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Green Campus Setting and Infrastructure Assessment using Geographical Information System and Future Initiatives

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Abstract

University Green Metric is one of the metrics to measure the sustainability on a specific campus. The metric has its own indicators to measure the sustainability in every aspect. Due to these indicators, a Geographical Information System (GIS) has been used as a tool to identify and calculate specific information based on each indicator. The sustainable university campus is always related with the setting and infrastructure. The setting and infrastructure involve the landscape including the buildings, vegetation, water absorption, forest, population, and university's budget toward sustainability. This paper aims to introduce the use of GIS to perform green metric calculation for setting and infrastructure indicators. There are six indicators involved in the setting and infrastructure cluster i.e. total open space area, forest vegetation, planted vegetation, water absorption area, ratio open space and population, and university budget toward sustainability. Each indicator was extracted using GIS to speed up the data acquisition for green metric calculation. In 2018, Universiti Teknologi MARA, Shah Alam campus had 188 buildings with a total ground floor area of 274,173.98 m^2 and total building area of 1,252,590.30 m^2, while forest vegetation covered 112,858.58 m^2, planted vegetation covered 380,796.56 m^2, and water absorbent areas accounted for 819,475.91 m^2. In terms of percentage, the campus area was composed of 17% buildings, 7% forest, 24% planted vegetation, and 52% water absorption area. Based on this study, it was found that GIS can give accurate data and is also geolocated for each indicator for future reference. GIS is a very organized tool which leads to reliable information for green metric calculation especially for the setting and infrastructure cluster. The sustainable green campus can be frequently monitored using GIS tools in the future.

Categories: Sustainable Technologies, Environmental and Sustainable Engineering, Environmental Engineering
Keywords: green metric, sustainability, campus, indicator, calculation

Introduction

Green campus is very important to produce holistic and healthy students. One of the most important criteria in green campus evaluation is the setting and infrastructure. The setting and infrastructure can determine the layout of the campus, whether the campus embraces the sustainable campus concept or not. The setting and infrastructure are always related to the green landscape, such as forest area, planted vegetation area, water absorption area, and open space ratio, and population at the campus. The well-being of the campus community requires green spaces for psychological revitalization. Higher education institutions are responsible for responding to sustainability issues by practicing sustainability management from the bottom to the top management. It is very important to nurture the importance of sustainability to the future generation. A sustainable university should minimize the negative environmental, social, landscape, and economic impacts by conducting more research on the environment, research, and outreach to promote sustainable lifestyles. The attitudes of students, academic staff, and administrative staff also should lead to sustainable practice. Due to the effects of global warming, many initiatives have been conducted to give awareness to the campus community about the importance of green campus, or what is known as a sustainability campus. The university policies also play an important role to keep up with the sustainable campus because the university budget towards sustainability efforts is a big issue to handle. The introduction of Universitas Indonesia Green Metric (UIGM) can measure sustainable behavior in the university. This green metric is online and open access, and is designed for developing and developed countries. Universiti Teknologi MARA, Shah Alam campus, is very enthusiastic toward sustainability efforts. There are a few initiatives that have been conducted throughout the campus to increase awareness of sustainability. A few environmental research centers have been established to carry out many research projects on a sustainable campus. This study evaluates the setting and infrastructure indicators using Geographical Information System (GIS) tools for green metric calculation. The indicators involved in this calculation are total open space area, forest area, planted vegetation area, water absorption area, open space ratio, and population and university budget toward sustainability efforts. The GIS tools were used to extract all the information above. This paper

reports the current achievements in a frame of UIGM criteria during the year 2018. The following sections describe a review of sustainability on university campus, the use of GIS tools in ArcGIS software for data extraction to fulfill six indicators in the setting and infrastructure cluster of UIGM, and initiatives at Universiti Teknologi MARA, Shah Alam campus.

Literature review

Green space is very important to every community in urban areas. The setting and infrastructure of the university campus can determine the level of sustainability efforts done by top management. Sustainability is always related to the green campus, which means the setting and infrastructure should reflect the green view. The sustainable university framework was analyzed based on a campus sustainability assessment review and a comparison of the results from Politecnico di Torino, Italy, and Hokkaido University, Japan [1]. This study only focused on climatic zones due to morphological structures and also introduced indicators to measure the energy efficiency at the campus. It can help homogeneous university buildings maintain a sustainable campus. Universities have been identified as key hubs for environmental education, innovation, and nurturing a sustainable attitude among the younger generation in their daily lives. Universities can manage environmental issues very practically by managing human resources on campus. A sustainable university can minimize the negative aspects on environmental, societal, health, and economic dimensions through teaching, outreach locally and internationally, and engagement to help society toward a sustainable lifestyle, and conduct much research on the environment. The younger generation in the university campus can actively engage within the university community and implement a holistic and multidisciplinary approach regarding sustainability. In Europe, 6.8% of total energy consumption was contributed by the education sector, where the total final energy use in Europe was about 40%. In China, total energy consumption was about 40% for public buildings with 30 million students. Therefore, the university is not only a hub for education but also serves as an anchor in the urban setting. Campus sustainability assessment has been used for more than a decade as a tool to measure the practicality of a specific campus in adapting sustainability in the campus area. Studies [2] reviewed 11 assessment tools on environmental data capturing and provided strategic planning, goals, and methods. However, this assessment is not suitable for comparison nationally or internationally due to the traditional stress on material utilization, regulatory compliance, and carbon dioxide emissions, which differ in many countries worldwide.

The purpose of campus sustainability assessment is to help the university management to develop a strategic plan to increase the sustainability within the campus area. Open space is very important for the physical activity for the university communities. The open space can maintain physical fitness and also promote physiological well-being. The sustainable campus can improve lifespan, led fewer to depression symptom, and also increase the work and study efficiency [3,4]. The sustainable environment could control the thermal comfort which means it depends on the human comfort temperature, whether warmer nor cooler. Many researchers have conducted studies on thermal sensation of the people. It was found that thermal sensation is based on environmental, physiological, and personal factors. However, the most influential factor affecting human comfort is the surrounding environment [5-7]. Studies [8,9] found that the environmental physical activity is always related to the urban parks setting. The human thermal comfort always refers to the setting and infrastructure at the area. The sustainable environment setting could influence the university community to carry out physical activity in a comfortable situation.

The university is responsible for leading sustainability development because many academic experts have conducted research and teaching in environmental aspects. Therefore, the university can become a role model to the public community on how to practice good sustainable development [10,11]. In fact, the university can be assumed as a small city which has a limited number of communities. This small communities can impact the environment condition in the campus [12]. There are many efforts and initiatives that have been done to transform unsustainable behavior into sustainable behavior among university communities not only in Western universities but also in Asian universities [13]. One of the taglines that has been used in many universities around the globe is "green universities", which means the university puts a lot effort to transform the campus planning, management, operation and construction toward sustainable development [14]. The involvement of all academic staff, administrative staff, maintenance staff, and students is very important to moving toward an eco-city and developing a green university campus. All resources should have consumption plans to save water, energy, waste, and the environment. The policies should be created on the university campus to implement the sustainable development. Green education and research also should be conducted to spread and expand the knowledge on the sustainable issues [15,16]. UI Green metric is one of the campus sustainable assessment to determine the level of sustainable practice in specific campus. The reserve green area can be rigorously preserved by more than 90% with the green initiatives in the university campus. The green building concept also an conserve energy by implementing the new design in building construction. The waste and water also could be managed in efficiently based on sustainability recycle and reuse concept. Smart transportation and shuttle service are one of the biggest challenges for university communities because of the habit of using personal vehicles around campus. The top management in the university should invest in equipment, research funding, and infrastructure to implement sustainable development on university campus. However, there are many challenges along the process to become a sustainable university

campus, such as physical development and the attitudes of people. Education awareness is really important to penetrate the sustainable concept among university communities.

This study contributes uniquely to the existing literature on green campus assessments by focusing on the Malaysian context, which remains underrepresented in global sustainability studies. While many frameworks have been developed in Western or temperate climate regions, this research considers the specific climatic conditions, campus morphology, and cultural aspects of Malaysian universities. It emphasizes thermal comfort, the role of open spaces in promoting physical and mental well-being, and localized sustainability practices that align with national development goals. By integrating environmental, infrastructural, and human-centered factors, the study offers a contextualized framework that can inform campus planning and policy-making tailored to Malaysia's needs.

Technical Report

UI green metric methodology

UIGM world university ranking evaluates six categories based on specific indicators. The metric categories are Setting and Infrastructure (SI), Energy and Climate Change (EC), Waste (WS), Water (WR), Transportation (TR), and Education and Research (ED). The SI category has six indicators, the EC category has eight indicators, the WS category has six indicators, the WR category has four indicators, the TR category has eight indicators, and the ED category has seven indicators. This paper discusses on the SI category which has six indicators, i.e., the ratio of open space area to total area, area on campus covered in forest, area on campus covered in planted vegetation, area on campus for water absorbance, total open space area divided by total campus population, and university budget for sustainable efforts. This paper uses GIS tools in ArcGIS software to extract information for SI indicators, utilizing high-resolution orthophoto, building footprint, and land use map. This paper concentrates on the UIGM score at Universiti Teknologi MARA, Shah Alam campus, Malaysia. The current campus setting is illustrated in Figure *1*.

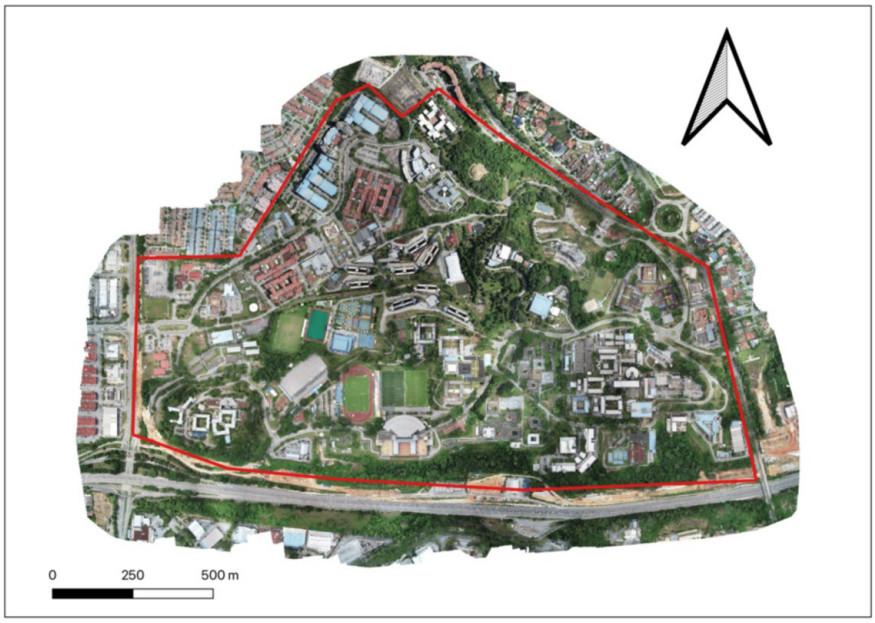

FIGURE 1: Campus Setting for Universiti Teknologi MARA, Shah Alam Campus

Figure *1* illustrates the Universiti Teknologi MARA from an aerial view. There are a few images that were taken from certain altitudes using a high- resolution camera on an airborne platform. These images went through photogrammetric image processing to produce an orthomosaic of the campus area. The total area of this campus is about 1587305.023 m^2 or about 158 hectares. The total area is obtained from the certified plan of the university which has been measured by the Department of Surveying and Mapping Malaysia. The red line shows the campus boundary, and the SI indicators' score was based on this base map. As mentioned before, all indicators were measured within this campus boundary. The extraction of forest, planted vegetation, and water absorbance was done using digitizing tools available in the GIS software. The digitization is based on the required input from the user; for example, the forest layer will be created to extract forest area, planted vegetation layer will be created to extract planted vegetation

area, and water absorbance layer will be created to extract water absorbance area. In this paper, all layers were polygon types used to extract the features. All digitizing results were discussed in the next section.

Discussion

The types of higher education institutions at Universiti Teknologi MARA, Shah Alam campus, are comprehensive with a tropical wet climate where the main campus setting is urban. The data used for UIGM calculation are from year 2018. The digitization result for each indicators is illustrated in Figure *2*. There are four main layers in this figure, for instance, forest, planted vegetation, building, and boundary.

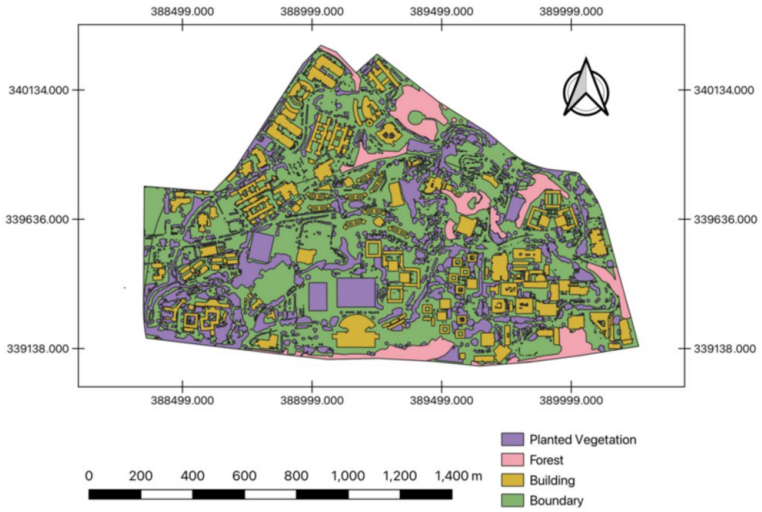

FIGURE 2: Digitization Results for all Extracted Layers

The current setting and infrastructure for Univesiti Teknologi MARA, Shah Alam campus, in year 2018 have been analyzed through the digitized layers. The attributes and area of the selected layers were identified using GIS tools as described in Figure *3*. Figure *3* shows examples of statistical results for the ground floor area of buildings and area covered by forest vegetation, which have been obtained from GIS tools. In this university, 188 building units were identified, contributing approximately 274,173.98m^2 of ground floor area. The total built-up area across all floors is about 1,252,590.30m^2. The high building density directly influences the sustainability score by reducing the proportion of green open space and increasing energy consumption, which can negatively affect the campus's performance in green metric assessments. The total area covered by forest vegetation is about 112858.576408 m^2, the total area for planted vegetation is about 380796.559569 m^2, and the total area for water absorbance beside forest and planted vegetation is about 819 475.91 m^2.

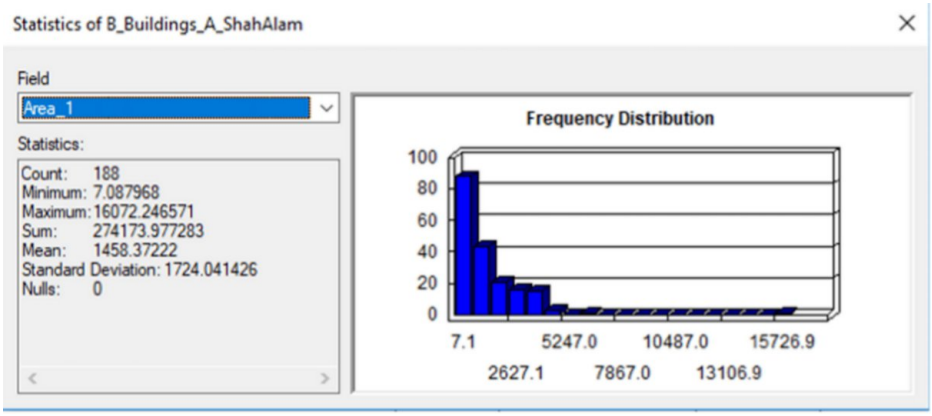

FIGURE 3: Statistic Results; (a) Ground Floor Building, (b) Forest Vegetation

Therefore, the percentage of main indicators in Universiti Teknologi MARA, Shah Alam campus, is illustrated in Figure *4*. The ground floor building area covers 17%, forest vegetation area covers 7%, planted vegetation area covers 24%, and water absorption area is about 52%. Based on the findings, the university still retains significant coverage of planted vegetation, forested areas, and water absorption zones. The percentage calculations were derived from the total area within the official university boundary. Benchmarks for adequate vegetation and water absorption were aligned with the UI GreenMetric criteria, which emphasize a minimum threshold of green and permeable surfaces to support sustainable stormwater management and ecological balance.

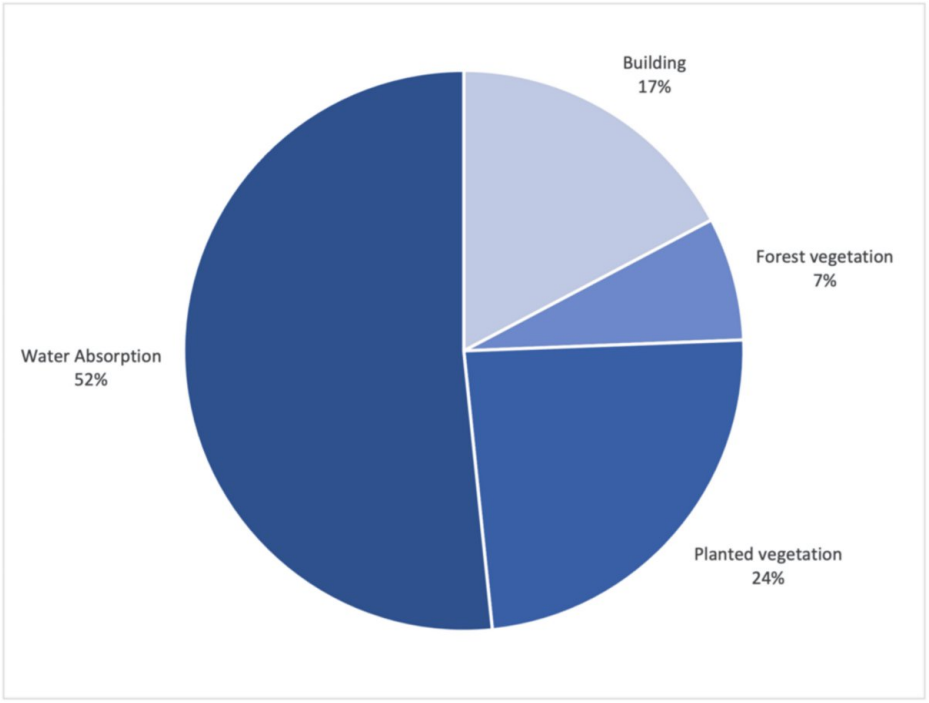

FIGURE 4: Percentage of Main Indicators for UIGM in Universiti Teknologi MARA, Shah Alam Campus

The university budget for sustainable efforts was classified into a few factors such as development and maintenance of green areas, including landscape and pruning trees, waste management, water usage, electricity usage, research and education on sustainability, and transport management. The university budget was obtained from 2016 to 2018. The UIGM calculation required the average of university budget related to the sustainability effort over the last three years. Figure *5* describes the university budget toward sustainability efforts for the last three years.

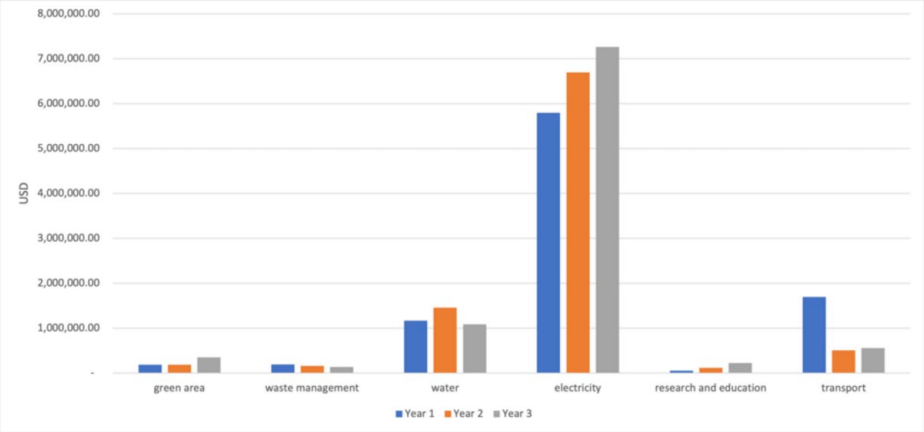

FIGURE 5: The University Budget for Sustainability Effort

Based on these findings, electricity usage is quite dominant in the university budget, followed by water, transport, waste management, green area maintenance, and research and education. The high electricity usage is due to the 188 building units in this university. The total population in this university is about 43,432 persons, including students, academic, and administrative staff. Therefore, many initiatives have been done and will be carried out to sustain the university budget toward sustainability efforts. However, this paper discusses the initiatives to increase the setting and infrastructure indicators in this university. Several initiatives should be taken to improve the setting and infrastructure in UiTM toward a green and sustainable campus. The following sections describe the comprehensive approaches integrated with sustainable development concepts to enhance significantly the learning, working, and living infrastructure on the campus. One of the initiatives towards a green and sustainable campus is developing the green building, also known as a high-performance sustainable building.

According to studies [1], green building is the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from siting to design, construction, operation, maintenance, renovation and deconstruction. Green buildings can include vertical gardens, rooftop gardens, and the installation of solar panels. In 2018, UiTM, in cooperation with other agencies, constructed a large-scale solar power plant in Gambang, Pahang. This project should be extended to UiTM campus Shah Alam, where solar panels can be installed on top of the academic and administrative buildings to reduce electricity usage. Besides that, the existing buildings can be designed with vertical or rooftop gardens. Other than supporting sustainable environmental purposes, the vertical or rooftop gardens can enhance the aesthetic value of the existing buildings on campus. In addition, other initiatives that should be taken towards a green and sustainable campus are replacing the lamps within the buildings with energy-efficient models, including LEDs, and providing bicycle tracks on campus. The energy-efficient lamps can be supported with lighting controls such as daylight sensors to reduce electricity usage, while the use of bicycles on campus can promote a healthy lifestyle as well as reduce carbon emissions into the atmosphere.

UiTM campus Shah Alam is designed with green landscapes, either with natural forest vegetation or planted vegetation. This campus has been planted with a variety of mature tree species such as *Plumeria rubra* (Kemboja merah), *Ficus benjamina* (Beringin), *Maniltoa brawneodes* (Handkerchief tree), *Peltophorum pterocarpum* (Batai laut), and oil palm trees. Trees are vital elements in enhancing the landscape and cooling the campus area. Proper management practices for managing trees on the campus will provide optimum value to human wellbeing. However, poor management and maintenance of trees will cause serious incidents on campus, especially during heavy rainfall. Thus, good maintenance practices should be done properly to maintain the forest and planted vegetation. Proper tree pruning, pest and disease control, and fertilizing will protect the trees and ensure they remain in good condition [5]. The trees on campus also should be tagged to assist in teaching and learning activities. In addition, aging and vulnerable trees should be eliminated. Tree elimination is aimed at eliminating the risk of fallen trees due to severe damage caused by pests and diseases. Replanting and reforestation should be conducted in several locations to replace fallen and eliminated trees and ultimately greener the campus.

Conclusions

Universiti Teknologi MARA, Shah Alam campus is one of the universities dedicated to pursuing a green campus. The current setting and infrastructure identify a few gaps that need to be addressed to increase the indicator scores as mentioned in UIGM. As of 2018, Universiti Teknologi MARA, Shah Alam campus comprised 188 buildings, with a ground floor area of 274,173.98 m^2 and a total built-up area of 1,252,590.30 m^2. The land cover comprised 112,858.58 m^2 of forest vegetation, 380,796.56 m^2 of planted

vegetation, and 819,475.91 m² of water-absorbent surfaces. These accounted for 17% building area, 7% forest, 24% planted vegetation, and 52% water absorption relative to the campus's total area. The high proportion of water-absorbent surfaces plays a crucial role in mitigating flood risks by enhancing stormwater infiltration and reducing surface runoff. Additionally, it helps regulate the campus microclimate by promoting evapotranspiration, lowering surface temperatures, and increasing thermal comfort in outdoor areas. The green area, water absorbance area, forest vegetation, and planted vegetation can be increased by implementing all initiatives mentioned in the previous section. These initiatives can only be done if the top management supports the sustainability effort. The top management needs to allocate more budget to develop the green campus. Electricity usage can be minimized using the green building concept, where natural resources can be utilized to provide building interior lighting. It is hoped that this university will achieve a better setting and infrastructure for a green campus in future years.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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Supervision: Khairul Nizam Tahar, Saiful Aman Hj Sulaiman, Nafisah Khalid, Ahmad Norhisyam Idris, Mohamad Hezri Razali

Disclosures

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