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RESEARCH ARTICLE

Value Engineering in Enhancing Green Building Innovation

I Nyoman Indra Kumara[1,*], I Gede Fery Surya Tapa[2], Decky Cipta Indrashwara[3], I Wayan Dikse Pancane[4], Made Aryatirta Predana[5]

[1]*Construction Management, Universitas Pendidikan Nasional, Denpasar, Indonesia*
[2,3]*Transportations, Universitas Pendidikan Nasional, Denpasar, Indonesia*
[4]*Electrical Engineering, Universitas Pendidikan Nasional, Denpasar, Indonesia*
[5]*Geotechnical Engineering, Universitas Udayana, Badung, Indonesia*

* Corresponding author : indrakumara@undiknas.ac.id
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Abstract

This research integrates the application of value engineering methods in buildings to enhance green building innovation. The use of value engineering methods, assisted by Dell'Isola Theory, functions as a structured framework to determine material substitution and streamline project value by considering quality, performance, cost, development sustainability, and energy efficiency. Through careful analysis and strategic application, this research presents innovations in improving cost efficiency and development sustainability in building construction projects. These findings indicate the potential for innovation in creating environmentally friendly yet economically viable environments. Furthermore, it can also contribute to reducing environmental impacts and supporting sustainable development goals

Keywords: Value Engineering, Green Building, Sustainable Development.

1. Introduction

The value of a product or service is evaluated based on its quality, cost-efficiency, the time required to complete the work, and how effectively the resulting building performs its intended functions. (Joibary and Nagaraja, 2010; Sobhanollahi *et al., 2014*). Therefore, the application of value engineering is a procedure aimed at cost reduction by concentrating on the product's function while considering user preferences, quality standards, and time constraints (Andelin *et al., 2015*; Shen and Yu, 2012). Thus, value engineering becomes an important approach in the construction industry (Uğural, 2023).

According to Alsaeed *et al.*, (2022), value engineering can optimize project value by balancing quality, performance, and cost. The increasing complexity and demands of building construction projects underscore the importance of applying value engineering (Sheikh *et al.*, 2022). However, cost reduction efforts might compromise aspects such as quality, performance, and reliability. Therefore, it becomes essential to innovate or try new products to maintain the functionality of construction structures in line with standards (Mahdi *et al.*, 2015). Additionally, value engineering aims to facilitate this innovation at minimal cost while maintaining building quality. Through function analysis, value engineering can ensure alignment with customer expectations and contribute to sustainable development (Annappa and Panditrao, 2013).

Research conducted by Salsabila *et al.*, (2024) shows that value engineering is feasible for providing cost efficiency in project planning. The potential cost savings achieved by applying value engineering to construction projects can reach up to 34-36% of the total budget (Sudiarsa *et al.*, 2018). On the other hand, according to Oguntona and Aigbavboa (2018), the construction industry also needs to consider sustainable development aspects to reduce environmental impact. Therefore, this study aims to investigate the application of value engineering in construction projects at the Denpasar Health Polytechnic Building, focusing on identifying potential cost savings, improving efficiency, and considering the importance of sustainability aspects in the construction industry.

In this study, the analysis focuses on how the use of materials can reduce environmental impact in construction projects. The research highlights the importance of implementing environmentally friendly materials in construction projects to support sustainable development goals (Marcelline, *et al.*, 2022). The alternative of value engineering that being proposed in this study, including deck plates, lightweight bricks, lightweight steel, and granite, which can be utilized to promote sustainable development. Implementing such practices can add value to projects, and value engineering can ensure maximum utilization of these benefits. Furthermore, from a sustainable development perspective, construction projects may need to shift from short-term to long-term approaches, from local considerations to global impacts, and from merely considering costs to assessing overall value (Al-Yami and Price, 2005). Therefore, this research is expected to provide useful guidance for practitioners in optimizing the value of building construction projects while reducing environmental impacts

2. Methodology

The Dell'Isola method involves the application of principles and techniques to enhance cost-effectiveness, timeliness, quality, and functional efficiency in construction efforts (Heiza *et al.*, 2016). This methodology is designed to support the implementation of value engineering in the building construction sector, particularly in developing countries where its use is limited (Natalia *et al.*, 2022). The application of the Dell'Isola method in this study follows four stages: information stage, creative stage, analysis stage, and recommendation stage

(Mahdi *et al.*, 2015; Dell'isola, 1970). The flow chart for the Dell'Isola Method can be seen in Figure 1.

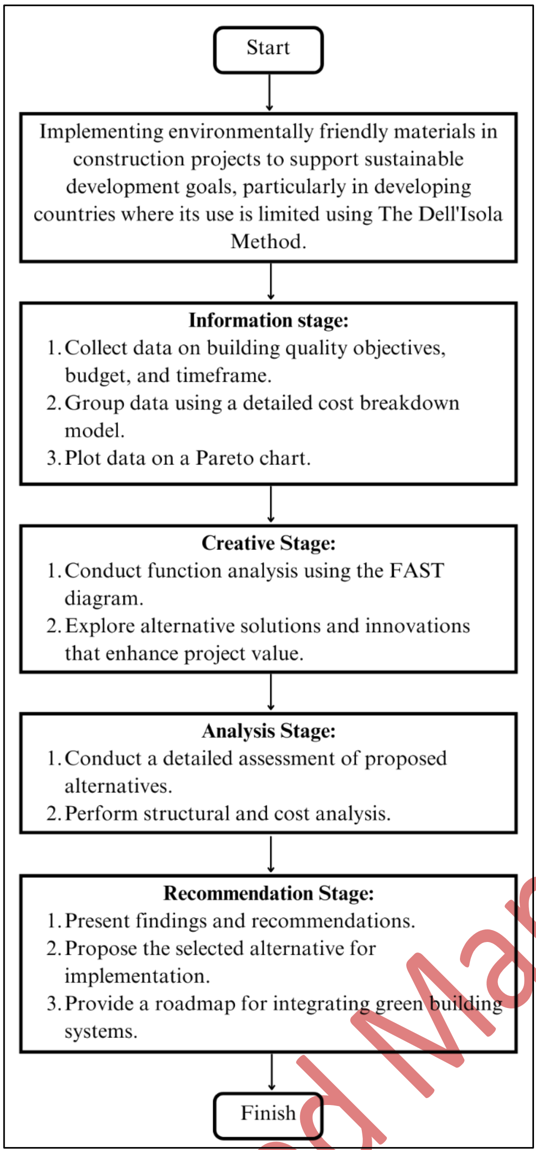

Fig 1. Dell'Isola Method.

In the information stage, data is collected regarding development projects at the Denpasar Health Polytechnic Building, including building quality objectives, budget, and timeframe. This data is then grouped using a detailed cost breakdown model and plotted on a Pareto chart to identify the scope of work items for value engineering analysis.

Next is the creative stage, where function analysis is conducted using the FAST (Function, Analysis, System, Technique) diagram principle. This aims to systematically describe the study and analysis referring to the function of the work items under investigation. The FAST diagram is particularly useful in developing green building materials as it helps systematically break down and understand the functional requirements and potential improvements. This concept is supported by several studies emphasizing the importance of using structured methodologies to optimize and enhance green building systems, such as using FAST method as a tool to improve green building facility management focusing on aspects like safety, maintenance, energy management, and asset management in Building Information Modeling (BIM) implementation (Cao *et al.*, 2022). Subsequently, alternative solutions and innovations that can increase project value are determined. Activities exploring various perspectives generate alternative solutions that enhance project value, considering objectives, function, cost, quality, and potential impacts on sustainable development.

Then, in the analysis stage, a detailed assessment of proposed alternatives is conducted, including structural analysis and cost analysis. The results of this analysis determine the most feasible alternative, maximizing value while aligning with project goals and constraints.

The last step is the recommendation stage, which presents findings and recommendations from the value engineering process. The selected alternative is proposed for implementation, detailing its benefits and expected outcomes, and providing a roadmap for integrating green building systems into the project based on value engineering outcomes.

3. Results and Discussion

The findings from this study indicate that the utilization of value engineering can substantially enhance innovation in construction projects towards sustainable green buildings. This assertion is supported by the methodology implemented, as described below:

3.1 Information Stage

Based on the project budget plan, costs are grouped from highest to lowest in Indonesian Rupiah (Rp). This cost grouping aims to limit the scope of work items to be performed based on the Pareto distribution law. In Table 1, the cost grouping of several work items is shown, including structural work items with the highest cost percentage, followed by wall installation, roofing work, and floor covering. Then, based on Table 1 with percentage and cumulative data, Figure 2 shows that 80% of the budget plan represents the total cost, which serves as the limit for the work items to be analyzed using value engineering.

Table 1. Breaking cost modeling

Work Items	Total Cost (Indonesian Rupiah)		Pct. (%)	Cum. (%)
Structure	Rp.	2.187.794.103,38	30.82	30.82
Wall	Rp.	1.204.158.896,55	16.96	47.78
Roof	Rp.	1.376.717.006,06	19.39	67.18
Floor covering	Rp.	976.220.752,83	13.75	80.93
Soil and foundation	Rp.	414.297.093,91	5.84	86.77
Jamb	Rp.	288.552.942,84	4.06	90.83
Ceiling	Rp.	193.592.923,38	2.73	93.56
Finishing	Rp.	149.636.258,03	2.11	95.67
Balinese style	Rp.	136.943.107,85	1.93	97.59
Preparation	Rp.	80.553.489,73	1.13	98.73
Waste	Rp.	51.081.853,54	0.72	99.45
Septic tank	Rp.	32.652.770,50	0.46	99.91
Sanitary	Rp.	6.482.155,31	0.09	100
Total	**Rp.**	**7.098.683.353,91**		

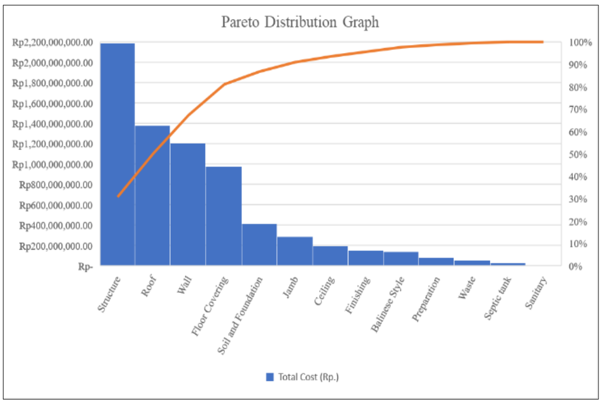

Fig 2. Pareto distribution graph.

Figure 2 also provides information on the visual representation of the cost distribution for each work item at the Denpasar Health Polytechnic Building. This underscores the importance of focusing value engineering analysis on the areas where costs are most concentrated. Based on Table 1 and Figure 1, the scope of work items to be studied has been determined, namely structural, walls, roofs and floor coverings. Next, creative stage can be processed.

3.2 Creative Stage

In the creative stage, the FAST method was used to describe and analyze the study focusing on the functions of the work items being investigated. This is presented in a logic diagram called the FAST model (Mahdi *et al.*, 2015). The FAST model for the work items can be seen in Figures 3–6.

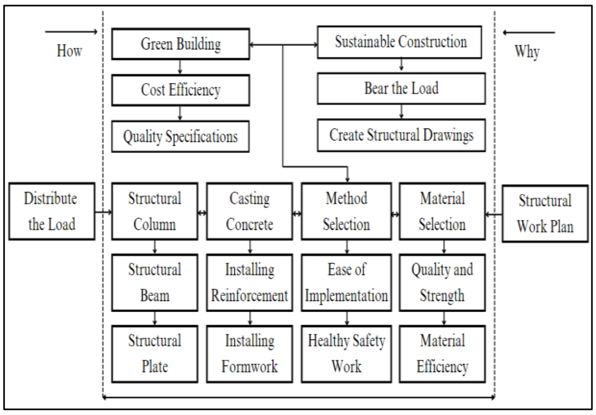

Fig 3. FAST model of work item structure.

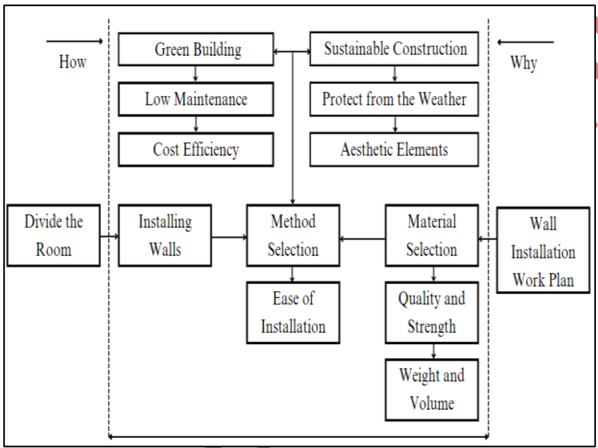

Fig 4. FAST model of work item wall

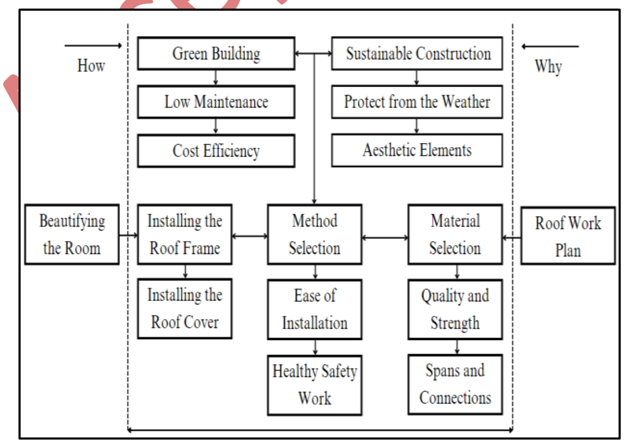

Fig 5. FAST model of work item roof.

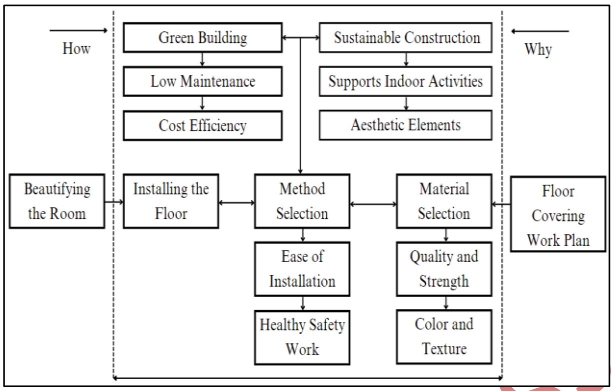

Fig 6. FAST model of work item floor covering.

For the structural work, an alternative of using deck plates on the second and third-floor slabs was considered because it meets the green building objectives in sustainable development, as well as cost efficiency and design quality specifications. Deck plates have excellent capabilities in regulating indoor temperatures, thereby reducing the cooling load and ultimately lowering energy consumption (Ouali *et al.*, 2021). Additionally, the steel used in deck plates is usually recyclable while maintaining structural strength in accordance with standards (Imron and Husin, 2021).

For the wall work, lightweight bricks were chosen as the material because green buildings must emphasize sustainable development, low maintenance costs, and cost efficiency. Lightweight bricks can reduce heat absorption, thereby allowing for the use of smaller cooling systems to reduce energy consumption (Becker *et al.*, 2022). Additionally, they are made from materials with a lower carbon footprint compared to traditional red bricks, which can reduce carbon emissions and environmental damage (Jonnala *et al.*, 2024). Their resistance to termites, mold, and moisture has the potential to reduce long-term maintenance costs.

For the roofing work, lightweight steel was chosen as an alternative because it meets the green building objectives of sustainable development, low maintenance, and cost efficiency (García *et al.*, 2018; Zhang and Xu, 2022). Lightweight steel has high structural strength while meeting the required standards for building roof construction, thereby reducing the load. It also reduces construction waste by using recycled and environmentally friendly materials. Maintenance is easier because it is resistant to corrosion and insects, which can reduce long-term maintenance costs and extend the lifespan of the building's roof.

Flooring was decided to use granite material because, according to green building objectives, it emphasizes low maintenance, cost efficiency, and sustainable development. The properties of granite as a flooring material provide scratch resistance, thereby minimizing maintenance needs and reducing long-term maintenance costs. Additionally, the use of granite is more efficient in maintaining room temperature and enhancing the aesthetic appeal and property value of the building due to its beautiful appearance.

Based on the alternative materials determined for the construction of the Denpasar Health Polytechnic building, the next step is the analysis stage, which is useful for ensuring that all chosen alternatives can meet the objectives of value engineering.

3.2 Analysis Stage

In this analysis stage, an analysis is conducted on each material chosen during the creative stage. The analysis includes structural analysis using SAP 2000 software and cost analysis of the work. For the structural work, the use of deck plates on the second and third-floor slabs was determined. Changes in structural design will affect the structural load, which may lead to changes in cross-sectional dimensions and reinforcement requirements. The input data for the frame and slabs can be seen in Table 2 and seismic loading is applied using autoload. The input for the loading can be seen in Table 3.

Table 2. Alternative Structural Element

Code	Dimension (cm)	Main Reinforcement	Stirrups Reinforcement
C1	35/35	16D19mm	Ø10 mm -125mm
C2	25/25	8D16mm	Ø10 mm -125mm
C3	14/20	4D12mm	Ø 8 mm -125mm
BI-1	25/45	12D16mm	Ø10 mm -125mm
BI-2	25/40	10D16mm	Ø10 mm -125mm
SB-1	25/35	6D16mm	Ø10 mm -125mm
Deck plates	12	M7 single layer + deck plates	-

Table 3. Loading Input Data

Load Name	Type	Quantity	Unit
Wall Load	Superdead	1200	kg/m
Live Load	Live	250	kg/m
Dead Load	Superdead	169	kg/m
Seismic Load	Quake	Autoload	kg/m

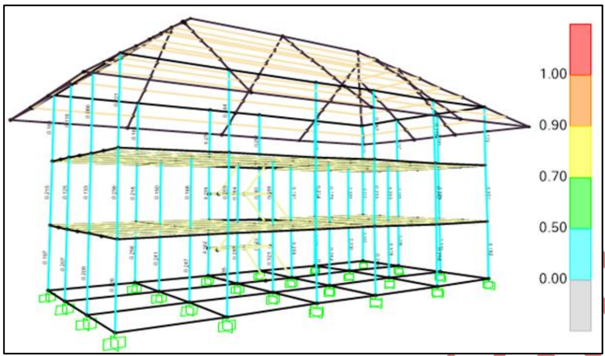

Fig 7. The results of running the structural model in the SAP 2000.

After creating the structural model according to the specified materials, the loads were then input into the model. The loading in SAP 2000 is based on the Indonesian National Standard (SNI 1727-2013) for minimum loads for building and structural design, while seismic loads are based on SNI 1726-2012 for earthquake resistance in building structures. The results of running the structural model in SAP 2000 are shown in Figure 7. In Figure 7, the stress-ratio for design elements is less than 1.0, where the stress-to-capacity ratio for column elements ranges from 0.00 to 0.50, and the stress-to-capacity ratio for beam elements is also less than 1.0. This indicates that none of the design elements are experiencing overstress and that the structure can adequately support the applied loads.

Next, the cost analysis of the work considers the expenses related to the planned design and alternative models. This calculation includes various aspects, such as work volume, unit prices, and specific work items for the structure, walls, roof, and flooring. Each aspect is examined to ensure the financial implications and potential savings that the alternative design may offer. The cost analysis comparing the total conventional model costs and detail the proposed alternative work items or innovations and the price difference that occurs from the conventional and alternative models offered can be seen in Table 4 – Table 11.

Based on Table 12, the cost analysis shows that the alternative model offers a more cost-effective solution compared to the planned design across all categories. Therefore, the alternative design can proceed to the recommendation stage, as it has been proven to be applicable with lower costs without compromising quality or performance.

Table 4. Conventional Model Costs Structure

Work Items	Unit	Volume	Total Cost	
Column 35/35	m^3	33.66	Rp.	466.214.057.06
Column 25/25	m^3	2.07	Rp.	119.798.269.26
Column 14/20	m^3	0.24	Rp.	96.138.390.87
Beam 25/45	m^3	28.55	Rp.	451.344.917,73
Beam 25/40	m^3	2.55	Rp.	125.742.622,49
Beam 25/35	m^3	6.87	Rp.	184.610.239,05
Slab 12 cm	m^3	72.99	Rp.	743.945.606,94
Total Cost Structure			**Rp.**	**2.187.794.103,38**

Table 5. Alternative Models Costs Structure

Work Items	Unit	Volume	Total Cost	
Column 35/35	m^3	33.66	Rp.	466.214.057,06
Column 25/25	m^3	2.07	Rp.	119.798.269,26
Column 14/20	m^3	0.24	Rp.	96.138.390,87
Beam 25/45	m^3	28.55	Rp.	451.344.917,73
Beam 25/40	m^3	2.55	Rp.	125.742.622,49
Beam 25/35	m^3	6.87	Rp.	169,703,594.64
Deck plates 12 cm	m^3	72.99	Rp.	406,749,937.97
Total Cost Structure			**Rp.**	**1.835.691.790,02**

Table 6. Conventional Model Costs Wall

Work Items	Unit	Volume	Total Cost	
Red Brick Wall	m^2	1486.97	Rp.	416.878.762,12
Column 10/10	m	978.20	Rp.	175.572.217,31
Beam 10/10	m	267.37	Rp.	134.310.189,18
Plastering	m^2	2973.90	Rp.	270.720.000,76
Smoothing	m^2	3081.64	Rp.	206.677.727,17
Total Cost Wall			**Rp.**	**1.204.158.896,55**

Table 7. Conventional Model Costs Wall

Work Items	Unit	Volume	Total Cost	
Lightweight bricks	m^2	1486.97	Rp.	267,556,759.03
Column 10/10	m	978.20	Rp.	175.572.217,31
Beam 10/10	m	267.37	Rp.	134.310.189,18
Smoothing	m^2	3081.64	Rp.	206.677.727,17
Total Cost Wall			**Rp.**	**784.116.892,69**

Table 8. Conventional Model Costs Roof

Work Items	Unit	Volume	Total Cost	
Steel Frame	kg	7629.1	Rp.	810.374.183,19
Roof Covering	m^2	555.46	Rp.	566.342.822,88
Total Cost Roof			**Rp.**	**1.376.717.006,06**

Table 9. Alternative Model Costs Roof

Work Items	Unit	Volume	Total Cost	
Lightweight Steel	m^2	7629.1	Rp.	447,734,151.68
Roof Covering	m^2	555.46	Rp.	515,967,752.56
Total Cost Roof			**Rp.**	**963.701.904,24**

Table 10. Conventional Model Costs Floor Covering

Work Items	Unit	Volume	Total Cost	
Ceramic 60/60	m^2	886.73	Rp.	504.335.965,53
Ceramic 40/40	m^2	22,63	Rp.	223.508.988,85
Ceramic Skirting 10/60	m	511,12	Rp.	248.375.798,44
Total Cost Floor Covering			**Rp.**	**976.220.752,83**

Table 11. Alternative Model Costs Floor Covering

Work Items	Unit	Volume	Total Cost	
Granite Polish 60/60	m^2	849,24	Rp.	293,766,462.38
Granite Unpolish 60/60	m^2	37,49	Rp.	107,592,294.83
Granite Unpolish 40/40	m^2	22,63	Rp.	181,541,443.99
Granite Polish Skirting 10/60	m^2	511,12	Rp.	191,478,801.85
Total Cost Floor Covering			**Rp.**	**774.379.003,05**

Table 12. Work Cost Analysis

Work Items	Conventional Model Costs	Alternative Model Costs
Structure	Rp. 2.187.794.103,38	Rp. 1.835.691.790,02
Wall	Rp. 1.204.158.896,55	Rp. 784.116.892,69
Roof	Rp. 1.376.717.006,06	Rp. 963.701.904,24
Floor covering	Rp. 976.220.752,83	Rp. 774.379.003,05

3.2 Recommendation Stage

In the recommendation stage, the decision-making process involves a comprehensive evaluation of the previous stages, assessing the feasibility of the selected materials, cost-effectiveness, and alignment with project objectives. Different alternatives are compared using an evaluation matrix, and the best alternative is chosen based on this analysis.

The evaluation matrix is used to compare the advantages and disadvantages of the planned design with the selected alternative for a specific work item. In this matrix, a score of 2 is assigned if the alternative is considered better than the planned design, 1 if the alternative is equal to the planned design, and 0 if the alternative is worse than the planned design (Das & Kanchanapiboon, 2011). The comparison of the strengths and weaknesses between the conventional model and alternative model structural is shown in Table 13.

Table 13. Comparison of Structural Works

Criteria	Conventional Model Using Slab	Alternative Model Offers Deck Plates
Strength	Grade 275 MPa according to planned specifications	Grade 275 MPa according to planned specifications
Cost	Work cost of Rp. 2.187.794.103,38	Work cost of Rp. 1.835.691.790,02
Sustainability	Slab tends to absorb and retain more heat, which can increase indoor temperatures and add to the cooling system's load.	Deck plates have excellent capabilities in regulating indoor temperatures, thereby reducing the cooling load and ultimately lowering energy consumption.

The advantages and disadvantages are then scored and entered into an evaluation matrix, resulting in a ranking as shown in Table 14.

Table 14. Structural Work Evaluation Matrix

Criteria	Conventional Model Using Slab	Alternative Model Offers Deck Plates
Strength	1	1
Cost	1	2
Sustainability	1	2
Total	**3**	**5**

Table 15. Comparison of Wall Works

Criteria	Conventional Model Using Red Bricks	Alternative Model Offers Lightweight Bricks
Strength	Red bricks have lower strength compared to lightweight bricks.	Lightweight bricks have better durability compared to red bricks.
Cost	Work cost of Rp. 1.204.158.896,55	Work cost of Rp. 784.116.892,69
Sustainability	Red bricks not offer the same level of insulation as lightweight bricks, potentially resulting in higher energy costs for heating and cooling.	Their resistance to termites, mold, and moisture has the potential to reduce long-term maintenance costs

As shown in Table 14, the alternative model received a higher score than the conventional model due to lower implementation costs can saving until Rp. 352.102.313,36. and sustainability can reduce the cooling load and ultimately lowering energy consumption.

In the wall construction work, the comparison of the advantages and disadvantages between the conventional model and alternative model is presented in Table 15. The evaluation matrix for the wall construction work is shown in Table 16.

Table 16. Wall Work Evaluation Matrix

Criteria	Conventional Model Using Red Bricks	Alternative Model Offers Lightweight Bricks
Strength	1	2
Cost	1	2
Sustainability	1	2
Total	**3**	**6**

Table 17. Comparison of Roof Works

Criteria	Conventional Model Using WF steel	Alternative Model Offers Lightweight Steel
Strength	The strength of WF (Wide Flange) steel frames is superior when compared to the strength of light steel frames.	Lightweight steel frames have low resistance to earthquakes and are weak at the joints, while meeting the required standards for building roof construction.
Cost	Work cost of Rp. 1.376.717.006,06	Work cost of Rp. 963.701.904,24
Sustainability	WF steel can be durable, but it tends to be more susceptible to corrosion if not properly protected, necessitating more attention in maintenance.	Can reduces construction waste by using recycled and environmentally friendly materials. Maintenance is easier because it is resistant to corrosion and insects, which can reduce long-term maintenance costs and extend the lifespan of the building's roof.

As shown in Table 16, the alternative model received a higher score than the conventional model due to strength, lower implementation costs can save until Rp 420,042,003.86 and sustainability can resistance to termites, mold, and moisture has the potential to reduce long-term maintenance costs.

In the roof construction work, the comparison of the advantages and disadvantages between the conventional model and alternative model is presented in Table 17. The evaluation matrix for the wall construction work is shown in Table 18.

Table 18. Wall Roof Evaluation Matrix

Criteria	Conventional Model Using WF steel	Alternative Model Offers Lightweight Steel
Strength	1	0
Cost	1	2
Sustainability	1	2
Total	**3**	**4**

As shown in Table 18, the alternative model received a higher score than the conventional model due to lower implementation costs can save until Rp. 413.015.101,82. and sustainability can reduce long-term maintenance costs and extend the lifespan of the building's roof because it is resistant to corrosion and insects.

In the floor covering construction work, the comparison of the advantages and disadvantages between the conventional model and alternative model is presented in Table 19. The evaluation matrix for the wall construction work is shown in Table 20.

Table 19. Comparison of Floor Covering Works

Criteria	Conventional Model Using Ceramic	Alternative Model Offers Granite
Aesthetics	Ceramic tiles are available in a variety of designs, patterns, and textures, offering flexibility in aesthetic choices.	The solid and durable surface of granite conveys a strong and long-lasting impression, which can enhance the overall aesthetic value.
Cost	Work cost of Rp. 976.220.752,83	Work cost of Rp. 774.379.003,05
Sustainability	Ceramic is fairly durable, but it is not as strong as granite and is more challenging to manage indoor temperatures. Additionally, it may appear to fade or scratch more easily over time.	granite is more efficient in maintaining room temperature, cost efficiency, and sustainable development because can reducing long-term maintenance costs.

Table 20. Wall Floor Covering Evaluation Matrix

Criteria	Conventional Model Using Ceramic	Alternative Model Offers Granite
Aesthetics	1	1
Cost	1	2
Sustainability	1	2
Total	**3**	**5**

As shown in Table 20, the alternative model received a higher score than the conventional model due to lower implementation costs can save until Rp 201,841,749.78. and sustainability can reduce long-term maintenance costs. These changes not only provide significant cost savings but also meet the green building objectives, ensuring that the project remains within budget while enhancing overall quality and sustainability.

4. Conclusion

The conclusion of the study on the application of value engineering in enhancing green building innovation at the Denpasar Health Polytechnic building identifies significant opportunities for savings across various work items to achieve cost efficiency and sustainable development. Additionally, by prioritizing green building aspects in material selection, the study contributes to reducing environmental impact. This study demonstrates that innovation, efficiency, and sustainability in the construction industry can pave the way for environmental protection. Although further discussion is needed regarding the challenges and limitations faced during the implementation of value engineering to enhance green building innovation, this research offers a new perspective on the construction world.

Acknowledgements

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References

Alsaeed, B.S., Hunt, D.V. & Sharifi, S., 2022. Sustainable water resources management assessment frameworks (SWRM-AF) for arid and semi-arid regions: A systematic review. *Sustainability*, 14(22), 15293.

Al-Yami, A.M. & Price, A.D.F., 2005. Exploring conceptual linkages between value engineering and sustainable construction. *In: 21st Annual ARCOM Conference. SOAS, University of London: Association of Researchers in Construction Management*, vol. 1, 375–384.

Annappa, C.M. & Panditrao, K.S., 2013. Optimization of furniture product in furniture industry by using value engineering with function analysis, function evaluation and decision matrix: A case study. *International Journal of Application or Innovation in Engineering & Management* (IJAIEM), 2(3), pp.55–64.

Andelin, M., Karhu, J. & Junnila, S., 2015. Creating shared value in a construction project - a case study. *Procedia Economics and Finance*, 21, 446–453.

Badan Standarisasi Nasional Indonesia. 2013. SNI 1727:2013. Beban minimum untuk perancangan bangunan gedung dan struktur lain. ICS 19.040; 17.120.20-93.020

Becker, P.F.B., Effting, C. & Schackow, A., 2022. Lightweight thermal insulating coating mortars with aerogel, EPS, and vermiculite for energy conservation in buildings. *Cement and Concrete Composites*, 125, 104283.

Cao, Y., Kamaruzzaman, S. N., & Aziz, N. M. 2022. Building information modeling (BIM) capabilities in the operation and maintenance phase of green buildings: a systematic review. *Buildings*, 12(6), 830.

Das, S., & Kanchanapiboon, A. 2011. A multi-criteria model for evaluating design for manufacturability. International Journal of Production Research, 49(4), 1197-1217.

Dell'isola, A.J., 1970. Value engineering for highway construction. *Roads and Streets*, 113, 64–65

García, H., Zubizarreta, M., Cuadrado, J. & Osa, J.L., 2018. Sustainability improvement in the design of lightweight roofs: A new prototype of hybrid steel and wood purlins. *Sustainability*, 11(1), 39.

Heiza, K.M., Abo Elenen, N.E. & Mahdi, I.M., 2016. State of the art review on application of value engineering, value analysis and value management on construction projects: high rise buildings. *In: International Conference on Civil and Architecture Engineering*. vol. 11(11), 1–15.

Imron, A. & Husin, A.E., 2021. Value engineering and lifecycle cost analysis to improve cost performance in green hospital project. *Archives of Civil Engineering*, 67(4), 497–510.

Jonnala, S.N., Gogoi, D., Devi, S., Kumar, M. & Kumar, C., 2024. A comprehensive study of building materials and bricks for residential construction. *Construction and Building Materials*, 425, 135931.

Joibary, A.R.M. & Nagaraja, N., 2010. The survey of the value engineering indexes in the function of the Sari region petroleum (oil) products distribution company in Iran. *Asian Journal of Development Matters*, 4(3).

Mahdi, I., Heiza, K. & Elenen, N.A., 2015. Value engineering and value analysis of vertical slip form construction system. *International Journal of Application or Innovation in Engineering & Management (IJAIEM)*, 4(6), 200–212.

Mahdi, I.M., Heiza, K.M. & Elenen, N.E., 2015. State of the art review on application of value engineering on construction projects: High rise building. *International Journal of Innovative Research in Science, Engineering and Technology*, 1(1).

Marcelline, T.R.S., Chengang, Y., Avotra, R. A.A., Hussain, Z., Zonia, J.E. & Nawaz, A., 2022. Impact of green construction procurement on achieving sustainable economic growth influencing green logistic services management and innovation practices. *Frontiers in*

Environmental Science, 9.
Natalia, M., Mirani, Z., & Syahputra, J., 2022. Penerapan Value Engineering Pekerjaan Balok, Kolom Dan Pelat Lantai (Studi Kasus: Gedung Perpustakaan Daerah Kabupaten Bengkalis). *Media Komunikasi Teknik Sipil*, 28(1), 32-39.
Oguntona, O.A. & Aigbavboa, C.O., 2023. Nature inspiration, imitation, and emulation: Biomimicry thinking path to sustainability in the construction industry. *Frontiers in Built Environment*, 9, 1085979.
Salsabila, A., Setyowulan, D. & Arifi, E., 2024. Analysis value engineering at work apartment building wall. *Astonjadro*, 13(1), 245–250
Sheikh, D.B.A., Dar, D.I.M., Khan, D.O.F. & Wani, I.B., 2022. Value engineering as a sustainable tool in construction industry. *International Journal of Research in Science & Amp*, 1–7.
Shen, Q.G. & Yu, A.T.W., 2012. Value management: Recent developments and way forward. *Construction Innovation Journal*, 12, 264–271
Sobhanollahi, M.A., Kazemi, A. & Ghodratnama, A., 2014. Assessment of improvement of preventive maintenance (PM) systems related to the civil projects using concepts of value engineering (VE). *International Journal of Engineering*, 27(12), 1872–1878.
Sudiarsa, M., Sudiasa, W. & Sutapa, K., 2018. Value engineering approach for construction materials selection of irrigation drainage: Case study on project of DAS irrigation drainage improvement at Cengcengan River in Gianyar. *International Journal of Physical Sciences and Engineering*, 2(1), 35–46.
Uğural, M.N., 2023. Material selection with value engineering technique - A case study in construction industry. *Tehnički vjesnik*, 30(1), 292–301.
Wang, J. & Xu, W., 2022. Advanced lightweight materials for automobiles: A review. *Materials & Design*, 221, 110994.
Zhang, W. & Xu, J., 2022. Advanced lightweight materials for automobiles: A review. *Materials & Design*, 221, 110994.