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Solar panel installation feasibility analysis based on techno-economic of PVSyst at Universitas Multimedia Nusantara

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ABSTRACT

Universitas Multimedia Nusantara (UMN) integrates green building principles to enhance environmental sustainability by reducing energy waste and utilizing renewable energy sources. This study conducts a feasibility analysis of installing solar panels in a green open space near building D to supply up to 20% of its electricity needs. PVSyst simulations evaluated different panel orientations (north, south, and east). The results indicated that the installation is currently unfeasible, with a net present value (NPV) of -134,346,450.22 IDR and an internal rate of return (IRR) of -4.64%. The challenges included shading from surrounding buildings, heat buildup, and limited installation space. To improve viability, future installations should focus on sites with minimal shading and explore advanced technologies to enhance efficiency. Additionally, optimizing panel orientation and investigating alternative renewable energy sources suited to UMN's conditions are crucial. These measures can enhance the effectiveness of solar installations and contribute to overall energy sustainability on campus.

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1. INTRODUCTION

Reducing the carbon footprint of buildings and the environment is of paramount importance to living things and the sustainability of their environment. Carbon emissions from the use of fossil fuels, such as coal, contribute to global climate change. This poses a long-term threat to ecosystems and public health. By integrating renewable energy sources such as solar power, buildings can significantly reduce their dependence on non-renewable energy, helping to lower greenhouse gas emissions. In addition to the environmental benefits, transitioning to renewable energy can yield economic benefits. The use of renewable energy is not only important for achieving global climate goals, but also for positioning a building to become one of the buildings in the green campus initiative, demonstrating a commitment to sustainable development for the future.

As an effort to protect the environment, the Universitas Multimedia Nusantara (UMN) campus buildings apply green building principles [1]. Green building is an environmentally friendly construction technique that includes various methods such as reducing energy/resource waste, improving building efficiency, and using renewable energy, all without disturbing the building users [2]-[4]. The application of green building principles at UMN is evident in features such as double facades to reduce thermal heating of buildings [5] and thus lessen the load on air conditioning systems. Double facades also allow for the use of cross ventilation [6], enabling air to flow through building corridors to maintain thermal comfort. Additionally, numerous openings in the building allow natural light to enter, reducing dependency on artificial lighting [7]. The use of renewable energy is an effort to reduce the carbon footprint [8], [9] of UMN campus buildings, in line with green building principles. If solar power generation can be integrated into UMN buildings, the dependence on coal-sourced electricity can be reduced, leading to lower carbon emissions [10]-[12].

Considering the UMN campus's land or location, there are several open areas that can receive sunlight, thus presenting potential sites for solar panel installation to help meet UMN's electricity needs. However, selecting the green open space on the UMN campus requires several considerations. One fundamental consideration is to avoid locations that may receive shadows from surrounding trees or buildings. Shadows on the solar panels will reduce the electricity production and shorten the lifespan of the panels [13], [14].

With these considerations in mind, a feasibility study will be conducted for the installation of solar panels at one of the green open space points on the UMN campus to meet part of the electricity load of UMN building D. It is noteworthy that UMN currently has four buildings, namely buildings A, B, C, and D, as shown in Figure 1. The study will utilize simulations from the PVSyst software and model the installation of solar panels on the land of building D. Given that the simulated land is south of building D, sunlight from the north is obstructed, so the panels used in the simulation will be tested when oriented to the north, south, and east to determine the optimal orientation.

Figure 1. Four buildings in UMN [15]

The goal of the solar panel installation study is to find the optimal panel installation configuration based on PVSyst simulations, determine the electricity production capacity of the solar panels under different installation conditions, and assess the feasibility of installing photovoltaic (PV) panels on the land of building D to meet electricity needs, in this case, up to 20%.

Feasibility studies have been conducted before using various methods. For example, Setiawan [16] conducted a study aiming to analyze the cost of solar power production compared to its annual yield, especially in Indonesia. The solar cell module used was poly-crystalline silicon. To obtain maximum power from the sun, the module was statically fixed at an angle of 10-20 degrees in line with the equator. The output was observed using a multimeter data logger, recording the average data every hour [16].

Another method is to analyze the factors involved in solar installation and examine the economic feasibility of solar installation. Using a qualitative approach, data were obtained from interviews with the Development and Maintenance Department and Detrolic Solar Company. The study concluded that solar installation could accelerate efforts towards a green and eco-friendly campus. The location of the study was at the Universiti Utara Malaysia (UUM) campus [17]. Feasibility studies are conducted at various locations, such as in this study, where the Environmental Protection Agency (EPA) selected the refuse hideaway landfill in Middleton, Wisconsin [18]. Another study by Kirbaş and Çifci [19] evaluated the feasibility of a solar power plant around Lake Burdur, Turkey. Then recent study also conducted feasibility in campus area [20].

Meanwhile, Windarta *et al.* [21] used the PVSyst simulation method to analyze the potential of small-scale off-grid PV from technical and economic perspectives. The results showed that although the system is not economically feasible with an net present value (NPV) < 0 and a payback period (PBP) > the project period, off-grid solar power plants are more profitable compared to generators or batteries using electricity charging from the State Electricity Company.

Other studies using the PVSyst simulation method include Revankar [22] who explored the potential of solar power plants PV for small houses in Hubballi, Karnataka, India, using PVsyst simulation software, and Islam *et al*. [23] which evaluated the grid-connected solar PV roof-top system at Tetulia, Panchagrah, Bangladesh. PVSyst can also be used to conduct simulations with specific power targets, for example by Grover who used PVsyst to design a 20 MW PV power plant in India [24].

Previous research has several limitations, such as region-specific limitations and methods that are not fully suitable when applied to different buildings and environments. Most studies focus on specific types of solar modules or use static approaches without considering solar panel orientation optimization in campus environments with specific challenges such as shadows or architectural design. In addition, some studies show less economical results, especially in off-grid systems, as well as less emphasis on the integration of renewable energy with green building principles.

The novelty of this research lies in the implementation of green building principles in the university setting, specifically in building D of UMN. These principles include reducing energy/resource waste, improving building efficiency, and utilizing renewable energy sources such as solar power. The aim of the study was to conduct a feasibility study for installing solar panels in one of the green open spaces near building D to supply up to 20% of its electricity needs, utilizing the PVSyst software for assessment.

2. METHOD

This section discusses the materials and methods employed in the research, with a focus on the specific parameters and limitations of the study. The scope of the study is confined to the simulation of solar panel installations in the area surrounding building D at UMN. The simulation was conducted with the solar panels oriented at a 15° angle relative to the ground, facing north, east, and south. The feasibility analysis specifically examines the capacity of the solar panels to generate sufficient electricity to meet 20% of the energy requirements for building D.

2.1. Location

The location chosen for the PV panel installation simulation is the ground area to the south of UMN building D, which is located on the third floor. building D is 17 floors high, with an approximate height of 3.5 meters per floor, so the total height of building D is about 59.5 meters from the ground on the third floor. The selected area has an area of 3,508 m² and minimal sources of shadows, although this location is less than ideal as the orientation of the sun in Indonesia is from the north, resulting in less than optimal sunlight reception. The shadow from building D appears in the morning, but during the day, the shadow is reduced so that the lighting is more even. Based on the field condition data, the orientation of the solar panel installation will be varied to face north, east, and south to determine the orientation that produces the most optimal energy and the feasibility of the installation. The Figure 2 illustrates the green area surrounding building D at UMN, which will be used as the simulation site for the proposed PV system installation. This location is being considered due to its potential for solar panel deployment as part of the feasibility study.

Figure 2. Green area of building D at UMN [25]

2.2. Solar panel system data

Simulation of the solar panel installation was carried out using PVSyst software, which enables technical and economic analysis of solar energy systems. The simulation procedure follows the previously published standards for solar energy simulation with PVSyst [26]. The stages are simulation location selection, panel orientation setting, panel specification determination, and 3D model design.

a. Site selection: the simulation site was selected using meteorological data from Meteonorm, which provides site-specific climate data for UMN building D (6.2577° S, 106.6181° E). This includes solar irradiation data and other environmental conditions needed for the simulation.
b. Panel orientation setup: the solar panels were set at an inclination angle of 15° with respect to the ground, with azimuth variations of 0° (facing north), -90° (facing east), and -180° (facing south). This tilt angle was chosen because it is considered optimal for maximizing sunlight reception during the day, in accordance with previous research on the optimal angle of solar panels in the tropics.
c. Solar panel system specifications: the solar panels used in the simulation are Canadian Solar Inc. (CSI) solar 290 Wp 27 V, with a total of 192 modules organized in 12 strings, each consisting of 16 modules per string. For inverters, 3 Ginlong Technologies 15 kW 200-800 V units were selected. The determination of the number of panels and inverters was done with the “resizing” feature in PVSyst, which automatically calculates the capacity according to the installation area of 350 m². The technical specifications of these solar panels and inverters can be found on the official datasheet
d. Three-dimensional (3D) design: a 3D model of the solar panel installation area was created in PVSyst to account for potential shadows from buildings and other structures around building D. The model takes into account the movement of the sun throughout the day and the impact of shadows on energy production.

2.3. Electricity consumption data

Electricity consumption data is obtained from the building manager of UMN, including peak load times and off-peak times electricity consumption in kWh and electricity bill costs from January to March 2023 for the entire building. The electricity usage data is presented in Table 1 [27].

Table 1. Electricity consumption data in UMN for January-March 2023 periods

Font size	Electricity consumption (kWh)		
	Off-peak times	Peak load times	Total of off-peak times and peak load times
January 2023	303,000	30,540	333,540
February 2023	293,940	32,040	325,980
March 2023	349,560	39,120	388,680
Total use for three months	946,500	101,700	1,048,200

From this data, it is assumed that the usage every three months will be the same throughout the year; thus, the annual electricity usage will be assumed as the electricity usage over three months multiplied by four. This usage represents the entire UMN building, and it is assumed that the electricity usage for all four UMN buildings is equal. Therefore, the electricity usage will be divided by four for each building. Then, from the annual electricity usage of each building, 20% will be taken as the amount of electricity needed to be supplied by the solar panel system. Table 2 shows the results of the assumptions presented to obtain the electricity value that must be supplied by the solar panel system in one year.

Table 2. Electricity consumption data processing

Category	Electricity
Use for 3 months	1,048,200 kWh
Use for a year	4,192,800 kWh
Use a building per year	1,048,200 kWh
20% building D per year	209,640 kWh
Panel surya need per year MWh for buidling D	209,64 MWh

It can be seen from the calculations with the assumption of even annual electricity usage from January-March 2023 data and assuming uniform electricity usage for each UMN building that an annual electricity production of 209.64 MWh is required by the solar panel system to meet 20% of the electricity needs of building D.

3. RESULTS AND DISCUSSION

In this section, we present the findings of the research conducted, along with an analysis of the results obtained. This section is divided into several subsections covering the analysis of PV simulation equipment, cable configuration, simulation results, feasibility study, and cost analysis. The first section discusses the equipment used in the PV system, including the specifications and number of components required. Next, the section on cable configuration explains the connection arrangement between components in the system. Simulation results are outlined in the third section, with comparisons between different solar panel orientations. The feasibility study section discusses the ability of the generated energy production to meet electricity demand, while the cost analysis section outlines the financial impact of installing the PV system.

3.1. Photovoltaic simulation equipment

Based on the simulation data, the required components and equipment for the PV system are outlined. The main equipment consists of PV panels, inverters, and a cabling system. The specifications for each component:

a. Solar panels: the CSI solar 290 Wp 27 V CS6K-290MB-FG solar panels are used, with a total of 192 modules for each installation variation at a cost of €0.25 per Wp.
b. Inverters*:* the inverters used are Ginlong Technologies 15 kW 200-800 V 50/60 Hz Solis-15K, with three inverters at a unit price of C795.
c. Cabling*:* for the cabling, it is assumed that the cable length depends on the number of inverters connected to the panels and that the cable length is the same for each connection. Therefore, the number of cables needed is the number of strings multiplied by the number of inverters. With 12 strings and 3 inverters, 36 cables are required.

3.2. Cabling configurating

Based on the component data, 192 PV modules are needed, consisting of 12 strings with 16 modules per string. For inverters, 3 Ginlong Technologies 15 kW 200-800 V units were selected. The wiring arrangement is shown in Figure 3, which illustrates the interconnection between the solar panels, the inverter, and the injection point into the power grid. This single-line diagram facilitates a clear understanding of how energy flows through the system and highlights the electrical pathways for each component. In this configuration, each set of modules is connected to a maximum power point tracker (MPPT) within the inverter. The presence of two MPPTs per inverter enables better energy harvesting, as it allows the system to adapt to varying light conditions across the string. This feature is especially beneficial in scenarios where partial shading may occur, as it helps reduce the negative effects of shadows on overall energy production.

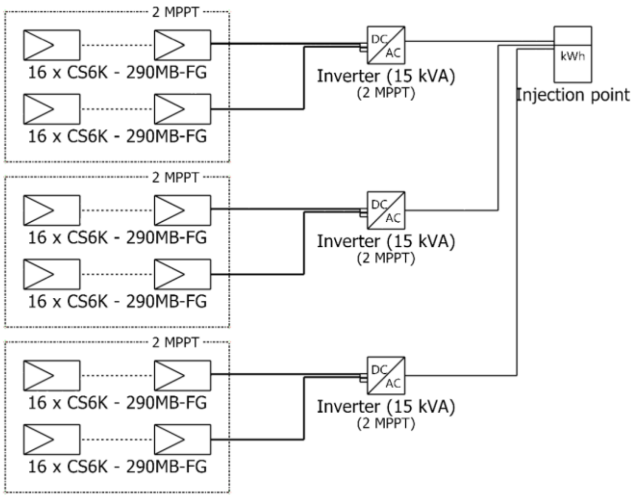

Figure 3. PV system cabling

In addition, the choice of cabling is critical to minimize resistive losses, which can affect the efficiency of energy transfer from the solar panels to the inverter. The system design considers the length, size, and type of cable to ensure that the voltage drop is kept within acceptable limits. By following these considerations, the installation not only improves performance but also extends the life of the system by reducing wear and tear on components.

3.3. Simulation results

There are three simulation results obtained from the variations in panel installation facing north, east, and south. The simulation results show the electricity production of the solar panel system over one year. From this data, it can be determined which installation configuration is the most efficient among the three variations. The simulation results for the north orientation, east orientation, and south orientation are presented in Table 3.

Table 3. Simulation results based on the orientation

Result overview	North-facing panel orientation	East-facing panel orientation	South-facing panel orientation
System production (MWh/yr)	77.3	73.9	75.4
Specific production (kWh/kWp/yr)	1389	1327	1354
Performance ratio	0.777	0.758	0.797
Normalized production (kWh/kWp/day)	3.80	3.64	3.71
Array losses (kWh/kWp/day)	1.00	1.07	0.86
System losses (kWh/kWp/day)	0.09	0.09	0.09

From the simulation results, it can be seen that the north-facing panel installation produces the highest electricity output compared to the other orientations. This occurs because, despite the shading from buildings that reduce electricity production, the increased production due to the optimal orientation outweighs the reduction. This is supported by the lower performance ratio factor of the north orientation compared to the south orientation, which still results in higher electricity production. Therefore, the north orientation installation is the most optimal among the three variations, with an electricity output of 77.3 MWh/year. Consequently, the north orientation installation will be adopted for further feasibility studies. Figure 4 shows the Sankey diagram of the energy received by the solar panels and the system losses per year.

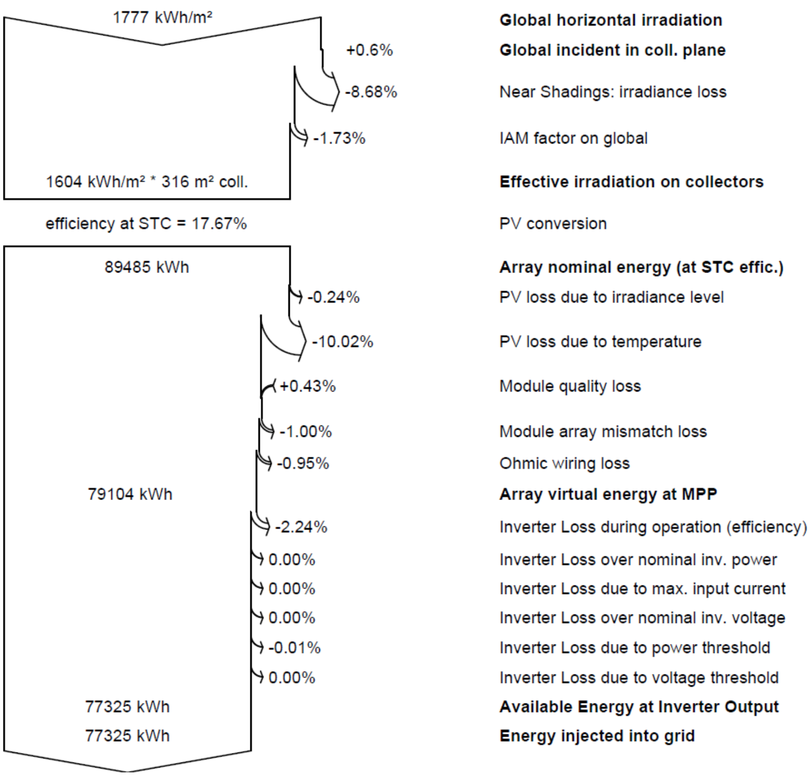

Figure 4. Solar panel system loss diagram

It can be seen that there is a 10% energy loss from electricity production due to heat and 8.7% shading loss, which significantly contributes to the overall loss. This is caused by the system configuration being obstructed by building D, leading to shading that reduces the received sunlight and increases heating, thus decreasing electricity production.

3.4. Feasibility study

The annual electricity production of 77.3 MWh is far below the requirement to meet the electricity needs of building D, only covering 7.37% of its annual electricity demand. Factors contributing to this insufficient production include the suboptimal installation location, limited panel installation area, and heating effects. Since the panels are located south of building D, sunlight from the north is blocked by the building, leading to suboptimal lighting and reduced electricity production. Additionally, although more panels could be added to increase production, the installation area can only support around 350 m^2 of solar panels, making it difficult to add more panels. Finally, the heating effect is significant due to uneven shading on the panels, hindering electrical flow and reducing production. Therefore, the installation of solar panels on building D's land is not feasible due to the suboptimal location for maximizing sunlight reception and increasing electricity production.

3.5. Cost analysis

The financial analysis of the PV system installation, as detailed in Tables 4 and 5, reveals the total installation and maintenance costs. The installation costs include expenses for the PV modules, inverters, cabling, accessories, and administrative fees, amounting to 373,737,300 IDR. The largest costs are the PV panels and inverters, accounting for a significant portion of the total budget. The maintenance costs, detailed in Table 5, consist of regular expenses such as depreciation, service fees, cleaning, and administrative duties, which total 61,830,000 IDR annually. These financial assessments highlight the considerable investment required for the solar panel system, both in terms of upfront installation and ongoing maintenance, which directly impact the project's overall financial viability.

Table 4. Installation cost of PV system

Module components device	Amount	Unit price (IDR)	Total price (IDR)
CS6K-290M-FG	192	1,000,000	192,000,000
Module support	192	250,000	48,000,000
	Inverter		
Solis-15K	3	13,050,000	39,150,000
	Other component		
Accessoris and jumper	192	90,000	17,280,000
Cabling	36	250,000	9,000,000
Combiner box	3	1,900,000	5,700,000
	Administration		
Administration and permission	1	10,000,000	10,000,000
	Installation		
Modul	192	100,000	19,200,000
Inverter	3	100,000	300,000
Insurance	1	2,500,000	2,500,000
	Tax		
PPN	11%	296,430,000	32,607,300
Total			375,737,300

Table 5. Annual maintenance cost of PV system

Maintenance type	Total price in a year (IDR)
Depreciation	7,830,000
Honor	25,000,000
Service	20,000,000
Cleaning	8,000,000
Administration	
Admin and accountant price	1,000,000
Total	61,830,000

The financial calculations are performed automatically by PVSyst in the form of NPV calculations. NPV assesses investment profitability by comparing the present value of cash inflows and outflows, factoring in the time value of money through discounting future cash flows. A positive NPV signals that the project is likely to yield more inflows than outflows, indicating its financial viability and potential profitability in project management and financial analysis [28], [29]. For this calculation, the project is assumed to start in 2024 and run for 20 years with 1% inflation and a 0% discount rate. It is also assumed that the funds are fully available to design the PV system. As for revenue, the feed-in tariff represents the savings that can be achieved with the PV system, i.e., the electricity that can be supplied by the system. The tariff is varied based on peak load time at 1,553.67 IDR/kWh and off-peak time at 1,035.78 IDR/kWh. peak load times electricity consumption is conditioned from 18:00-22:00, with other times being off-peak times electricity consumption. Realistically, since peak load time only occurs at night, the solar panel system can only utilize the off-peak times electricity tariff for savings. The NPV calculation results are shown in Figure 5.

Financial analysis

Simulation period
Project lifetime 20 years Start year 2024

Income variation over time
Inflation 1.00 %/year
Production variation (aging) 0.00 %/year
Discount rate 0.00 %/year

Income dependent expenses
Income tax rate 0.00 %/year
Other income tax 0.00 %/year
Dividends 0.00 %/year

Depreciable assets

Asset	Depreciation method	Depreciation period (years)	Salvage value (IDR)	Depreciable (IDR)
PV modules				
CS6K - 290MB-FG	Straight-line	20	0.00	192,000,000.00
Supports for modules	Straight-line	20	0.00	48,000,000.00
Inverters				
Solis-15K	Straight-line	20	0.00	39,150,000.00
Accessories, fasteners	Straight-line	20	0.00	17,280,000.00
		Total	0.00	296,430,000.00

Financing
Own funds 374,737,300.00 IDR
Subsidies 1,000,000.00 IDR

Electricity sale
Feed-in tariff Peak tariff 1,553.6700 IDR/kWh
Off-peak tariff 1,035.7800 IDR/kWh 22:00-18:00
Duration of tariff warranty 20 years
Annual connection tax 0.00 IDR/kWh
Annual tariff variation 0.0 %/year
Feed-in tariff decrease after warranty 0.00 %

Return on investment
Payback period Unprofitable
Net present value (NPV) -134,346,450.22 IDR
Internal rate of return (IRR) -4.64 %
Return on investment (ROI) -35.9 %

Figure 5. Financial analysis of the solar panel system installation project

The financial analysis shows that the project is not feasible. The required investment is too large compared to the potential savings. The NPV of the project is -134,346,450.22 IDR with an internal rate of return (IRR) of -4.64%. The results and discussion show that although the installation of a PV system in the green space of building D offers insights regarding the potential configuration and performance, this system is not feasible to implement. The orientation of the north panel produces the highest electrical output, but it still does not meet the needs of building D due to the shadow and limited area. In addition, financial analysis shows negative NPV and IRR, so the investment is much greater than the potential savings over 20 years. Thus, other approaches or optimizations are needed for future projects.

4. CONCLUSION

This study demonstrates that the PV system installation on the south side of building D at UMN is not feasible from both a technical and financial perspective. The system's inability to meet 20% of the building's electricity demand and its negative financial outlook, with a NPV of -134,346,450.22 IDR and an IRR of

-4.64%, confirm that the project is not viable under the current conditions. Several factors, such as shading from the building, limited installation space, and heat buildup on the panels, significantly hinder the system's performance. These findings emphasize the importance of choosing a minimally shaded and optimally sunlit location for PV installations in space-constrained urban environments. For other areas of UMN or similar locations, it is recommended to prioritize locations without sunlight interference and consider solutions such as vertical surface utilization or integration of solar panels on building facades. Future research should explore technologies such as bifacial solar panels that capture rays from two sides or shadow-resistant inverters to optimize electricity production despite shadows. Integrating energy storage systems can also improve efficiency in managing volatile solar production. A cost-benefit analysis of these technologies will provide further insight into the economic viability of solar systems in limited urban areas. Findings from this study can be applied to similar projects in urban university environments or densely populated areas where space and shade limitations are unavoidable. By identifying factors that affect system performance, this research contributes to the growing body of knowledge in renewable energy planning and implementation, especially in complex urban landscapes.

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AUTHOR CONTRIBUTIONS STATEMENT

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

INFORMED CONSENT

We have obtained informed consent from all individuals included in this study.

ETHICAL APPROVAL

The research related to human use has been complied with all the relevant national regulations and institutional policies in accordance with the tenets of the Helsinki Declaration and has been approved by the authors' institutional review board or equivalent committee.

DATA AVAILABILITY

The authors confirm that the data supporting the findings of this study are available within the article.

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