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Development of a smart campus framework

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ABSTRACT: The industrial revolution 4.0 is moving the world into a new technology-based ecosystem, and the higher education sector is not an exception. At present, there are no guidelines established for universities campuses that can enable them to properly apply information and communication technology to better develop their campus ecosystem or smart campus. Hence, in this research, using design science research methodology (DSRM), a smart campus framework has been developed that can be used as a guideline to enable higher education institutions (HEIs) to measure, plan, prepare and implement smart campus technology. The framework starts with the definition of a smart campus; this is then used as the basis of a smart campus model. From the smart campus model, a smart campus measurement model can be developed that measures the current smart campus level, based on anthropocentric, systemic and technological perspectives. This research can be useful to leaders of higher education institutions to determine the current condition of their smart campus, as well as serving as a guideline for planning and implementing smart campus strategies.

INTRODUCTION

The goal of a smart campus is to meet the needs of a new generation of students who are already familiar with IT and who value digital tools for learning, staying informed and staying connected with the outside world. These studies also point to the importance of using technology, such as the Internet and big data, for improving the university teaching environment [1].

Utilising smart campus technology can also enhance the quality of campus policy, increase instructor and student interest in teaching/learning, and enhance teacher-student relationships by enriching the campus life of both teachers and students [2].

Ideally, a smart campus should be able to use all modern technology and smart solutions to ensure reliability, interactivity, flexibility and accessibility for students and teachers at anytime and anywhere [3]. The impact of Covid-19 also has added impetus for higher education institutions (HEIs) to change and implement new learning technology [4][5].

Lecturers and staff also expect a digital workplace that allows them to focus on meaningful goals and activities that fulfil the vision and mission of HEIs. These institutions must be able to adapt to the industrial revolution 4.0 in order to increase their level of competitiveness and increase attractiveness for prospective students which are needed to survive in today's highly competitive educational market.

There are many institutions that already recognise that a smart campus is one that applies information and communication technology (ICT). On the other hand, there are no guidelines or reference points about how to properly implement ICT on campus to enable it to have a better campus ecosystem or smart campus. Therefore, this study aims to create a smart campus framework that can be used by HEIs as a guideline or frame of reference on how to apply technology appropriately so that their campuses have a better campus ecosystem or smart campus.

In this article, such a smart campus framework is outlined based on the following research question: how to create a smart campus framework that can be used as a reference for campuses to become smart campuses and that can measure the current state of campus smartness.

The development of a smart campus framework in this research entails having a smart campus definition that can be used as a reference point in developing both a smart campus model and a smart campus measurement model. The smart campus model is designed as an ideal model for transforming a campus into a smart campus because it includes the essential services that a smart campus must have, and the smart campus measurement model is designed to measure the services provided by a smart campus.

The novelty of this research lies in the smart campus framework developed, which includes a definition of a smart campus that is expected to become the standard for a smart campus that can be accepted by all parties. A smart campus model will be developed based on the definition, which will be a model that can be referred to if campus administration and other stakeholders wish to create a smart campus, including a smart campus measurement model that will measure service quality, system smartness and technological smartness.

This research may have a significant impact by making it easier to build a smart campus and increasing the smartness level towards a smarter campus using this framework. This article will also contribute to the expansion of the body of knowledge in the field of smart campuses by broadening the perspective on smart campuses, allowing them to be used as references when constructing a smart campus.

This research can contribute to the field of higher education in terms of proposing a smart campus framework. The smart campus model that is created will refer to the generic campus model in Indonesia and can be used by HEIs throughout Indonesia that intend to implement smart campus technology. The smart campus measurement model can be used to measure the current condition of HEIs. Research by Imbar et al has been used as the basis for measuring a smart campus based on the anthropocentric, systemic and technological perspectives [6].

RESEARCH METHODOLOGY.

As mentioned above, this research aims to develop a smart campus framework which can be used by HEIs to plan, measure and implement smart campuses. DSRM was used to achieve the objectives of this research [7].

Phase 1 of DSRM consists of identifying the main research problem, i.e. the purpose of this research which has been explained in the introduction.

Phase 2 of DSRM involves conducting an in-depth study including a literature review and performing an analysis in the form of requirements for the framework to be created. This phase of the research will focus on the requirements of the smart campus model and the smart campus measurement model.

Phase 3 design and development begins with making a smart campus framework, consisting of a smart campus definition, a smart campus model and a smart campus measurement model.

Phase 4 evaluation is the validation stage to determine whether the model that was made is in accordance with the requirements and evaluation of the smart campus framework that was developed by inviting feedback from experts regarding the framework.

LITERATURE REVIEW

At present, a standard definition of what a smart campus entails does not exist. Each researcher makes their own definition of a smart campus based on the research topic they are undertaking. Most smart campus definitions are based on one of the following three approaches: technological, smart city-adoptive or the organisational/business-process approach [8].

In the technological approach, a smart campus can be defined as having an advanced university informatisation or information-based form, as well as being further enhanced as a digital campus through the combined usage of emerging information technologies, such as cloud computing, the Internet of things, mobile Internet, big data and 5G technology [9].

In the smart-city adoptive approach, a university campus is considered, in terms of management, as a city. By applying the smart city approach to a campus, it is hoped that the quality of life on a smart campus can be improved by the efficient usage of modern technology in managing energy, health, mobility and education [10].

In the organisational approach, a smart campus is seen as a reform of the entire educational process, including the methods and techniques, by utilising existing resources, so that the services provided are maximised and are of a high quality [11].

In this study, the definition of a smart campus is not based on any of the three approaches mentioned above. Instead, this research focuses on the operation of the smart system within every service that the campus provides. A smart campus is thus defined as one that can utilise existing resources to solve campus challenges and problems by providing smart services that improve the quality of life for all stakeholders. Smart services utilise technology that can automatically operate smart system processes.

A smart campus needs a framework to plan and successfully implement all smart campus elements. Based on the Cambridge Dictionary, a framework can be defined as a supporting structure on which something can be built or a system of rules and ideas used to plan or decide on something [12]. In relation to research, a framework is usually defined as a set of principles and guidelines for preparing the right components and people, and using the right steps and

stages to achieve results. Based on these two definitions, it can be concluded that the smart campus framework contains guidelines containing each of the appropriate stages that are needed for planning a smart campus.

DESIGN AND DEVELOPMENT.

The purpose of developing a smart campus framework is so that Indonesian HEIs can plan, prepare and implement the concept of a smart campus in their respective campuses according to their needs. The smart campus framework starts with the definition of a smart campus. Based on this definition, the direction of development of the smart campus can then be undertaken. The definition of a smart campus in terms of this research has been discussed in the literature review above. A smart campus is thus defined as one that can utilise existing resources to solve campus challenges and problems by providing smart services that improve the quality of life for all stakeholders.

Based on the definition of a smart campus, a smart campus model can be developed that will serve as a reference point for the expansion of a smart campus. Based on the smart campus model, a smart campus measurement model can be developed that refers to the smart campus model. The architecture for the smart campus framework can be derived from the Garuda Smart City Framework, which has been developed by the Smart City and Community Innovation Centre (SCCIC) [13].

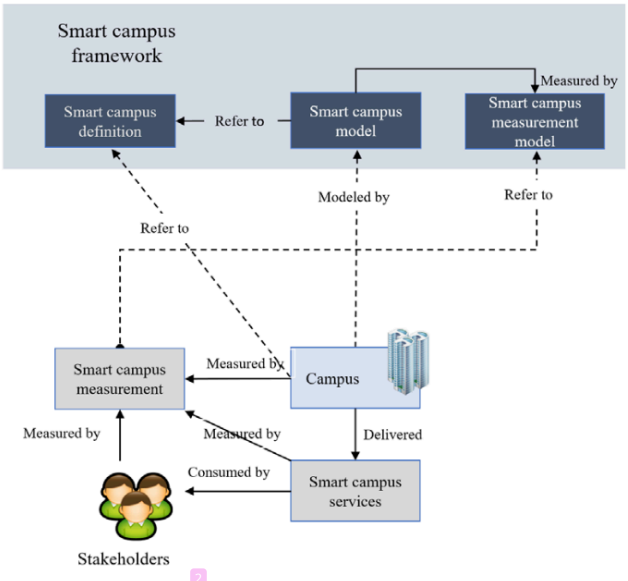

Figure 1: Smart campus framework.

Figure 1 illustrates the framework of such elements as a smart campus, consisting of a definition, a smart campus model and a measurement model. The direction of development will be adjusted according to whatever definition of smart campus is used. The smart campus model is thus developed in reference to the preferred smart campus definition. A real-life campus will then follow the smart campus model, so that smart campus measurements can be carried out and the present conditions of the campus can be determined, including the present level of smartness, so that steps can be taken to close any gap and reach the expected smart campus levels.

Smart Campus Model

A campus can be described as a collection of services. Service can be described as any action or benefit that one party can provide to another that is intangible and does not result in ownership of something.

A campus has three main services: *tridharma,* i.e. the three pillars of higher education. The three pillars consist of: first, carrying out the role of education and teaching; second, conducting research and innovation; third, applying the knowledge gained to contribute to society, management and living.

In addition to *tridharma* services, HEI campuses also provide management services and living services. Management services consist of managing human resources, governance service, stewardship service, and managing institutional co-operation. Living services consist of financial service and provide infrastructure to improve the quality of services for stakeholders (See Figure 2 for further details of the smart campus model).

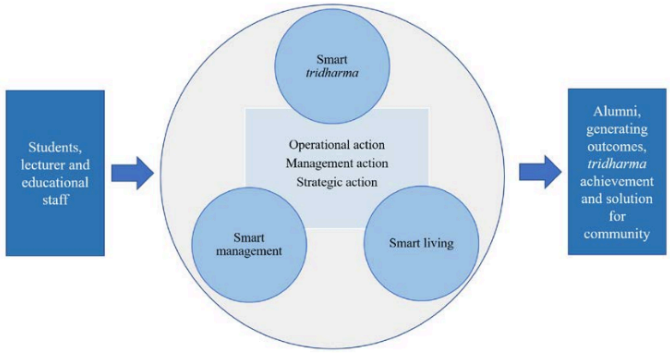

Figure 2: Smart campus model.

The difference between a traditional campus and a smart campus is the use of the smart system in operating *tridharma,* and the management and living services which also helps improve the quality of these services for stakeholders.

A smart system can solve problems rationally, similar to humans, but with a minimum of human intervention. It has the ability to reflect, explain and justify how problems are solved [6].

The smart system will be integrated into existing services, so they become smart services. The *tridharma* service consists of the educational, research and community services processes. The educational process is comprised of systems that support the education process and enable it to run well. Academics and e-learning are two examples of systems that support the educational process. By integrating these existing systems with a smart system, the academic system can become a smart academic system. An academic system can be considered smart if it has incorporated processes of perception, understanding, decision making and action, as well as a learning process. In this way, an academic system can be operated automatically with minimal human intervention, but with the ability to make decisions, learn from these decisions and become smarter.

Strategic actions are those that are carried out in order to impact the achievement of the HEI's vision, mission and goals. Management action is carried out to impact the increasing value of institutional accreditation, which involves a change process in moving from current campus conditions to the desired campus conditions, in accordance with the HEI's vision, mission and goals. Operational action is a daily, on-going process that ensures the HEI runs well.

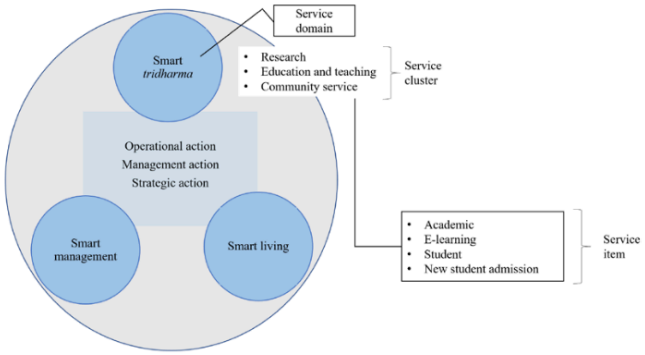

Figure 3: Interconnection between services in the smart campus model.

A service domain consists of one or more service clusters and each service cluster will consist of one or more service items. Service items will differentiate between a smart campus and a regular campus. Where the service is run with a smart system, then the life cycle of the smart system must be run accordingly. See Figure 3 for further details of the interconnections of services in the smart campus model.

Smart Campus Measurement Model

Measuring the level of smartness is very much dependent on the research area being undertaken. Measuring a smart city, for example, will require measuring how the city can maximise services for its citizens by implementing technological initiatives to optimise resources and integrating present urban systems in planning and serving preventive actions and monitoring security.

Measuring the level of smartness of a smart building is another example; in this case, the use of design solutions, technology and processes for developing comfortable and safe facilities for the occupants are considered, as well as the economic benefits for the owner [14].

Measuring the level of smartness of a smart campus will entail measuring the existent smart services provided by the HEI designed to improve service quality for stakeholders, where technology is being used to run smart system processes. Thus, the smart campus measurement will determine smartness from three perspectives based on the research by Imbar et al [6].

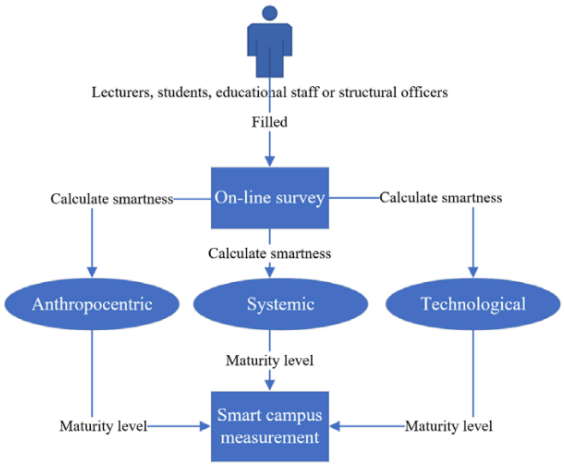

Figure 4: Smart campus measurement model.

Each stakeholder fills out an on-line questionnaire, so that the questionnaire results can be automatically processed, and the average of each measured smartness is calculated. The smartness results will then be mapped according to the maturity level, so that the overall level of the smart campus can be obtained.

Maturity Model

A maturity model (MM) is used to make process improvements beginning from the initial state up until the desired state. The basic concept of a MM is to guide decision makers in reaching their desired level of digital maturity according to specified dimensions.

A maturity model for the smart campus was created to assist HEI leaders in measuring the current level of campus smartness and providing direction for improvements. The maturity model is proving its usefulness as an instrument that can enable HEIs to better position themselves and find more effective solutions for change.

A capability maturity model (CMM) was used in this study as the best practice method in measuring the maturity level of the organisation based on the goals to be achieved [15]. Levels of campus smartness based on the anthropocentric, systemic and technological perspectives are depicted in Tables 1, Table 2 and Table 3.

Table 1: Maturity level based on the anthropocentric perspective [6].

Level	Description
1.	Expected quality of service (quality/cost/delivery - QCD) was not achieved.
2.	Standard service quality with only 1 service (QCD) achieved.
3.	Standard service quality with 2 services (QCD) was achieved.
4.	Service quality was achieved as expected (QCD).
5.	Quality of service was achieved with an exceptional experience of being treated as one of the core assets of the university.

This perspective measures services on the basis of the quality of services provided (quality), the costs incurred to obtain these services (cost) and the required speed needed to acquire these services (delivery). Level 5 is the highest level. At this level, the service quality of the system is above the expectations of users, and users are treated according to the noble values adopted by the university. Level 1 is the lowest level, where the service quality of the system, in terms of quality, cost and deliverability are not achieved.

Table 2: Maturity level based on the systemic perspective [6].

Level	Description
1.	The system only receives data as input.
2.	Impulsive (elementary level of smartness; at this level the system accepts input information and immediately acts without thinking).
3.	Reactive (intermediate level of smartness; at this level, the perception cycle goes directly to the action cycle, so that there is no planning or decision making). Intelligence reacts quickly to emergencies.
4.	Responsive (the level of smartness where all smart cycles are carried out automatically using commands/scripts that have been defined from the start).
5.	Initiative-taking/proactive (the level of smartness where all cycles are carried out automatically based on knowledge that has not been defined from the beginning and can predict actions that must be taken).

From a systemic perspective, level 5 is the highest level. The characteristics of the system at level 5 are that all processes of perception, understanding, decision making, action and learning run automatically, based on the knowledge possessed by the system; and the system can predict actions that could be taken by learning from past experiences.

Table 3: Maturity level based on a technological perspective.

Level	Description
1.	Humans perform the entire process of sensing, understanding, decision-making, action and learning.
2.	The sensing process is carried out by technology.
3.	The process of sensing and understanding is carried out by technology.
4.	The process of sensing, understanding, decision and action is carried out by technology.
5.	Technology handles the entire process of sensing, understanding, decision-making, action and learning.

From a technological perspective, level 5 as the highest level has characteristics that require technology to support all smart system's life cycle.

EVALUATION

At this stage, the smart campus framework is evaluated, using the method of expert judgment [16]. Ten experts were asked to provide opinions and input related to the smart campus framework which consists of the definition of smart campus, smart campus model and smart campus measurement model. All experts selected were university lecturers and experts in the field of smart campus technology and had more than ten years of experience in education.

Table 4: Expert employed for model evaluation.

No.	Name	Academic experience	Position
1.	YMD	21 years	Lecturer, former vice-rector
2.	FP	24 years	Lecturer, vice president Asia Pacific International College (APIC) *smart campus*, dean
3.	OCP	30 years	Lecturer, vice rector
4.	TMZ	15 years	Lecturer, dean
5.	W	12 years	Lecturer, vice rector
6.	SS	30 years	Professor, chairman of the university senate
7.	ACN	27 years	Lecturer, former structural officer

8.	JK	23 years	Lecturer, department head
9.	BRS	20 years	Lecturer, structural officer
10.	SF	13 years	Lecturer, researcher at SCCIC

The evaluation was carried out using Google Forms which each expert used to provide input regarding the smart campus framework. Qualitative feedback was provided in the form of opinions, comments or recommended revisions. Following are the questions asked and the responses:

1. Was the definition of smart campus made in reference to the smart campus model? All respondents gave input that the definition of a smart campus was acceptable to them.
2. Can the developed campus model describe the conditions of Indonesian HEIs? All of the experts said that the campus model described the condition of Indonesian HEIs. However, there was input from ACN suggesting that the finance process be transferred to management services which includes services that regulate HEI operations.
3. Is the smart campus measurement model sufficient to measure the smart campus from the anthropocentric, systematic and technological perspectives? All experts said that the measurement model was more than sufficient. One expert added that previously the measurement of smartness has been taken from system automation, but in this model, it has been measured from the quality of services provided by the system and the technology it uses, so it is able to measure the smart campus in detail.
4. Are the maturity levels of the anthropocentric, systematic and technological perspectives acceptable? All experts said that the maturity level can well represent the level of smartness of each perspective of the campus being measured.

Based on the qualitative evaluation, it can be concluded that the smart campus framework can be used as a reference for HEIs to design and implement smart campuses and to measure the current level of smartness of their individual HEI.

In regard to the smart campus measurement model, the authors of this article have used it by measuring 36 HEIs in Indonesia and as a result, the tested model can be used to measure campus smartness from an anthropocentric, systemic and technological perspective [6].

CONCLUSIONS

In this study, in order to help Indonesian HEIs adapt to the industrial revolution 4.0, a smart campus framework has been developed that can be used to plan and implement smart campuses. As part of the DSRM, a literature review was conducted. It was found that existing definitions of smart campuses do not reflect the aspects that were of particular importance in this study. As a result, the researchers have come up with their own definition and based on that designed a smart campus framework which consists of a smart campus model and a smart campus measurement model.

A smart campus model consists of three main services: *tridharma,* management and living. Each service consists of a collection of processes, and each process further consists of one or more support systems to ensure that the process runs properly.

A smart campus measurement model consists of anthropocentric, systemic and technological measurements that measure campus smartness based on the quality of services provided. It also measures the smart system processes already in operation in each service, as well as the technology on which the system is built.

To evaluate the smart campus framework that was developed, experts were asked to evaluate the framework. These experts stated that the smart campus framework could be used as a reference for planning, implementing and measuring smart campuses. The research, however, does have its limitations in that only expert judgment was used to evaluate the framework, and other stakeholders were not included.

In the future, further research will be undertaken to develop a smart campus model that can be implemented by HEIs worldwide, with the goal being to enable the smart campus framework to be used by HEIs globally as a frame of reference for planning, implementing and measuring smart campuses.

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