a shift in the orientation, from river to land. Additionally, Kuin that is named after the Kuin River, one of the branches of the Barito river, also has a tourism asset that is the floating market. This market is the only traditional market that represents trade activities in the past.

The objectives of this research were to assess the effectiveness of the performance of urban renewal in the form of riverfront kampung cityblock to discover the performance of spatial and thermal comfort and to assess the effectiveness of spatial permeability performance and comfort by comparing existing conditions with the new redesigned program.

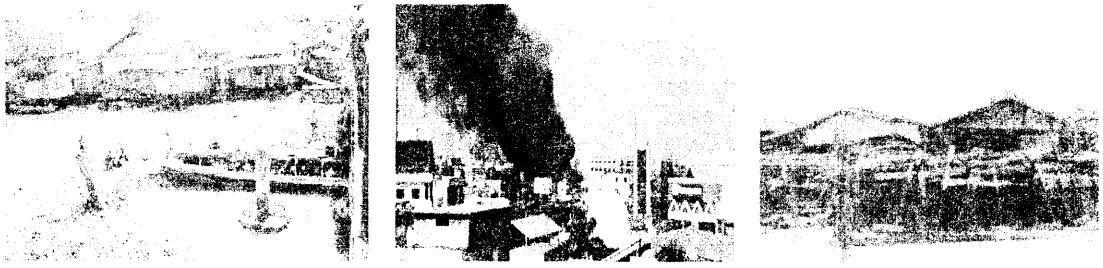

Fig 1. Impact of backyard settlement cause environmental degradation

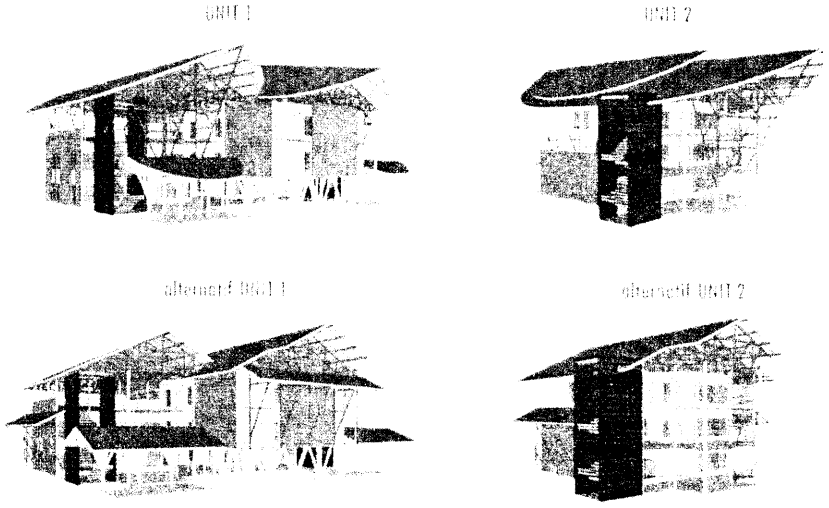

Fig 2. Proposed model of kampung riverfront cityblock

METHODOLOGY

Modeling Simulation Approach

Space syntax approach

Each region will have a different spatial relation adjusted to the lifestyle of its inhabitants (Peponis, et al.1984; Hillier et al. 1993, Turner. 2004). This indicates the existence of interlocking relationship between the configuration and direction of growth and the inhabitants' habits. Permeability or the ability of a space to be penetrated from all directions becomes a success in developing a densely populated area.

Figure 3 (a) shows that if the segment of main road is in the middle, it will be more frequently used than the segment in the periphery. Figure 3 (b) show about vertical elements that are above and below the main road will function more as the shortest routes rather than as elements of the vertical branch.

Kampung riverfront can be freely interpreted as a group of houses in a mass of building that is formed a cluster on a small piece of land or a kampung area. The concept of kampung riverfront cityblock is driven by local values and aimed at overcoming the problem of limited land in densely populated areas.

As shown in the fig 3 is the relationship between A as an attractor, C as a configuration, M as a movement with a line of influence. Attractor and the movement can influence each other, but the other two relations are asymmetrical. Configuration can affect the location of attractor, but the location of attractor cannot affect the configuration. Kampung riverfront cityblock is implemented as a vertical settlement adapted to the limited land and spatial values that affect the movement and activities of a region.

Wind fluid dynamic approach

Urban ventilation is an air flow in an urban environment with a high density. The effort is expected to reduce the effect of urban heat island by making use of air flow that occurs naturally in a city (Ng, 2010). In rivers of urban areas hydrological cycle occurs (Hough, 1984). Rivers is one of the water providers having a stable temperature throughout the day. The temperature difference between morning and evening is only 3-4 °C (Hough, 1984). The forms of the building mass with height, width, and shape of the building plan can cause air to move. Air movement within an environment is determined by the building orientation (Terry, 1987).

Rivers close to the estuary can be useful to bring wind from the sea and then can be channelled into the city (Yamamoto, 2006). However, it will not be effective if the location of the river is away from the free zone or coastal areas. This is because with a long distance the coolness of the air cannot reach the city so the temperature of the air reaching the city is similar to that of the city.

Research Methods

The study mapped the existing spatial condition and thermal comfort that can be achieved by assessing the proposed village cityblock through spatial integration approach and the numeric calculation with spatial software Space Syntax UCL Depthmap 10 and assessed the thermal comfort by using Envmet 3.1 beta 4. The next stage was to assess the level of performance of spatial intelligibility improvement and thermal comfort through a comparative analysis on the existing conditions and the proposed model.

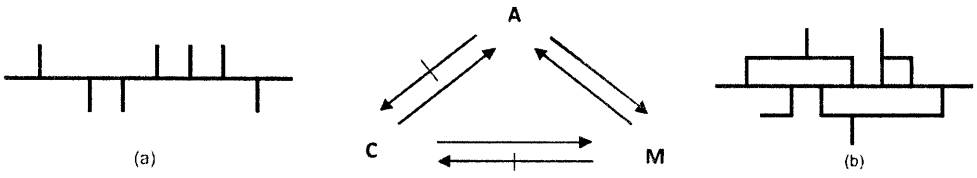

Fig 3. Space syntax spatial relationship principle

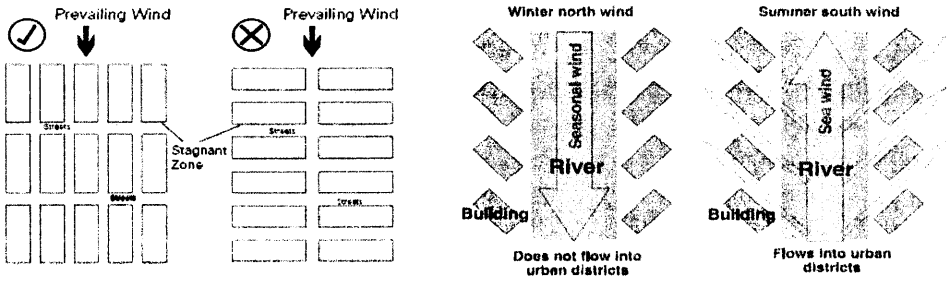

Fig 4. Wind flow principles

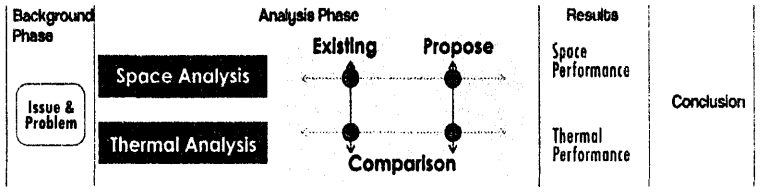

Fig 5. Research conduct

To carry out the model approach Kuin region was divided into 5 observation units that are regarded representative of the physical conditions of residential areas, rivers, and local elements.

The followings are the distribution of the observation units The first observation is the Kuin region which is directly on the side of the Barito River. This area has the highest number of layers with diverse settlement perpendicular to the river, The second observation unit is the area of the Kuin River estuary to the Barito River. This area is a dense residential area with diverse variations, The third observation unit is the Kuin River area which is physically located in the bend zone which is spatially different from the bend zone in the second observation unit; The fourth observation unit is the Kuin River area, which has straight physical form. This is an addition to the bend zones, The fifth observation unit is the confluence of three rivers which are physically different from the bend zones and elongated form.

Research Location

Banjarmasin is a river city that has more than 70 rivers classified as large to small rivers. It triggers the city to use the rivers as asset to sustain people's the city's ecology. Banjarmasin, particularly Kuin area, is an area with many small rivers flowing through each segment of the region. Kuin is also where Banjarmasin began.

Kuin River is considered to represent the spatial configuration of river and land that in terms of social and activities it is closely related to river life. Kuin River and the residential area on its bank have very diverse spatial configurations. When viewed based on the residential configuration along the river, the configuration form can be classified into diverse patterns, which are the width of the river, canal zones and bend zones. These patterns were used as the study samples.

RESULT AND DISCUSSION

Simulation, Analysis, and Concept Layout of kampung riverfront cityblock

The spatial settlement analysis describes that there is a core of the vernacular form of settlement in Banjarmasin. Banjarmasin has developed with a range of variations expressed by each inhabitant. Based on the diagrammatic analysis, houses in Banjarmasin are divided into two types, houses with stage structure and floating structure (*lanting*). Based on the

basic diagram, the houses can be restructured into residential layout that can be seen in the figure below.

Residential layout is the basis of the smallest module in the unit scale of observation so that layout variants can still be developed and arranged in such a manner appropriate for the residents' needs. Spatially, '*lanting*' house layout can be used for various purposes suitable and flexible to the needs of additional residential space or support functions, such as store or stall, transit, or just open space floating on water areas.

New structures in riverside kampung taking its form as a cityblock are a form of transformation of local elements. These structures are made efficient based on the present needs with a modular system. Some local elements such as *batang*, *titian* (wooden alley), *lanting* (floating house), and *jukung* (a kind of a small boat) are interpreted into new forms that can be seen in Fig 7.

Fig 6. Research location

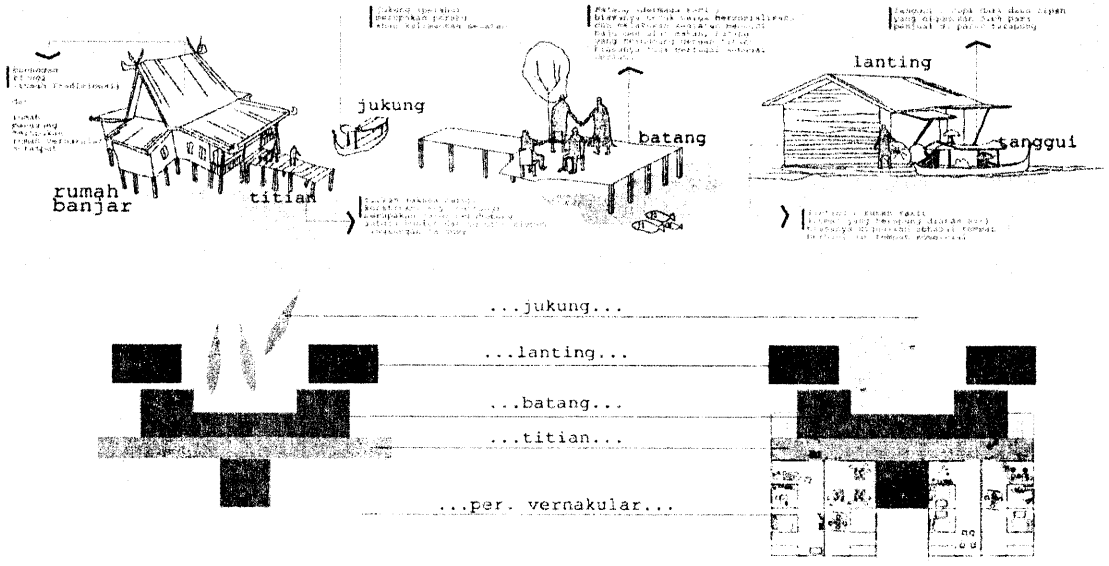

Fig 7. Housing unit layout plan

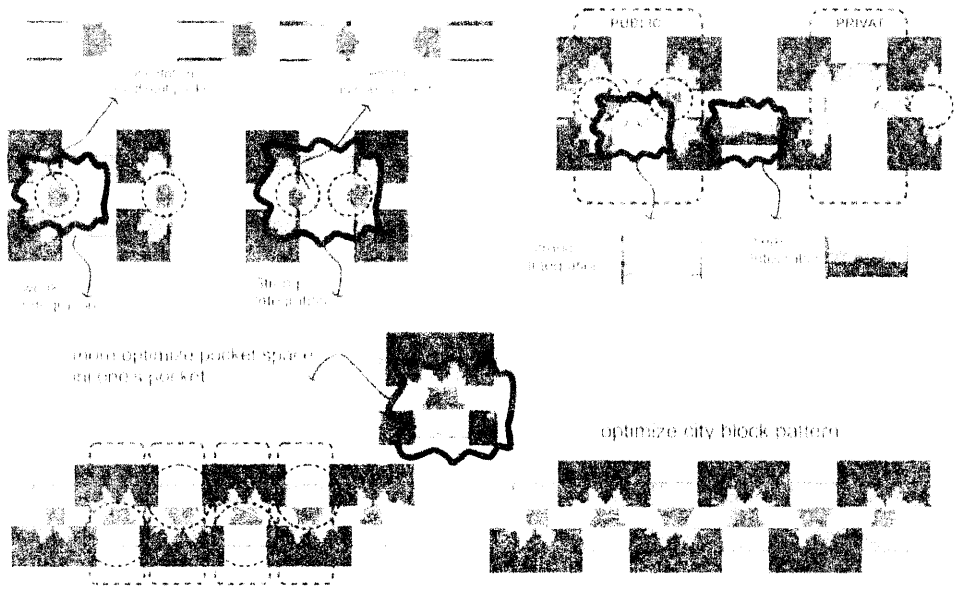

Fig 8. Corriodor and pocket spaces

Regional visibility and permeability

Visibility is used to discover how a space functions and how residents perceive a space. In this context visibility is used to perceive integrity degree relations between regional visibility and the accessibility permeability level of a space.

Linear corridor and pocket space

In the focus of a single corridor, pocket system is divided into four types in terms of the placement and divided into four types based on the multiplication unit. Pocket system was analyzed in various model forms in order to discover spatial system with strong and weak spatial integrations. This discovery will be used for the development of prototype in the future.

The correlation of the corridor study can principally be adapted to the existing walkway system in Kuin region. This corridor is used for the development of the cityblock unit which will be inserted in Kuin's residential areas. This corridor is then devoted to link existing road network system and the existing walkway network system.

Based on the study of several models and unit samples where there is integration between visibility and pocket space, pocket development patterns based on its placement are divided into 4 patterns as below Firstly, aperture factor of each unit toward the pocket determines the strength of the pocket as a space that has more public characteristic. On the contrary, if the unit aperture of the residence moves away from the pocket position it can be stated that the space has weak space visual integration and tend to be more private Secondly, the placement of the pocket is stronger with front-on pattern rather than crosswise or single. The front-on pattern that is tied to the door opening is a composition that can create strong visual integration Thirdly, the longer the corridor is the stronger the corridor integration will be and the weaker pocket space visual integration in residential unit The fourth is crosswise shape of unit and pocket that is a maximum composition to increase the pocket space visual integration on the linier residential unit.

Based on 4 linear corridor spatial principles, it can be concluded that the construction of corridor at the Kuin riverbank area is possible with small units, maximum of two residential units and a pocket is inserted as a public space or additional space for activities like trading, or for shared storage. Based on that development principle, the concept was applied to the room

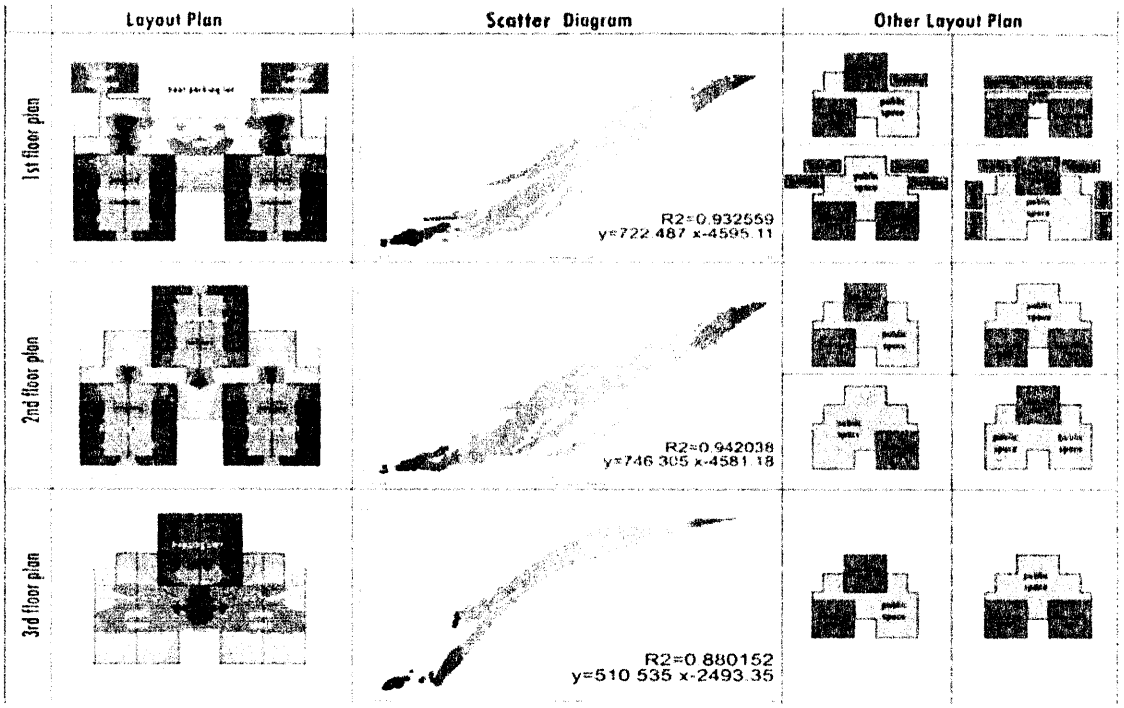

Fig 9 Roads and *titian* integration

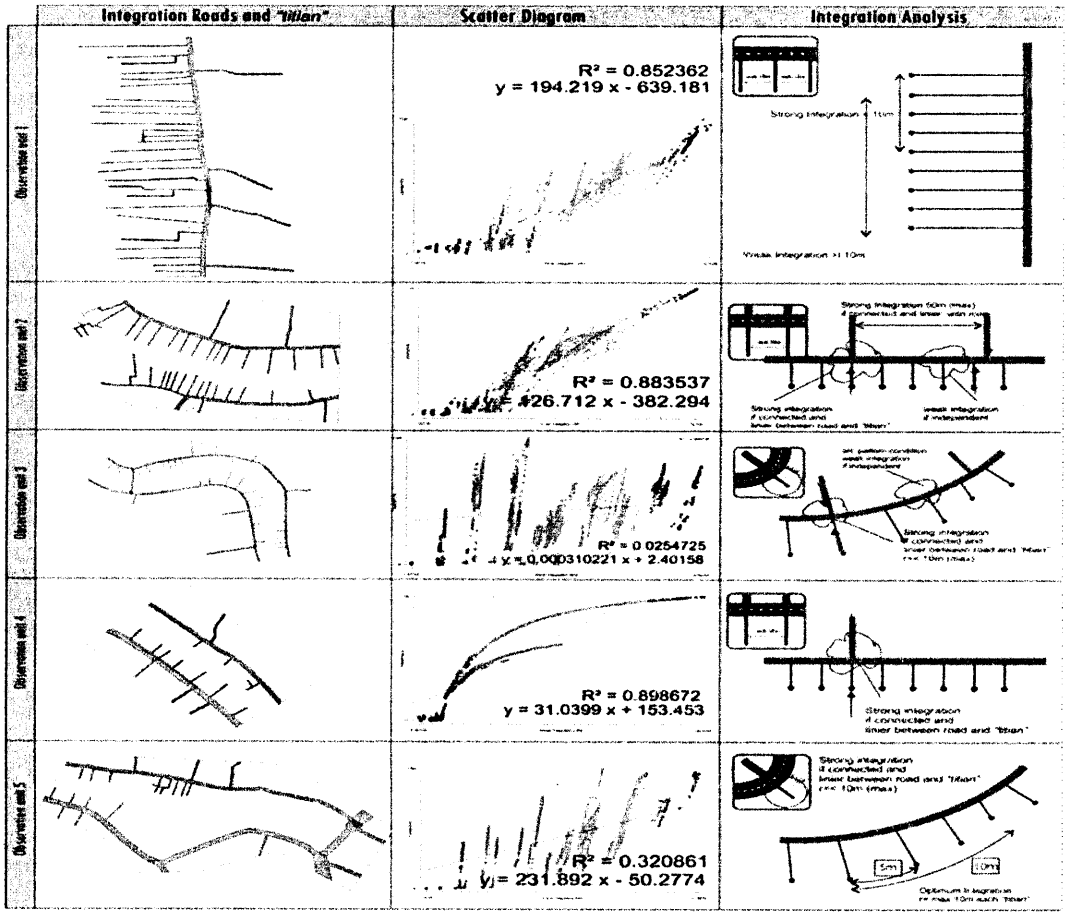

Fig 10. Kampung riverfront cityblock model

Layout from local vernacular architectural essence and the analysis result shows that the strength of inner space and public space and the additional values for adopting local vernacular values were reached optimally.

Based on the space syntax analysis on residential basic layout and analysis on corridor integration with residential unit, various models for Banjarmasin kampung riverfront cityblock vertical residence were obtained. The model of residence generally has two types, the model placed for the residential areas on big rivers and the model placed for the residential areas on small rivers. The river physical factor can directly affect the success of kampung riverfront cityblock building seen from connectivity, integration, and spatial visibility aspects.

Kampung riverfront cityblock networks

With the road and walkway networks in the Kuin River's residential area Kuin has become an area with a spatial integration connecting land and river areas. Spatial permeability between roads and walkways determines the level of integration between land and river areas in terms of accessibility and connectivity. This integration level has impacts on the development of each unit of the Kuin River's riverside residential areas.

Based on the analysis result of visual integration of land road network with the *'titian'* at five observation units at the Kuin River area, it is concluded that the road perpendicular to the footbridge will have high visual integration value and intelligibility degree. It was seen from observation units 1,2, and 4 with high intelligibility R^2= 0.89 and low visual intelligibility value if the connection between land road and footbridge has winding shape as it was seen from observation units 3 and 5 with intelligibility value R^2= 0.02 and 0.3. Those five patterns are highly influential toward the spatial permeability for each cluster residential unit. Based on those five principles, there are three principles of configuration development of road space and footbridge network as well as the components of residential area within. These three principles are as followings:

a. **First principle:** The maximum length of elongated footbridge should be constructed is 10m between footbridge so that the connection between road space and footbridge remains strong.
b. **Second principle:** The distance of inter footbridge can be expanded up to 50m provided that if there are land road network in line with the footbridge network.
c. **Third principle**: In the bend zones with maximum radius of 10m or with the distance of 20m, the construction of inter footbridges is supported by land road network

Cityblok model in Figure 10 is a development from the concept of vernacular houses in the Kuin's residential areas (figure 6) which are adapted by using the principle of spatial integration level. In this principle a space with high integration value is used as a public space whereas a space with low integration value is used as a private living space. The result of 'scatter diagram' analysis shows that each floor of cityblock has high intelligibility value. The higher the intelligibility value of a cityblock floor, the higher the permeability value of a dwelling unit.

Fig 11 is the result of the development of three principles of kampung network and a combination of a cityblock unit. From the analysis before and after the development it is seen in Table 1 that there is an increase in the permeability value of observed unit 1, 2, 3, and 5. Whereas in observed-unit 4 there is a decrease in permeability value caused by the existence of new walkway networks connecting the land and the river. On the other hand, in the existing permeability analysis the development of network only occurs to land roads and not the river so that high permeability value is only assigned to these roads and not to the relationship between the river and the land area.

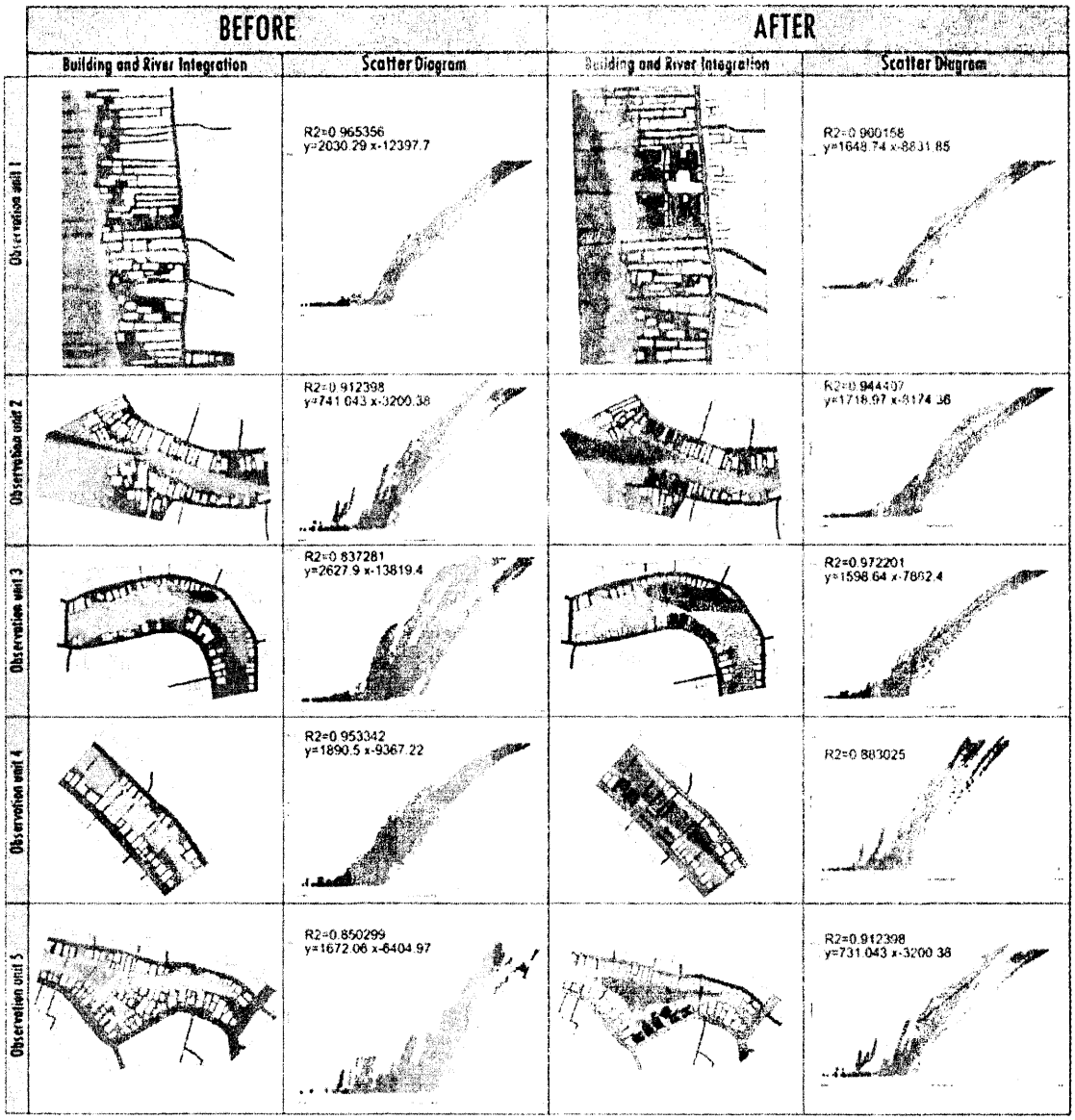

Fig 11. Comparison of area visibility with permeability

Comparison of Simulation

Comparison of area visibility with permeability

Based on Table.1 the value with high visibility is at observation unit 1 with intelligibility value of 0.96. High visibility integration value causes a lot of pedestrians/ movements that use space. Generally the space with high visibility located at the river space. This space has high perspective toward all directions. This means the space with high visibility has a clear relevance with other spaces or in other words space with high visibility relatively has a high permeability from other place outside the space. There are two space patterns affecting visual integration that block the space permeability on rivers and land causing the permeability to decrease. These patterns are residential cluster that expands to the middle of the river, winding footbridge, and narrow visibility degree in the residential unit.

Based on the integration visibility analysis result of the five observation unit, there are some findings influential toward the connection between land and river at the

Kuin River residential area. Based on the spatial strength, an early reference point was obtained in the development of kampung riverfront cityblock that could improve the low visibility and regional spatial connectivity.

Comparison of proposal with the existing area based on the wind motion pattern

This study not only test the spatial permeability but also permeability of wind flows. It is based on the consideration that comfort level of living can be achieved through a spatial engineering design and a thermal engineering design. This study aims to reveal the effectiveness of the rearrangement of the residential areas alongside the Kuin River through designing cityblock residential areas. This rearrangement is done to increase the performance of living comfort that is studied based on the aspects of spatial integration and spatial accessibility and to increase thermal comfort performance that is examined based on the aspect of wind motion patterns. Observations of wind motion patterns are conducted in the same 5 sites as the observations of spatial patterns.

1) Observation unit 1

In the existing condition, the wind speed in the morning, afternoon and evening were not much different, that is on average of 0-8 m/s (at the designed spot). The change can be sensed mainly at the area proposed design, by opening space and making wind trap on the building design. At the same area the wind speed turned into 1.27–2.11 m/s. In the morning, afternoon and evening the speed was not much different. The change of temperature happened in this observation unit was around 1.5 °C. Existing temperature was 27.5 –28.0 °C meanwhile the temperature at the proposed design was around 27.0 –27.5 °C.

2) Observation unit 2

In the existing condition the wind speed in the morning, afternoon and evening were around 0–0.43 m/s, the wind movement was more optimal in the morning. In the proposed design the wind speed change turned into 0.43–1.27 m/s, the optimal condition was reached in the morning and the space on the north side of the river was more optimal than that of the south side. Therefore, the optimum kampung riverfront cityblock residence could be directed to the north part of the river. The change in thermal condition in this unit was around 1.0 °C, where the existing temperature was 27.0–28.0 °C while the in the proposed design was 26.5–28.0 °C.

3) Observation unit 3

At the observation unit 3 the wind speed between the existing conditions and the proposed design was not much different. This was because the spatial pattern in the bend zones was in line with the wind direction thus to optimize the kampung riverfront cityblock concept in these zones façade element is needed or other elements whose nature directs and detours wind toward buildings. The thermal condition at observation unit 3 was similar to observation unit 1; the change was around 0.5 °C – the temperature in the existing condition was 27,5–28,0 °C while the in the proposed design was around 27.0–27.5 °C.

4) Observation unit 4

In existing condition the wind speed was on average 0–0.43 m/s (through the space between the buildings). The speed was relatively similar from the morning to the evening. In the proposed design the average wind speed at those three different times was relatively similar, 0.43–0.85 m/s. This condition is somewhat similar to that of the observation unit 3 because of the perpendicular wind direction. Therefore, it needs wider gap between buildings to channel the wind crosswise between the river and the roads. Based on the thermal analysis, the temperature change was not too significant between the existing and the proposed design.

5) Observation unit 5

The wind speed at those three different times was relatively similar, in average of 0 – 0.85 m/s, while the wind speed for design simulation was relatively similar, in average of 0.8–2.11 m/s. This condition showed the density of space with irregular mass block that makes the wind movement in this observation unit was not optimum. The

thermal condition of this unit was similar to observation unit 1 and 3. The temperature change was only around 0.5 °C. The temperature in the existing conditions was around 27.5–28.0 °C, while the temperature in the proposed design was around 27.0 – 28.0 °C.

The Simulation Result

This simulation resulted that the area intelligibility performance increased but the degree of thermal comfort, performance was relatively unchanged and showed no significant improvement, and spatially, the intelligibility performance degree increased because the space was accessible from all directions in an area spatial system and a building spatial system.

In terms of thermal comfort, the performance degree did not show significant improvement. This was because the morphology of riverbank was relatively flat and the heights of buildings were relatively low, therefore, the wind-path that could have allowed air flow to penetrate the buildings' cracks did not form.

Table 1. Integibility value

Observation unit	1	2	3	4	5
Intelligibility value (Before)	0.96	0.91	0.83	0.95	0.85
Intelligibility value (after)	0.96	0.94	0.97	0.88	0.91

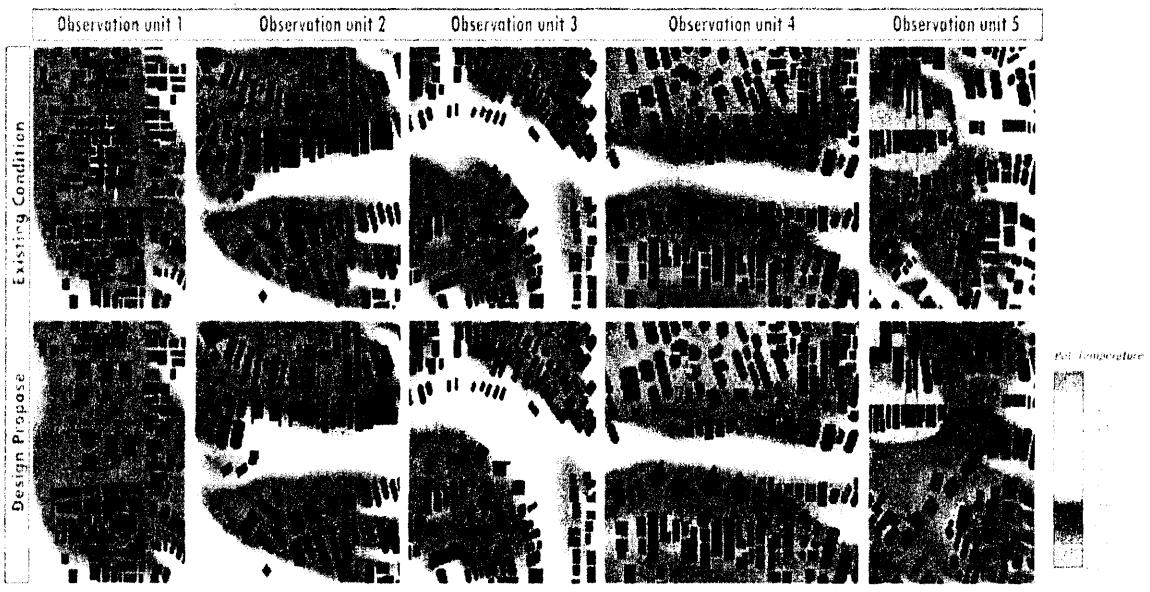

Fig 12. Comparison of proposal with the existing area based on the temperature condition

Fig 13. Comparison of proposal with the existing area based on the wind motion pattern

Table 2. Comparison temperature

Observation unit	1	2	3	4	5
Temperature (Before) (°C)	27.5–28.0	27.0–28.0	27.0–28.0	27.0–28.0	27.0– 28.0
Temperature (after) (°C)	27.0–27.5	26.5–28.0	27.0–27.5	27.0–28.0	27.0– 28.0

CONCLUSION

By comparing the existing condition with kampung riverfront cityblock riverside kampung development program, the paper was able to obtain a number of major findings. The performance of local spatial permeability degree increased. It could be seen through the area interconnectivity, spatial accessibility that supported land and water spaces, and the non-physical increase of area intelligibility. The land roads, footbridges, and rivers are important elements related to the value of visual integration of an area. These elements would determine whether or not the permeability of a space/unit decrease from all spaces in the area system. The roads perpendicular to the footbridges or winding would affect the area intelligibility that had a further effect on the permeability of a space or residential unit. For a residential unit, the corridor with pocket space would create corridor function as a public space or culture alley in the custom of landed settlement in the dense urban residential areas.

The permeability degree of spatial comfort did not show good performance based on the thermal comfort and wind speed. This was caused by the river morphology that is a long and low slope and the relatively low and similar heights among the buildings. Based on the physical form of the area, this low degree had a great impact because wind corridor as the wind-path did not form. The kampung riverfront cityblock development pattern of dense residential areas on riverbanks had distinctive characteristics, which are different among the river areas. Therefore, the method of kampung riverfront cityblock development should adopt local values that are developed with the latest technology.

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