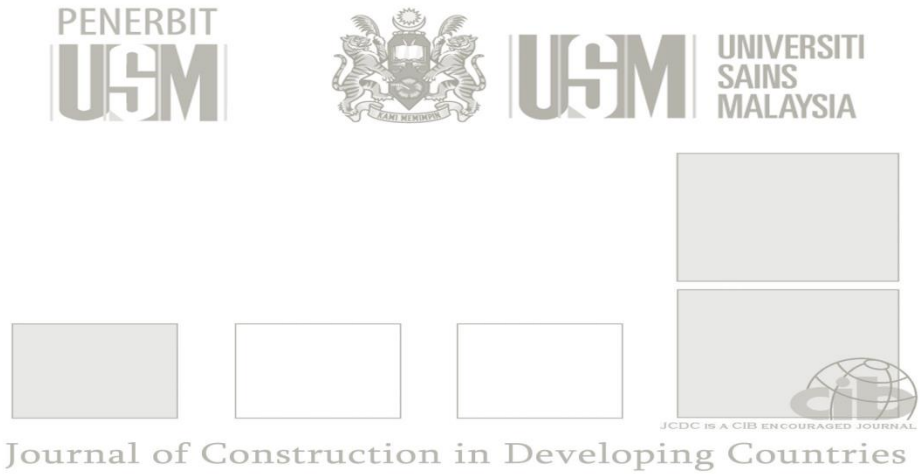

Manuscript Title	An IDEF0 Functional Planning Model for the development of Asset Management Framework: A case study of Chiang Mai University
Authors	Achara Khamaksorn, Acrapol Nimmolrat, Noorsaidi Mahat and Orawit Thinnukool
Submitted Date	12-Jan-2021 (1st Submission)
Accepted Date	16-Dec-2021
DOI	https://doi.org/10.21315/jcdc-12-20-0249

An IDEF0 Functional Planning Model for the Development of an Asset Management Framework: A Case Study of Chiang Mai University

Achara Khamaksorn[1], Acrapol Nimmolrat[2], Noorsaidi Mahat[3] and Orawit Thinnukool[4]

[1 and 2] Department of Knowledge and Innovation Management, College of Arts, Media and Technology, Chiang Mai University, Chiang Mai, 50200, Thailand

[3] Faculty of Architecture, Planning and Surveying, Universiti Teknologi MARA Sarawak, Malaysia

[4] Department of Modern Management and Information Technology, College of Arts, Media and Technology, Chiang Mai University, Chiang Mai, 50200, Thailand

Corresponding author. E-mail: achara.k@cmu.ac.th

ABSTRACT

Asset management (AM) focuses on the life cycle of assets and provides a systematic process for developing and maintaining an organisation's assets using a set of asset-related planning and control activities. Chiang Mai University (CMU) is a public university in Thailand founded in 1964. The university was the first provincial university in Thailand and aims to be the university of prototyped innovation for sustainable development in communities. CMU's AM planning process is a critical aspect of its mission to develop the university. This study developed an asset management framework (AMF) based on IDEF0 functional modelling—a modelling process that facilitates the decisions, actions, and activities of an organisation or system. Moreover, the study used an analytic hierarchy process (AHP) to perform pairwise comparison, produce matrices, and calculate priorities for CMU's assets. The researchers employed a strengths, weaknesses, opportunities, and threats (SWOT) analysis to evaluate the organisation's competitive position and support its strategic planning. This paper presents the resulting CMU AMF (AMF-CMU), the development of which contributed to prioritising and managing the university's assets.

Keywords: asset management framework, analytic hierarchy process, IDEF0

INTRODUCTION

Due to increasingly elaborate industry-related procedures, there is an ever-growing demand for assets and processes to be sustainable across their entire life cycles (Niekamp et al., 2015) . Management's function is to

coordinate people's efforts to accomplish goals based on the efficient and effective use of available resources. This involves planning, organising, monitoring, and controlling all aspects of a project, and motivating people to achieve project goals (Sjekavica and Radujković, 2017). Management can relate to diverse scenarios, including property management, facilities management, and asset management (AM).

Nowadays, the development of assets plays a crucial role in strategy formulation and, to be effective, certain AM systems, activities, relationships, and mechanisms need to be managed adequately within an organisation. An AM system, as a collaborative control system that crosses organisational levels, can be integrated with an enterprise system (El-Akruti, 2012), but this process has never been well understood within organisations; therefore, AM needs to become a recognised discipline within organisations (El-Akruti et al., 2013).

AM means operating a group of assets across their life cycles, guaranteeing a reasonable return, and ensuring defined service and security standards (Schneider et al., 2005). It is a systematic process that focuses on controlling the development, operation, maintenance, upgrading, and disposal of assets in the most cost-effective manner possible and evaluating the risks to and performance attributes of those assets throughout their life cycles (Campelo et al., 2016; El-Akruti et al., 2013, Visser and Botha, 2015). Its activities have significant potential to influence all aspects of an asset's life cycles (ibid). Most research on AM has focused on service delivery and AM's potential to support the management of risks and costs (Asset Management Council, 2007, 2009, 2010; Government of South Australia, 1999).

The Institute of Asset Management (IAM; based in the UK) is a relatively new body that aims to support professionals engaged in strategic and tactical aspects. The IAM recently published a framework defining the IAM body of knowledge and a process for conducting pilot studies to develop a certification and assessment programme (Lloyd, 2010; Woodhouse, 2006). The IAM defines the goal of AM as 'a technical activity focused on managing and maintaining assets to achieve a desired and sustainable outcome', which has prompted researchers to develop efficient AM programmes (Charles and Alan, 2005; Frolov et al., 2009; Niekamp et al., 2015; Ouertani et al., 2008). In fact, AM is recognised as involving highly diverse knowledge, and as such, it is becoming increasingly popular for driving further economic growth (Visser and Botha, 2015) . Most of the literature on AM has concentrated on asset management frameworks (AMFs), which are used to assist in the development of formal corporate approaches to identifying AM requirements. An AMF is a systematic approach to managing AM activities and practices throughout an organisation or business (Hale et al., 2008).

Since an AMF establishes clear links to various AM functions, it requires significant, specialised planning and management expertise. Effective AM involves planning based on an integrated organisational structure and appropriate allocation of resources (Hale et al., 2008). In recent years, a determined effort by those working in the field has resulted in the development of a formal approach to AM systems, knowledge, and

education. AM has therefore gained considerable momentum and interest in academia and industry for the development of business processes and as a discipline (El-Akruti et al., 2013), leading to the publication in 2014 of the International Organization for Standardisation's ISO 55000 series of AM standards. The first real effort to develop a comprehensive framework for AM specifications was PAS 55 (Asset Management Council, 2010), published by the British Standards Institute (BSI). The Australian Asset Management Council (AMC) also compiled an asset management body of knowledge (AMBoK; British Standards Institute), which supported comprehensive AMF and best practices as a subset of the broader AM discipline. Based on analytical decision support, multicriteria decision analysis can address a variety of concerns by providing methodologies that can be used to evaluate all AM options, as well as to identify and rank them in order of preference (Asset Management Council, 2010; Bertolini et al., 2006; Mahdi and Alreshaid, 2005).

Chiang Mai University (CMU) aims to be a 'green and healthy university' and has introduced 'CMU transformation' to encourage educational reform, promote lifelong learning, and become the university of prototyped innovation for sustainable development in communities (Chiang Mai University, 2019). To promote and innovate learning environments, one of CMU's most significant responsibilities is to provide and manage a safe and healthy environment for the university community and the required assets for its students and staff; thus, the planning and development of university assets is a critical aspect of the development of CMU's administration and management system. CMU's AMF (AMF-CMU) was developed to fulfil this goal by allowing the university to keep track of all assets, ensure efficient operations, and understand its assets' capabilities.

This study brings together the key concepts relating to AM in organisations, based on the IDEF0 functional model theory. The IDEF0 functional model offers a structured representation of functions, actions, activities, processes, and decisions in modelled systems, providing planning opportunities and facilitating an understanding of and a means to access knowledge assets in organisations.

Assets' capabilities are deeply anchored in the continued solvency of organisations and industries; therefore, AM must be a priority for all sectors or industries, including the education sector. Current assets generally constitute a significant component of an organisation's total assets, and for some organisations, AM can improve their financial performance. The current understanding of what contributes to knowledge assets in organisations, especially in universities, is still limited. Another important gap identified in the literature is that, despite the growing number of studies on AM, little research has been conducted on AM in universities in developing countries.

Consequently, this study aimed to close these gaps by identifying and evaluating CMU's existing assets and developing an AMF based on IDEF0 functional modelling. The IDEF0 functional planning model was used to model the organisation's decisions, actions, and activities and develop an AMF. An analytic hierarchy process (AHP) was used to produce pairwise comparison matrices and calculate the priorities for its assets. A strengths (S), weaknesses

(W), opportunities (O), and threats (T; SWOT) analysis was employed to evaluate CMU's competitive position and enhance its strategic planning. This paper presents the development of the AMF-CMU, which contributed to prioritising and managing the university's assets.

LITERATURE REVIEW

This section reviews approaches for integrating AM with IDEF0 functional modelling and SWOT analysis. First, it presents the concept of AM and its social and economic evolution in organisations. IDEF0 functional modelling continues to be crucial for representing functions, actions, activities, processes, and decisions in organisations, and SWOT analysis focuses on critical issues that influence a firm's strategy and business development; thus, this research employed an integrated approach combining AM to develop a framework based on IDEF0 functional modelling and SWOT analysis. Finally, the section reviews actions, activities, and critical issues that were relevant to the development of an AM framework.

AM

The concept of AM has evolved in recent decades to support social and economic development (Grinstein-Weiss et al., 2007). Building asset management (BAM) has been studied for many decades,since assets often relate to natural resources, land, plant, equipment, heritage and cultural assets, building structures, or other forms of infrastructure, although financial information, human resources, and intellectual property are notable exceptions. Some studies have developed building asset policies to improve various aspects of household security, including resources, knowledge, and functional skills (El-Akruti et al., 2013; Grinstein-Weiss et al., 2007; Hegazy et al., 2012; Macchi et al., 2018). The term AM is often associated with financial investment. Building components, such as roofs, windows, boilers, elevators, and landscaping, require significant investment, and BAM is a process and decision-making framework that covers the full-service life of such physical assets from cradle to grave (Campelo et al., 2016; El-Akruti et al., 2013, Grinstein-Weiss et al., 2007; Visser and Botha, 2015). A building's life cycle involves a series of stages, and sustaining the operation of existing buildings is a highly challenging task, particularly in view of tight budgets for capital renewal. Various AM tools have also been introduced to enable building asset managers to make difficult decisions about how and when to repair/ renew their existing building stock (Hegazy et al., 2012). Numerous publications have explored effective maintenance approaches (Chu et al., 2008; Grinstein-Weiss et al., 2007; Koksal and Ozdemir, 2016).

Effective AM enables building managers to identify the need for repairs and renewals and to provide stakeholders with accurate, up-to-date information. They can obtain important asset information, which enables them to make critical decisions regarding the evolution of their building stock using life cycle costing principles based on acceptable levels of risk (Carlucci and Schiuma, 2007; Farghaly et al., 2018; Gerbasi and Marchand, 2005). Asset

managers are responsible for the integration of asset planning, budgeting, reporting, and monitoring as part of the overall management processes within their organisations (Macchi et al., 2018). An integrated approach may involve consultation with central agencies and coordinated reporting, and the benefits of such an approach may include 1) criteria and standards for the ownership and management of assets; 2) strategies and processes for procurement, maintenance, disposal, and risk management; and 3) priorities for allocating resources for AM**.**

IDEF0 Functional Modelling

The purpose of this study was to identify and evaluate CMU's existing assets and develop an AMF based on IDEF0 functional modelling. IDEF0 Functional modelling produces a structured representation of functions, actions, activities, processes, and decisions in modelled systems and organisations (Grover and Kettinger, 2000). An IDEF0 functional model was used to configure the organisation's decisions, actions, and activities and to represent its activities and processes in an organised and standardised manner. A functional model consists of a series of hierarchical schemes of interrelated functions, data, and objects; hence, it was an ideal research method for representing organisational management activities and processes and focusing on inputs, controls, outputs, and mechanisms (ICOMS; Akasah et al., 2010; Bargelis and Stasiškis, 2008; Godlevskyi et al., 2018). IDEF0 is used to produce a functional model that can represent a wide range of businesses in the manufacturing industry by illustrating the flow of data, functional flows, and system controls in a life cycle process. It has been defined as a set of activities that takes certain inputs and transforms them into outputs using mechanisms that are subject to certain controls. These ICOMS can be used to model the relationships between various activities. Figure 1 presents the IDEF0 model used in this study.

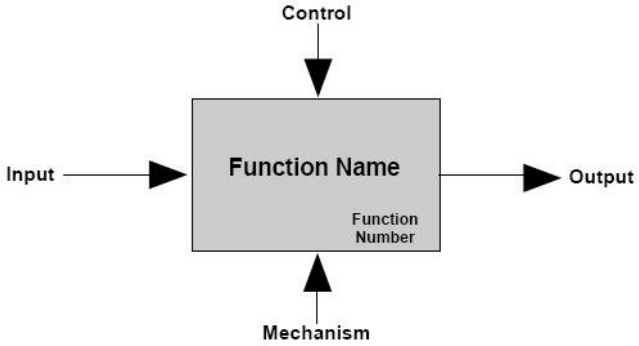

Figure 1. Input–process–output paradigm.

Grover and Kettinger (2000) and Koskela (1992) described information/knowledge content and processes as a combination of flow processes that can be identified using the IDEF0 function modelling approach. An IDEF0 functional model, for example, can model a flow of data relating to activities and mechanisms that provide planning opportunities and facilitate an understanding of knowledge assets in organisations.

Therefore, the AMF for this study was developed based on the IDEF0 functional modelling method.

SWOT Analysis

An analysis of the business environment is extolled as a fundamental part of strategic planning processes. A SWOT analysis is a commonly used tool for analysing external and internal environments simultaneously to provide a systematic approach and support for decision-making. SWOT analysis is highly recommended for its simplicity and value in focusing attention on critical issues that affect business development and growth. It, therefore, has potential as an effective tool for identifying the factors that are likely to influence a firm's strategy and success. SWOT analysis is not merely a static analysis tool that helps generate an understanding of business activities; it can also play an active role in the management process, facilitating management development. It is therefore a valuable management tool that can be easily absorbed with good effect into the realities and practicalities of an organisation's existing planning and strategy formulation processes.

A SWOT analysis can be used to assess the strengths and weaknesses of organisations and the external influences and threats that can affect their operations. It is mostly used for the fundamental identification of the current state of a firm, and it summarises the basic factors influencing the effectiveness of organisational activities and affecting the achievement of goals (Bambuch, 2013). Djurkovic (2012) pointed out that SWOT analysis is a descriptive method used for the designations of the strategic planning of a certain industry. Furthermore, SWOT analysis helps organisations understand their statuses and gives them visibility of their overall business performance.

This term correlates well with Omer's (2019) study, which stressed the important role of SWOT in the strategy planning of organisations. SWOT analysis gives a clear picture and helps a business analyse its strengths, weaknesses, opportunities, and threats; understand and better penetrate the market; and meet business targets. SWOT analysis, therefore, helps to establish links between strengths, weaknesses, opportunities, and threats and show how well the business is operating.

Based on a review of the BAM, AM, IDEF0 functional modelling, and SWOT analysis literature, it is worth highlighting that AM has been recognised as a mechanism and process for planning and managing the criteria and standards necessary to manage assets and allocate resources for AM**.** Also, IDEF0 functional modelling and SWOT analysis help organisations make decisions and develop their strategic planning, based on a framework that combines activities and flow processes, and focus attention on critical issues, such as those affecting asset development at CMU.

RESEARCH DESIGN AND METHODOLOGY

The critical factors of AM identified from the literature review were used to design a questionnaire for collecting quantitative data from building managers, staff, and students. The quantitative questionnaire included key

factors and was based on a multicriteria decision-making technique (an AHP). IDEF0 functional modelling was used to determine and represent how functions, actions, activities, processes, and decisions in CMU could be managed and to identify the factors that could affect the development of an AMF. This approach was taken to achieve the aims and objectives of the research, as illustrated in Figure 2.

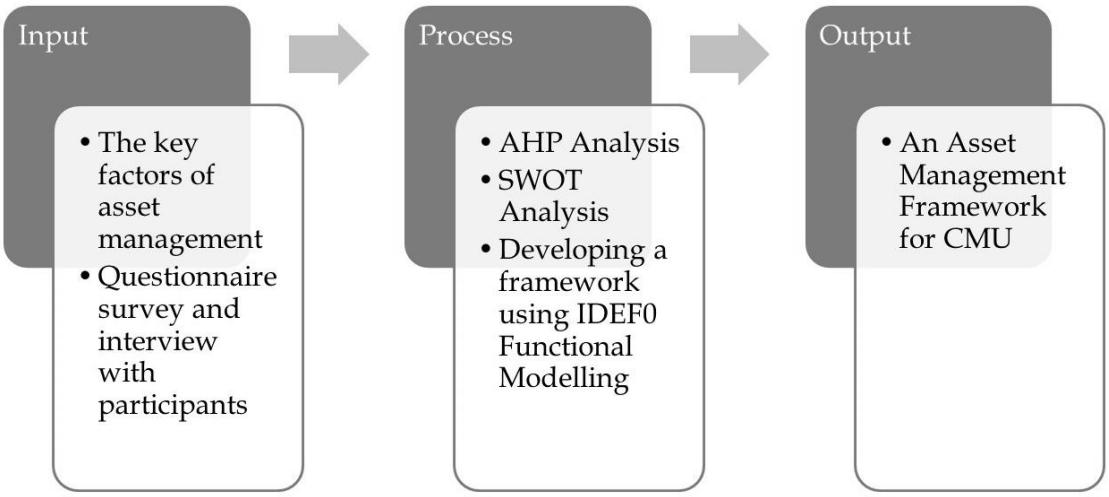

Figure 2. The research methodology framework.

Figure 2 presents the development of the research methodology framework used in this study. This framework was divided into three main sections. To develop the AMF-CMU, the key factors of AM were identified from the literature review and a questionnaire survey. The research was based on a combination of quantitative and qualitative data. The quantitative data for the AHP analysis were collected from questionnaires, whereas the qualitative data relating to key concepts were collected from face-to-face interviews with building managers, faculty, staff, and students across CMU to analyse the SWOT of the CMU case study. A SWOT analysis of the responses to the qualitative questions indicated strengths, weaknesses, opportunities, and threats. Strengths characterised the advantages of the university assets; weaknesses identified the disadvantages relative to others; opportunities represented factors that the university could exploit to its advantage; and threats showed the elements in the environment that could cause problems for the university's assets. SWOT identification was an important step for gaining information to plan and achieve the university's goals, and the AMF was developed based on the key factors and functions of IDEF0 functional modelling.

AHP is a multicriteria decision-making technique proposed by Saaty in 1976 (Al-Harbi, 2001; Dikmen and Birgonul, 2006). An AHP requires a pairwise comparison for each criterion, including a relative weighting of its importance at the data-entry stage (Ho and Ma, 2018; Ngai and Chan, 2005; Tanaka et al., 2010). The decision-maker provides relative judgements about the scoring of the alternatives for each criterion, such as 'alternative A is much better than alternative B', and the weighting of the criteria against

each other, such as 'criterion A is slightly less important than Criterion B'. A comprehensive framework is suitable when people make multi-objective, multicriteria, and multi-actor decisions with or without being certain of any number of alternatives. The hierarchy chart for the decision-making and calculations is presented in Figure 3.

X^1	1	2	3	$X^{1'}$	1	2	3	Weight
1	1	A	B		11'	21'	31'	W1
2	1/A	1	C		12'	22'	32'	W2
3	1/B	1/C	1		13'	23'	33'	W3

11'	=	1/(1+(1/A) +(1/B))	31'	=	B/(B+C+1)
12'	=	(1/A)/(1+(1/A) +(1/B))	32'	=	C/(B+C+1)
13'	=	(1/B)/(1+(1/A) +(1/B))	33'	=	1/(B+C+1)
21'	=	A/(A+1+(1/C))	W1	=	(11'+21'+31')/n
22'	=	1/(A+1+(1/C))	W2	=	(12'+22'+32')/n
23'	=	(1/C)/(A+1+(1/C))	W3	=	(13'+23'+33')/n
n	=	Number of factors	1, 2 and 3	=	Factor

Figure 3. Hierarchy chart and calculations for decision-making.

Conditional values are derived from a pairwise comparison in an AHP because the derived value for each element relates to the other values with which it is compared. Comparative matrices are constructed to define the pairwise comparison, allowing consistency ratios to be calculated as a control measure. In this way, decision-makers can later understand whether the evaluations are consistent (Saaty, 2000, 2004; Saaty and Ozdemir, 2003). Determining the level of the decision using an AHP to compare 'importance', 'weight', and 'choice' can lead to a successful evaluation of important criteria.

The calculation table for the AHP analysis was used to evaluate the AM criteria. Qualitative in-depth interviews based on an interview schedule were used to collect empirical evidence to supplement the questionnaire survey findings. The interview schedule was designed with open-ended questions to enrich the qualitative data regarding the criteria for the management of existing assets. Moreover, a SWOT analysis was conducted to determine the strengths, weaknesses, opportunities, and threats relating to the assets. The outcomes of these approaches were then comprehensively analysed to develop the AMF-CMU. The questionnaire was divided into three main sections, the first of which was designed to collect the background information of the participants, the organisation, and the existing assets of CMU. The second part of the questionnaire survey was designed to map the management of the existing buildings and their renovation and management, together with criteria for improving the environment and infrastructure, using an AHP. In section 2, the data were analysed using an AHP to measure the levels of the decisions and evaluate and rank the importance of the criteria by comparing them to find the 'weight' of each

'choice'. The AHP considered information about the management of the buildings and facilities, the criteria for comparing the building renovation and management, and the criteria for comparing the university's environment and infrastructure. It was also used to measure the level and priority of the direction of the assets. Finally, the third section of the interview contained open-ended questions to analyse the strengths, weaknesses, opportunities, and threats relating to CMU's existing assets.

DATA ANALYSIS AND FINDINGS

This section presents the research findings based on an analysis of the collected data. It contains four subsections: 1) background and information of the respondents, 2) AHP, 3) SWOT analysis, and 4) development of the AMF-CMU.

Based on the responses to the questionnaire survey, 86.00% of the participants were faculty, 8.00% were from colleges, and 6.00% were from the graduate school. Moreover, the findings revealed that 26.00% were lecturers, 16.00% were administrative staff, 26.00% were students, 26.00% were building managers, and 6.00% did not specify their job positions. These details are shown in Table 1.

Table 1. Participants' backgrounds.

General Information of Respondents	**Quantity (n)**	**Percentage** (%)
1. Organisation		
- Faculty	86	86.00
- College	8	8.00
- Graduate school	6	6.00
Total	100	**100.00**
2. Position		
- Lecturer	26	26.00
- Administrative staff	16	16.00
- Student	26	26.00
- Building manager	26	26.00
- Not specified.	6	6.00
Total	100	**100.00**

AHP

The AHP was used to provide the guidelines for the level and priority of the planning, maintenance, and acquisition of assets from an AM perspective. The results showed that the acquisition of assets required the highest level of decision-making, with a score of 0.465, followed by the maintenance of assets (score 0.324) and planning of assets (score 0.212). Table 2 indicates that the acquisition of assets was the first-ranked feature from an AM perspective.

Table 2. Comparison matrix from an AM perspective.

No.	**AM Perspective**	'**Weight**' **of the decision**

		Max.	Min.	Average	Rank
1	Planning of assets	0.633	**0.052**	0.212	3
2	Maintenance of assets	0.738	0.083	0.324	2
3	Acquisition of assets	**0.748**	0.065	**0.465**	**1**

The findings shown in Table 2 indicated the 'weight' of the main features from an AM perspective. Planning of assets was the most important criterion for decision-making with a score of 0.489, followed by effectiveness and efficiency (score 0.315) and users' criteria (score 0.195), respectively. In terms of the maintenance of assets, supervision and inspection of the building's utilities was the most important criterion for decisions, with a score of 0.432, followed by maintaining and monitoring the building's systems (score 0.292) and supervision and inspection of the areas of the building (score 0.275). Moreover, the most important criterion for decisions from the perspective of acquisition of assets was classrooms/laboratories with a score of 0.344, followed by research and academic services (score 0.337). By contrast, the least important criterion was the students' activity areas (score 0.319).

Table 3. Comparison matrix for the criteria of the AM perspective.

AM Perspective	Criteria	'Weight' of the decision			
		Max.	Min.	Average	Rank
Planning of assets	Planning	0.750	0.052	**0.489**	**1**
	Users' criteria	0.716	0.052	0.195	3
	Effectiveness and efficiency	0.711	0.068	0.315	2
Maintenance of assets	Supervision and inspection of the building's areas	0.767	0.052	0.275	3
	Supervision and inspection of the building's utilities	0.778	0.052	**0.432**	**1**
	Maintaining and monitoring the building's systems	0.685	0.072	0.292	2
Acquisition of assets	Classrooms / laboratories	0.765	0.053	**0.344**	**1**
	Students' activity area	0.729	0.059	0.319	3
	Research and academic services	0.778	0.057	0.337	2

According to Tables 2 and 3, it was clear that the acquisition of assets was the most critical factor in managing CMU's existing assets. The participants indicated that classrooms and laboratories were the most critical assets, followed by research and academic services and students' activity areas. The likely explanation for this finding is that classrooms and laboratories are essential for the university's operations. This result was consistent with that of Forneris et al. (2015), who pointed out that the acquisition of assets relies on examining and facilitating the participation of students, especially in

classroom and laboratory learning environments in the twenty-first century. The development of a classroom and laboratory learning environment affects students' motivation for learning and influences their developmental outcomes and engagement. This result correlated well with Karpudewan's (2017) research, which found that the learning environment is an important construct influencing students' attitudes. This result suggests that educational institutions should seriously consider developmental assets to encourage and support students and facilitate the development of twenty-first-century skills.

SWOT Analysis

The previous section explained that classrooms/laboratories were identified as the most critical factors that needed to be managed by CMU. Abdel-Basset et al. (2018) used a SWOT analysis to achieve an orderly approach to decision-making. It is a robust methodology for making accurate decisions, used by managers to construct successful strategies by analysing the strengths, weaknesses, opportunities, and threats for the organisation and thus select and implement the best method for achieving organisational goals. It is a robust methodology for making accurate decisions (Abdel-Basset et al., 2018; Lee et al., 2011).

The data collection involved interviews with key actors from different faculties using open-ended questions. The interviewees were briefed on the background of the research topic. They were also briefed on the framework adopted to analyse AM in this study. A summary of the data derived from interviewing the main actors regarding the SWOT analysis of the assets (buildings and facilities) is provided in Table 4.

Table 4. SWOT analysis of the CMU's assets (based on interviews).

Strengths (S)	**Weaknesses (W)**
1. A beautiful natural environment surrounds the area around the university.	1. The numbers of the buildings/ units are inconsistent. 2. There is insufficient space inside buildings for the number of users. 3. The faculties do not focus sufficiently on the planning, maintenance, and management of the buildings, physical environment, and landscape.
Opportunities (O)	**Threats (T)**
1. Certain faculties currently have many buildings. They can leverage investments in the management area or existing property to generate future revenue for the university. 2. Certain buildings in CMU that are 40 or more years old are valuable architectural buildings; hence, they are worth preserving. 3. CMU has sufficient capacity to develop and create an environment	1. The rate of depreciation of the property value of the buildings needs to be calculated.

and facilities to cater to everyone (i.e. 'design for all').	

According to Table 4, the natural environment around the university was considered a strength and high-value university asset. Moreover, participants indicated that most of the existing CMU assets were important assets that should be preserved and developed to cater to everyone. However, the numbers of buildings were inconsistent, and the faculties did not focus sufficiently on the planning, maintenance, and management of the buildings; hence, CMU should engage in decision-making to develop and sustain this university asset. The empirical findings align with those of Bambuch (2013), Djurkovic (2012), and Omer (2019), who argued that SWOT analyses influence organisations, helping them to understand their statuses and gain visibility of their overall business performance. Moreover, SWOT analysis can facilitate better market penetration to meet business targets. This finding emphasises the need for the university to pay attention to SWOT analysis to understand and establish its strengths, weaknesses, opportunities, and threats.

Development of CMU's AMF

Based on the evidence from the AHP and SWOT analysis presented and discussed in the previous section, the AMF-CMU was further developed to enhance CMU's sustainable development, AM strategic planning, control of planning assets, maintenance of assets, acquisition of assets, and mechanisms.

It was evident that the significant criteria regarding CMU's assets, determined from the literature review, the results of the AHP, and a SWOT analysis, would help in developing an AMF for the university; hence, IDEF0-type notation was used to identify the three main parts of the framework. The researchers developed an AMF-CMU containing the significant controls and mechanisms discussed in this article. Further details of the development of the AMF-CMU are provided, as shown in Figure 4.

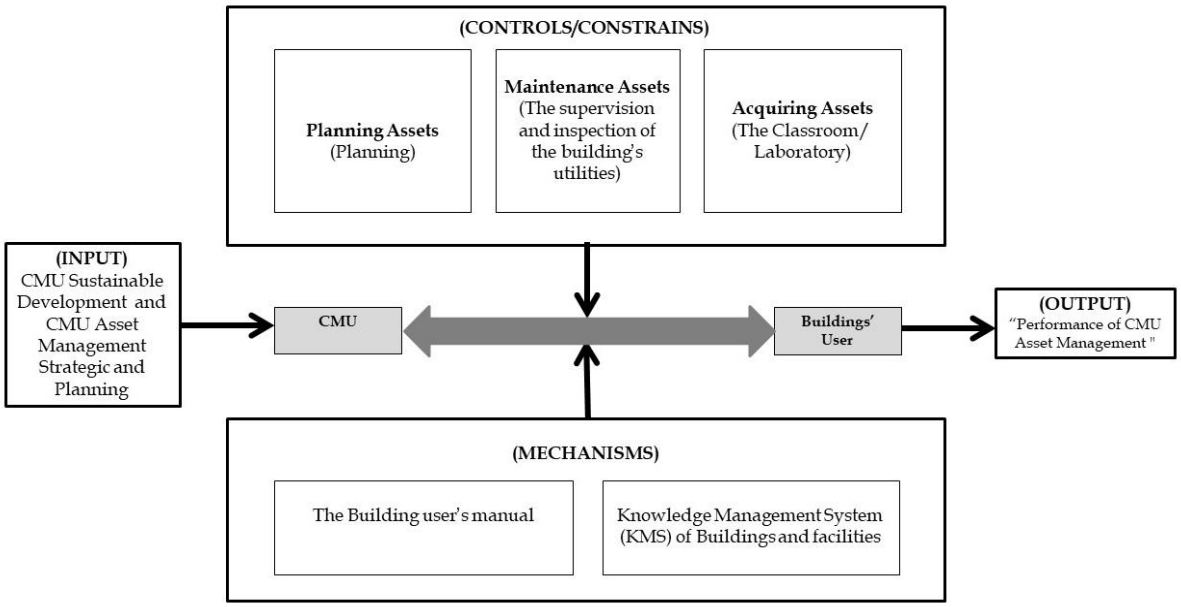

Figure 4. Overview of the AMF.

Figure 4 shows that the AMF-CMU, which was based on the inputs, processes, and outputs identified from the prior literature, related to the CMU's sustainable development and AM strategic planning. This framework not only included the fundamental mechanisms that influenced the AMF-CMU, which should be noted, but also paved the way for future research aiming to identify the key factors that influence decision-making in a university. This outcome was consistent with that of Grover and Kettinger (2000), who found that IDEF0 functional modelling effectively represents the functions, actions, activities, processes, and decisions in modelled systems and organisations. Bargelis and Stasiškis (2008) and Godlevskyi et al. (2018) also claimed that IDEF0 functional modelling effectively represents the activities and processes of organisational management. As a result, IDEF0 functional modelling was deemed to be an ideal research method for representing the activities and processes of organisational management in an educational institution and for modelling the relationship between various activities.

DISCUSSION

The aim of this study was to identify and evaluate CMU's existing assets and develop an AMF based on IDEF0 functional modelling. An IDEF0 functional planning model was used to model CMU's decisions, actions, and activities and develop an AMF. AHP was used to produce pairwise comparison matrices and calculate the priorities for CMU's assets. SWOT analysis was used to evaluate the university's competitive position and to develop its strategic planning.

AHP techniques and SWOT analysis were used to identify the critical factors affecting AM. The first objective was achieved by reviewing CMU's current AM system according to its five-fold major mission, the results of an

AHP and SWOT analysis, and information derived from a questionnaire and in-depth interviews. The results showed that the acquisition of assets required the highest level of decision-making, followed by the maintenance and planning of assets. The likely explanation for these findings is that acquisition of assets was the first-ranked feature from an AM perspective. This result correlated well with the research of Chu et al. (2008), Funk (2003), Grinstein-Weiss et al. (2007), and Koksal and Ozdemir (2016), who discussed how organisations can acquire assets and take a practical approach to maintenance management. Acquisitions, investments, and a practical method of maintenance management can provide slight information advantages for obtaining preferential access to complementary assets.

It was clear from the data gathered in this study that the acquisition of assets was the most essential factor for managing the existing assets of the university. The management of classrooms/laboratories was essential, followed by research and academic services and the students' activity areas. The likely explanation for these findings is that classrooms and laboratories are necessary for the university. Previous research on educational communities and the capacity of institutions to establish educational communities, such as Zainea's (2008) research, has suggested that students are likely to persist and learn when the institution provides needed academic support, in particular in the classrooms, laboratories, and studios on campus. The empirical findings align with those of Tinto (2009), who found that the classroom might be the only place where students meet each other and engage in formal learning activities. Therefore, this finding emphasises that classrooms and laboratories are crucial for students and for shaping learning activities in the classroom and laboratories.

Also, SWOT analyses could be used as the basis for further evaluation of AM, which corresponds with Dyson's (2004) and Luo and Qin's (2012) research proposing that SWOT analysis is one of the most effective tools for assessing strategic situations and formulating and identifying strategic options for a university. Moreover, Grover and Kettinger (2000) indicated that IDEF0 functional modelling represents organisations' functions, processes, and decisions. IDEF0 models helped this study develop an AMF to model the quality of collaborative processes and guide the reengineering process.

The data clearly showed that the acquisition of assets was the most critical factor for managing CMU's existing assets. The research participants indicated that classrooms and laboratories were the most critical assets, followed by research and academic services and students' activity areas. The likely explanation for this finding is that classrooms and laboratories are essential for the university's operation. This result was consistent with the results obtained by Forneris et al. (2015), who pointed out that the acquisition of assets relies on examining and facilitating the participation of students, especially in classrooms and laboratory learning environments in the twenty-first century. The development of a classroom and laboratory learning environment affects students' motivation for learning and influences their developmental outcomes and engagement. This result correlated well with Karpudewan's (2017) research claiming that the learning environment is

an important construct influencing students' attitudes. According to the findings and an overview of the AMF, CMU should adjust its educational development plan towards sustainable development with SCGs. CMU should also pay serious attention to developmental assets to encourage and support students and facilitate the development of twenty-first-century skills, as well as supporting and integrating decisions, actions, and activities to become an innovative university for the community and contribute to sustainable social development.

CONCLUSION

This research determined significant key factors for managing assets by combining AHP techniques, SWOT analysis, and IDEF0 functional modelling. IDEF0 functional modelling was utilised to identify the three main aspects of the AMF and develop the framework, which makes an important contribution to prioritising and managing the university's assets. The acquisition of assets requires the highest level of decision-making, with a score of 0.465, followed by the maintenance of assets (score 0.324) and planning of assets (score 0.212). Table 2 indicates that the acquisition of assets was the first-ranked feature from an AM perspective. The findings showed that the acquisition of assets requires the highest level of decision-making, followed by the maintenance and planning of assets. Additionally, acquisition of assets is critical for managing CMU's existing assets. The participants indicated that classrooms and laboratories were the most valuable assets, followed by research and academic services and students' activity areas. The likely explanation for this finding is that classrooms and laboratories are essential for the university's' operation.

The SWOT analysis facilitated an orderly approach to decision-making by showing the best strategy for achieving CMU's goals. The significant criteria for CMU's assets, which were determined from the literature review, the results of the AHP, a SWOT analysis, and the functional modelling, helped in developing the AMF-CMU.

The outcomes of this research support the development of CMU because they can be applied as a framework for managing and enhancing the quality of life for everyone at the university. CMU recognises the importance of this project. It supports the implementation of AM guidelines and the establishment of a practical framework to enable CMU to follow the university's social responsibility principles and achieve its vision, mission, and goals by ensuring the sustainable use of its most important assets. Future research could establish standard guidelines for designing and installing building systems, including disabled access. Not only should the building facilities and AM teams efficiently evaluate information across the university, but all CMU departments should also be involved. All departments should be encouraged to plan, monitor, and improve the use of CMU's assets. A building users' manual could also be produced together with a knowledge management system for the buildings and facilities departments. The main three approaches of the AMF, which comprise CMU's goals and objectives,

can be categorised according to three main aspects: 1) development and enterprise management; 2) development of the environment, buildings, and facilities; and 3) development of corporate personnel, information technology, and databases.

ACKNOWLEDGEMENTS

The authors would like to express their gratitude to CMU for supporting this research and to all the individuals who agreed to participate in it. Thanks to all the research participants for taking the time to answer the questionnaires, take part in the interviews, and respond to the authors' questions. This study would not have been possible without their valuable input.

REFERENCES

Abdel-Basset, M., Mohamed, M. & Smarandache, F. (2018). An Extension of Neutrosophic AHP–SWOT Analysis for Strategic Planning and Decision-Making. Symmetry, 10.

Advanced Asset Management (Firm). (1986). Advanced Asset Management credit union directory (pp. v.). San Diego, CA: AAM.

Akasah, Z. A., Amirudin, R. & Alias, M. 2010. Maintenance management process model for school buildings: An application of IDEF0 modelling methodology. Australian Journal of Civil Engineering, 8, 1-12.

Al-Harbi, K. M. A. S. (2001). Application of the AHP in project management. International journal of project management, 19(1), pp.19-27.

Analytical tools for asset management. (2005) . Washington, DC: Transportation Research Board of the National Academies.

Asset Management Council. (2010). Asset management body of knowledge (AMBoK) . Retrieved from http: / / www. am council. com. au/ asset-management-body-of-knowledge.

Bambuch, O. (2013). A marketing strategy of a new product launch, Tomas Bata University in Zlin.

Bargelis, A. & Stasiskis, A. (2008). IDEF0 modelling technique to estimate and increase the process capability at the early product design stage. GAMYBOS PROCESO GALIMYBIŲ ĮVERTINIMAS IR GERINIMAS NAUDOJANT IDEF0 MODELIAVIMO METODIKĄ ANKSTYVOJOJE GAMINIO KONSTRAVIMO STADIJOJE., 71, 45-50.

Bertolini, M., Braglia, M. and Carmignani, G. (2006). Application of the AHP methodology in making a proposal for a public work contract. International Journal of Project Management, 24(5), pp.422-430.

British Standards Institute (BSI). PAS 55:2008 – Publicly available specification. Retrieved from http://www.bsigroup.com. (Accessed on 6 March 2015).

Campelo, F., Batista, L. S., Takahashi, R. H. C., DinizZ, H. E. P. & Carrano, E. G. (2016). Multicriteria transformer asset management with maintenance and planning perspectives. IET Generation, Transmission & Distribution, 10, 2087-2097.

Carluccil, D. & Schiuma, G. (2007). Knowledge assets value creation map: Assessing knowledge assets value drivers using AHP. Expert Systems with Applications, 32, 814-821.

Chiang Mai University (2019). CMU Development Plan Phase.12 (Year 2017-2021). Retrieved from http://www.cmu.ac.th (Accessed on 6 March 2019).

Chu, L. K., Leung, A. K. Y. and Sculli, D. (2008). A portfolio approach to maintenance: a case study of a residential estate. Quality and Reliability Engineering International, 24(3), pp.251-264.

Dikmen, I. and Birgonul, M.T. (2006). An analytic hierarchy process based model for risk and opportunity assessment of international construction projects. Canadian Journal of Civil Engineering, 33(1), pp.58-68.

Djurkovic, M. (2012). SWOT analysis of Serbia's raspberry sector in the competitive marketplace, master thesis, Norwegian university of life science.

El-Akruti, K., Dwight, R. & Zhang, T. (2013). The strategic role of Engineering Asset Management. *International Journal of Production Economics,* 146, 227-239.

Farghaly, K., Abanda, F. H., Vidalakis, C. & Wood, G. (2018). Taxonomy for BIM and Asset Management Semantic Interoperability. *Journal of Management in Engineering,* 34.

Gerbasi, D. (2005). An Asset Management System for School Buildings in Quebec. PEB Exchange, 10-12.

Godelevskyi, M. D., Orlovskyi, D. L. & Kopp, A. M. (2018). Structural Analysis and Optimization of Idef0 Functional Business Process Models. Radio Electronics, Computer Science, Control, 0.

Government of South Australia. (1999) . Strategic Asset Management Framework. Second Edition. Retrieved from http://www.dpti.sa.gov.au /__data/assets/pdf_file /0007/51676/ sam_framework.pdf (Accessed on 6 March 2015).

Grinstein-Weiss, M., Curley, J. and Pajarita, C., (2007). Asset building in rural communities: The experience of Individual Development Accounts. Rural Sociology, 72(1), 25-46.

Grover, V. and Kettinger, W. (2000). Process Think: Winning Perspectives For Business Change in the Information Age. IDEA Group Publishing Inc. ISBN: 1-878-28968-3.

Hale, David P. and Gibson, G. Edward and Woolridge, Richard W. and Stogner, Claude R., Sustaining the Nation's Aging Infrastructure Systems: Lessons Learned Applying an Asset Management Framework. (2008). Industry Studies Conference Paper, Available at SSRN: https://ssrn.com/abstract= 1135013 or http://dx.doi.org/10.2139/ssrn.1135013

Han, Z., Nimmolrat, A. and Khamaksorn, A., (2021), March. Knowledge Transfer Mechanisms and Social Networks in New-born Intensive Care Unit Teams. In 2021 Joint International Conference on Digital Arts, Media and Technology with ECTI Northern Section Conference on Electrical, Electronics, Computer and Telecommunication Engineering (pp. 96-101). IEEE.

Hegazy, T., Elhakeem, A., Singh Ahluwalia, S. and Attalla, M. (2012). MOST-FIT: Support techniques for inspection and life cycle optimization in building asset management. Computer- Aided Civil and Infrastructure Engineering, 27(2), pp.130-142.

Ho, W. & Ma, X. (2018). The state-of-the-art integrations and applications of the analytic hierarchy process. European Journal of Operational Research, 267, 399-414.KOKSAL, A. & OZDEMIR, A. (2016). Improved transformer maintenance plan for reliability centred asset management of power transmission system. IET Generation, Transmission & Distribution, 10, 1976-1983.

Karpudewan, M., & Chong Keat, M. (2017). The effects of classroom learning environment and laboratory learning environment on the attitude towards earning Science in the 21st -century Science lessons. Malaysian Journal of Learning and Instruction (MJLI), Special issue on Graduate Students Research on Education, 25-45.

Khamaksorn, A., Kurul, E., and Tah, J. (2016). Project Management Knowledge and Skills for the Construction Industry, International Conference on Civil, Architecture and Sustainable Development (CASD-2016), London, UK, 1st-2nd December 2016.

Khamaksorn, A., Kurul, E., & Tah, J. H. M. (2016). Factors Affecting Knowledge Transfer in International Construction Joint Venture Project, International Conference on Civil, Architecture and Sustainable Development (CASD-2016), London, UK, 1st-2nd December 2016.

Khamaksorn, A., Tah, J., and Kurul, E. (2020). Knowledge Creation: A Case Study of International Construction Joint Venture Projects in Thailand,

International Journal of Innovation, Management and Technology vol. 11, no. 1, pp. 10-17.

Khamaksorn, A., Kurul, E., and Tah, J. (2019). Knowledge Creation: A Case Study of International Construction Joint Venture Projects in Thailand, 2019 The 10th International Conference on Construction and Project Management (ICCPM 2019), Hong Kong, China, 27th-29th September 2019.

Khamaksorn, A., Kurul, E., and Tah, J. (2018). Social Network Analysis of International Construction Joint Venture Project: A Case Study in THAILAND, The Construction, Building and Real Estate Research Conference of the Royal Institution of Chartered Surveyors (RICS COBRA 2018), London, UK in association with University College London, 23th-24th April 2018.

Koksal, A. & Ozdemir, A. (2016). Improved transformer maintenance plan for reliability centred asset management of power transmission system. *IET Generation, Transmission & Distribution,* 10**,** 1976-1983.

Lee, S.-H., Jeon, R.-K., Kim, J.-H. & Kim, J.-J. (2011). Strategies for Developing Countries to Expand Their Shares in the Global Construction Market: Phase-Based SWOT and AAA Analyses of Korea. Journal of Construction Engineering & Management, 137**,** 460-470.

Li, X, and Khamaksorn, A. (2020), "An Overview of Creativity in Multicultural Experiences (MCEs) approach," *2020 Joint International Conference on Digital Arts, Media and Technology with ECTI Northern Section Conference on Electrical, Electronics, Computer and Telecommunications Engineering (ECTI DAMT & NCON)*, Pattaya, Thailand, 2020, pp. 347-351, doi: 10.1109/ECTIDAMTNCON48261.2020. 9090727.

Lloyd, C. (2010). Asset management Whole-life management of physical assets, Published by Thomas Telford Limited, 40 Marsh Wall, London E14 9TP.

Macchi, M., Roda, I., Negri, E. & Fumagalli, L. (2018). Exploring the role of Digital Twin for Asset Lifecycle Management. IFAC-PapersOnLine, 51**,** 790-795.

Mahat, N, Tah, J., Vidalakis, C, Khamaksorn, A, Orawit Thinnukool, and Malek, M (2021). Data Identification of Determinants Affecting the Adoption of Sustainable Construction; The Perspective of Residential Building Developers, Data in Brief (Accepted and available online)

Mahdi, I.M. and Alreshaid, K. (2005). Decision support system for selecting the proper project delivery method using analytical hierarchy process (AHP). International Journal of Project Management, 23 (7), pp.564-572.

Niekamp, S., Bharadwaj, U.R., Sadhukhan, J. and Chryssanthopoulos, M.K. (2015). A multi-criteria decision support framework for sustainable asset management and challenges in its application. Journal of Industrial and Production Engineering, 32(1), pp.23-36.

Ngai, E. W. T. & Chan, E. W. C. (2005). Evaluation of knowledge management tools using AHP. Expert Systems with Applications, 29, 889-899.

Omer, S. (2019). SWOT ANALYSIS IMPLEMENTATION'S SIGNIFICANCE ON STRATEGY PLANNING SAMSUNG MOBILE COMPANY AS AN EXAMPLE. *Journal of Process Management – New Technologies, International Vol. 7, No 1, 2019. 56-63.*

Peng, X, Khamaksorn, A, and Nimmolrat, A, (2020), "Effective Factors in Behavioral Economies and Organizational Management—based on the Knowledge Management Context," 2020 Joint International Conference on Digital Arts, Media and Technology with ECTI Northern Section Conference on Electrical, Electronics, Computer and Telecommunications Engineering (ECTI DAMT & NCON), Pattaya, Thailand, 2020, pp. 352-357, doi: 10.1109/ECTIDAMTNCON 48261.2020. 9090 723.

Saaty, T.L. (2000). Fundamentals of decision making and priority theory with the analytical hierarchy process. RWS Publications, Pittsburgh, Pa.

Saaty, T.L. (2004). Rank from comparisons and from ratings in the analytical hierarchy/ network processes. European Journal of Operational Research, 168(2): 557-570.

Saaty, T.L., and Ozdemir, M. (2003). Negative priorities in the analytical hierarchy process. Mathematical and Computer Modeling, 37: 1063-1075.

Tanaka, H., Tsukao, S., Yamashita, D., Niimura, T. & Yokoyama, R. (2010). Multiple Criteria Assessment of Substation Conditions by Pair-Wise Comparison of Analytic Hierarchy Process. IEEE Transactions on Power Delivery, 25, 3017-3023.

Visser, J.K. and Botha, T.A. (2015). Evaluation of the importance of the 39 subjects defined by the global forum for maintenance and asset management. South African Journal of Industrial Engineering, 26 (1), pp.44-58.

Wang, M., Nimmolrat, A. and Khamaksorn, A., (2021), March. Knowledge Flows Through Social Networks in New-born Intensive Care Units. In 2021 Joint International Conference on Digital Arts, Media and Technology with ECTI Northern Section Conference on Electrical, Electronics, Computer and Telecommunication Engineering (pp. 96-101). IEEE.

Woodhouse. (2006). IAM Competencies Project, Institute of Asset Management (UK) Members Conference.

Yalun, L, and Khamaksorn, A. (2020), "A Review of Applying Healthy Dietary Nutrition Knowledge in Tertiary Education Setting," 2020 Joint International Conference on Digital Arts, Media and Technology with ECTI Northern Section Conference on Electrical, Electronics, Computer and Telecommunications Engineering (ECTI DAMT & NCON), Pattaya, Thailand, 2020, pp. 342-346, doi: 10.1109/ECTI DAMTNCON48261.2020. 9090755.