Internet of Things and Big Data for a Sustainable Smart University

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This study aims to analyze existing research regarding sustainable smart universities via internet of things and big data. Document analysis was conducted using 1,737 research documents relevant to the domain of smart university, smart campus, sustainable university, internet of things, and big data from international databases including Scopus, IEEE, Web of Science and ERIC. The matrix analysis method was used to identify the relevant publications produced 158 items and six cluster themes and proposed conceptual frameworks illustrating elements necessary for a sustainable smart university via internet of things and big data. The illustrated networks demonstrated that a smart campus involves a technology of internet of things and big data. The targets for a smart campus/smart university includes resource management, security management and the provision of a digital service to students and staff. By linking a smart campus with sustainability, the network models show that some research focus on applying smart technologies to improve the sustainability of a campus by concentrating on natural resource management and environmental care.

Keywords: smart university, sustainable university, IoT, big data, matrix analysis for network model

INTRODUCTION

The rapid technological advancement of the 21st century significantly changes lifestyles and the ways people interact as digital technologies become more prominent in their daily lives. To improve the efficiency of education and the management of resources, the use of technology has been suggested and supported. Thus, universities have gradually changed their visions to include the advancement of technologies in their endeavor for reforms which change the way educators provide instruction and teach students. In Thailand, the government declared a master plan for 2022-2027, known as Digital Thailand 2020, to apply information technologies to improve education, the economy, and the daily life of Thai people (Singsungnoen et al., 2021). However, due to the Covid-19 pandemic and lockdown, the change towards the use of information technology in the field of education, such as the creation of online classrooms, has become more urgent (Pete & Soko, 2020).

With the acceptance of technology advancement in the education field (Duc et al., 2020), several studies, focusing on the concept of a smart university and/or smart campus, have been conducted (Pornphol & Tongkeo, 2018; D. Rico-Bautista et al., 2020). A smart university/campus applies smart technologies to improve services, decision making, and campus sustainability (Maciá Pérez et al., 2021; Min-Allah & Alrashed, 2020). The use of advanced network infrastructure and internet-connected devices can provide supportive and engaging experiences for students and staff. It also allows universities to use insight data to improve security and optimize resource management. Information and digital technology, such as Internet of Things (IoT), big data, and artificial intelligence, is used to visualize data, inform decision making, automate processes, and support the activity of students and staff (Ceccarini et al., 2021). Generally, a university campus composes of many buildings and facilities. Such areas require the use of energy and human resource to manage and maintain them effectively (D. W. Rico-Bautista, 2019). Furthermore, the areas are often used to highlight innovative adaptations to demonstrate the latest technology being studied and researched (Moura et al., 2021). The smart campus is therefore considered to be the small-scaled prototype towards the appropriate development of a smart city (Fortes et al., 2021).

However, another concept that emerged during technological reforms is that of a sustainable university (Mohamed Hashim et al., 2022). Sustainability plays an important role in maintaining the balance in technological development regarding the economy, the environment, and society factors. This is achieved through promoting the sustainability of natural resources, economic development, and a better quality of life for the benefit of future generations (Leo et al., 2017; Serban et al., 2020). Sustainability is not only linked to environmental and economic effects, but is also involved in social standing such as gender equity, human rights, and social standing discrimination (Smaniotto et al., 2020).

To develop both smart and sustainable university campuses, a balance between technology integration and sustainability is required. As a prototypical approach towards the development of a smart city (Zaballos et al., 2020), the use of information communication technology (ICT), including the use of IoT (Anagnostopoulos et al., 2021) and big data (Maciá Pérez et al., 2021) in a smart campus, should be studied in combination with the effects this has on the quality of life (Fortes et al., 2019; Min-Allah & Alrashed, 2020; Villegas-Ch et al., 2019) and sustainability (Přibyl et al., 2018). In this work, we aim to determine to study in the existing research based on two main concepts, “smart campus” and “sustainable university.” We then examine keywords that are related to both concepts and how they are related in the existing work.

LITERATURE REVIEW

Internet of Things

Internet of Things (IoT) uses an integration of sensors, computer devices, mechanical machines, and digital machines to transfer data and execute actions over the internet (Swamy & Kota, 2020). IoT is used in many domains including healthcare, industry, and home use (Meneghello et al., 2019). With the advancement in internet speed and mobile/wireless technology, IoT applications have been increasingly applied and developed (Tseng et al., 2021).

An IoT ecosystem consists of web-enabled smart devices including processors, sensors, and communication hardware. The devices are responsible to collect and send data they acquire from their environments or to act according to the obtained data. The data are shared among devices by connecting to an IoT gateway where collected data is sent to the cloud to be analyzed or is analyzed locally. Some devices are programmed to act based on the information sent from another device, without human intervention. Data from sensors in IoT services can be large in terms of volume and velocity. In recent research, data collected in IoT platforms have been used with machine learning techniques to generate a decision-making model for automated action execution (Mkrttchian et al., 2021). Smart applications/services are mostly implemented based on IoT technology (Anagnostopoulos et al., 2021).

Big Data

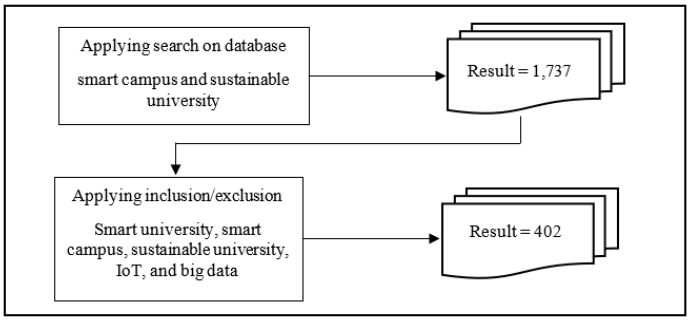
Big data is a collection of complex and oversized data that cannot be managed and processed by traditional relational databases. Characteristics of big data include high volume, high velocity, and high

variety. The data can be structured data (from an IoT source) or unstructured data (from social media) generated in real time at a large scale. Big data are often used to provide insight for analytic studies or to generate prediction models (Pratsri & Nilsook, 2020). The use of big data analytics can help reveal patterns of human behavior (Favaretto et al., 2020) and data trends for prediction purposes. In terms of a smart campus, data detected from the campus environment using IoT can be used to analyze student and staff behavior which can then be used to design a management of natural resources (Balbin et al., 2020), prevent undesirable incidents (Balazka & Rodighiero, 2020), and develop a smart service towards the smart campus (Villegas-Ch et al., 2019).

MATERIALS AND METHODS

Data for metric analysis was from four source databases of journal articles and conference proceedings including Scopus, IEEE, Web of Science, and ERIC. Since some articles may appear in several databases, duplicated articles were removed. Data collection (Figure 1) involved two steps, namely searching and selecting.

FIGURE 1
DATA COLLECTION PROCESSES



All the relevant articles identified through the data collection step, were analyzed by applying a list of keywords and their combinations (Table 1). The search limit was set to articles published in 2013 to 2021. This step produced an output of 1,737 articles from three sources and were related to particular keywords such as smart university, smart campus, sustainable university, IoT, and big data.

TABLE 1
CRITERIA USED TO SEARCH FOR RELEVANT PUBLICATIONS

Source	Input Variables
• Scopus • IEEE • Web of Science • ERIC	"smart university" OR "smart campus" OR "sustainable university" AND "internet of thing" OR "big data"
Limits	Year 2013 - 2022

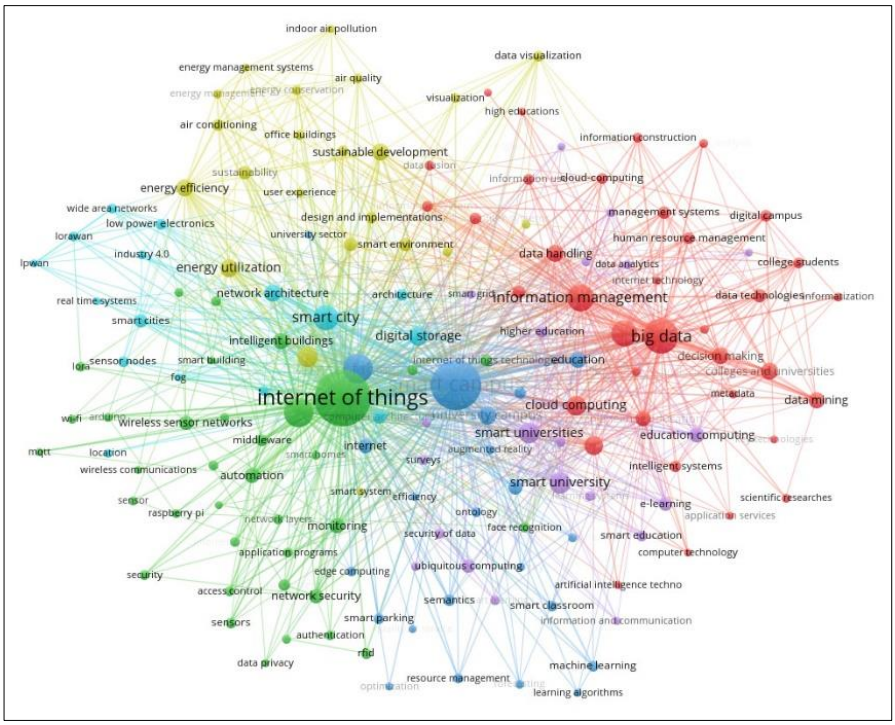
The second stage involved reviewing and selecting suitable articles by evaluating the content of the abstracts. This allowed the exclusion of publications that were not appropriate to the scope based on the designated topics. After filtering, there were 402 articles remaining used for the data analysis matrix.

RESULTS AND VISUALIZATION

The analysis was performed using the VOSViewer software which produces nodes and edges. The nodes correspond to the keywords in a network, and the edges represent the connecting lines for each node within a network. The nodes and edges were derived from the abstracts and keywords. Then, the nodes and edges were used to visualize the relationship between topics in VOSViewer. The network model for smart university, smart campus, sustainable university, IoT, and big data is displayed in Figure 2.

A network Model of Sustainable Smart University via IoT and Big Data

FIGURE 2
MAPPING RELATIONSHIPS IN A NETWORK MODEL FOR SMART UNIVERSITY, SMART CAMPUS, SUSTAINABLE UNIVERSITY, IOT, AND BIG DATA



The analysis showed that all the keywords used to create the network are associated with each other in some way. Some keywords, such as IoT, big data, information management, and smart city, were more frequent as indicated by the larger nodes within the network model. We then analyzed and acquired the network based on focused topics as follows.

FIGURE 3
A NETWORK MODEL OF TOPICS IDENTIFED USING SMART CAMPUS AS A KEYWORD

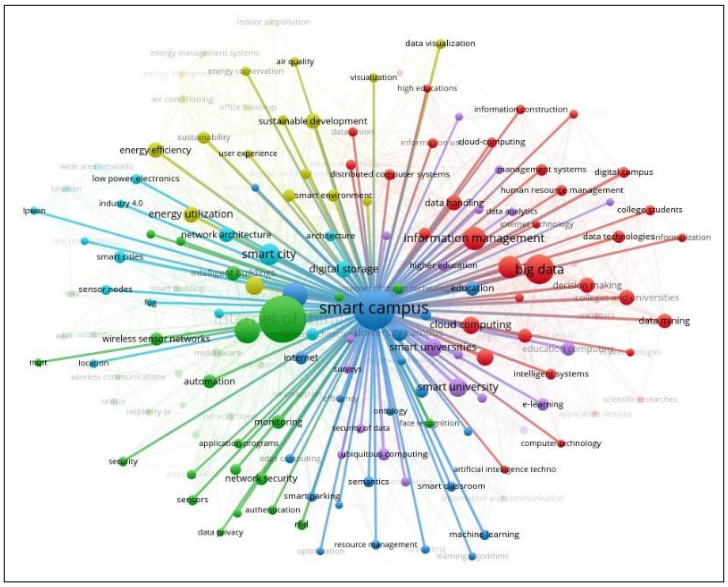


FIGURE 4
A NETWORK MODEL OF TOPICS IDENTIFIED FROM A DATA SEARCH USING SMART UNIVERSITY AS THE KEYWORD

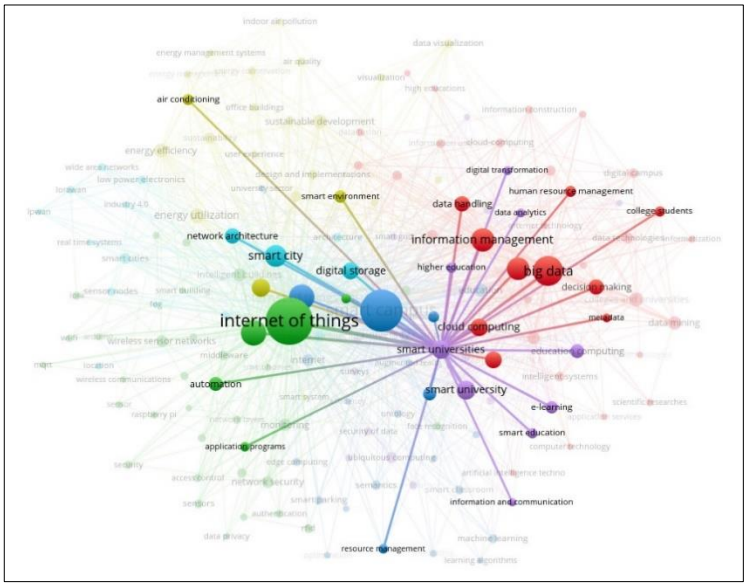


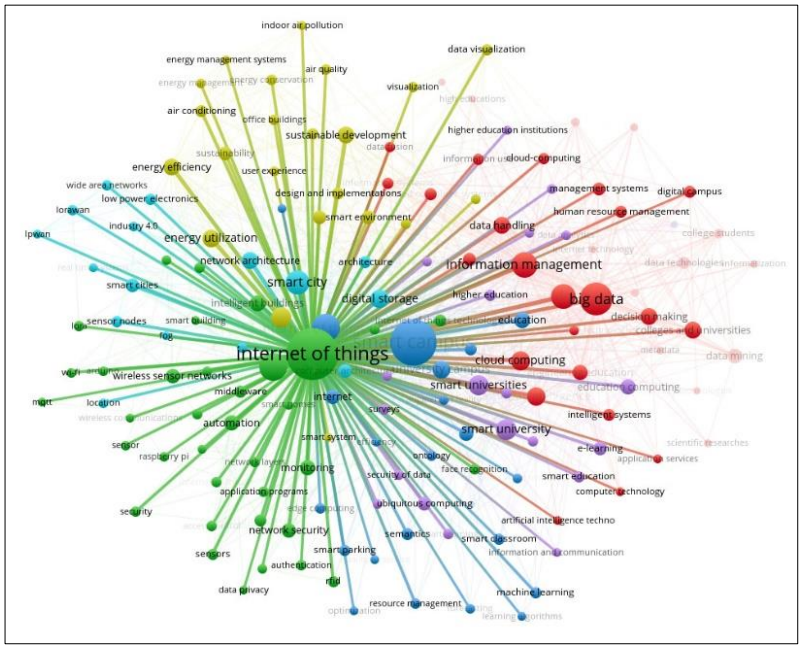
Figure 3 and 4 illustrated the relationship among topics related to smart campus and smart university, respectively. The network for smart campus had more relevant topics than the network for smart university. Despite a similar meaning for smart campus and smart university, those interested in a larger collection of topics related to each term specifically, should perform a search using the specific keyword only. We observed that certain topics, such as IoT, big data, human resource management, and data transformation,

were common between these two keywords. However, some topics are specific to only one keyword; for example, topics such as data privacy and air quality are only observed in a search on smart campus.

Internet of Things

The network topics related to IoT are visualized in Figure 5. We observed that this keyword produced a great number of relevant topics due to its major technological role in smart campus and smart university. The analysis confirmed many related topics including sensor, automation, energy management system, resource management, and monitoring system.

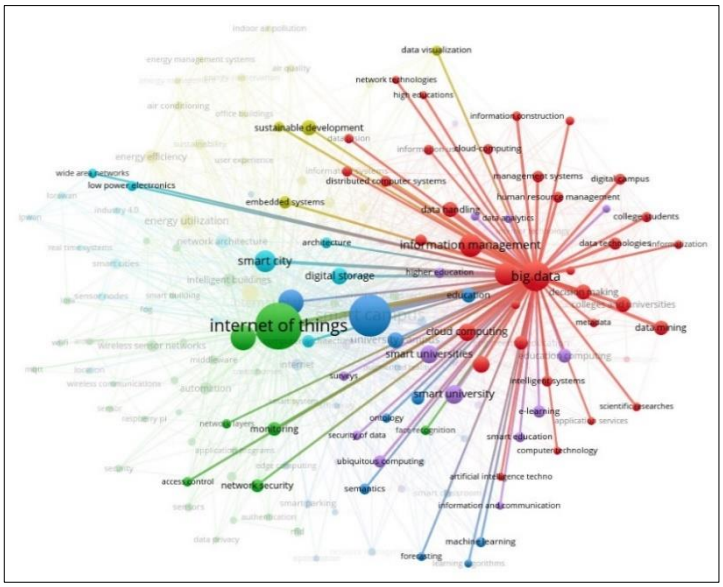
FIGURE 5
A NETWORK MODEL DISPLAYING TOPICS IDENTIFIED FROM A SEARCH USING INTERNET OF THINGS AS A KEYWORD



Big Data

Using the keyword big data also displays many topics related to smart campus and smart university but less than the IoT network (Figure 6). Thus, it can be concluded that big data is less popular than IoT in a domain of smart campus/smart university. The analysis also signifies that the number of research publications focusing on smart campus/smart university, has gradually increased.

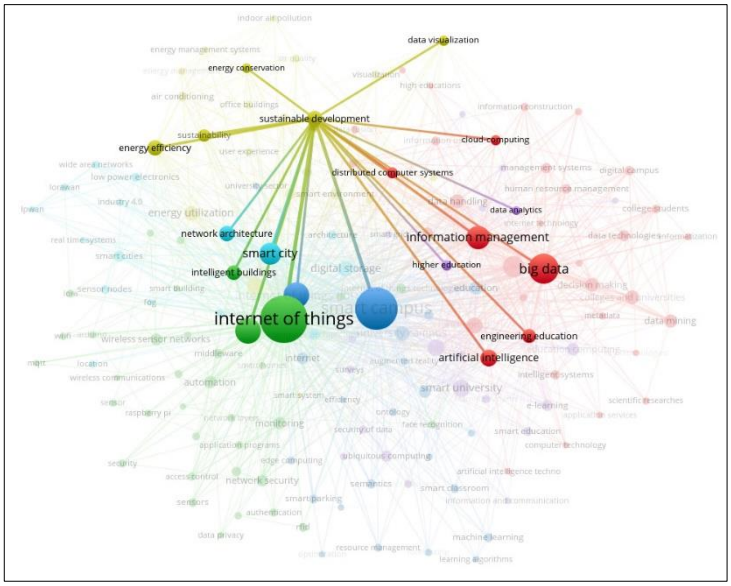
FIGURE 6
A NETWORK MODEL OF TOPICS IDENTIFIED FROM A SEARCH USING BIG DATA AS A KEYWORD



Sustainability

The keyword sustainability relates to a smart campus, smart university or smart city (Figure 7). However, the number of relevant topics is low because sustainability is mainly associated with topics concerned with the management of energy such as energy conservation and energy efficiency. The results highlight the need for more focused research on sustainability for smart campuses and smart cities.

FIGURE 7
A NETWORK MODEL OF TOPICS RELATED IN A SEARCH USING SUSTAINABILITY AS A KEYWORD



Synthesis Sustainable Smart University via IoT and Big Data

Table 2 lists the elements and components required to create a smart university, smart campus, or sustainable university using IoT and big data. A smart university consists of three elements including smart people, smart infrastructure, and smart management. A smart campus consists of six elements that are smart people, smart living, smart environment, smart mobility, smart economy, and smart governance. A sustainable university consists of seven elements that are community, education, energy, environment, governance, infrastructure, and transportation. IoT consists of four elements including sensors, network connections, processer, and actuator. Big data consists of five elements that are volume, variety, velocity, value, and veracity.

TABLE 2
SYNTHESIS OF A SUSTAINABLE SMART UNIVERSITY VIA IOT AND BIG DATA

Topic	Concept	Elements/Component	References
Smart university	A university which applies innovative ways of working, learning, and teaching by integrate advanced hardware and software platforms to improve its management and education process.	Smart people, smart infrastructure, and smart management	Hou et al., 2020; Maciá Pérez et al., 2021; Mbombo & Cavus, 2021; Pham et al., 2020; D. Rico-Bautista et al., 2021
Smart Campus	A concept to apply smart city to a university campus by connecting devices, applications, and people to enable new services, improve efficiencies and enhance the experience of students and staff on campus.	Smart people, smart living, smart environment, smart mobility, smart economy, and smart governance	Abualnaaj et al., 2020; Anagnostopoulos et al., 2021; Imbar et al., 2020; Jurva et al., 2020; Longo et al., 2021; Martins et al., 2021; Min-Allah & Alrashed, 2020; Omotayo, Awuzie, et al., 2021; Omotayo, Moghayedi, et al., 2021; Villegas-Ch et al., 2019
Sustainable university	A university aiming to be self-sustainable in terms of natural resource management, and environmental care towards sustainability.	Community, education, energy, environment, governance, infrastructure and transportation	Alomari & Khataybeh, 2021; Gamage et al., 2022; Hussain et al., 2019; Martins et al., 2021; Min-Allah & Alrashed, 2020; Pham et al., 2020; Villegas-Ch et al., 2019
Internet of Things	The system of interrelated computing devices, machines, objects, and people over a network	Sensor, network connection, processor, and actuator	Frustaci et al., 2018; Karmakar et al., 2021; Martins et al., 2021; Meneghello et al., 2019; Swamy & Kota, 2020

Topic	Concept	Elements/Component	References
Big Data	A collection of large data (in volume growing exponentially with time and able to be analyzed for prediction and planning	Volume, variety, velocity, value and veracity	Mbombo & Cavus, 2021; Mkrttchian et al., 2021; Pratsri & Nilsook, 2020; Villegas-Ch et al., 2019

The Conceptual Framework Illustrating Elements Required for the Development of a Sustainable Smart University Using IoT and Big Data

FIGURE 8
ILLUSTRATING THE CONCEPTUAL NETWORK FOR SUSTAINABLE SMART UNIVERSITY VIA IOT AND BIG DATA

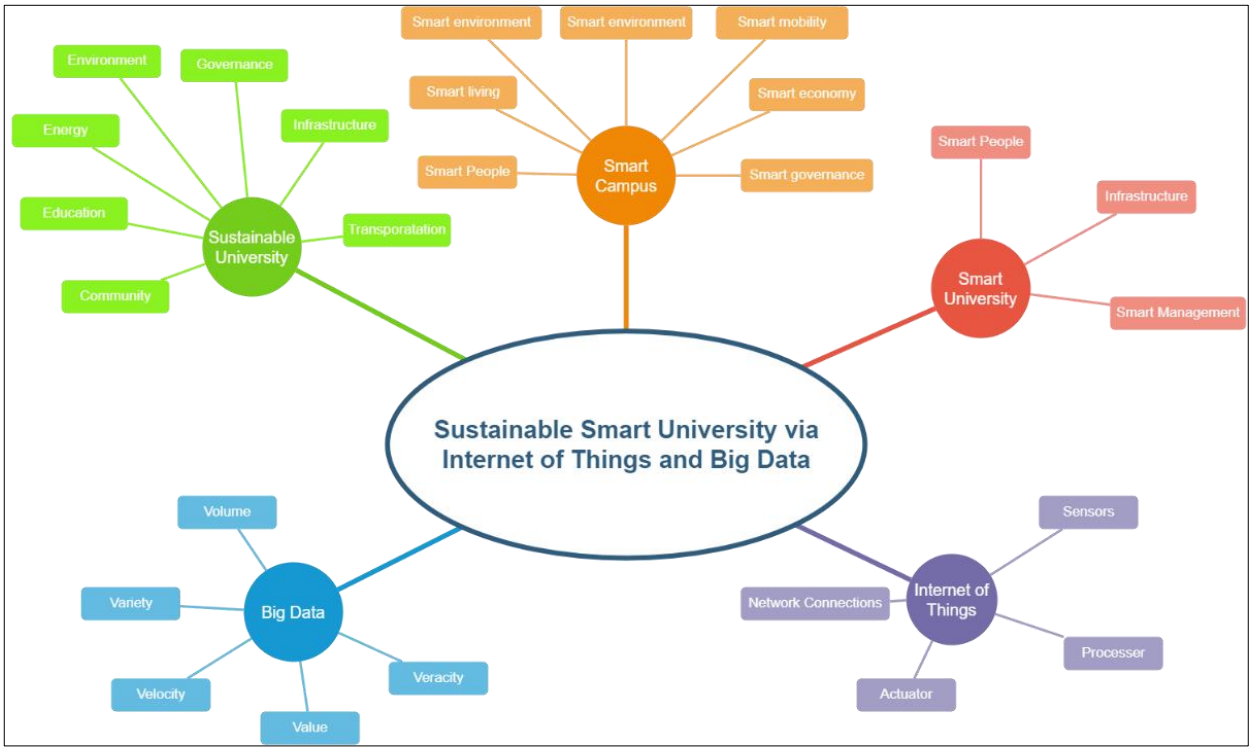


Figure 8 shows that the conceptual framework of sustainable smart university via IoT and big data with five main components; smart university, smart campus, sustainable university, IoT and big data, and presents the elements of each main component necessary for the successful transition of a traditional university into a smart university following sustainable development.

CONCLUSION

The network of concepts observed from this study show that the development of a smart campus involves technology such as IoT and big data that can also be used in the development of sustainability. The targets of a smart campus/smart university include resource management, security management and providing digital service to students and staff. The development of a smart campus will improve campus

management efficiency and enhance the experience of students by applying innovative technology through the integration of advanced hardware and software platforms.

By linking a smart campus with sustainability, the network models show that research is focused on applying smart technologies to improve a sustainable campus concept for natural resource management and environmental care. Since a smart campus is a smaller scale or an interface of a smart city, these preliminary studies can be used for the development of a sustainable city in the future, with digitalized and intelligent services for citizen benefits.

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