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Measuring Sustainability of Kampong Tudong Riverside Settlements Using Urban Modeling Interface Simulation

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ABSTRACT

Coastal settlements are the most vulnerable area to climate change, which has had an increasing impact on natural changes and human life in recent years. Therefore, sustainable riverside settlement models need to be developed by maximizing welfare with minimal environmental damage through modeling simulations that can help understand, compare and evaluate buildings and settlements. Simulation of Kampong Tudong on the banks of Kapuas River used Urban Modeling Interface to analyze the floor area ratio, daylighting, operational energy, and mobility. The simulation results show values of 0.21 on Floor Area Ratio, 30% on average natural resources for building daylighting, 86 kWh/m^{2}year on operational energy, and 66 on mobility. Meanwhile, the efficient standard values are <3.2 on FAR, 55% on average daylighting, 10.08-30 kWh/m2.year on operational energy, and 90-100 on mobility. Existing simulation values indicate that these values can still be improved and maximized further for the sustainability of the riverside settlements.

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1. INTRODUCTION

Climate change has constantly been worsening for a long time and has increasingly impacted various parts of the world in recent years. As many as 11% of the world's population, or 800 million people, are currently vulnerable to the effects of climate change [1], [2]. Human activities directly or indirectly cause climate change. It is associated with changes in nature and human life, such as water quality, health, population diversity, exposure, and vulnerability of forest habitats, agricultural land, and coastal ecosystems. [3]–[5]. The areas most vulnerable to climate change are coastal areas [4].

Pontianak City has 61 rivers and ditches, still used for daily needs and as supporting facilities and infrastructure by some communities. [6]. Thus, the Pontianak City Government has established a waterfront city-oriented development policy by focusing on the maximum use of the potential of Pontianak City as a waterfront city to improve the community's welfare. There have long been houses on stilts in the cities along the Pontianak River. These houses are hereditary from the past and have been used until now and have relevant legal regulations. The dilemma is between buildings that have become the identity of an area and buildings that violate regulations. Meanwhile, traditional buildings usually need to consider the rationale for sustainability in their design process. So that, what is happening at this time is the buildings hurt the environment. Uncontrolled development and climate change have caused a decrease in the physical quality of housing and the ecological environment.

Through its Center of Excellence activity, Kyushu University explained that [7], with the theme of a Sustainable Habitat System, it has succeeded in formulating the theory of environmental sustainability with

T=W-D formulation. T (throughput) results from architectural and regional design, with theoretically must produce the maximum value. It maximizes W (welfare) in the area using safety, relief, health and comfort, and sense. Efficiency is the fact of bringing the same amount of abundance for the same amount of energy. Sufficient is the adequacy of how much glut is enough for whom. Therefore, efficiency must lead to sufficiency. On the other hand, the results of the urban design must have the most negligible possible impact on E (environmental damage) realized through reducing damage from each recycling, reusing, reducing process, and evaluating the risk of general ecological damage from human activities, LCE, LCCO2 and LCC [7], [8].

Sustainable housing is part of sustainable architecture, which seeks to minimize the negative impact of the building environment, renewable energy use, and the broader ecosystem. Sustainable settlements have several policies, such as increasing green open space, increasing transportation mobility, saving energy consumption, maintaining and improving the water cycle, waste management, using environmentally friendly materials, expanding the variety of functions of shared facilities, and increasing the relationship between the biodiversity of the surrounding environment. [9], [10].

The 2015 Paris Agreement, which involved several countries, responded to climate change – one of which was by increasing the building framework. Simulations can help to understand, compare, and evaluate buildings and residential areas. The building or space uses software, especially on one focus, such as energy or mobility simulation. In 2013, the Massachusetts Institute of Technology (MIT) created software that can simulate four focuses in an integrated manner. The four focuses are floor area ratio, energy operational, daylighting, and mobility.

2. RESEARCH METHOD

The simulation method is used in the research to measure the current situation of Kampong Tudong. The modeling in this research is in the form of a reference settlement resulting from maximizing the increase in the present value of the Kampong Tudong settlement. The study began with an initial survey on climate change and riverside settlements in Indonesia which was supported by the literature as a vital reference through primary and secondary data, enabling researchers to observe all phenomena in the field.

It then proceeded with the simulation. The software used in the research was Rhinocheros and the Urban Modeling Interface 2.8 (UMI). Rhinoceros helps in processing settlement data into a base map. UMI contributes to the modeling simulation process. At first, UMI had five simulation focuses: Floor Area Ratio (FAR), operational energy, lifecycle, daylighting, and mobility. In 2022 it was developed with the addition of district energy and harvest. This study only simulated FAR, daylighting, operational energy, and mobility. Research based on UMI software between each component is not serial but interrelated (simultaneous). The WWR (windows-to-wall ratio) value in daylight will also affect operational matters because if the openings in buildings are large, energy use, such as ventilation and artificial lighting, will be reduced. Likewise, the existing mobility facilities will affect the FAR's value.

After the base map at the rhinoceros exists, the initial step for UMI simulation is to enter the initial data. The first is climate data from climate.onebuilding.org. Then the template library is related to building data starting from the type of material used and construction methods to the use of time for the building. After that, the next step is to continue with the simulation of each focus sequentially. Finally, the buildings will be divided based on the type of construction material for FAR and energy operational simulations and the function of the buildings for operational energy and mobility simulations.

2.1 Floor Area Ratio (FAR)

The Floor Area Ratio in the Urban Modeling Interface (UMI) is the ratio of the total floor area of a building to the outside area of the building. FAR value simulation requires a model and the land, which must be flat or closed surfaces [11]. Ensure the building to be analyzed is already in the 3D form in Rhinoceros. FAR also coincides with a maximum building height regulation that can control the partial shading of the environment by the building's shadow. Therefore, it is crucial to fill in the Building Settings at UMI and fill in the data based on the material and the height of each floor.

The FAR value has implications for land use whose common values are related to building floor coefficient (BFC) local government regulations. The higher the FAR value, the higher the density of the human population and buildings. The FAR value will affect the operational energy value [12]. In spatial planning, identify the most energy-efficient FAR value of 1.5-2.5 [13], and as Pontianak, local government regulations for FAR must < 3.2. Other necessary rules related to land, because in Kampong Tudong, some of the buildings are on the banks of the river, so they must comply with the riverbank line according to local regulations, which is 15 m from the highest point of the river tide.

2.2 Daylighting

Daylighting at Urban Modeling Interface (UMI) is the annual daylight availability for each building floor. The daylighting calculation is done automatically and does not require additional input parameters beyond that for the energy model. Building orientation and WWR in residential buildings affect the intensity of daylight entering [14]. There are two assessments in daylighting, namely sDA (spatial daylight autonomy) and cDA (continuous daylight autonomy) [15]. The daylighting assessment indicator for UMI in this research uses sDA (spatial daylight autonomy). sDA is an indicator assessing the reference space regarding adequate % lighting of the total effective activity (08.00 a.m.- 06.00 p.m.) [16]. The natural light value suitable for daylight is sDA300lux50% [15]. Before calculating the sunrise, make sure when analyzing we have filled in the openings on each side of the building with the percent numbers in the building settings.

2.3 Operational Energy

Operational energy at Urban Modeling Interface (UMI) is the energy used by the building during operation or occupancy, including HVAC, artificial lighting, use of hot water, and other equipment. There is a division of zones based on the category of construction type, schedule, and infiltration rate on the building template [17]. In general, the primary operational energy simulation at UMI relies on the mass/volume of buildings, settings on building templates, and geometric shading on shading layers. Floor volumes based on the building floor height setting in the building template divide the building envelope. Location, climate, building orientation, building area, windows-to-wall ratio (WWR), type of material and construction, building lifespan, schedule, and loads influence operational energy at UMI.

There is a color display from blue to red in the amount of radiation [11]. The redder the color produced means the energy needed by the building is more significant and vice versa. The bluer the color of the building, the less energy is required for the building. The wider and taller the building, the greater the energy consumption; the shorter and narrower the building, the less power it consumes. The following are the input and output software variables [18] divided into non-AC buildings and air-conditioned buildings, as follows:

Table 1. Operational energy standard value

Criteria	Non-AC kWh/m².month	AC kWh/m².month
Efficient	0.84 – 1.67	7.93 – 12.08
Quite efficient	1.67 – 2.50	12.08 – 14.58
Wasteful	2.50 – 3.34	19.17 – 23.75
Very Wasteful	3.34 – 4.17	23.75 – 37.5

Source: [18]

2.4 Mobility

Mobility at Urban Modeling Interface (UMI) measures an area's sustainability level through the ease with which people can move between locations by non-motorized transportation. Mobility can only analyze pedestrians and bicycles. Walkability measures how friendly an area is for walking [17]. One of the calculation indicators is the Walkscore which measures the ease with which people can move in an area without relying on motorized vehicles. This calculation works using "Points" or points for proximity to 9 North American-oriented facilities, namely, schools, restaurants, coffee shops, shopping centers, parks, entertainment, banks, grocery stores, and bookstores.

Walk Score®	Description
90–100	**Walker's Paradise** Daily errands do not require a car.
70–89	**Very Walkable** Most errands can be accomplished on foot.
50–69	**Somewhat Walkable** Some errands can be accomplished on foot.
25–49	**Car-Dependent** Most errands require a car.
0–24	**Car-Dependent** Almost all errands require a car.

Figure 1. Walkscore
Source: [19]

The steps needed in mobility start from drawing a line using the line tools that connect the main road with the entrance to each building in a predetermined area representing the original road in Rhinoceros. Then each building is given a point and select a layer according to the function of each building. At UMI, these functions include groceries, restaurants, coffee shops, bookstores, shopping areas, banks, entertainment, and schools. The following are the input and output software variables:

Table 2. Software variable for this research

Application	**Input variable**		**Output variable**
Rhinoceros	Kampong Tudong's residential area Kampong Tudong's building size (house & facilities) Building height (without roof height) Green area Kampong Tudong		
Urban Modeling Interface (UMI)	Floor Area Ratio (FAR)	Building area Building volume	Land use ratio Standard: < local BFC (3.2) 1.5-2.5 [15]
	Daylighting	Window-to-wall ratio	
	Operational energy	Location, climate, building orientation Building function Building area Window-to-wall ratio Building height Material Building life span Building operational period HVAC	Building energy use Standard: AC 7.93-12.08 $kWh/m^2/month$ Non-AC 0.84-1.67 $kWh/m^2\cdot month$ [18]
	Mobility	Buildings function in Kampong Tudong and its surrounding Pedestrian path	Paradise moving people Standard: 90-100 [19]

2.5 Study Area

The location of Tudong kampong is on the banks of the Kapuas River, Bansir Laut, Pontianak Tenggara, Pontianak City, and West Borneo. Residential areas infest a portion of the Southeast Pontianak District [20]. Residential areas on the riverbanks have a high density in Bansir Laut and Bangka Belitung Laut Kampongs. General provisions regarding spatial use [20]are as follows:

- The highest building base coefficient is 80 percent
- The highest building floor coefficient is 3.2
- The lowest green area coefficient is 20 percent
- The 15-meter river border line is measured from the highest point of the river tide.

This kampong has three land accesses: Gang H. Ali, Gang Family, and Gang Mendawai via Imam Bonjol Street. Then, it has direct access to the Kapuas River. The area of Kampong Tudong is ±0.14km^2 with a population of 270 families. It has several 1-storey residential units, 2-storey residential units, one 2-storey boarding house unit, one 3-storey hotel, and one 1-storey Early Childhood Education Center. Buildings in the form of housing and stalls are five units in total. In addition, there are also two cemeteries, as well as a shared parking lot. The existing buildings are classified as dense and have a narrow 1.2-2-meter circulation path for vehicles and pedestrians on the riverbank area.

The border of Tudong Kampong is adjacent on the east to Caping Kampong, on the southeast to Bansir Kampong, on the south to Tanjung Pura University Area, and on the north to the Kapuas River. Within a radius of 0.5 km from the kampong, there are two elementary schools, a middle school, a high school, a university, a public health center, and a bank. All of the facilities are accessible by foot.

Figure 2. Kampong Tudong's Siteplan

There are two types of materials used in the buildings in Kampong Tudong: concrete and wooden. Concrete buildings are found on the land and multistorey buildings, while the buildings are on the edge of rivers or stilt buildings using wood. Therefore, the type of material will affect resistance to energy use. Building materials used are ironwood, concrete, gypsum, plaster, and glass. Ironwood has a conductivity of 0.14W/mK, a density of 650 kg/m^3, and a specific heat of 1,200J/kgK. Concrete has a conductivity of 1.65 W/mK, a density of 2.100 kg/m^3, and a specific heat of 1.040 J/kgK. Plaster has a conductivity of 0.42W/mK, a density of 900 kg/m^3, and specific heat of 840J/kgK. The glass used is clear glass with a conductivity of 0.9 W/mK, density 2.500 kg/m^3, IR transmittance of 0.01, back-side solar reflectance and front-side solar reflectance of 0.07, back-side visible reflectance and front-side of visible reflectance 0.08 and visible transmittance of 0.89.

3. RESULTS AND DISCUSSION

3.1. Floor Area Ratio (FAR)

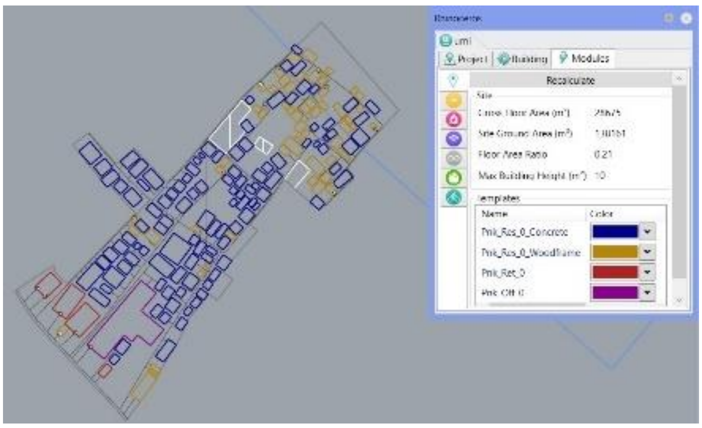


Figure 3. Kampong Tudong's FAR result

Based on the results of the Floor Area Ratio Urban Modeling Interface (FAR UMI) simulation on the existing conditions of Tudong Kampong, it reached a value of 0.21. This FAR value is low, which means that Tudong Kampong is still within the safe limits in the category of medium-density settlements. However, the problem is that Kampong Tudong still needs green open space. According to the local government, at least 20% of the city has green open space; moreover, Kampong Tudong is an area on the water's edge, so it needs a standard amount of green open space and spreads for water absorption. And another fact, the existing condition in the field is that several buildings cross the river borderline. So, to restore the current river bank area, it is necessary to relocate these buildings.

3.2. Daylighting

The window-to-wall ratio of each building and climate data influenced lighting. Some houses and retail are row buildings, so there is one side of 0% for WWR, and the largest is 80%. The building area varies from the largest Merpati Hotel (6,698.76 m^2), then terraced houses (324 m^2), medium houses (162 m^2), and tiny houses (60 m^2). The WWR percentage for the front facade of the building is at most 40%, the rear facade is around 10-20%, the side facades start from 10-20%, and the other side facades have no openings.

Table 3. Building Sample for Daylighting Simulation

Buildings	Building area	Building height	*Window-to-wall ratio*
Merpati Hotel 	6,698.76 m^2	10m	Front facade: 20% Rear facade: 40% Side facade 1: 40% Side façade 2: 40%
Retail 	1,608.63 m^2	9m	Front facade: 30% Rear facade: 20% Side facade 1: 10% Side façade 2: 10%
2-storey residential unit 	216 m^2	6m	Front facade : 40% Rear facade: 20% Side facade 1: 20% Side façade 2 : 10%
Middle house 	108 m^2	3m	Front facade: 40% Rear facade: 20% Side facade 1: 20% Side façade 2 : 0%
Small house 	60 m^2	3m	Front facade: 30% Rear facade: 20% Side facade 1: 10% Side façade 2 : 0%

These two indicators present daylighting simulation results in Urban Modeling Interface (UMI), namely Spatial Daylight Autonomy (sDA) and Continuous Daylight Autonomy (cDA). The simulation results in the Spatial Daylight Autonomy (sDA) indicator in the effective activity time from 08.00 a.m. to 06.00 p.m. showed that the average daylighting of Kampong Tudong is 30%.

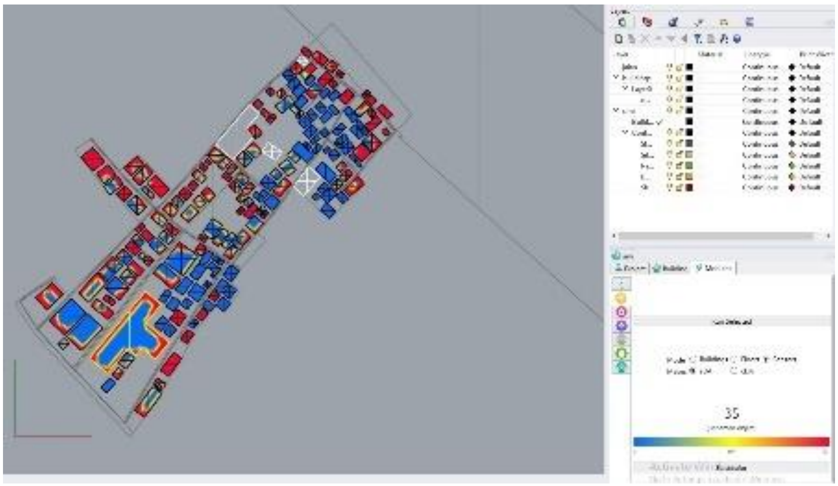


Figure 4. Kampong Tudong's daylighting result

Based on the table above from the results of the simulation of natural resources, the buildings in the form of offices, retail, multi-story houses, and medium-sized houses need to meet the minimum standards of natural resources. Buildings such as retail only have two sides that have openings, as well as a medium house. This building can still be maximized.

Table 4. sDA simulation results based on efficiency standard.

Building	sDA	sDA standard	Description
Office	35	55% minimum	X
Retail	16	is met widely	X
Multiple storey house	28	and maximum	X
Middle house	25	75%	X
Small house	100		X

3.3. Operational Energy

The simulation used Pontianak City climate data in 2018. The buildings were divided into residential (wooden stilt houses and concrete houses), retail and office. The energy use of each building in Kampong Tudong varies depending on the group. Residential buildings use artificial lighting energy (lighting) and electricity for equipment in operational energy. This use occurs in the morning and night because the occupants are more active outside the home during the day. Group Office buildings, including schools, use operational energy, including artificial lighting, electrical equipment, cooling systems, and water heaters. The intensity of this energy use is more familiar from morning to evening on regular days. On weekends the building tends to be used elsewhere. Group retail buildings consist of restaurants, coffee shops, and groceries. Its energy uses artificial lighting, electrical equipment, and cooling systems. The energy use intensity is high from the noon to evening every day. The building's operational period depends on the function of the building itself:

Figure 5. Residential Operational Period

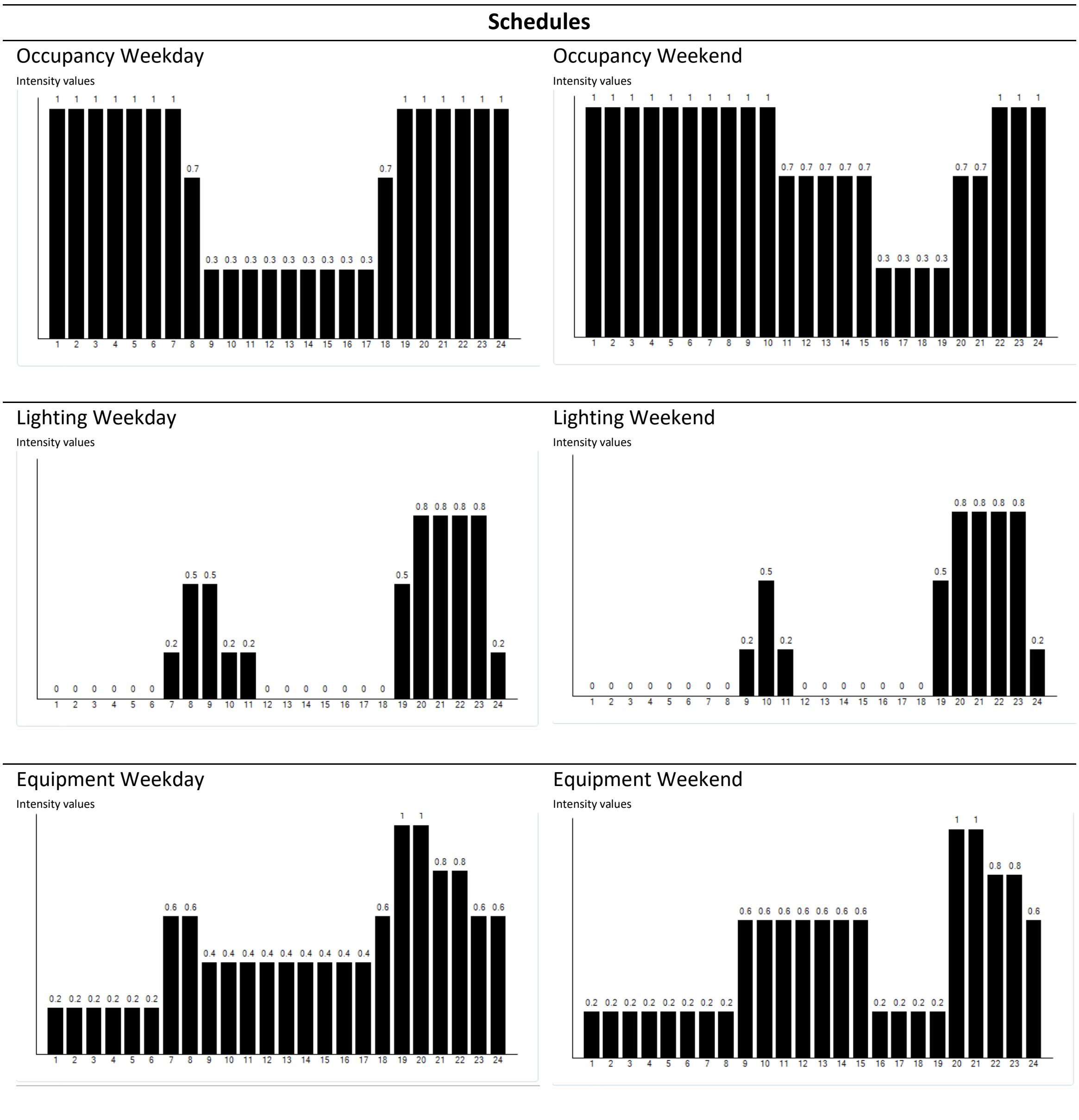


Figure 6. Office Operational Period

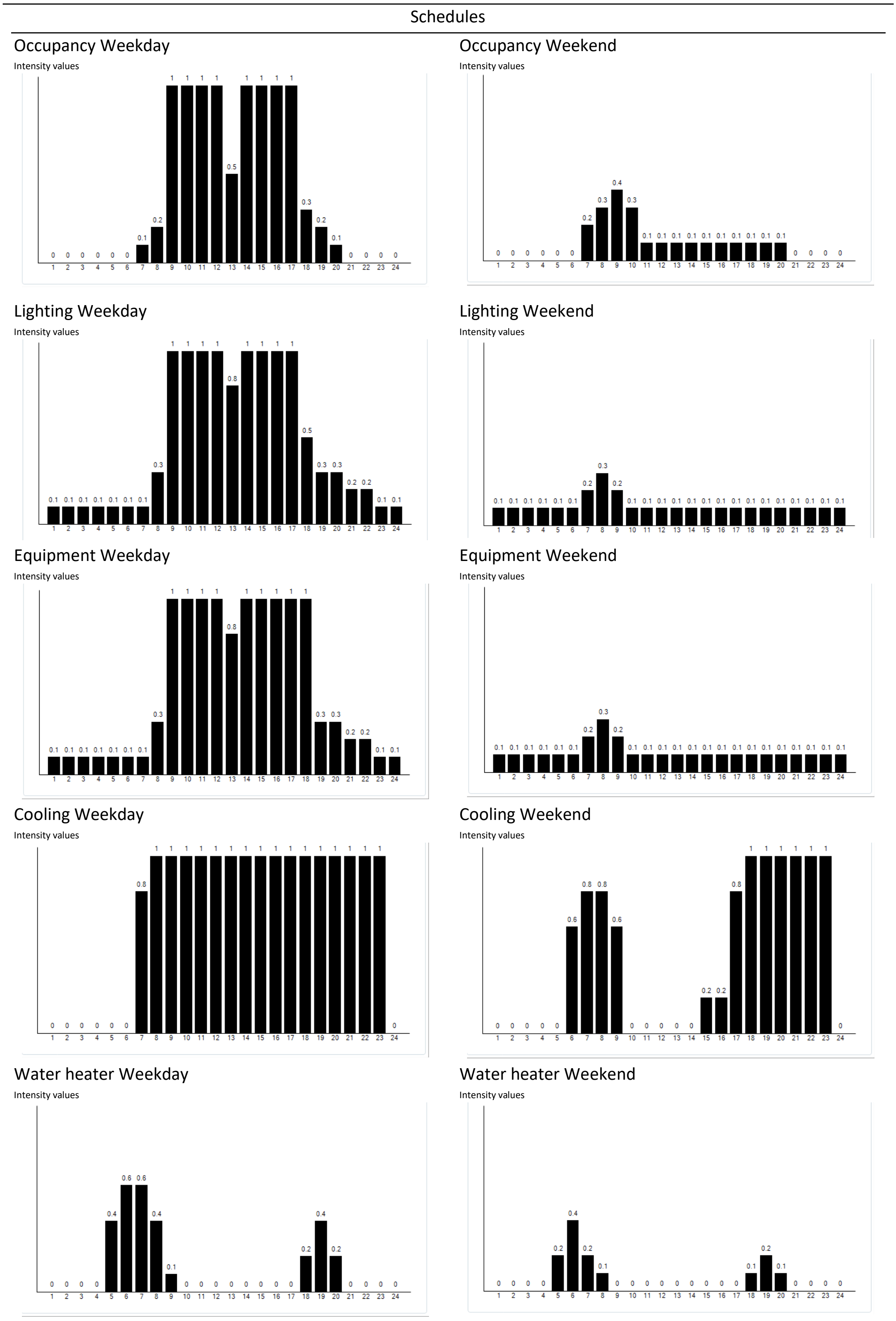
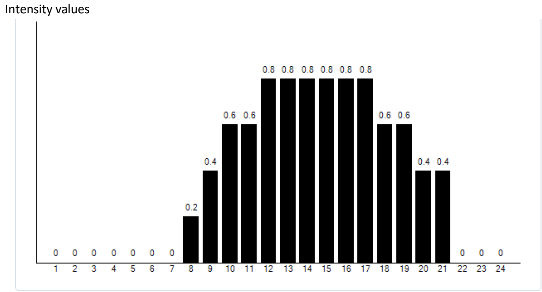


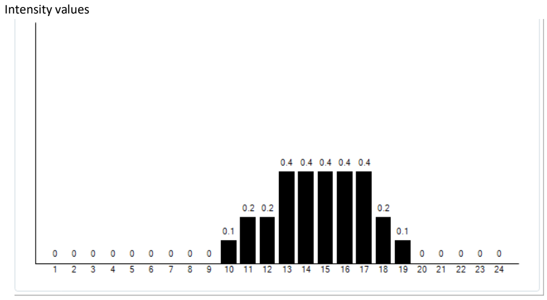
Figure 7. Retail Operational Period

Schedules

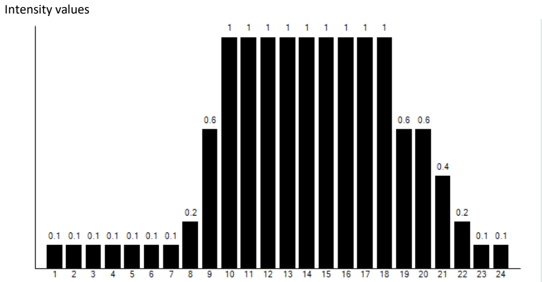
Occupancy Weekday



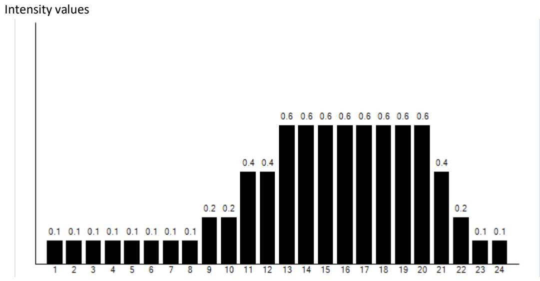
Occupancy Weekend



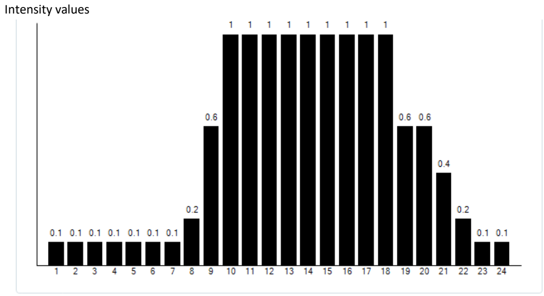
Lighting Weekday



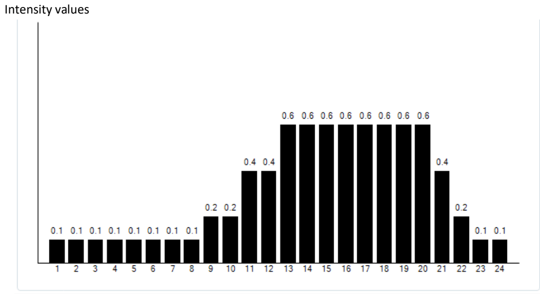
Lighting Weekend



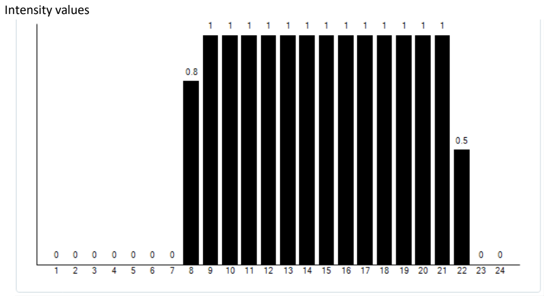
Equipment Weekday



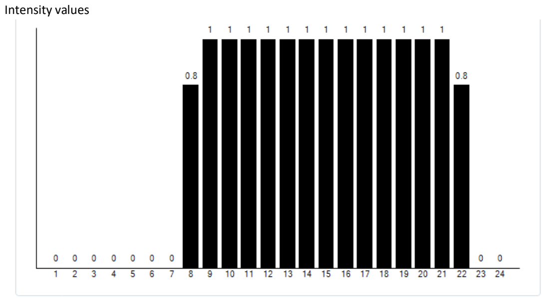
Equipment Weekend



Cooling Weekday



Cooling Weekend



The materials used in the buildings in Kampong Tudong are mainly divided into 2, namely concrete and wooden buildings. Concrete buildings are found on land and terraced buildings, while buildings on riverbanks or stilts use wood. The type of material will affect the durability of energy use. The operation of building with wood tends to use something other than artificial conditioning. The house's electrical capacity without air conditioning and water heater is mostly 450 kWh.

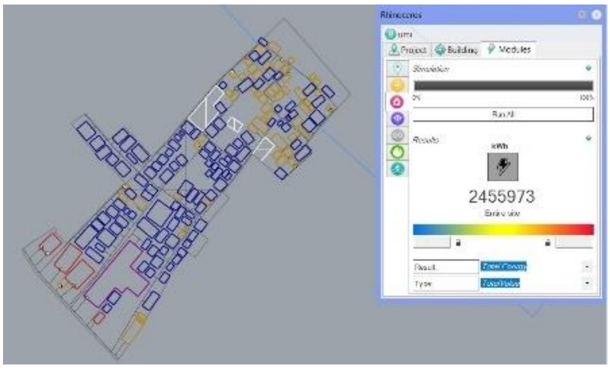


Figure 8. Kampong Tudong's Operational Energy Result

The total operational energy Urban Modeling Interface (UMI) of Kampong Tudong showed 2,455,973 kWh. The simulation results show a value of 86kWh/m^2, while the annual standard for non-air-conditioned buildings is 10.08-30 kWh/m^2.year (IKE, 2015). If we prefer non-air-conditioned building standards, Kampong Tudong is within the standard. However, when referring to the air-conditioned building standards of 95.16-144.96 kWh/m^2.year, Kampong Tudong is far below the standard. Most houses without air conditioning produce an operational energy value of 36 kWh/m^2. So, the operational energy value of Kampong Tudong still needs to be more efficient and improved.

3.4. Mobility

The settlement pattern of Kampong Tudong is linear, like most other kampongs on the banks of the Kapuas River. This kampong has three land accesses: Gang H. Ali, Gang Family, and Gang Mendawai via Jalan Imam Bonjol. Jalan Imam Bonjol with a width of 6 m, then Mt. H. Ali and GG. Mendawai 1 for access in and out of 4-wheeled vehicles to settlements with a width of 3.5 m. GG. Mendawai Tengah, with a width of 3.5 m, is in the middle of a residential area and the last limit for 4-wheeled vehicles in the area, followed by small alleys with a width of 1.5 m. In ancient times, wooden bridges were the material to make these small alleys. As time passed and many residents used motorbikes, the road in a small alley was improved with concrete pavement. Then another direct access from the Kapuas River.

Mobility in Kampong Tudong has an average walkability value in the public facilities area near the main road, 66. Meanwhile, the average walkability value in the middle of residential areas is 64. Average walkability indicates that Tudong Kampong is "somewhat walkable" and that the people of Kampong Tudong mostly use motorized vehicles to reach the available and accessible facilities. Kampong Tudong lacks variety in the facilities required for comfortable mobility. Locations of existing facilities are also not spread.

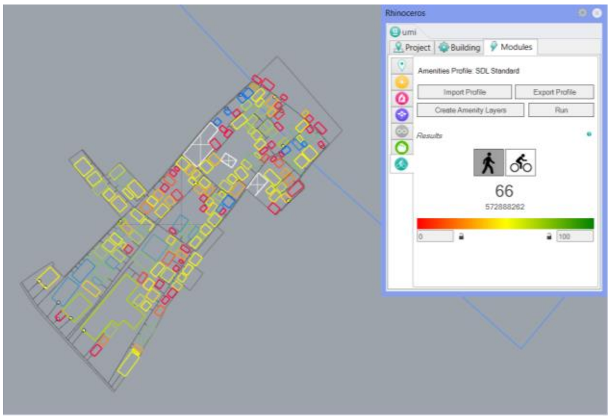


Figure 9. Kampong Tudong's Mobility Result

Maximizing this value is important because the existing facilities need to be diverse. For example, healthcare facilities and banks should be farther away. The location of facilities that are likely to be seen near highways very far from residential areas.

Kampong Tudong's current condition, according to Urban Modeling Interface (UMI) simulation, is 0.21 on FAR, 30% on average natural resources for building daylighting, 86 kWh/m^2.year on operational energy, and 66 on mobility. Maximizing the daylighting value can increase openings. This maximization will also affect the operational value of energy that can be maintained and encourage residents to refrain from using AC.

There is a need to improve the FAR value in Tudong Village. Even though the value is much lower than the standard, this kampong needs green open spaces, which can hinder the sustainability of Tudong Kampong. Therefore, it is necessary to add green open areas to spread throughout the village area for water absorption pockets.

Another improvement that the people of Kampong Tudong need is mobility. Roads within the kampong which are relatively small and not connected, need to be improved. In addition, Kampong facilities that still need to be more diverse and spread out are also a factor in the low mobility value of Tudong Kampong.

Table 5. Kampong Tudong's Current Situation UMI Values

Simulation	Values	Standard	Sustainability
FAR	0.21	Max. 3.2	The FAR value is far below the maximum limit, but has no green space area
Daylighting (rata-rata sDA)	30	300lux/50%	Value can still be maximized
Operational Energy (kWh/m^2.year)	86	10.08-30 buildings without AC; 95.16-144.96 buildings with AC (IKE)	The OE value is quite efficient
Mobility	66	90-100 (Walkscore)	Value below the limit for pedestrian comfort

4. CONCLUSION

Based on the UMI simulation, the results showed the values of Kampong Tudong's current condition, which are 0.21 on FAR, 30% on average natural resources for building daylighting, 86 kWh/m^2.year on operational energy, and 66 on mobility. Meanwhile, the efficient standard values are <3.2 on FAR, 55% on average daylighting natural resources, 10.08-30 kWh/m^2.year on operational energy, and 90-100 on mobility. The hope is that the preservation and development of settlements will continue. The grouping of buildings in Tudong village based on construction materials, wood, and concrete is the basis for UMI simulation calculations. Then in the building function group are residential buildings, office buildings, and retail buildings. Furthermore, development with good maintenance and control will lead to a sustainable riverside settlement. Keep in mind that UMI simulations are interrelated so that when you make improvements to one focus, it will affect the focus of the others.

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