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Development of an instrument to measure smart campus levels in Indonesian institutions of higher education

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ABSTRACT: In this article, the authors present a study under which an instrument for measuring smart campus levels has been developed, using design research to create a smart campus model and a smart campus measurement matrix. The created model was evaluated by experts in smart campus development. The measuring instrument was used to determine the current smart campus level in thirty-six (36) institutions of higher education in Indonesia based on anthropocentric, systemic and technological perspectives. Data were collected using a questionnaire filled out by members of the academic community who were selected based on their respective educational roles. The developed measuring tool has been evaluated and deemed useful for leaders in higher education to determine the level of smart campus in regard to their respective educational institution. Also, the findings indicate that there is a significant need to improve and implement smart information systems and Industrial Revolution 4.0 technologies in higher education institutions in Indonesia.

Keywords: Smart campus, smart campus level, higher education, measuring tool

INTRODUCTION

The world is entering the Fourth Industrial Revolution (4IR), which is the result of the increased usage of information technology, such as the Internet of Things (IoT), big data and artificial intelligence (AI), which have become an integral part of societal life, including universities. The use of IoT, AI, smart devices and virtual reality has created unprecedented, highly potential opportunities in higher education to improve the quality of educational services for stakeholders [1].

Many universities around the world have already developed applications that make use of smart technology to provide improved educational services. Machine learning, cloud computing, IoT, big data, and radio-frequency identification (RFID) sensors will be the primary technologies used to build the smart campus [2]. Utilising the smart campus idea can enhance the quality of campus policy, increase instructor and student interest in teaching and learning, and enhance teacher-student relationships by enriching the campus life for both teachers and students. A smart campus should be able to implement modern technologies to provide good smart services. Good smart service has several features including secure, sustain, integrated, scalable, reliable, responsive and highly efficient [3].

At present, smart campuses have already been implemented at many universities worldwide, such as: the University of Rome, University of Johannesburg, Stanford University, Duke University, New York University, University of Sharjah, Shandong Normal University [4].

Indonesia has approximately 4,600 universities with a total of nine million students. The challenge faced by these institutions of higher education today is to adapt teaching and learning to 4IR in order to boost their competitive edge and attract potential students in order to survive on the educational market.

Indonesian universities are required to carry out *tridharma* or the three pillars of higher education. The three pillars consist of: firstly, to carry out the role of theoretical education and teachings; secondly, to conduct research and innovation; and thirdly, to apply the knowledge obtained to improve societal life. A smart campus aims to optimise these three teachings by integrating the three pillars with management services and living services.

The Times Higher Education (THE) index generates universities rankings based on well-established factors, such as research productivity, teaching and impact [5]. With the increased implementation of smart campus among educational institutions, it has become necessary to develop a similar instrument that can measure the *smart* level attained by a particular campus. Presently, there are very few studies that have resulted in developing such a tool for measuring smart campus attributes. Thus, there still is a need to design a proper measurement instrument to assess smart campus levels.

In view of that, the study outlined in this article is innovative as the focus of it was the development of a tool for measuring smart campus levels: a tool that would be both integrated and easily applied to determine levels of smart campus at universities, including comparisons.

The measuring tool developed in this study is able to estimate smart campus levels based on the university model. The university model is the basis of the smart campus model because the various educational services it provides must also be incorporated in the smart campus model.

Thus, this study is a contribution to the field of higher education in the social sciences by following these main objectives:

- Develop a comprehensive smart campus model that integrates the *tridharma* of higher education with the domains of management and living.
- Integrate levels of smart campus that are used in measuring tools, based on the perspective of cyber-physical systems (CPSs).

Kalluri et al carried out a study to define the distinguishing dimensions and characteristics of smart CPSs. They argue that system smartness can be evaluated based two categories: principle and perspective. In this study, the smartness level of a smart campus has been measured using a broad perspective, which is divided into three categories: anthropocentric, systemic and technological [6].

1. Anthropocentric perspective

This perspective emphasises the human factor as the primary driver in the *smart* concept. Subsequently, the role of technological infrastructure is important in a smart campus and is measured by focusing on the quality of life of its citizens [6].

2. Systemic perspective

This perspective characterises *smart* ideas as interconnected components that interact with one another in a system. However, the relevance of technology and people in this perspective cannot be overstated. A campus can also be seen as a system with many sub-systems that are analysed and transformed into services [6].

3. Technological perspective

Technology, in this perspective, is a key driver for increased smart levels. This study focuses on the interconnectivity of technology, such as big data, AI and semantic interoperability. Subsequently, smart campuses leverage communication and sensor capabilities to optimise campus operations, which are embedded in the infrastructure. In the technological perspective, the measurement of smart levels is based on the use of IoT technology and intelligent cyber-physical systems, which is a collaborative system that supports systemic smartness [6][7].

DEFINITIONS

This study defines *smart* as the ability to act and immediately act on a problem until it is properly resolved. The term *campus* is used in this study because it has a broader meaning than *university* and also includes the physical facilities that are available. So according to this definition, *a smart campus* is a campus that can utilise its resources to solve any campus challenges by providing smart services to improve the quality of life. Smart services utilise available technologies to run smart system processes automatically with a minimum intervention of humans.

RESEARCH METHODOLOGY

The methodology used in this study is design research (DR), which emphasises the design and construction of applicable artefacts, such as systems, constructs, models and methods [8].

The first stage is identifying the goals that are expected to be achieved or the focus of the study and the main research problems, questions, hypotheses, as well as relevant disciplines and fields to review, and areas where contributions are expected to be useful, which is explained in the Introduction of this article.

In the second stage, a better understanding of the existing model is obtained by investigating the elements that influence the developed model [8]. This is done by conducting a literature review, and developing a smart campus model and measuring tools that can estimate the level of smart campus.

In the third stage, campus smartness is assessed based on the measurement of tools. In this study, 36 campuses in Indonesia were measured using the developed tool.

In the fourth stage, the model is evaluated by an expert in the field of higher education [9]; the created measuring instrument is also evaluated to see if it can correctly estimate the level of smart campus.

RESEARCH RESULT

In this section, is demonstrated the development of the smart campus model and the measuring tools used to measure smart campus levels, which is the second phase of the DR methodology. The model's development was accomplished by conducting a literature review and interviewing several experts with experience as university leaders, so that the best smart campus model could be developed.

Development of a Smart System Model

A model is a conceptual object that consists of constructs and the resulting relationships between these constructs in order to describe and represent a subset of real-world phenomena.

A smart system is an intelligent system that can be fully utilised by users and can rationally solve problems, similar to humans, and having the ability to reflect, explain and justify how problems are solved [10].

Figure 1 explains the process of a smart system based on the level of automation, which consists of perception, planning, decision, action and learning.

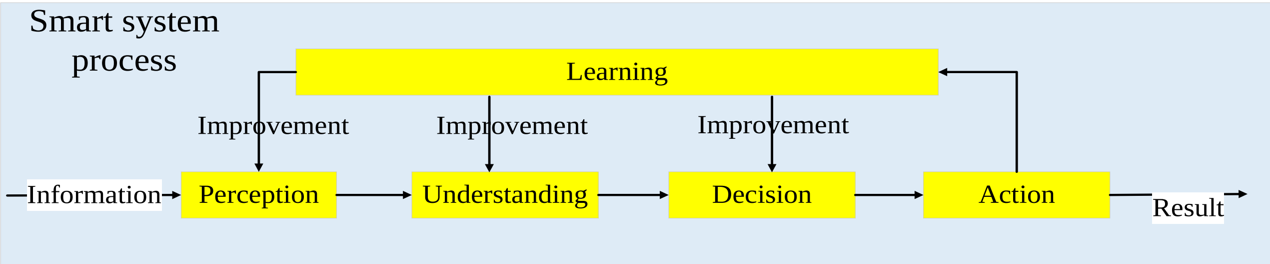

Figure 1: Smart system processes.

Table 1 provides the definition of each smart system process, also included in an earlier publication by the authors [11].

Table 1: Definitions of the characteristics of a smart system [11].

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.*
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.*

Development of a Smart Campus Model

Based on its legal framework (Law No. 22, dated 1961), the Indonesian government has divided higher education into several categories: universities, high schools, institutes, academies and polytechnic schools. Traditional universities in Indonesia use the standards of the National Accreditation Body for Higher Education, or *Badan Akreditasi Nasional-Perguruan Tinggi* (BAN-PT), to determine the feasibility of higher educational study. The criteria of these higher education standards guarantee the quality of external study programmes and higher education in both academic and non-academic fields.

The first benefit of accreditation for campuses is proof of the quality of education they provide. Accreditation has several criteria. If a university obtains a high accreditation level, it is proof that the campus is of high quality. Thus, the created smart campus model needs to integrate the accreditation criteria of the national higher educational standards. It is hoped that the results of this study will enable universities to use this smart campus model to improve the quality of their campuses, increase the value of accreditation, and help to achieve the university's vision, mission and goals.

A campus can be described as a collection of systems. The input for a campus system is students, lecturers and educational staff. The output from a campus system is alumni, and the outcomes are the achievements of *tridharma* and other solutions for the community. These outcomes often reflect interest in studying at a particular campus.

A campus system provides the three *tridharma* principles (learning, research and community service) [12], along with management services (guidance, governance, HR and co-operation), and living services (finance and infrastructure) for all campus stakeholders.

A campus system consisting of *tridharma*, management and living services needs to be integrated with a smart system, so that the system itself becomes smart. Thus, the circle that describes the *tridharma*, management and living systems has to be embedded in a smart system entitled smart *tridharma*, smart management and smart living.

Strategic action is a guideline for the process of change involved in moving from the current campus situation to the desired campus, in keeping with the university's vision, mission and goals. Supportive action from management is needed to realise the objectives of strategic action. The success of these strategic and management actions depends on the achievement of operational objectives. Figure 2 illustrates the smart campus model.

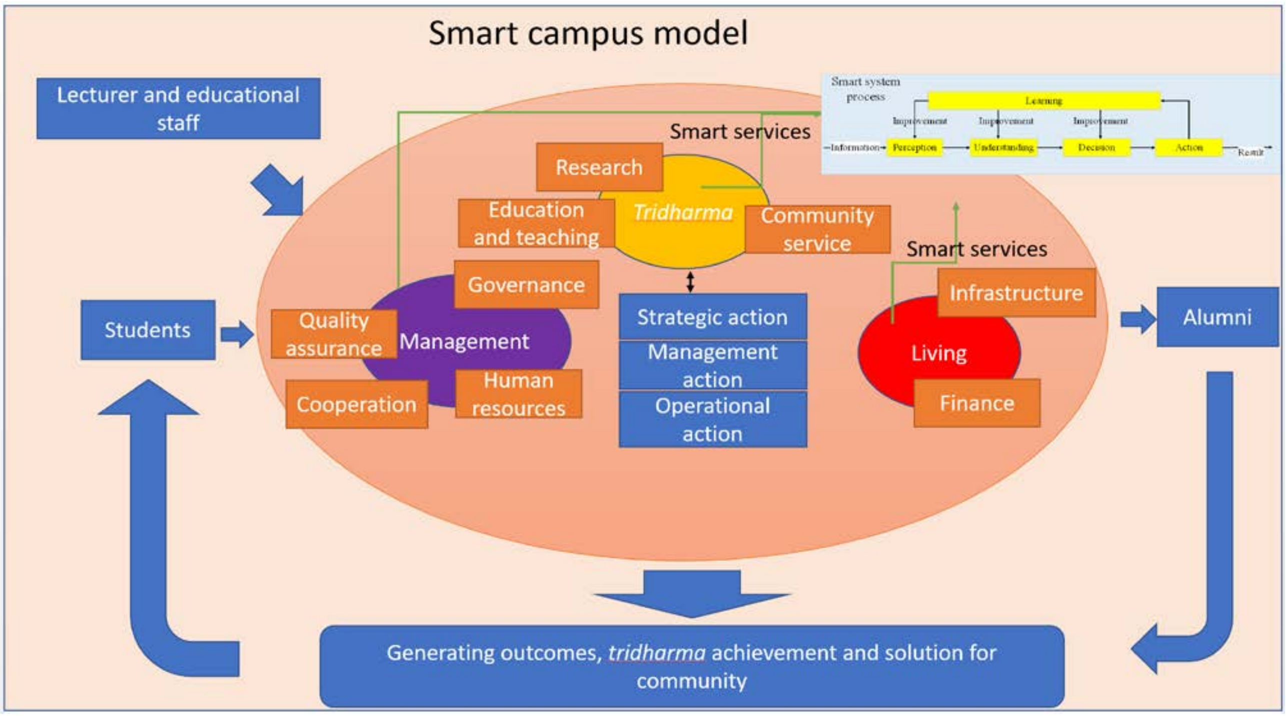

Figure 2: Smart campus model.

Development of a Smart Campus Measurement Matrix

The smart campus measurement matrix can be derived from the smart campus model. The matrix can be seen in Table 2 in the Appendix at the end of the article.

The smart campus measurement matrix identifies what systems must exist, so that the campus can be assessed as a smart campus. Each box in the matrix contains a smart system that must exist for each criterion of the smart *tridharma*, smart management and smart living. For example, it is necessary to identify what systems must exist in the learning column of the smart *tridharma* column and the operational action row. From the research results, the following systems must exist on a smart campus: academic, on-line learning management, new student admission, and student and alumni systems.

To demonstrate the developed instrument that can measure the level of smart campus, the matrix model of smart campus measurement is detailed in the third stage of the DR methodology in the form of a questionnaire based in each box of the matrix; an evaluation plan for the developed measuring instrument has also been prepared.

Questionnaire to Measure Smart Campus Levels

The questionnaire designed to determine the smart level of the system owned by each campus included questions for leaders of higher education institutions. The questions were dichotomous with *yes* or *no* answers, and were used to determine whether the system used could solve campus problems effectively and efficiently. Evidence was collected in the form of application images or manuals to prove that the features of the system were in accordance with the answers that were given. Open-ended questions were used to find out how the respondents solved the problems that occurred according to the respondent's position.

In regard to the systemic and the technological perspective, questions were asked about whether the campus had the system and the technology necessary to run the system. As far as the anthropocentric perspective is concerned, users were asked about the quality of services provided by the system. These questions were posed to each leader, staff member and user of the system.

Sample question: does the university have an academic system? If the answer was *yes*, then the next question asked measured the *smart* level of the academic system. Sample question: can the academic system help users in making decisions?

Based on the questions, interviewers asked for evidence to prove that such a system does exist. After that, evidence checks were performed by interviewing random campus administrators. After the data was collected, the smartness level was calculated with all values from each system being averaged, so that the level of smart *tridharma*, smart management and smart living could be obtained based on the three perspectives.

The questionnaires were filled out on-line using each academic community on campus who filled out questionnaires independently, according to their respective roles as either lecturers, students, educational staff or structural officials.

A Web site application was used to make it easier for the researchers to calculate the smartness level in each question, ensuring that all calculations were carried out automatically by the system. The researchers' task was to check that the evidence attached was in accordance with the answers given by respondents. The total number of respondents per campus can be seen in Table 6.

Validity and reliability tests were performed using IBM SPSS Statistics 25 software. The validity test was used to determine whether each item in the instrument was valid or not, which can be determined by correlating the item scores and the total score. To find the correlation value, the Pearson product-moment correlation coefficient was used to test validity in this study [13].

A reliability test is used in research to measure whether the measurement of a test remains consistent after repeated tests on the same subject and under the same conditions. This study used Cronbach's alpha, which is often used to measure reliability in the social and organisational sciences [14]. All questions in the questionnaire were tested: all were found to be valid and reliable.

Maturity Model

In this study, a maturity level is described in relation to three perspectives: anthropocentric, systemic and technological. Maturity levels for each of the three perspectives can be seen in Table 3, Table 4 and Table 5.

The anthropocentric 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).

Table 3: Maturity level from the anthropocentric perspective.

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.

Table 4: Maturity level from the systemic perspective.

Level	Description
1	Not smart
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).

Table 5: Maturity level from the technological perspective [15].

Level	Description
1	Not smart
2	*Reactive (adapts to a changing environment)* [15]
3	*Adaptive (has the long-term ability to change behaviour; for example, learning from historical data or usage patterns)* [15]
4	*Autonomous (acts independently, without direct intervention from human agents)* [15]
5	Collaborative (ability to support and instantly adapt to all environments) [15].

Smart Campus Measurement Result

The study was carried out in both public and private Indonesian universities with the use of questionnaires. Data collection took place between September 2021 and February 2022. The questionnaire was composed of both closed and open-ended questions, and was validated by three experts (a professor with experience as Director of the Smart City and Community Innovation Center (SCCIC) in Indonesia, a professor with experience as a university rector, and an associate professor from Bandung Institute of Technology).

An analysis of each question used in the questionnaire was carried out and mapped into the appropriate *smart* level - in terms of the anthropocentric, systemic and technological perspectives. The analysis was done by checking the answers to each question with the evidence uploaded and analysed at each level of smartness [16]. After that, each system in smart *tridharma* was averaged so that the level of smartness of smart *tridharma* could be determined. The same procedure was followed for smart management and smart living. After analysing the data, the verification of questionnaire data was carried out by conducting interviews with campus administrators and visiting several campuses (samplings).

After ranking the campuses based on the three perspectives, the smart campus level was generated with an average value for each perspective; the weight was 20% for the anthropocentric perspective, 40% for systemic and 40% for technological. A bigger percentage was given to the systemic and technological perspectives because the goal of a smart campus can only be realised if the systemic and technology perspectives are smart. Service quality is the result when the smartness of the system and the technology is high. The results of the 36 campuses measured can be seen in Table 6. Campus names have been disguised, so that data confidentiality could be maintained. However, it is still possible to determine the city and whether the university is private or public.

Table 6: Campus smart level measurement results.

No	Campus name	Total	Anthropocentric	Systemic	Technological	Smartness
1	Private A University Jakarta	70	2.92	1.89	1.78	2.05
2	Private B University Jakarta	230	3.73	2.81	2.91	3.03
3	Private C University Jakarta	2404	4.11	3.41	3.42	3.55
4	Private D University Riau	605	3.24	1.92	1.80	2.14
5	Private E University Bandung	350	3.67	3.08	2.96	3.15
6	Public A University Bandung	1665	3.44	2.89	2.89	3.00
7	Private F University Jakarta	227	4.49	2.70	2.56	3.00
8	Public B Institute Surabaya	1237	3.39	3.28	3.17	3.26
9	Private G University Surabaya	796	4.08	3.25	3.32	3.44
10	Private H Polytechnic Riau	102	4.00	2.97	2.97	3.18
11	Private I University Medan	779	3.82	2.30	2.73	2.78
12	Private J Institute Garut	176	3.59	1.97	2.12	2.35
13	Public C University Bandung	1729	3.35	2.36	2.39	2.57
14	Private K University Jakarta	259	3.33	2.19	2.30	2.46
15	Private L University Bandung	549	3.25	1.98	2.22	2.33
16	Public D University Padang	728	2.43	2.09	2.00	2.12
17	Private M University Medan	559	3.18	1.80	1.67	2.02
18	Public E Institute Bogor	1122	3.42	2.55	2.47	2.69
19	Private N University Jogjakarta	519	3.20	1.96	1.83	2.16
20	Public F University Medan	1672	2.94	2.37	2.39	2.49
21	Public G Polytechnic Semarang	75	3.23	1.55	1.86	2.01
22	Public H Institute Bandung	247	3.47	2.06	2.10	2.36
23	Public I University Jember	1761	3.05	2.23	2.12	2.35
24	Private O University Jogjakarta	402	3.70	3.00	3.04	3.16
25	Private P Institute Jakarta	115	3.08	2.02	2.09	2.26
26	Private Q University Jakarta	828	2.77	2.29	2.02	2.28
27	Public J University Semarang	1689	3.13	2.42	2.46	2.58
28	Private R University Bandung	168	3.01	1.44	1.42	1.75
29	Private S Institute Bogor	396	3.43	2.39	2.52	2.65
30	Private T University Bandung	957	4.11	3.31	3.43	3.52
31	Private U University Jogjakarta	1458	4.10	3.28	2.97	3.32
32	Private V University Tegal	73	2.92	1.30	1.18	1.58
33	Private W Polytechnic Salatiga	35	2.95	1.45	1.51	1.77
34	Private X Institute Majalengka	123	2.69	1.27	1.25	1.55
35	Public K University Ambon	756	2.71	1.79	1.64	1.91
36	Private Y Institute Indramayu	32	2.46	1.46	1.31	1.60

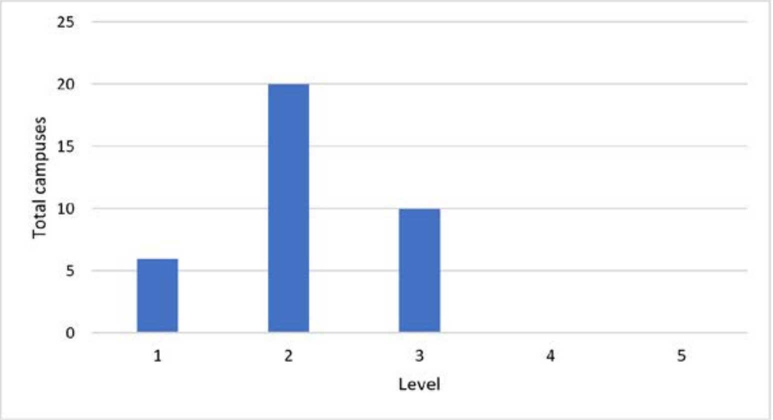

Figure 3: Total campuses per smart levels.

Out of the 36 campuses measured, there were six campuses at level 1, 20 campuses at level 2 and 10 campuses at level 3. No campuses were at levels 4 and 5. The measurement results for all 36 campuses are shown in Figure 3. There is still a significant need for implementing smart information systems on higher education institutions' campuses. Technology used in Industrial Revolution 4.0 also needs to be implemented, so that campuses in Indonesia can compete with campuses abroad.

EVALUATION

In this section, the evaluation results of the model smart campus and model smart campus measurement matrix are explained. The evaluation of the results of measuring the levels of smart campus that have been carried out is also explained.

Evaluation Model

The smart campus and smart campus measurement matrix models were evaluated using the expert judgment method [9]. Six experts were asked to give their opinion and input regarding the campus model and matrix assessment smart campus model. All the experts were lecturers and experts in the field of smart campuses and have more than ten years of experience in the field of education (Table 7).

Table 7: Experts for model evaluation.

No	Name	Academic Experience	Position
1	YMD	21 years	Lecturer, former Vice-Rector
2	FP	24 years	Lecturer, Vice President APIC Smart Campus, Dean from 2011
3	OCP	30 years	Lecturer, Vice-Rector from 2016
4	TMZ	15 years	Lecturer, Dean
5	W	12 years	Lecturer, Vice-Rector
6	SS	30 years	Professor, Chairman of the University Senate

A Google form with the suggested smart campus model and smart campus measurement matrix model was sent to each of the above experts and their qualitative feedback was requested in the form of opinions, comments or recommended revisions.

Based on the qualitative evaluation, the majority of the participants emphasised various favourable elements of the model. Regarding the smart campus measurement matrix model, all of the experts agreed that the matrix was detailed enough in smart campus measurements and could be used to measure smart campus levels.

Thus, based on the overall expert evaluation, it can be concluded that the smart campus model accurately represents the current campus condition, and the measurement smart campus matrix model is complete in describing the smart campus.

Evaluation of Campus Smart Level Measurement Results

To test whether the measuring tool developed in this study is able to estimate smart campus levels based on the campus model, the results of this study were shared with all the campuses and feedback was requested from each campus in the form of a survey questionnaire. Following are the questions in the questionnaire:

- Survey question 1 (SQ1): Are the results of this study helpful in learning about the current conditions of your campus ? (yes or no).
- Survey question 2 (SQ2): Are the results of the campus smartness level in accordance with the current conditions of your campus? (yes or no).
- Survey question 3 (SQ3): In your opinion, was filling out the questionnaire easy to do? (scale 1 to 5).

Of the 36 campuses that participated, 25 campuses provided feedback by filling out the questionnaire (70%).

Based on SQ1, 100% answered that this study was helpful in learning about the current conditions of their campus.

Based on SQ2, 100% answered that the results of the campus smartness level were in accordance with the current situation.

Based on SQ3, results from respondents related to the level of ease of filling out the questionnaire indicate that level 3 has the highest number of respondents (14) followed by level 4 (10). All participants stated that filling out the questionnaire was done at a good level of ease (mean = 3.48). These statistics can be seen more clearly in Figure 4.

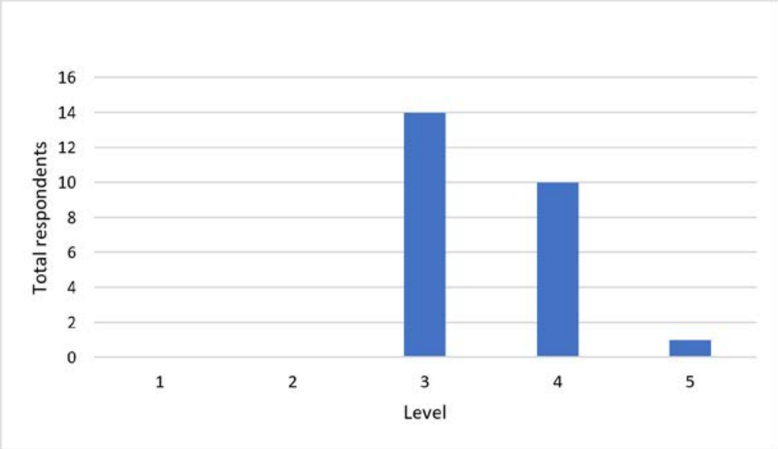

Figure 4: Level of ease of filling out the questionnaire.

CONCLUSIONS

This study was focused on the development of a measuring instrument to measure smart campus levels, and subsequent measurements of campus smartness. A campus model and smart campus measurement matrix were developed, and serve as the basis for an instrument for measuring smart campus levels. The instrument was tested on 36 campuses in Indonesia. The results of the evaluation of the instrument were also tested; all participants agreed the measuring instrument could estimate the smart level of each campus.

The study has some limitations, such as the evaluation of the model using expert judgments, and the fact that the measurements were made based on a small sampling of only 36 campuses in Indonesia, which cannot describe the smart level of all campuses throughout Indonesia, numbering around 4,600 campuses. In future, the researchers aim to encompass an increased number of campuses in Indonesia in their study. Improvements will also be made in terms of data collection, so that the data can be filled out more efficiently, and so that strategies can be easily determined that will help increase smart campus levels throughout Indonesia.

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BIOGRAPHIES

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APPENDIX

Table 2: Smart campus measurement matrix.

Action	Smart *tridharma*			Smart management				Smart living	
	Learning	Research	Community service (CS)	Quality assurance (QA)	Governance	HR	Co-operation	Infrastructure	Finance
Operational	Academic system, on-line learning management system, new student admission system, student system, alumni system	Research system	CS system	Internal quality assurance system	E-office system	HR system	Co-operation system	Library system, asset and facility system, parking, payment, sports facilities, classrooms, laboratories	Finance system
Management	The system can help monitor and evaluate the implementation of academic activities	The system can help monitor and evaluate the implementation of research and CS activities		The system ensures that the integrity and quality of the institution is implemented consistently, effectively and efficiently	Operational and functional management systems are implemented consistently, effectively and efficiently	Leadership can create a conducive work atmosphere	The system can help determine policies, co-ordinate, monitor and evaluate the implementation of co-operative activities	The system can help determine policies, co-ordinate, monitor and evaluate the condition of the infrastructure	The system can help determine policies, co-ordinate, monitor and evaluate financial conditions
Strategic	Strategic decision-making system related to academic activities	Strategic decision-making system related to research and CS activities		Strategic decision-making system related to QA	Communication system between stakeholders and university leaders	A strategic decision-making system that involves all stakeholders	Strategic decision-making system related to co-operation activities	Strategic decision-making system related to infrastructure	Strategic decision-making system related to finance