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A holistic framework for evaluating and planning sustainable rural drinking water projects in sub-Saharan Africa

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ABSTRACT

Clean water facilities and services are failing the population of sub-Saharan Africa (SSA), hindering the goal of "Water for All" owing to unsustainable drinking water projects and infrastructure. A vast body of literature has examined the lack of sustainability in drinking water projects, identifying: economic, technological, planning, social and political factors. However, much of the existing literature reflects fragmented and siloed thinking, often focusing on specific issues without a holistic view, masking root causes, and overlooking multi-level stakeholder involvement, necessitating deeper analysis. In addition, most studies view individual projects as pertaining to a single spatial level—such as the village level—detached from its regional or global ecosystem. This paper introduces the "Holistic Integrated Framework" developed through a study in Siaya County, Kenya, on the sustainability of water projects aimed at bridging these gaps. This tool can enhance our understanding of sustainability, allowing for a comprehensive examination and understanding of the problems. It enables the identification of multiple spatial and governance levels and their cross referencing with sustainability categories. It uncovers essential underlying factors driving project sustainability and assesses stakeholders' interconnectedness as well as the direct impact of their actions, thus assisting in addressing the myriad obstacles to sustainability. Furthermore, it identifies the regional feedback loops that perpetuate these problems. The tool is exemplified through a case study illustrating the complexity and fragility of sustainability's, emphasizing the need for a detailed, comprehensive analysis to mitigate risks.

1. Introduction – problem statement

Potable water production, distribution, and services have failed to meet the requirements of sub-Saharan Africa (SSA). In 2020, the Joint Monitoring Program (JMP) Progress Report stated that 26% of the global population lacked access to safe drinking water services, and an estimated 387 million people in SSA do not have access to basic clean water—defined by the JMP as an improved water source with a round-trip collection time not exceeding 30 min—thus relying on limited, unimproved, and surface drinking water (WHO, 2021, p. 3). In Kenya for example, 38% of the population lacked basic water in 2020 (WHO, 2021), and in Siaya County, Kenya—the study area—the statistic was 55% of the population in 2018 (Avidar, 2020). Sustainable Development Goal 6 (SDG 6) for clean water and sanitation is severely off-track, and projections suggest that by 2030, 1.6 billion people worldwide will lack access to safe drinking water (UN-Water, 2020; WHO, 2021). This persistent problem prompts the question of why "Water for All" remains elusive.

One primary reason for inadequate access to potable water is the lack of sustainable drinking water projects and infrastructure throughout SSA. The term, drinking water projects in this study include planning, treatment, and design and implementation of infrastructure as well as distribution, training operators, and social issues concerning the project. Between 30% and 60% of water supply systems and projects across rural SSA are defective or fail after completion, impeding their sustainability over time (Franks and Cleaver, 2009; Koehler, 2014; Carter and Ross, 2016; World Bank, 2021). Additionally, the current statistics on safe and basic water coverage are suspected to be even lower, as some studies consider only the presence of infrastructure, regardless of functionality, water rationing, or water quality (Carter and Ross, 2016). This sustainability crisis extends beyond the technical issues observed on the surface and encompasses social, economic, and political factors. The insufficient attention to long-term project sustainability, which can be prevented if holistic measures are taken, has resulted in the wastage of

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hundreds of millions of dollars spent annually on water projects by international agencies, governments, donors, and private investors. Hypothetically, for every $1 million spent on water, up to $600,000 must be spent again, perpetuating a feedback loop of failure. Calderon and Serven (2008) demonstrate how deficient infrastructure is a major obstacle to growth and poverty reduction across the region. Hutton and Varughese (2016), reiterate the high rate of breakdown in water infrastructure and inefficient water delivery services, rationalizing the need for "a major new focus on sustainability" (p. 6). They emphasize that new approaches "should be designed and implemented to ensure the quality and sustainability of new infrastructure, thereby reducing costs in the long run" (p. 6). Although climate change and water availability pose challenges beyond academic and practitioner control, project sustainability can be enhanced. This study aims to address this challenge by introducing the Holistic Integrated Framework (HIF), a comprehensive approach for evaluating and planning project sustainability.

Amid extensive research on Africa's water crisis, universal access to potable water remains elusive. Although practitioners and organizations may understand the importance of sustainability, its complexity may be highly overwhelming, leaving them with scant knowledge of how to move toward it. Based on these observations, this paper seeks to answer the following questions: How can we comprehensively assess project sustainability? Which factors should be examined, to uncover the fundamental determinants of sustainability? Why are drinking water projects unsustainable, and how can we address this issue effectively?

The Holistic Integrated Framework (HIF) developed by the author, serves as a tool for comprehensively evaluating project sustainability by considering various interrelated factors and stakeholders. It adopts a systems perspective (Wright and Meadows, 2008) to reveal the entire ecosystem of a project beyond its technical components, identifying the broader dynamics affecting sustainability and regional feedback loops. This article has three objectives: (i) to remind us of the cruciality of sustainability given that it is severely lacking in many water projects across the African continent and to assist in learning from previous mistakes and preventing their recurrence; (ii) to present the HIF as a comprehensive, holistic approach, a perspective that is currently lacking in many studies; (iii) to present the framework in a manner that can be adopted by practitioners and academics when evaluating project sustainability or planning a new water project.

The next section presents the research methodology. Section three presents a literature review on sustainability and its various factors. Section four presents the framework and its development process. Section five discusses a case study illustrating the application of the HIF in evaluating project sustainability. This is followed by concluding remarks and limitations.

2. Research approach and methodology

The HIF was developed during a study on the sustainability of drinking water projects in Siaya County, Kenya. The complete Siaya County study included four case studies and a regional analysis involving open-structured interviews with government officials, NGO representatives, rural and urban inhabitants; questionnaires; and observations conducted between July 2017 and February 2018. Several of these interviews are referenced in this paper, as (I-X, year). Additionally, an extensive review of the literature, government documentation, and organizational reports was conducted. A research permit and ethical approval were obtained from the National Commission for Science Technology and Innovation (NACOSTI) (permit: NACOSTI/P/18/33568/20743) and the Institutional Review Board of the United States International University-Africa in Nairobi, Kenya.

Siaya County was selected owing to its abundant water resources, allowing a focus on infrastructure sustainability rather than the biophysical aspects of water scarcity or climate change, which were also considered but were not the focus of this study. The study aimed to understand why areas with ample water resources still face poor clean water access, as seen in many African countries. The case studies were representative of different water access schemes in various ecological environments, planned and implemented by different types of organizations. Interviews covered project details, planning, stakeholders, and user satisfaction, and improvement suggestions, through questions pertaining to their perception of the drinking water situation, planning and implantation processes, participating actors, their satisfaction level with the project and suggested modifications. Multiple site observations were conducted to assess infrastructure conditions and social dynamics.

The study sought to determine what makes a project sustainable, if so, how, and if not, why. It started with several hypotheses based on the literature and its gaps, as detailed in section three: (i) sustainability factors are vast and complex and must be considered holistically rather than through fragmented siloed thinking (MacArthur et al., 2020); (ii) surface issues may obscure underlying factors and must be assumed and uncovered; (iii) ecosystems and systems perspectives are necessary for a comprehensive assessment; (iv) many stakeholders at multi-governance levels impact projects that are not necessarily obvious.

Each case study presented a wealth of diverse information that led to the need to organize, categorize, and evaluate the information better, which in turn led to the devising of the framework. The data and information from the various methods were first categorized using NVivo 12 software, employing thematic analysis of different general sustainability factors such as economic, social, or others, based on the existing literature. Stakeholders from different organizations and governance levels were identified and categorized, which later determined the general categories of the HIF.

Some projects lacked documentation, and existing documentation often offered a limited perspective. Interviews provided valuable but sometimes contradictory or incomplete information. It was also unclear who the stakeholders were in each project, to which organization they belonged, which decision led to which outcome, and who made it and where, necessitating verification through multiple perspectives. Consequently, thematic categorization was insufficient, necessitating an additional evaluation tool which will enable to look further into additional factors and stakeholders enabling a more holistic understanding of the vast subject of sustainability.

The HIF emerged as the study progressed, featuring a matrix of two dimensions: (i) a vertical multi-level spatial and governance categorization of stakeholders (stakeholders' levels) and (ii) a horizontal general categorization of sustainability factors (sustainability factors). This matrix facilitated deep analysis through cross-referencing of the different categories. This enabled to uncover the sustainability factors as well as the underlying factors, and thus present the full picture from different project levels and stakeholders' viewpoints and provide a comprehensive understanding of sustainability challenges, as detailed in section four. Although the field study concluded in 2018 and revealed the specific challenges of the projects at the time, the framework offers a timeless approach because it uses general categories, allowing for replicability in other territories.

3. Sustainability and its importance

Prior to exploring the concept of sustainability, it is important to comprehend why this framework was developed for SSA. This region has the lowest access to clean water and the least increase in clean water coverage over the years (Hutton and Chase, 2016; Fukuda et al., 2019), thereby increasing poverty and human suffering. Several factors have contributed to this disparity. Historical neglect during colonial times left a weak infrastructural foundation, particularly in rural areas (Nyanchaga, 2007). Post-colonial states witnessed state disengagement (Tripp, 2012) owing to government instability, limited development funds, and the influence of Structural Adjustment Programs (SAPs) during the 1980s and 1990s (Stiglitz, 2002). SAPs have been criticized for the lack of essential infrastructure in several African countries, owing to government downsizing encouraged by foreign intervention (Stiglitz, 2002). Consequently, civil society and NGOs took over numerous essential services (Animashaun, 2009), resulting in a complex interplay between official, unofficial, private, and public entities (Rothchild and Chazan, 2019). Globalization further widened spatial divides, fostering a multitude of stakeholders and complicating project governance (Ferguson and Gupta, 2002). In addition, projects in the African continent rely heavily on external and donor funding, knowledge, and technology, limiting their independence and subjecting them to external influences (Sambu and Tarhule, 2013; Breuer et al., 2019). Consequently, a multi-level analysis involving global governance becomes crucial for development projects in these regions. Decentralization—adopted as the accepted method for water distribution around the continent, particularly in Kenya through the Devolution Constitution—necessitates a focus on the regional level (Rono, 2002). Persistent poverty challenges initiatives that rely on cost recovery, depending on people's ability and willingness to pay (Whittington et al., 1990) and the capability of governments to implement and sustain such efforts. Finally, ongoing governmental restructuring based on global trends leads to political turmoil (Sambu and Tarhule, 2013), necessitating a thorough social and political analysis.

The concept of sustainability was popularized by the UN Brundtland Commission's "Our Common Future" report in 1987. However, despite its formal adoption as an overall goal of the UN's Sustainable Development Goals (SDGs) since 2015, its true implementation remains elusive. Although often used to validate efforts, achieving genuine sustainability remains distant. That said, we cannot dismiss sustainability simply because it is overwhelming. Without a commitment to promote sustainability, we may continue to create unsustainable projects hindering the global goal of "Water for All."

In this study, sustainability primarily pertains to the sustainability of drinking water infrastructure projects. A sustainable water project is simplistically understood based on its functionality as defined by the IRC and WHO guidelines (Brikké, 2002). However, other factors are also involved, such as quality, quantity, convenience, reliability, institutionalized management, Operations and Management (O&M), community resilience, and avoidance of environmental degradation. Some studies have defined a sustainable water project as the continuous delivery and maintenance of services (Carter et al., 1999) or the "maintenance of an acceptable level of services throughout the design life of the water supply" (Mwnagi and Daniel, 2012, p. 579). Based on these definitions, the definition of sustainability used in this study is a functioning, continuous, and reliable system for the supply of potable water to communities designed for longevity while preserving natural resources.

The three main pillars of sustainability—social, economic, and environmental factors—originate from the Brundtland Report (Brundtland, 1987) are integral to water project sustainability. However, additional components need further elaboration to progress toward sustainability, although, these are not self-evident (Prugh et al., 2000; Clark et al., 2002). Moreover, there is no consensus on an index for measuring sustainability (Böhringer and Jochem, 2007). Numerous studies have examined the factors influencing the sustainability of water projects, revealing multiple facets of the challenge. Many of them analyze sustainability fragmentedly, discussing only one or two factors at a time, some of which are listed here. Poor planning is a fundamental factor that induces lack of sustainability (Mukhwana and Hukka, 1995; Brikké and Bredero, 2003; Barnes, 2009) and failure to conduct adequate evaluation and feasibility studies is also a major issue. Some studies discuss how projects are established by plans that have only a short-term focus or lack a clear regional access plan, which is developed in a piecemeal fashion depending on what the donor entity is willing to fund (Weiner, 1972; Butters, 2004; Moe and Rheingans, 2006). Other studies have examined policy issues, inappropriate legal and institutional frameworks (Whittington et al., 1990; Brikké and Bredero, 2003), and a lack of standards or quality control (I-11, 2017). Corruption as a hindrance has been mentioned in several studies (e.g., Zinnbauer and Dobson (eds.), 2008; Otieno, 2014), as well as mismanagement owing to poor governance or low capacity associated with rural management (I-11, 2017), all of which are related to planning and management issues. Some studies attribute the lack of sustainability to implementational tools and frameworks that are inappropriate for developing countries (Kalbermatten et al., 1999) or inadequate regard for local needs and financial capabilities (Whittington et al., 1990). Others point to insufficient consideration of related social, cultural, and economic aspects (Carter et al., 1999; Dunmade, 2002; Sobsey, 2006); lack of community empowerment (Schouten and Moriarty, 2003); and lack of participation and involvement in the community (Brikké and Bredero, 2003; Lockwood, 2004; Barnes, 2009). Chowns (2015) argued that community management is not an effective framework, and added external capacities that are needed. Technological aspects and decision-making factors have particularly been emphasized (Dunmade, 2002) owing to inappropriate technology and a lack of O&M (Brikké and Bredero, 2003; Lockwood, 2004; Abebe and Hawassa, 2008). Finally, environmental issues, such as water contamination and lack of conservation, have also played a leading role. These are only examples and a fraction of the studies.

Some studies argue for a more comprehensive view, emphasizing the integration of various factors essential for a truly sustainable project. Marcus and Onjala (2008) found that the sustainable management of water resources depends on economic factors and financing, as well as legal and regulatory frameworks. Peter and Nkambule (2012) conclude that technological and social factors are more important than financial and institutional ones (see also Juwana et al., 2012; Spaling et al., 2014). Malmqvist et al. (2006) proposed five key sustainability factors for water and sanitation systems: environmental, economic, social, technological, and health. Franks and Cleaver (2009) discuss water governance as an encompassing concept that includes resources, stakeholders, and mechanisms, thus enabling a comprehensive approach for analyzing sustainability; however, they do not elaborate on the different impact levels such as global factors. Brikké (2002) compiled the most inclusive sustainability guide for water projects, presenting multiple factors, followed by Brikké and Bredero (2003) and Abebe and Hawassa (2008). They conclude that a sustainable water supply service should meet ten criteria, defining a sustainable water project as one that is being used, functioning, and supplying the planned "benefits of appropriate quality, quantity, convenience, continuity, and health to all" (Brikké, 2002, p. 9), as well as its reliability and yield of economic benefits. They consider managerial, social, and environmental issues, contending that a range of factors specifically related to O&M should be accounted for, at the local level. However, they refer to particular trends, such as private sector involvement or concerns for health or gender equity as the overall goals of the project, which might be less relevant in some projects. However, through these models, often only the technical or financial challenges come to the surface and they do not propose a process to uncover the underlying factors: those that may be fundamental problems such as social and political factors.

Socio-technical approaches, such as ecosystems and systems theory (Wright and Meadows, 2008) and political ecology theories that focus on human agency (Buechler and Hanson, 2015; Bisung et al., 2016) provide comprehensive methods for analyzing social inequalities and broader dimensions that include global and political factors. They allow the positioning of a project within its ecosystem, revealing connections between water elements, sustainability factors, as well as relationships and interactions between stakeholders, while assisting in identifying feedback loops. A feedback loop is a process in which the outputs circle back into the system as inputs, which can be positive or negative.

According to Nunan et al. (2016), the "complexity of natural resource governance suggests that a multi-level governance perspective is needed to help understand who is involved and how actors interact, and to identify opportunities and challenges for greater cooperation" (p. 1). They also argue that working at multiple levels is extremely challenging, and stakeholders and policies are seldom considered (Nunan et al., 2016). Kemp and Martens (2007) argue that sustainability is an inherently subjective concept requiring a heterogeneous local understanding. Understanding the shortcomings of sustainability is also important (Swidler and Watkins, 2009; Nebbia, 2012), and raises the question of whether it is truly achievable. This position was also expressed by Hardin (1968), who describes the inherent conflict between an individual's use of the commons and the collective good. Similarly, issues such as war and global security (Lempert and Nguyen, 2011), alongside persistent challenges such as corruption and greed (serious problems yet to be addressed), as well as the dynamics of political and social trust or distrust (Levi and Stoker, 2000) all exert significant repercussions that pose a critical threat to sustainability.

The literature has shed light on the gaps in analyzing sustainability which the HIF aims to address. The first is the siloed thinking and absence of a comprehensive, holistic perspective encompassing the vast and intricate array of factors, as described in this section. The HIF categories allow to include as many relevant factors as possible and were derived and synthesized from the literature and interviews. The second gap lies in focusing solely on surface-level issues. Technological issues often overshadow the root causes of problems. The HIF Matrix was developed to uncover the underlying factors, by posing questions around the main categories.

The third gap involves a narrow perspective that leans toward micro-level assessments rather than adopting an ecosystem approach. Evaluations typically occur at either a micro-project level (Abebe and Hawassa, 2008) or a broader, macro-national level (Hope et al., 2014), neglecting the significance of regional analyses. Examining projects at the regional level is crucial, as it unveils the ecosystem surrounding a project. Drawing on systems theory and ecosystem approaches (Wright and Meadows, 2008; Bisung et al., 2016), the HIF can identify the ecosystem and regional feedback loops that serve as the framework within which a project operates.

The fourth gap pertains to the oversight of multiple stakeholders across various levels of governance. The success or failure of a project cannot be ascribed solely to the community involved. Stakeholders at different governance levels wield influence over a project and should be considered even if their impact is not immediately evident. The HIF addresses this gap by simultaneously examining stakeholders across multiple spatial-governance levels (Nunan et al., 2016). This multi-level analysis offers a systems perspective that unveils the broader political interconnections and social dynamics related to sustainability.

While a narrow focus allows for a detailed analysis of specific sustainability components, this study contends that a comprehensive approach is better suited for achieving sustainability for water projects because of its intricate nature.

4. The Holistic Integrated Framework (HIF)

To address the complexity of sustainability in drinking water projects, a matrix was developed, as described in the methodology, which includes two main dimensions: vertical – stakeholders' levels and horizontal - sustainability factors dimensions, as shown in Fig. 1. and detailed below. Fig. 2. portrays that each vertical level has an impact on each horizontal category.

The matrix enables us to understand the full ecosystem of a project in terms of its sustainability factors, as well as all stakeholders, and governance entities that might have an impact on the project. This format enables an in-depth analysis required for a full understanding of the situation by cross-referencing the two dimensions. This enables us to uncover the underlying factors and reveal all stakeholders through a systems perspective, demonstrating the nuances of sustainability as determined by the circumstances of the local case studies as well as identifying the regional feedback loops.

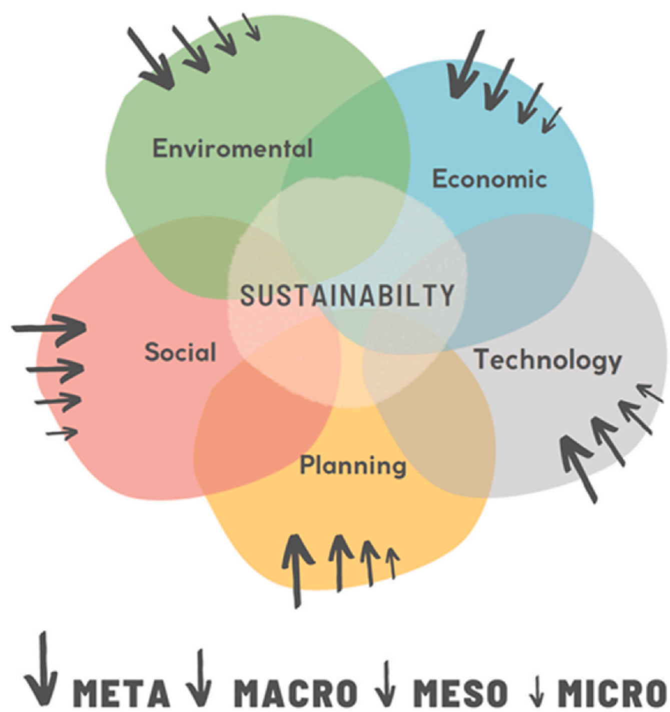

Fig. 2. Impact of vertical players on horizontal categories.

Stakeholders' levels / Sustainability factors	Planning	Social	Economic	Technological	Environmental
Meta-Global					
Macro-National					
Meso-Regional					
Micro-Utility/Community					

Fig. 1. Holistic integrated framework (HIF) matrix for evaluation.

4.1. HIF dimension #1: Vertical stakeholders' levels

The concept and definitions of stakeholders are complex, Miles (2017) enumerates 885 published definitions. In this study, stakeholders are defined as any players who have a role, responsibility, or significant input in a project from planning and funding to implementation and usage—at any spatial-governance level—from the local community to the global level, and at any stage of the project. Spatial levels imply the place where a certain decision is made, from where a certain stakeholder comes, and where the project is implemented, such as the global, national, regional or community level, which are also governance levels. Stakeholders and players include government entities, officials, institutions, donors, NGOs, contractors, suppliers, and local communities. They also encompass contributing factors such as development trends, legislative frameworks, policies, and political hierarchies and structures. Often, analyses focus solely on the micro-level where the project was implemented, evaluating only the actions of the community, and overlooking the substantial influence of external players. For example, global institutions shape water development programs, policies, and trends, impacting projects positively or negatively. Many such programs—although well intended—have created new problems and some were even extremely harmful, such as SAPs, which were intended to stabilize and liberalize countries (Rodrik, 2006), but in fact created state disengagement and halted many basic needs services (Stiglitz, 2002) such as drinking water projects. Other examples, notably the Millennium Village Project (MVP), one of the most comprehensive and generously funded international initiatives based on the Millennium Development Goals (MDGs) from 2005 to 2015, was severely criticized for failing to achieve its goals, which had a detrimental effect on the local community (Kimanthi and Hebinck, 2018). As demonstrated in the case study below, even macro national and regional political aspects such as a new constitution may affect a project's sustainability. These examples are all elements of the ecosystem for any individual micro-project, that must be evaluated; however, performance evaluations of funding entities or international programs are rarely made as part of the assessment of a specific project. The HIF recognizes these multi-level stakeholders and players, ensuring that all relevant entities are considered and assessed at all levels, as shown in the case study.

The HIF employs four main spatial-governance levels: (Table 1):

Meta-global, Macro-national, Meso-regional, and Micro-village/scheme/utility/project levels. The meta- and meso-levels were added to the typical macro- and micro-assessments with two intentions: to reveal and map all relevant external and internal stakeholders and players, their functions, and responsibilities. The process includes the analysis and uncovering of the alignment of interests between the stakeholders, their interactions, cooperation, partnerships, and the political and social dynamics behind the scenes, shedding light on their impact on project sustainability. Questions that should be asked within this dimension are: Who are the players at each level; what are their responsibilities; what is the interaction between them; how were they involved in the project and what impact did they have on the project; both positive and negative impacts must be considered. The second to identify the ecosystem and its feedback loops by asking questions about the regional historic, political, economic, and environmental situations. Even if a certain level was not apparent initially, this dimension compels the researcher to investigate all levels. Table 1 provides examples of stakeholders and players to be considered.

4.2. HIF dimension #2: Horizontal sustainability factor categories

The second dimension includes five general categories of sustainability factors: the three basic factors from the Brundtland Report (1987), social, economic, and environmental factors and two additions extrapolated from the literature: planning and technology. While the framework delineates individual factors, the case study illustrates their interconnectedness. Each of these categories encompasses multiple factors that must be considered in assessing sustainability. Table 2 details the many possibilities, several of which have come up through interviews in the study. The vast number of factors and their specific interconnectivity emphasize the necessity of considering local contexts and conducting assessments tailored to the unique circumstances of each project. Thus, unveiling the factors pertinent to individual projects (Kemp and Martens, 2007) and going beyond the evaluation of predetermined or trending factors. All categories must be considered at each vertical level thereby enabling the identification of the interactions and dynamics of the situation. For each category, the researcher must ask several questions:

4.2.1. Planning and managerial factors (Mukhwana and Hukka, 1995; Brikké and Bredero, 2003; Barnes, 2009)

What was planned and how, in all stages of the project? What was designed and by whom? What scenarios were taken into consideration? Managerial questions must also be asked: How was responsibility allocated? How was the project organized? by whom? And how was it managed and supervised?

4.2.2. Social and political factors (Brundtland et al., 1987; Brikké and Bredero, 2003; Otieno, 2014) including culture, history, gender etc

What is the social structure of the community? What are the political issues in the different levels? Are there ethnic issues, marginalization,

Table 1
HIF dimension #1: vertical stakeholder levels.

Meta-Global	Macro-National
a. Global trends, programs, and inputs: MDGs, MVP, SDGs, other development doctrines. b. International institutions: international development agencies; international financial institutions, such as the UN and all its agencies, the World Bank, the IMF, ADB, etc. c. Other international players: NGOs, donors, foundations, corporations, suppliers, contractors etc.	a. National government: legislation, water acts, regulations, policy. b. Ministries: water, economy, finance, agriculture, irrigation, environment, and health. c. Institutions: LVS, WASREB, WSTF; operational, funding, regulatory. d. Governance trends: e.g., devolution. e. Donors; private investors; NGOs; suppliers and contractors.
Meso-Regional	**Micro-Local**
a. Government: county, province, municipality, sub county, water officers, ward administrator, county secretary. b. Elected officials: members of parliament, members of council, etc. c. Water service providers, cooperatives, associations, and employees. d. Donors; private investors; NGOs; suppliers and contractors.	a. Village, community. b. Utility, water scheme, project. c. Water committees, sectorial representatives, *baraza*, development committee, other committees. d. Local leaders: chief, elder, secretary. e. Consumers, users. f. Donors; private investors; NGOs; suppliers and contractors

Other levels might be added where relevant, such as: Meta regional (African Union), higher meso (Province), lower meso (District, location, sub location).

Table 2
HIF dimension #2: horizontal sustainability factors categories.

Planning and management factors
a. Pre-planning, data gathering and design, how the project should be constructed, how many water points, whom will it serve, how will they reach the area, inclusive planning, etc. b. Adjustments to national, regional, legal, and institutional framework c. O&M, who will take responsibility for it and how, financing d. Training on tech, knowhow, O&M e. Life cycle assessment (LCA), durability of equipment, spare parts f. Social and economic planning, community involvement, Does the community want change, induce ownership, local opinion, affordability estimations, fees, and price regimen, etc. g. Information flow, reporting, transparency h. Responsibility allocation, supervision mechanism, project assessment, accountability measures i. Management structure and capabilities; regulatory issues and governance structure j. Exit strategy; the day after the NGO or government leave the project k. Resiliency, the ability to withstand financial, social, political, and environmental pressures, exit strategy l. Dual teams, system for scale up and transfer of knowhow, inclusive planning m. Alternative 'good enough' existing projects
Social and political factors
a. Cultural norms b. Historical issues c. Human behavior and dynamics: malgovernance, corruption, power struggles, political interactions d. Interest groups e. Social structurers, collectivism vs. individualism f. Community integration, cohesiveness g. Community involvement/participation/buy-in/ownership, and implications h. Community empowerment i. Gender and social differentiations j. Creating norms k. Creating trust and legitimization
Economic factors
a. External funding: donors, government funding, investment capabilities b. Community funding c. Appropriate tariff setting d. Fee collection, willingness, and ability to pay e. Allocation for O&M f. Long-run scheme income generation, and scaling up for viability, economies of scale g. Water/agriculture/food nexus h. Sanitation nexus, energy nexus i. Future expenses j. Local income generation k. Management issues and governance
Technological factors
a. Appropriate tech and compatibility with the operators b. Availability, accessibility, cost of spare parts and enhancing the supply chain c. Standardized technology d. O&M design, training, and cost e. Required skill training f. Tech constraints g. Cost/benefit analysis h. Innovation
Environmental factors
a. Do no harm b. Climate change and biophysical factors c. Conservation and future supply d. Quantity e. Quality f. Foot printing: carbon, ecological and water g. Alternative energy and efficiency h. Water security

These are some examples for reference.

corruption allegations? What are the community dynamics, are they united or fragmented? What are the interactions between external stakeholders and locals and between levels? Were gender and inequality issues considered? Can cultural norms or historical issues impact the project? What was the level of participation? Is the community empowered and can they take ownership of the project? Has community resiliency been addressed? This category enables one to uncover the underlying factors that might be hidden.

4.2.3. *Economic, and funding factors* (Brundtland et al., 1987; Whittington et al., 1990)

What is the extent of governmental or institutional funding? What is the financial viability of the utility company or the project and their ability to generate income and recover costs? What is the national and local economic situation? What is the poverty level? Can the local population pay for services and are they willing to do so?

4.2.4. *Technology factors* (Dunmade, 2002; Brikké and Bredero, 2003; Lockwood, 2004; Abebe and Hawassa, 2008)

What technology was used? Was it appropriate to the local

Table 3
The system- and customer-based regional feedback loops (Avidar, 2020).

	Feedback loop	Description
1	**"Water First" loop**	Water—though a fundamental element—is in practice sidelined and deprioritized (Grey and Sadoff, 2007), thereby denying appropriate funding and programs.
2	**External multiple-player's loop**	External players may bring their own agenda, act in contradiction to local needs, and cause power struggles; multiple players cause responsibility ambivalence. **Seen in the case study**.
3	**Economic loops**	Malfunctioning projects waste much-needed funds; do not generate revenue, obstructing the company's growth, detract from the project's ability to sustain and expand and prevent water coverage increase and growth; a continuous vicious circle. **Seen in the case study**.
4	**Lack of accountability – malgovernance spectrum loop**	Lack of responsibility instigates weak supervisory structures resulting in an inability to enforce accountability causing malgovernance on a spectrum from incompetence to corruption. This includes norms of lack of transparency, mismanagement, misappropriation of funds, systems weakness, non-compliance with procedures, subpar work ethics and thus the cycle continues. **Seen in the case study**.
5	**Regional projects vs. ad hoc projects loop**	Stakeholders opt for investing in a smaller project, such as a surface storage pond which can provide an immediate ad hoc solution, rather than in a larger project such as a utility line, that will assist in the long run, thus preventing a cohesive, regional long-term solution.
6	**The international development loop**	The gap between theory/intentions and practice/reality; formed from external development interventions that create undesirable outcomes.
7	**Population poverty loop**	A poverty-stricken population cannot pay for water services or taxes, thus decreasing county and utility revenue potential, which decreases clean water availability causing more poverty.
8	**The discouragement and distrust loop**	A discouraged community, where people have lost hope because they know in advance that projects will not succeed (Levi and Stoker, 2000) giving up hope and unable to strive to change the situation.

circumstances? Does it take climate change into consideration? Is it cost effective? Can it be adjusted to the local eco-system? How much electricity does it use and is electricity available?

4.2.5. *Environmental factors (Brundtland et al., 1987)*

What are the climate change circumstances in the region? How might the project harm the environment? Has an environmental sustainability assessment been made?

4.3. *HIF regional assessment*

The regional perspective of the HIF identifies critical regional feedback loops that perpetuate issues and create environments that impact the sustainability of individual projects. This is enabled through matrix analysis. Table 3 lists eight system- and customer-based feedback loops that were identified in the complete Siaya County study. Although not all pertain to the case study, they are mentioned here as examples.

4.4. *The HIF process for evaluation*

The HIF process for evaluation comprises five steps: developing a stakeholder map; collecting data through interviews and other methods and inquiring about each category at each level; evaluating and analyzing the factors present in the project and the pertinent local circumstances by cross-referencing each category at the stakeholder level, exploring their interactions and dynamics; reviewing and reflection, to ensure ample coverage of all categories across all levels and uncovering underlying factors; identifying both the apparent and underlying sustainability factors specific to the project, determining the responsible stakeholders, outlining occurred dynamics, and highlighting feedback loops. Fig. 3 illustrates the process flow.

4.5. *The HIF as a planning tool*

While initially developed as an analytical tool for evaluating existing projects, the HIF can also serve as a valuable planning tool for

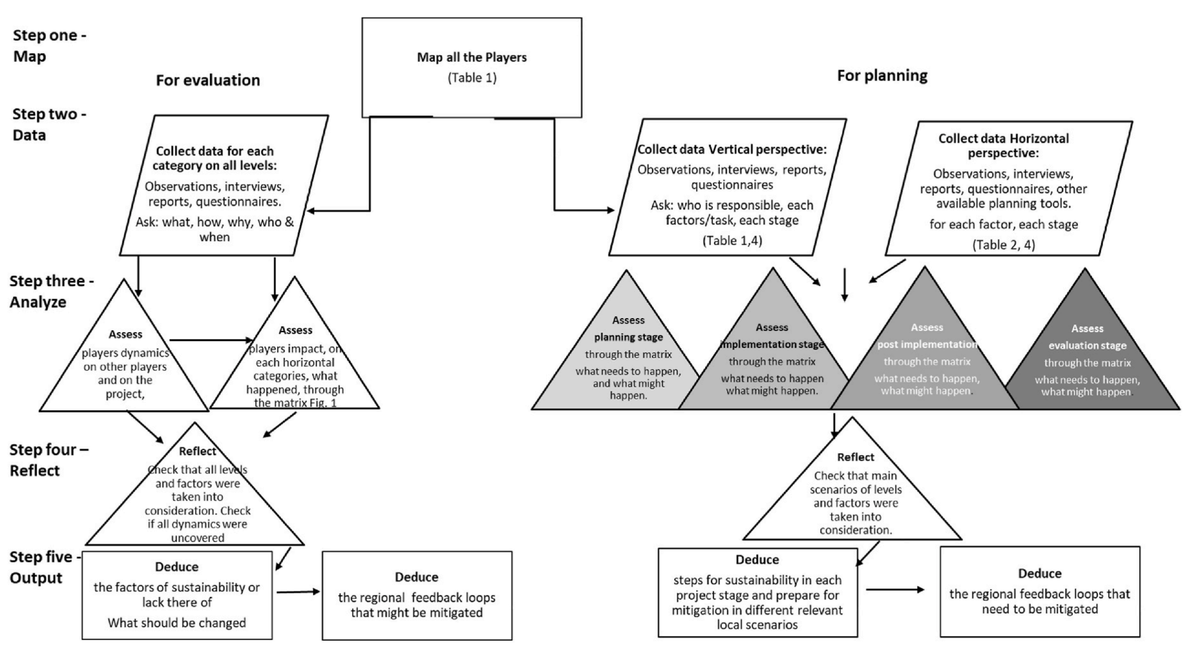

Fig. 3. Sustainability analysis – HIF flow chart.

Table 4
HIF dimension #3: project stages.

Project stage	Description
Planning	Pre-planning, data gathering, design, and feasibility study. The early phase of a project is one of the most significant factors contributing to project sustainability (Barnes, 2009). It is also critical when planning for future scenarios.
Implementation:	Construction and training
Post-implementation and "the day after":	Continuous training, operations and maintenance and fee collection.
Periodic evaluation	Reassessment, evaluation, and improvement

sustainable water projects. It can assist practitioners and researchers in navigating the complexity of sustainability by considering potential challenges and scenarios during the planning process. It can aid in bridging the divide between theoretical concepts and practical implementation when considering these aspects. The planning tool has a third dimension, consisting of four project stages (see Table 4): planning, implementation, post-implementation, and evaluation. As a planning tool, it is beneficial to create distinct matrices for each project stage. These matrices should outline the necessary actions and anticipate potential issues that could arise in various scenarios for each stakeholder and category, considering the local context and regional feedback loops. By creating separate matrices for each stage, stakeholders can anticipate issues, mitigate risks, and enhance a project's long-term sustainability.

5. Case study analysis and discussion

This section delves into the sustainability analysis utilizing the Holistic Integrated Framework of one case study out of the four from the complete study. It begins with a brief overview of the project and an initial assessment of its physical condition. Subsequently, it proceeds with a detailed analysis, mapping stakeholders and examining their involvement across the five sustainability categories while elucidating the reasons behind different scenarios.

This case study analyzes the Sidindi Malanga-African Development Bank Project (SM-ADB), a $20 million project, within the Siaya-Bondo Water and Sanitation Company (SIBO), the primary Water Service Provider (WSP) in Siaya County. Although intended to enable clean water access to 50% of the population, of about one million people, SIBO faced many challenges and was able to provide clean water to a mere 25% of the population by 2019. The company was established in 2006, and is currently fully owned by the Siaya County government. In 2017, all its ten facilities, operated below capacity, of which two were nonfunctioning, and 47% of the pipes were inactive (SIBO, 2017). The SM-ADB, was the latest upgrade and extension of an existing facility, developed and implemented as a national governmental development project known as a flagship project. It is the largest piped water scheme in the county through which the county aimed to increase its potable water coverage. The project is environmentally appropriate because it is hydraulically powered with gravitational distribution, thus using a minimum amount of electricity making it cost-effective, if it were executed as planned. In 2017, it was planned to quadruple the water production of SIBO and add 19,000 m^3/day to the existing 5200 m^3/day, thus expecting it to cover over 50% of the population. However, in 2019, the company was able to produce only 7760 m^3/day (SIBO, 2019).

The case study analysis draws from 32 interviews with SIBO board members, management personnel, employees, Siaya County Government and National government officials, other stakeholders such as NGOs, and users around the county, as well as five observations. Initial perceptions from the observations and interviews (I-17, I-76, 2017, I-180, I-181, 2018) suggested that technical issues such as faulty construction and placing inappropriate clean water turbines, unsuitable for the highly sedimented water from the Yala River, which incapacitated the facility, were the primary challenges hindering the performance of the SM-ADB. However, as the HIF analysis progressed, it became apparent that these technical issues were merely the surface of a more complex problem.

The first step of the analysis involved mapping stakeholders across multi-spatial-governance levels. This process revealed at least 15 internal and external players, each impacting the SM-ADB project in unforeseeable ways. Only the most significant players are mentioned here. The subsequent analysis explored the interactions and cross-referencing between stakeholders and sustainability factors (see Table A1, in the appendix for a summary).

The Meta-global level: The African Development Bank (ADB), played a major role as the primary external financier of the project, impacting economic factors. Although the interviews did not attribute the impact of the ADB to other categories or link them to the project's failure, the HIF analysis prompted queries regarding additional responsibilities they may have had. Although not directly involved in day-to-day project progression, the ADB played a role in shaping water management philosophies and priorities as a trendsetter and planner. Their emphasis on "clean water coverage for small towns" (ADB, 2018) conflicted with Siaya County's predominantly rural nature. Consequently, the project overlooked rural communities physically close to the project site and some in which the project infrastructure was spread on their land, leading to frustration among the excluded residents. This caused unrest in these communities, and some residents resorted to vandalism. Furthermore, the ADB also held a significant supervisory role, ensuring project compliance with the governance regulations outlined in their documentation (ADB, 1999; 2005) and establishing a global-level oversight role. Despite an ADB evaluation report in 2005 emphasizing the need for increased project supervision, these measures were either neglected on-site or delegated to others. This lack of oversight resulted in the technical mismanagement of faulty installations. In April 2018, an ADB official inaugurated the project, affirming its completion and functionality, despite reported deficiencies (Daily Nation, 2018), raising concerns about malgovernance. These instances indicate a global impact on planning, managerial, social, and political factors, presenting part of the underlying causes for the technical challenges. The influence of the ADB extended to the technical and environmental category as well, as they sanctioned environmentally sound and cost-effective technology, positively impacting the project.

A second player at the meta-global level was a Chinese contracting company, which received the project after a tender process in 2012 by Lake Victoria South Water Service Board (LVS). They were expected to hand over a viable working project, but did not. Under their execution, incorrect turbines were installed, and many of the pipes burst, leading to a non-functioning project. This issue remained unresolved in 2019 (I-180; I-181, 2018) and coincides with accusations across Kenya, that Chinese contractors deliver subpar work (I-164, 2018), along with allegations of contributing to malgovernance and corruption (Brautigam, 2009; Transparency International, 2018). Despite allegations of corruption connected to the faulty turbines, investigations into these claims were never conducted, highlighting their influence on management and political factors.

The Macro-national level: The Government of Kenya (GoK) was a co-financer and was responsible for flagship projects through the Ministry of Water and Irrigation. However, a less obvious factor uncovered was the Devolution Constitution. In 2010, the new Constitution of Kenya (CoK) was promulgated, creating a two-tier system of governance; the national and the counties, which were given devolved power, transferring responsibility from national to regional governments, bringing it closer to home. This policy is intended to enable more local control and decision making; in addition, it aimed at correcting injustices such as corruption and patronage politics (Ghai, 2008, p. 215). However, flagship projects remained under the jurisdiction and responsibility of the national government excluding local entities. This half-hearted devolution (Avidar, 2018), as mentioned by the interviewees, encouraged power struggles, and caused confusion in responsibilities (e.g., I-17; 2017, I-180; I-181, 2018), which contributed to reduced responsibility and poor accountability (I-23, 2017), but was not initially depicted as a direct factor of sustainability of the project. This presents an example of the national impact on economic, planning, and managerial factors.

Administrative and implementation responsibility for the project was given by the GoK to the Lake Victoria South Water Service Board (LVS), a national-regional entity responsible for water service providers (WSP). The LVS had a dominant role in the project vision, planning, contracting and supervision. However, owing to a lack of supervision, they too enabled the faulty installation of incorrect turbines. However, they did not take responsibility for this issue and blamed other parties (I-180; I-182, 2018). Furthermore, improper national funding and predating devolution, coupled with inadequate supervision of LVS in other SIBO projects, resulted in existing faulty infrastructure and corruption allegations. These circumstances weakened SIBO and disadvantaged the SM-ADB project from its inception. This highlights the macro-national external influences on planning, management, and technological factors.

The Meso-regional level: Siaya County Government (SCG). Despite formal local responsibilities as per the Constitution, flagship projects were not under the responsibility or control of the SCG, as mentioned in the macro-national section. Thus, they did not execute or supervise the SM-ADB project and were excluded from it (Avidar, 2018). This setup placed them in a delicate position, leading to an inherent conflict of roles: the SCG was best positioned and most incentivized to supervise the project as they were ultimately accountable to their constituents as per legislation; however, they could not do so because they had no jurisdiction over the flagship project. Thus, the SCG's position within the devolution framework created confusion and weakened accountability, impacting economic, planning, and managerial factors. Additionally, they faced accusations of various forms of misgovernance (I-40, 2017; I-41b, 2017; I-180, 2018). This demonstrates the impact of the regional level on the project and the national-regional dynamics affecting the local project.

A main player at the meso level is SIBO, the utility company for which the scheme was built. Under standard economic and political circumstances, a utility company is an entity that issues tenders for loans and contractors and supervises the contractor. However, in Kenya's case, because of the devolution's structure, SIBO was only the recipient and future operator of the flagship project and was assigned a minimal role in its implementation. Thus, SIBO did not have a formal position in the project construction. However, its readiness to operate the project was compromised by historical factors. Interviews and documentation from the Water Services Regulatory Board (WASREB) at the national level, which regulates all WSPs, uncovered long-term mismanagement. From 2007 to 2018, there have been detailed reports of continuous underachievement of almost all key performance indicators. The company suffered a lack of funding and was not self-sufficient. The company had high operational costs and could not adhere to cost-recovery regulations due to the population's high poverty rate. Meters were not installed, leading to the inability to collect accurate revenues (I-182, 2018). Lack of funds led to a long-term lack of payment to workers who became disgruntled and sabotaged some pipes, but also caused disgruntled customers who refused to pay because they felt underserviced. This lack of trust (Levi and Stoker, 2000) is a symptom of lack of sustainability as well as a cause for additional revenue loss suppressing income and growth. The result is a continuous feedback loop of failure in which less revenue leads to less investment, which in turn leads to less production and inadequate services for the population, all of which impede company growth, and the cycle continues. Thus, the company relied on external funds to provide its services, but was also in disarray owing to the situation. However, funding was not the only problem; owing to the unclarity of SIBO's status under a national or regional entity, as well as mutual accusations of corruption, power struggles evolved between the former board and the Siaya County government. This made them adversaries from 2013 until the replacement of the board in October 2017. In addition, some of the management officials were accused of misappropriation of funds but never charged. However, in 2018, the entire management team and board members were replaced. This array of intertwined underlying economic, management, social, and political factors had a detrimental effect on the functioning of the staff, paralyzing and weakening the company and thereby, the sustainability of SIBO. Throughout this time span and until the project's implementation, the company did not function properly, meters were not read, taps were dry, and several pumps malfunctioned without being repaired, causing a delay in the testing of the SM-ADB scheme, which delayed exposing the inadequate turbines and faulty pipes. All of which, influenced the SM-ADB project through a lack of technical support and supporting infrastructure, and finally managerial capacity, causing an inability of the company to deal with external stakeholders such as the contractor and LVS, which also affected the situation.

The Micro-community level: The community and SIBO customers. Many customers were discouraged by the lack of water because of shortages and rationing. This situation greatly interfered with their lives, causing them to pay more for water, further impoverishing them. This situation added to the company's financial instability because many users refused to pay their bills or even to be connected, while others vandalized the infrastructure (I-40, I-76, 2017; I-104, 2018), contributing to the inability of SIBO to cover costs, thereby affecting both social and economic factors.

The SM-ADB analysis demonstrates how the HIF revealed unforeseeable stakeholders, underlying sustainability factors and intricate interactions among stakeholders. The interaction between SIBO and SCG, which caused political and social instabilities, is an example of how social and political dynamics impact the project. The general HIF categories and levels led to questions that would not have been asked in a standard sustainability analysis, which usually only evaluates the local-spatial level. The HIF revealed that what appeared to be a technical problem of incorrect turbines and dry taps was only the tip of the iceberg, hiding an array of underlying problems and regional ecosystem feedback loops.

Using the HIF, this study uncovered several issues affecting sustainability pertaining to the specific case study. First, all spatial-governance levels had a hand in the lack of sustainability of the project, directly or indirectly. Second, the issue of multiple stakeholders and players was also problematic because it manufactured power struggles which caused confusion and disorder and weakening of accountability measures. This multiplicity of players created a third situation in which many entities had responsibility; therefore, no one took responsibility. Forth, this arrangement diminished the possibility of developing proper supervisory mechanisms, and the result was a weakening of accountability measures that although were put in place by regulations were not enforceable. Fifth, interestingly enough, those players the SCG and SIBO, who should have been the leading entities under conventional circumstances were missing from the game due to half-hearted devolution (Avidar, 2018) and thus decision-making, implementation and supervisory responsibilities were taken away from the local players contrary to the very core values of devolution. This caused a sixth occurrence of malgovernance, on a spectrum between incompetence, mismanagement, and corruption. Throughout the study there were many allegations of malgovernance at all levels: contractors, SIBO's board, management, and employees, the SCG, LVS and the national government. However, corruption can only be proven in court and it is very hard to verify, especially when there is a lack of supervisory and accountability measures, thus, the precise nature of the malgovernance, in this case could not be determined.

The seventh issue exposed by the analysis is the feedback loops as detailed above. The economic feedback loop is an example. Water projects are anticipated to achieve predetermined milestones for increased coverage, this is especially important due to limited funding. However, malfunctioning projects, such as the SM-ADB project, squander these essential funds, failing to meet the intended milestones. Consequently, a subsequent loop occurs when new funds are allocated to reach the previous coverage goal, leading to further wastage. Moreover, malfunctioning projects hinder revenue generation, resulting in lost revenues and preventing self-sufficiency, thereby stalling growth, impeding coverage, and consequently, the inability to accrue more revenue. These interconnected loops create a detrimental impact: an unsustainable water project which adversely affected the lives of hundreds of thousands of people in Siaya county who were promised water but did not receive it.

The HIF unveils complex interactions, regional ecosystems, and feedback loops that may not be evident through conventional project sustainability analyses. Other case studies of the complete study, also evaluated by the HIF, revealed other sustainability factors such as community involvement or lack thereof, community discouragement, environmental matters, and historical factors. In this case, what appeared as a technical issue stemmed from an array of underlying political problems and a heightened lack of responsibility and supervision, highlighting the cruciality of comprehensive assessments.

6. Conclusions

Considering the prevalence of unsustainable drinking water projects across Sub-Saharan Africa, achieving sustainability in this context is evidently challenging. As discussed in the literature review, numerous efforts have been made to plan, attain, and measure sustainability. However, sustainability remains an elusive concept, akin to the idea of "world peace," requiring continuous research and ongoing pursuit. The challenge arises from the multifaceted nature of sustainability and the various perspectives, disciplines, and funding sources that model builders offer.

In view of Hutton and Varughese's (2016) recommendation to design new approaches for water project sustainability, the Holistic Integrated Framework was developed to provide a comprehensive approach for assessing sustainability. Drawing from the study, literature review, and identified gaps, the HIF introduces additional elements of sustainability and the interactions between them. It serves as a framework designed to uncover as many sustainability factors as possible, revealing underlying issues and identifying feedback loops that perpetuate unsustainable situations and enabling researchers and practitioners to identify areas that require correction or mitigation.

The analysis of the vertical players in the project emphasizes the importance of acknowledging and involving all spatial and governance levels, addressing the concerns raised by Nunan et al. (2016). Mapping various players assists to clarify the responsibilities and allocation of tasks among different entities, which is often overlooked in many projects. Additionally, the vertical dimension accentuates the gap between planning and on-the-ground implementation.

The horizontal sustainability categories provide a foundation for evaluators to explore multiple factors. Researchers can use these categories as checklists to uncover relevant issues and to pose relevant questions. Analyzing the same data from a regional perspective revealed regional feedback loops that influenced the project regardless of horizontal factors and proved to be a substantial component of the project's sustainability.

Moreover, the HIF highlights that sustainability is a subjective and context-specific concept, and that each project, even within the same county, possesses unique sustainability factors influenced by local circumstances, the environment, and various stakeholders. Therefore, sustainability can only be determined at the project-specific local level. Although universal factors may be identified, successful solutions must be tailored to the local context, aligning with the insights of Kemp and Martens (2007).

This approach aims to expand our understanding of sustainability, offering an encompassing approach through which to analyze problems and derive insights from past mistakes. Its goal is to facilitate the development of more sustainable water projects or, at the very least, mitigate challenges, when planning a project. By leveraging the HIF, it is anticipated that global development agencies and practitioners can make significant strides in achieving sustainable solutions, ultimately accelerating progress toward UN SDG 6.1, "Water for All," in SSA and other developing regions by 2030.

7. Limitations

The study is constrained by the analysis of one county in Kenya and the paper is constrained by a single case study analysis. Nevertheless, as highlighted in section three, similar circumstances prevail throughout SSA and in many other developing countries in Asia and Latin America. Most developing nations are influenced by global development initiatives and share commonalities in their decentralization policies, making the framework adaptable to a broader context, therefore, the HIF can be employed to analyze cases in other developing countries.

An additional limitation is that, although it aims to create awareness, it does not prescribe specific solutions for addressing these sustainability flaws. The third limitation is the extensive range of skills and financial resources required to effectively implement this framework in projects. The complexity of these requirements may initially appear overwhelming and challenging. However, it is crucial to recognize that perceived complexity should not deter us from utilizing this framework. Instead, it serves as a valuable tool offering numerous examples and insights to guide our efforts.

Disclosure statement

There are no competing interests to declare.

CRediT authorship contribution statement

Ornit Avidar: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

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