Heliyon 10 (2024) e30159

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

The knowledge and holistic management indicators to measure the sustainability of area-based infrastructure project (AIP)

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ARTICLE INFO

Keywords:
Sustainable development
Area-based infrastructure
Sustainability infrastructure
Infrastructure development
Sustainability indicators
Knowledge management

ABSTRACT

For determining the effectiveness of area-based infrastructure management, a comprehensive measurement to implement and develop an infrastructure project would need to be integrated in holistic and knowledge management. The main objective of this study was to identify the keys to measurement the sustainability of area-based infrastructure project (AIP) management. First, the key performance indicators were reviewed and selected. Next, the interviews with project developers and managers of the pilot site were conducted to investigate the real context of significant keys. The discussion with five experts who have relevant experience in area-based infrastructure projects management then arose to validate possible key performance indicators. Based on the expert comments, the questionnaire was revised for its validity and clarity. Then, the data collection using a questionnaire was sent out to representative samples across Thailand. Later, there was the analysis to interpret the survey results. The results revealed that there are two groups of keys to measure the sustainability of AIP management. One was the "Holistic Management (HM)", which consisted of seventeen components. The other was the "Knowledge Management (KM)", which involved six similarity items. It was found that the aforementioned factors can explain 70.024% of the total cumulative variance in the entire datasets compiled for the assessment of keys to measurement the sustainability of AIP management. The main outcomes from this study can be beneficial for the development of effective and good governance strategies for achieving sustainability patterns of area-based infrastructure project management. This theory offers the understanding of how the effectiveness of key measurement of AIP management can drive sustainable development project s, which can help in project manager and developer research on identity-related transitions.

1. Introduction

It is a true fact that the concept for area-based sustainable development should emphasise on a more holistic and integrated perspective to avoid failure in meeting project requirements and satisfaction of stakeholders, which will result in social equity, economic efficiency, and environmental performance [1–4]. Therefore, the processes of operational planning, project monitoring and implementation with environmental, economic, and socio-geographic acceptance, as well as driving infrastructure development, should be underlined. Besides that, the dimensions related to social, culture, natural resources, technology, knowledge, networking

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https://doi.org/10.1016/j.heliyon.2024.e30159
Received 25 February 2024; Received in revised form 13 April 2024; Accepted 21 April 2024
Available online 23 April 2024

opportunities, and changing global trends, is also of paramount importance for sustainable development of the relevant areas (Office of the Royal Development Projects Board [5–12].

Regarding the achievement of infrastructure sustainability, there are several studies related to the influencing factors possibly driving sustainability [13–18]. However, the projects might not be functioning at full efficiency as expected due to a lack of appropriate project investigation and evaluation processes [7,11,19,20]. In addition, the combination between top-down and bottom-up approaches could fulfil both community requirements and policy guidelines for public sectors [21,22].

The critical problems of area-based infrastructure management are exacerbated by a community participation barrier, unsuitable plans, local economic instability, inappropriate management, administrative complication [23–25] and lack of knowledge strategy on sustainability [26]. Also, the key measurement to measure the sustainability of area-based infrastructure project management needs to be explored [1,7,11]. Although, the previous research studied the key measurement to measure community infrastructure sustainability [19]. However, the subcomponents need to be identified. Based on the aforesaid concerns, this research objective intended to address the key performance of knowledge and holistic management indicators which measured the sustainable management of the area-based infrastructure project (AIP).

2. Literature review

Infrastructure projects provide benefits to communities and nations at the social, economic and environmental levels [9,12]. The development of area-based infrastructure is also likely to be incremental in response to area-based needs, which requires a massive budget and immediate responses from public sectors in managing projects. Since the plan and management of rural infrastructures is under the supervisory authority of the local administrative organisations, mutual understandings among relevant parties would then need to be formed and driven for availability and accessibility of infrastructure services [25]. The local authorities would also be asked to allocate more resources for shifting policies towards sustainability, while networking and collaborative relationships with public agencies could help them in saving resources and sharing knowledge and best practices [27,28].

To obtain more open, effective, and equitable public participation, the local authorities should also show their commitment, response, and accountability [29]. Moreover, the tool called "performance measurement" is also vital for the management of infrastructure facilities and services by revealing how well the services can be performed [30–33]. However, it was found that the council and staff are unable to make progress in developing infrastructure projects [25], while the detailed descriptions of project objectives, identification of principal issues, and expected outcomes, are still needed for clarification. In addition, a set of management indicators for assessing the success and sustainability of infrastructure projects seem to be lacking, while there is also a lack of infrastructure project management standards and the integration of multi-dimensional knowledge. In fact, the area-based development plan can be targeted with clear objectives that lead to more effective and sustainable development and management of area-based infrastructures with the three pillars of sustainability, i.e. economic growth, social development, and natural conservation pattern [34,35].

For instance, starting with Aksorn and Charoenngam [23] who found that there are multiple interrelated factors that contribute to successful implementation of local infrastructure projects, including management and administration, information and knowledge, policy and plan, environmental and natural resources, facility and infrastructure, and finance and budget. Mancini and Marek [36] developed a Program Sustainability Index (PSI) based on a homogeneous group (242 respondents) for evaluating the sustainability of community-based programs. In detail, the PSI includes 53 items reflecting seven sustainability elements, i.e. leadership competence, effective collaboration, understanding of relevant areas, demonstrating program results, strategic funding, staff involvement and integration, and program responsivity.

From empirical research, the Integrated Management System (IMS) is a significant positive predictor of Corporate Sustainability (CS) and all its dimensions [37]. Furthermore, the role of governance and sustainable development included policies, organisational structure, certification, budget, reports, staff training, team for sustainability, and integration of sustainability and governance [38]. Also, the establishment and evolution of the environmental protection agency also attracted the most attention for addressing environmental governance, resource management, and pollution control [39,40]. Moreover, the knowledge of research development in infrastructure management and engineering has been used for evaluating and identifying the impact of procedures or events on the process of construction [41]. The knowledge-based development centre can transfer and contribute to a knowledge-based economy through developing an environment that will attract knowledge and creative human activities and careers [42]. In addition, the academy could promote the sustainable development by incorporating education on sustainability into curricular requirements and extracurricular activities, taking responsibility for training future professionals, and evaluating the impact of public initiatives in generating sustainable behaviour [43,44]. Likewise, the management of complex social-ecological systems also requires information and knowledge on ecological and social variables for describing their characteristics and interactions [45]. Aksorn and Charoenngam [1,19,46] conducted the study on factors and measurements for the sustainable development of Community Infrastructure Projects (CIP) in the areas of socio-economic conditions, natural environment, and related culture. Similarly, Mridha et al. [47] also identified the key components such as policy and plan, information and knowledge, finance and budget, natural resources and environment, management and administration, and facility and infrastructure, for the efficient sustainable smart approach to biofuel production with emphasising the environmental and energy aspects. In fact, several studies emphasised the role of effective management in fostering trust, respect, and collaboration between community members and stakeholders. However, as suggested by Kavalić et al. [48], there is a need for additional research on the influencing factors model and keys to measurement qualified sustainability to promote community cooperation and attain desired outcomes.

In brief, the subcomponents of knowledge and holistic management indicators to measure the sustainability of AIP are required to be identified. The aforesaid keys are actually based on the capability of adjusted variables, development projects coping with expanding and maintaining benefits for a longer period after the project inputs have come to an end. To fulfil all the requirements, the outputs of area-based infrastructure projects are taken in proceeding to implement the plan.

3. Research methodology

Overall, this study employed a combination of qualitative and quantitative approaches. Firstly, the theoretical background, which illustrates professional practices in achieving the sustainability of AIP, was compiled from different sources. Then, the pre-survey was conducted for examining and estimating the preliminary keys to measure the sustainability of AIP management. The interview was carried out with regional and area-based experts and then through focus group discussions. The semi-structured interviews were then undertaken with five key experts to gather in-depth information on area-based conditions.

The step-by-step procedure, which was employed for selecting a set of indicators to measure the sustainability of AIP management, can be summarised as follows.

1) First, there are more than 90 indicators from literatures in different perspectives and regions were found. However, only 32 key indicators were related with knowledge and holistic management of infrastructure development. Then, the group discussions with experienced project managers and infrastructure developers in Thailand were hold. The discussion purposed to follow the right procedure to combine both qualitative and quantitative process. However, many indicators were cut off and some could be combined. Consequently, only 29 indicators of knowledge and holistic management to measure the sustainable development and area-based infrastructures sustainability were selected to proceed in the next step.
2) Next, the content validity of selected indicators has to be confirmed. For this stage, the five experts who were willing to participate and have at least 15 years of experience in managing, implementing, and developing infrastructure projects were asked to provide their opinions. Only 27 key indicators were confirmed from at least 3 of 5 experts' selection. The 3 indicators were cut off (see Table 1).
3) Then, the draft questionnaire was developed for conducting the survey which a five-point Likert scale-based with categories ranging from 1 = strongly disagree to 5 = strongly agree. The questionnaire consisted of three parts that are: 1) general information of interviewees, 2) questions on keys indicators of sustainability infrastructure project management in practice, and 3) comments and suggestions on questionnaire. The details of every part of questionnaire are presented below and in Table 2. The questionnaire was sent back to five experts from the same group in stage 2 for commenting and suggesting.
4) After that, the modified questionnaire based on the expert comments was mailed to Local Administrative Organisations (LAOs) throughout Thailand. The relevant stakeholders, i.e. project developers, project managers, practitioners, researchers, and on-site

Table 1
Knowledge and holistic management indicators to measurement the sustainability of AIP, item coding and content validity.

No	Attributes	Coding	Descriptions	Expert Validated	References
1	Productivity centre	Ind01	Learning centre for productivity improvement	Yes	[11,49–52]
2	Knowledge centre	Ind02	Information and knowledge centre	Yes	[11,53–55]
3	Evaluation	Ind03	The satisfactory evaluation of project from service users	Yes	[56,57]
4	Efficiency	Ind04	Promoting higher organisational efficiency	Yes	[35,55,58]
5	Investment	Ind05	Other investment projects followed	Yes	[55,59]
6	Project objectives	Ind06	Carrying out projects according to objectives	Yes	[60]
7	Competence	Ind07	Local leadership competence to manage and cooperate project	Yes	[19,61]
8	Product and income	Ind08	Creating new products or generate income for the area	Yes	[35,62]
9	Infrastructure	Ind09	Long period physical infrastructures support	Yes	[35,63–65]
10	Quality of life	Ind10	Better quality of life for people in area	Yes	[35,66,67]
11	Participation	Ind11	Public and private participation	Yes	[35,56,68]
12	Environment conservation	Ind12	Area-based environment conservation	Yes	[69–76]
13	Community participation	Ind13	Integration of public and community participation	Yes	[35,55,77,78]
14	Time frame	Ind14	Project implementation is within the specified time frame	Yes	[55,79]
15	Resources	Ind15	Worthwhile utilising resources	Yes	[35,80]
16	Employment	Ind16	Increasing of area-based employment	Yes	[35]
17	Development pattern	Ind17	The development and management of the area-based pattern	Yes	[81]
18	Economy	Ind18	The continuous of area-based economy growing	Yes	[35]
19	Existing infrastructure	Ind19	Able to build on the existing infrastructure in area	Yes	[82,83]
20	Conflict management	Ind20	Reducing conflicts that arise within the area	Yes	[35]
21	National resource	Ind21	Natural resources have been restored	Yes	[84,85]
22	Environment	Ind22	Project implementation process that does not poison the environment	Yes	[86,87]
23	Integration	Ind23	Integration of economic, social, environmental, and cultural aspects	Yes	[5,8,13]
24	Project implementation	Ind24	Implementation project by considering environmental conservation	Yes	[71–73,88,89]
25	Budget	Ind25	Budget allocation to the project during operation	Yes	[90]
26	Local knowledge	Ind26	The application of local knowledge to project	Yes	[42]
27	Forests and watersheds	Ind27	The conservation of forests and watersheds	Yes	[69]
28	Implementation	Ind28	The standard achievement to implement project	No	[55,91]
29	Environment conservation	Ind29	The conservation of forest and headwater	No	[71]

Note: Yes = the key indicators selected by at least 3 of 5 experts (content validity) No = the key indicators selected less than 3 of 5 experts (not content validity).

Table 2
Demographic profile of respondents (n = 645).

Respondents' profile	Number	Percentage
Organisations		
Subdistrict Administrative Organization (SAO)	424	65.74
Provincial Administrative Organization (PAO)	9	1.40
Subdistrict Municipality (SM)	172	26.67
City Municipality (CM)	36	5.58
Town Municipality (TM)	3	0.47
Positions		
Policy maker	31	4.81
Manager	45	6.98
Specialist	7	1.09
Inspector	30	4.65
Researcher	40	6.20
Technician	492	76.28
Educations		
Undergraduate	96	14.88
Bachelor	404	62.64
Master	141	21.86
Doctoral	4	0.62
Sex		
Male	326	50.54
Female	319	49.46
Working's experience (years) mean =	13.03	std = 9.337
Age (years) mean =	42.21	std = 9.528

project staff, who serve the LAOs need to participate. Also, the link to the online version was attached for the ease of replying for all LAOs.

5) Finally, the completed questionnaire was then analysed and interpreted the results descriptively by using SPSS program.

3.1. Questionnaire details

The questionnaire consisted of three parts. The first part is general information of the interviewees (including gender, age, education, position, and professional experience). The second part is the questions developed with categories of indicators ranging from 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree to measure the sustainability of infrastructure project management in practice. The third part is the comments and suggestions on questionnaire content. The part of questionnaire is shown as below.

Part I: General information of interviewees.

Explanation: Please insert ✓ into *F0A6* which the exactly related your characteristic.

1 Organization
F0A6 Subdistrict Administrative Organization (SAO)
F0A6 Provincial Administrative Organization (PAO)
F0A6 Subdistrict Municipality (SM)
F0A6 City Municipality (CM)
F0A6 Town Municipality (TM)
F0A6 Other …. …. …. …. …. …. …. …. …. …. …. …. …. …. …

2. Your work or responsibility (you can choose more than 1 item)
F0A6 Policy maker
F0A6 Manager
F0A6 Specialist
F0A6 Inspector
F0A6 Researcher
F0A6 Technician
F0A6 Other …. …. …. …. …. …. …. …. …. …. …. …. …. …. …

3 Education
F0A6 Under bachelor
F0A6 Bachelor
F0A6 Master
F0A6 Doctor

4. Sex

F0A6 Male
F0A6 Female
F0A6 Not specified
5. Age … … … … …. years old
6. Work eexperience … … … … …. years

Part II: Please read each statement in this part carefully. Using the ranking scale of 1 through 5 below, for your opinion, how these indicators effect on sustainability infrastructure project management in practice. Please check a mark (✓) in an appropriate box on the right of each statement. Interpretations of the scale 1 through 5 are:
5 defined as the factors that are strongly agreed.
4 defined as the factors that are agreed.
3 defined as the factors that are neutral.
2 defined as the factors that are disagreed.
1 defined as the factors that are strongly disagreed.

Key indicators for sustainability of infrastructure project management in practice			Scale				
			1	2	3	4	5
Coding and key indicators							
Ind00	0.	Example indicators					✓
Ind01	1.	Learning centre for productivity improvement					
Ind02	2.	Information and knowledge centre					
Ind03	3.	The satisfactory evaluation of project from service users					
Ind04	4.	Promoting higher organisational efficiency					
Ind05	5.	Other investment projects followed					
…	…	…					

Part III: Please give your comment and suggestion.
… ….

4. Data collection and analysis

The majority of infrastructure projects with high significant impacts on area-based development in Thailand are connected with transportation systems, water resources, and other related issues [11,23]. In details, there are many LAOs who take full responsibility for the development of area-based infrastructure projects, i.e. Subdistrict Administrative Organization (SAO), Provincial Administrative Organization (PAO), Subdistrict Municipality (SM), City Municipality (CM), and Town Municipality (TM). All of the organisations mentioned above are worth coping very well with studying all target populations for the expected outcome (Department of Local Administration [92].

In the context of questionnaire development, a survey was conducted to verify the applicability of keys to measurement for AIP management. All of the target respondents were from 7850 LAOs in Thailand who were involved with related projects during the past decades [92]. Therefore, it can be assured that the selected target respondents are the best representatives for describing the focused key performance indicators.

4.1. Data analysis and results

The questionnaire was analysed and confirmed by the SPSS program for Windows. An Exploratory Factor Analysis (EFA) was used to examine content validity and reliability of the questionnaire. The Cronbach's alphas were calculated to investigate the reliability of the instrument, to evaluate the internal consistency of factors, and help to determine where the items best fit when multiple factors influence the items. For a new instrument development, a higher cutoff of 0.70 was the normal number of measurements used in calculating the content reliability coefficient [93]. The analysis showed that the reliability of all constructs was higher than 0.70, which means that it meets the standard practice for enhancing the likelihood of acceptance. There are five major steps to be undertaken for factor analysis as listed below [94]:

(1) Identifying the variables;
(2) Computing a correlation matrix among the variables;
(3) Extracting the unrotated factors to see whether the chosen model fits the data reasonably well or not;
(4) Rotating the factors;
(5) Interpreting and labelling the rotated factor matrix.

The total number of 8000 revised offline and online (Google forms) questionnaires with some comprehensive issues to meet all expected outcomes were sent to target respondents, including project developers, project managers, staff, and project representatives. Besides that, the 645 forms with complete response were analysed. According to the analysis, it was found that most of the respondents are from SAOs (65.74%), 76.28% of respondents are technicians, 62.64% have a bachelor degree, and 50.54% are male. Moreover, the average working experience was found to be 13.03 years, with the average age of 42.21 years, while more detailed information can be seen in Table 2 below.

4.2. Validity and reliability test

In this study, both Bartlett's test of Sphericity and Kaiser-Meyer-Olkin (KMO) test were applied. The latter test was used to evaluate sampling adequacy and measure whether the partial correlations among variables (0.986) is larger than 0.70. The Bartlett Sphericity test was performed to determine whether the correlation matrix is an identity matrix. With a significant value (p-value) of 0.001 is less than 0.05, the correlation matrix is considered to be significant and it is not an identity matrix, which recommended that variables are correlated as shown in Table 3 (Pett et al., 2003). Moreover, Cronbach's alpha was also calculated to assess the reliability of the questionnaire, as shown in Table 7. Based on the Cronbach's alpha coefficient of more than 0.70, it can be stated that all variables have good internal consistency reliability, and they can be used to conduct this research [93].

The multicollinearity test and correlation matrix were also analysed as shown more details in Table 4. According to Pett et al. [95], the correlation matrix was constructed using variables indicated in the questionnaire for examining the item consistency, and for identifying items that were either too highly correlated ($r \geq 0.80$) or not sufficiently correlated with the others ($r \leq 0.30$). In case the items were too highly correlated, there will be a problem of multicollinearity and one or more highly correlated items would need to be ignored from the analysis. When the items are not correlated with each other, this could result in not much shared common variance and would lead to as many factors as items for further study. According to Nunnally and Berstein [94], the p-value was set as less than 0.05 for statistical significance, which corresponds to a confidence level of 95%. Based on the calculation as indicated in Table 4, the items of management indicator as abbreviated as Ind, including Ind02, Ind12, Ind24, and Ind26 were cut off (from 27 indicators in total) since the correlations were higher than 0.80.

4.3. Mean and ranking

The mean and ranking of the keys to measure the sustainability of AIP can be shown in Table 5. The maximum mean score was "the development and management of the area-based pattern" with the value of 4.05 (Ind17), while the minimum mean score of 3.29 was for "the learning centre for productivity improvement" (Ind01). The distribution of scores for each of the top three indicators, which is considered as part of the key performance indicators and is essential for the sustainable development and management of AIP in Thailand, was also described by a box plot shown in Fig. 1. There is a significant difference between the top three indicators, i.e. Ind17, Ind18, and Ind22, because the numerical values of the minimum, lower quartile, and mean are all skewed up. This statement is confirmed by the average mean values which increased from 3.93 for Ind22 to 4.05 for Ind17).

According to Pett et al. [95], the approach for determining the numbers of initial factors was to select only those factors with eigenvalues of greater than 1.00. In this case, the eigenvalues of factors as listed in Table 6, represent how much the total variance of all variables can be explained by the factors. This means that those factors would account for a large share of the total variance explained by the items. To evaluate the number of components required for capturing most information contained in the data, a graphical representation known as a scree plot was constructed as seen in Fig. 2.

4.4. Exploratory factor analysis (EFA)

In this study, the Principal Component Analysis (PCA) with a varimax rotation was conducted to assign factor loading. The factor loading on possible factors that cannot clearly be assigned to just one factor, shall be removed from the samples and the principal component analysis. Under the criterion of eigenvalues of greater than one, the two extracted factors were explained by approximately 70.024% of the variance in responses. Referring to Fig. 2, it was noticed that the relative eigenvalues decrease when the component number increases. The scree plot curve was almost flat from the second factor onwards, which means that two factors would probably be appropriate to be taken into consideration in subsequent analysis.

The Exploratory Factor Analysis (EFA) using a varimax rotation was carried out to investigate the factor structure of the questionnaire, to examine its internal reliability, and also to eliminate items. Referring to the obtained results indicated in Table 7 and Fig. 2, the analysis revealed a two-factor solution based on eigenvalues greater than one. The two groups of key performance indicators were Holistic Management (HM) consisting of 17 key performance indicators, and Knowledge Management (KM) with 6 key

Table 3
Bartlett's test of Sphericity and the Kaiser-Meyer-Olkin (KMO) test.

Bartlett's test of Sphericity	Approx. Chi-Square	56628.227
	df	3321
	Sig.	0.001
Kaiser-Meyer-Olkin measure of sampling adequacy		0.986

Table 4
Correlation matrix for variables.

Items	Ind01	Ind02	Ind03	Ind04	Ind05	Ind06	Ind07	Ind08	Ind09	Ind10	Ind11	Ind12	Ind13	Ind14	Ind15	Ind16	Ind17	Ind18	Ind19	Ind20	Ind21	Ind22	Ind23	Ind24	Ind25	Ind26	Ind27
Ind01	1.000	0.857	0.667	0.585	0.652	0.525	0.530	0.680	0.501	0.439	0.523	0.553	0.538	0.424	0.472	0.560	0.429	0.410	0.532	0.520	0.483	0.450	0.498	0.502	0.522	0.501	0.514
Ind02	0.857	1.000	0.703	0.654	0.703	0.540	0.537	0.675	0.514	0.435	0.547	0.538	0.565	0.458	0.528	0.597	0.450	0.426	0.520	0.522	0.475	0.491	0.558	0.554	0.527	0.548	0.544
Ind03	0.667	0.703	1.000	0.773	0.715	0.661	0.653	0.687	0.622	0.540	0.610	0.604	0.627	0.522	0.596	0.608	0.569	0.572	0.626	0.573	0.555	0.568	0.595	0.617	0.617	0.615	0.592
Ind04	0.585	0.654	0.773	1.000	0.750	0.736	0.701	0.661	0.665	0.636	0.671	0.653	0.671	0.596	0.672	0.624	0.654	0.631	0.630	0.582	0.611	0.645	0.673	0.714	0.684	0.687	0.620
Ind05	0.652	0.703	0.715	0.750	1.000	0.713	0.660	0.744	0.591	0.565	0.632	0.604	0.611	0.522	0.586	0.624	0.543	0.526	0.562	0.547	0.566	0.561	0.636	0.584	0.590	0.599	0.622
Ind06	0.525	0.540	0.661	0.736	0.713	1.000	0.752	0.626	0.690	0.645	0.657	0.642	0.663	0.640	0.681	0.624	0.703	0.658	0.603	0.525	0.587	0.652	0.638	0.667	0.664	0.677	0.622
Ind07	0.530	0.537	0.653	0.701	0.660	0.752	1.000	0.688	0.669	0.626	0.625	0.660	0.695	0.607	0.648	0.591	0.650	0.595	0.618	0.526	0.607	0.629	0.649	0.664	0.665	0.664	0.582
Ind08	0.680	0.675	0.687	0.661	0.744	0.626	0.688	1.000	0.649	0.597	0.651	0.669	0.663	0.540	0.576	0.664	0.542	0.530	0.611	0.571	0.582	0.537	0.603	0.595	0.599	0.599	0.604
Ind09	0.501	0.514	0.622	0.665	0.591	0.690	0.669	0.649	1.000	0.714	0.692	0.685	0.682	0.640	0.666	0.621	0.626	0.618	0.609	0.540	0.595	0.656	0.590	0.678	0.655	0.661	0.626
Ind10	0.439	0.435	0.540	0.636	0.565	0.645	0.626	0.597	0.714	1.000	0.723	0.731	0.706	0.625	0.635	0.580	0.639	0.598	0.633	0.543	0.603	0.640	0.604	0.652	0.680	0.650	0.641
Ind11	0.523	0.547	0.610	0.671	0.632	0.657	0.625	0.651	0.692	0.723	1.000	0.767	0.771	0.624	0.688	0.668	0.634	0.618	0.668	0.553	0.629	0.629	0.614	0.678	0.679	0.678	0.625
Ind12	0.553	0.538	0.604	0.653	0.604	0.642	0.660	0.669	0.685	0.731	0.767	1.000	0.851	0.662	0.737	0.687	0.683	0.660	0.707	0.591	0.645	0.680	0.658	0.694	0.726	0.714	0.695
Ind13	0.538	0.565	0.627	0.671	0.611	0.663	0.695	0.663	0.682	0.706	0.771	0.851	1.000	0.719	0.742	0.679	0.708	0.678	0.705	0.607	0.688	0.693	0.683	0.723	0.747	0.726	0.686
Ind14	0.424	0.458	0.522	0.596	0.522	0.640	0.607	0.540	0.640	0.625	0.624	0.662	0.719	1.000	0.791	0.580	0.690	0.673	0.640	0.563	0.651	0.649	0.630	0.692	0.696	0.668	0.642
Ind15	0.472	0.528	0.596	0.672	0.586	0.681	0.648	0.576	0.666	0.635	0.688	0.737	0.742	0.791	1.000	0.739	0.732	0.698	0.681	0.603	0.672	0.701	0.682	0.744	0.721	0.730	0.698
Ind16	0.560	0.597	0.608	0.624	0.624	0.624	0.591	0.664	0.621	0.580	0.668	0.687	0.679	0.580	0.739	1.000	0.673	0.612	0.662	0.590	0.595	0.591	0.563	0.635	0.631	0.638	0.683
Ind17	0.429	0.450	0.569	0.654	0.543	0.703	0.650	0.542	0.626	0.639	0.634	0.683	0.708	0.690	0.732	0.673	1.000	0.757	0.661	0.534	0.620	0.675	0.593	0.681	0.699	0.653	0.611
Ind18	0.410	0.426	0.572	0.631	0.526	0.658	0.595	0.530	0.618	0.598	0.618	0.660	0.678	0.673	0.698	0.612	0.757	1.000	0.720	0.598	0.642	0.678	0.603	0.667	0.696	0.638	0.601
Ind19	0.532	0.520	0.626	0.630	0.562	0.603	0.618	0.611	0.609	0.633	0.668	0.707	0.705	0.640	0.681	0.662	0.661	0.720	1.000	0.684	0.689	0.654	0.667	0.692	0.729	0.693	0.701
Ind20	0.520	0.522	0.573	0.582	0.547	0.525	0.526	0.571	0.540	0.543	0.553	0.591	0.607	0.563	0.603	0.590	0.534	0.598	0.684	1.000	0.695	0.572	0.615	0.620	0.633	0.630	0.654
Ind21	0.483	0.475	0.555	0.611	0.566	0.587	0.607	0.582	0.595	0.603	0.629	0.645	0.688	0.651	0.672	0.595	0.620	0.642	0.689	0.695	1.000	0.674	0.664	0.670	0.724	0.663	0.679
Ind22	0.450	0.491	0.568	0.645	0.561	0.652	0.629	0.537	0.656	0.640	0.629	0.680	0.693	0.649	0.701	0.591	0.675	0.678	0.654	0.572	0.674	1.000	0.720	0.763	0.722	0.723	0.652
Ind23	0.498	0.558	0.595	0.673	0.636	0.638	0.649	0.603	0.590	0.604	0.614	0.658	0.683	0.630	0.682	0.563	0.593	0.603	0.667	0.615	0.664	0.720	1.000	0.763	0.716	0.760	0.714
Ind24	0.502	0.554	0.617	0.714	0.584	0.667	0.664	0.595	0.678	0.652	0.678	0.694	0.723	0.692	0.744	0.635	0.681	0.667	0.692	0.620	0.670	0.763	0.763	1.000	0.821	0.831	0.752
Ind25	0.522	0.527	0.617	0.684	0.590	0.664	0.665	0.599	0.655	0.680	0.679	0.726	0.747	0.696	0.721	0.631	0.699	0.696	0.729	0.633	0.724	0.722	0.716	0.821	1.000	0.804	0.738
Ind26	0.501	0.548	0.615	0.687	0.599	0.677	0.664	0.599	0.661	0.650	0.678	0.714	0.726	0.668	0.730	0.638	0.653	0.638	0.693	0.630	0.663	0.723	0.760	0.831	0.804	1.000	0.810
Ind27	0.514	0.544	0.592	0.620	0.622	0.622	0.582	0.604	0.626	0.641	0.625	0.695	0.686	0.642	0.698	0.683	0.611	0.601	0.701	0.654	0.679	0.652	0.714	0.752	0.738	0.810	1.000

Note: Correlation is significant at less than 0.05 level (2-tailed).

Table 5
Mean and ranking of the keys to measurement the sustainability of AIP management.

No.	Coding	Attributes	Mean	SD	Ranking
1	Ind01	Learning centre	3.29	1.148	27
2	Ind02	Information and knowledge	3.40	1.088	26
3	Ind03	Evaluation	3.70	0.971	21
4	Ind04	Efficiency	3.80	0.890	15
5	Ind05	Investment	3.60	0.976	24
6	Ind06	Project objectives	3.90	0.879	**5**
7	Ind07	Competence	3.81	0.847	14
8	Ind08	Product and income	3.57	1.027	25
9	Ind09	Infrastructure	3.84	0.880	11
10	Ind10	Quality of life	3.88	0.849	8
11	Ind11	Participation	3.81	0.874	13
12	Ind12	Environment conservation	3.80	0.865	17
13	Ind13	Community participation	3.85	0.853	10
14	Ind14	Time frame	3.90	0.829	**4**
15	Ind15	Resources	3.90	0.846	6
16	Ind16	Employment	3.71	0.954	18
17	Ind17	Development pattern	4.05	0.859	**1**
18	Ind18	Economy	4.00	0.857	**2**
19	Ind19	Existing infrastructure	3.80	0.867	16
20	Ind20	Conflict management	3.66	0.961	23
21	Ind21	National resource	3.71	0.893	20
22	Ind22	Environment	3.93	0.844	**3**
23	Ind23	Integration	3.67	0.920	22
24	Ind24	Project implementation	3.87	0.857	9
25	Ind25	Budget	3.89	0.868	7
26	Ind26	Local knowledge	3.83	0.869	12
27	Ind27	Forests and watersheds	3.71	0.917	19

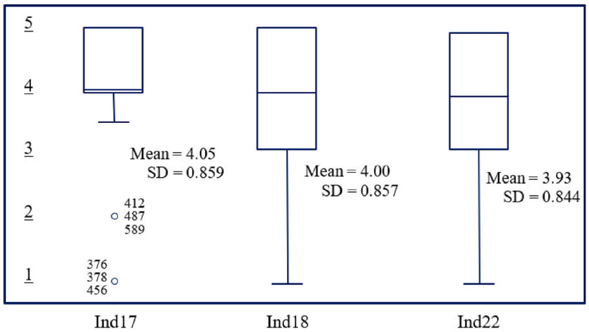

Fig. 1. Box plot of the scores corresponding to the top three indicators essentially important for the measurement of the sustainability of AIP management.

performance indicators, in which both of them accounted for 70.024% of the variance in responses and should also be extracted. Apart from that, the principal axis factor analysis with varimax rotation was conducted to reduce the 23 explanatory variables to two factors having eigenvalues of greater than 1.00, and also to explore the underlying structure that explains the variance in a set of 23 remaining items from 27 items indicated in the questionnaire. After varimax rotation, the first group of factors called HM accounted for 42.292% of the variance, while the KM group was for 27.733%.

A set of keys to measurement the sustainability of AIP was presented, in which a strong positive correlation between the two groups (i.e. HM and KM) was found with the coefficient of 0.645 as shown by the dotted line in Fig. 3. Regarding the group of HM, the first five indicators with the highest Loading Factor (LF) were listed as follows.

1) Project implementation is within the specified time frame (Ind14, LF = 0.805);
2) Worthwhile utilising resources (Ind15, LF = 0.803);
3) The continuous of area-based economy growing (Ind18, LF = 0.794);
4) The development and management of the area-based pattern (Ind17, LF = 0.784);
5) Budget allocation to the project during operation (Ind25, LF = 0.776).

Meanwhile, the first five indicators with the highest LF under the group of KM can also be listed below.

Table 6
Total variance explained by the key performance indicators.

Component	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative (%)	Total	% of Variance	Cumulative (%)
1	14.903	64.796	64.796	9.727	42.292	42.292
2	1.203	5.228	70.024	6.379	27.733	70.024
3	0.788	3.427	73.451			
4	0.587	2.553	76.005			
5	0.566	2.461	78.466			
6	0.462	2.007	80.473			
7	0.407	1.769	82.242			
8	0.388	1.686	83.928			
9	0.368	1.598	85.527			
10	0.352	1.531	87.057			
11	0.327	1.421	88.478			
12	0.312	1.357	89.835			
13	0.299	1.299	91.135			
14	0.276	1.201	92.336			
15	0.257	1.119	93.455			
16	0.232	1.007	94.462			
17	0.218	0.950	95.412			
18	0.210	0.912	96.324			
19	0.188	0.819	97.143			
20	0.183	0.794	97.936			
21	0.168	0.730	98.666			
22	0.163	0.710	99.376			
23	0.143	0.624	100.000			

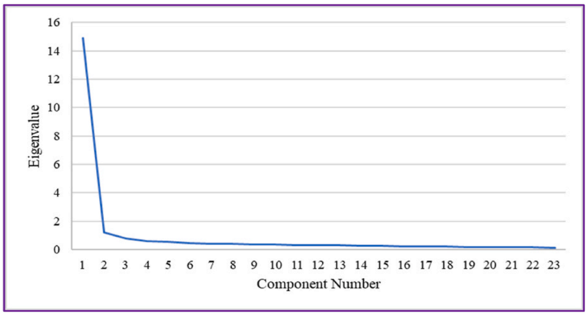

Fig. 2. Scree plot of the eigenvalues and number of components from the Principal Component Analysis (PCA).

1) Learning centre for productivity improvement (Ind01, LF = 0.820);
2) Other investment projects followed (Ind05, LF = 0.810);
3) Creating new products or generate income for the area (Ind08, LF = 0.787);
4) The satisfactory evaluation of project from service users (Ind03, LF = 0.775);
5) Promoting higher organisational efficiency (Ind04, LF = 0.681).

5. Discussion and conclusion

In this study, the development of a scientific and methodological approach for the formation of keys to measurement the sustainability of Area-based Infrastructure Project (AIP) in Thailand was concentrated. It was evident that there are two significant groups of key performance indicators that should be considered separately in discussing their obtained results in details, namely "Holistic Management (HM)" and "Knowledge Management (KM)" referring to Table 7, the first five indicators with the highest loading factor for HM were 1) project implementation is within the specified time frame (Ind14), 2) worthwhile utilising resources (Ind15), 3) the continuous of area-based economy growing (Ind18), 4) the development and management of the area-based pattern (Ind17), and 5) budget allocation to the project during operation (Ind25). Moreover, the important issues related to project implementation process that does not poison the environment, integration of public and community participation, and integration of economic, social, environmental, and cultural aspects, were also ranked as the 6th to 8th indicators, respectively, that are likely to affect the sustainability of AIP in Thailand. In brief, the aforesaid indicators could be one of the key management factors behind the success of the sustainability of AIP in Thailand if they are considered as important factors in decision-making processes under a clear/holistic integration policy and participation management strategy. Furthermore, the obtained findings from this study, especially the issue

Table 7
Factor analysis results after varimax rotation used for generating meaningful key performance indicators of the sustainability of AIP management.

Item	Component		Factors	Cronbach's alpha		% of variance explained	% Cumulative of variance
	1	2					
Ind14	0.805		Holistic management (HM)	0.923	**0.978**	42.292	**70.024**
Ind15	0.803						
Ind18	0.794						
Ind17	0.784						
Ind25	0.776						
Ind22	0.768						
Ind13	0.744						
Ind21	0.732						
Ind19	0.726						
Ind27	0.693						
Ind10	0.692						
Ind23	0.670						
Ind11	0.648						
Ind09	0.633						
Ind20	0.606						
Ind16	0.600						
Ind06	0.599						
Ind01		0.820	Knowledge management (KM)	0.970		27.733	
Ind05		0.810					
Ind08		0.787					
Ind03		0.775					
Ind04		0.681					
Ind07		0.598					

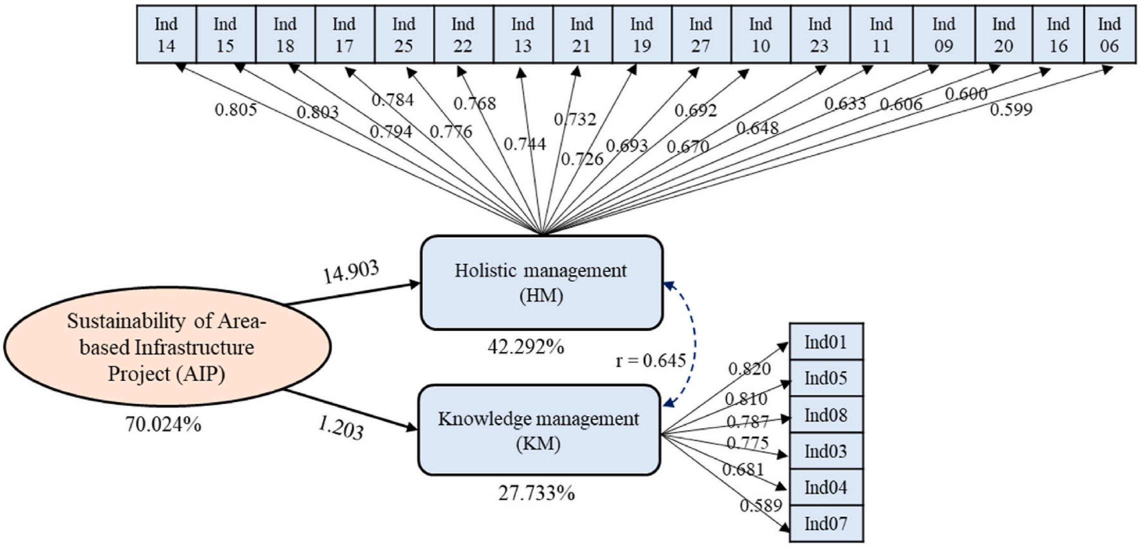

Fig. 3. Keys to measurement the sustainability of AIP management.

related to holistic integration, was found to be correspondent with the statement of Rist and Dahdouh-Guebas [96]. In fact, the holistic integration of indigenous knowledge and technoscientific approaches into contemporary frameworks for sustainable management of natural resources become important at the national level, both in countries that are industrialised and developing status. The participation management issue emphasised in this study was also in line with Kandpal and Saizen [97] who proved that the policy-level support to participation management can help in fostering local partnerships and community initiatives towards better service delivery in the communities. This kind of social empowerment forms the basis for social sustainability, which in turn promotes environmental and economic sustainability. The results are consistent with that reported by Vasconcelos et al. [98], who expressed that the area-based participation and collaboration need to play an active role in decision-making to co-construct action guidelines, aiming for higher implementation success for an effective and inclusive management of infrastructure. Additionally, the local community engagement in conservation also plays a fundamental role in sustainable management of natural resources. The lack of information and feedback provision were also the major internal obstacles for a successful infrastructure project. Meanwhile, the arrangements for collaboration in knowledge production would also need community-based participatory research which engaged research and hybrid forums [99].

For the “KM” group, there were five out of six indicators labelled as the highest loading factor for success and sustainability of area-based infrastructure project management. Among those indicators indicated in Table 7, the learning centre for productivity improvement was the key performance indicator with the highest loading factor (Ind01), and it should be given the highest priority for implementation. The second highest was other investment projects followed (Ind05), followed by creating new products or generating income for the area (Ind08). The next and fourth highest loading factor was the satisfactory evaluation of projects from service users (Ind03), while the last one was the promotion of higher organisational efficiency (Ind04). In short, the indicators mentioned earlier would influence the success or failure of knowledge management of AIP in Thailand, whereas the strategy should also be adopted in AIP in Thailand to avoid project extension and possible failure. Importantly, the findings from this study are complementary to those of the cited previous studies of Fugate [100], where the knowledge management of infrastructure project is in fact a critical element of successful process integration, and the transfer of implementation of knowledge management to other projects is crucial for how successfully a project is managed and implemented [101].

In summary, the knowledge and holistic management indicators to measure the sustainability of Area-based Infrastructure Project (AIP) management would need to be identified and thereby accept their usefulness for implementing area-based policy. In fact, as recommended by this study, the local and regional administrators could adopt the indicators as the keys to success towards the sustainability of area-based infrastructure projects. The combination of certain key performance indicators is worth putting into practice to accomplish the improvement of infrastructure project sustainability performance. For contribution, with a range of the most appropriate and effective management techniques, the suggested key performance indicators and the initiative forward taking all the stakeholders into account, could be very useful for the successful and sustainable execution of the area-based infrastructure project.

CRediT authorship contribution statement

Kittiwet Kuntiyawichai: Writing – review & editing, Supervision. **Preenithi Aksorn:** Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Preenithi Aksorn reports financial support and article publishing charges were provided by Khon Kaen University. Preenithi Aksorn reports a relationship with National Science, Research and Innovation Fund (NFRF) that includes: funding grants. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This research was supported by the Fundamental Fund of Khon Kaen University. The research has received funding support from the National Science, Research and Innovation Fund or NSRF [code 179521, 2023].

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