Journal of Geological Resource and Engineering 7 (2016) 305-327
doi:10.17265/2328-2193/2016.07.001

# Indicators and Influence Factors for Sustainability Assessment of Inclusive Smart Innovation Clusters

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**Abstract:** A new manufacturing and business infrastructure industrial ecosystem model with the state-of-the art core infrastructure and smart applications in the form of inclusive smart innovation cluster is seen as a powerful tool to drive industrial symbiosis, economic, social and inclusive development. Essentially an integrated eco-industrial park, these clusters demonstrate applications of industrial ecology principles among the occupant units, besides promoting sustainable societies from economic, environmental and social perspectives. The holistic planning and development of these clusters from economic, environmental and social sustainability considerations or alternatively, the sustainability assessment of these clusters is highly complex. The research reported upon forms part of a larger study that aims to develop an integrated decision support system for sustainability assessment of inclusive smart innovation cluster. The paper discusses the conceptual model of the cluster and the need to establish context specific key indicators and influence factors from economic, environmental and social sustainability considerations. The paper proposes a structured methodology for development of key indicators and influence factors. The paper concludes by identifying a set of 184 key indicators and influence factors for comprehensive sustainability assessment of inclusive smart innovation cluster.

**Key words:** Eco-industrial cluster and park, sustainability indicator and assessment, influence factors, smart development, sustainable infrastructure.

## 1. Introduction

Clustering and aggregation is an important instrumentality of the manufacturing policy [1]. Businesses and enterprises are increasingly congregating together through the phenomenon of clustering to engender competitive advantage.

The concepts of industry innovation clusters are emerging and these clusters are anticipated to nurture the right environment for responsible, sustainable and inclusive innovations across geographies [2].

In pursuit of inclusive and sustainable industrial and economic development, various forms of business infrastructure like industrial park, industrial estate, special economic zone, EIP (eco industrial park) have been extensively practiced in India [3] and in other countries [4-13].

Going by the definition of Ref. [14], EIP can be considered as an industrial system for conserving natural and economic resources, improving operating efficiency and providing waste valorization opportunities. On the other hand, EIP can be visualized as a community of manufacturing and service businesses aiming for increased environmental and economic performance in managing environmental and resources issues through collaborative efforts [15]. In the literature, the development of Kalundborg EIP, Denmark [16-20] has evoked considerable interest in the application of IS (industrial symbiosis) network. The multidimensional role performed by various forms of eco-industrial networks i.e. IS networks, sustainable supply networks, environmental issue networks, environmental solution networks in advancing sustainability was analyzed by Ref. [21].

EIP as a tool to implement sustainable polices was

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studied by Ref. [22]. A well-conceived functioning EIP has immense potential to both benefit the economy and considerably relieve environmental pressure not only within the EIP but also near the location of EIP development [9]. The definition of EIP as cited in Ref. [23] incorporates the need for networking between EIP actors, focus on the social and policy contexts apart from the natural science and engineering frameworks [24]. According to Ref. [25], sustainable development can be operationalized through IE (industrial ecology) principles. As cited in Ref. [26], IE application at EIP is immense wherein the clustering of complementary industries and businesses provides the required complexity of functions.

The strategies, policies and initiatives to enhance inclusive, sustainable infrastructure and industrial development, based on innovation, eco design approach, circular economy principles, eco industrial networks, entrepreneurship and creativity, are drawing global attention.

A new manufacturing and business infrastructure industrial ecosystem model in the form of ISIC (inclusive smart innovation clusters) is increasingly seen as a powerful tool to drive IS, economic, social, and inclusive development. ISIC essentially (a) attracts infrastructure and industrial investment; (b) brings economies of scale of operation both for the infrastructure developer and for the occupant units through symbiotic cooperation; (c) increases industrial output; (d) promotes IE in terms of exchange of by-products and cascades of energy use between occupant units; (e) rewards entrepreneurship; (f) improves skill sets; and (g) ensures the generation of IS network, flow of knowledge and technology.

According to Ref. [17], analyzing and conceptualizing socio-economic systems are required for achieving economic growth and environmental protection. If the goal is sustainability of the industrial community and ecosystem, a more comprehensive perspective of EIP involving economic, environment, and social (collectively denoted as EES) aspects is necessary [27].

The perception towards SD (sustainable development) changes considerably depending on whether it is viewed in a holistic manner across EES dimensions as a multi-dimensional issue or merely as an environmental issue.

SA (sustainability assessment) of infrastructure is a critical step, which is based on measuring the performance of an infrastructure in terms of the KSI (key sustainability indicators) [28].

Though different methods towards practicing SD principles while executing infrastructure projects are prevalent, context specific appropriate KSIs are unavailable, which obviously create a barrier towards proper SA of infrastructure project. As enumerated in Ref. [29], the KSI adopted for project SA are not holistic and it is uncommon to find a method that incorporates the EES dimensions of SD. While attempts have been made for identifying KSIs for EIP [30], lack of a user-specific and a project specific approach factoring the entire development cycle is perceived as a gap. Hence, evolving research methodologies for SA factoring context specific issues is vital.

The holistic approach of planning and developing ISIC from EES sustainability perspectives or alternatively SA of ISIC from EES perspectives is a highly critical and complex problem (Fig. 1). One of the major challenges is to identify the appropriate KSIs that not only reflect EES perspectives but also factor key considerations involved in the entire planning and development cycle.

Hence, it is imperative to develop customized selection criteria and determine the KSI and KIF (key influence factors) collectively denoted as ${}^{ISIC}KIFs$ that can significantly influence the sustainability of ISIC and develop appropriate methodology for the computation of baseline data.

The research reported upon forms part of a larger study that aims to develop an integrated decision support system (${}^{ISIC}DSS_{SI}$) for SA of ISIC and to determine SI (sustainability index) of ISIC from EES

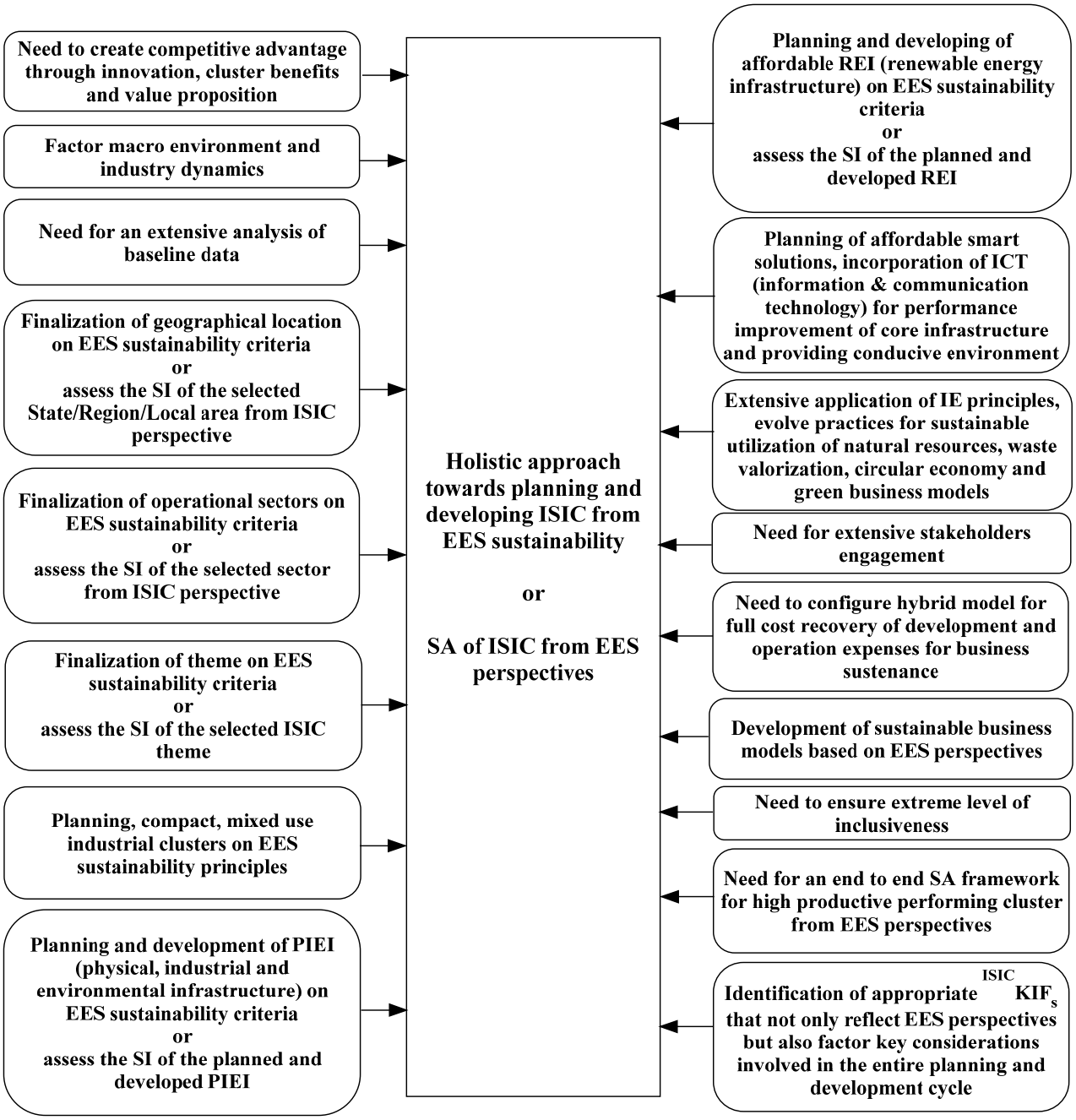


**Fig. 1 Complexities involved in planning and developing sustainable ISIC (Source: Authors).**

perspectives on a 0-5 scale.

This article intends to bridge the identified gap and proposes a structured methodology for conceptualization and development of $^{ISIC}$KIFs. The numerous qualitative and quantitative considerations involved in the entire planning and development cycle that can have significant influence on the sustainability of ISIC were meticulously identified. Further, the research reported herein factors specific peculiarities of ISIC and EES considerations.

This article discusses the conceptual model of ISIC and the need to establish context specific $^{ISIC}$KIFs from EES considerations. A set of comprehensive DQC (data quality criteria) is evolved in this article for

providing input towards the selection process of $^{ISIC}$KIFs. This article concludes by identifying a set of $^{ISIC}$KIFs in a comprehensive manner for each stage of ISIC development from EES perspectives that are encapsulated within the $^{ISIC}DSS_{SI}$ model either to perform SA of ISIC or plan ISIC on a sustainable basis.

## 2. Conceptualization Model for Identifying $^{ISIC}$KIFs for SA of ISIC

ISIC is a new concept of evolving an ecosystem that:

- creates befitting environment conducive for manufacturing or business activities in an inclusive growth mode;
- provides the state of the art core infrastructure;
- incorporates key themes of IE;
- incorporates smart solutions and applications, using ICT tools;
- bridges the widening gap between academia and industry;
- establishes a powerful platform to boost scientific and technological advancement, enabling researchers and scientists to meet international standards.

ISIC can be conceived as a large delineated region that shall provide an excellent conducive environment for business and innovation coupled with infrastructure and smart application for envisaged industrial, manufacturing, and business theme. It focuses on development of large, medium, and small-scale industries, as also trading and services. The state of the art PIEI and REI with smart applications are integral parts of the ISIC. The developed plots and built-up spaces shall be allotted to the occupant units for establishing the envisaged business units. ISIC shall have adequate connectivity to airports & seaports, highways & rail network for freight movement. It is pertinent that the facilities not only need to be conceptualized and developed to excellent standards but also regularly maintained and continuously upgraded to be globally competitive.

ISIC, essentially an eco-industrial cluster, demonstrates the application of IE principles in terms of exchanges of waste, by-products and energy among the occupant units. ISIC shall effectively deploy energy cascading approaches and harness utilization of industrial by-products as feedstock for processes by other co-located occupant units in line with IS principles [17]. As cited in Ref. [31], IE will have limited applicability if it is seen only as material and energy flows. ISIC is an industrial ecosystem with closely related IS network and its efficiency is enhanced by stimulating the linkages between the occupant units besides promoting sustainable societies from EES perspectives. The occupant units of ISIC share utilities and services thus reflecting symbiotic collaboration.

Fig. 2 illustrates the conceptual model of ISIC, founded on EES perspectives, considered in this research. ISIC planning and development are conceptualized in six stages (Fig. 2).

## 3. Research Motivation and Question

In spite of absence of universally accepted definition or assessment metrics for SD, various stakeholders have suggested indicators and indices. The state of SD at local, regional or national level is measured by these existing KSI. In addition, some indicators have been developed to measure whether the milestones of long-term strategies or policies are being reached.

Lack of global acceptability is witnessed in the list of KSI that can be deployed to define infrastructure project objectives at different stages of the project lifecycle [32]. Ref. [29] reviewed the KSI for infrastructure projects from previous studies and developed 30 assessments indicators. Ref. [33] proposed a set of 30 indicators in four categories covering ecological, health, socio-cultural and economic indicators for assessing green infrastructure sustainability performance.

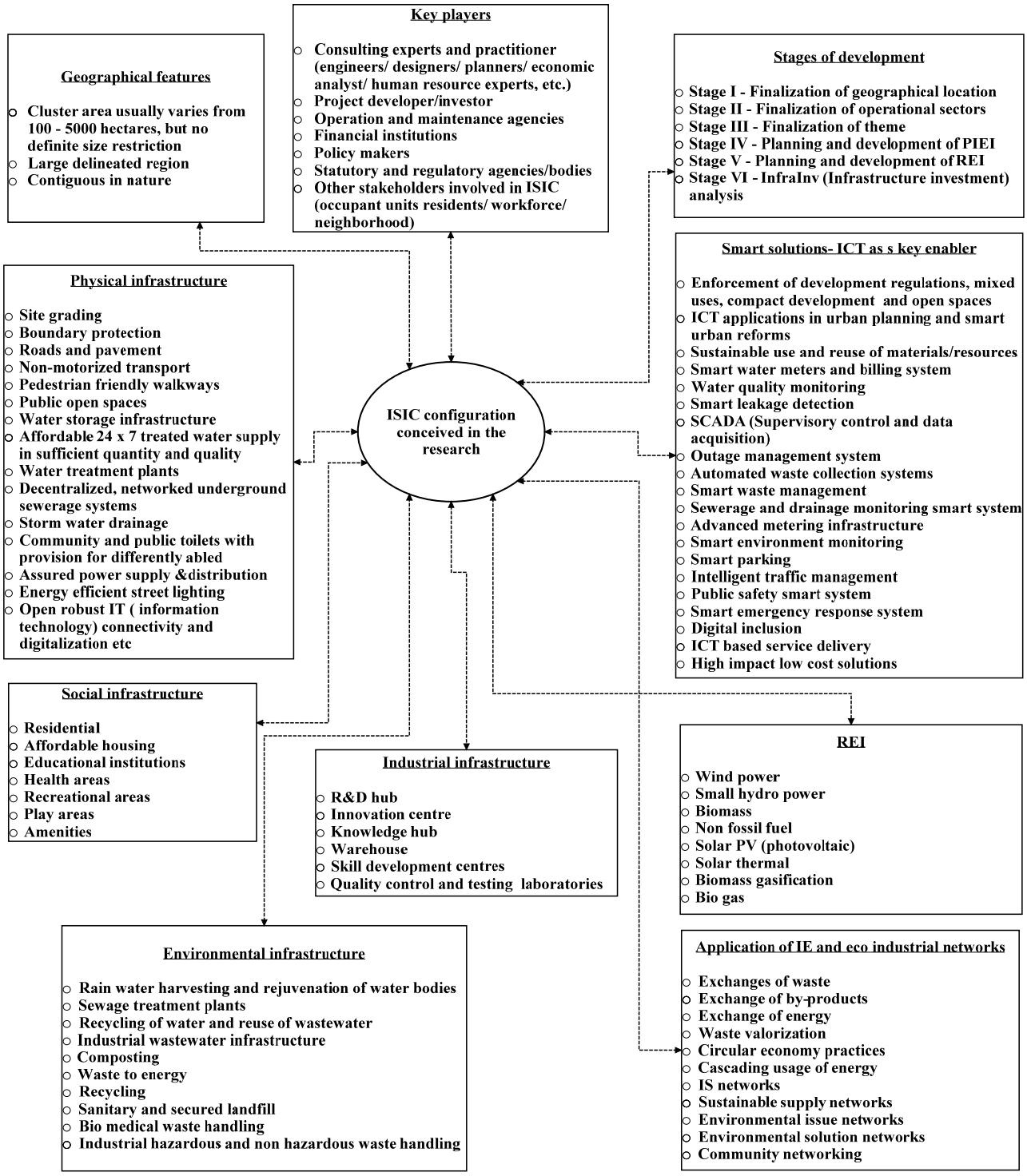


**Fig. 2 Conceptual model of ISIC founded on EES sustainability perspectives (Source: Authors).**

Attempts were also made in previous studies to develop country specific and context specific indicators [34-37].

Specifically in the context of EIP, a recent work on sustainability indicators for EIP by Ref. [30] provided an exhaustive list of 249 indicators covering EES dimensions.

Despite many attempts by various scholars and

researchers [29, 36, 38-46] the current literature in the absence of not factoring the regional context, does not provide adequate information about how the infrastructure sector key players—consulting experts, developers, practitioners, operation and maintenance agencies and policy makers perceive the level of importance and the degree of utilization of KSI with respect to infrastructure projects. Hence, it is imperative to: (a) develop customized $^{ISIC}$KIFs selection criteria, and (b) based on the selection criteria, identify an exhaustive list of $^{ISIC}$KIFs for each stage of development for SA of ISIC especially factoring EES perspectives.

Since huge emphasis are laid towards creation of industrial infrastructure, industrial corridors and other such business infrastructure dovetailed with the concept of IE and smart applications, there is an urgent need to evolve a methodology for SA of ISIC in a holistic manner. One of the key challenges in this process is the determination of appropriate context specific $^{ISIC}$KIFs. The research has to focus on the development of $^{ISIC}$KIFs for enhancing the sustainability of ISIC.

Even though the existing studies have suggested various methods for practicing SD principles in the process of implementing infrastructure projects or EIPs, effective KSIs are unavailable for ISIC which need to factor ISIC specific issues besides EES considerations dovetailing entire development cycle, thus presenting a barrier for the effective SA of ISIC.

Based on the above considerations, the leading research questions investigated are:

(1) "What are the DQC for selection of indicators for SA of ISIC?"

(2) "What are $^{ISIC}$KIFs that can significantly affect the sustainability of ISIC from EES perspectives?"

## 4. Development of $^{ISIC}$KIF for SA of ISIC

As enumerated earlier, mapping the criteria for selection of $^{ISIC}$KIFs requires extensive consideration from EES perspective. Ref. [47] defined indicators as a conceptual tool, expressed in clear and precise terms that measure progress towards, or away from, an objective. In the literature, considerable attention is given to the qualities of "good" KSI. As stated in Ref. [48], a good indicator is responsive to external stimuli thus alerting the investigator to a problem before the problem grows too large and that a good indicator recognizes what needs to be done to remedy such a problem. Various authors have provided DQC for the selection of KSI [49-54].

DQC conceived in Ref. [52], are significant in that others engaged in developing KSI [48, 55, 56] have utilized them frequently. Even though, significant degree of variability in KSI adopted for SA in the previous studies was witnessed, there was a considerable level of similarity in DQC towards which KSIs were expected to comply with.

A detailed analysis has been undertaken in the research in order to group proposed sets of criteria for the selection of $^{ISIC}$KIFs and a mapping exercise was carried out to match with these criteria with the ISIC development cycle, EES perspectives and context specific issues.

A set of 22 comprehensive DQC is evolved in the research for providing input towards the selection process of $^{ISIC}$KIFs and is presented in Fig. 3. The overview of the methodology for identifying the $^{ISIC}$KIFs for SA during each stage of development of ISIC in a holistic manner is depicted in Fig. 4.

## 5. Discussion on $^{ISIC}$KIFs

Based on methodology and criteria described above, the $^{ISIC}$KIFs under each stage of ISIC development, towards ecosus (economical sustainability), denoted as $KIF_{ecosus}$, evnsus (environmental sustainability) denoted as $KIF_{evnsus}$ and socsus (social sustainability) denoted as $KIF_{socsus}$ are identified in the research. In the analysis, it is found that there are instances wherein during certain stages of development, all the three dimensions of sustainability, eessus can be expressed by single influence parameter denoted as $KIF_{eessus}$.

Further certain main $KIF_{ecosus}$ and $KIF_{eessus}$ are constituted by several sub influence factors and these are mapped in the research.

There are six stages to the development of ISIC as pointed in Fig. 2. In order to achieve overall sustainability of the ISIC, it is necessary to analyze how each stage of development can effectively contribute to achieving the same. Scientific and rational assessment on the ISIC location, targeting and positioning of the ISIC, developing PIEI, REI systems, financial sustainability and affordable infrastructure have significant influence on the sustainability of the ISIC. Further, it is imperative for achieving the overall sustainability, $EES_{SI}$ should be ensured in the each stage of the development and operation cycle of the ISIC Hence, the research was focused on developing

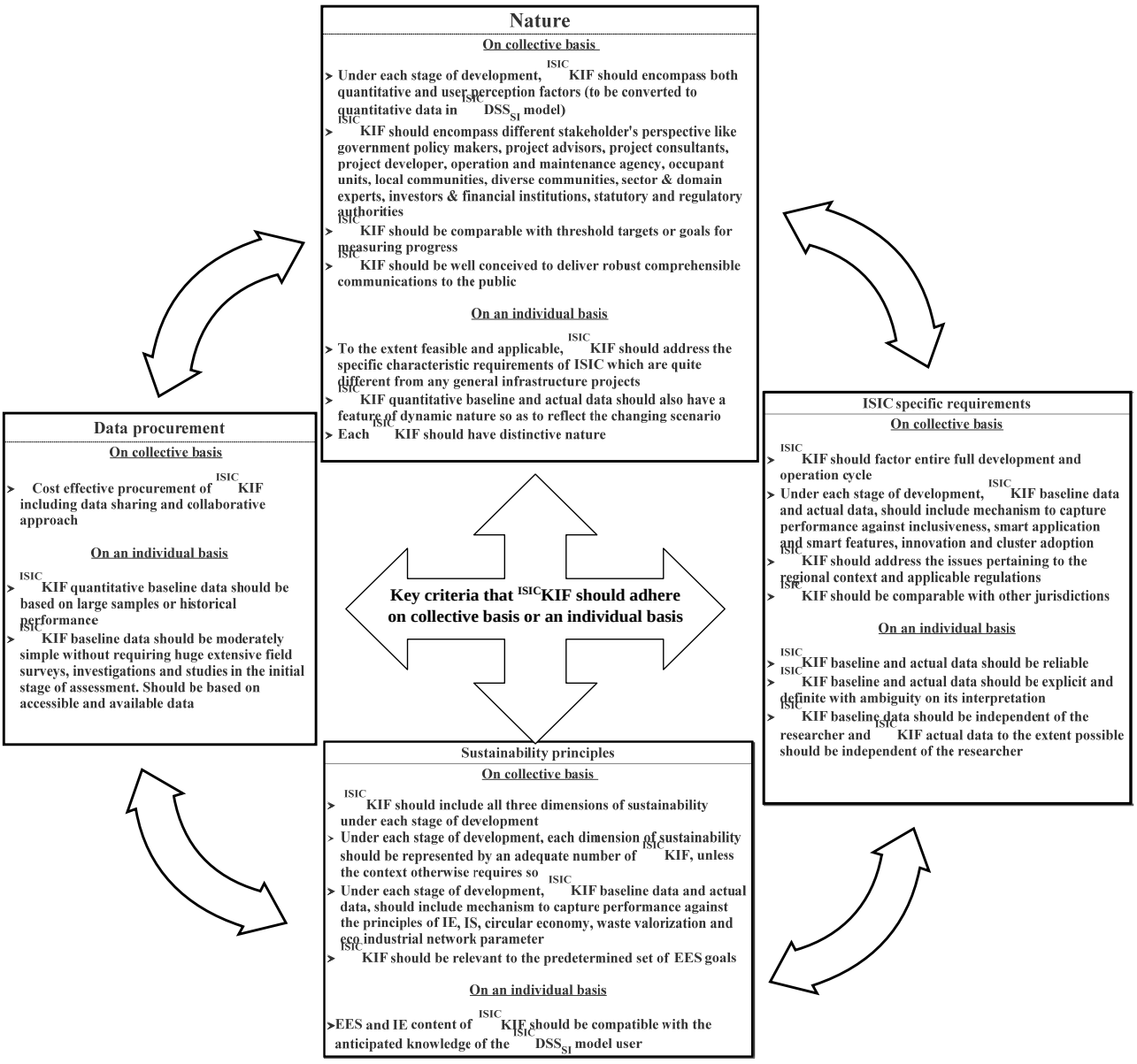


**Fig. 3 DQC adopted in the research towards selection of ISIC KIFs (Source: Authors).**

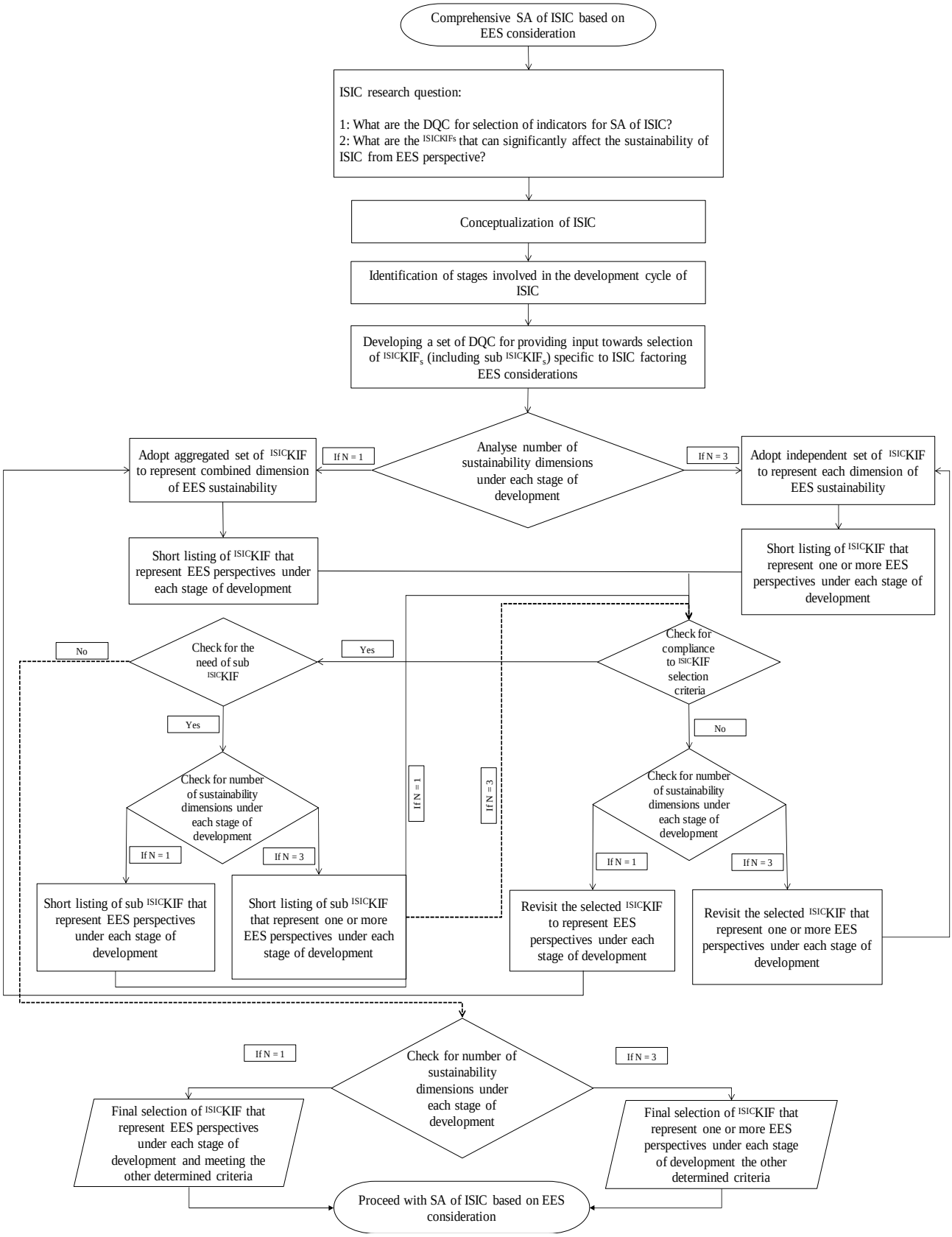


**Fig. 4 Overview of methodology for identifying ISICKIFs for SA of ISIC (Source: Authors).**

stakeholder relevant $^{ISIC}$KIFs, reflecting EES perspectives, during the different stages of ISIC development.

Table 1 highlights the stakeholders engaged in the development and operation of ISIC. Tables 2-7 provide $^{ISIC}$KIFs, under each stage of ISIC development, reflecting EES perspectives and fulfilling the established DQC adopted in the research. The Tables 2-7 also discuss the objective and rationale for selecting $^{ISIC}$KIFs and also its relevance towards different stakeholders involved in development of ISIC.

A decision support system model based on multi criteria decision analysis [57], developed as a spreadsheet based tool (designated as $^{ISIC}DSS_{SI}$) can effectively utilize the identified $^{ISIC}$KIFs to determine SI of ISIC (denoted as $^{ISIC}EES_{SI}$) from EES perspectives on a 0-5 scale.

### *5.1 Stage I—Finalization of Geographical Location*

The geographic location of ISIC has significant influence on sustainable operations of the ISIC. Hence, for achieving the overall sustainability, $EES_{SI}$ should be ensured even in the conceptualization stage of deciding the location of ISIC. It is a common practice to ignore or not to analyze EES sustainability considerations while finalizing the location of ISIC. The prevailing KSIs are not suitable for locating ISIC, based on EES sustainability criteria or to assess the sustainability score of the selected geographic location from ISIC perspective. In this research, this gap in the approach is identified and a rational method for developing $^{Geo}$KIFs is evolved.

The economic dimension of sustainability can be reflected by analyzing the industry's perception towards investment in a particular Region/State/Local area; the user perception of the geography in promoting ISIC and production of goods and services of the geography.

The environment performance, user perception of environment clearance and RE (renewable energy) potential of the geography are direct indicators of the environment dimension of sustainability that need to be considered while finalizing the location of ISIC. On the social dimension front, the industry's perception towards employment and user perception of the law and order are critical elements to be considered.

Table 2 provides the list of $^{Geo}$KIFs identified under stage I—finalization of geographical location reflecting the EES perspectives and fulfilling the established DQC. Also, the identified $^{Geo}$KIFs can be used to determine $EES_{SI}$ score of the selected region/state/local area, if the location of ISIC is decided based on other considerations.

### *5.2 Stage II—Finalization of Operational Sectors*

The operational sustainability of the ISIC largely depends on the focus sector harnessing the regional skill sets, resources etc. Thus finalizing the operational sectors of ISIC is an important activity in the development cycle. Yet, the finalization is not possible on a rational basis without due consideration of all the three dimensions of sustainability. This is an intricate issue as several factors influence this decision. The $EES_{SI}$

**Table 1 Relevant stakeholders in development and operation of ISIC (Source: Authors).**

| Stakeholders involved in development of ISIC | Denoted by |
|---|---|
| Consulting experts and practitioner (engineers/designers/planners/economic analyst/human resource experts, etc.) | A |
| Project developer/investor | B |
| Operation and maintenance agencies | C |
| Financial institutions | D |
| Policy makers | E |
| Statutory and regulatory agencies/bodies | F |
| Other stakeholders involved in ISIC (residents/workforce/neighborhood) | G |

**Table 2** **$^{ISIC}$KIF for SA of ISIC—Stage I of ISIC development: finalization of geographical location ($^{Geo}$KIF) (Source: Authors).**

| S. No. | Identified $^{ISIC}$KIFs (with sustainability dimension and designation), reflecting EES perspectives, fulfilling the established DQC | Objective/rationale | Relevance of $^{ISIC}$KIFs towards stakeholders involved in development of ISIC |
|---|---|---|---|
| 1 | Region/state/local area wise total investment proposed in approved documents, in value terms, **Economic-$^{Geo}$KIF$_{ecosus1}$** | Industry's perception towards investment in a particular region/state/local area | A/B/D/E |
| 2 | Region/state/local area wise investment applications filed, in numbers, **Economic-$^{Geo}$KIF$_{ecosus2}$** | | A/B/D/E |
| 3 | Region/state/local area LOIs (letters of intent)–DILs (direct industrial licenses), numbers granted, **Economic-$^{Geo}$KIF$_{ecosus3}$** | | A/B/D/E |
| 4 | Region/state/local area LOIs–DILs, proposed investment, in value, **Economic-$^{Geo}$KIF$_{ecosus4}$** | | A/B/D/E |
| 5 | Region/state/local area wise FDI (foreign direct investment) in value **Economic-$^{Geo}$KIF$_{ecosus5}$** | FII (foreign institutional investors) and other foreign investor's perception towards investment in a particular region/state/local area | A/B/D/E |
| 6 | Region/state/local area policies/initiatives/ approach in promoting ISIC **Economic-$^{Geo}$KIF$_{ecosus6}$** | User perception about region/state/local area in promoting ISIC | A/B/D/E |
| 7 | GDSP (gross domestic product at current prices) (% growth over previous year) **Economic-$^{Geo}$KIF$_{ecosus7}$** | GDSP is a measure, in monetary terms, of the volume of all goods and services produced within the boundaries of the region/ state/local area during a given period of time, accounted without duplication | A/B/D/E |
| 8 | EPI (environmental performance index) **Environmental-$^{Geo}$KIF$_{evnsus1}$** | EPI is a measure of region/state/local area environmental performance | A/B/D/E/F/G |
| 9 | Environmental approval and clearance **Environmental-$^{Geo}$KIF$_{evnsus2}$** | Critical consideration for investment decision and for locating ISIC | A/B/C/D/E/F/G |
| 10 | Region/state/local area wise RE (renewable energy) potential **Environmental-$^{Geo}$KIF$_{evnsus3}$** | The potential for RE generation could be a decisive factor towards locating ISIC | A/B/C/D/E/F |
| 11 | Region/state/local area wise employment proposed in approved investment documents, numbers **Social-$^{Geo}$KIF$_{socsus1}$** | Industry's perception towards employment | A/B/D/E/F/G |
| 12 | Region/state/local area wise LOIs+DILs, proposed employment, numbers **Social-$^{Geo}$KIF$_{socsus2}$** | | A/B/D/E/F/G |
| 13 | Region/state/local area law and order situation **Social-$^{Geo}$KIF$_{socsus3}$** | Has significant influence on the investment decision and for locating ISIC | A/B/C/D/E/G |

should be ensured even while deciding the operational sectors of ISIC and again these aspects are ignored. The prevailing KSIs are not suitable in finalizing the operational sectors based on EES sustainability criteria or assess the sustainability score of the selected sectors from ISIC perspectives. Having realized this gap, a rational method is evolved in this research for developing $^{Sector}$KIFs.

The economic dimension of sustainability can be reflected by analyzing industry's perception towards investment in a particular sector, user perception about the sector in promoting ISIC and economic analysis of the sector. The environment friendliness of the sector, user perception of environment clearance and extent of waste or pollution generation of a sector are key considerations from environment sustainability consideration while finalizing the operational sector of ISIC.

The critical elements that need to be considered on the social dimension front include the industry's

perception towards employment opportunities offered by a sector and user perception on the employment and skill development opportunities offered by the sector.

Table 3 provides the list of $^{Sector}$KIFs identified under stage II—finalization of operational sectors reflecting the EES perspectives and fulfilling the established DQC.

Similar to earlier situation, the identified $^{Sector}$KIFs can be used to determine $EES_{SI}$ score of the selected sector, if the operation sector of ISIC is decided based on other considerations.

### *5.3 Stage III—Finalization of Theme*

ISICs are a thematic confluence of related sectors and interlinked activities founded on the principles of inclusive growth, IS networking, IE applications with smart features. Thus, by developing theme based targeting and positioning, the ISIC assumes significant importance to maximize the synergy between the sectors. The ideal method for finalizing the theme of the ISIC should be based on EES sustainability criteria. However, a systematic approach for targeting and positioning is required to tackle this multifaceted issue as several factors influence this decision.

Based on the sector, theme analysis and qualitative assessment, it is possible to target and position the ISIC. Theme analysis incorporates synergy mapping, IS network mapping and it will be adequate if the targeting and positioning is captured for SA of ISIC. Systematic targeting and positioning of theme for ISIC

**Table 3 $^{ISIC}$KIF for SA of ISIC—Stage II of ISIC development: finalization of operational sectors ($^{Sector}$KIF) (Source: Authors).**

| S. No. | Identified $^{ISIC}$KIFs (with sustainability dimension and designation), reflecting EES perspectives, fulfilling the established DQC | Objective/rationale | Relevance of $^{ISIC}$KIFs towards stakeholders involved in development of ISIC |
|---|---|---|---|
| 1 | Sector wise investment proposed in approved documents, in value terms **Economic-$^{Sector}$KIF$_{ecosus1}$** | Industry's perception towards investment in a particular sector | A/B/D/E/F/G |
| 2 | Sector wise investment applications filed, in numbers **Economic-$^{Sector}$KIF$_{ecosus2}$** | | A/B/D/E/F/G |
| 3 | Sector wise LOIs–DILs, numbers granted **Economic-$^{Sector}$KIF$_{ecosus3}$** | | A/B/D/E/F/G |
| 4 | Sector wise LOIs–DILs, proposed investment, in value **Economic-$^{Sector}$KIF$_{ecosus4}$** | | A/B/D/E/F/G |
| 5 | Sector wise FDI, in value **Economic-$^{Sector}$KIF$_{ecosus5}$** | Foreign investor's perception towards investment in a particular sector | A/B/D/E/F/G |
| 6 | Sector wise policies/initiatives/approach **Economic-$^{Sector}$KIF$_{ecosus6}$** | User perception about the sector | A/B/D/E/F/G |
| 7 | Annual growth rate of GDP (gross domestic product) by industry of origin at constant (in per cent) **Economic-$^{Sector}$KIF$_{ecosus7}$** | Provides information for current economic analysis, from an industry point of view | A/B/D/E/F/G |
| 8 | Environmental friendliness of the sector **Environmental-$^{Sector}$KIF$_{evnsus1}$** | User perception about the environmental friendliness of the sector | A/B/C/D/E/F/G |
| 9 | Extent of waste/pollution generation **Environmental-$^{Sector}$KIF$_{evnsus2}$** | User perception about the extent of waste or pollution generation | A/B/C/D/E/F/G |
| 10 | Environmental approval and clearance for the sector **Environmental-$^{Sector}$KIF$_{evnsus3}$** | Project approval process and time frame involved has a significant role in achieving the financial closure | A/B/C/D/E/F/G |
| 11 | Sector wise proposed employment, numbers **Social-$^{Sector}$KIF$_{socsus1}$** | Industry's perception towards employment opportunities in a particular sector | A/B/D/E/F/G |
| 12 | Sector wise LOIs +DILs, proposed employment, numbers **Social-$^{Sector}$KIF$_{socsus2}$** | | A/B/D/E/F/G |
| 13 | Employment and skill development opportunities in the sector **Social-$^{Sector}$KIF$_{socsus3}$** | User perception on the opportunities offered by the sector | A/B/D/E/F/G |

eventually ensures sustainability in all three dimensions and hence targeting and positioning index is an indirect measure of $EES_{SI}$.

Thus, all the three dimensions of sustainability are eventually addressed in the identified $^{Theme}KIF$ as explained in Table 4.

### *5.4 Stage IV—Planning and Development of PIEI*

As enumerated earlier, ISIC provides a conducive environment for manufacturing and business activities through creation of state of the art core infrastructure and smart solutions with ICT tools. The sustained operations of the ISIC largely depend on its PIEI and thus sustainable planning and development of the PIEI of ISIC assumes significant importance. The most common approach adopted in the SA of the infrastructure project is to assess the sustainability of key components of the project and rarely SA of micro infrastructure components are determined. For achieving the overall sustainability, $EES_{SI}$ should be ensured even in the sub component of PIEI development and operation. Further, extreme importance is laid on economical or environmental aspects and rarely holistic SA from EES perspectives are carried out. This gap is adequately addressed in this study.

From the conceptual model of PIEI, it can be concluded that a huge number of influence factors at this stage of the development need to be considered for SA of ISIC. $^{PIEI}KIFs$ extensively capture the site and project specific aspects including user perception.

The economic dimension of sustainability during this stage of development would include optimized quantities, optimized designs, minimized utilization of resources, least capital and operation cost, cost recovery and adequacy of level of preparatory studies encompassing various PIEI components and sub-components.

While economic dimension's objective is to optimize quantities and minimize the cost, the environment dimension focuses on extensive usage of local materials, recycling of materials, waste utilization and recycling, incorporation of IE principles and the level of environmental studies and impact analysis of PIEI development.

Social impact of PIEI development, inclusive growth, health and hazard related issues, employment, diversity, inclusive growth and transparent project development processes are key considerations of the social dimension of PIEI development.

Table 5 provides the list of $^{PIEI}KIFs$ identified under Stage IV—planning and development of PIEI reflecting the EES perspectives and fulfilling the established DQC.

The identified $^{PIEI}KIFs$ are project specific thus offering scope for optimization utilizing $^{ISIC}DSS_{SI}$ model. Further the identified $^{PIEI}KIFs$ can be used to determine $EES_{SI}$ score of the planned or developed PIEI, if the planning and development of ISIC is based on other considerations.

### *5.5 Stage V—Planning and Development of REI*

Perhaps one of the most significant aspects for investment decision for an occupant industry is availability of 24×7 reliable and affordable energy. Sustained operations of the ISIC largely depend on its strategy to meet the energy needs in an affordable and reliable manner. Also, the concept of smart development involves extensive deployment of RE for energy demand. This enhances the share of RE in the ISIC and hence, the sustainable planning and development of the REI assumes significant importance.

REI initiative by itself is: (a) an environmental friendly solution to meet the energy demands; (b) compliant to environment laws with numerous benefits from an environmental perspective; (c) creates local employment opportunities; and (d) promotes social inclusion. The economic dimension of RE generation is reflected as output generation and hence, it will be adequate if: (a) REI is incorporated in the ISIC for addressing the power requirement, and (b) affordability of the REI planned in the ISIC is captured in the SA of ISIC.

**Table 4** **$^{ISIC}$KIF for SA of ISIC—Stage III of ISIC development: finalization of theme ($^{Theme}$KIF) (Source: Authors).**

| S. No. | Identified $^{ISIC}$KIFs (with sustainability dimension and designation), reflecting EES perspectives, fulfilling the established DQC | Objective/rationale | Relevance of $^{ISIC}$KIFs towards stakeholders involved in development of ISIC |
|---|---|---|---|
| 1 | Synergy potential and IS network potential between the themes and sectors<br>**EES perspectives-$^{Theme}$KIF$_{eessus1}$** | Systematic targeting and positioning of theme eventually ensures sustainability in all three dimensions | A/B/C/D/E/F/G |

**Table 5** **$^{ISIC}$KIF for SA of ISIC—Stage IV of ISIC development: planning and development of PIEI ($^{PIEI}$KIF) (Source: Authors).**

| S. No. | Identified $^{ISIC}$KIFs (with sustainability dimension and designation), reflecting EES perspectives, fulfilling the established DQC | Objective/rationale | Relevance of $^{ISIC}$KIFs towards stakeholders involved in development of ISIC |
|---|---|---|---|
| 1 | Site grading<br>**Economical-$^{PIEI}$KIF$_{ecosus1}$** | Objective is to minimize the site grading activities and achieve optimized grade levels between various zones | A/B/C/D/F/G |
| 2 | Compound wall/fencing/other forms of boundary protection<br>**Economical-$^{PIEI}$KIF$_{ecosus2}$** | Has significant influence on project cost. Objective is to minimize the quantities | A/B/D/F |
| 3 | Road and pavement area/pedestrian friendly pathways/ bicycle lane/non-motorized transport<br>**Economical-$^{PIEI}$KIF$_{ecosus3}$** | Important both in the context of its capability for transportation network and optimized solutions to increase the usage area | A/B/C/D/F |
| 4 | Road and pavement thickness and are constituted by the following sub-influence factors like thickness of:<br>arterial road/sub arterial road/primary road/secondary road/collector street/local street<br>**Economical-$^{PIEI}$KIF$_{ecosus4}$, $^{PIEI}$KIF$_{ecosus4}^{1-6}$** | Optimized pavement design | A/B/C/D/F |
| 5 | Road and pavement quantities and are represented by the following sub-influence factors: Earth work/filling in basement/granular sub-base/wet mix macadam/primer coat with bitumen emulsion, tack coat with bitumen emulsion/dense graded bituminous macadam/bituminous concrete/semi dense bituminous concrete/premix carpet/seal coat/kerb stones<br>**Economical-$^{PIEI}$KIF$_{ecosus5}$, $^{PIEI}$KIF$_{ecosus5}^{1-12}$** | Optimization of quantities | A/B/C/D/F |
| 6 | Foot paths/pedestrian friendly pathways/bicycle lane/culverts quantities and are constituted by the following sub-influence factors: Earth work excavation/filling in basement/ PCC (plain cement concrete)/ RCC (reinforced cement concrete)/reinforcement for RCC work/centering and shuttering/precast cement concrete kerb/heavy duty cobble stones interlock pavers<br>**Economical-$^{PIEI}$KIF$_{ecosu6}$, $^{PIEI}$KIF$_{ecosus6}^{1-8}$** | Optimization of quantities | A/B/C/D/F |
| 7 | Drainage quantities and are constituted by the following sub-influence factors:<br>Earth work/PCC/RCC/ reinforcement for RCC work/centering and shuttering/coping and screed concrete/cement plaster/weep holes/RCC pipes/stone pitching on slopes<br>**Economical-$^{PIEI}$KIF$_{ecosus7}$, $^{PIEI}$KIF$_{ecosus7}^{1-10}$** | Important for effective functioning as well as for rainwater harvesting. Objective is to optimize the quantities | A/B/C/D/F |

(Table 5 continued)

| S. No. | Identified $^{ISIC}$KIFs (with sustainability dimension and designation), reflecting EES perspectives, fulfilling the established DQC | Objective/rationale | Relevance of $^{ISIC}$KIFs towards stakeholders involved in development of ISIC |
|---|---|---|---|
| 8 | Water demand<br>**Economical-$^{PIEI}$KIF$_{ecosus8}$**<br>Water supply infrastructure and are constituted by the following sub-influence factors: | Objective is to minimize water requirements, maximize recycling activities and optimized water usage between various zones | A/B/C/D/E/F/G |
| 9 | Excavation/filling with approved quality material/polypropylene random pipes of various diameters/socket & spigot centrifugally cast (spun)/ductile iron of various diameters/butterfly valve/air valve/gate valve of various dimensions/masonry chamber<br>**Economical-$^{PIEI}$KIF$_{ecosus9}$, $^{PIEI}$KIF$_{ecosus9}^{1-8}$** | Ensuring 24×7 supply of adequate quality and quantity with least capital and operating cost | A/B/C/D/F |
| 10 | Water storage infrastructure and are constituted by the following sub-influence factors:<br>Sump capacity—potable and non-potable—processing and non-processing/overhead tank capacity—potable and non-potable—processing and non-processing/water pump—potable and non-potable—processing and non-processing/pump house—potable and non-potable—processing and non-processing/water treatment plant capacity<br>**Economical-$^{PIEI}$KIF$_{ecosus10}$, $^{PIEI}$KIF$_{ecosus10}^{1-17}$** | Objective is to maximize the utility value with least capital and operating cost | A/B/C/D/F |
| 11 | Sewage generation<br>**Economical-$^{PIEI}$KIF$_{ecosus11}$** | Objective is to minimize sewage generation and maximize recycling activities | A/B/C/D/E/F/G |
| 12 | Sewer infrastructure and are constituted by the following sub-influence factors:<br>Excavating trenches and back filing/brick masonry circular manhole/sewer pipe—RCC hume pipe of various diameters/pipe for plot connection including construction of manhole/sewage treatment plant—processing and non-processing area<br>**Economical-$^{PIEI}$KIF$_{ecosus12}$, $^{PIEI}$IF$_{ecosus12}^{1-6}$** | Objective is to maximize the utility value with least capital and operating cost with maximum recycling and reuse opportunities | A/B/C/D/F |
| 13 | Solid waste infrastructure<br>**Economical-$^{PIEI}$KIF$_{ecosus13}$** | Objective is to minimize wastage and maximize the recycling with least operating cost | A/B/C/D/E/F/G |
| 14 | Street light infrastructure and are constituted by the following sub-influence factors: Street lighting feeder pillar panel suitable for outdoor installation/street lighting poles of various heights with energy efficient street light fixture/underground cable route markers and end termination/high mast light system with lighting fixtures with earthing and cabling/route markers/hume pipe for cable crossing across the road/solar street light system<br>**Economical-$^{PIEI}$KIF$_{ecosus14}$, $^{PIEI}$IF$_{ecosus14}^{1-7}$** | Optimization of quantities | A/B/C/D/F |

(Table 5 continued)

| S. No. | Identified $^{ISIC}$KIFs (with sustainability dimension and designation), reflecting EES perspectives, fulfilling the established DQC | Objective/rationale | Relevance of $^{ISIC}$KIFs towards stakeholders involved in development of ISIC |
|---|---|---|---|
| 15 | Power infrastructure and are constituted by the following sub-influence factors: Incoming with main receiving substation with SCADA system/overhead distribution system/underground distribution system with ring main unit/distribution substation/unitized substation/pole mounted substation/low voltage power distribution **Economical-$^{PIEI}$KIF$_{ecosus15}$, $^{PIEI}$KIF$_{ecosus15}^{1-6}$** | Important for effective functioning. Objective is to optimize the quantities in power infrastructure | A/B/C/D/F |
| 16 | PIEI development, engineering challenges and development risk **Economical-$^{PIEI}$KIF$_{ecosus16}$** | Objective is to evaluate the development challenges, assess development risk. Overall approach should be aimed to mitigate or minimize the risks | A/B/D/E/F/G |
| 17 | Level of feasibility studies, detailed geotechnical investigation and engineering, early contractor involvement, early supplier involvement before commencement of PIEI field work **Economical-$^{PIEI}$KIF$_{ecosus17}$** | Objective is to ensure adequate geotechnical and other engineering studies before commencement of actual development works | A/B/C/D/E/F/G |
| 18 | Full cost recovery mechanism of PIEI including investment and operation cost of smart applications **Economical-$^{PIEI}$KIF$_{ecosus18}$** | For achieving inclusive affordable sustained operations and business sustainability, it is imperative that full cost recovery should be achieved | A/B/C/D/E/G |
| 19 | Usage of locally available materials within ISIC for site grading activities **Environmental-$^{PIEI}$KIF$_{evnsus1}$** | Objective is to maintain the existing terrain without any ecological impact. If site grading cannot be avoided then attempt shall be made to utilize the materials available within boundaries of ISIC with minimum site grading | A/B/D/E/F/G |
| 20 | Usage of locally available materials within ISIC for compound wall/fencing and other forms of boundary protection development **Environmental-$^{PIEI}$KIF$_{evnsus2}$** | | A/B/D/E/F/G |
| 21 | Usage of locally available materials for road and pavement **Environmental-$^{PIEI}$KIF$_{evnsus3}$** | While ecosus objective is to optimize the quantities, evnsus focus is towards maximizing the usage of local materials | A/B/D/E/F/G |
| 22 | Usage of locally available materials for foot paths and culverts **Environmental-$^{PIEI}$KIF$_{evnsus4}$** | | A/B/D/E/F/G |
| 23 | Usage of locally available materials in drainage development **Environmental-$^{PIEI}$KIF$_{evnsus5}$** | The approach is to ensure proper water harvesting and achieve self-sufficiency in water usage through proper drainage | A/B/D/E/F/G |
| 24 | Wastewater recycling and incorporation of IE principles **Environmental-$^{PIEI}$KIF$_{evnsus6}$** | Objective is to maximize the recycling of wastewater using multi piping system/treatment plants and recycling of industrial trade effluent/domestic wastewater and extensive application of IE | A/B/C/D/E/F/G |
| 25 | Waste management, waste utilization and incorporation of IE principles **Environmental-$^{PIEI}$KIF$_{evnsus7}$** | Integrated waste management approach shall include end to end handling of bio-degradable waste/non-hazardous & hazardous industrial waste/bio-medical waste/e-waste and other forms of waste and extensive application of IE | A/B/C/F/G |
| 26 | Incorporation of IE principles/ green features/waste valorization/ circular economy/ energy efficiency/ sustainability elements in PIEI, smart applications in the core infrastructure including requirements for certification and green rating **Environmental-$^{PIEI}$KIF$_{evnsus8}$** | To improve IE/eco industrial network/eco efficiency/circular economy/direct & indirect waste valorization and ability for ISIC for getting accreditation and certification | A/B/C/D/E/F/G |

(Table 5 continued)

| S. No. | Identified $^{ISIC}$KIFs (with sustainability dimension and designation), reflecting EES perspectives, fulfilling the established DQC | Objective/rationale | Relevance of $^{ISIC}$KIFs towards stakeholders involved in development of ISIC |
|---|---|---|---|
| 27 | Level of environmental studies, base line data generation studies **Environmental-$^{PIEI}$KIF$_{evnsus9}$** | Objective is to ensure adequate environmental studies before filing for necessary approval | A/B/C/D/E/F/G |
| 28 | Environmental impact of the PIEI development and operation, subject to meeting the basic requirements for establishment of ISIC **Environmental-$^{PIEI}$KIF$_{evnsus10}$** | Significant from the overall development and impact on environment | A/B/C/D/E/F/G |
| 29 | Environmental approval challenges/risk and compliance to the regulations in the context of PIEI development and operations **Environmental-$^{PIEI}$KIF$_{evnsus11}$** | Can significantly influence project decision | A/B/C/D/E/F/G |
| 30 | Usage of recycled materials, renewable materials in the PIEI development and operation **Environmental-$^{PIEI}$KIF$_{evnsus12}$** | This criterion is significant from the overall development perspective and impact on environment | A/B/C/D/E/F/G |
| 31 | Level of rehabilitation and resettlement (R&R) requirement in developing ISIC **Social-$^{PIEI}$KIF$_{socsus1}$** | Important for community friendly development. Objective is to ensure minimum level of rehabilitation and resettlement | A/B/D/E/F/G |
| 32 | Industrial land for ISIC development adhering to transparent, fair procurement practices and process **Social-$^{PIEI}$KIF$_{socsus2}$** | All efforts should be taken to ensure to a fair degree that only industrial land is being used adhering to transparent, fair procurement practices and process for developing ISIC | A/B/D/E/F/G |
| 33 | Improvement in socio economic development beyond the statutory norms in the influence zone of ISIC **Social-$^{PIEI}$KIF$_{socsus3}$** | Social inclusion is an essential component of sustainable inclusive growth. Objective is to maximize the socio-economic benefits | A/B/D/E/F/G |
| 34 | Level of social impact studies/base line data generation studies/capacity assessment and building studies/studies on social safeguard measures **Social-$^{PIEI}$KIF$_{socsus4}$** | Important for inclusive growth. Objective is to ensure adequate social impact studies and other related studies before filing for necessary approval | A/B/C/D/E/F/G |
| 35 | Project approval challenges/development risk and compliance to the social and R&R regulations in the context of ISIC development and operation **Social-$^{PIEI}$KIF$_{socsus5}$** | Objective is to evaluate the development challenges, assess development risk from social and R&R regulations, land procurement process, and the overall approach should be aimed to mitigate or minimize the risks from social perspective | A/B/D/E/F/G |
| 36 | Incorporation of social/cultural traditions in ISIC development and operation **Social-$^{PIEI}$KIF$_{socsus6}$** | For achieving inclusive growth and social inclusion | A/B/C/E/G |
| 37 | Long term and short term occupational health in ISIC development and operation beyond statutory provisions **Social-$^{PIEI}$KIF$_{socsus7}$** | Mandatory parameter | A/B/C/D/E/F/G |
| 38 | Public safety and occupational safety in ISIC development and operation beyond statutory provisions **Social-$^{PIEI}$KIF$_{socsus8}$** | | A/B/C/D/E/F/G |

(Table 5 continued)

| S. No. | Identified $^{ISIC}$KIFs (with sustainability dimension and designation), reflecting EES perspectives, fulfilling the established DQC | Objective/rationale | Relevance of $^{ISIC}$KIFs towards stakeholders involved in development of ISIC |
|---|---|---|---|
| 39 | Disaster and risk management, training and capacity building in ISIC development and operation beyond statutory provisions **Social-$^{PIEI}$KIF$_{socsus9}$** | Mandatory parameter | A/B/C/D/E/F/G |
| 40 | Incorporation of social and corporate social responsibility elements in the contract/promoting green vendors & suppliers/extensive local employment/adherence to labor laws and other initiatives for social inclusion in ISIC development and operation beyond those specified under statutory provisions **Social-$^{PIEI}$KIF$_{socsus10}$** | Going forward the infrastructure and industrial development shall be assessed not only on financial/environmental/IE considerations and but also from how the business is seamlessly integrated for overall societal development | A/B/C/D/E/F/G |
| 41 | Employment to local people and skill set development in ISIC development and operation beyond those specified under statutory provisions **Social-$^{PIEI}$KIF$_{socsus11}$** | Objective is to maximize the local employment opportunities and skill set development | A/B/C/D/E/F/G |
| 42 | Employment to women in ISIC development and operation **Social-$^{PIEI}$KIF$_{socsus12}$** | For achieving inclusive growth and gender equality | A/B/C/D/E/F/G |
| 43 | Diversity in ISIC development and operation **Social-$^{PIEI}$KIF$_{socsus13}$** | Objective is to have diversity of all formats | A/B/C/D/E/F/G |

**Table 6 $^{ISIC}$KIF for SA of ISIC—Stage V of ISIC development: planning and development of REI ($^{REI}$KIF) (Source: Authors).**

| S. No. | Identified $^{ISIC}$KIFs (with sustainability dimension and designation), reflecting EES perspectives, fulfilling the established DQC | Objective/rationale | Relevance of $^{ISIC}$KIFs towards stakeholders involved in development of ISIC |
|---|---|---|---|
| 1 | Usage of RE for meeting energy demand of ISIC<br>**EES perspectives-$^{REI}$KIF$_{eessus1}$** | Meeting 100% of energy demand of ISIC through conventional power generation methods has significant influence on sustainability. Objective is to maximize power through various RES (RE sources), use of industrial by-products, cascading use of energy while ensuring affordability | A/B/C/D/E/F/G |
| 2 | LCoE (levelized cost of energy) from wind which is the function of output, CoG (cost of generation) denoted as (Output/CoG/LCoE) wind<br>**EES perspectives-$^{REI}$KIF$_{eessus2}$** | | A/B/C/D/E |
| 3 | LCoE using small hydro potential denoted as (Output/CoG/LCoE) small hydro<br>**EES perspectives-$^{REI}$KIF$_{eessus3}$** | | A/B/C/D/E |
| 4 | LCoE utilizing biomass denoted as (Output/CoG/LCoE) biomass<br>**EES perspectives-$^{REI}$KIF$_{eessus4}$** | | A/B/C/D/E |
| 5 | LCoE using non-fossil denoted as (Output/CoG/LCoE)nonfossil fuel<br>**EES perspectives-$^{REI}$KIF$_{eessus5}$** | Harnessing the RES potential of the ISIC location/nearby vicinity. Objective is to generate affordable power through RES and IE principles like exchanges of wastes/by-products/cascading use of energy | A/B/C/D/E |
| 6 | LCoE using solar PV denoted as (Output/CoG/LCoE) solarpv<br>**EES perspectives-$^{REI}$KIF$_{eessus6}$** | | A/B/C/D/E |
| 7 | LCoE using concentrated solar power denoted as (Output/CoG/LCoE) solar thermal<br>**EES perspectives-$^{REI}$KIF$_{eessus7}$** | | A/B/C/D/E |
| 8 | LCoE generated from biomass gasifier denoted as (Output/CoG/LCoE) biomass gasifier<br>**EES perspectives-$^{REI}$KIF$_{eessus8}$** | | A/B/C/D/E |
| 9 | LCoE generated from biogas (Output/CoG/LCoE) biogas<br>**EES perspectives-$^{REI}$KIF$_{eessus9}$** | | A/B/C/D/E |

Table 6 provides the list of $^{REI}$KIFs identified under Stage V—planning and development of REI reflecting the EES perspectives and fulfilling the established DQC.

The identified $^{ISIC}$KIFs i.e. output generation, CoG (cost of generation), LCoE (levelized cost of energy) of various forms of REs eventually assess the sustainability in all three dimensions.

The identified $^{REI}$KIFs are project specific thus offering scope for optimization utilizing $^{ISIC}$DSS$_{SI}$ model. Further the identified $^{REI}$KIFs can be used to determine EES$_{SI}$ score of the planned or developed REI, if the planning and development of ISIC is based on other considerations.

### *5.6 Stage VI—InfraInv Analysis*

The financial performance of infrastructure is a key element for business sustenance. The literature review of KSI indicates that extreme importance is laid on the economic aspects of the project. The sound financial performance of InfraInv of ISIC cannot be overemphasized as ISIC has to meet the multiple objectives of quality services, affordability, value for money and full cost recovery of the initial investment and operational expenses. However this is a complex problem as several factors influence this decision and it is not appropriate to structure and perform diagnostic analysis of InfraInv of the ISIC on a rational basis without due consideration towards incorporation of

eco-friendly elements, envisaged quality of PIE infrastructure, incorporation of REI.

In most of the circumstances, InfraInv sustainability aspects are ignored in the technical analysis of the ISIC. This gap has been addressed sufficiently in this paper.

InfraInv analysis essentially incorporates: (a) investment on core infrastructure; (b) smart applications; (c) IE principles and environmental friendly solutions; (d) REI to meet the energy demands; (e) PIEI adhering to various environment and regulatory laws; (f) investment decision factoring environmental considerations; (g) local employment opportunities; and (h) social inclusion. Hence, it will be adequate if the economic dimension, reflected as financial performance of $^{ISIC}$InfraInv, is captured in the SA of ISIC. Thus, all the three dimensions of sustainability are eventually addressed in the identified $^{ISIC}$KIFs as explained in Table 7.

The identified $^{InfraInv}$KIFs are project specific thus offering scope for examining viability and sensitivity analysis utilizing $^{ISIC}DSS_{SI}$ model. Further the identified $^{InfraInv}$KIFs can be used to determine $EES_{SI}$ score of the financial performance of the developed ISIC, if the planning and development of ISIC is based on other considerations.

**Table 7 $^{ISIC}$KIF for SA of ISIC—Stage VI of ISIC development: infrastructure investment analysis ($^{InfraInv}$KIF) (Source: Authors).**

| S. No. | Identified $^{ISIC}$KIFs (with sustainability dimension and designation), reflecting EES perspectives, fulfilling the established DQC | Objective/rationale | Relevance of $^{ISIC}$KIFs towards stakeholders involved in development of ISIC |
|---|---|---|---|
| 1 | Infrastructure investment per unit area **EES perspectives-$^{InfraInv}KIF_{eessus1}$** | It is pertinent to keep minimum investment of the ISIC while ensuring quality of the infrastructure/incorporation of eco-friendly elements/smart applications/REI including extensive applications of IE principles | A/B/C/D/E |
| 2 | Leverage ratios and are constituted by the following sub-influence factors: Total debt ratio/ debt equity ratio/ capital equity ratio/ interest coverage ratio **EES perspectives-$^{InfraInv}KIF_{eessus2}$, $^{InfraInv}KIF_{eessus2}{}^{1-4}$** | Indicate proportion of debt and equity in financing | A/B/C/D |
| 3 | Profitability ratios and are constituted by the following sub-influence factors: Gross margin/ net margin/ PAT to EBIT ratio/ Return on investment (RoI) before tax/ RoI after tax/ return on equity **EES perspectives-$^{InfraInv}KIF_{eessus3}$, $^{InfraInv}KIF_{eessus3}{}^{1-6}$** | Measure of overall performance and effectiveness | A/B/C/D |
| 4 | Activity ratios and are constituted by the following sub-influence factors: Inventory turnover/number of days of inventory/debtors turnover/collection period/assets turnover/working capital turnover **EES perspectives-$^{InfraInv}KIF_{eessus4}$ $^{InfraInv}KIF_{eessus4}{}^{1-6}$** | Reflect efficiency in utilizing its assets | A/B/C/D |
| 5 | Liquidity ratios and are constituted by the following sub-influence factors: Current ratio/quick ratio/internal measure **EES perspectives-$^{InfraInv}KIF_{eessus5}$, $^{InfraInv}KIF_{eessus5}{}^{1-3}$** | Measure of ability to meet current obligations | A/B/C/D |
| 6 | Tariff or revenue modeling for full cost recovery of ISIC development and operation expenses **EES perspectives-$^{InfraInv}KIF_{eessus6}$** | For achieving inclusive, affordable, sustained operations and business sustainability, it is imperative that full cost recovery should be achieved | A/B/C/D |

**Table 8 Summary on number of $^{ISIC}$KIFs identified for SA of ISIC (Source: Authors).**

| Stages \ EES perspectives | ecosus | evnsus | socsus | eessus | Total |
|---|---|---|---|---|---|
| Finalization of geographical location | 7 | 3 | 3 | | 14 |
| Finalization of operational sectors | 7 | 3 | 3 | | 14 |
| Finalization of theme | | | | 1 | 1 |
| Planning and development of PIEI | 98 | 12 | 13 | | 123 |
| Planning and development of REI | | | | 9 | 9 |
| InfraInv analysis | | | | 25 | 25 |
| **Total** | **112** | **18** | **19** | **35** | **184** |

## 6. Conclusion and Recommendation

ISIC is a powerful industrial ecosystem that can promote EES sustainable societies, if we adopt a holistic approach in the entire planning and development cycle. ISIC brings economies of scale of operation, both for the infrastructure developer and for the occupant units through symbiotic cooperation, encourages IE like exchange of by-products and cascades of energy use between occupant units.

The identification of appropriate KSI is usually a major challenge. These should not only reflect EES perspectives but also need to factor key considerations involved in the entire planning and development cycle. From the literature, it is evident that there are no well-defined or clearly articulated KSIs especially factoring EES considerations. While some literatures are available for SA of infrastructure projects, these do lack in many aspects more specifically, the KSIs do not reflect the contextual requirements and only few characteristics are analyzed. Further, the review of the prevailing KSI indicates that extreme importance is usually laid on one dimension of sustainability and rarely holistic SAs from EES are carried out.

It can be concluded from the above considerations that the DQC and KSI adopted in the previous studies are not adequate or directly relevant for SA of ISIC.

This article bridges the identified gap by (a) developing a set of comprehensive DQC for providing input towards selection of $^{ISIC}$KIFs and (b) identifying a set of $^{ISIC}$KIFs for each stage of ISIC development from EES perspectives that are encapsulated within the $^{ISIC}DSS_{SI}$ model for SA of ISIC.

A significant contribution made in this article is the identification of 184 $^{ISIC}$KFIs (including sub-influence factors) for SA of ISIC. In comparison with the generally adopted approach for SA of infrastructure projects, the identified $^{ISIC}$KFIs are much larger both in terms of depth and width as evident from Table 8.

The identified $^{ISIC}$KFIs are founded strongly on an underlying concept of inclusive, smart, sustainable development with an adequate consideration to EES dimensions of sustainability while addressing the issues on an end-to-end basis from different stakeholder perspectives. Also, from the research, it is evident that the $^{ISIC}$KIFs specifically developed for the ISIC can also be suitably adapted for SA of other individual infrastructure systems.

A significant contribution of the article deserving emphasis is the flexibility incorporated in SA methodology towards developing the $^{ISIC}$KIFs, as enumerated below:

- reflect changes in the economy;
- reflect changes in the performance of various influence parameters, policy changes;
- enhancing the approach towards inclusive smart development;
- incorporate changes in the design approach or design input of ISIC;
- factor changes in the construction methodology;
- incorporate the changing trends in green aspects of the PIEI;
- conceive RE related developments and market dynamics of REI;
- reflect changes in financing structure and project

evaluation criteria.

A decision support system model based on multi criteria decision analysis, developed as a spreadsheet based tool (designated as $^{ISIC}DSS_{SI}$) can effectively utilize the identified $^{ISIC}$KIFs to determine SI of ISIC (denoted as $^{ISIC}EES_{SI}$) from EES perspectives on a 0-5 scale. The SA methodology developed in this article towards establishing 184 $^{ISIC}$KIFs makes the $^{ISIC}DSS_{SI}$ models apposite for real life situations and actual field applications.

It can be concluded from the identified $^{ISIC}$KIFs that for achieving overall sustainability, it is pertinent to develop SA methodology for each stage of planning and development. A well-defined EES evaluative framework is conceptualized in this research underlying the concept of IE and triple bottom line approach towards ISIC development. Scientific and rational assessment of the ISIC location, finalization of operational sectors of ISIC, targeting and positioning of the ISIC, planning and developing PIEI and REI systems, financial sustainability and affordable infrastructure have significant influence on the sustainability of ISIC. Unlike other SI and rating systems, $^{ISIC}$KIFs developed in this article will not only help to assess sustainability but also guide in planning and development of ISIC from EES perspectives and provide a mechanism for enhancing the EES sustainability of ISIC.

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