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Improving Building Performance Using Smart Building Concept: Benefit Cost Ratio Comparison

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Abstract. Smart building concept is an implementation of technology developed in the construction industry throughout the world. However, the implementation of this concept is still below expectations due to various obstacles such as higher initial cost than a conventional concept and existing regulation siding with the lowest cost in the tender process. This research aims to develop intelligent building concept using value engineering approach to obtain added value regarding quality, efficiency, and innovation. The research combined quantitative and qualitative approach using questionnaire survey and value engineering method to achieve the research objectives. The research output will show additional functions regarding technology innovation that may increase the value of a building. This study shows that smart building concept requires higher initial cost, but produces lower operational and maintenance costs. Furthermore, it also confirms that benefit-cost ratio on the smart building was much higher than a conventional building, that is 1.99 to 0.88.

INTRODUCTION

Technology contributes greatly to daily life and has become a pioneer in advanced social development shortly. Information and communication technology (ICT) contributes significantly to various aspects of life ranging from economic growth and lifestyle such as behavior, appreciation, and expectation [1]. Every company and organization in many industries nowadays use ICT intensively to increase their chances of becoming the leader in services for customers. It also occurs in construction industry particularly in building sector where companies try to suit to users' lifestyle. One of the applications to accommodate ICT in a building is through the development of intelligent building/smart building.

The smart building integrates the complex system in certain coordination to manage resources efficiently [2]. The key to smart building concept lies on the integrated system called smart building system that uses automation in its operational stage [3]. The system mostly installed on heating, ventilation and air conditioning (HVAC) to provide energy efficiency, security protection, telecommunication interface, and vertical transportation.

The number of buildings using this concept has risen around the world in the past years as a strategy to mitigate energy consumption, environmental issues and climate change [4, 5]. An increased implementation of this concept in the building sector is supported by the benefits for owners and users such as technical performance, reduced operational costs and investment, building flexibility and marketability [6, 7]. In contrast, the practice of smart building in Indonesia faces obstacles such as owner perception, higher risk compared to a conventional building, higher initial cost, and perception of the low rate of return [8]. Initial design and development play a crucial role in value for money [9] for smart building by reducing uncertainty and achieving target quality. This research will

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develop the concept of the smart building using value engineering (VE) approach. VE has been proven to enhance process design through systematic stages that may produce innovation and value for the project.

METHODOLOGY

The research method defined as a systematic data collection focused on obtaining information to address research problems or response research questions [10]. This research combines qualitative and quantitative approach to achieve the research objectives. A qualitative approach is one way to generate others' perspective and perception of the proposed research topic. The investigation will focus on individuals' assumption, opinion, and judgment on problems or variables of research. The data collection may be unstructured, but the raw data might produce a rich and broad scope of study [11]. On the other hand, quantitative approach relates to seeking, combining and investigating the correlation between facts and existing theory. It aims to measure available data and present them into a conclusion through numeric result [12].

This research will use a questionnaire survey as a quantitative approach and a focused group discussion as a means of qualitative approach. The survey was structured by employing a close – ended method and providing multiple choice answers. The questionnaire instrument categorized into four sections. First, general information of the respondents followed by key success factor in building the project, identification of potential additional functions, and lastly, the total cost. In total, 52 questionnaires distributed to high – level individuals in building industries in the government, private companies, academics, and others. On the other hand, the online approach used by sending it to the related mailing lists and various groups in building the project.

The returned questionnaire was analyzed using a descriptive method as an input before value engineering process. It is a systematic way to generate added value and innovation which is not only used by building project but also by other sectors. Lastly, the life cycle cost method will be used to evaluate the benefit over the cost of Smart Building concept in this research [13, 14].

RESULT AND DISCUSSION

A total of about 35 copies of questionnaire survey from online and offline approach were returned. The result shows that most of the respondents (31%) work as private contractors and the consultants accounted for 29%. The educational background varied showing 23% of respondents holds a master's degree and 11% has a doctoral degree. Regarding position level in an institution, the position of director contributed 9%. Lastly, work experience mostly ranged from 1 to 10 years, which accounted for 69%, whereas about 20% had 1 – 20 years of work experience.

Additional Functions

This part aims to investigate innovation for building construction by exploring ideas and stimulating respondents' understanding and knowledge of idea generation in value engineering. An additional function potentially integrated into the building comprises of six components such as energy efficiency, environmentally friendly, security and safety, comfort and health, accessibility and mobility as well as maintainability. Energy efficiency function is the most feasible variable to be integrated into a building as supported by 20% of respondents. Security and safety were voted by 17.42% of the respondents, whereas 16.77% voted for maintainability and environmental friendly. The details can be seen in table 1.

TABLE 1. Potential additional functions for building

Additional Functions	Response	Percentage (%)
Energy efficiency	31	20.00
Environmentally friendly	26	16.77
Security & safety	27	17.42
Comfort & health	22	14.19
Accessibility & mobility	23	14.84
Maintainability	26	16.77

As energy efficiency plays a significant role in improving building design and construction sustainability, respondents confirmed several concepts that might be beneficial to the building. About 29.73% of the respondents agreed that the concept has to consider proper planning in designing an efficient artificial lighting with energy saving. Other concepts for improving building design are designing an efficient artificial air conditioning with energy saving and planning suitable building envelope with a coefficient of the response of about 27.93% and 21.62% respectively. The detailed concept summarized in table 2.

TABLE 2. Concept of efficient energy in building

Concept of Efficient Energy in Building	Response	Percentage (%)
Plan a suitable building envelope	24	21.62
Select efficient vertical transportation	9	8.11
Design artificial light with energy saving	33	29.73
Design artificial air conditioning with energy saving	31	27.93
Use renewable energy	14	12.61

Additionally, improving the quality of design and development of building regarding sustainability and being environmental friendly shall be achieved through seven components. It consists of efficiency in structure, energy, water, materials, improvement in the quality of the environment in space, operational and maintenance optimization and waste reduction. About 23.08% of the respondents agreed that energy efficiency has first to accommodate. Secondly, 20.77% efficiency should also reach water efficiency. The detailed variables of this research can be seen in table 3.

TABLE 3. Design improvement of eco–friendly buildings

Concept	Response	Percentage (%)
Placement and structure design efficiency	15	11.54
Energy efficiency	30	23.08
Water efficiency	27	20.77
Material efficiency	15	11.54
Improvement in the quality of environment in a space	17	13.08
Operational and maintenance optimization	16	12.31
Waste reduction	10	7.69

Furthermore, a function for safety and security to improve building design comprises seven components. Procurement of fire protection system and integration of accident prevention using material and construction technique were selected as the most feasible function by 17.73% of the respondents. It follows by a user emergency evacuation system with 15.60%. They are summarizedin following table 4.

TABLE 4. Additional functions in fire protection

Concept	Response	Percentage (%)
Procurement of fire protection system	25	17.73
User emergency evacuation system	24	17.02
Design development to reduce accidents	22	15.60
Integration of accident prevention by the use of material and construction technique	25	17.73
Integrated security system	22	15.60
Authorized entry system	16	11.35
ICT crime prevention	7	4.96

The result of the questionnaire survey was then used as an input to develop the potential innovation of the building project further. It will use function analysis called FAST diagram, which aims to stimulate a group of multi – stakeholders in building industry to generate an appropriate concept for the project. The fast diagram of thesmart building can be seenin Fig. 1. The FAST diagram has assisted in delivering smart building model. It consists of building envelope, fire alarm, electricity, security system, HVAC, elevator, lighting and building management system (BMS). The smart building skin will respond to various external effects to maintain thermal comfort optimally.

The system has been broadly applied in buildings such as "Shape Shift" in Gallery StarkArt in Zurich, "intelligent double skin" in Terrence Donnelley Centre for Cellular and Biomolecular Research at the University of Toronto, ABI Strata™ System demonstrated in Emergent Surface exhibition and many others. On the other hand, HVAC system will control humidity, mechanical properties of speed, air support, and others. In general, HVAC comprises the following components but not limited to the actuator, air control support, damper support, sensors, thermostat, valve, speed drive variable, control panel and enclosure and current sensor and transducer.

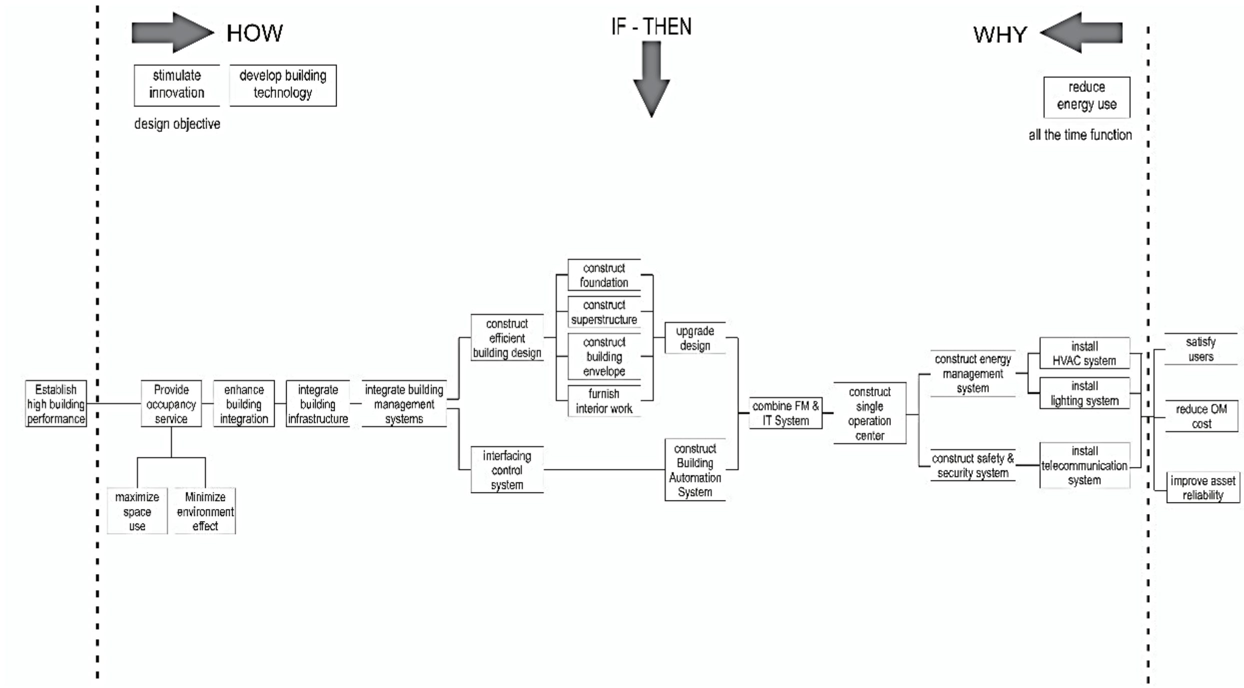

FIGURE 1. Fast diagram of smart building

Overall, the BMS has the most crucial part of the smart building as it computerized the activity of every component in the building. Metasys@operates in an integrated manner, combines all building systems - comfort control, lighting, fire safety, security, and equipment. With IT-based infrastructure, software and wireless capabilities, Metasys integrate network that coordinates and organizes all information logically and then delivers it whenever necessary. Another technology in BMS is also provided by Design – Siemens, Panoptix® - Johnson Controls and IBM.

Conventional Building vs. Smart Building

An eight-storied and 1,500-square – meter campus building was used as the case study to be compared to the proposed alternative design. The component consists of four items, namely architecture, structure, M & E, general and external. Unit cost for each item was generated from the primary data of the building. Meanwhile, the life cycle of building components is used to compare the cost for both conventional building and smart building. It shall adopt Life Expectancy of Building Components (Building Cost Information Service/BCIS, 2006), Intelligent Buildings in South East Asia and local experts in Indonesia's building sector.

The differences between both concepts are from HVAC, elevator, electrical system, lighting, security system and fire alarm system. In general, the concept of the smart building presents higher cost at the initial stage, yet it provides shorter component renewals, thus reducing the cost of replacement. The different life cycle for both concepts is shown in Table 5 as follows.

Both concepts were then evaluated using life-cycle cost approach to show the NPV value of each building for a lifespan of 30 years. The conventional building shows the initial cost of about Rp. 86.93 billion with operational and maintenance costs of about Rp. 78.25 billion. On the contrary, smart building produces the higher initial cost of about Rp. 108.28 billion with operational and maintenance cost of about Rp. 48.45 billion. The NPV of each concept was Rp. 165,183,447,187.08 and Rp. 156,733,900,411.66.

TABLE 5. Comparison of conventional and smart building

Building Components	Conventional Building (years)	Smart Building (years)
HVAC		
- Chiller	15	30
- Cooling Tower		20
- AHU		20
- Ducting		30
- HVAC control system		20
Elevator	20	24
Electrical System	12	24
Lighting	3	30
Security System	15	20
Fire Alarm System	15	5

Benefit – Cost Ratio (BcR)

This analysis investigated consumption energy between the conventional building and smart building. HVAC and fire alarm system were the major contributors to the use of energy in both concepts. HVAC generates around 96% of power in the building, while fire alarm uses around 2%. Based on the analysis, the smart building was able to save energy from all components and reduce energy power from 765,228.16 kWh to 499,067.01 kWh or equal to a 34.78% reduction. The detailed comparison between the two concepts is summarized in the following table 6.

TABLE 6. Comparison of energy cost between conventional building and smart building

Components	Conventional Building (C)		Smart Building (S)		Energy Saving (C-S)	
	Power (kWh)	Energy Cost (Rp. million)	Power (kWh)	Energy Cost (Rp. million)	Power (kWh)	Energy Cost (Rp. million)
HVAC	736,968.96	996.38	479,520.77	648.31	257,448.19	348.07
Elevator	6,480.00	630.79	4406.40	428.94	2,073.60	201.85
Lighting	288.00	1,168.13	96.00	389.38	192.00	778.75
Security System	3,470.63	4.69	2,429.44	3.28	1,041.19	1.41
Fire Alarm System	18,020.57	24.36	12,614.40	17.05	5,406.17	7.31
Total	765,228.16	2,824.35	499,067.01	1,486.96	266,161.15	1,337.39

Note: 1 US$ = 13,400 rupiah

Besides power efficiency, the smart building also provides carbon emission reduction which may decrease the negative impact of building on nature. According to IPPC, the coefficient for carbon emission in Indonesia is about 781.26 gr/kWh. Apotential reduction of energy sector per ton CO_2 per annum is about US$ 1.83; the emission carbon reduction is around 3,752,057.01. The benefit-cost ratio of 1.99 to 0.88 confirms the greater value of smart building over a conventional building.

Overall, the smart building requires 25% higher initial cost than conventional building to produce 38% of efficiency regarding operational and maintenance for 30 years. The analysis shows that smart building has a slightly lower score of NPV but holds the lead over the conventional building regarding BcR value. Based on this result, investors may hesitate to invest their fund in a smart building in Indonesia. A subsidy or incentive is encouraged to be formulated as a means to attract the interest of the private sectors in using smart building concept. It can also serve as government support towards a sustainable building and construction in Indonesia.

CONCLUSION

Smart building concept which emphasizes the use of technology is argued as an approach to connect the needs of sustainable construction with environmental issues. On the other hand, value engineering is a systematic method that aims to generate an optimum outcome regarding project quality, innovation, and competitive cost. Both concepts have been used in this research to produce alternative concept in building industry.

This research identified several potential additional functions such as energy efficiency, environmentally friendly, security, and safety, comfort and health, accessibility and mobility as well as maintainability. Those functions were evaluated using value engineering process and generated smart building concept comprising eight components; building envelope, fire alarm, electricity, security system, HVAC, elevator, lighting and building management system (BMS). Life cycle cost confirmed that smart building required about 25% initial cost compared to the conventional building. However, it generated lower operational and maintenance costs as much as 38% for 30 years of the operational period. Both concepts show positive value of NPV, but BcR on a smart building was much higher than on a conventional building that is 1.99 over 0.88.

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