Measurement of campus smartness: The development of Smart Campus Model

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***Abstract*— Due to an increase in competitiveness between universities in Indonesia, the implementation of a Smart Campus was needed to be carried out by various universities. Subsequently, this implementation by universities requires a Smart Campus reference model. This Smart Campus model consists of a Higher Education model integrated with a Smart System model. Furthermore, it serves as a reference for the Higher Education model which simulates the enforcement of the Smart Campus model. This study created a Smart Campus measurement model comprising of two parts, namely the maturity level of Digital Transformation and the smartness level. The smartness level measurement is based on smart systems, technology and service quality used to improve the quality of life of university stakeholders. Furthermore, the result of this measurement was that the Digital Twin Smart Campus model provided a baseline for Smart Campus development such as the Digital Transformation of a traditional campus into a Smart Campus.**

Keywords—smart campus, smart campus measurement, smart campus model

I. INTRODUCTION

The world is currently entering the Fourth Industrial Revolution, which makes use of information technology (such as IoT, Big Data, and Artificial Intelligence), which is an essential component of Digital Transformation. Digital technology entails the incorporation of digital technology into all areas of business, resulting in a fundamental shift in how businesses operate and deliver value to customers. Furthermore, it is a cultural shift that organizations must recognize in order to compete in the Fourth Industrial Revolution. As a result of this revolution, universities must adapt to an increasingly competitive environment while attracting prospective students in order to ensure their survival.

As a result, it is hoped that by implementing a Smart Campus, universities will not face difficulties in improving and achieving the performance of the three pillars of higher education (outcome-based accreditation), increasing competitiveness, obtaining an excellent international outlook, and providing a digital learning experience when at full capacity as an added value for the institution.

The implementation of innovative digital technologies into a Smart Campus holds the promise of improved performance, cost efficiency, energy efficiency, and other appealing advantages [1].

Currently, the implementation of Smart Campuses has been carried out by several universities in the world. Studies from Alrashed [2] show examples of some of these universities and they include the University of Rome, Italy [1], University of Malaga Spain [3]), University of Johannesburg [4]), Aveiro University [5]), and Covenant University Nigeria [6]).

In addition, almost all of the current Smart Campus implementations have adopted the smart city model, which is

used to measure the level of campus smartness. This is carried out with the assumption that the campus is a small city where has a level of complexity associated with an actual small city. An example of a Smart Campus study with a different approach that did not adopt the smart city model is the iCampus model used at MIT [7] developed by MIT and Microsoft.

In Indonesia, the Smart Campus model known as the Garuda Smart Campus Model [8] was created by the Smart City and Community Innovation Center (SCCIC) of the Bandung Institute of Technology.

Furthermore, Kalluri [9] conducted research to define the dimensions and characteristics that distinguish smart CPSs and contends that the level of system smartness can be evaluated through two lenses: principle and perspective. The Smart Campus smartness level is measured in this study using the perspective category, which is divided into three categories: Anthropocentric, Systemic, and Technological.

Traditional universities in Indonesia use National Accreditation Body for Higher Education standards to determine the viability of higher education study. This is accomplished through criteria established by the National Higher Education Standards, which externally ensure the quality of Study Programs and Higher Education in both academic and non-academic fields.

Consequently, this leads to the protection of the interests of the students and society. It is shown that a Smart Campus occurs when there is integration between smart systems and campus models using the standards of the National Accreditation Board.

Furthermore, studies from Alter [10] and Kalluri [9] used measurement levels in addition to the National Accreditation Body for Higher Education standard to understand the smartness in terms of smart devices and smart systems. This ensures that the universities do not efforts in measuring smart campuses through the National Accreditation Body for Higher Education standard.

This study aims to:

1. Produce the Smart Campus measurement model through a combination of the concept of higher education in Indonesia with a smart system in the Garuda Smart Campus model.

2. Produce a Smart Campus Model as a representation of the current state of the campus using measurements obtained from the Smart Campus model to enable universities to find out how Smart Campus provides input for transformation to the expected level.

II. STUDY MODEL

The study model carried out can be seen in Figure 1.

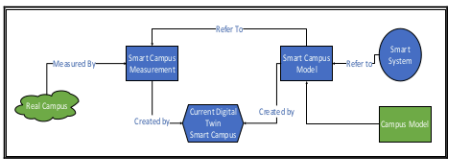

Figure 1. Study Model Smart Campus.

In this study, a Smart Campus model will be developed using the existing higher education model combined with the concept of a smart system.

Therefore, existing Smart Campus models are known to use the measurement of Smart Campuses as a reference to ensure the smartness level of Smart Campuses. A Digital Twin Smart Campus which described the current state of the campus was generated after the measurement of a Smart Campus.

Based on the Smart Campus model in Figure 1, a study model with three hypotheses was proposed and they include:

1. The adoption of the Digital Twin concept on the Smart Campus can be carried out by combining the Smart Campus model and the smart system model with the existing campus reality to ensure the simulation of plans that increase the smartness of a campus.

2. Measurement of Smart Campus smartness can be based on three perspectives, namely anthropocentric, systemic, and technology to enable the level of smartness of a campus to be accessed.

3. The maturity level of the Digital Transformation Smart Campus is used to increase the smartness level of that measured Smart Campus.

A. Campus Model

The meaning of campus and university has several perplexities. From the Merriam-Webster Dictionary, the campus has a broader definition when compared to that of a university that only talks about academics, in contrast to a campus that includes buildings and facilities supporting lectures.

According to the Higher Education Law of the Republic of Indonesia No. 12 of 2012, the purpose of higher education is to develop the potential of students to eventually become people who have faith in God, integrity, creativity, independence, and fluency in science and technology. As a result, a campus is a place where knowledge is valued. For all campus stakeholders, a campus provides Tridharma services (education, research, and community service), Management Services (guidance, governance, human resources, and cooperation), and Living Services (finance and infrastructure).

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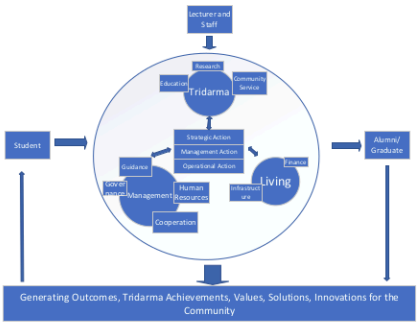

Figure 1 Model Campus

B. Model Smart System

According to Von Bertalanffy [11], the definition of a system is a series of interacting elements, Furthermore, a system is a collection of interconnected elements that function as a single unit.

A smart system, according to Romero, is an intelligent system whose services can be fully utilized by users and which rationally solves problems like humans, with the ability to reflect, explain, and justify how those problems are solved. Imbar [14] defined smart as the ability to act and immediately execute on a problem until it is properly resolved. Figure 2 depicts the process of a smart system based on automation level, which includes perception, planning, decision, action, and learning.

Figure 3 Process of a Smart System.

Table 1 is the definition of each smart system process.

Table 1 Definition characteristic smart system[12].

Process	Definition
Perception	The ability of the system to obtain meaningful and relevant information on its own.
Understanding	The process of translating information that can be used to generate alternative courses of action for the next step.
Decision	The capability to select the best solution from a set of alternatives based on a variety of criteria
Action	An execution that produces a result
Learning	The system's ability to improve its cognitive skills due to its information-handling experience.

C. Model Smart Campus

The Smart Campus has several definitions that have been studied by Vasileva [13], Coccoli [14], Rutkauskiene [15], Kwok [7], Nachandiya [16], and Huang [17]. Overall, some of the literature obtained from their studies indicates that when describing a 'Smart Campus' the emphasis is on digital technology which is a key component of a Smart Campus. This is because the goal of a Smart Campus is to improve the quality of life of the entire community involved in it by applying ICT when needed.

Definition of Smart Campus according to this study is a university that has an innovative system that enables the three pillars of various universities to be carried out in an integrated manner. Furthermore, this leads to the creation of excellent value, products, services, and knowledge by adopting tangible and intangible resources owned through the utilization of information technology to obtain wealth, value, and financial growth.

In addition, a university/campus is said to be smart if it uses knowledge to produce the desired response and resolves conflicts of interest from stakeholders while utilizing the contributions of a lot of people. This is in terms of knowledge in system smartness through the aid of Information Technology. Therefore, the Smart Campus model was based on the Smart City and Community Innovation Center (SCCIC) Smart Campus model, as shown in Figure 4.

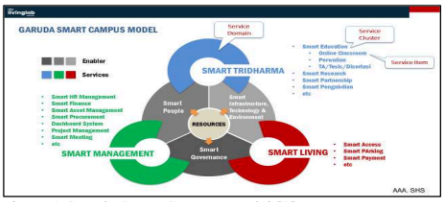

Figure 4 Garuda Smart Campus Model [2]

The Association of Indonesian Smart Initiative (APIC) adopted GSCM as a model for the Indonesia Smart Campus. GSCM which is divided into 3 (three) layers namely 1, 2, and 3 are the resources, enabler, and services respectively. An Enabler is a form of resources needed to run the services.
In general, GSCM measures the smartness level of the campus during the implementation of a Smart Campus through the measurement of 3 main clusters, namely: Smart Tridharma, Smart Management, and Smart Living.
The merging of the Smart System Model with the Garuda Smart Campus model used service layers integrated with the smart system model to enable the characteristics of a Smart System

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will appear in every Smart Campus service [13]. More details can be seen in Figure 5.

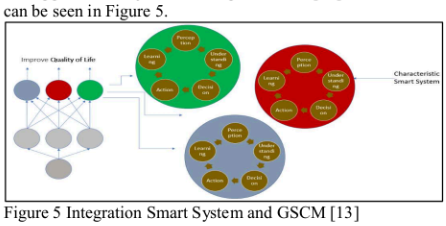

Figure 5 Integration Smart System and GSCM [13]

Furthermore, campus stakeholders were pleased with the high quality of service provided. These services include the incorporation of digital technology into the university system which holds the promise of improved performance, cost and energy efficiency, alongside other appealing advantages

III. RESULT AND DISCUSSION

A. Proposed Smart Campus Measurement

Smart Campus measurements are divided into two (Figure 6), namely:

1. Smart Campus smartness level used to measure Smart Campus smartness level [9].
2. Maturity level towards Digital Transformation Smart Campus utilized to transform the Smart Campus and learning efforts for an increased level of smartness in the Smart Campus.

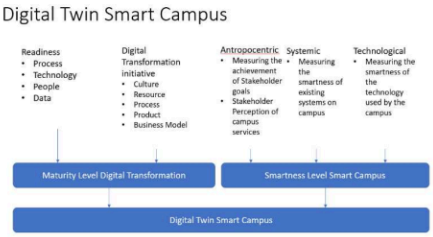

Figure 6 Smart Campus Measurement

B. Smart Campus Smartness Level

The measured smartness level perceived in a Smart Campus is divided into 3 points of view, namely [9] :

1. Anthropocentric perspective

This approach emphasizes the human element as the primary motivator in the concept of smartness. As a result, the role of technological infrastructure in campus smartness is important, and this is measured by focusing on the quality of life of its citizens. Furthermore, this viewpoint assesses services based on the quality of the services provided (Quality), the costs incurred to obtain these services (Cost), and the time required to acquire these services (Delivery).

2. Systemic perspective

Smartness concepts are described using systems that function as interconnected components that interact with one another. However, the significance of technology and people in the concepts presented from this point of view cannot be overstated. Furthermore, the campus is depicted as a system with multiple sub-systems that are analyzed and translated into services. Meanwhile, smart systems have embedded system features such as sensors and actuators, allowing them to carry out actions based on their level of intelligence when assisting humans in performing tasks.

3. Technological perspective

Technology is a major driver of increased smartness. This research focuses on the interconnectivity of technology such as Big Data, AI, and semantic interoperability. As a result, Smart Campuses use the communication and sensor capabilities built into their infrastructure to optimize campus operations. Campus smartness is defined by its ability to leverage the potential of ICT to support various services provided. As a result, if the technology is not sufficiently intelligent, employees will have to spend a significant amount of time preparing data.

C. Digital Transformation Smart Campus Maturity Level

A Digital Transformation Smart Campus maturity model was proposed to increase the measured Smart Campus's smartness level and to classify the readiness of Smart Campus development in colleges/universities or the evolutionary status of traditional universities towards Smart Campus. In addition, the model is based on the CMMI (Capability Maturity Model Integrated), which is widely used in the software development industry to improve the quality of software engineering processes and final products [19]. Furthermore, it is influenced by the SCCIC smart city maturity model [8] and a De Carolis study [20].

The maturity level of the Smart Campus is divided into 5 levels in Table 2.

Table 2. Maturity Level of Digital Transformation Smart Campus

Level	Explanation
Adhoc	Management is skeptical of digital technology's business value. IT automation on a small scale; no digital culture yet. The use of digital has no bearing on the process.
Initial	There is no comprehensive vision for business digitization yet. Management began to develop a digital vision. Large-scale IT automation is being implemented.
Scattered	An all-encompassing digital vision exists. Management is starting to take active steps to build digital skills and culture. Large scale IT automation but not yet integrated.
Integrated	Strong all-in-one digital vision. Digital culture exists in every department. Many digital initiatives that generate value for businesses

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	are sometimes not well coordinated. Integrated IT system.
Transform	Transformation is now an accepted part of corporate culture. Every activity is coordinated, automated, and efficient. They continue to increase the competitive advantage they get from implementing Digital Transformation because they have a strong digital culture and good governance. IT systems are secure, integrated, and highly available (anytime, anywhere, and on any device).

IV. Discussion and Finding

A. Discussion of Finding

The study encompasses several important findings. The first finding of a Smart Campus model was suitable for use in Indonesia. Furthermore, the model used is the Garuda Smart Campus Model was developed by SCCIC through additional smart system characteristics in the Smart Campus service measurements of the system. Furthermore, the second findings were that the Smart Campus measurement model consists of two parts, namely the Smart Campus Smartness Level (which can be measured from three perspectives, namely the Anthropocentric perspective, the Systemic perspective, and the Technological perspective [9]) and the maturity level of Digital Transformation which is used to determine the next level transformation and evolutionary status of traditional universities towards Smart Campus.

B. Limitation and Future Study Direction

Despite the significant findings of this study, the results were interpreted based on the limitations obtained. In the first place, it was necessary to implement the model by taking measurements in several Indonesian universities. This was carried out to ensure the generation of conclusions to determine the usability of the model and indicators. Furthermore, model validation is carried out by measuring campus smartness for a private university, a state university and a polytechnic to obtain iterations that will refine the model. This will lead to the production of the best model that can be transformed into a Smart Campus.

C. Implication For Study and Practice

This study offers several implications for study such as Smart Campus model which used for measuring the smartness of Smart Campus. Although previous studies examined and discovered the Smart Campus model was also obtained from the smart city model, this study specifically contributes to the Smart Campus model through a smart system model and campus model.

This study identified the maturity of Digital Transformation campus and smartness level of Smart Campus based on an Anthropocentric, Systemic and Technological perspective. Finally, from these measurements, a Digital Twin Smart Campus model was developed.

V. Conclusion

The study highlighted the fact that a Digital Twin Smart Campus Model contained the current condition of a university after measurements were obtained from the Smart Campus using the Garuda Smart Campus model. Meanwhile, the Smart Campus Smartness contained smartness levels based on three perspectives, namely Anthropocentric, Technological, and Systemic perspectives. In the future, this study will be continued by developing criteria and indicator measurements to enable Indonesian Smart Campus Rating to be carried out by several universities in the country. Furthermore, this study was used as a reference for universities in Indonesia to carry out the transformation process from their various current states into Smart Campuses. It is expected that more effort should be devoted to this important study area. Also, the proposed model should serve as useful guides for future studies.

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