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Sustainability of Engineering Faculty Complex in Universitas Gadjah Mada and the Surroundings Area Based on Urban Modelling Interface Simulation

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Abstract: This research simulated the engineering faculty complex of UGM using UMI Software, to assess how green is the campus complex. The methodology of this research was simulated by UMI software with 3 parameters. The size of the Floor Area Ratio is 0.26 with a total area of ± 183,534 m^2. The highest amount of Operational Energy is 116 kWh/m^2/year and the lowest amount is 75 kWh /m^2/year. Those are still considered lower than 240 kWh/m^2/year as a standard of energy usage. The mobility-value in the walkability aspect is 67, and 86 for Bikeability values. The results of the mobility-value are obtained and supported by questionnaire with a percentage of 62.60% which is considered as enough (60%). The results of the study show that the Engineering Faculty of UGM Campus is proved as a sustainable area. The results of this study can be used to improve the sustainability in UGM toward the green campus in the future. The Dean of engineering Faculty is suggested to maintain the efficiency of energy that is achieved today. Then, students are suggested to change their lifestyle by using bicycle and walking to improve mobility aspect.

Key words: sustainability, green campus, urban modelling interface

1. Introduction

Universitas Gadjah Mada has goal to be *green campus* by creating a safe, pollution-free and environmentally-friendly campus [1, 2]. The objective to be green campus is derived into several strategies which include planning, design, development, and maintenance [1, 3]. Developing campus with concern in sustainability will influence the quality of lives in economic, social and environmental aspects [4]. It is important because universities should be role model that have a large responsibility in educating and giving an example in implementing environmental sustainability and in minimizing negative impacts in environmental, economic, social and health [5]. Universities can be assumed as small towns because the land area, population, and the complex of the activities can give significant direct and indirect impacts on the environment, such as pollution and energy consumption. All buildings in campus block have a large impact on the environment due to the use of electricity, waste generated, operation of machinery, lighting, and transportation [6].

Three main principles of Sustainable Development are social, economic, and environmental principles [7, 8]. The three pillars of sustainability are the main considerations to develop sustainable campus [9]. These principles are manifested in the application of green architecture, where the development of a building and the area seeks to minimize the negative impact on the environment and maximize welfare [7]. A Building should be seen comprehensively not only as an end product where because it will take long process in its life span that and give impact on the environment

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and the ecosystem. A building's life-span is started from material collection, manufacture, transporting all materials to the site, construction, operation, building maintenance, demolition, recycling and reusing materials, where the life cycle or building maintenance is the phase with the highest energy consumption and the greatest impact on the environment. Moreover, human factors have a major influence on the ecosystems or the natural environment [10]. Human population and density in an area has an impact on the consumption of energy needed, where the more people occupy an area, the higher the level of energy consumption [11].

In addition, one of elements in a sustainable campus is transportation, such as parking spaces, and vehicles causing traffic problems, pollution and emissions. Related to the spatial aspect, the campus area and its surroundings with mixed-uses various functions and active human activities, give great impact on the social and environment [12]. In addition to the physical elements in the campus such as buildings, landscape, and road patterns have an important role to enhance the sustainability in the campus [13].

Therefore, Because the built-environment and building blocks of the campus have great impact to the nature so some considerations in sustainable campus is urgently needed. The sustainability in built-environment can be measured through 3 aspects, namely: the level of building density, energy consumption, and access. This study to measure the level of sustainability of Engineering Faculty campus of Universitas Gadjah Mada, is needed to determine the current sustainability conditions and to formulate future strategy and action to be more sustainable.

This study is an effort to develop Universitas Gadjah Mada torward Green Campus. This study was started with creating existing model of engineering faculty campus and the surrounding area of UGM, and then simulating the model with UMI (Urban Modelling Interface) Software to measure the level of sustainability through 3 parameter. The three parameter are *floor area ratio* (FAR), *operational energy*, and *mobility*. The FAR aspect is to determine the density of buildings. The operational energy is to determine the intensity of energy use of buildings to operate. And the mobility is used to find out the quality of access between one place to another, especially for walking and cycling.

1.1 Sustainable Campus

Sustainable development is a development concept that puts the vision to serve the requirement of the current generation without sacrificing future generation to meet their necessity with the 3 main pillars namely economic, social and environmental pillars [7]. Meanwhile, Sustainable campus is "A Healthy campus environment, with a prosperous economy through energy and resource conservation, waste reduction and an efficient environmental management, and promotes equity and social justice in its affairs and export these values at community, national, and global levels" [6]. Reference [5] mentioned that sustainable campus is "A Higher educational institution, as a whole or as a part, that addresses, involves and promotes, on a regional or a global level, the minimization of negative environmental, economic, societal, and health effects generated in the use of their resourced in order to fulfill its functions of teaching, research, outreach and partnership, and stewardship in ways to help society make the transition to sustainable lifestyles." Reference [14] stated sustainable campus is "A sustainable campus community acts upon its local and global responsibilities to protect and enhance the health and well-being of humans and ecosystems. It actively engages the knowledge of the university community to address the ecological and social challenges that we face now and in the future". From the explanation above can be concluded that energy factors, the population, and aspects of the physical environment are important in achieving a sustainable campus.

The important factors in sustainability of campus are the campus population (students, staff and others) and physical elements (buildings, landscapes, walkways, natural and artificial features in the campus environment) [15]. In general, sustainable infrastructure is an understanding between people, places, and the environment. The implementation of this concept supports ecological functions, social needs, and economic improvement. The characteristics of sustainable infrastructure are integrating landscapes and mixed-uses various functions [16]. Transportation facilities are also very important, such as bicycle and pedestrian lanes on streetscape in campus [6]. Transportation can create the convenience mobility of people to move from one place to another places. The convenience of mobility can be influenced by land use patterns that consist of density, mix land use, non-motorized conditions, and network connectivity [17]. Moreover, good mobility can be achieved through a road configuration that facilitates access to public transportation networks safely and comfortably [18].

A sustainable campus has to apply the principle of green building in order to create a healthy environment and to reduce energy-usage so that energy consumption in the building can be reduced to be more efficient for lighting, temperature control, improving circulation and air quality in the inner space [19]. The amount of energy consumed by buildings indicates the level of efficiency and effectiveness of buildings. Reducing energy-usage could give significant impact to the environment and building operation because mostly energy-usage is sourced from non-renewable natural resources [7]. The non-renewable natural resource can increase Carbon emissions which can drive a negative effect on the environment such as climate change. Carbon dioxide can be eliminated through absorption by plants [20].

1.2 Green Architecture

Green Architecture is part of the implementation of sustainable development which is transformed into the concept of building and regional development that respects to natural environment, minimize negative impact on the environment. The simple theoretical formulation in Green Architecture formulated by Kyushu University through an event of the Center of Excellent, with the theme of the Sustainable Habitat System [7, 21].

Throughput (T) value should be maximum. Increasing the value of T can be done with increasing the value of W and reducing the value of D. Welfare (W) value was constructed by the level of prosperity and quality inside and outside the building that is achieved by security, comfort, health, comfort to be efficient, and feeling to be sufficient. This value is endeavored maximum. Meanwhile, the value of environmental damage (D) which includes the cycle of energy, CO_2, and costs must be as minimal as possible, which can be in the form of energy and resource consumption during the life-span period. The value of welfare and environmental damage should not be the same. This is not valid or there are no basic principles and design of green areas if the value of welfare and environmental damage are directly proportional. It means both values having one a large and the other one small value [7, 21, 22].

Welfare can be realized by controlling physical elements and populations in an area or Floor Area Ratio and Mobility, while Damage can be reduced through energy consumption. In order to measure the sustainability of an area based on this theory a measurement instrument is needed that can describe

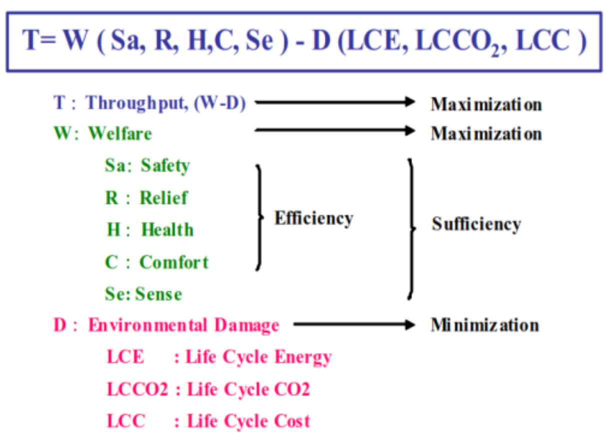


Fig. 1 Teori T=W-D, fundamental formulation for "sustainable habitat" [21].

existing conditions. Urban Modeling Interface is a software that can measure the sustainability of an area through physical elements and operational energy.

1.3 Urban Modelling Interface

Urban Modelling Interface (UMI) The Urban Modeling Interface (UMI) is a plug-in developed by the Massachusetts Institute of Technology (MIT) and launched in 2013 [23]. This program is integrated with Rhinoceros software to simulate operational energy and walkability at the regional scale to ensure that each building in the area designed uses minimal energy and efficient resources [24, 25]. UMI is software that can be used to assess the level of sustainability of a building and area through 4 parameters, namely floor area ratio (FAR), operational energy, embodied energy and mobility.

1.3.1 Floor Area Ratio (FAR)

FAR is a comparison between the total floor area of the building and the total area of the land where the building establish. The FAR value on UMI is obtained by modeling the building and land.

1.3.2 Operational Energy

The energy is used by buildings for air conditioning (cooling or warming), artificial lighting, and electronic equipment. *Standar Intensitas Konsumsi Energi (IKE)* translated to be The Standard of Energy Consumption Intensity is used to determine the level of efficiency in a building. Energy conservation or energy efficiency is one of many dimensions of sustainable development [12].

1.3.3 Embodied Energy

Energy is needed by life-cycle process in the building including the material used, which includes production, transportation, maintenance and disposal after construction (demolishing, recycling or reusing).

1.3.4 Mobility

This parameter measures the level and quality of the accessibility and movement especially with walking and cycling. Modeling the road system is needed to represent the connecting between buildings and to determine the value of Mobility. The higher the Walking-Score, the better the level of accessibility of the area.

2. Methods

2.1 Research Method

The research method used is simulation. Simulation methods with software through computers started with remodeling the existing buildings and regions and then reviewing the model and result of the simulation with theories. Simulation is used to overview of the condition of an area both micro and macro levels. And It is fit for research related to scale and complexity [26]. Modeling a building and an area related to energy is useful to understand, to compare and to make estimates in a design or a review [27].

In this study, the Faculty of Engineering, UGM and its surrounding complex will be modeled through the Rhinoceros software, and simulated using the Urban Modeling Interface to obtain the value of Floor Area Ratio, Operational energy, and mobility. Then the results of the use of energy in the building and complex will be assessed for the sustainability with the recognized parameter standards created by ASEAN-USAID in 1987 for the Operational Energy. For the Mobility value will be assessed to the Walk Score standard to measure walkability-levels, while bike score is to measure the comfort level of an area for cycling [28]. In order to get the results of this simulation, road system must be modelled by creating lines to connect all the buildings. The score range used to assess mobility is 0 to 100. The classification of *walkability* and *bikeability* can refer to the walk score and bike score [28]. For the Mobility, the simulation results are supported by a questionnaire using Purposive Sampling Techniques with a rating scale, to determine population perceptions on aspects of Mobility in the Engineering Faculty complex of UGM and surrounding areas. The result of this Sampling is based on judgment (criteria in the form of a certain consideration) and quota (percentage of samples according to the percentage of the population) [29]. The questionnaire was given to 50 people from the UGM faculty of engineering population from a total of ± 8419 people consisting of 377 lecturers (2.24%), 459 employees (2.73%) and 7583 students (45.03%). The largest percentage or number of students from the population shows the importance of students' perceptual responses. There are 14 statements relating to mobility in the the Engineering Faculty complex of UGM and its surroundings with 5 rating option, namely: 1) Very Bad, 2) Poor, 3) Good enough, 4) Good, 5) Very Good. Table 1 is a list of questions on the Mobility questionnaire at the Engineering Faculty complex of UGM and surrounding areas.

Table 1 List of statements on the questionnaire about mobility.

No.	Statement about *Mobility* in Engineering Faculty Complex in UGM and surrounding area.
1	There is a convenience to move from one place to another place in the engineering faculty complex UGM and the surroundings.
2	There is a pedestrian and bicycle route (Cycling route) that connects one place to another in the area of the Engineering Faculty UGM and its surroundings.
3	Pedestrian and bicycle lanes the Engineering Faculty UGM and surrounding areas are in good condition
4.	Pedestrians, bicycle lanes, and vehicle lanes have easy access to various places in the area of FT UGM and its surroundings.
5	Easiness and accesibility both walking and cycling to the location of public transport if it is reached from the UGM Faculty of Engineering.
6	The existence of non-motorized transportation modes provided by the campus such as bicycle facilities (Cycling facilities).
7	Buildings between facilities are classified as close together and easily to access especially by walking or cycling.
8	Good connectivity on the transportation network of the Engineering Faculty UGM area and its surroundings.
9	Accesibility for reaching public facilities, such as: shops, offices, hospitals around the Engineering Faculty UGM easily and safely and comfortably.
10	Facilities for pedestrian and cyclist networks such as lighting, trash cans, bicycle parking.
11	Prefererance to use more public transportation compared than private vehicles to and from campus
12	Easiness of using public transportation from the campus area to public facilities close to the campus
13	Convenience to go to campus using private vehicles than public transportation.
14	Sufficiency in parking area and easiness to find parking lots.

Table 2 Formula of *Rating Scale* [30][33].

Total criteria score	= (highest score on the item) × (total quantity of items) × (total number of respondents)
Intepretation	= (total number of data-collection score-result) : (total criteria score) × 100%

And then the rating scale is calculated and analyzed to get an interpretation. Firstly, it calculates the total number of criteria scores and the total number of scores from the data collection. Furthermore, the percentage of interpretation can be obtained from the results of dividing the number of scores resulting from data collection and the number of criteria scores.

2.2 Object and Variable of Research

The research object is Engineering Faculty complex of UGM. In general, Land-uses is divided into 5 zones, namely: (1) Commercial Zones, (2) Research Zones or Engineering Faculty of UGM Zone, (3) UGM zones, (4) residential zones, and (5) *Sardjito's* Hospital Zones.

Table 3 shows the variables used in modelling and analyzing FAR, operational energy, and mobility in the engineering faculty complex of Gadjah Mada University and its surroundings area.

2.3 Phases of Simulation

The steps to simulate the model in this study are as follows:

1) Creating Model of existing buildings in Rhinoceros 5.0 which cover the floor area and building height.
2) Entering the elements of modeling in the type of layers in the Urban Modeling Interface.
3) Making changes to the building template on the Urban Modeling Interface (UMI) related to the operational time of the building and its energy

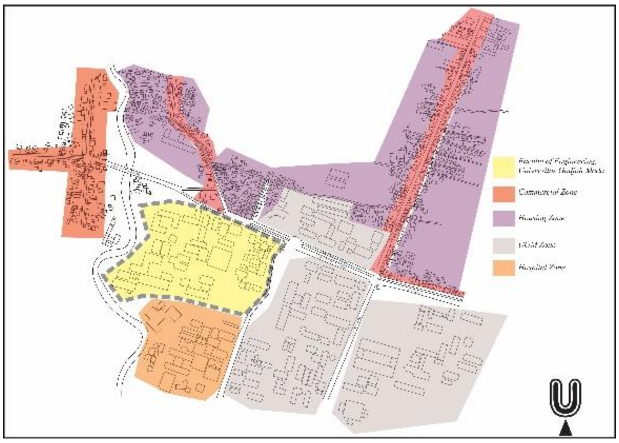


Fig. 2 Zoning in engineering faculty complex of UGM.

Table 3 Research variable.

1	Research Object	
	Engineering Faculty complex of Universitas Gadjah Mada and its surroundings area.	
2	Variable	
	T = W - D	
	Dependent Variable	
	T = Throughput	
	Independent Variable	
	W = Welfare	
	D = Environmental Damage	
3	Indicators	
	FAR	The area of Engineering Faculty complex of Universitas Gadjah Mada.
		Buildings in Engineering Faculty complex of UGM.
	Mobility	Function of Building in Engineering Faculty complex of UGM.
		Lane for motorized vehicles in Engineering Faculty complex of UGM.
		Cycling Tracks in Engineering Faculty complex of UGM.
		Pedestrian Path in Engineering Faculty complex of UGM.
		Parking lots of Cycling Tracks in Engineering Faculty complex of UGM.
	Operational energy	Floor-to-Floor height of buildings in the campus complex.
		Wall-to-Window Ratio (WWR)
		Cooling Type (AC/Non-AC)

usage load (AC/Heating/Lighting/Electrical Equipment/Mechanical Ventilation).

4) Classifying building functions in the Urban Modeling Software Interface based on the existing conditions.
5) Entering indicators on Urban Modeling Interface version 2.1 to assist the simulation devices in translating building density, amount of energy use, and the accessibility in Engineering Faculty of UGM complex and its surroundings.
6) Entering climate data of Yogyakarta.
7) Running a simulation on *floor area ratio, operational energy, and mobility* in Urban Modelling Interface.
8) Changing the value of the result of simulation in another format such as table or graphics so that it could be easy to be understood and analyzed.

3. Results and Discussions

3.1 Spatial Analysis

Faculty of Engineering Complex of UGM has a total land area of 183,534 m^2, with a total effective building area of 60,241 m^2 [30]. The limitation in seeing the ground-figure of Engineering Faculty complex of UGM and its surrounding area, was surmounted by tracing the map through satellite imagery. And the results show that the engineering faculty complex is an area that still has sufficient open space, while the surrounding area tends to have high density.

In Urban Modeling Interface, Floor Area Ratio (FAR) is a comparison between the total floor area and the total area of land where the building stands. The higher the FAR value indicates that the higher the population density of humans and buildings in an area.

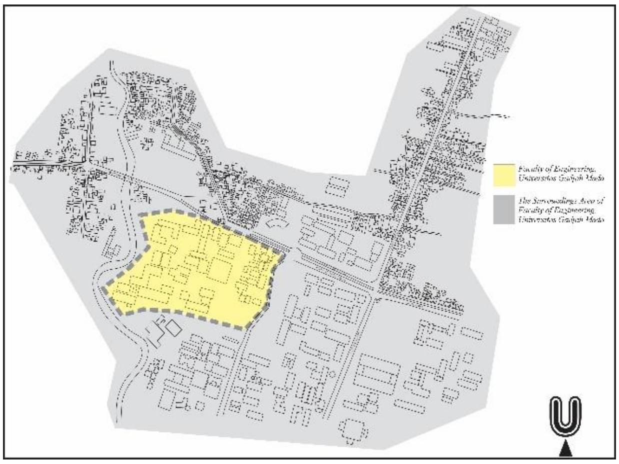


Fig. 3 Spatial condition of engineering faculty complex and its surroundings area.

3.2 Floor Area Ratio (FAR)

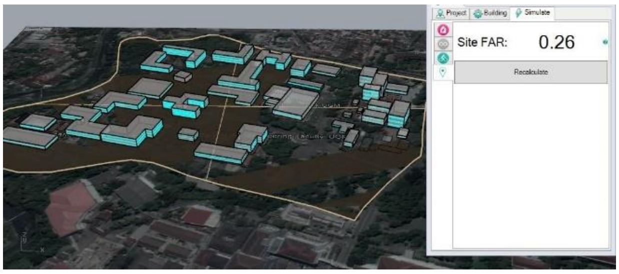


Fig. 4 FAR at the Faculty of Engineering of UGM complex.

This condition will cause a high consumption of energy needed to achieve a comfortable environment both inside and outside of the building. Based on the simulation results, FAR of the Faculty of Engineering of UGM complex is 0.26. It means that the density of buildings and the human population in the area are relatively low because the open space is almost 3 times greater than the total building area. Open spaces in the Faculty of Engineering complex of UGM are parks, parking spaces, and green land.

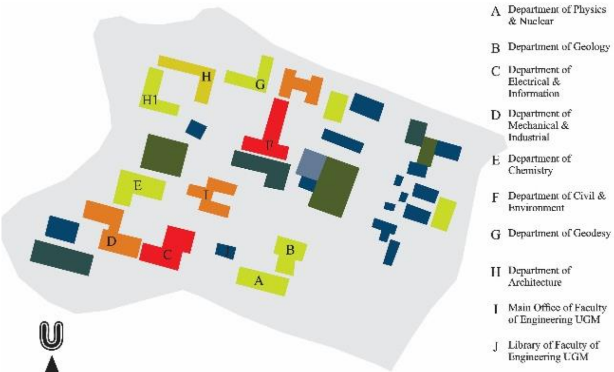
Fig. 5 Open space in engineering faculty UGM complex.

The vast open space of an area is one manifestation of a sustainability concept through aspects of the environment, in addition to economics and social. This has a positive influence on the human population in terms of health. FAR has an influence on environmental thermal comfort conditions. Because the adequacy of direct sunlight and the flow of air that passes can give impact to human healthy issue [31].

3.3 Operational Energy

Operational energy is the energy used for building for water heating, cooling, lighting, and equipment and appliances when a building is occupied [4]. In this study, the operational energy used in *the Urban Modeling Interface* is the energy used by buildings during operation which includes the energy load of artificial lighting, cooling/AC, and electrical equipment. This is required to provide comfort in the building. The total amount of operational-energy is influenced by the length of time the building operates in one day. There are 10 main buildings on the Engineering Faculty of UGM with operational periods ranging from 7:00 to 17:00.

Looking at the side of the total floor area, the largest building is the Department of Electrical Engineering and IT Engineering, while the smallest is the library of engineering faculty. The Operational energy at the Urban Modeling Interface is influenced by several factors, namely: type of materials, building volume, construction, schedule, and loads (Occupancy density, equipment, lighting, cooling) and window-to-wall ratio. Taking data of 1-year period of building operations, the overall consumption use is 4,654,009 kWh. The building with the highest consumption intensity is the building of the Department of Electrical and Information Technology with 721,498 kWh/year, where the building also has the largest floor area. While the lowest energy consumption is the library of engineering building with 76,111 kWh/year, which has the smallest floor area compared to other buildings.



	WWR Window-to-Wall Ratio (North/South/ West/East)	Number of Floor	Building Height (m)	Area of 1st floor (m^2)	Total Floor Area (m^2)	Cooling (AC)
A	40 / 40 / 40 / 40	2	6.7	±1408	±2816	√
B	40 / 20 / 60 / 40	3	11.5	±1288	±3864	√
C	60 / 40 / 60 / 40	3	12.8	±2261	±6783	√
D	40 / 40 / 40 / 40	2	8	±2564	±5128	√
E	20 / 40 / 60 / 20	2	8	±1932	±3864	√
F	60 / 40 / 40 / 60	3	12.6	±2191	±6573	√
G	40 / 60 / 20 / 40	3	12.6	±1290	±3870	√
H	40 / 60 / 60 / 60	3	12.6	±1305	±3915	√
H1	40 / 60 / 60 / 60	2	8	±1452	±2904	√
I	40 / 80 / 20 / 20	3	12.3	±1526	±4578	√
J	60 / 20 / 20 / 20	3	8.8	±345	±1035	√

Fig. 6 Building data of 10 main buildings of Engineering Faculty of UGM Complex.

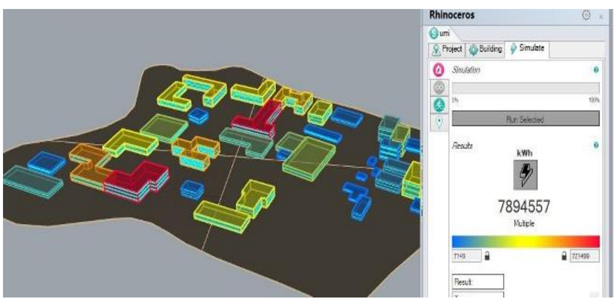


Fig. 7 The result of simulation in operational energy at Engineering Faculty of UGM Complex.

Meanwhile, looking at the energy consumption in units of kWh/m^2/Year, the building with the highest energy consumption is Department of Architecture Engineering Building with 116 kWh/m^2/Year and the lowest is a library of engineering building with 75 kWh/m^2/Year. The parameter-standard of energy consumption efficiency is based on the results of research done by ASEAN-USAID in 1987 which is the final report was issued in 1992. The target amount of energy consumption intensity of electricity with the function of office buildings for Indonesia based on *IKE* is 240 kWh/m^2/Year [30].

Taking the parameter-standard of office building typology is based on the consideration of activities. The building functions of Engineering Faculty of UGM complex is typical university functions for student to

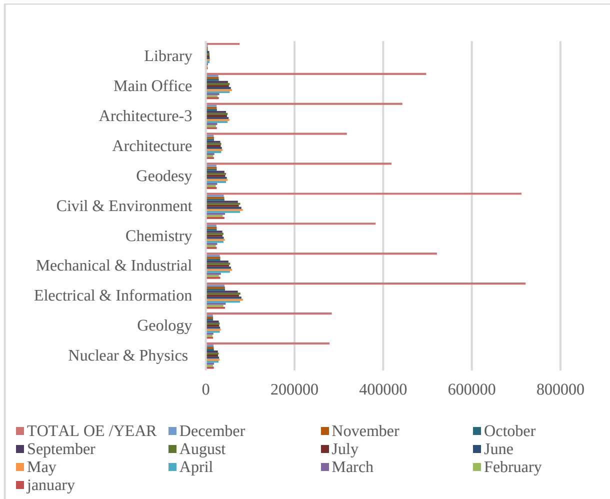


Fig. 8 The result of simulation in operational energy (kWh/Year) at Engineering Faculty of UGM Comple.

Table 4 The result of simulation in operational energy (kWh/Year) at Engineering Faculty of UGM Complex.

Building	Electrical & Information	Library
	kWh	kWh
Month		
1	43235.37569	4396.68
2	39245.67059	3990.96
3	44741.69293	4549.86
4	77463.37804	8219.979365
5	83783.67134	9072.219167
6	80227.60427	8866.675704
7	74669.73297	8190.822742
8	77903.22803	8305.309089
9	72354.13012	7515.209191
10	43235.37569	4396.68
11	42909.68548	4363.56
12	41729.05846	4243.5
Total OE		
	THE HIGHEST	THE LOWEST

learn and officer, lecturer and researcher to work in typical working hours. Therefore, Engineering Faculty of UGM complex is classified as efficient in terms of energy-usage because it is under the applicable standards. Minimizing the energy-consumption can reduce CO_2 emissions, that mostly those sourced from fossil fuels (oil, natural gas, and coal) [20].

Building	Electrical & information	Library
	kWh/m²	kWh/m²
Month		
1	6.574285714	4.344545455
2	5.967619048	3.943636364
3	6.803333333	4.495909091
4	12.9077089	8.122509254
5	14.00843229	8.964643445
6	13.54079213	8.761537257
7	12.53722606	8.093698362
8	12.99415918	8.206827163
9	12.01598282	7.426096038
10	6.574285714	4.344545455
11	6.524761905	4.311818182
12	6.345238095	4.193181818
Total OE	116.7938252	75.20894788
	THE HIGHEST	THE LOWEST

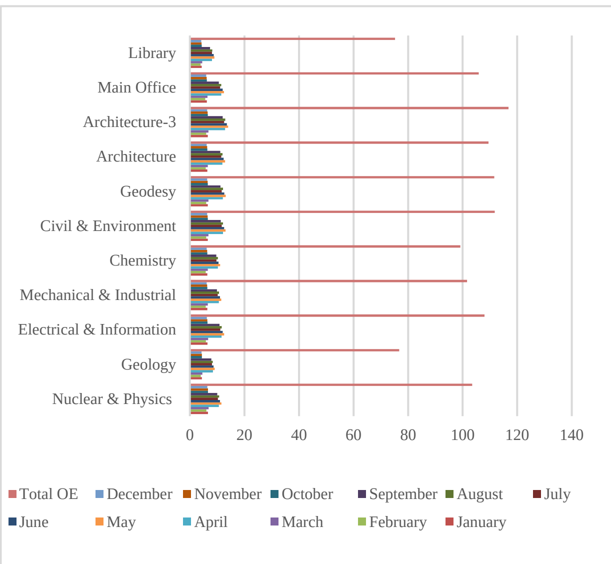


Fig. 9 The result of simulation in operational energy (kWh/m²/Year) at Engineering Faculty Complex of UGM.

3.4 Mobility

Walking, cycling and public transportation are the priorities in sustainable transportation modes [32]. The sustainability of land can be influenced by the mobility from one location to another. An area developed sustainably should encourages walking, biking, and taking public transportation than taking motorized private transportation.

The results of simulation show that the mobility at the area of the engineering faculty complex of UGM and its surroundings in walkability aspects is 67. This value indicates that somewhat walkable or some errands can be accomplished on foot. While the value of bikeability is 86. This value shows that the engineering faculty complex of UGM and its surroundings is very bikeable. It means that bikers can ride their bike comfortably for most trips. This is caused by various physical element factors, namely:

1) Buildings in the campus complex and the surrounding area are very diverse in terms of activities and functions. There are commercial and office functions, hospitals, educational function and residential function. The shops, restaurants, offices, and other commercial

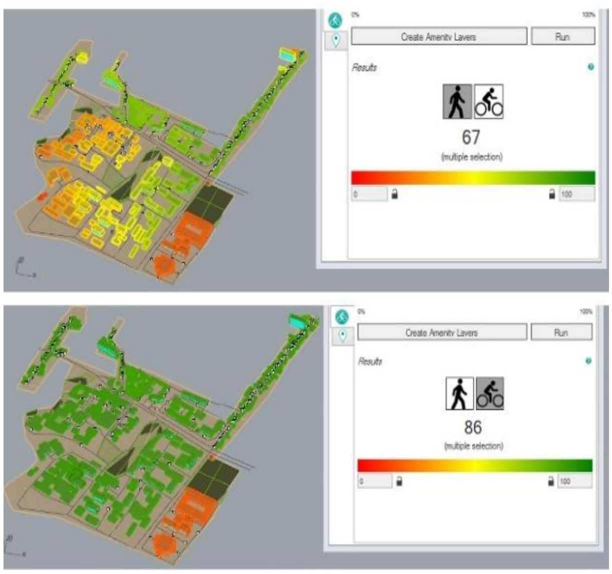


Fig. 10 The result of simulation in mobility at Engineering Faculty of UGM Complex and its surrounding area (top-walkability, bottom-bikeability)

facilities are located along Kaliurang Street, Jalan Monjali, and Am Sangaji. While residential zones are concentrated on Pogung-District and Selokan Mataram roads. The Mixed functions makes it easier for people to move different places in quite short distance so that it can also reduce the length of travel when using motorized vehicles and can encourage walking and cycling activities which results in reduced pollution and CO_2.

Fig. 11 Pedestrian path at FT UGM.

Fig. 12 Parking space at Engineering Faculty of UGM.

2) Pedestrian lanes at Engineering Faculty Complex of UGM and surrounding areas are in good condition. Moreover, the continuity of pedestrian constantly adjacent to the road system supports to move on foot.
3) Connectivity of motorized vehicle lanes, and the availability of public transport facilities on Kaliurang street and Kesehatan Street have provided high accessiblities for users of private and public-transportation.
4) Availability of parking lots for motorized vehicles and bike on campus. And the bicycle parking bag and rental bike at several points at the campus complex supports the mobility.

Taking perception of users through the sampling of questioner to 50 people consisting of lecturers, staff, and students of FT UGM is fairly good category

(62.60%) where the result of the interpretation shows Enough to Strong category.

Highest Critical Score	= Highest Score × Total Respondents × Total Quantity Items = 5 × 50 × 14 = 3500					
Perception	= Total Score ÷ Highest Critical Score × 100% = **2191**/3500 × 100% = **62.60%**					
Interpretation	0	20	40	60	80	100
		SL	L	C	K	SK
	0	700	1400	2100	2800	3500

Noted:
SL: Very Weak L: Weak C: Enough
K: Strong SK: Very Strong

Fig. 13 The sampling interpretating result of users' perception about mobility at engineering faculty of UGM complex and surroundings area.

The accessibility and mobility of people in the FT UGM complex is supported by the road system located at surrounding this complex and the parking lots or pockets for both car, motorcycle and bike that are easily found at each department. In addition, there are public transportation and bus stops located close to the entrance of the FT UGM.

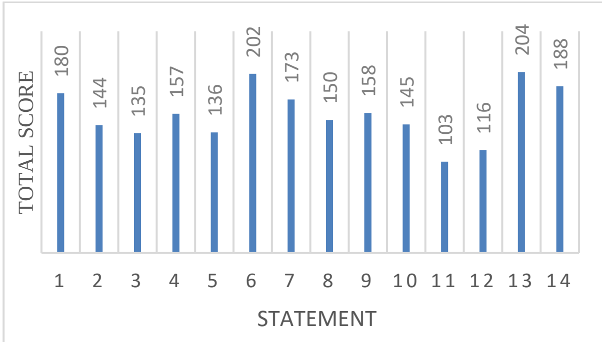


Fig. 14 Total score of perception of samples about mobility at FT UGM complex and surroundings area.

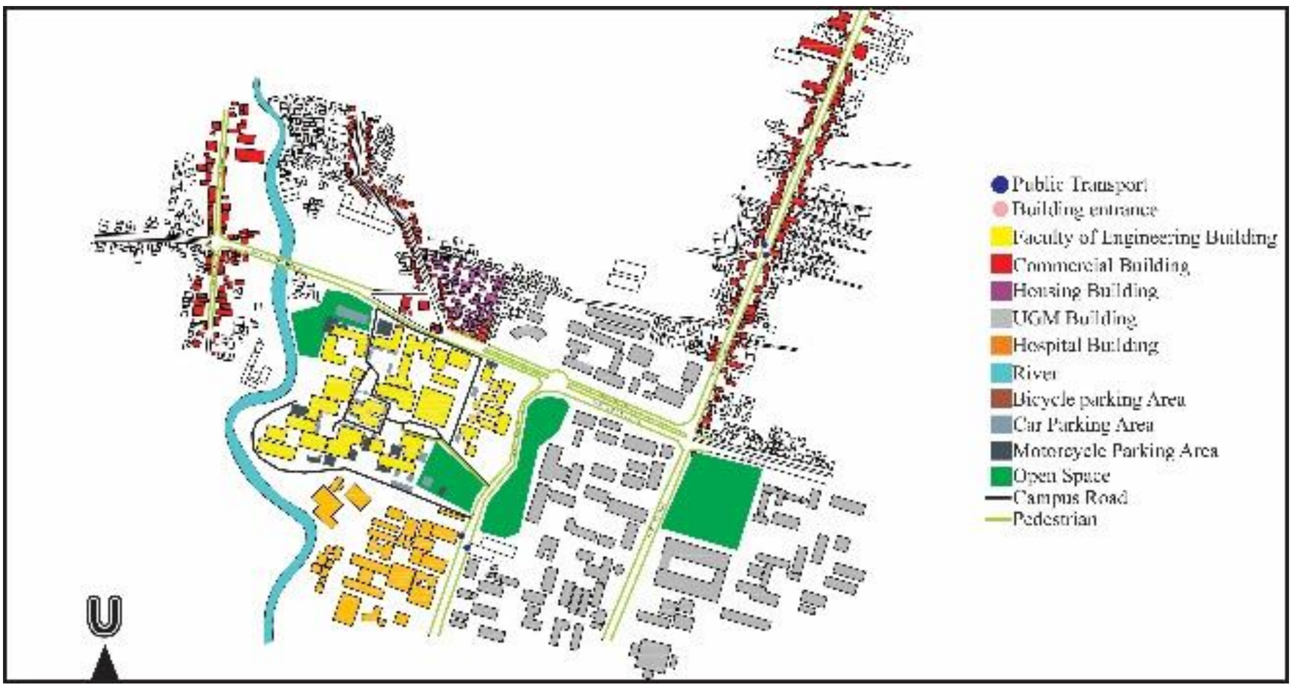


Fig. 15 Mobility at the FT UGM complex and surrounding area.

3.5 Sustainability at Engineering Faculty Complex of UGM and The Surrounding Area

Engineering Faculty Complex of UGM is proved as a sustainable area through Taking the formula and theory of sustainable habitat system because the study of this complex show maximum value of *Throughput* (T) and *welfare* (W) and minimum value of *environmental damage*. Welfare (W) Aspect can be seen from the values of Floor Area Ratio (FAR) and Mobility simulated by UMI.

The value of Floor Area Ratio at the FT UGM complex is 0.26, which means that the open space is almost 3 times larger than the built area. This affects the health and comfort aspects for human`s lives which are affected by the adequacy of sunlight and air in the area. Moreover, it can save the use of electrical energy for lighting and artificial ventilation. In addition, this number also shows that the complex is not a dense in term of the buildings and its population, so that the aspects of relief and safety at engineering faculty complexof UGM are also maximal. Furthermore, the mobility aspect especialy in the walkability value is 67% and bikeability score is 86%. Those values indicate that the engineering faculty complex of UGM complex and surrounding areas are sustainable due to some physical elements such as pedestrians, vehicle lanes, availability of parking lots and the mixed functions which encourages non-motorized transportation such as walking and cycling and reduces carbon emissions and pollution. Those affect the quality of the environment, health and comfort in the area. The maximum value of health (Health), safety (Safety), relief, and comfort (Comfort) will maximize the welfare value (W).

The environmental damage (D) at the engineering faculty complex of UGM is showed below the standard energy consumption intensity of 240 kWh/m^2/Year through operational-energy simulation so it indicates a minimum operational energy.

4. Conclusion

Engineering Faculty of UGM Complex is a sustainable area. Taking the formula and theory of sustainable habitat system, the Engineering Faculty complex has a maximum Throughput (T) value, with a minimum environmental damage (D) value, and maximum welfare (W). Environmental damage (D) values can be seen from operational energy, while welfare (W) can be seen from the value of the floor area ratio and mobility.

Based on the simulation with Urban Modeling Interface (UMI), the value of the Floor Area Ratio is 0.26. The highest operational energy is 116 kWh/m^2/Year, and the lowest is 75 kWh/m^2/Year, where the value is under the applicable standard energy consumption intensity of 240 kWh/m^2/year. Regarding the Mobility, walkability scores (67%) and bikeability score (86%) indicate that some trips can be done by walking and cycling. These three aspects need to be considered for the future sustainable development towards green campus.

5. Suggestion

Toward the Green Campus, the development of the UGM should maximize Throughput (T). This can be done by minimizing operational energy through implementing passive-strategies. Implementing passive strategies can help reduce energy requirements [33].

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